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THERMAL ANALYSIS WORKBOOK

Edited by James W. Owen

Structures and Dynamics Laboratory
Science and Engineering Directorate

January 1992

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George C. Marshall Space Flight Center

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This workbook is intended to allow the user to gain a better understanding of thermal analysis, problem solving techniques, and interpretation of results. Many simple and complex engineering problems are presented and solved. These are solved using state-of-the-art thermal analysis codes, closed form solutions (which are used as "sanity checks" for the codes), and many different numerical techniques with explanations of the methods and assumptions used in solving the problems. Physical phenomena which are considered include conduction, convection, radiation, change of phase, compressible and incompressible flow, N-dimensional branching networks, conjugate thermal/hydraulic analysis, Joule-Thompson heating, analysis of gas mixture concentrations, venting, ablation, and related subjects. Some codes discussed include SINDA, TRASYS, ANSYS, PATRAN, and other job specific codes.

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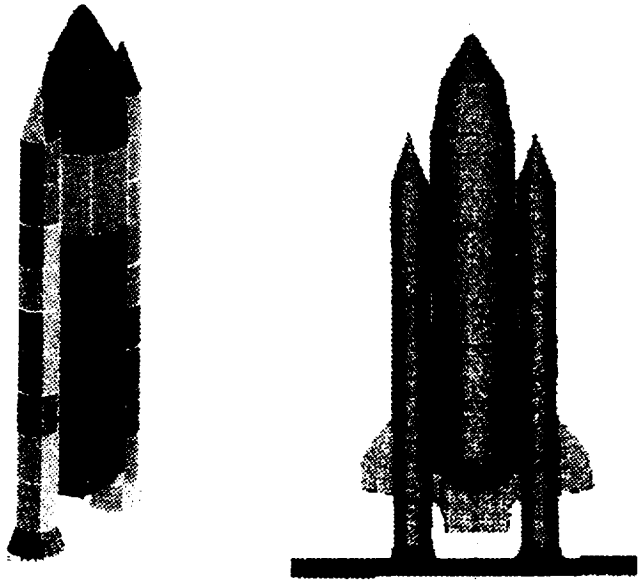

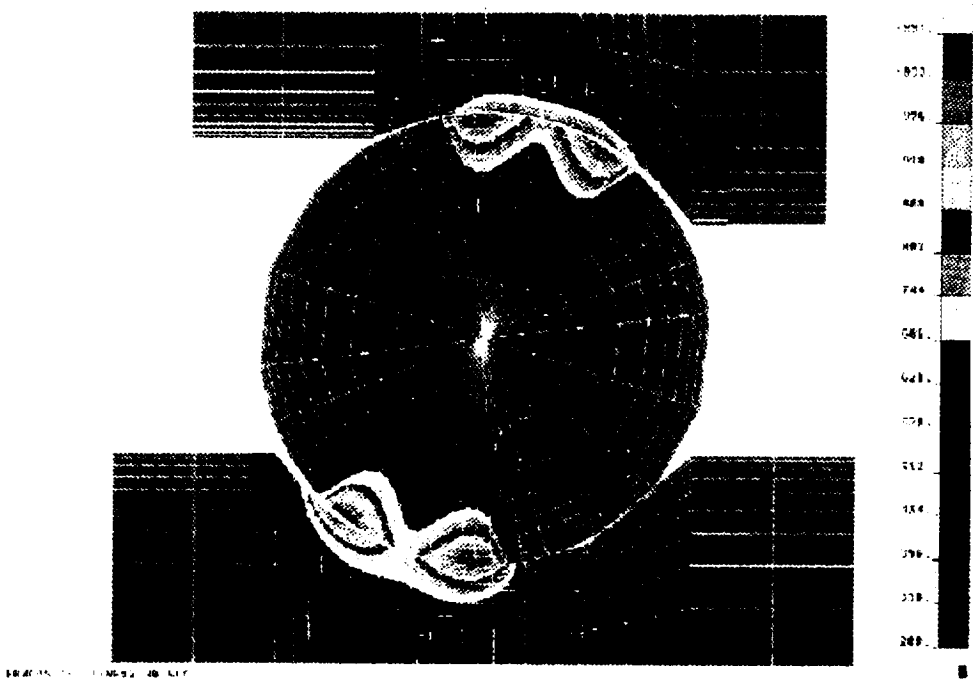

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THERMAL ANALYSIS WORKBOOK

Preface

In support of diverse programs at the Marshall Space Flight Center, the Thermal Analysis Branch is challenged with a variety of complex problems, related primarily to heat transfer, mass transport, and thermodynamics. Over the past two decades, analysis of physical phenomena has migrated toward sophisticated numerical techniques using state-of-the-art computing systems. As a result of the rapid increase in computing speed and memory, codes have been developed to fully utilize this resource. These codes are typically network analyzers which are based upon finite difference or finite element analysis techniques. These analytical methods have led to detailed understanding of many complex physical problems. The focus of this document is to provide examples of simple and complex engineering problems, solved using the codes most commonly used at MSFC.

The motivation for this document is related to several managerial and technical developments. During the middle and late 1980's, the Marshall Space Flight Center experienced a massive turn over in engineering personnel; this was due to the lack of hiring in the 1970's, both at NASA and within the aerospace industry. In the latter part of the 1980's, personnel who had been with the agency during the SATURN/APOLLO era began to retire, prompting the agency to replace these retirees with younger college graduates. The influx of inexperienced graduates and the exodus of experienced personnel left many mid-career level positions vacant and resulted in a number of problems. It became apparent that management was ill prepared to deal with matters of training, experience transfer, and rapid career development. Within the engineering disciplines, the change in personnel created such a discontinuity that the center lost significant analysis and design capability. This problem did not manifest itself in simple code utilization but in the more important areas of problem definition, the ability to identify valid engineering assumptions, imposition of appropriate boundary conditions, interpretation of results, and the use of problem bounding techniques and hand calculations ("sanity checks").

Many of the examples in this collection include closed-form solutions with which the numerical solutions are compared. These fundamental closed-form solutions are also useful for problem bounding, mentioned above. Additionally, several examples are solved using more than one numerical technique (also for comparative purposes). Numerical techniques which are often transparent to the user are illustrated so that the occasional user will understand the basic assumptions and numerical methods used within the code(s).

Another objective of this work is to provide an avenue by which the experience of others can be transferred to many entry level employees, simultaneously. This work is part of a dedicated effort to overcome the effects of the large number of mid-career level vacancies.

A collection of more complex (hardware-specific) problems is also presented to illustrate the versatility of the state-of-the-art codes. These examples have been included because so many of the problems encountered at NASA require innovative analytical approaches. Illustrative examples of conjugate solutions to problems that involve heat and mass transfer, as well as thermodynamics, are provided. In addition, analogies between heat and mass transfer are drawn in several examples. Such examples have proven to be excellent learning tools for beginning code users because they illustrate variable dependencies and modeling technique.

The codes discussed and used in this work include:

SINDA ..... Systems Improved Numerical Differencing Analyzer
TRASYS ..... Thermal Radiation System Analyzer
ANSYS ..... Finite Element Engineering Analysis System
PATRAN ..... Model Generator; Pre and Post Processor
SINGEN ..... Model Generator
ABL ..... Thermal Protection System/ Ablation Design Code with SINDA
CMA ..... Charring Material Ablation 1-D Code
ACE ..... Aerothermal Chemical Equilibrium Code
MEIT ..... Momentum and Energy Integral Technique Code
GASKET ..... Graphite Surface Kinetics Code

The SINDA code, because of its versatility, is emphasized. Physical phenomena which are considered include conduction, convection, change of phase, oxidation of metals, 1-D compressible and incompressible flow, choked flow, N-dimensional branching networks, transient pressurization, conjugate thermal/hydraulic analysis, Joule-Thompson heating, transient analysis of gas mixture concentrations, venting, ablation modeling, radiation and grey body exchange, and condensation and frost formation. Specific numerical techniques include differencing techniques, linearization of radiation terms, enthalpy summation, use of working arrays (in SINDA), linearization of 1-D flow resistances, choked flow simulation, convergence techniques for non-linear flow networks, numerical solution of radiation form factors, and time step/node size sensitivity analysis. Closed-form solutions are provided for steady state and transient conduction, convection, and radiation problems. Combined modes of heat transfer are considered. Also included is a closed form solution for transient concentrations of gas mixtures.

This document begins with simple examples and concludes with more complex techniques, including an analogy between heat and mass transfer. Later chapters include more complex extensions of the analysis techniques, as well as the model generation section. While early examples include detailed descriptions of input formats, the latter examples concentrate on modeling technique and accurate numerical representation of specific physical phenomena.

This work is to supplement existing instruction manuals, with specific examples and detailed illustrations of code usage. Several of these examples will be useful as learning exercises for entry level engineers. It is hoped that this document, with periodic additions, will serve as a valuable reference for years to come.

Introduction

The authors have assumed that the user of this workbook has completed undergraduate courses including heat and mass transfer, thermodynamics, fluid dynamics, and numerical analysis. Typically, however, undergraduates are not exposed to network analysis codes in school. Therefore, while inexperienced users should be familiar with the fundamentals of physical processes and will have had an exposure to numerical techniques, they can be overwhelmed by the many codes used to do state-of-the-art engineering analysis. As stated in the preface, the purpose of this work is to provide a set of examples for use by the inexperienced, and a set of reference problems illustrating specific techniques used in past and present analyses. A brief review is given here of some fundamental heat transfer relationships. These and others will be illustrated in detail in the workbook.

First, the understanding of network analysis can be enhanced through analogies. Given below is the classical electrical to thermal analogy along with an analogy for one dimensional flow of fluids.

	Electrical	**Thermal**	**Fluid**
Variables	i,current	$\dot{q}$, rate of heat flow	$\dot{m}$, rate of mass flow
	v, voltage	T, temperature	P, pressure
	C, capacitance	C, ($\rho V C_p$), thermal capacitance	C, mass storage with pressure (gas), or volume (liquid)
	R, resistance	R, $\frac{1}{kA/x}$	R, resistance to fluid flow (e.g., pipe, orifice, etc.) (see chapter 5)
Relationships Energy Storage	$i = C\dot{v}$	$\dot{q} = C\frac{dT}{dt}$	$\dot{m} = C\frac{dP}{dt}$ (gas storage)
Energy Dissipation	$i = \frac{1}{R}v$	$\dot{q} = \frac{1}{R}(T_1 - T_2)$	$\dot{m} = \frac{1}{R}(P_1 - P_2)^{1/2}$ (see chapter 5)

Analogies are quite useful in developing fundamental understanding of relationships among variables. While some concepts appear somewhat abstract such as electrical current and thermal rate of heat flow, others are easily observed such as rate of mass flow. Therefore, through analogies, the analyst can develop "feeling" for the more abstract variables, concepts, and relationships. Analogies will be explored in detail in Chapter 5.

Some fundamental equations used in this work are summarized below, in a simplified format. These include the three modes of heat transfer, and storage of latent and sensible thermal energy.

Conduction:

The simplified conduction equation through solids can be written:

$$q_{cond} = \frac{kA}{x}(T_1 - T_2)$$

where: k, thermal conductivity
A, area
x, length
T_1, T_2, temperature at given locations in solid

Convection:

The rate of heat flow to and from fluids and solids can be expressed:

$$q_{cond} = h_c A (T_{fluid} - T_{surface})$$

where: h_c, convective heat transfer coefficient
A, surface area
T_{fluid}, fluid free stream temperature
$T_{surface}$, surface temperature of solid body

The convective heat transfer coefficient is most often empirically derived (based upon dimensional analysis), depending upon flow regime (continuum, slip, free molecular, etc.), laminar or turbulent conditions, geometry (spherical, cylindrical, conical, plate, etc.), and orientation with respect to the flow and with respect to body forces (horizontal versus vertical, stagnation versus wake, buoyancy induced flow, etc.). Typical correlations take the following form:

free convection:

$$h_c = C \frac{k}{L} Gr^n Pr^m$$

forced convection:

$$h_c = C \frac{k}{L} Re^n Pr^m$$

where: Gr = Grashof No. $= \frac{g\beta L^3 \rho^2 \Delta T}{\mu^2}$

Pr = Prandtl No. $= \frac{C_p \mu}{k}$

Re = Reynolds No. $= \frac{\rho v L}{\mu}$

C, n, & m = empirically derived constants found in the literature for specific correlations

See the literature for definition of terms and of appropriate correlations most closely representing the geometric and flow conditions for specific problems.

Radiation:

$$q_{rad} = \varepsilon\sigma AF\left(T^4_{surface} - T^4_{sink}\right)$$

where: ε = emissivity
σ = Stefan-Boltzmann constant
A = surface area
F = geometric form factor

Parameters which affect thermal radiation include the following:

surface properties:

- reflectivity (ρ), the ratio of reflected to incident radiation
- absorptivity (α), the ratio of absorbed to incident radiation
- transmissivity (τ), the ratio of transmitted to incident radiation
- $\rho + \alpha + \tau = 1$

For most materials, thicknesses, and use temperatures:

- $\tau = 0$, and $\alpha = \varepsilon$, where ε = emissivity

where : emissivity (ε) = ratio of the emissive power of any surface to that of a black body surface ($\alpha = 1$) of equal temperature

geometric form factors:

- form factors account for the geometric view from one surface to another
- the geometric view that A_1 has of A_2 is denoted F_{1-2}

where: $F_{1-2} = f(A_1, A_2, 1/D_{1-2})$

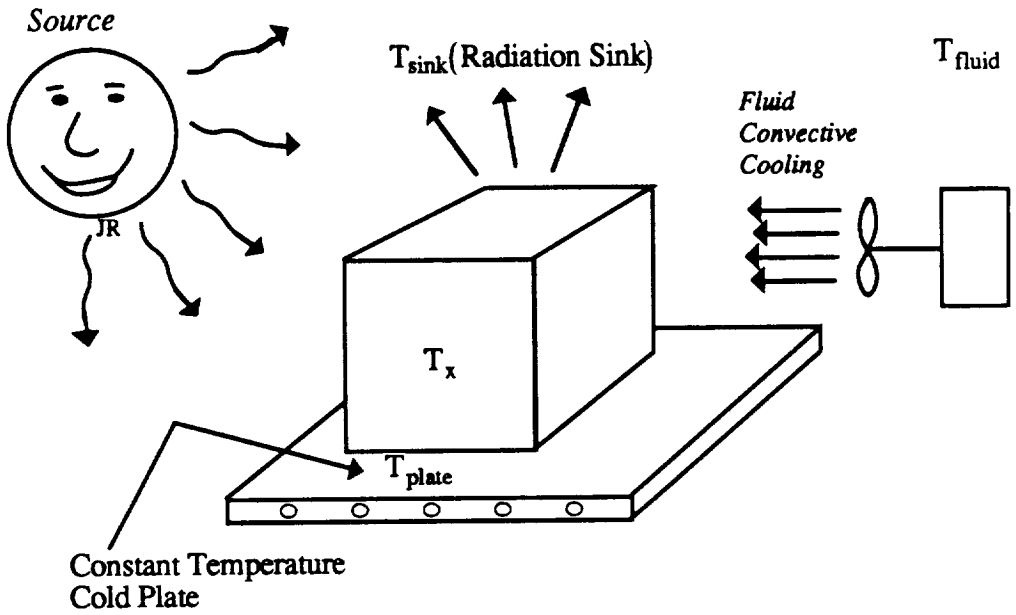
$$A_1 F_{1-2} = A_2 F_{2-1}$$

Stored Thermal Energy:

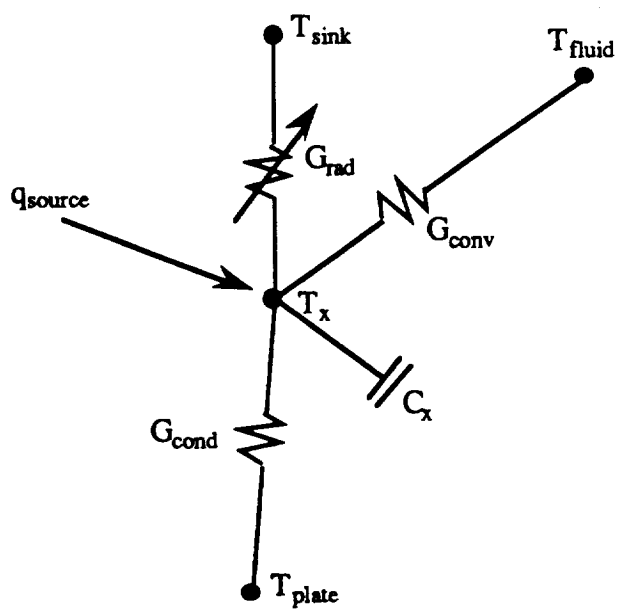
$$q_{stored} = \rho V C_p \frac{dT}{dt}$$

where: ρ, density
V, volume
C_p, specific heat
$\frac{dT}{dt}$, change in temperature with respect to time

Combining many of these mathematical descriptions of physical phenomena in a transient analysis is the function of network analyzers. Consider the simple energy balance illustrated below.



An R-C network of this problem can be drawn as follows.



The mathematical representation is:

$$q + G_{conv}(T_{fluid}-T_x) + G_{cond}(T_{plate}-T_x) + G_{rad}(T_{sink}-T_x) = \rho V_x C_p \frac{dT}{dt}$$

where: q = source heat flux

$G_{conv} = h_c A$

$G_{cond} = \frac{kA}{x}$

$G_{rad} = \varepsilon\sigma AF\left(T_{sink}^2 + T_x^2\right)\left(T_{sink} + T_x\right)$

(Note: linearization of radiation conductors will be discussed at length in chapter 2)

The equation can be written in a differencing format as follows (differencing techniques will be discussed at length in chapter two).

let: $$\frac{dT}{dt} = \frac{\left(T_x' - T_x\right)}{\Delta t}$$

where: T_x' = new temperature at time $t + \Delta t$

T_x = old temperature at time t

Δt = time step

then:

$$q + G_{conv}(T_{fluid}-T_x) + G_{cond}(T_{plate}-T_x) + G_{rad}(T_{sink}-T_x) = \rho V_x C_p \frac{\left(T_x' - T_x\right)}{\Delta t}$$

Thermal analyzers solve this energy balance (a form of the diffusion equation) at each time step. For multi-node problems, simultaneous equations are solved with a heat balance applied to each node at each time step. This workbook will explore in detail the various modes of heat transfer and energy storage, and mathematical representations of these phenomena in thermal network analyzers. Analogies will also be developed and explored in detail. A discussion in Section 1-8 will show relationships between node size and time step for stable solutions. This deals with modeling technique required to obtain accurate results. Other sections show specific problems and specialized codes used by the Thermal Analysis Branch.

An area not explicitly discussed in the workbook relates to documentation of results. The format used here for the example problems provides an excellent framework for future reference. The problems are clearly stated, all information that is given is shown along with a statement of all assumptions and boundary conditions required for the analysis. The modeling technique is described in some detail, and the results of the analysis are given with all necessary supporting comments. The detailed description of input decks and listings will not normally be required for documentation of engineering studies, but are included here to aid in the learning process. Documentation of results is as important as the analysis itself. The analyst should be very clear about assumptions required for an analysis, so that management can participate in determining the applicability of results to physical problems, and can make appropriate programmatic decisions.

These examples should provide both a learning tool (self-teaching) and a reference book for thermal analysts at MSFC, and potentially the contractor community. The authors consider this workbook to be a living document that can be expanded and improved with new techniques and clearer examples. We welcome any additional examples that the reader thinks would increase the workbook's usefulness. Please send your example problems, comments, and suggestions to:

Thermal Analysis Workbook
c/o James W. Owen
Mail Stop: ED64
NASA/MSFC
Marshall Space Flight Center, AL 35812

THERMAL ANALYSIS WORKBOOK

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SCHEMATIC REPRESENTATIONS OF EXAMPLES

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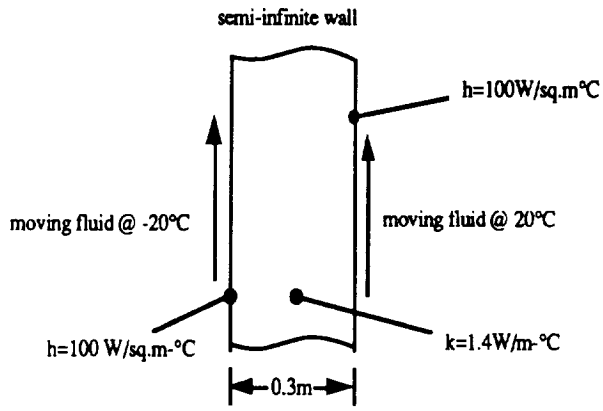
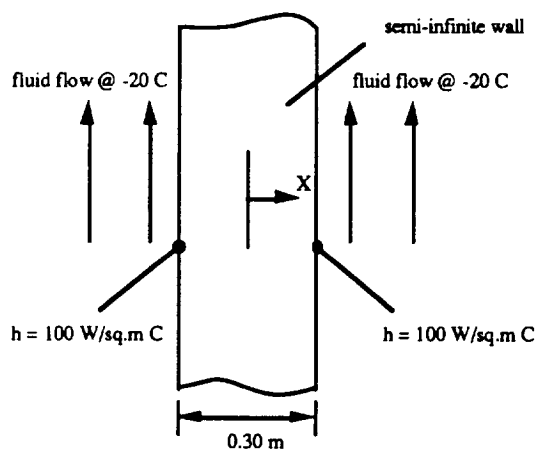


Schematic of semi-infinite wall which separates fluid flows of differing temperatures

CHAPTER 1 SECTION 2: TRANSIENT CONDUCTION WITH CONVECTION



Homogeneous, semi-finite plane wall with convective heat transfer on opposing faces

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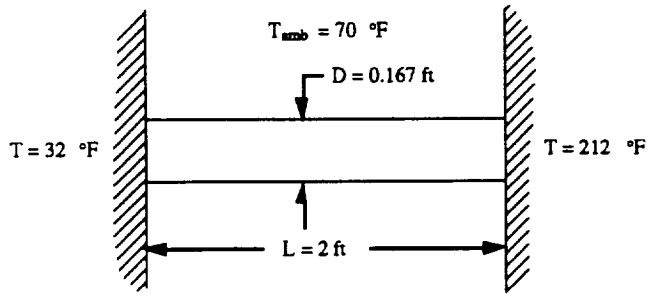
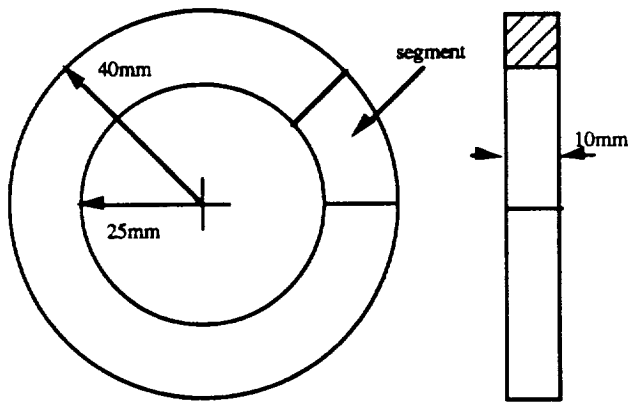
CHAPTER 1 SECTION 3: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

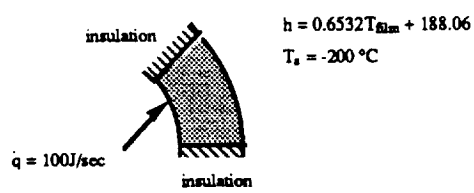


Schematic of Circular Rod Connected to Walls at Different Temperatures

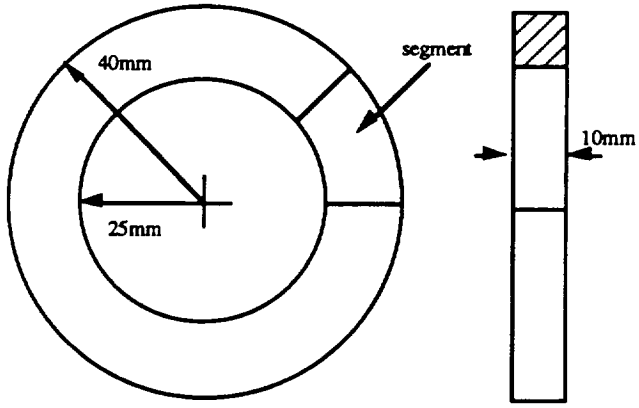
CHAPTER 1 SECTION 4: STEADY STATE CONDUCTION WITH CONVECTION



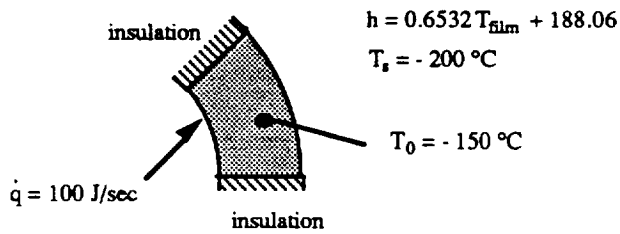
One eighth segment of a 40 x 10mm homogeneous ring



Schematic of ring segment showing insulated end "panels".
Heat flux per unit of exposed surface area is constant and uniform.

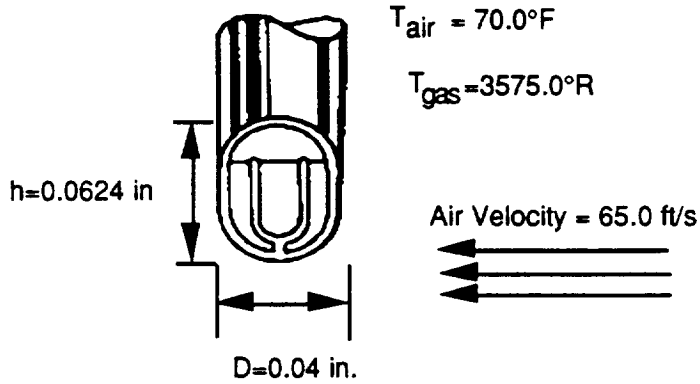


One eighth segment of a 40 x 10 mm homogeneous ring



Schematic of ring segment showing insulated end "panels".
Heat flux per unit of exposed surface area is constant and uniform

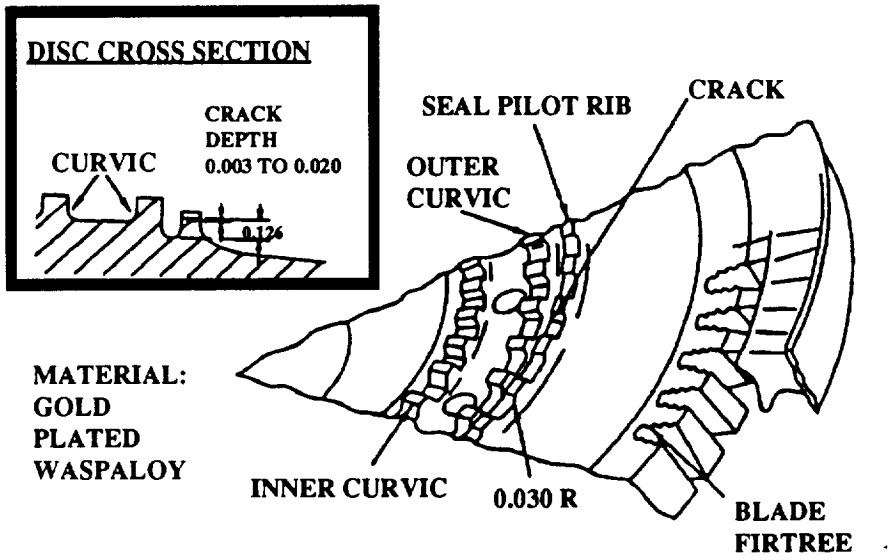
CHAPTER 1 SECTION 6: TRANSIENT CONDUCTION WITH CONVECTION, MULTIPLE MATERIAL BODY



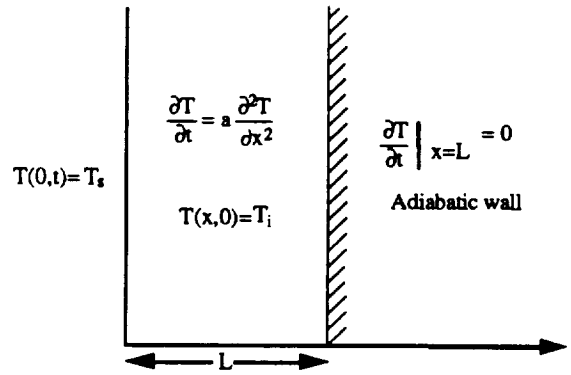
A ground junction thermocouple

CHAPTER 1 SECTION 7: SSME HPTOP FIRST DISC SEAL PILOT RIB CRACKING THERMAL ANALYSIS

HPOTP FIRST STAGE TURBINE DISC

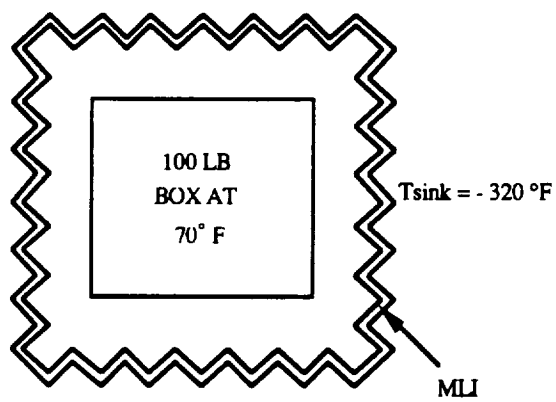


CHAPTER 1 SECTION 8: TIME STEP / NODE SIZE SENSITIVITY



Schematic of semi-infinite wall, insulated on ones side with high heat flux imposed on the other surface.

CHAPTER 2 SECTION 1: TRANSIENT RADIATION HEAT TRANSFER



Schematic of 100 lbm box wrapped in MLI

CHAPTER 2 SECTION 2: GREYBODY RADIATION BETWEEN SURFACES RADIATION SHAPE FACTORS, ORBITAL HEATING RATES

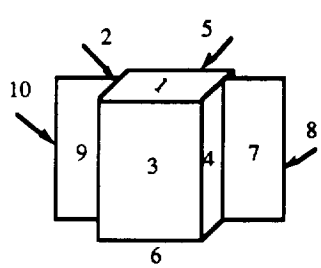


Figure 1. Spacecraft Description

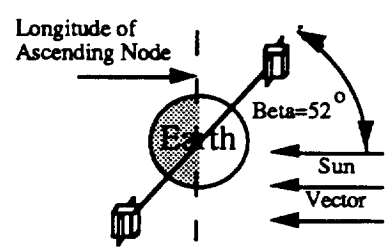
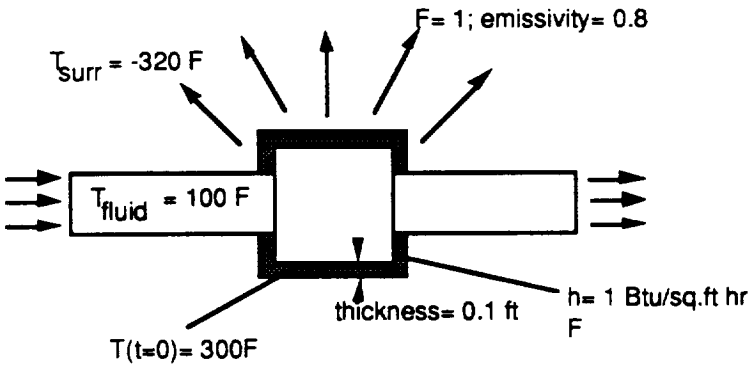


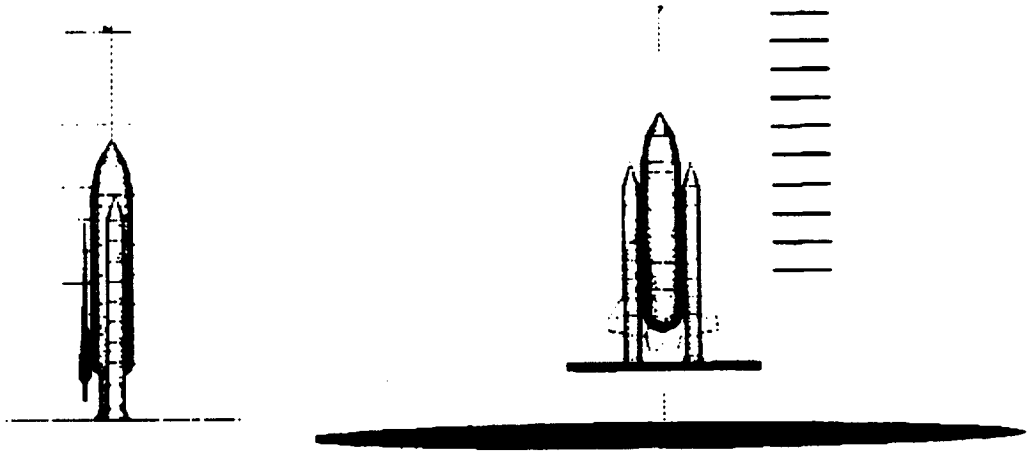
Figure 2. Orbit Description

CHAPTER 2 SECTION 3: TRANSIENT RADIATION WITH CONVECTION, LINEARIZATION OF NON-LINEAR TERMS, DIFFERENCING TECHNIQUES

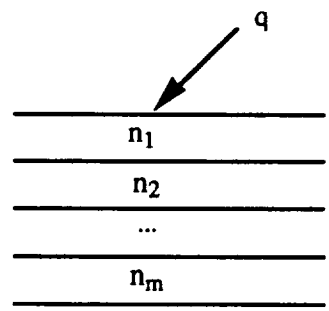


Flow through a pre-heated tank which radiates to its surroundings

CHAPTER 2 SECTION 4: TRASYS MODEL EXAMPLE OF SPACE TRANSPORTATION (STS) PRE-LAUNCH MODEL

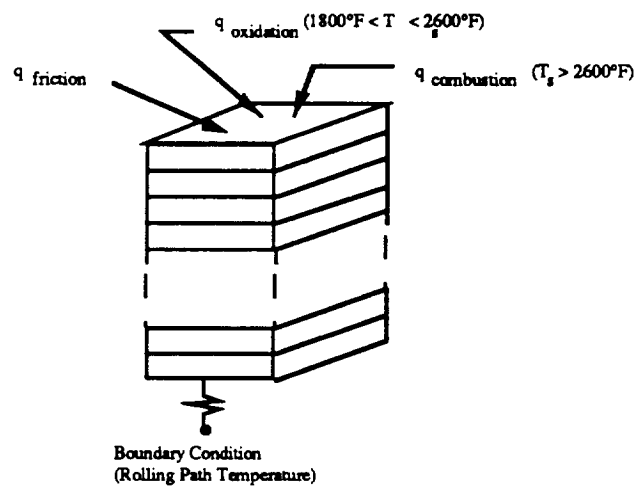


CHAPTER 3 SECTION 1: PHASE CHANGE OF A METAL



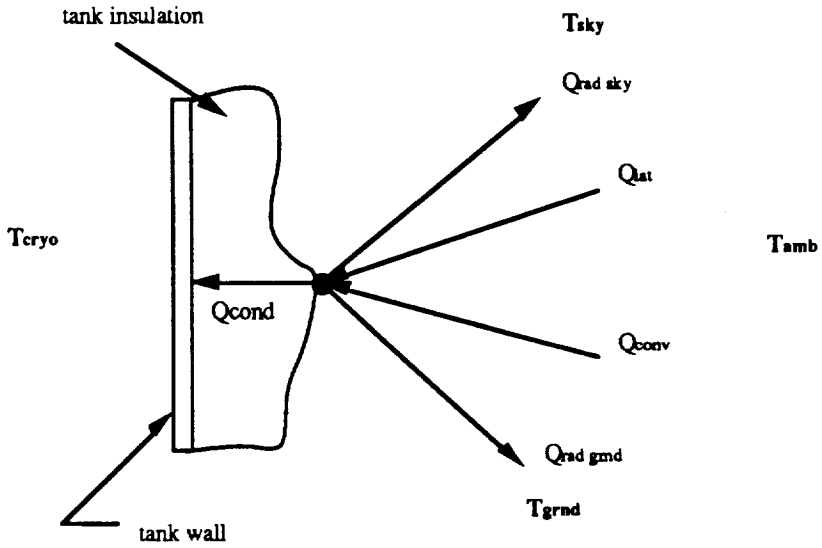
One Dimensional Node Stack

CHAPTER 3 SECTION 2: OXIDATION CHARACTERISTICS OF METALS



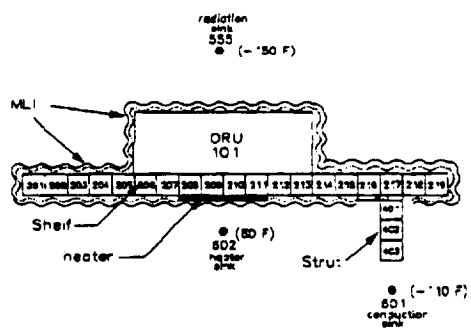
One-Dimensional Network

CHAPTER 3 SECTION 3: CONDENSATION AND FROST FORMATION ON THE EXTERNAL TANK



Schematic of heat flow into tank foam and wall

CHAPTER 4 SECTION 1: SIZING OF SPACECRAFT HEATER ELEMENTS

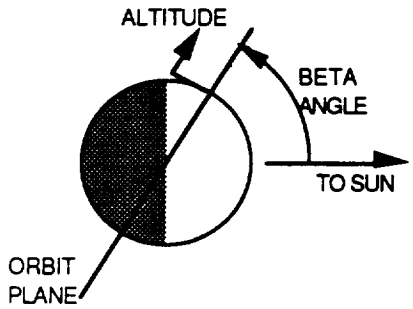


Thermal control using resistive heaters

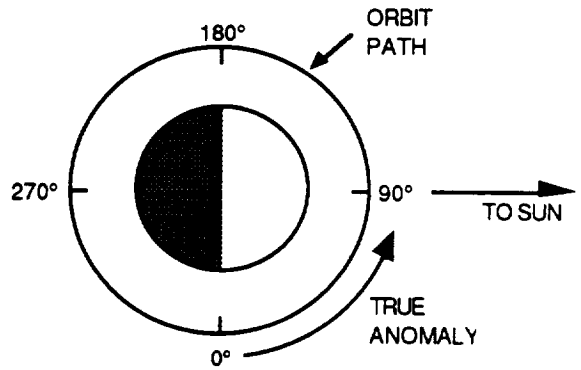
CHAPTER 4 SECTION 2: THERMAL MATH MODEL MANIPULATION

No Schematic Available

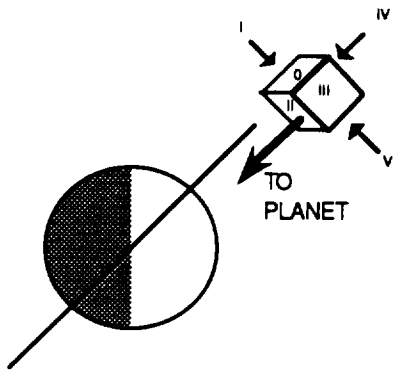
CHAPTER 4 SECTION 3: SIMPLIFIED SPACECRAFT IN VARIOUS EARTH ORBITS



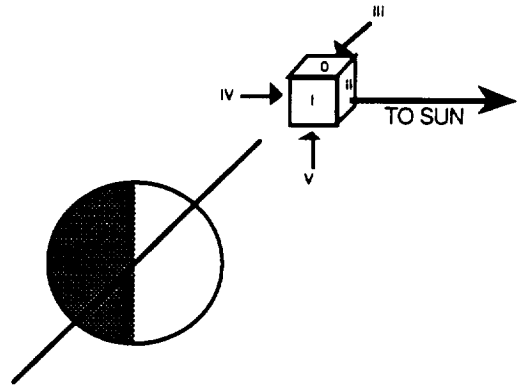
SIDE VIEW OF PLANET



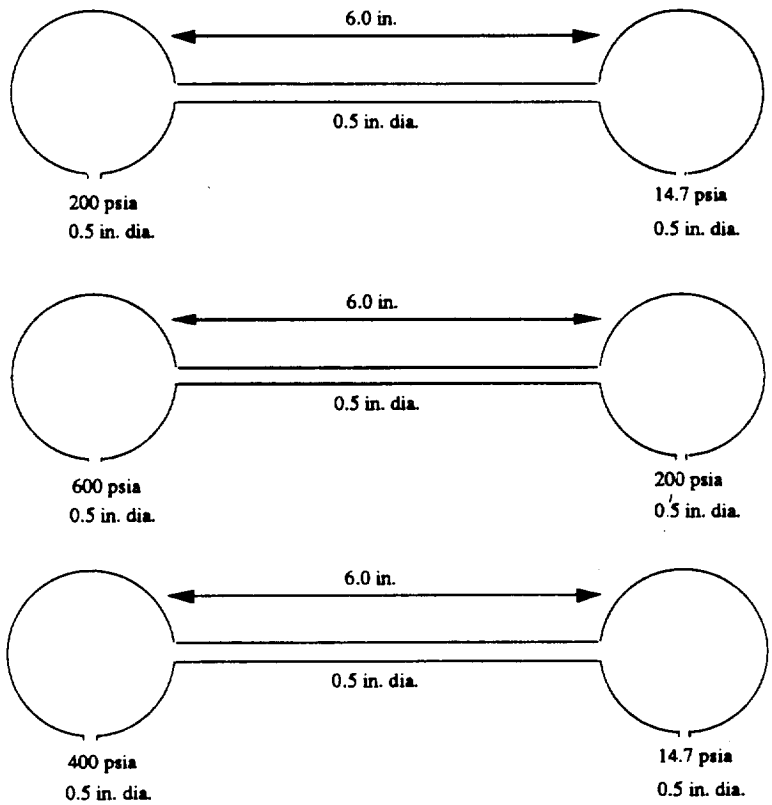
TOP VIEW OF PLANET



PLANET ORIENTED

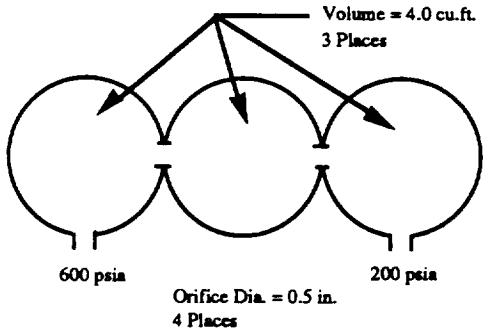


SUN ORIENTED



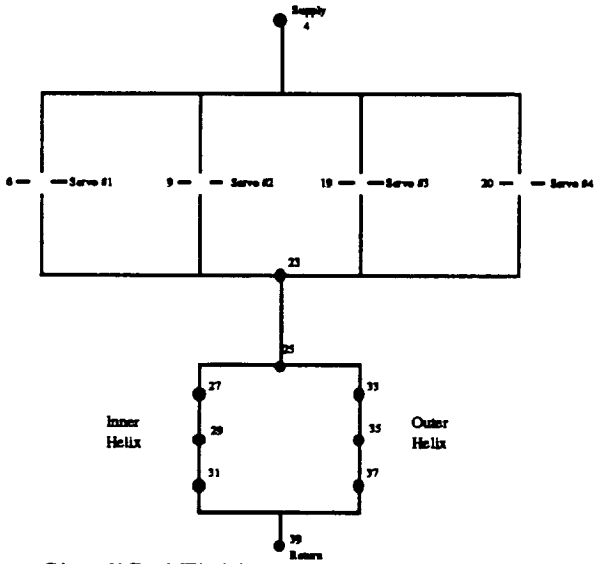
Schematics of 1-D fluid network

CHAPTER 5 SECTION 2: TRANSIENT (ISOTHERMAL) PRESSURIZATION

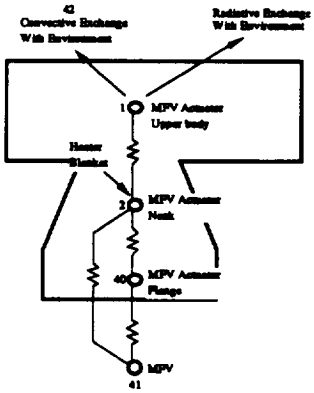


Schematic of one dimensional tank pressurization

CHAPTER 5 SECTION 3: THERMAL / HYDRAULIC NETWORK ANALYSIS

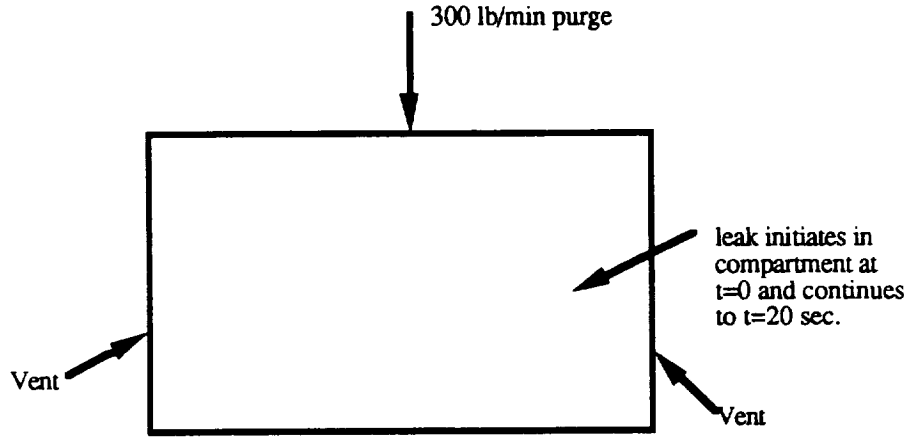


Simplified Fluid Model During Prelaunch

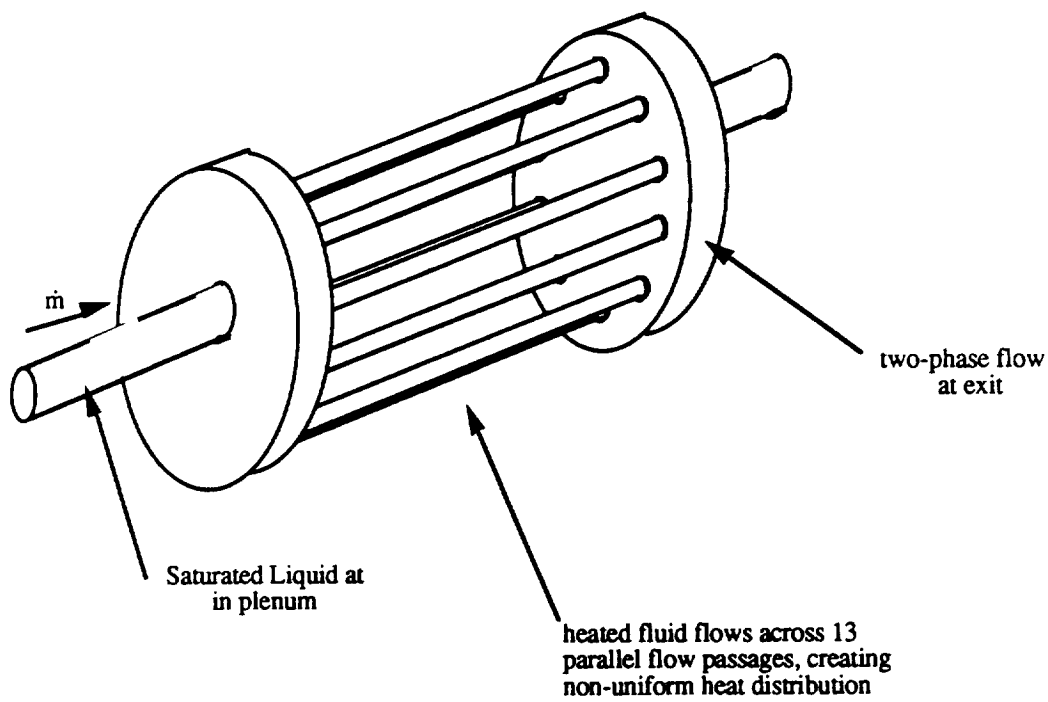


MFV Actuator Simplified Thermal Model

CHAPTER 5 SECTION 4: HAZARDOUS GAS CONCENTRATION IN OXYGEN/ HYDROGEN SYSTEMS

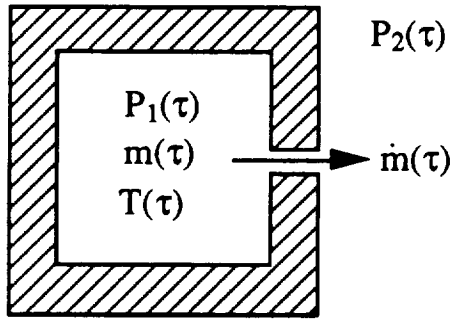


CHAPTER 5 SECTION 5: PRESSURE BALANCING TECNIQUE FOR SATURATED (TWO-PHASE) FLOW



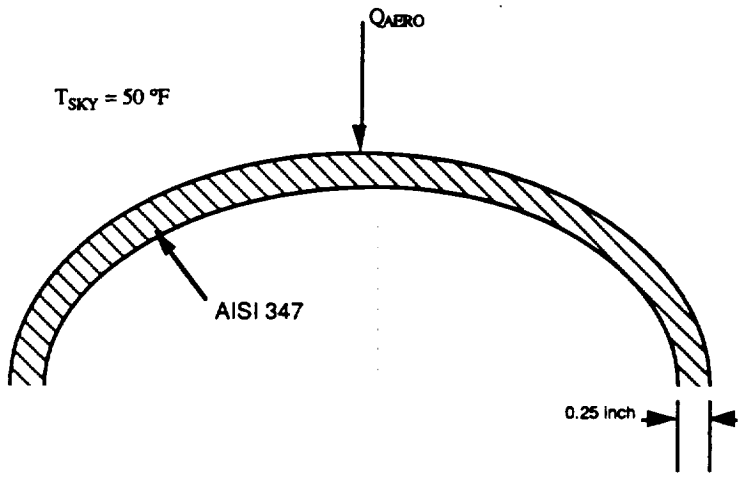
Schematic Representation of Flow Passages

CHAPTER 5 SECTION 6 VENTING OF AN ELECTRONIC BOX IN THE SPACE SHUTTLE CARGO BAY DURING ASCENT



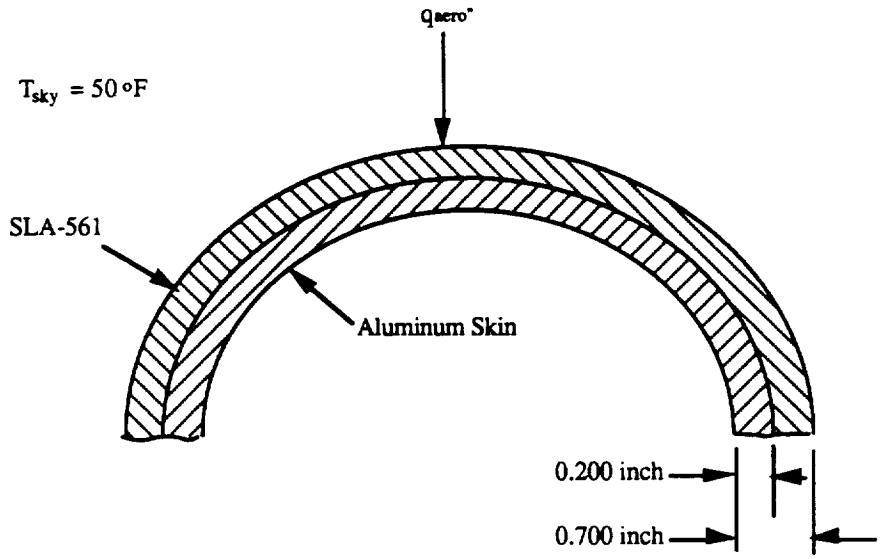
Schematic of Transient Depressurization of the Box

CHAPTER 6 SECTION 1: AEROHEATING TEMPERATURE ANALYSIS



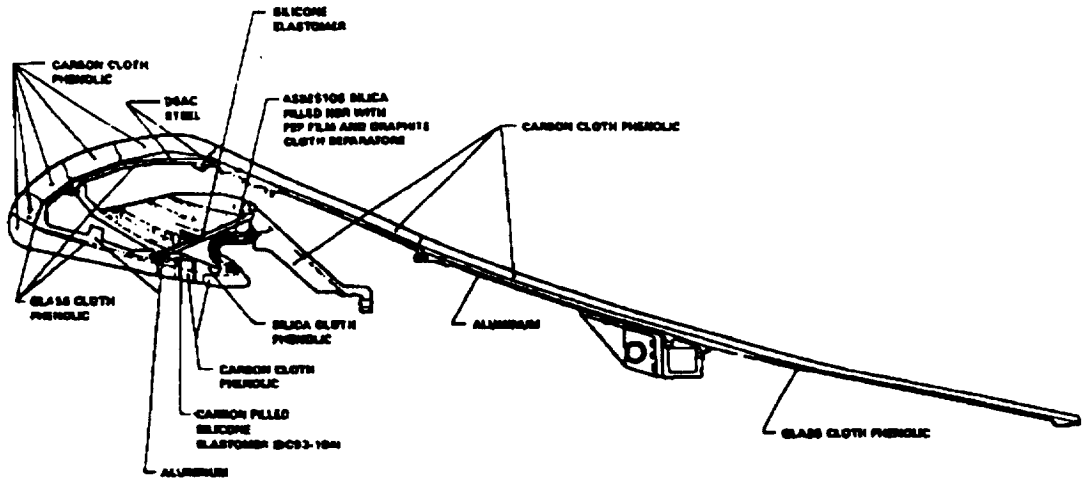
Cross Section of proposed HLLV nose cone

CHAPTER 6 SECTION 2: VEHICLE THERMAL PROTECTION SYSTEM DESIGN ANALYSIS METHODS

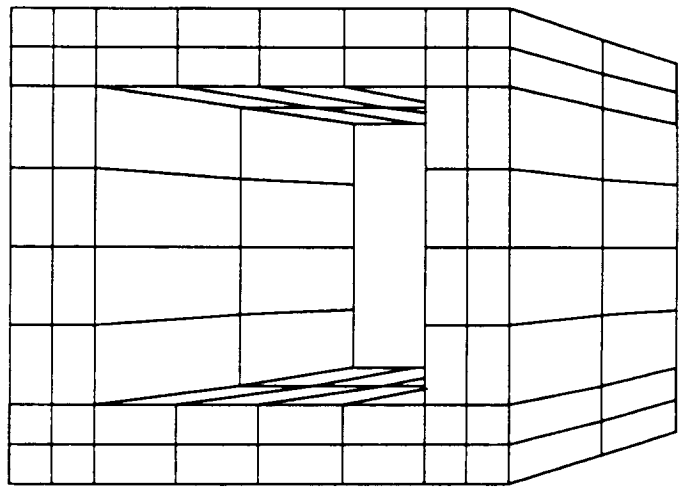


Cross Section of Nosecone

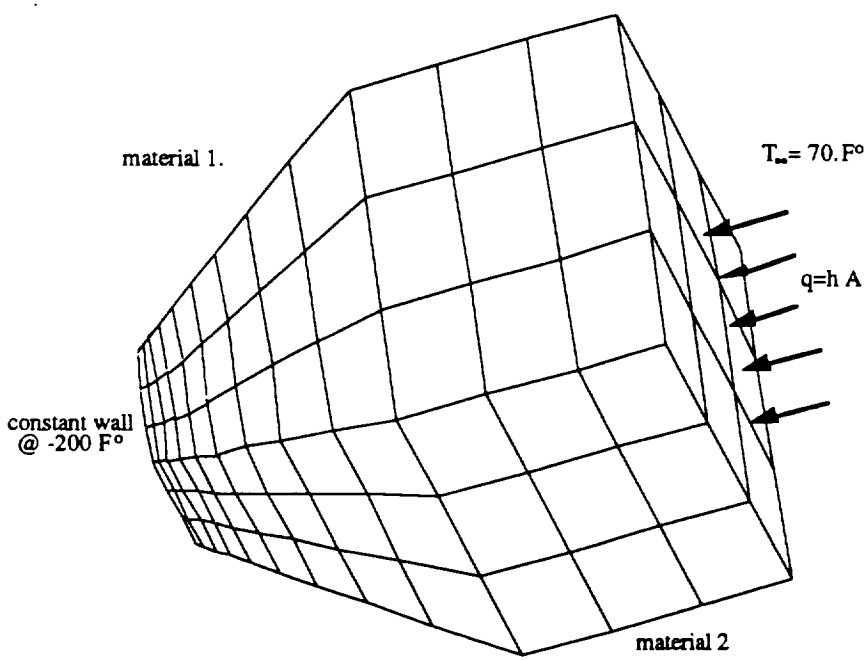
CHAPTER 7 SECTION 1: SOLID ROCKET MOTOR NOZZLE ANALYSIS DESCRIPTION OF STATE-OF-THE-ART TECHNIQUES



CHAPTER 8 SECTION 1: MODEL GENERATION - SINGEN EXAMPLE



CHAPTER 8 SECTION 2: MODEL GENERATION - PATRAN EXAMPLE



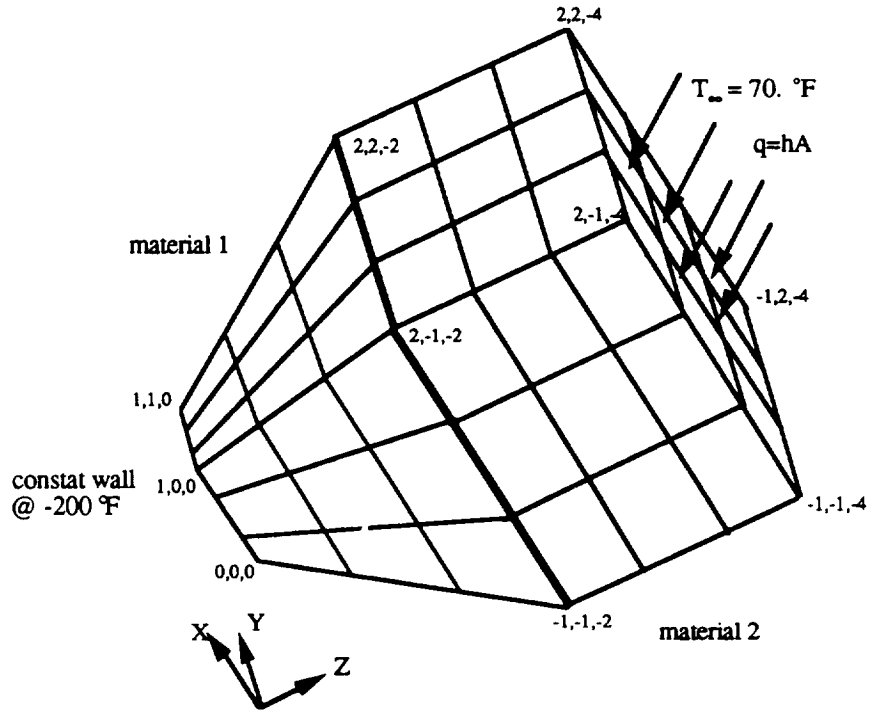


Figure 2: Schematic of the Problem

Introduction to Chapter 1

Steady State and Transient Conduction with Convection

Chapter one is intended to provide introductory examples illustrating simple heat transfer problems. The heat transfer modes of conduction and convection (because they can be described as linear functions of temperature) are included. Detailed descriptions of input decks are given, to initiate the inexperienced code user. In each example, closed-form solutions are developed or presented without derivation. In all cases, the numerical solutions are compared to the exact solutions. Both steady state and transient analyses are shown.

Section 3 of this chapter illustrates several analytical techniques including finite volume, finite difference, and the finite element methods. The results of these numerical methods are compared to a closed-form solution. This comparison of techniques is considered to be a valuable exercise for both experienced and inexperienced analysts.

Section 8 is included to illustrate thermal modeling techniques required to capture transients and temperature gradients accurately. Specifically, relationships between grid size and time step are explored. Also, implicit and explicit time step constraints are discussed. An approach for estimating acceptable time steps is developed. A closed form solution is given and example network analysis schemes are compared to an exact solution. This chapter is an important addition to volume one as it deals with subtle issues of modeling physical systems which are exposed to severe loads or transients.

Finally, the beginning code user is advised to examine the closed- form solutions, at some length. Many engineering problems lend themselves to rough "order-of-magnitude" calculations via these techniques. The analyst (through use of hand calculations) can develop an intuitive feeling for the reasonableness of results, for the more complex multi-node network analyses, required for detailed prediction of results.

CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 1: - Steady State Conduction with Convection

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A. Statement of the Problem:

Consider a homogeneous, semi-infinite wall which is 0.3 m thick. The thermal conductivity, k, of the wall is 1.4W/m°C. Fluid flows over opposite faces of the wall such that the convective heat transfer coefficient, h, is 100W/sq.m°C, for both faces, and may be assumed constant. The free-stream temperatures of fluid flowing over the left and right faces of the wall are -20°C and 20°C, respectively. Determine the steady state temperature distribution through the wall.

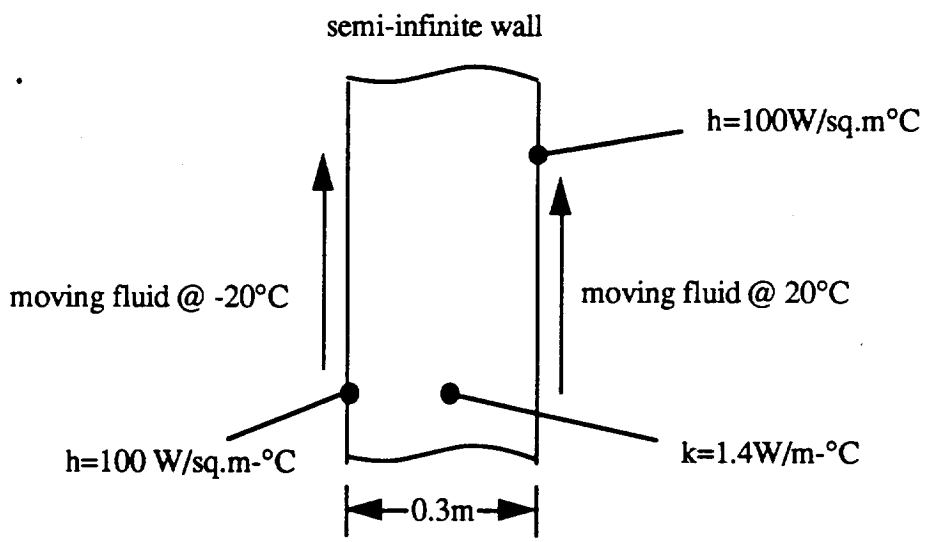


Figure 1. Schematic of semi-infinite wall which separates fluid flows of differing temperatures

B. Schematic:

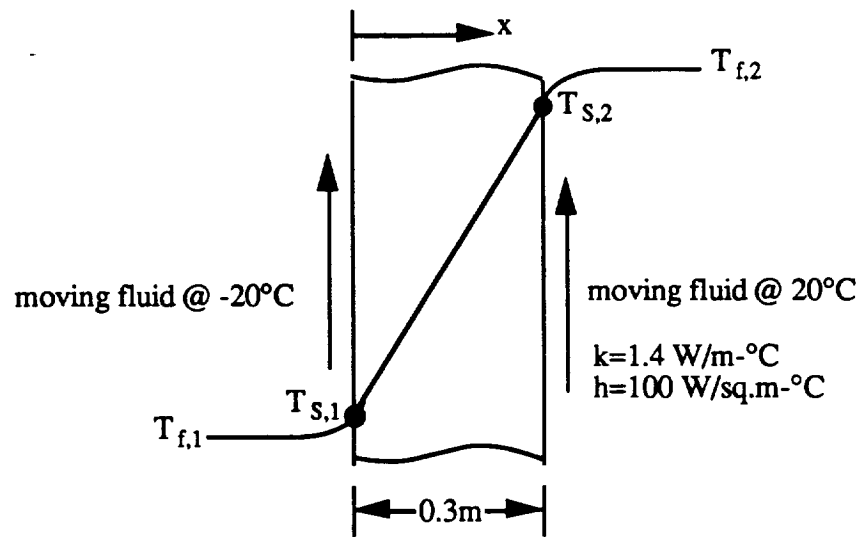


Figure 2. Schematic of semi-infinite wall showing temperature distribution for a homogeneous wall of uniform cross section with no internal heat generation

C. Given:

1. Wall has constant cross-sectional area and is homogeneous.
2. $T_{f,1}$= -20°C; $T_{f,2}$= 20°C.
3. $h_1 = h_2 = 100 W/m^2$ °C.
4. k= 1.4W/m°C.

D. Find:

1. Steady state temperature distribution across the wall.

II. Formulation of the Problem:

A. Simplifying Assumptions:

1. Constant thermal conductivity; we are given that the wall is a homogeneous solid; subsequently, the assumption that k remains constant is reasonable.
2. Constant convective heat transfer coefficient, h.
3. Steady state, one-dimensional heat transfer through the wall.
4. No internal heat generation.

B. Initial/Boundary Conditions:

1. Initial conditions have no real significance as the problem involves a steady state analysis.
2. The only boundary conditions given are those which apply to the free-stream, namely

$$T_{f,1} = T(-\infty) = -20°C$$

and

$$T_{f,2} = T(+\infty) = 20°C$$

C. Discretization:

As is the case with most problems analyzed using SINDA, it is important to realize that there are most often several ways to discretize the model, each of which may be entirely correct. For the problem at hand, the analysis is performed assuming steady state heat transfer. The wall is modeled using three diffusion nodes, two arithmetic nodes, and two boundary nodes, as shown in Figure 3.

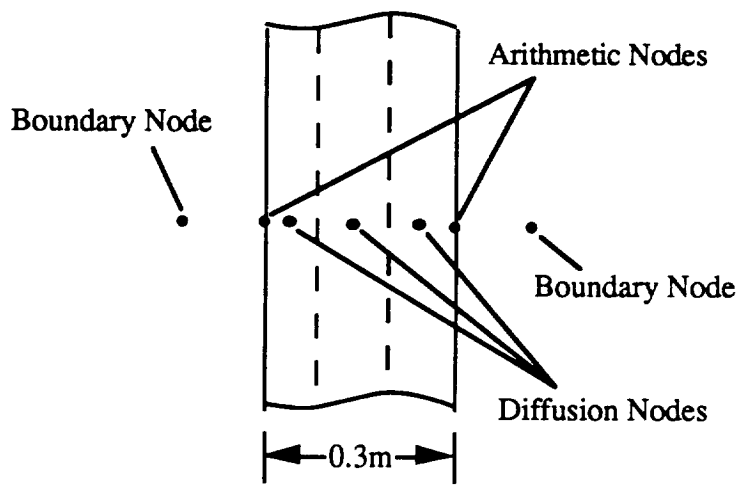


Figure 3. Definition of node types and locations.

Recall that diffusion nodes have finite thermal capacitance and, therefore, do not react instantly to the loss or addition of heat. Conversely, arithmetic nodes placed on the exposed surfaces of the wall, have no capacitance and respond to the loss or addition of heat, without delay. For a steady state analysis, all surface and interior nodes could have been defined as arithmetic nodes because capacitance is of no consequence. The use of diffusion nodes, however, facillitates a change to a transient analysis, thereby adding some degree of flexibility to the model. The boundary nodes, by definition, have infinite capacitance and maintain temperature regardless of how much heat is transferred to (or from) them. For this case, the fluid streams are assumed to flow at constant temperature; therefore, boundary nodes have been placed to either side of the wall. The total number of nodes used to model the problem is seven and the nodes are labeled as shown in Figure 4. Numeric labels are assigned quite arbitrarily, with exception to the fact that negative node labels always imply boundary nodes.

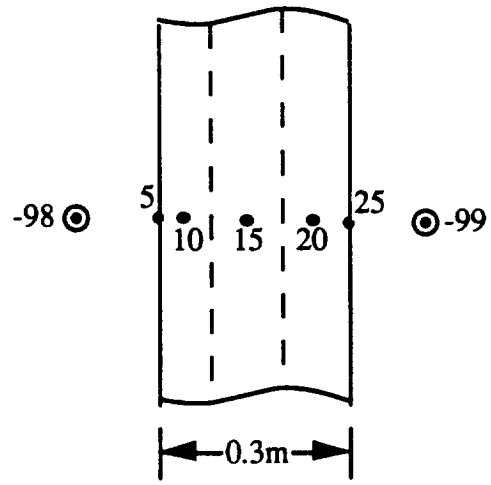


Figure 4. Definition of node labels.
Negative signs indicate boundary nodes.

III. Analysis:

A. The Input Deck:

This section is included to explain how information given in the statement of the problem is conveyed to SINDA and to present a corresponding input deck. The input deck provided on the following page is a "Gaski" SINDA deck, Gaski being a popular version of the code developed by Mr. J.D. Gaski. The input deck comprises nine major "blocks" or parts; these include, 1) the title block, 2) the node data block, 3) the conductor data block, 4) the constants data block, 5) the array data block, 6) the execution block, 7) the "variables 1" block, 8) the "variables 2" block, and 9) the output block. All Gaski SINDA blocks begin with the letters, "BCD" followed by a single space and the digit, 3. The block designation follows the digit and there is no space between the two. Letters, "BCD" appear in columns eight through 10.

The title block is always required and contains information about the type of analysis to be performed. In this case, a thermal analysis is performed and the word, "thermal" follows the number, 3, in line one. The thermal qualifier, LPCS, determines the pseudo compute sequence constructed by SINDA's pre-processor. Line two is an end-statement and must be used at the close of all blocks.

THE NODE DATA block conveys information about the nodes, or "lumped masses", which the user has defined. There are typically three entries in each line of this block. The first entry is the label, or name, associated with a particular node. The second entry is the initial temperature of the node and the third defines the thermal capacitance of the node. Node label assignments are completely arbitrary, with exception to the fact that boundary nodes always bear negative labels and are usually defined after any arithmetic and/or diffusion nodes. Initial temperatures are floating point values and may have any associated units the user desires, provided the same units are used when calculating conductances and capacitances. Thermal capacitances are also floating point field entries and are calculated in accord with equation 1.

SINDA INPUT LISTING

```
BCD 3THERMAL LPCS
END
BCD 3NODE DATA
    5,10.0,-1.0
    25,10.0,-1.0
    10,10.0,1.0
    15,10.0,1.0
    20,10.0,1.0
    -98,-20.0,0.0
    -99,20.0,0.0
END
BCD 3CONDUCTOR DATA
    598,5,98,100.0
    2599,25,99,100.0
    510,5,10,28.0
    1015,10,15,14.0
    1520,15,20,14.0
    2025,20,25,28.0
END
BCD 3CONSTANTS DATA
    NLOOP=500
    DRLXCA=0.010
    ARLXCA=0.010
    NDIM=1000
END
BCD 3ARRAY DATA
END
BCD 3EXECUTION
    STDSTL
END
BCD 3VARIABLES 1
END
BCD 3VARIABLES 2
END
BCD 3OUTPUT CALLS
F       CALL TPRINT
END
BCD 3END OF DATA
```

$$C_i = r_i V_i C_{pi} \quad (1)$$

Because the present analysis is steady state, thermal capacitances have no real significance. Hence, the capacitances of all diffusion nodes have been arbitrarily assigned a value of one (as the value, here, is meaningless anyway). Values for the capacitances of the boundary nodes have been inserted only to fill the field; SINDA neglects boundary node capacitances because they are assumed infinite. Diffusion nodes have been numbered 10, 15, and 20 whereas the two boundary nodes have been numbered 98 and 99. Arithmetic nodes (2) are numbered 5 and 25. Arithmetic nodes are signified by negative thermal capacitance.

The CONDUCTOR DATA block defines the interrelationship between the nodes. There are typically four entries in each line of this block, the first of which is a user defined conductor label. The second and third entries determine which two nodes are connected by the designated conductor. The final entry denotes conductance, given by kA/L for "conduction conductors" and hA for "convection conductors." For the case at hand, the wall is semi-infinite; hence a unit of area has been assumed such that $A=1m^2$.

The CONSTANTS DATA block contains information which, in general, controls execution of the code. While there are cases where several control constants are necessary, many problems require specification of only three or four constants. For this problem, only four constants have been identified; these include NLOOP, DRLXCA, ARLXCA, and NDIM. The leading constant, NLOOP, determines the maximum number of iterative loops allowed in the course of the solution. DRLXCA and ARLXCA denote permissible relaxations on the diffusion and arithmetic nodes. NDIM is a special constant which is used to set the amount of dynamic storage space. The user is directed to the Gaski SINDA users manual for further information regarding these and other control constants used by SINDA.

Solving the given problem really does not warrant use of the ARRAY or VARIABLES blocks; these, however, must be included, whether they convey information or not. Furthermore, the blocks must appear in the indicated order. Failure to include or properly order any of the blocks will result in a fatal error message upon executing the program.

The EXECUTION block contains information that directly controls program execution. It is most often used to identify the type of analysis to be performed, using avilable data. The STDSTL selection corresponds to a steady state analysis and must be used with an LPCS thermal qualifier in the title block.

The OUTPUT CALLS block contains information which determines what parameters are to be printed. Only the steady state nodal temperatures are of interest in the present analysis. The subroutine, TPRINT, accomplishes the objective and prints only the nodal temperatures. The letter, F, which preceds the call for TPRINT, merely indicates (to SINDA) that the line to follow is a FORTRAN statement and must be handled/translated accordingly.

Finally, it should be noted that all Gaski input decks are closed with a line which reads, "END OF DATA," followed by a carriage return at the end of the line.

IV. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are given on the following page. All nodal temperatures are output in degrees Celsius.

According to information given in the output file, the temperature distribution across the wall is linear, as shown in Figure 5. The free stream temperatures have been conserved (as one would expect) and the two surface temperatures appear to be reasonable.

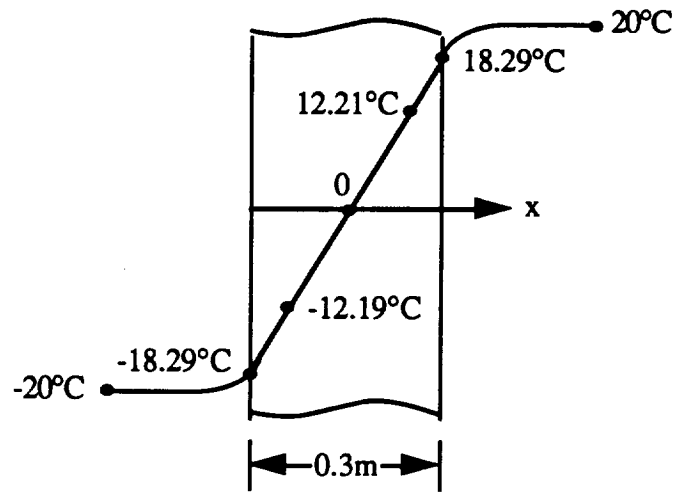


Figure 5. Predicted temperature distribution across the wall

B. Generation of an Alternative Solution:

In order to check the preceding results, we may choose to develop a classical solution to the problem. More often than not, a rigorous closed-form solution cannot be obtained; in this case, however, an exact solution is possible. We can model the system using the equivalent circuit of Figure 6.

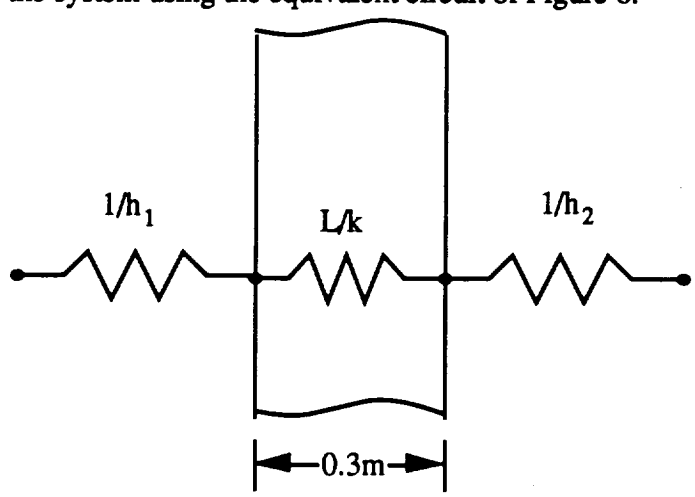


Figure 6. Representation using an equivalent circuit

SINDA OUTPUT LISTING

```
(C) COPYRIGHT  1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987ANSI  1.31 NETWORK

*** NOTE *** STDSTL REQUIRES     10 DYNAMIC STORAGE LOCATIONS OUT OF     987

****************
TIME= 0.00000E+00,  DTIMEU= 0.00000E+00,  CSGMIN(     0)= 0.00000E+00,  ATMPCC(     0)= 0.00000E+00
   LOOPCT=     0                                                        ,  ARLXCC(     0)= 0.00000E+00
+                    , SENGIN= 1.00000E+03,  ENGBAL=-2.00000E+03

T     10 =   10.0000  T     15 =   10.0000  T     20 =   10.0000  T     5 =   10.0000  T     25 =   10.0000  T     98 =  -20.0000
T     99 =   20.0000  T

STDSTL RUN,  ARLXCA= 0.10000E-01,  BALENG= 0.10000E+31,  BENODE= 0.50000E+30,  NLOOP= 500

*** NOTE *** RELAXATION CRITERIA HAS BEEN MET WITH LOOPCT =     9

   ENGBAL =  0.186157     AT LOOPCT =     9

*** NOTE *** SYSTEM ENERGY BALANCE CRITERIA HAS BEEN MET, ENGBAL =  0.186157     ,  LOOPCT =     9

   EBNODE(     10)= 0.139282     AT LOOPCT=     9

*** NOTE *** NODAL ENERGY BALANCE CRITERIA HAS BEEN MET, EBNODE(     10)= 0.139282     , LOOPCT =     9

****************
TIME= 0.00000E+00,  DTIMEU= 0.00000E+00,  CSGMIN(     0)= 0.00000E+00,  ATMPCC(     0)= 0.00000E+00,  DTMPCC(     0)= 0.00000E+00
   LOOPCT=     9                                                        ,  ARLXCC(     5)= 2.04468E-03,  DRLXCC(    10)= 9.39941E-03
+                    ,  SENGIN= 1.70786E+02,  ENGBAL= 1.86157E-01

T     10 =  -12.2011  T     15 =   -0.0054  T     20 =   12.1926  T     5 =  -18.2940  T     25 =   18.2921  T     98 =  -20.0000
T     99 =   20.0000  T
```

Recognizing that $q_{conv}(in)=q_{cond}=q_{conv}(out)$, we may write

$$q_x = \frac{T_{f,2} - T_{s,2}}{\left(\frac{1}{h_2}\right)} = \frac{T_{s,2} - T_{s,1}}{\left(\frac{L}{k}\right)} = \frac{T_{s,1} - T_{f,1}}{\left(\frac{1}{h_1}\right)}$$

or

$$q_x = \frac{T_{f,2} - T_{f,1}}{R_{total}} \quad \text{where} \quad R_{total} = \frac{1}{h_2} + \frac{L}{k} + \frac{1}{h_1}$$

The total equivalant resistance is

$$R_{total} = \frac{1}{(100W/m^2{}^\circ C)} + \frac{0.3m}{(1.4W/m^\circ C)} + \frac{1}{(100W/m^2{}^\circ C)}$$
$$= 0.234\ \frac{m^2{}^\circ C}{W}$$

from which

$$q_x = \frac{[(20-(-20))\ ^\circ C]W}{0.234\ m^2{}^\circ C} = 170.7W/m^2$$

Because $q_{conv}(in) = q_x$, we may now write

$$170.7W/m^2{}^\circ C = \frac{T_{f,2} - T_{s,2}}{\left(\frac{1}{h_2}\right)} = \frac{20^\circ C - T_{s,2}}{\left(\frac{1}{100W/m^2{}^\circ C}\right)}$$

Solving for $T_{s,2}$ gives $T_{s,2}$= 18.29 °C. Similarly,

$$170.7W/m^2{}^\circ C = \frac{T_{s,1} - (-20^\circ C)}{\left(\frac{1}{100W/m^2{}^\circ C}\right)}$$

from which $T_{s,1}$= -18.29 °C.

We now have the surface temperatures on both sides of the wall and can show that these values compare well with those predicted by SINDA. We have yet to show, however, that the temperature distribution in the wall is linear. Beginning with Fourier's heat equation, we have

$$Q = kA\left(\frac{dT}{dx}\right) \quad \text{or} \quad q = \frac{Q}{A} = k\frac{dT}{dx} \tag{2}$$

For steady state conditions, q = constant. Therefore taking the derivative with respect to x, of both sides of equation 2 gives

$$\frac{d(\text{constant})}{dx} = \frac{d}{dx}\left(k\frac{dT}{dx}\right) = 0$$

Integrating twice, with respect to x, yields

$$T(x) = C_1x + C_2 \tag{3}$$

Substitution of the boundary conditions, T(0)= -18.29 °C and T(x=0.3m)= 18.29°C, into equation 3 gives

$$C_2 = -18.29°C$$

and

$$C_1 = \frac{18.29°C + 18.29°C}{0.3m} = 122°C/m$$

and equation 3 then becomes

$$T(x) = 122x - 18.29$$

Thus, the temperature distribution is indeed linear and the temperature at the mid-plane is zero. We are led to conclude, for the example considered that SINDA produces satisfactory results. A graphical comparison between the numerical (SINDA) and exact solutions is made in Figure 7, from which it may be seen that the two are in agreement.

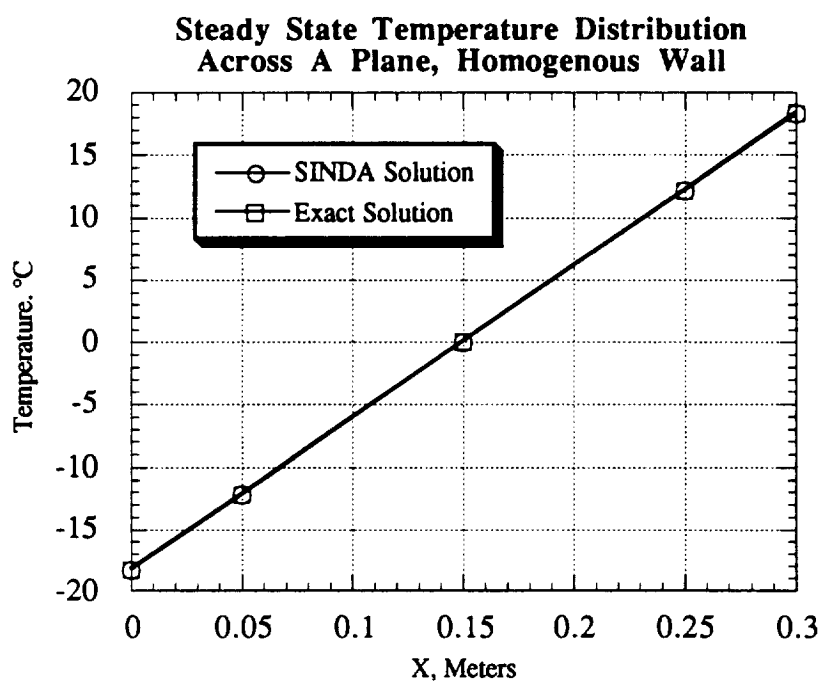


Figure 7. Comparison of results obtained using SINDA analyzer with those obtained from the exact solution to the problem.

V. Closing Comments:

None

VI. References:

A. Incropera, F.P. and DeWitt, D.P.; Fundamentalts of Heat Transfer; Copyright 1981 by John Wiely and Sons; New York; PP 66-68

CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 2: Transient Conduction through a Homogeneous, Semi-infinite Plane Wall with Convection on Two Sides

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A. Statement of the Problem:

Consider a homogeneous, semi-infinite, plane wall of constant thickness. The thickness of the wall is 0.30 m and the initial temperature of the wall is 20 °C. Fluid flows over the opposite faces of the wall such that the convective heat transfer coefficient, h, is 100 W/m^2°C. Given that the thermal conductivity, k, of the wall is 1.4 W/m°C and that the product of density and specific heat is

$$\rho C_p = 6070 \text{ W/m}^3\text{°C}$$

determine the temperature distribution across the wall after 15 sec.

B. Schematic:

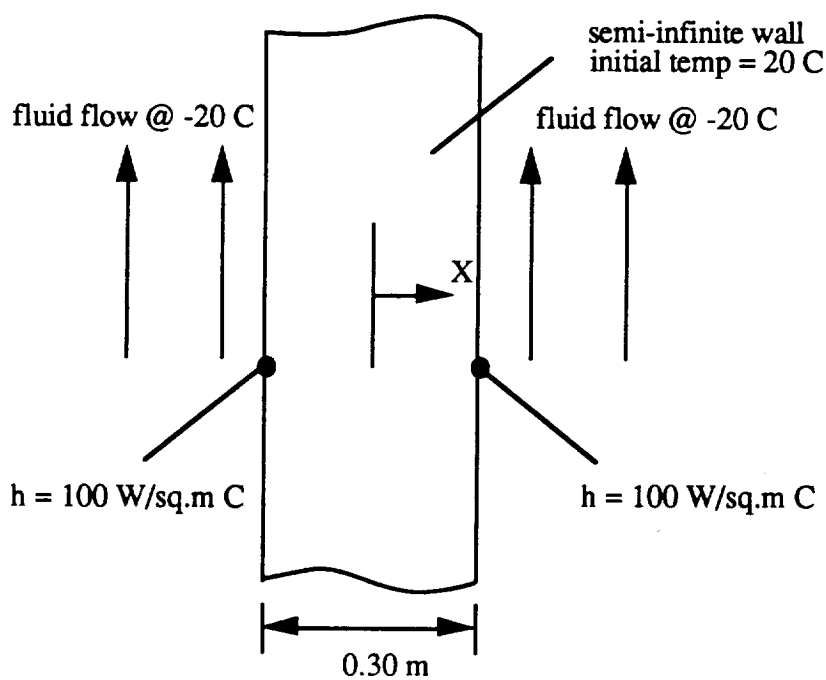


Figure 1. Homogeneous, semi-finite plane wall with convective heat transfer on opposing faces

C. **Given:**

1. Wall is homogeneous (i.e. has uniform thermophysical properties)
2. $h = 100\ W/m^2{}^\circ C$ = constant
3. Thickness of wall is constant; $L = 0.30$ m
4. Uniform initial temperature distribution; $T(x,0) = 20\ ^\circ C$
5. Constant free-stream temperature; $T(\pm\infty,t) = -20^\circ C$

D. **Find:**

1. Temperature distribution in the wall after 15 sec; $T(x,t)$ where $t = 15$ sec

II. Formulation of the Problem:

A. **Simplifying Assumptions:**

1. Constant thermophysical properties of the wall
2. Uniform initial temperature of the wall
3. A symmetrical temperature profile about the centerline Because the initial temperature distribution is uniform and the two fluid streams are at the same temperature, we may assume no heat flux at the center plane and analyze only half of the wall (because the temperature distribution will be symmetric about the center)
4. No internal heat generation

B. **Initial/Boundary Conditions:**

1. The one initial condition defines the starting temperature of the wall; $T(x,0) = 20\ ^\circ C$
2. Two boundary conditions apply to one-half of the wall. The extreme left-hand face of the section, shown in Figure 2, is considered as an adiabatic boundary; hence, the first boundary condition becomes $q\ (x=0,t) = 0$. The second condition considers the free stream temperature as a constant -20 °C.

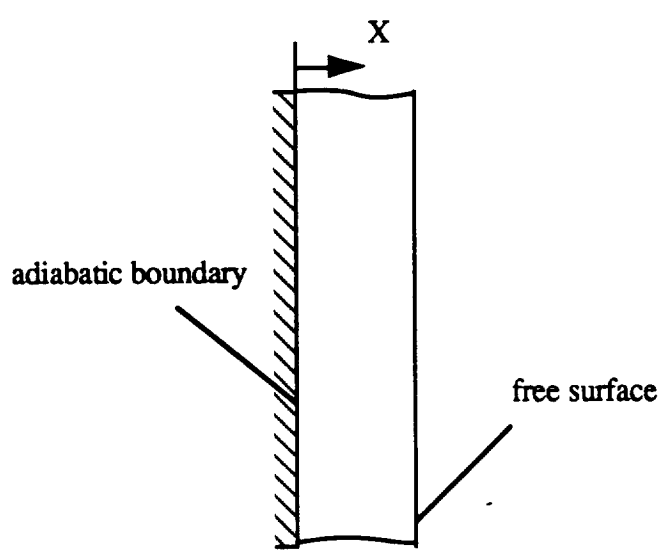


Figure 2. Half-section of a semi-infinite plane wall showing adiabatic and free surfaces

C: Discretization:

While development of a closed-form solution to the present example is a great deal more difficult than for the preceding problem, it shall be demonstrated that the SINDA model is no more difficult to build. Again, there are many number of (correct) ways to discretize the model. In this case, the half-section of the wall is represented using five diffusion nodes and two arithmetic nodes, located as shown in Figure 3. Five nodes have been so chosen to provide enough nodes to give a reasonably smooth temperature distribution without undue complexity or computation time. The adiabatic boundary is easily modeled by assuming no conductance between node 35 and the other half-section of the wall. A single boundary node represents the flowing fluid to the right of the half-section.

III. Analysis:

A. The Input Deck:

The input deck is presented is attached. Each of the five diffusion nodes has the same mass and thermal capacitance; similarly, initial nodal temperatures are equal. Arithmetic nodes have been defined at the center plane and at the exposed surface of the wall. By definition, these nodes have no thermal capacitance and respond instantly to heat addition or loss. Arithmetic nodes have been so chosen to obtain the temperatures at the adiabatic boundary and at the free surface. In all cases, convection and conduction conductances have been computed on a "per unit of area" basis. Since the wall is infinite in the y-direction, this (practice) is correct and quite common.

Three constants have been defined in the CONSTANTS data block, the first two of which are TIMEND and OUTPUT. The value of TIMEND simply limits the real-time duration of the transient analysis. The value of TIMEND has been set to 15 seconds as we are interested only in the transient temperature rise in the wall and the temperature distribution after 15 seconds. The control constant, OUTPUT = 1, prompts SINDA to print the desired information (nodal temperatures in this case) for every second.

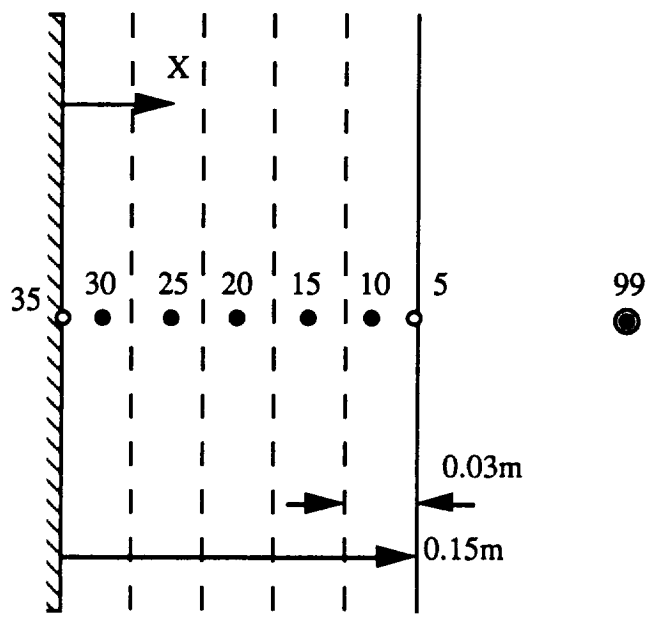


Figure 3. Nodal layout of the SINDA model

SINDA INPUT LISTING

```
        BCD 3THERMAL LPCS
        END
        BCD 3NODE DATA
            10,20.,182.1
            15,20.,182.1
            20,20.,182.1
            25,20.,182.1
            30,20.,182.1
            5,20.,-1.0
            35,20.,-1.0
            -99,-20.,0.0
        END
        BCD 3CONDUCTOR DATA
            510,5,10,93.33
            1015,10,15,46.67
            1520,15,20,46.67
            2025,20,25,46.67
            2530,25,30,46.67
            3035,30,35,93.33
            599,5,99,100.00
        END
        BCD 3CONSTANTS DATA
            TIMEND=15.,OUTPUT=1.
            NDIM=500
        END
        BCD 3ARRAY DATA
        END
        BCD 3EXECUTION
            SNFRDL
        END
        BCD 3VARIABLES 1
        END
        BCD 3VARIABLES 2
        END
        BCD 3OUTPUT CALLS
F       CALL TPRINT
        END
        BCD 3END OF DATA
```

IV. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are given on the following pages. The seven nodal temperatures are printed in degrees Celsius. Transient temperature distribution for times 0, 5, 10, and 15 seconds are shown in Figure 4.

SINDA OUTPUT LISTING

```
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*** NOTE *** SNFRDL REQUIRES      13 DYNAMIC STORAGE LOCATIONS OUT OF    485 AVAILABLE ***
             TIMEND=  15.000    , CSGFAC=  1.0000    , DTIMEI= 0.00000    , NLOOP =          10
             TIMEO = 0.00000    , OUTPUT=  1.0000    , DTIMEH= 0.10000E+09, DTIMEL= 0.00000
             ARLXCA= 0.10000    , ATMPCA= 0.10000E+09, DRLXCA= 0.00000    , DTMPCA= 0.10000E+09

****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   20.0000 T     15 =   20.0000 T     20 =   20.0000 T     25 =   20.0000 T     30 =   20.0000 T      5 =   20.0000
T     35 =   20.0000 T     99 =  -20.0000 T

****************
TIME= 1.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-2.06900E+01, DTMPCC(      0)= 0.00000E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   20.0000 T     15 =   20.0000 T     20 =   20.0000 T     25 =   20.0000 T     30 =   20.0000 T      5 =   -0.6900
T     35 =   20.0000 T     99 =  -20.0000 T

****************
TIME= 2.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-5.11914E+00, DTMPCC(     10)=-1.06040E+01
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =    9.3960 T     15 =   20.0000 T     20 =   20.0000 T     25 =   20.0000 T     30 =   20.0000 T      5 =   -5.8091
T     35 =   20.0000 T     99 =  -20.0000 T

****************
TIME= 3.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-2.45007E+00, DTMPCC(     10)=-5.07523E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =    4.3207 T     15 =   17.2823 T     20 =   20.0000 T     25 =   20.0000 T     30 =   20.0000 T      5 =   -8.2592
T     35 =   20.0000 T     99 =  -20.0000 T

****************
TIME= 4.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-1.50885E+00, DTMPCC(     10)=-3.12558E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =    1.1952 T     15 =   14.6569 T     20 =   19.3035 T     25 =   20.0000 T     30 =   20.0000 T      5 =   -9.7680
T     35 =   20.0000 T     99 =  -20.0000 T

****************
TIME= 5.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-1.04697E+00, DTMPCC(     15)=-2.25922E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -0.9736 T     15 =   12.3977 T     20 =   18.2911 T     25 =   19.8215 T     30 =   20.0000 T      5 =  -10.8150
T     35 =   20.0000 T     99 =  -20.0000 T

****************
TIME= 6.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-7.80640E-01, DTMPCC(     15)=-1.91650E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -2.5906 T     15 =   10.4812 T     20 =   17.1729 T     25 =   19.4750 T     30 =   19.9543 T      5 =  -11.5956
T     35 =   19.9543 T     99 =  -20.0000 T
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****************
TIME= 7.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-6.10718E-01, DTMPCC(     15)=-1.63514E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -3.8557 T     15 =    8.8461 T     20 =   16.0479 T     25 =   19.0079 T     30 =   19.8315 T      5 =  -12.2064
T     35 =   19.8315 T     99 =  -20.0000 T

****************
TIME= 8.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-4.94568E-01, DTMPCC(     15)=-1.40957E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -4.8803 T     15 =    7.4365 T     20 =   14.9608 T     25 =   18.4604 T     30 =   19.6204 T      5 =  -12.7009
T     35 =   19.6204 T     99 =  -20.0000 T

****************
TIME= 9.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(      5)=-4.11133E-01, DTMPCC(     15)=-1.22825E+00
    LOOPCT=      2                                                   , ARLXCC(      5)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -5.7319 T     15 =    6.2083 T     20 =   13.9293 T     25 =   17.8607 T     30 =   19.3231 T      5 =  -13.1121
T     35 =   19.3231 T     99 =  -20.0000 T

****************
TIME= 1.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(     35)=-3.74786E-01, DTMPCC(     15)=-1.08130E+00
    LOOPCT=      2                                                   , ARLXCC(     35)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -6.4543 T     15 =    5.1270 T     20 =   12.9581 T     25 =   17.2279 T     30 =   18.9483 T      5 =  -13.4608
T     35 =   18.9483 T     99 =  -20.0000 T

****************
TIME= 1.10000E+01, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(     35)=-4.40918E-01, DTMPCC(     15)=-9.61103E-0
    LOOPCT=      2                                                   , ARLXCC(     35)= 0.00000E+00, DRLXCC(      0)= 0.00000E+0

T     10 =   -7.0771 T     15 =    4.1659 T     20 =   12.0454 T     25 =   16.5745 T     30 =   18.5074 T      5 =  -13.7615
T     35 =   18.5074 T     99 =  -20.0000 T

****************
TIME= 1.20000E+01, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(     35)=-4.95361E-01, DTMPCC(     15)=-8.62022E-0
    LOOPCT=      2                                                   , ARLXCC(     35)= 0.00000E+00, DRLXCC(      0)= 0.00000E+

T     10 =   -7.6216 T     15 =    3.3038 T     20 =   11.1867 T     25 =   15.9091 T     30 =   18.0121 T      5 =  -14.0243
T     35 =   18.0121 T     99 =  -20.0000 T

****************
TIME= 1.30000E+01, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(     35)=-5.38940E-01, DTMPCC(     20)=-8.09980E
    LOOPCT=      2                                                   , ARLXCC(     35)= 0.00000E+00, DRLXCC(      0)= 0.00000E

T     10 =   -8.1031 T     15 =    2.5241 T     20 =   10.3767 T     25 =   15.2378 T     30 =   17.4731 T      5 =  -14.2567
T     35 =   17.4731 T     99 =  -20.0000 T
```

```
****************
TIME= 1.40000E+01, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(     35)=-5.72845E-01, DTMPCC(     20)=-7.66712E-01
    LOOPCT=     2                                                   , ARLXCC(     35)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -8.5334 T     15 =    1.8130 T     20 =    9.6100 T     25 =   14.5648 T     30 =   16.9002 T      5 =  -14.4645
T     35 =   16.9003 T     99 =  -20.0000 T
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****************
TIME= 1.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     30)= 1.30071E+00, ATMPCC(     35)=-5.98541E-01, DTMPCC(     20)=-7.20411E-01
    LOOPCT=     2                                                   , ARLXCC(     35)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   -8.9215 T     15 =    1.1596 T     20 =    8.8816 T     25 =   13.8935 T     30 =   16.3017 T      5 =  -14.6519
T     35 =   16.3017 T     99 =  -20.0000 T
```

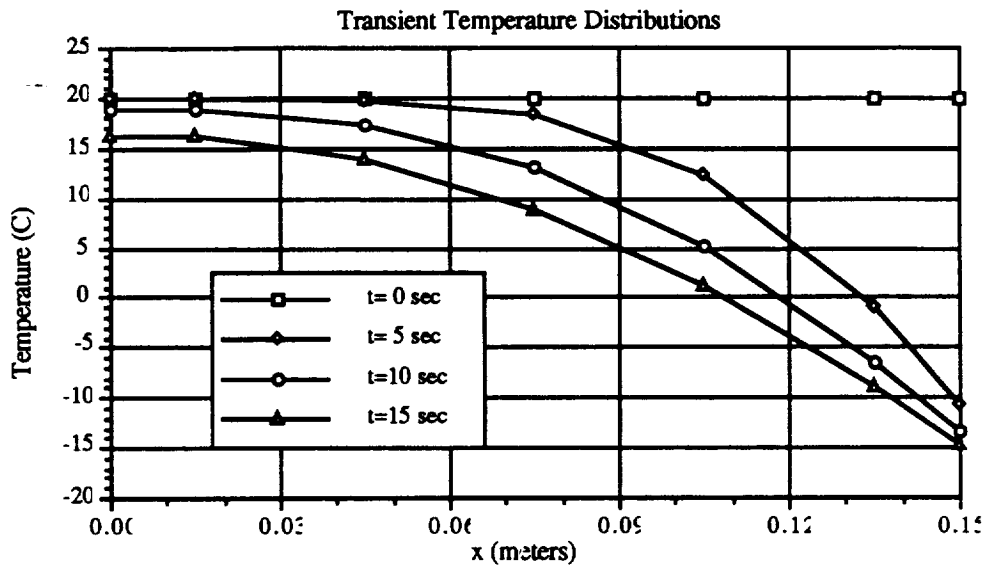

Figure 4. SINDA Transient temperature results

B. Generation of an Alternate (Exact) Solution:

Because the fluid temperatures on both sides of the wall are equal, the steady state temperature of the wall must be -20 °C. The problem, however, calls for the temperature distribution in the wall after 15 seconds. Since it is not known whether steady state conditions are reached after 15 seconds, a complete solution to the problem must be developed. Because the temperature distribution must be symmetric about the center of the wall, we may consider only one side of the wall and assume an adiabatic boundary at the inward facing side of the half-section. Considering the wall "element" shown in Figure 5, we may write

$$\Sigma\dot{E}_{in}=\dot{E}_{sto}+\Sigma\dot{E}_{out} \tag{1}$$

from which

$$\dot{q}_x=\dot{q}_{sto}+\dot{q}_{x+dx} \tag{2}$$

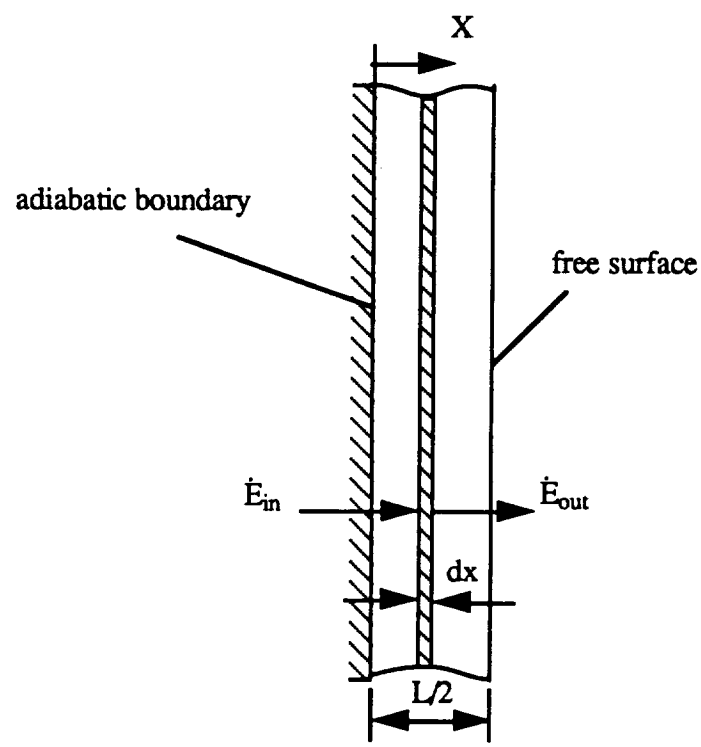

Figure 5. Energy balance on half-section of a semi-infinite plane wall

From equation (2), we may write

$$-kA\frac{\partial T}{\partial x} = \rho(Adx)C_p\frac{\partial T}{\partial t} + \left[-kA\frac{\partial T}{\partial x} - kA\left(\frac{\partial^2 T}{\partial x^2}\right)\right] \tag{3}$$

Simplifying and regrouping terms in (3) gives

$$0 = \rho C_p \frac{\partial T}{\partial t} - k\frac{\partial^2 T}{\partial x^2}$$

or

$$\frac{\partial^2 T}{\partial x^2} = \frac{\rho C_p}{k}\frac{\partial T}{\partial t} \tag{4}$$

We are now left to find a solution to (4) which satisfies the appropriate set of boundary conditions. The boundary conditions are:

1. no heat transfer across the adiabatic boundary such that

$$\dot{q}(x=0,t) = -kA\frac{\partial T(x=0,t)}{\partial x} \equiv 0$$

or, for constant thermal conductivity,

$$\frac{\partial T(x=0,t)}{\partial x} \equiv 0 \tag{5}$$

2. conduction and convective heat transfer are exactly balanced at the free surface of the section such that

$$\dot{q}_{cond}(x=L/2,t) = \dot{q}_{conv}(x=L/2,t)$$

or

$$-kA\frac{\partial T(x=L/2,t)}{\partial x} = hA\left[T(x=L/2) - T_\infty\right]$$

We may then write

$$\frac{\partial T(x=L/2,t)}{\partial x} = \frac{h}{k}\left[T(x=L/2) - T_\infty\right] \tag{6}$$

The one initial condition is $T(x,0) = 20$. So then, setting

$$\frac{\rho C_p}{k} = \frac{1}{\beta} \text{ and } -\frac{h}{k} = \alpha,$$

the complete problem is that of solving

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\beta}\frac{\partial T}{\partial t} \tag{7}$$

subject to

$$\frac{\partial T(x=0,t)}{\partial x} = 0 \tag{8}$$

$$\frac{\partial T(x=L/2,t)}{\partial x} = \alpha\left[T(l/2,t) - T_\infty\right] \tag{9}$$

and

$$T(x,0) = 20 \tag{10}$$

Having clearly defined the problem, we may now represent the solution, T(x,t), as the sum of its steady state and transient parts. Thus,

$$T(x,t) = w(x,t) + v(x) \tag{11}$$

In this case, the steady state solution is easily identified. Since there is no internal heat source and the fluid streams flowing on either side of the wall are at -20 C,

$$v(x) = -20\ C = \text{constant}$$

and

$$T(x,t) = w(x,t) - 20$$

Therefore, the transient part of the complete solution is given by

$$w(x,t) = T(x,t) + 20 \tag{12}$$

The transient part must satisfy the original partial differential equation (PDE) as well as the boundary and initial conditions. It follows from (12) that

$$\frac{\partial w}{\partial x} = \frac{\partial T}{\partial x};\quad \frac{\partial^2 w}{\partial x^2} = \frac{\partial^2 T}{\partial x^2};\quad \frac{\partial w}{\partial t} = \frac{\partial T}{\partial t} \tag{13}$$

and substitution of (13) in to the original PDE leaves us to solve

$$\frac{\partial^2 w}{\partial x^2} = \frac{1}{\beta}\frac{\partial w}{\partial t} \tag{14}$$

subject to

$$\frac{\partial w(x=0,t)}{\partial x} = 0 \tag{15}$$

$$\frac{\partial w(x=L/2,t)}{\partial x} = \alpha w(L/2,t) \tag{16}$$

and

$$w(x,0) = 40 \tag{17}$$

Setting w(x,t,) equal to the product of a function of x and a function of t, we may write

$$w(x,t) = \phi(x)\gamma(t) \tag{18}$$

such that

$$\frac{\partial w}{\partial x} = \phi'(x)\gamma(t) \tag{19}$$

$$\frac{\partial^2 w}{\partial x^2} = \phi''(x)\gamma(t) \tag{20}$$

and

$$\frac{\partial w}{\partial t} = \phi(x)\gamma'(t) \tag{21}$$

Substitution of (19), (20), and (21) into (14) gives

$$\phi''(x)\gamma(t) = \frac{1}{\beta}\phi(x)\gamma'(t)$$

or

$$\frac{\phi''(x)}{\phi(x)} = \frac{1}{\beta}\frac{\gamma'(t)}{\gamma(t)} \tag{22}$$

Since the right-hand side of (22) is a function only of t and the left-hand side is a function only of x, the equation is only satisfied when both sides are equal to the same non-zero constant; that is to say that

$$\frac{\phi''(x)}{\phi(x)} = C \tag{23}$$

$$\frac{1}{\beta}\frac{\gamma'(t)}{\gamma(t)} = C \tag{24}$$

These equations may be rewritten to obtain

$$\phi''(x) - C\phi(x) = 0 \tag{25}$$

and

$$\gamma'(t) - \beta C\gamma(t) = 0 \tag{26}$$

both of which are homogeneous differential equations. Setting C equal to a

negative constant, $-\lambda^2$, gives

$$\phi''(x) + \lambda^2\phi(x) = 0 \tag{27}$$

and

$$\gamma'(t) + \lambda^2\beta\gamma(t) = 0 \tag{28}$$

which have solutions of the form,

$$\phi(x) = A_1\cos\lambda x + A_2\sin\lambda x$$

and

$$\gamma(t) = A_3\exp\left(-\lambda^2\beta t\right),$$

respectively. The boundary conditions, (15), together with (19), yields

$$\frac{\partial w(x=0,t)}{\partial x} = \phi(0)\gamma'(t) = 0$$

which implies that

$$\phi'(0) \equiv 0$$

Hence,

$$\phi'(x) = -A_1\sin 0 + \lambda A_2\cos 0 = \lambda A_2 = 0$$

Since $\lambda \neq 0$, A_2 must be zero, identically, and

$$\phi(x) = A_1\cos\lambda x \tag{29}$$

The second boundary condition then gives

$$\frac{\partial w(x=L/2,t)}{\partial x} = \phi'(L/2)\gamma(t) = \alpha\phi(L/2)\gamma(t)$$

or

$$A_1\left[\alpha\cos(\lambda L/2) + \lambda\sin(\lambda L/2)\right] = 0$$

Since we cannot let $A_1 = 0$, as this leads to a trivial solution, the only choice is

$$\alpha\cos(\lambda L/2) + \lambda\sin(\lambda L/2) = 0$$

which leads to

$$1 + \frac{\lambda}{\alpha}\frac{\sin(\lambda L/2)}{\cos(\lambda L/2)} = 0$$

or

$$\tan(\lambda L/2) = -\frac{\alpha}{\lambda}$$

We are able to sketch the graphs of

$$f(\lambda) = \tan(\lambda L/2) \text{ and } g(\lambda) = -\alpha/\lambda.$$

The family of curves that defines the function, f, crosses the lambda-axis at even multiples of π/L and that which defines the function, g, asymptotically approaches zero, regardless of the values of h and k (which determine alpha). From the sketch of Figure 6, it is clear that there are an infinite number of values for lambda which satisfy

$$\tan(\lambda L/2) = -\alpha/\lambda$$

and that these values are generally very close to the zeros of the function, f. For n greater than or equal to one, we find that

$$\lambda_n = 19.88n - 10.4$$

gives good results, for all n. The relationship between lamda and n is obtained by plotting calculated values of lamda, as a function of n, and studying the nature and characteristics of the resulting curve. Fine tuning of the function is by trial-and-error.

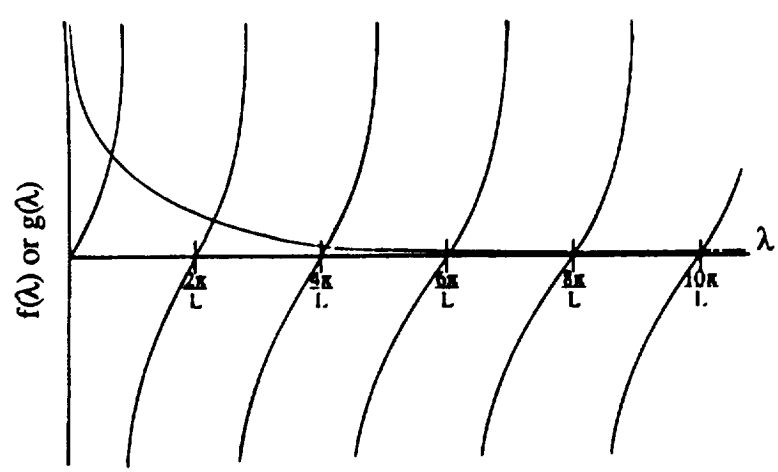

Figure 6. Sketch of functions, f and g

Referring back to the solutions to (27) and (28), it must be borne in mind that these differential equations, as well as the boundary conditions used to solve them, are homogeneous. Therefore, any constant multiple of a solution is also a solution and the constants, A_1 and A_2 may be omitted for the time being. The general form of the transient solution then becomes

$$w_n(x,t) = \phi_n\gamma(t) = \cos(\lambda_n x)\left[\exp(-\lambda_n^2\beta t)\right]$$

which may be shown to satisfy the original P.D.E., as well as the first boundary condition. Forming a linear combination of solutions, we may express the transient solution as

$$w_n(x,t) = \sum_{n=1}^{\infty} A_n\cos(\lambda_n x)\left[\exp(-\lambda_n^2\beta t)\right]$$

where

$$\lambda_n = 19.88n - 10.4$$

The full solution to the original problem (in T) becomes

$$T(x,t) = w(x,t) + v(x) = \sum_{n=1}^{\infty} A_n\cos(\lambda_n x)\left[\exp(-\lambda_n^2\beta t)\right] - 20$$

and we are left only to determine the constants, A_n , and, in doing so, satisfy the one initial condition. The initial condition is

$$w(x,0) = \sum_{n=1}^{\infty} A_n\cos(\lambda_n x) = 40$$

While (30) looks like a Fourier series, it is not. The eigenvalues, $\lambda_{1,2,3,\ldots,n}$ are not integer multiples of λ_1 and the series is, therefore, not a Fourier series. The coefficients, however, may still be evaluated using the principle of othogonality. It may be shown that

$$\int_0^{L/2} \cos\lambda_n x\cos\lambda_m x\,dx = 0 \text{ if } n\neq m \qquad (31)$$

Now then, if both sides of (30) are multiplied by

$$\cos\lambda_m x$$

where m is fixed, and the resulting equation is integrated from 0 to L/2, all the terms in the series vanish <u>except</u> the one for which n=m (due to (31)). The equation for A_m then becomes

$$A_m = \frac{\int_0^{L/2} 40\cos\lambda_m x\,dx}{\int_0^{L/2} \cos^2\lambda_m x\,dx}$$

$$= \frac{160 \sin (L\lambda/2)}{L\lambda + \sin(L\lambda)}$$

For the case where L = 0.30m, the complete solution to the problem at hand finally becomes

$$T(x,t) = \sum_{m=1}^{\infty} \left(\frac{160 \sin (0.15\lambda)}{0.30\lambda + \sin(0.30\lambda)} \right) \cos (\lambda x) \left[\exp(-\lambda^2 \beta t) \right] - 20$$

where

$$\lambda_m = 19.88m - 10.4$$

and

$$\beta = \frac{k}{\rho C_p} = (1.4W/mC)(6070W\ sec/m^2C)^{-1} = 2.31 \times 10^{-4} m^2/sec$$

The short code given on the following page was developed to expedite evaluation of the series in the temperature equation. Results obtained form the closed-form solution are given on page 1-2-20 and 21 for times of 10, 15, and 20 seconds. The temperature distribution at t = 15 seconds is compared with that predicted by SINDA, in Figure 7. In this case, the two sets of results compare favorably with one another.

V. Closing Comments:

It is immediately evident that the closed-form solution to the present example is very involved whereas the corresponding SINDA input deck is of the simplest type. In this case, use of SINDA leads to an acceptable solution with a minimal expenditure of time and effort

VI. References:

[1] Powers, D., Boundary Value Problems, 2nd Edition, Copyright 1979 by Academic Press, New York, pp 113-116.

Program Listing for the Exact Solution

```
      PROGRAM TX
      OPEN(UNIT=20,FILE='tx.out',STATUS='UNKNOWN')
         SUM=0.
       DO T=10,20,5
      WRITE(20,10)
10    FORMAT(//,10X,'TIME (SEC)',T25,'X (m)',T40,'TEMP (C)',/)
         DO X=0.,.15,.01
            SUM=0.
            DO XN =1.,50.,1.
               XLAM=(19.88*XN)-10.4
               AN=160.*(SIN(.15*XLAM))
               AN=AN/((.30*XLAM)+(SIN(.30*XLAM)))
               SUM=SUM+(AN*(COS(XLAM*X))*(EXP(-(XLAM**2.)*.0002310*T)))
            END DO
         TEMP=SUM-20.
         WRITE (20,20)T,X,TEMP
20       FORMAT(10X,F7.3,T25,F9.6,T40,F8.2)
         END DO
       END DO
       STOP
       END
```

Exact Solution Results

TIME (SEC)	X (m)	TEMP (C)
10.000	0.000000	18.80
10.000	0.010000	18.70
10.000	0.020000	18.42
10.000	0.030000	17.93
10.000	0.040000	17.20
10.000	0.050000	16.21
10.000	0.060000	14.92
10.000	0.070000	13.28
10.000	0.080000	11.28
10.000	0.090000	8.89
10.000	0.100000	6.08
10.000	0.110000	2.88
10.000	0.120000	-0.71
10.000	0.130000	-4.63
10.000	0.140000	-8.83
10.000	0.150000	-13.24

TIME (SEC)	X (m)	TEMP (C)
15.000	0.000000	16.12
15.000	0.010000	15.99
15.000	0.020000	15.60
15.000	0.030000	14.94
15.000	0.040000	14.00
15.000	0.050000	12.78
15.000	0.060000	11.28
15.000	0.070000	9.48
15.000	0.080000	7.39
15.000	0.090000	5.01
15.000	0.100000	2.35
15.000	0.110000	-0.57
15.000	0.120000	-3.73
15.000	0.130000	-7.09
15.000	0.140000	-10.62
15.000	0.150000	-14.27

TIME (SEC)	X (m)	TEMP (C)
20.000	0.000000	13.00
20.000	0.010000	12.86
20.000	0.020000	12.45
20.000	0.030000	11.77
20.000	0.040000	10.82
20.000	0.050000	9.60
20.000	0.060000	8.11
20.000	0.070000	6.37
20.000	0.080000	4.39
20.000	0.090000	2.16
20.000	0.100000	-0.28
TIME (SEC)	X (m)	TEMP (C)
20.000	0.110000	-2.92
20.000	0.120000	-5.74
20.000	0.130000	-8.71
20.000	0.140000	-11.80
20.000	0.150000	-14.97

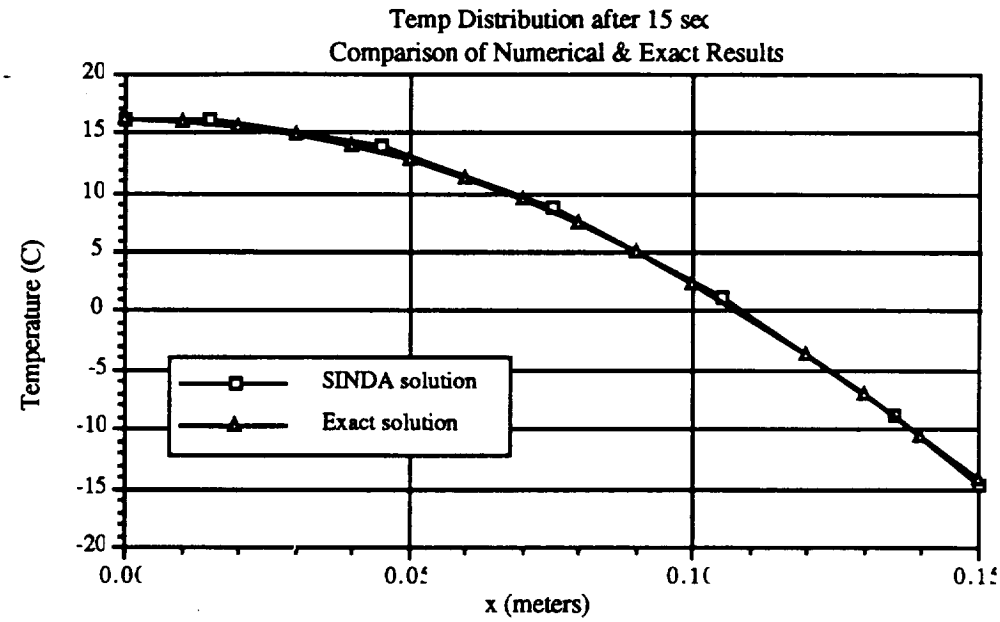

Figure 7. Comparison of SINDA and exact solution results

CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 3: -- **Steady State and Transient Conduction Through a Circular Rod, with Convection**

ANALYSIS CODE: **SINDA (Gaski Version)**

I. Identification of the Problem:

A. Statement of the Problem:

Consider a homogeneous circular rod between two walls. The two walls (Figure 1) are held at temperatures of 32 °F and 212 °F, respectively. The 0.167 ft diameter rod is 2 ft in length and is initially at a temperature of 70 °F. The heat transfer coefficient between the rod and the ambient air is 1.14 BTU/ft^2 hr R and the thermal conductivity of the rod is 9.4 BTU/ft hr R. Determine the transient temperature rise and the steady state temperature of the rod by four different methods including:

1. Closed-Form Solution of the differential equation of energy conservation
2. Network Analysis Method using SINDA
3. Finite Volume Method of solving energy conservation equation (Ref. 1)
4. Finite Element Method using ANSYS (steady state only)

B. Schematic:

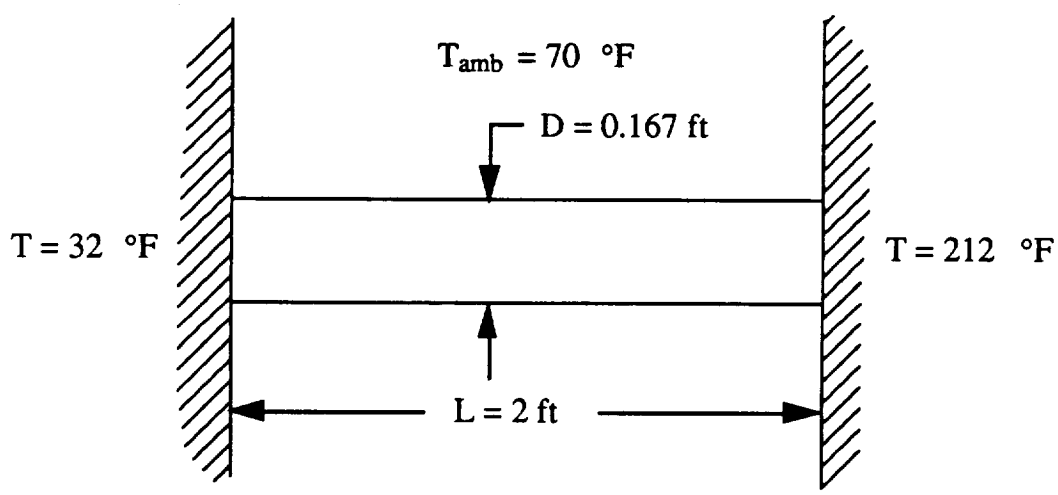

Figure 1. Schematic of Circular Rod Connected to Walls at Different Temperatures

C. Given:

The following data is given in this problem:

1. The rod is homogeneous (has uniform thermophysical properties)
2. The left wall temperature is 32 °F
3. The right wall temperature is 212 °F

4. The heat transfer coefficient between the rod and the ambient air is 1.14 BTU/hr-ft^2-°F
5. The thermal conductivity of the rod is 9.4 BTU/hr-ft-°F
6. The rod has uniform initial temperature distribution: T = 70 °F

D. Find:

The steady state and transient temperature distributions in the rod by the four methods mentioned above

II. Steady State Formulation of the Problem:

A. Closed-Form Solution

The differential equation of energy transport is given by

$$\frac{d^2T}{dx^2} - \frac{4h}{Dk}\left(T - T_\infty\right) = 0 \tag{1}$$

with the following boundary conditions

$$T(0) = 32\ °F$$

and

$$T(L) = 212\ °F$$

The closed-form solution to equation (1) is given by

$$T(x) - T_{amb} = c_1 e^{\xi x} + c_2 e^{-\xi x} \tag{2}$$

where $\xi = \sqrt{\frac{4h}{Dk}} = 1.714\ ft^{-1}$

$c_1 = 4.653$

$c_2 = -42.650$

$T_{amb} = 70\ °F$

B. Network Analysis Method Using SINDA

The solution to the heat conduction problem, using SINDA, involves the following steps:

1. Sub-division of the calculation domain into discrete control volumes
2. Definition of the node and conductor numbers
3. Calculation of the conductor and capacitance values
4. Definition of the solution control parameters

Discretization:

Figure 2 shows the nodal distribution used to create the SINDA model. The circular rod is sub-divided into eight equally spaced nodes, numbered 10 through

80. Temperatures are defined at the center of the control volumes. Nodes 10 through 80 are diffusion nodes, where the temperatures are to be calculated. The temperatures at the boundary nodes (-15, -55 and -85) are given. The boundary nodes are identified by negative signs.

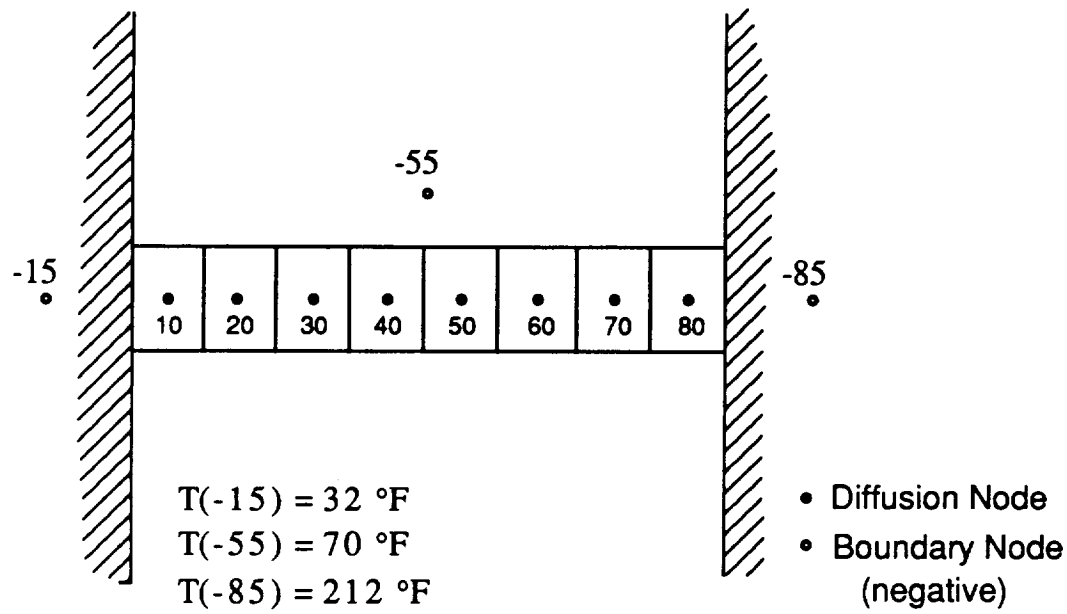

Figure 2. Discretization of the Calculation Domain into Control Volumes

Conductor Data:

The conductance values of conductors connecting specific pairs of nodes are calculated from the following expression

$$\text{Conductance} = \frac{\text{Thermal Conductivity x Cross-sectional Area}}{\text{Inter-nodal Distance}}$$

Table 1 gives the conductor numbers, the node numbers, and the conductor values. It is noted that the conductance values of conductors connecting the boundary (wall) nodes to adjacent diffusion nodes are twice the values of the conductances between interior nodes; this is due to the fact that the inter-nodal distance is half as large between diffusion and boundary nodes (see Figure 2).

Solution Control Parameters:

The maximum number of iterations is set to 1000. The iterative solution will terminate after 1000 iterations and may terminate earlier if the energy conservation error is less than a pre-specified small number of 0.0001.

SINDA Input Listing:

In the "NODE DATA" block, the initial temperatures of the diffusion nodes and their respective capacitances are defined. This particular problem is a steady state problem; therefore, the capacitances were set to unity. The temperatures of the

boundary nodes are also specified. In the "CONDUCTOR DATA" block, the conductor numbers, node numbers, and their respective conductor values are defined (see Table 1). The SINDA input listing (steady state) is given on page 1-3-14.

Conductor Number	Node Number	Node Number	Conductor Value (BTU/hr-°F)
1510	15	10	1.6394
1020	10	20	0.8197
1055	10	55	0.1492
2030	20	30	0.8197
2055	20	55	0.1492
3040	30	40	0.8197
3055	30	55	0.1492
4050	40	50	0.8197
4055	40	55	0.1492
5060	50	60	0.8197
5055	50	55	0.1492
6070	60	70	0.8197
6055	60	55	0.1492
7080	70	80	0.8197
7055	70	55	0.1492
8055	80	55	0.1492
8085	80	85	1.6394

Table 1. Definition of Conductor Numbers and their Values

C. Finite Volume Method of Solving the Energy Conservation Equation

The Finite Volume Method consists of three basic steps:

1. Sub-division of the domain into discrete control volumes
2. Derivation of conservation equations in algebraic form
3. Solution of conservation equations

The first step is to divide the circular rod into a finite number of control volumes, as shown in Figure 3.

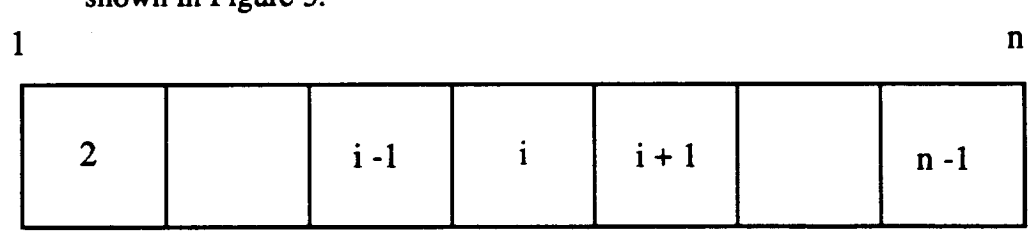

Figure 3. Division of the Circular Rod into a Finite Number of Control Volumes

Temperatures are calculated at the center of the control volumes. Boundary temperatures are specified at the surface of the boundaries. The next task is to obtain a finite volume equation which is an algebraic relation connecting the temperature at the ith control volume with the (i - 1)th and the (i + 1)th control volume. This relation is derived from the application of the energy conservation law for the ith control volume. Let us denote the temperature of the ith control volume as T_P and the temperatures of the (i - 1)th and (i + 1)th control volumes as T_W and T_E, respectively. Figure 4 shows a typical control volume.

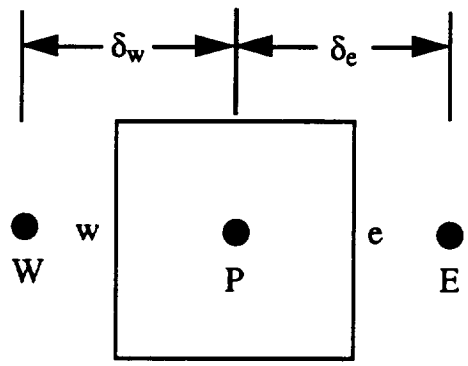

Figure 4. Schematic of the ith Control Volume

The rate of heat transport through the west face (Figure 4) is given by

$$\dot{q}_{in} = -kA\frac{dT}{dx}_{w} = -(kA)_w \frac{T_P - T_W}{\delta_w}$$

and the rate of heat transport through the east face is given by

$$\dot{q}_{out} = -kA\frac{dT}{dx}_{e} = -(kA)_e \frac{T_E - T_P}{\delta_e}$$

Under steady-state conditions,

$$\dot{q}_{in} = \dot{q}_{out}$$

and $$-(kA)_w \frac{T_P - T_W}{\delta_w} = -(kA)_e \frac{T_E - T_P}{\delta_e}$$

or $$T_P\left[\frac{(kA)_w}{\delta_w} + \frac{(kA)_e}{\delta_e}\right] = \frac{(kA)_w}{\delta_w} T_W + \frac{(kA)_e}{\delta_e} T_E$$

or $$a_P T_P = a_W T_W + a_E T_E \qquad (3)$$

where $a_E = \frac{(kA)_e}{\delta_e}$

$$a_W = \frac{(kA)_w}{\delta_w}$$

$$a_P = a_E + a_W$$

As noted from equation (3), the temperature at point P is influenced by the temperatures of its east and west neighbors. The influence of the neighboring node could be quite strong when the product of the conductivity and surface area is large or the distance between nodes is small.

Equation (3) can be rewritten in terms of the index, i and becomes

$$a_i T_i = b_i T_{i+1} + c_i T_{i-1} \tag{3a}$$

where $a_i = b_i + c_i$

and $b_i = \frac{(kA)_e}{x_{i+1} - x_i}$

and $c_i = \frac{(kA)_w}{x_i - x_{i-1}}$

The next task is to solve the finite volume equation (3a). There are eight equations corresponding to each control volume. It is noted that the finite volume formulation uses an identical discretization of nodes as in the SINDA model (Figure 2). Therefore, the total number of control volumes is the same as the number of diffusion nodes in SINDA. The location of nodes are identical in both models.

The set of simultaneous equations is solved using a "point-by-point" Jacobian method where

$$i = 2,\ N - 1$$

and

$$T_i = \frac{(b_i T_{i+1} + c_i T_{i-1})}{a_i}$$

The loop is repeated until the difference in temperature at each point in successive iterations becomes sufficiently small.

D. Finite Element Method Using ANSYS

The Finite Element Method (FEM) was initially developed to calculate stresses in irregularly shaped objects and to analyze structural problems in aircraft. The underlying advantage of the FEM is its ability to easily solve problems described by complex boundary shapes. In recent years, the FEM methods have also been found effective in heat transfer problems.

In many analytical methods, the differential equations are solved with the series expansion of the functions themselves. In a typical series expansion, an infinite number of global basis functions (sines, cosines, etc.) span the entire domain. The coefficients of the series are determined from the boundary conditions. However, in the FEM, only a finite number of basis functions that are local in nature (nonzero over only a small segment of the domain) are employed. With the use of local basis functions, the coefficient matrices that result from the approximation procedure of the governing equation became banded and sparse. Conventional Finite Difference and Finite Volume procedures also produce banded sparse matrices with different approximation procedures of the governing equation. However, in the FEM, the resulting matrices become considerably fuller due to the greater degree of coupling among nodes. The system of equations is then solved by matrix solution techniques.

The finite element solution of the present problem was obtained using ANSYS. Ten nodes have been used. Of the ten nodes, three were boundary nodes, and temperatures were obtained in the other seven nodes. Two of the boundary nodes represent wall temperatures of the two ends of the rod. The third boundary node represents the ambient temperature.

The resulting equation becomes

$$[K]\{T\} = \{Q\}$$

where

$$[K] = \begin{bmatrix} \frac{2KA_c}{\Delta x} + hA_s & -\frac{KA_c}{\Delta x} & \\ -\frac{KA_c}{\Delta x} & \frac{2KA_c}{\Delta x} + hA_s & -\frac{KA_c}{\Delta x} \\ & -\frac{KA_c}{\Delta x} & \frac{2KA_c}{\Delta x} + hA_s \end{bmatrix}$$

$$\{T\} = \begin{Bmatrix} T_2 \\ T_3 \\ T_9 \end{Bmatrix}$$

$$\{Q\} = \begin{Bmatrix} \frac{T_1 KA}{\Delta x} + T_\infty h A_s \\ T_\infty h A_s \\ \frac{T_9 KA}{\Delta x} + T_\infty h A_s \end{Bmatrix}$$

The above equation can be rewritten as

$$\{T\} = [K]^{-1} \{Q\}$$

Gaussian elimination was used to solve the matrix.

The input file for ANSYS is listed on page 1-3-19. The corresponding output file follows. The solution converges in two iterations and the converged temperature distribution is given on page 1-3-23. Also provided are the heat rates between the nodes. The negative sign in the calculated heat rate indicates that heat "flows" in the negative x-direction.

E. Presentation and Discussion of Results:

The analytical solution, the numerical solution (SINDA), the finite volume solution, and the finite element solution (ANSYS) are compared in Figure 5. All three numerical solutions compared well with the analytical solution. Figure 5 also shows the solution with no convection. Without convective heat loss, the temperature distribution within the rod is linear.

III. Formulation of the Transient Problem:

The initial temperature of the rod is assumed to be at 70 °F. At $\tau = \infty$, the steady state solution is obtained.

A. Closed Form Solution

The differential equation which determines the transient temperature distribution in the circular rod can be written as

$$\alpha \frac{dT}{d\tau} = \frac{\partial^2 T}{\partial x^2} - \xi^2 (T - T_\infty) \tag{4}$$

where

$$\alpha = \frac{\rho c}{k} \tag{4a}$$

$$\xi^2 = \frac{4h}{Dk} \tag{4b}$$

The boundary conditions are

$$T(0,t) = 32°F, \quad T(L,t) = 212°F$$

and the initial condition is

$$T(x,0) = 70°F.$$

The analytical solution to equation (4) may be obtained using the method of separation of variables. In this case, the complete transient solution is expressed as the sum of its steady state and transient parts, whereupon the two "components" of the complete solution are developed, separately. A rigorous development of the analytical solution has been omitted for the sake of brevity. The solution can be written as

$$T(x,\tau) = \sum_{n=1}^{\infty} \left[\frac{59.7n + 222.9n\cos n\pi}{2.938 + 2.467n^2}\right]\left[\sin\frac{n\pi x}{2}\right]$$

$$\left[\exp\left(-0.097\left(\frac{n^2\pi^2}{4} + 2.936\right)\tau\right)\right] + 4.65e^{1.714x} - 42.65e^{-1.714x} + 70$$

where the three terms on the far right-hand side of the equation represent the steady state part of the solution. The series denotes the transient part.

B. Network Analysis Method Using SINDA:

The steps to obtain the transient solution using SINDA are similar to those of the steady state solution described in the previous section. Transient calculations, however, require additional information to calculate capacitances of the nodes and the parameters for performing integration in time. These parameters include the end time and time step which are required for integration. The nodal distribution is similar to that shown in Figure 2.

Capacitance Data:

The capacitances of the nodes are calculated from the following expression

Capacitance = Density x Specific Heat x Volume

The SINDA input listing for the transient problem is given on page 1-3-14.

C. Finite Volume Method of Solving the Unsteady Energy Conservation Equation:

Discretization of the solution domain is identical to the steady state case. Derivation of the unsteady energy conservation equation, however, requires inclusion of the resident energy of the node given by

$$\dot{q}_R = (\rho V c_p)\frac{T_P - T_P^-}{\delta\tau}$$

The unsteady energy conservation equation, therefore, can be written as

$$\dot{q}_{in} = \dot{q}_R + \dot{q}_{out}$$

$$-(kA)_w \frac{T_P - T_W}{\delta_w} = (\rho V c_p)\frac{T_P - T_P^-}{\delta\tau} - (kA)_e \frac{T_E - T_P}{\delta_e}$$

$$T_P\left[\frac{\rho V c_p}{\delta\tau} + \frac{(kA)_w}{\delta w} + \frac{(kA)_e}{\delta e}\right] = \frac{\rho V c_p}{\delta\tau} T_P^- + \frac{(kA)_w}{\delta w} T_W + \frac{(kA)_e}{\delta e} T_E$$

$$a_P\, T_P = a_T\, T_P^- + a_W\, T_W + a_E\, T_E \qquad (5)$$

where $a_T = \dfrac{\rho V c_p}{\delta\tau}$

and $a_W = \dfrac{(kA)_w}{\delta w}$

and $a_E = \dfrac{(kA)_e}{\delta e}$

and $a_P = a_T + a_W + a_E$

It may be noted that equation (5) has an additional $a_T T_P^-$ term which did not appear in the steady state formulation (Equation 3). The temperature at point P is influenced by the temperature prevailing at the same point, at the previous time. The influence of the earlier time would be large if the node has a large thermal inertia (product of mass and specific heat) and/or if the time step is very small.

Equation (5) can now be solved using a "point-by-point" Jacobian method, as described in the previous section. The FORTRAN listing of the computer program, based upon the Finite Volume method, is given on pages 1-3-17 and 1-3-18.

D. Presentation and Discussion of Results:

The analytical solution, the numerical solution (SINDA) and the finite volume solution are compared after 30 minutes in Figure 6. The temperature distributions in the rod at two other times are shown in Figures 7 and 8. Figure 7 shows the comparison of the three different solutions after 1 hour. Figure 8 shows the solutions after 8 hours.

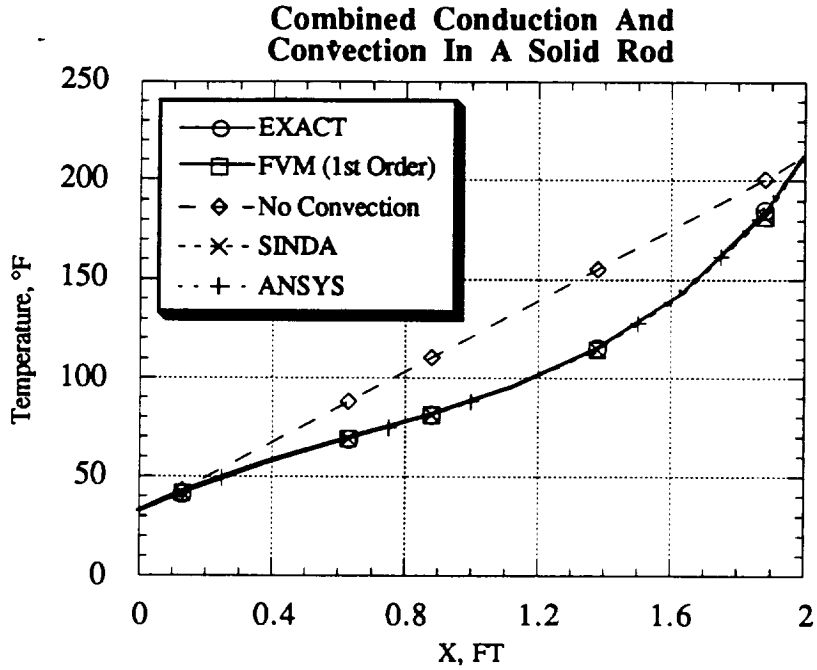

Figure 5. Steady State Solution

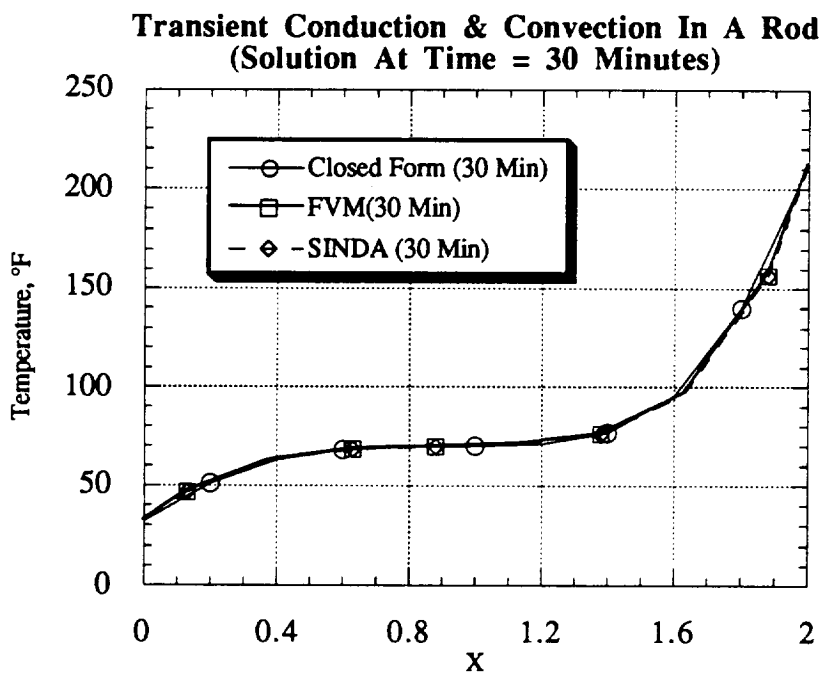

Figure 6. Transient Solution After Thirty Minutes

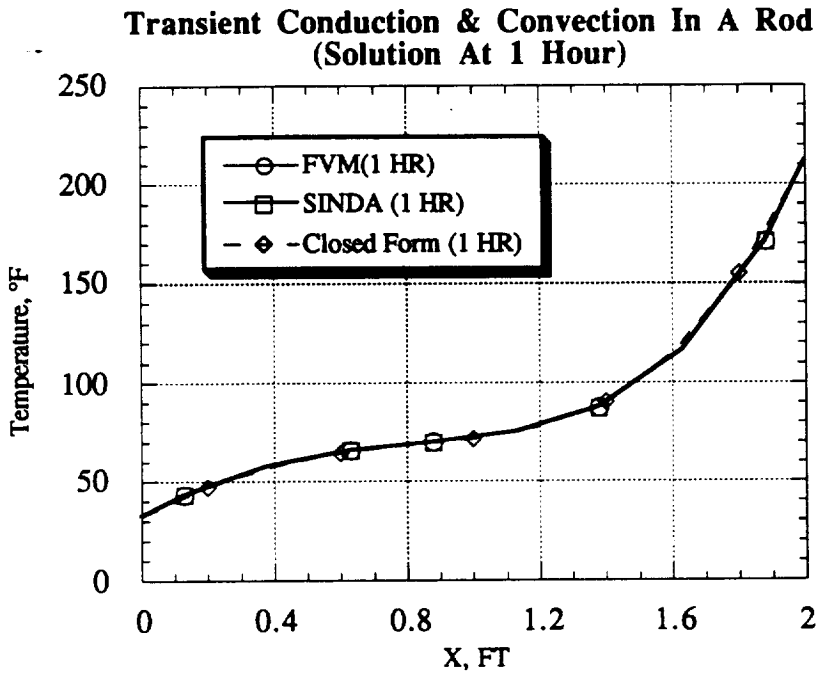

Figure 7. Transient Solution After One Hour

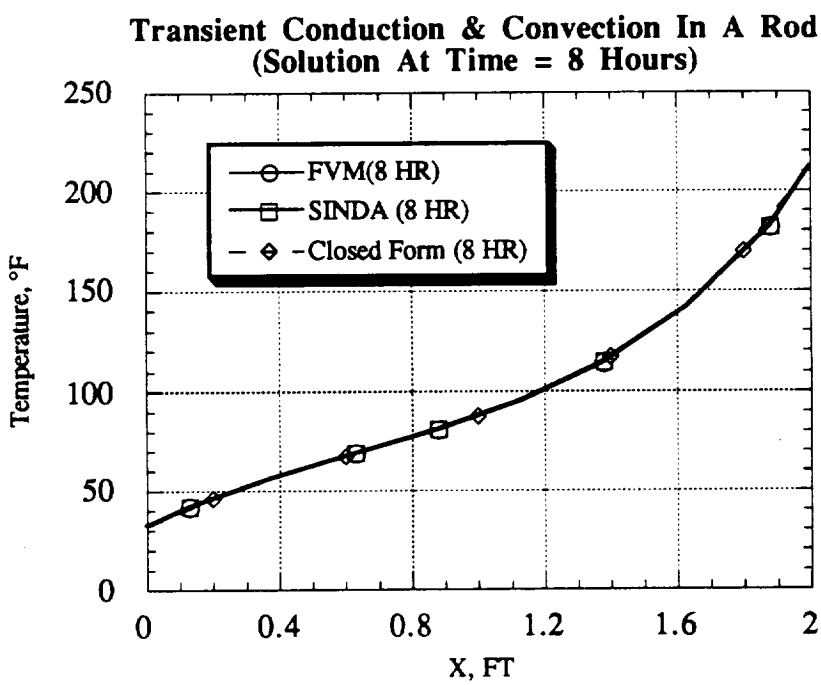

Figure 8. Transient Solution After Eight Hours

SINDA INPUT LISTING (STEADY STATE)

```
BCD 3THERMAL LPCS
BCD 9COMBINED CONDUCTION & CONVECTION FROM HEATED ROD
BCD 9STEADY-STATE SOLUTION TO COMPARE WITH ANALYTICAL DATA
END
BCD 3NODE DATA
    10,70.,1.$NODES FOR TEMPERATURE CALCULATION
    20,70.,1.
    30,70.,1.
    40,70.,1.
    50,70.,1.
    60,70.,1.
    70,70.,1.
    80,70.,1.
    -85,212.,1.$EAST BOUNDARY NODE;T=212 DEG F
    -55,70.,1.$NODE REPRESENTING AMBIENT;T=70 DEG F
    -15,32.,1.$WEST BOUNDARY NODE;T=32 DEG F
END
BCD 3CONDUCTOR DATA
    1510,15,10,1.6394
    1020,10,20,0.8197
    1055,10,55,0.1492
    2030,20,30,0.8197
    2055,20,55,0.1492
    3040,30,40,0.8197
    3055,30,55,0.1492
    4050,40,50,0.8197
    4055,40,55,0.1492
    5060,50,60,0.8197
    5055,50,55,0.1492
    6070,60,70,0.8197
    6055,60,55,0.1492
    7080,70,80,0.8197
    7055,70,55,0.1492
    8085,80,85,1.6394
    8055,80,55,0.1492
END
BCD 3CONSTANTS DATA
    NDIM=500
    NLOOP=1000
    BALENG=.001
    DRLXCA=.01
    ARLXCA=.01
END
BCD 3ARRAY DATA
END
BCD 3EXECUTION
    STDSTL
END
BCD 3VARIABLES 1
END
BCD 3VARIABLES 2
END
BCD 3OUTPUT CALLS
    TPRINT
END
BCD 3END OF DATA
```

SINDA INPUT LISTING (TRANSIENT)

```
        BCD 3THERMAL LPCS
        BCD 9COMBINED CONDUCTION & CONVECTION FROM HEATED ROD
        BCD 9TRANSIENT SOLUTION TO COMPARE WITH ANALYTICAL DATA
        END
        BCD 3NODE DATA
C           N#,#N , IN,  T,  CP, RHO,   A ,  L
        GEN 10, 8, 10, 70.,.1981,487.51,.021904,.25
            -85,212.,0.$EAST BOUNDARY NODE;T=212 DEG F
            -55,70.,0.$NODE REPRESENTING AMBIENT;T=70 DEG F
            -15,32.,0.$WEST BOUNDARY NODE;T=32 DEG F
        END
        BCD 3CONDUCTOR DATA
C           CONVECTION TO AMBIENT
C           G#, #G,  IG, NA, IA, NB, IB,  H,    A,   1., 1.
        GEN 1,   8,   1, 10, 10, 55,  0,3.167E-04,.1309,1., 1.
C           CONDUCTION IN THE ROD
C           G#, #G,  IG, NA, IA, NB, IB,  K,    A,   1., L
        GEN 10,  7,   1, 10, 10, 20, 10,2.6111E-03,.0218,   1.,.25
C           G#, NA,NB,  K,   A,  1.,  L
        CAL 20, 15,10,2.6111E-03,.0218,1.,.125
        CAL 21, 80,85,2.6111E-03,.0218,1.,.125
        END
        BCD 3CONSTANTS DATA
            NDIM=500
            NLOOP=100
            TIMEND=3600.
            DTIMEI=1.
            OUTPUT=200.
            BALENG=.0001
            DRLXCA=.001
            ARLXCA=.001
        END
        BCD 3ARRAY DATA
        END
        BCD 3EXECUTION
            FWDBKL
        END
        BCD 3VARIABLES 1
        END
        BCD 3VARIABLES 2
        END
        BCD 3OUTPUT CALLS
            TPRINT
        END
        BCD 3END OF DATA
```

SINDA OUTPUT LISTING (TRANSIENT)

```
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    COMBINED CONDUCTION & CONVECTION FROM HEATED ROD      TRANSIENT SOLUTION TO COMPARE WITH ANALYTICAL DATA

*** NOTE *** FWDBKL REQUIRES      59 DYNAMIC STORAGE LOCATIONS OUT OF     472 AVAILABLE ***
             TIMEND=  3600.0     , CSGFAC=  1.0000     , DTIMEI=  1.0000     , NLOOP =          100
             TIMEO = 0.00000     , OUTPUT=  200.00     , DTIMEH= 0.10000E+09, DTIMEL= 0.00000
             ARLXCA= 0.10000E-02, ATMPCA= 0.00000     , DRLXCA= 0.10000E-02, DTMPCA= 0.10000E+09
             EXTLIM=  50.000

****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
    LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 =   70.0000 T     20 =   70.0000 T     30 =   70.0000 T     40 =   70.0000 T     50 =   70.0000 T     60 =   70.0000
T     70 =   70.0000 T     80 =   70.0000 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 2.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 9.33838E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 6.10352E-05

T     10 =   64.2688 T     20 =   69.7542 T     30 =   69.9958 T     40 =   70.0000 T     50 =   70.0000 T     60 =   70.0239
T     70 =   70.9005 T     80 =   91.4150 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 4.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 7.18994E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     80)= 0.00000E+00

T     10 =   59.8771 T     20 =   69.1556 T     30 =   69.9515 T     40 =   70.0000 T     50 =   70.0046 T     60 =   70.1692
T     70 =   73.1238 T     80 =  107.8218 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 6.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 5.57861E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     80)= 0.00000E+00

T     10 =   56.4852 T     20 =   68.3550 T     30 =   69.8577 T     40 =   70.0000 T     50 =   70.0280 T     60 =   70.4998
T     70 =   76.1150 T     80 =  120.4965 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 8.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 4.37012E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     60)= 6.10352E-05

T     10 =   53.8407 T     20 =   67.4438 T     30 =   69.7123 T     40 =   69.9840 T     50 =   70.0745 T     60 =   71.0271
T     70 =   79.5035 T     80 =  130.3760 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 1.00000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 3.45459E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     80)= 0.00000E+00

T     10 =   51.7589 T     20 =   66.4932 T     30 =   69.5158 T     40 =   69.9658 T     50 =   70.1658 T     60 =   71.7484
T     70 =   83.0474 T     80 =  138.1507 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 1.20000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 2.76489E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     80)= 0.00000E+00

T     10 =   50.1048 T     20 =   65.5427 T     30 =   69.2797 T     40 =   69.9393 T     50 =   70.3028 T     60 =   72.6320
T     70 =   86.5911 T     80 =  144.3299 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T
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    COMBINED CONDUCTION & CONVECTION FROM HEATED ROD      TRANSIENT SOLUTION TO COMPARE WITH ANALYTICAL DATA

****************
TIME= 1.40000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 2.23389E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     80)= 0.00000E+00

T     10 =   48.7757 T     20 =   64.6185 T     30 =   69.0084 T     40 =   69.9076 T     50 =   70.4913 T     60 =   73.6528
T     70 =   90.0357 T     80 =  149.2911 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 1.60000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     80)= 1.81885E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     80)= 0.00000E+00

T     10 =   47.6974 T     20 =   63.7368 T     30 =   68.7114 T     40 =   69.8829 T     50 =   70.7297 T     60 =   74.7793
T     70 =   93.3256 T     80 =  153.3174 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 1.80000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 1.50146E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   46.8135 T     20 =   62.9044 T     30 =   68.3961 T     40 =   69.8574 T     50 =   71.0194 T     60 =   75.9845
T     70 =   96.4289 T     80 =  156.6186 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 2.00000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 1.39771E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   46.0808 T     20 =   62.1272 T     30 =   68.0710 T     40 =   69.8331 T     50 =   71.3550 T     60 =   77.2444
T     70 =   99.3333 T     80 =  159.3548 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 2.20000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 1.30005E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   45.4672 T     20 =   61.4055 T     30 =   67.7336 T     40 =   69.8131 T     50 =   71.7231 T     60 =   78.5335
T     70 =  102.0366 T     80 =  161.6460 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 2.40000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 1.20850E-02
    LOOPCT=     2                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(     60)= 6.10352E-05

T     10 =   44.9492 T     20 =   60.7368 T     30 =   67.3978 T     40 =   69.8033 T     50 =   72.1296 T     60 =   79.8383
```

```
T     70 =  104.5435 T     80 = -163.5842 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T
****************
TIME= 2.60000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 1.11694E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   44.5063 T     20 =   60.1177 T     30 =   67.0682 T     40 =   69.7979 T     50 =   72.5665 T     60 =   81.1409
T     70 =  106.8636 T     80 =  165.2396 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 2.80000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 1.03149E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   44.1248 T     20 =   59.5480 T     30 =   66.7510 T     40 =   69.7997 T     50 =   73.0305 T     60 =   82.4302
T     70 =  109.0081 T     80 =  166.6650 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T
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    COMBINED CONDUCTION & CONVECTION FROM HEATED ROD      TRANSIENT SOLUTION TO COMPARE WITH ANALYTICAL DATA

****************
TIME= 3.00000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 9.46045E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   43.7939 T     20 =   59.0236 T     30 =   66.4426 T     40 =   69.8160 T     50 =   73.5168 T     60 =   83.7009
T     70 =  110.9899 T     80 =  167.9051 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 3.20000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 8.78906E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   43.5049 T     20 =   58.5410 T     30 =   66.1559 T     40 =   69.8487 T     50 =   74.0247 T     60 =   84.9409
T     70 =  112.8220 T     80 =  168.9902 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 3.40000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 8.11768E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   43.2493 T     20 =   58.0984 T     30 =   65.8871 T     40 =   69.8983 T     50 =   74.5486 T     60 =   86.1472
T     70 =  114.5165 T     80 =  169.9481 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T

****************
TIME= 3.60000E+03, DTIMEU= 1.00000E+00, CSGMIN(     80)= 7.29930E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     70)= 7.56836E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     70)= 0.00000E+00

T     10 =   43.0239 T     20 =   57.6920 T     30 =   65.6335 T     40 =   69.9561 T     50 =   75.0781 T     60 =   87.3159
T     70 =  116.0840 T     80 =  170.7984 T     85 =  212.0000 T     55 =   70.0000 T     15 =   32.0000 T
```

FORTRAN PROGRAM LISTING

```
C*********************************************************************
C     A COMPUTER PROGRAM TO SOLVE FOR 1D TRANSIENT HEAT CONDUCTION
C                              EQUATION
C
C                            JANUARY,1990
C*********************************************************************
C     VARIABLES
C     T(I)- TEMPERATURES
C     TM(I)-TEMPERATURES AT THE PREVIOUS TIME-STEP
C     TAU  -TIME
C     XG(I)-X-CO-ORDINATE OF FORWARD FACE OF THE CONTROL VOLUME
C     XN(I)-X-CO-ORDINATE OF CENTER OF THE CONTROL VOLUME
C     AXP(I)-COEFFICIENT CONNECTING WEST POINT
C     AXM(I)-COEFFICIENT CONNECTING EAST POINT
C     AP(I)- COEFFICIENT OF THE POINT
C     AT(I)- COEFFICIENT CONNECTING PREVIOUS TIME
C**   HEAT SOURCE IS EXPRESSED AS Q =  SU(I)+SP(I)*T(I)
C     SU(I)- CONSTANT OF SOURCE TERM
C     SP(I)- COEFFICIENT OF TEMPERATURE IN SOURCE TERM
C     TIME(I)- GIVEN TIME WHEN HEATFLUX ARE SPECIFIED
C     HFLX(I)- GIVEN HEATFLUX AT THE BOUNDARY
C*****************************************************************
      DIMENSION T(12),TM(12),XG(12),XN(12),AXP(12),AXM(12)
     &          ,AP(12),AT(12),TIME(52),HFLX(52),DHFDT(52),SU(12)
     &          ,SP(12)
      INTEGER OPTION
      REAL K
      LOGICAL PRNT
      DATA TINIT/70./
      DATA NITER/100/
      DATA XL/2.0/
      DATA XG/0.,0.125,0.250,0.375,0.500,0.625,0.750,0.875,1.00,3*1./
      DATA XN/0.,.0625,.1875,.3125,.4375,.5625,.6875,.8125,.9375,3*1./
      DATA NX/10/
      DATA CC/1.E-6/
      DATA DTAU/1.E06/
      DATA TAUF/1./
      DATA RHO,CP/79.48,.42/
      DATA A,K/0.0218,0.00261/
      DATA AS/0.1309/
      DATA PAI,D/3.14159,0.166667/
      DATA H/3.167E-04/
      DATA TAMB/70./
      DATA PRNT/.TRUE./
      H=0.
      NXM1=NX-1
      NXM2=NX-2
      DO I =1,NX
      XG(I)=XG(I)*XL
      XN(I)=XN(I)*XL
      ENDDO
C     SUPPLY INITIAL CONDITION
      DO I=2,NXM1
      T(I)=TINIT
      TM(I)=TINIT
      END DO
C     SUPPLY BOUNDARY CONDITION
      T(1)=32.
      T(NX)=212.
C     SELECT OPTION
C
```

```
C     POINT BY POINT METHOD
C     START OF ITERATION
      TAU=0.
C     START OF A NEW TIME STEP
 1200 TAU=TAU+DTAU
      ITER=0
    1 CONTINUE
      DIF=0
      DO 100 II=2,NXM1
      I=II
C     CALCULATE COEFFICIENTS
      AXP(I)=K*A/(XN(I+1)-XN(I))
      AXM(I)=K*A/(XN(I)-XN(I-1))
      VOL=A*(XG(I)-XG(I-1))
      AS=PAI*D*(XG(I)-XG(I-1))
      AT(I)=RHO*CP*VOL/DTAU
      SU(I)=H*AS*TAMB
      SP(I)=-H*AS
      TOLD=T(I)
      SUM=AXP(I)+AXM(I)+AT(I)-SP(I)
      T(I)=(AXP(I)*T(I+1)+AXM(I)*T(I-1)
     &      +AT(I)*TM(I)+SU(I))/SUM
      DIF=AMAX1(DIF,ABS((T(I)-TOLD)/T(I)))
  100 CONTINUE
      ITER=ITER+1
      WRITE(*,*) ITER,T(4),DIF
      IF(ITER.GT.NITER)GO TO 9999
      IF(ITER.LT.2) GO TO 1
      IF(DIF.GT.CC) GO TO 1
 9999 CONTINUE
      IF(PRNT) CALL PRINT(TAU,T,XN,DIF,SUMERR,NX,ITER)
      DO I=2,NXM1
      TM(I)=T(I)
      ENDDO
      IF (TAU.LT.TAUF) GO TO 1200
      STOP
      END
      SUBROUTINE PRINT(TAU,T,XN,DIF,SUMERR,NX,ITER)
      DIMENSION T(12),XN(12)
      OPEN(UNIT=6,FILE='HCON.OUT',STATUS='UNKNOWN')
      NXM1=NX-1
C      IF (ITER.EQ.0) WRITE(6,100) (I,I=1,NXM1)
C  100 FORMAT(3X,4HTIME,4X,4HITER,11I6,7X,3HDIF)
      WRITE(6,110)(T(I),I=1,NX),ITER
      WRITE(6,115)(XN(I),I=1,NX)
  115 FORMAT(10F7.2)
  110 FORMAT(10F7.2,I4)
      RETURN
      END
```

ANSYS INPUT LISTING

```
/PREP7
/title ROD BETWEEN TWO WALL IN AIR ENVIRONMENT
kan,-1
KXX,1,9.4
N,1
N,9,2
FILL,1,9
N,100,1,1

ET,1,32
R,1,.02182
E,1,2
rp8,1,1
NT,1,TEMP,32
NT,9,TEMP,212
ET,2,34
TYPE,2
HF,2,1.14
MAT,2
R,2,.06545,0,0
REAL,2
E,2,100
rp6,1
NT,100,TEMP,70
KBC,1
ITER,-100,100,100
LWRITE
AFWRITE
FINISH
```

ANSYS OUTPUT LISTING

```
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IF RUNNING INTERACTIVELY, ENTER  /INTER
1
                    **********  ANSYS INPUT DATA LISTING (FILE18)  **********

     1   /input,input
     2   /input,27
     3   finish

***** INPUT SWITCHED FROM FILE18 TO FILE38  NAME=input
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4              SVERDRUP TECH.   MAY 1,1989
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 TITLE                                                                    12.5233  SEP  4,1990 CP=      2.133

         ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

 NEW TITLE= ROD BETWEEN TWO WALL IN AIR ENVIRONMENT


 ANALYSIS TYPE= -1   (THERMAL ANALYSIS)

  MATERIAL   1          COEFFICIENTS OF KXX  VS. TEMP EQUATION
   C0 =   9.400000

 PROPERTY TABLE KXX   MAT=   1  NUM. POINTS=  2
     TEMPERATURE      DATA     TEMPERATURE      DATA
      -9999.0       9.4000       9999.0       9.4000

 NODE      1  KCS= 0  X,Y,Z= 0.00000E+00 0.00000E+00 0.00000E+00

 NODE      9  KCS= 0  X,Y,Z=  2.0000      0.00000E+00 0.00000E+00

 FILL    7 POINTS BETWEEN NODE     1 AND NODE     9
  START WITH NODE     2 AND INCREMENT BY     1

 NODE    100  KCS= 0  X,Y,Z=  1.0000      1.0000      0.00000E+00

 ELEMENT TYPE  1 USES STIF 32
  KEYOPT(1-9)=   0   0   0     0   0   0      0   0   0
  INOTPR= 0  NUMBER OF NODES=   2

 CONDUCTING BAR, 2-D

 CURRENT NODAL DOF SET IS  TEMP
  TWO-DIMENSIONAL STRUCTURE

  REAL CONSTANT SET   1  ITEMS   1 TO   6
   0.21820E-01  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 ELEMENT      1        1      2
 ELEMENT      2        2      3
 ELEMENT      3        3      4
 ELEMENT      4        4      5
 ELEMENT      5        5      6
 ELEMENT      6        6      7
 ELEMENT      7        7      8
 ELEMENT      8        8      9

 SPECIFIED TEMP. DEFINITION FOR TEMP FOR SELECTED NODES IN RANGE     1 TO     1 BY    1
  VALUES=  32.000      ADDITIONAL DOFS=

 SPECIFIED TEMP. DEFINITION FOR TEMP FOR SELECTED NODES IN RANGE     9 TO     9 BY    1
  VALUES=  212.00      ADDITIONAL DOFS=

 ELEMENT TYPE  2 USES STIF 34
  KEYOPT(1-9)=   0   0   0     0   0   0      0   0   0
  INOTPR= 0  NUMBER OF NODES=   2

 CONVECTION LINK

 CURRENT NODAL DOF SET IS  TEMP
  TWO-DIMENSIONAL STRUCTURE

 ELEMENT TYPE SET TO  2

  MATERIAL   2          COEFFICIENTS OF HF   VS. TEMP EQUATION
   C0 =   1.140000

 PROPERTY TABLE HF    MAT=   2  NUM. POINTS=  2
     TEMPERATURE      DATA     TEMPERATURE      DATA
      -9999.0       1.1400       9999.0       1.1400

 MATERIAL NUMBER SET TO     2

  REAL CONSTANT SET   2  ITEMS   1 TO   6
   0.65450E-01  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT NUMBER=     2
 ELEMENT     9        2   100
 ELEMENT    10        3   100
 ELEMENT    11        4   100
 ELEMENT    12        5   100
 ELEMENT    13        6   100
 ELEMENT    14        7   100
```

```
SPECIFIED TEMP. DEFINITION FOR TEMP FOR SELECTED NODES IN RANGE   100 TO   100 BY    1
 VALUES=  70.000       ADDITIONAL DOFS=

STEP BOUNDARY CONDITION KEY= 1

NITTER=   -100  NPRINT=   100  NPOST=   100

USE CONVERGENCE AND/OR TIME STEP OPTIMIZATION
 BOUNDARY CONDITION STEP OR RAMP DEPENDENT UPON KBC COMMAND.

ALL PRINT CONTROLS RESET TO   100
 ALL POST DATA FILE CONTROLS RESET TO   100

LOAD STEP     1  WRITTEN ON FILE23

***  NOTE  ***
DATA CHECKED - NO FATAL ERRORS FOUND.
CHECK OUTPUT FOR POSSIBLE WARNING MESSAGES.

LOADS DATA READ FROM FILE23

*** PREP7 GLOBAL STATUS ***

TITLE= ROD BETWEEN TWO WALL IN AIR ENVIRONMENT
ANALYSIS TYPE=    -1
NUMBER OF ELEMENT TYPES=     2
    14 ELEMENTS CURRENTLY SELECTED.  MAX ELEMENT NUMBER =     14
    10 NODES CURRENTLY SELECTED.     MAX NODE NUMBER =       100
MAXIMUM LINEAR PROPERTY NUMBER=     2
MAXIMUM REAL CONSTANT SET NUMBER=     2
ACTIVE COORDINATE SYSTEM=     0  (CARTESIAN)
NUMBER OF NODAL TEMPERATURES=     3

ANALYSIS DATA WRITTEN ON FILE27

ALL CURRENT PREP7 DATA WRITTEN TO FILE16   NAME= file16.dat
 FOR POSSIBLE RESUME FROM THIS POINT


***** ROUTINE COMPLETED *****  CP =          3.017

***** END OF INPUT ENCOUNTERED ON FILE38.  FILE38 REWOUND

***** INPUT FILE SWITCHED FROM FILE38 TO FILE18


***** INPUT SWITCHED FROM FILE18 TO FILE27  NAME=file27.dat

NEW TITLE= ROD BETWEEN TWO WALL IN AIR ENVIRONMENT

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ROD BETWEEN TWO WALL IN AIR ENVIRONMENT                                          12.5244  SEP  4,1990 CP=      3.033


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     ERRORS ENCOUNTERED IN EITHER THE DOCUMENTATION OR THE
     RESULTS SHOULD BE IMMEDIATELY BROUGHT TO OUR ATTENTION.


          ***** ANALYSIS OPTIONS *****

                                  VALUE

 ANALYSIS TYPE . . . . . . . .     -1


          ***** ELEMENT TYPES *****

 TYPE  STIF       DESCRIPTION                      KEY OPTIONS                    NJ   INOTPR
                                                1  2  3    4  5  6    7  8  9

NUMBER OF ELEMENT TYPES=   2


          ***** TABLE OF ELEMENT REAL CONSTANTS *****
  NO.

NUMBER OF REAL CONSTANT SETS=   2


          ***** ELEMENT DEFINITIONS *****

ELEMENT    NODES                                MAT  TYPE                    ELEMENT REAL CONSTANTS
```

```
SWITCHED TO FIXED FORMAT INPUT

 INTEGER STORAGE REQUIREMENTS FOR ELEMENT INPUT                    CP=     3.167  TIME= 12.52444
FIXED DATA =     1034  TEMPORARY DATA =      200   TOTAL=     1234
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000
 MAXIMUM NODE NUMBER FOR AVAILABLE AUXILIARY MEMORY SIZE=     499482

 NUMBER OF ELEMENTS =      14      MAXIMUM NODE NUMBER USED =     100


            ***** NODE DEFINITIONS *****

                    LOCATION           ROTATION (DEGREES)

  NODE          X              Y              THXY
              (OR R)       (OR THETA)       (OR RT)


SWITCHED TO FIXED FORMAT INPUT

 XMIN= 0.0000E+00  XMAX=  2.000      YMIN= 0.0000E+00  YMAX=  1.000      ZMIN= 0.0000E+00  ZMAX= 0.0000E+00

 INTEGER STORAGE REQUIREMENTS FOR NODE INPUT                       CP=     3.217  TIME= 12.52444
FIXED DATA =     1034  TEMPORARY DATA =      600   TOTAL=     1634
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000
 MAXIMUM NODE NUMBER FOR AVAILABLE AUXILIARY MEMORY SIZE=     332988


            ***** MATERIAL PROPERTIES *****

MAXIMUM MATERIAL NUMBER=   2


            ***** MASTER DEGREES OF FREEDOM  *****

  NODE        DEGREES OF FREEDOM LIST


NUMBER OF SPECIFIED MASTER D.O.F.=      0
TOTAL NUMBER OF MASTER D.O.F.    =      0

 INTEGER STORAGE REQUIREMENTS FOR MATERIALS, ETC. INPUT            CP=     3.317  TIME= 12.52472
FIXED DATA =       34  TEMPORARY DATA =        0   TOTAL=       34
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000
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ROD BETWEEN TWO WALL IN AIR ENVIRONMENT                                    12.5247  SEP  4,1990 CP=     3.400


LOAD STEP NUMBER=    1

         *** LOAD OPTIONS SUMMARY ***

TIME   = 0.00000E+00 (TIME AT END OF LOAD STEP)
NITTER=   -100       (NUMBER OF ITERATIONS)
TUNIF =   0.0000     (UNIFORM TEMPERATURE)
KBC   =   1          (LOADS STEPPED TO FINAL VALUES FOR ALL ITERATIONS)
KRF   =   2          (PRINT SUMMARY OF HEAT FLOWS AT FIXED TEMP. NODES)
TCR   =  1.0000      (TEMPERATURE CONVERGENCE CRITERION)
TOCR  =  10.000      (TRANSIENT OPTIMIZATION CRITERION)

NPRINT=   100        (OVERALL PRINT FREQUENCY)
NPOST =   100        (OVERALL POST FREQUENCY)

 DISPLACEMENT PRINT FREQUENCIES
  FREQ   NSTRT  NSTOP   NINC
   100      1 999999      1

 ELEMENT PRINT AND POST FREQUENCIES
  TYPE  STIFF  STRESS  FORCE      STRESS  STRESS  FORCE
         NO.   PRINT  PRINT       POST    LEVEL   POST
    1     32    100    100        100      3     100
    2     34    100    100        100      3     100


***** LOAD SUMMARY -      3 TEMPERATURES       0 HEAT FLOWS     0 CONVECTIONS      *****


 INTEGER STORAGE REQUIREMENTS FOR LOAD DATA INPUT                  CP=     3.433  TIME= 12.52472
FIXED DATA =       90  TEMPORARY DATA =        0   TOTAL=       90
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000

 RANGE OF ELEMENT MAXIMUM CONDUCTIVITY IN GLOBAL COORDINATES


MAXIMUM= 0.820432E+00  AT ELEMENT      8.
MINIMUM= 0.746130E-01  AT ELEMENT     14.

 INTEGER STORAGE REQUIREMENTS FOR ELEMENT FORMULATION              CP=     3.700  TIME= 12.52500
FIXED DATA =       90  TEMPORARY DATA =        0   TOTAL=       90
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000

  *** ELEMENT STIFFNESS FORMULATION TIMES
 TYPE  NUMBER  STIF  TOTAL CP   AVE CP

   1       8    32     0.033    0.004
   2       6    34     0.000    0.000
```

```
TIME AT END OF ELEMENT STIFFNESS FORMULATION  CP=        3.700

MAXIMUM IN-CORE WAVE FRONT ALLOWED FOR REQUESTED MEMORY SIZE=  997.

 INTEGER STORAGE REQUIREMENTS FOR WAVE FRONT MATRIX SOLUTION       CP=      3.783  TIME= 12.52528
FIXED DATA =       90  TEMPORARY DATA =       81   TOTAL=      171
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000

MAXIMUM IN-CORE WAVE FRONT=       7.

     MATRIX SOLUTION TIMES
 READ IN ELEMENT STIFFNESSES   CP=          0.000

 NODAL COORD. TRANSFORMATION   CP=          0.000
 MATRIX TRIANGULARIZATION      CP=          0.033

TIME AT END OF MATRIX TRIANGULARIZATION  CP=          3.783
EQUATION SOLVER MAXIMUM PIVOT=  1.7155     AT NODE     2. TEMP
EQUATION SOLVER MINIMUM PIVOT= 0.71172     AT NODE     7. TEMP

 INTEGER STORAGE REQUIREMENTS FOR BACK SUBSTITUTION                 CP=      3.817  TIME= 12.52528
FIXED DATA =       90  TEMPORARY DATA =      204   TOTAL=      294
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000

  *** ELEM. HT. FLOW CALC. TIMES
 TYPE  NUMBER  STIF  TOTAL CP   AVE CP

  1       8    32     0.000   0.000
  2       6    34     0.000   0.000

  *** NODAL HT. FLOW CALC. TIMES
 TYPE  NUMBER  STIF  TOTAL CP   AVE CP

  1       8    32     0.000   0.000
  2       6    34     0.000   0.000

*** LOAD STEP    1   ITER     1  COMPLETED.  TIME=  0.000000E+00  TIME INC=  0.000000E+00 NEW TRIANG MATRIX  CUM. ITER.=    1

 INTEGER STORAGE REQUIREMENTS FOR HEAT FLOW CALCULATIONS            CP=      3.933  TIME= 12.52528
FIXED DATA =       90  TEMPORARY DATA =      600   TOTAL=      690
FIXED AVAIL= 1000000  TEMPORARY AVAIL= 1000000   TOTAL AVAIL= 1000000

 *** STORAGE REQUIREMENT SUMMARY
MAXIMUM FIXED MEMORY USED    =    1034
MAXIMUM TEMPORARY MEMORY USED=     600
MAXIMUM TOTAL MEMORY USED    =    1634
MAXIMUM TEMPORARY AVAILABLE  =  999908

  *** PROBLEM STATISTICS
 NO. OF ACTIVE DEGREES OF FREEDOM =       7
 R.M.S. WAVEFRONT SIZE =      4.5

 *** ANSYS BINARY FILE STATISTICS
BUFFER SIZE USED= 2048
POST DATA WRITTEN ON FILE12
RESTART DATA WRITTEN ON FILE03    (          13324 BYTES)
TEMPERATURES WRITTEN ON FILE04

 TEMPERATURE INCREMENT =  0.00000E+00 AT NODE     1     CRITERION =   1.0000
*** LOAD STEP    1   ITER     2  COMPLETED.  TIME=  0.000000E+00  TIME INC=  0.000000E+00 NEW TRIANG MATRIX  CUM. ITER.=    2

 *** SOLUTION CONVERGED - LOAD STEP   1  CONVERGED AFTER ITERATION     2  CUM. ITER.=    2
      NEXT ITERATION (IDENTIFIED AS ITERATION   100) SATISFIES PRINTOUT OR POST DATA REQUEST.
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ROD BETWEEN TWO WALL IN AIR ENVIRONMENT                                          12.5256  SEP  4,1990 CP=      4.133

 ***** TEMPERATURE  SOLUTION *****     TIME =   0.00000E+00  LOAD STEP=   1  ITERATION=   100  CUM. ITER.=    3
     NODE    TEMP          NODE    TEMP          NODE    TEMP          NODE    TEMP          NODE    TEMP
        1   32.000            2   50.501            3   67.229            4   83.705            5   101.43
        6   122.01            7   147.32            8   179.66            9   212.00
                                                                                              100   70.000

  MAXIMUM TEMPERATURE=  212.00     AT NODE     9
  MINIMUM TEMPERATURE=  32.000     AT NODE     1

 ***** ELEMENT HEAT FLOW RATES *****  TIME =  0.000000E+00   LOAD STEP=    1   ITER.=   100   CUM. ITER.=    3

EL=     1 NODES=     1     2 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =   32.0   50.5 HEAT RATE= -15.179     2D COND BAR 32

EL=     2 NODES=     2     3 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =   50.5   67.2 HEAT RATE= -13.724     2D COND BAR 32

EL=     3 NODES=     3     4 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =   67.2   83.7 HEAT RATE= -13.517     2D COND BAR 32

EL=     4 NODES=     4     5 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =   83.7  101.4 HEAT RATE= -14.540     2D COND BAR 32

EL=     5 NODES=     5     6 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =  101.4  122.0 HEAT RATE= -16.885     2D COND BAR 32

EL=     6 NODES=     6     7 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =  122.0  147.3 HEAT RATE= -20.765     2D COND BAR 32

EL=     7 NODES=     7     8 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =  147.3  179.7 HEAT RATE= -26.534     2D COND BAR 32

EL=     8 NODES=     8     9 LENGTH= 0.2500     AREA= 0.2182E-01  TEMP(I,J) =  179.7  212.0 HEAT RATE= -26.534     2D COND BAR 32

EL=     9 NODES=     2   100 HFILM=  1.140      AREA= 0.6545E-01  TEMP(I,J)=   50.5   70.0  HEAT RATE= -1.4549      CONV LINK  34
```

```
EL=    10 NODES=     3   100 HFILM=  1.140      AREA= 0.6545E-01  TEMP(I,J)=   67.2   70.0  HEAT RATE=-0.20676      CONV LINK  34

EL=    11 NODES=     4   100 HFILM=  1.140      AREA= 0.6545E-01  TEMP(I,J)=   83.7   70.0  HEAT RATE=  1.0226      CONV LINK  34

EL=    12 NODES=     5   100 HFILM=  1.140      AREA= 0.6545E-01  TEMP(I,J)=  101.4   70.0  HEAT RATE=  2.3449      CONV LINK  34

EL=    13 NODES=     6   100 HFILM=  1.140      AREA= 0.6545E-01  TEMP(I,J)=  122.0   70.0  HEAT RATE=  3.8804      CONV LINK  34

EL=    14 NODES=     7   100 HFILM=  1.140      AREA= 0.6545E-01  TEMP(I,J)=  147.3   70.0  HEAT RATE=  5.7689      CONV LINK  34
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ROD BETWEEN TWO WALL IN AIR ENVIRONMENT                                          12.5256  SEP  4,1990 CP=      4.267

  ***** NODAL HEAT FLOW RATES *****   TIME =  0.00000E+00  LOAD STEP=    1  ITERATION=  100  CUM. ITER.=    3

 NOTE - HEAT FLOW RATES ARE POSITIVE INTO THE NODE.
        SPECIFIC HEAT FLOWS ARE NOT INCLUDED.

   NODE       HEAT

     1     -15.1789
     9      26.5340
   100     -11.3551

TOTAL     0.177636E-14

 TEMPERATURE INCREMENT =  0.00000E+00 AT NODE     1     CRITERION =   1.0000
*** LOAD STEP    1   ITER   100  COMPLETED.  TIME=  0.000000E+00  TIME INC=  0.000000E+00 NEW TRIANG MATRIX  CUM. ITER.=    3

***** END OF INPUT ENCOUNTERED ON FILE27.  FILE27 REWOUND

***** INPUT FILE SWITCHED FROM FILE27 TO FILE18

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ROD BETWEEN TWO WALL IN AIR ENVIRONMENT                                          12.5256  SEP  4,1990 CP=      4.333


***** ANSYS SOLUTION PHASE RUN TIME ESTIMATOR *****

COMPUTER = TEK XD88                NUMBER OF MASTER DOF =    0
ANALYSIS TYPE = -1                 RMS WAVE FRONT =    5
NUMBER OF ACTIVE NODES =      8    TOTAL NO. OF ITERATIONS =     3
MAX. DOF PER NODE =  1             STIFF. MATRIX SAVE KEY = 0
NUMBER OF MATRICES = 1             ELEM. MATRIX SAVE KEY = 0
NUMBER OF STRESS SOLUTIONS=    1   ROTATED NODE FRACTION= 0.000

  STIF  NUMBER   FORM. TIME  STRESS TIME    NAME
   32      8        0.001        0.001   CONDUCTING BAR, 2-D
   34      6        0.001        0.001   CONVECTION LINK


                          FIRST      SUBSEQUENT
  ANALYSIS PHASE        ITERATION   ITERATIONS      TOTAL

ELEMENT FORMULATION        0.01        0.01         0.04
NODE ROTATION              0.00        0.00         0.00
WAVE FRONT SOLUTION        0.00        0.00         0.00
BACK SUBSTITUTION          0.00        0.00         0.00
ELEMENT STRESSES           0.01        0.01         0.01
NODAL FORCES               0.00        0.00         0.00

    TOTAL TIME (SEC)       0.02        0.02         0.05

***** ROUTINE COMPLETED *****  CP =          4.367

***** END OF INPUT ENCOUNTERED ON FILE18


PREP7 AFWRITE OR SFWRITE WARNING MESSAGES =   0
NUMBER OF SOLUTION PHASE WARNING MESSAGES =   0


***** RUN COMPLETED *****  CP=        4.3833   TIME=   12.5256
```

E. Closing Comments:

In this section, four methods are used to solve a one-dimensional, steady state heat conduction problem. This particular problem involves a circular, homogeneous rod for which the end temperatures are fixed and the surface is subject to convective losses. Three numerical solutions, obtained using a finite difference method (SINDA), a finite volume method, and a finite element method (ANSYS), were found to compare favorably with the closed-form solution. Following the development of a transient formulation, it has been further demonstrated that the numerical solutions to the transient problem are in agreement with the corresponding closed-form solution.

IV. References:

Patanker, S.V.; Numerical Heat Transfer and Fluid Flow; Hemisphere Publishing; Washington D.C.; Copyright 1980

CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 4: Steady State Conduction in a Section of a Homogeneous Ring, with Convection

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A. Statement of the Problem:

Consider the segment of a circular ring, shown in Figure 1. The inner and outer radii of the ring are 25 and 40mm, respectively. The thickness of the ring is 10mm. Heat is transferred to the segment at the rate of 100J/sec (100W). The surrounding fluid is at a temperature of -200°C and flows over the surfaces of the segment such that the convective heat transfer coefficient, known to depend upon the film temperature, is given by

$$h = 0.6523\ T_{film} + 188.06$$

Units for h are $J/m^2 sec\ °C$ (or simply $W/m^2\ °C$). Find the steady state temperature of the segment if the "ends" of the segment are insulated.

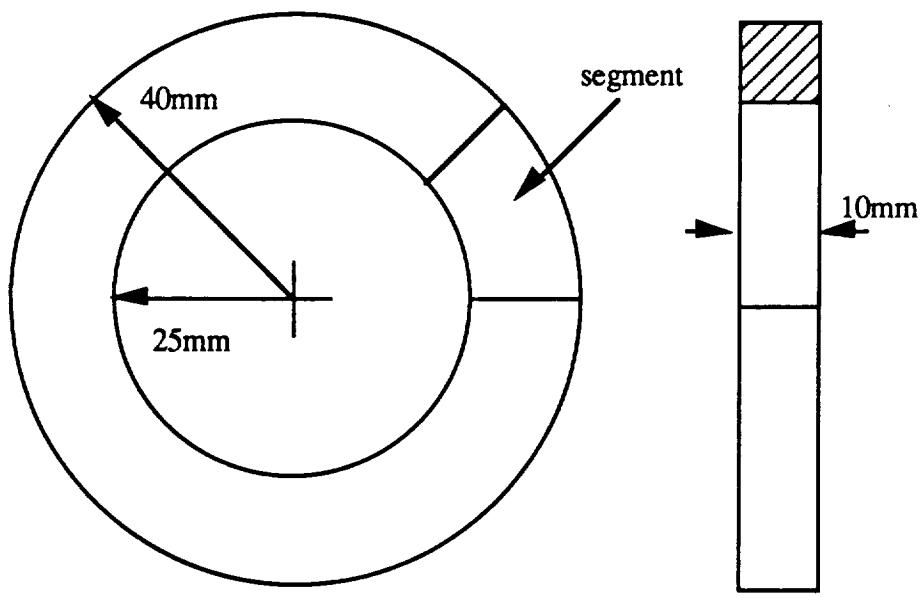

Figure 1. One eighth segment of a 40 x 10mm homogeneous ring

B. Schematic:

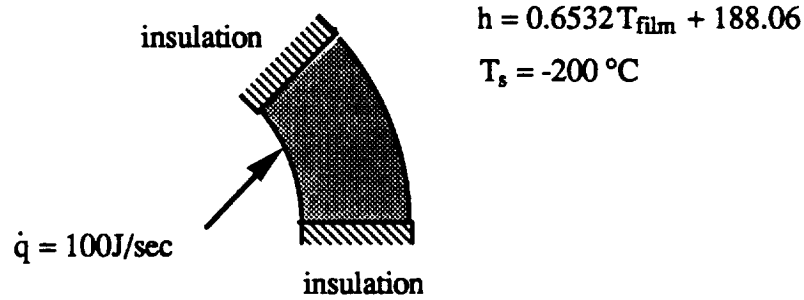

Figure 2. Schematic of ring segment showing insulated end "panels". Heat flux per unit of exposed surface area is constant and uniform.

C. Given:

1. Circular segment is homogeneous
2. Physical dimensions of the segment are furnished
3. Ambient temperature is -200°C
4. Convective coefficient is temperature dependent and is defined as a function of T_{film}
5. Rectangular end "panels" of the segment are insulated

D. Find:

1. Steady state temperature of the segment

II. Formulation of the Problem:

A. Simplifying Assumptions:

1. Uniform thermal properties throughout the segment
2. Temperature dependent heat transfer coefficient
3. Steady state heat transfer
4. Uniform heat flux of 100W

B. Initial/Boundary Conditions:

1. Initial conditions have no significance as the problem involves a steady state analysis
2. The only boundary condition given is that which applies to the surrounding fluid, namely $T_S = -200°C$

C. Discretization:

For the problem at hand, the analysis is performed assuming steady state heat transfer. The segment of a circular ring is modeled using one diffusion node and a single boundary node. Figure 3 shows the 2-node model used to analyze the problem. The diffusion node is labeled, 10, while the boundary node has been assigned the label, 99. No arithmetic nodes are necessary and none have been included.

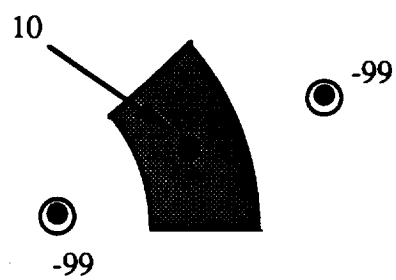

Figure 3. Nodal layout of the SINDA model

III. Analysis:

A. The Input Deck:

The input deck presented on the following page is not unlike those which accompany previous examples. The only note-worthy difference is that the VARIABLES 1 block is now used to model a temperature dependent convective heat transfer coefficient. In this case, the conductance of the conductor connecting node 10 to (boundary) node 99 is calculated within the VARIABLES 1 block. The included input deck provides a clear but simple example of the type of internal calculations possible using the VARIABLES 1 block. The value given for conductor 1099 is an initial value which SINDA will use for the first iteration.

SINDA INPUT LISTING

```
        BCD 3THERMAL LPCS
        END
        BCD 3NODE DATA
C        GEN 1,2,1,-200.,1.
            10,-200.0,1.
            -99,-200.0,1.0
        END
        BCD 3SOURCE DATA
            10,100.0
        END
        BCD 3CONDUCTOR DATA
            1099,10,99,4.183E-02
C            1,1,2,1.
C            2,1,99,1.
        END
        BCD 3CONSTANTS DATA
            NLOOP=1000
            DRLXCA=.001
            ARLXCA=.001
            NDIM=1500
        END
        BCD 3ARRAY DATA
        END
        BCD 3EXECUTION
F       CALL STDSTL
        END
        BCD 3VARIABLES 1
M           G1099=(0.6532*(T10+T99)/2.+188.06)*1.276E-03
        END
        BCD 3VARIABLES 2
        END
        BCD 3OUTPUT CALLS
F       CALL  TPRINT
        END
        BCD 3END OF DATA
```

SINDA OUTPUT LISTING

```
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 *** NOTE *** STDSTL REQUIRES        2 DYNAMIC STORAGE LOCATIONS OUT OF     1497 AVAILABLE ***

 ****************
 TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(       0)= 0.00000E+00, ATMPCC(       0)= 0.00000E+00, DTMPCC(       0)= 0.00000E+00
     LOOPCT=      0                                                    , ARLXCC(       0)= 0.00000E+00, DRLXCC(       0)= 0.00000E+00
+                  , SENGIN= 1.00000E+02, ENGBAL= 1.00000E+02

 T     10 = -200.0000 T     99 = -200.0000 T

 STDSTL RUN, ARLXCA=0.10000E-02, DRLXCA=0.10000E-02, BALENG=0.10000E+31, BENODE=0.50000E+30, NLOOP=   1000

 *** NOTE *** RELAXATION CRITERIA HAS BEEN MET WITH LOOPCT =      41

     ENGBAL = 0.000000      AT LOOPCT =      41

 *** NOTE *** SYSTEM ENERGY BALANCE CRITERIA HAS BEEN MET, ENGBAL = 0.000000     , LOOPCT =      41

     EBNODE(      10)=-0.113352E-03 AT LOOPCT=      41

 *** NOTE *** NODAL ENERGY BALANCE CRITERIA HAS BEEN MET, EBNODE(      10)=-0.113352E-03, LOOPCT =      41

 ****************
 TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(       0)= 0.00000E+00, ATMPCC(       0)= 0.00000E+00, DTMPCC(       0)= 0.00000E+00
     LOOPCT=     41                                                    , ARLXCC(       0)= 0.00000E+00, DRLXCC(      10)= 6.71387E-04
+                  , SENGIN= 1.00000E+02, ENGBAL=-1.14441E-04

 T     10 =  209.7734 T     99 = -200.0000 T
```

IV. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are given on the previous page. The nodal temperatures are printed in degrees, Celsius. According to information given in the output deck, the steady state temperature of the segment is approximately 209.8 °C. The surrounding temperature has been conserved, as would be expected.

B. Generation of Alternate (Exact) Solution:

Assuming steady state heat transfer, there may be no net heat flux. Therefore,

$$\Sigma Q = \Sigma \dot{q} = \Sigma \dot{q}_{in} - \Sigma \dot{q}_{out} \equiv 0 \tag{1}$$

From the statement of the problem, it is clear that there is only one source of heat transfer to the segment and that

$$\Sigma \dot{q}_{in} = 100 J/sec = 100W \tag{2}$$

Neglecting heat loss via radiation, there is but one mode of heat loss from the segment. Hence,

$$\Sigma \dot{q}_{out} = hA_s \Delta T = hA_s(T-T_\infty), \tag{3}$$

where A_s denotes the exposed surface area of the segment and h is given by

$$h = 0.6523\ T_{film} + 188.06 \tag{4}$$

Generally, the film temperature is defined as the mean temperature, $\frac{(T+T_\infty)}{2}$, such that

$$h = \frac{0.6523}{2}(T + T_\infty) + 188.06$$

from which

$$h = 0.3262(T - 200) + 188.06$$

or

$$h = 0.3262T + 122.82 \tag{5}$$

Substitution of (5) into (3) gives

$$\Sigma \dot{q}_{out} = (0.3262T + 122.82)A_s(T - T_\infty)$$

$$= (0.3262T + 122.82)A_s(T + 200) \tag{6}$$

and substitution of (6) and (2) into (1) gives

$$100 - [(0.3262\ T + 122.83)A_s(T + 200)] = 0 \tag{7}$$

in which the only unknown values are A_s and T. Because T is the parameter of interest, A_s must be calculated before the steady state temperature may be obtained. Recognizing that heat is lost only through convection, A_s is the sum of all (surface) areas exposed to the surrounding fluid. Because the ends of the segment are insulated, there are four exposed surfaces including the upper, lower, inner, and outer faces. Therefore, A_s is given by equation (8).

$$\begin{aligned} A_s &= A_{upper} + A_{lower} + A_{inner} + A_{outer} \\ &= \frac{1}{8}[\pi(40mm^2 - 25mm^2)] + \frac{1}{8}[\pi(40mm^2 - 25mm^2)] \\ &= \frac{1}{8}[2\pi(40mm)(10mm)] + \frac{1}{8}[\pi(25mm)(10mm)] \end{aligned} \tag{8}$$

Simplifying (8) gives

$$\begin{aligned} A_s &= \frac{\pi}{4}(40mm^2 - 25mm^2) \\ &\quad + \frac{\pi}{4}[(40mm)(10mm) + (25mm)(10mm)] \\ &= 765.8mm^2 + 510.5mm^2 \\ &= 1276.3mm^2 = 1.276 \times 10^{-3}m^2 \end{aligned}$$

Equation (7) then becomes

$$\begin{aligned} &100J/sec - [(0.3262\ T + 122.83)J/m^2sec\ °C \\ &\times (1.276 \times 10^{-3})m^2(T + 200)°C] = 0 \end{aligned} \tag{9}$$

from which

$$100J/sec - [4.16 \times 10^{-4}T^2 + 0.240T + 31.346] = 0. \tag{10}$$

Further simplifying (10) yields

$$-4.16 \times 10^{-4}T^2 - 0.240T + 68.654 = 0$$

or

$$T^2 + 576.7T - 165033.6 = 0. \tag{11}$$

Solving (11), for T, gives

$$T = 209.8 \text{ or } T = -786.5.$$

Recognizing that the second value is unreasonable (as the surrounding temperature is -200°C and heat is being added to the segment), the first value is accepted as the actual steady state temperature. Hence,

$$T_{\text{steady state}} = 209.8°C$$

and the exact solution matches that predicted by SINDA.

V. Closing Comments:

None

VI. References Used:

None

CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 5: Transient Conduction in a Segment of a Homogeneous Ring with Convection

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A. Statement of the Problem:

Consider the segment of a homogeneous circular ring, shown in Figure 1. The inner and outer radii of the ring are 25 mm and 40 mm, respectively. The thickness of the ring is 10 mm. Heat is transferred to the segment at the rate of 100 J/sec (100 W). The surrounding fluid is at a temperature of - 200 °C and flows over the surfaces of the segment such that the convective heat transfer coefficient, known to depend upon the film temperature, is given by

$$h = 0.6532\ T_{film} + 188.06$$

Units for h are J/sec m^2 °C (or W/m^2 °C). Find the transient temperature rise of the segment if the "ends" of the segment are insulated and the initial temperature of - 150 °C. Material density is 7700 kg/m^3 and the specific heat of the segment is 460 J/kg °C.

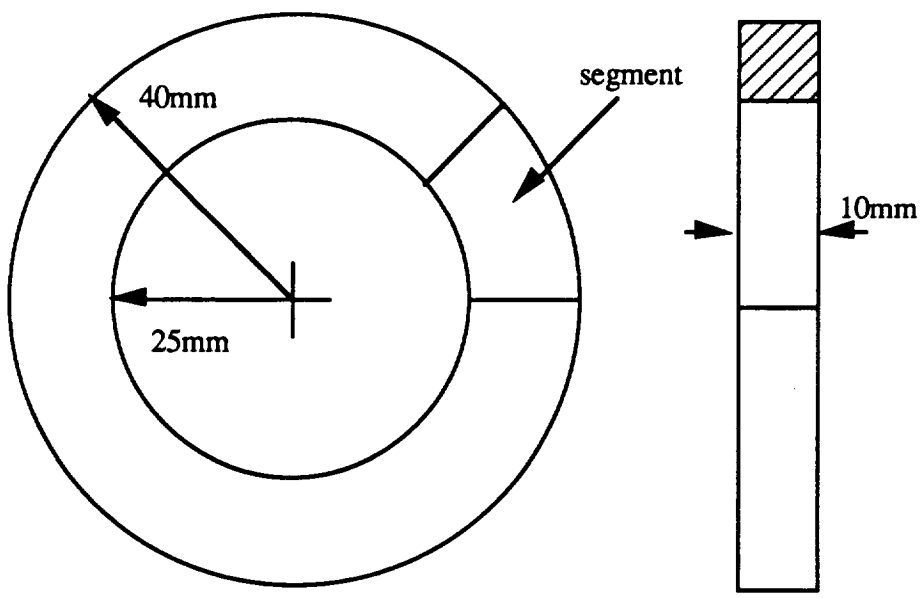

Figure 1. One eighth segment of a 40 x 10 mm homogeneous ring

B. **Schematic:**

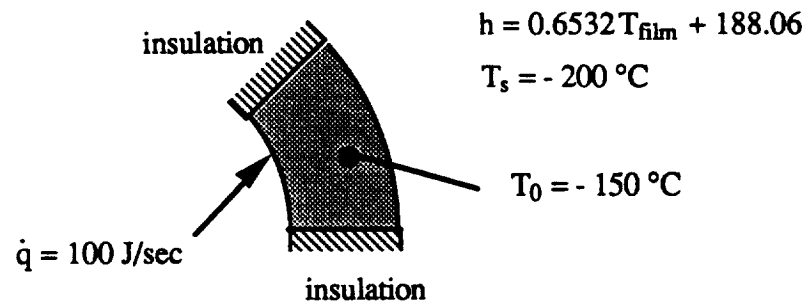

Figure 2. Schematic of ring segment showing insulated end "panels.
Heat flux per unit of exposed surface area is constant and uniform

C. **Given:**

1. Circular segment is homogeneous (has uniform thermophysical and thermodynamic properties)
2. Physical dimensions of the segment are furnished.
3. Ambient temperature is - 200 °C
4. Convective coefficient is temperature dependent and is defined as a function of T_{film}.
5. Initial temperature of the segment is - 150 °C.
6. Rectangular end "panels" of the segment are insulated.

D. **Find:**

1. Transient temperature rise of the segment

II. Formulation of the Problem:

A. **Simplifying Assumptions:**

1. Uniform thermal properties throughout the segment.
2. Uniform heat flux of 100 W.
3. Steady state temperature of the segment is 209.8 °C (see solution to problem 1-4)

B. **Initial/Boundary Conditions:**

1. We are given that the segment is initially at a temperature of - 150 °C; that is $T(t = 0) = -150$ °C.

2. The only boundary condition given is that which applies to the surrounding fluid, namely T_s = - 200 °C.

C. Discretization:

For the problem at hand, the analysis is performed to determine the temperature as a function of time. Like the steady state formulation of the same problem (Chapter 1, Section 4), the segment of the circular ring is modeled using one diffusion node and a single boundary node. Figure 3 shows the 2-node model used to analyze the problem. The diffusion node is labeled, 10, while the boundary node has been assigned the label, 99. No arithmetic nodes are necessary and none have been included.

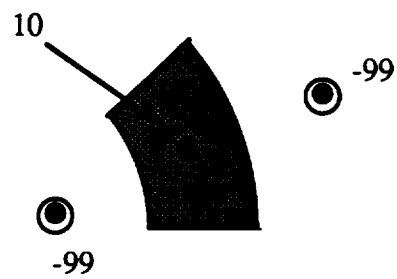

Figure 3. Nodal layout of the SINDA model

III. Analysis:

A. The Input Deck:

The input listing presented on the following page differs only slightly from that developed in the solution of example 1-4. Indeed, the NODE, SOURCE, CONDUCTOR and VARIABLES 1 data blocks are identical to those used in the steady state analysis of problem 1-4; only the CONSTANTS and EXECUTION blocks differ. For the transient case, relaxation parameters and loop counts have been appropriately replaced. The constant, TIMEND, determines to what time the analysis will be carried out. In this case, TIMEND = 360 indicates that SINDA will simulate the transient response of the segment for 360 sec. DTIMEI=1 specifies the time step to be 1 sec. OUTPUT = 5 partially supresses program output and causes SINDA to print nodal temperature at 5 second intervals. In the EXECUTION block, the FWDBKL differencing routine has been selected to obtain the transient solution to the problem.

SINDA INPUT LISTING

```
        BCD 3THERMAL LPCS
        END
        BCD 3NODE DATA
            10,-150.0,13.562
            -99,-200.0,0.0
        END
        BCD 3SOURCE DATA
            10,100.0
        END
        BCD 3CONDUCTOR DATA
            1099,10,99,4.183E-02
        END
        BCD 3CONSTANTS DATA
            NDIM=500
            NLOOP=100
            TIMEND=360.
            DTIMEI=1.
            OUTPUT=5.
            BALENG=.0001
            DRLXCA=0.001
            ARLXCA=0.001
        END
        BCD 3ARRAY DATA
        END
        BCD 3EXECUTION
            FWDBKL
        END
        BCD 3VARIABLES 1
M           G1099=(0.6532*(T10+T99)/2.+188.06)*1.276E-03
        END
        BCD 3VARIABLES 2
        END
        BCD 3OUTPUT CALLS
F       CALL  TPRINT
        END
        BCD 3END OF DATA
```

IV. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained using SINDA are presented on the following pages. The temperature of node 10, corresponding to each time step, is printed. Both nodal temperatures are specified in degrees, Celsius. According to information given in the output deck, the temperature of the segment monotonically increases from its initial value of -150 °C to a final (steady state) value of 209.75 °C. The ring is predicted to reach its steady state temperature of 209.75 °C in approximately 340 sec.

SINDA OUTPUT LISTING

```
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*** NOTE *** FWDBKL REQUIRES       8 DYNAMIC STORAGE LOCATIONS OUT OF     497 AVAILABLE ***
             TIMEND=  360.00     , CSGFAC=  1.0000     , DTIMEI=  1.0000     , NLOOP =          100
             TIMEO = 0.00000     , OUTPUT=  5.0000     , DTIMEH= 0.10000E+09, DTIMEL= 0.00000
             ARLXCA= 0.10000E-02, ATMPCA= 0.00000     , DRLXCA= 0.10000E-02, DTMPCA= 0.10000E+09
             EXTLIM=  50.000

*****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T     10 = -150.0000 T     99 = -200.0000 T

*****************
TIME= 5.00000E+00, DTIMEU= 1.00000E+00, CSGMIN(     10)= 1.28404E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 6.74271E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 = -115.6259 T     99 = -200.0000 T

*****************
TIME= 1.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 1.13615E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 6.37189E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  -83.0067 T     99 = -200.0000 T

*****************
TIME= 1.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 1.02502E+02, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.96231E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  -52.3634 T     99 = -200.0000 T

*****************
TIME= 2.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 9.39365E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.52774E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  -23.8482 T     99 = -200.0000 T

*****************
TIME= 2.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 8.72037E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.08105E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =    2.4529 T     99 = -200.0000 T

*****************
TIME= 3.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 8.18295E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.63373E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =   26.5145 T     99 = -200.0000 T

*****************
TIME= 3.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 7.74871E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.19540E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =   48.3628 T     99 = -200.0000 T
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*****************
TIME= 4.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 7.39437E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.77380E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =   68.0670 T     99 = -200.0000 T

*****************
TIME= 4.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 7.10289E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.37457E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =   85.7283 T     99 = -200.0000 T

*****************
TIME= 5.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.86153E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.00177E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  101.4717 T     99 = -200.0000 T

*****************
TIME= 5.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.66058E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.65765E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  115.4364 T     99 = -200.0000 T

*****************
TIME= 6.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.49252E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.34314E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  127.7692 T     99 = -200.0000 T

*****************
TIME= 6.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.35143E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.05835E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  138.6189 T     99 = -200.0000 T

*****************
TIME= 7.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.23260E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.80237E+00
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  148.1314 T     99 = -200.0000 T
```

```
*****************
TIME= 7.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.13226E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.57373E+00
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  156.4468 T-    99 = -200.0000 T

*****************
TIME= 8.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 6.04733E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.37073E+00
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  163.6966 T     99 = -200.0000 T
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*****************
TIME= 8.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.97532E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.19141E+00
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  170.0030 T     99 = -200.0000 T

*****************
TIME= 9.00000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.91415E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.03339E+00
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  175.4778 T     99 = -200.0000 T

*****************
TIME= 9.50000E+01, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.86213E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 8.95081E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  180.2227 T     99 = -200.0000 T

*****************
TIME= 1.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.81783E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 7.74170E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  184.3289 T     99 = -200.0000 T

*****************
TIME= 1.05000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.78007E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 6.68701E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  187.8774 T     99 = -200.0000 T

*****************
TIME= 1.10000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.74786E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.77087E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  190.9410 T     99 = -200.0000 T

*****************
TIME= 1.15000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.72036E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.97498E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  193.5832 T     99 = -200.0000 T

*****************
TIME= 1.20000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.69687E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.28589E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  195.8598 T     99 = -200.0000 T

*****************
TIME= 1.25000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.67679E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.68958E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  197.8203 T     99 = -200.0000 T
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*****************
TIME= 1.30000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.65963E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.17505E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  199.5074 T     99 = -200.0000 T

*****************
TIME= 1.35000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.64494E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.73010E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  200.9589 T     99 = -200.0000 T

*****************
TIME= 1.40000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.63238E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.34619E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  202.2063 T     99 = -200.0000 T

*****************
TIME= 1.45000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.62163E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.01660E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  203.2784 T     99 = -200.0000 T

*****************
TIME= 1.50000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.61242E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.73157E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  204.1996 T     99 = -200.0000 T

*****************
TIME= 1.55000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.60454E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.48743E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  204.9907 T     99 = -200.0000 T
```

```
*****************
TIME= 1.60000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.59779E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.27747E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  205.6702 T_    99 = -200.0000 T

*****************
TIME= 1.65000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.59200E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.09619E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  206.2534 T     99 = -200.0000 T

*****************
TIME= 1.70000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.58705E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 9.41162E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  206.7540 T     99 = -200.0000 T
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*****************
TIME= 1.75000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.58280E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 8.06885E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  207.1837 T     99 = -200.0000 T

*****************
TIME= 1.80000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.57916E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 6.92749E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  207.5524 T     99 = -200.0000 T

*****************
TIME= 1.85000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.57604E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.93262E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  207.8685 T     99 = -200.0000 T

*****************
TIME= 1.90000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.57337E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.09644E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  208.1398 T     99 = -200.0000 T

*****************
TIME= 1.95000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.57108E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.37012E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  208.3726 T     99 = -200.0000 T

*****************
TIME= 2.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56912E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.74756E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  208.5721 T     99 = -200.0000 T

*****************
TIME= 2.05000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56744E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.21045E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  208.7434 T     99 = -200.0000 T

*****************
TIME= 2.10000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56600E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.75879E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  208.8902 T     99 = -200.0000 T

*****************
TIME= 2.15000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56476E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.36816E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.0161 T     99 = -200.0000 T
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*****************
TIME= 2.20000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56370E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.02026E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.1240 T     99 = -200.0000 T

*****************
TIME= 2.25000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56280E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.73340E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.2162 T     99 = -200.0000 T

*****************
TIME= 2.30000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56202E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.50146E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.2958 T     99 = -200.0000 T

*****************
TIME= 2.35000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56135E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.27563E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.3638 T     99 = -200.0000 T

*****************
TIME= 2.40000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56078E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.09863E-02
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.4222 T     99 = -200.0000 T
```

```
****************
TIME= 2.45000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.56029E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 9.46045E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.4725 T     99 = -200.0000 T

****************
TIME= 2.50000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55987E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 8.05664E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.5153 T     99 = -200.0000 T

****************
TIME= 2.55000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55951E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 6.95801E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.5522 T     99 = -200.0000 T

****************
TIME= 2.60000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55920E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.85938E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.5837 T     99 = -200.0000 T
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****************
TIME= 2.65000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55894E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.12695E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.6106 T     99 = -200.0000 T

****************
TIME= 2.70000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55871E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.39453E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.6337 T     99 = -200.0000 T

****************
TIME= 2.75000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55851E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.72314E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.6537 T     99 = -200.0000 T

****************
TIME= 2.80000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55835E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.17383E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.6708 T     99 = -200.0000 T

****************
TIME= 2.85000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55820E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.74658E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.6855 T     99 = -200.0000 T

****************
TIME= 2.90000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55808E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.31934E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.6980 T     99 = -200.0000 T

****************
TIME= 2.95000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55798E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 2.07520E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.7087 T     99 = -200.0000 T

****************
TIME= 3.00000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55789E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.77002E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.7179 T     99 = -200.0000 T

****************
TIME= 3.05000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55781E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.52588E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.7256 T     99 = -200.0000 T
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****************
TIME= 3.10000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55774E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.28174E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.7325 T     99 = -200.0000 T

****************
TIME= 3.15000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55768E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 1.03760E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 0.00000E+00

T     10 =  209.7383 T     99 = -200.0000 T

****************
TIME= 3.20000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55764E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 9.76563E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 9.76563E-04

T     10 =  209.7432 T     99 = -200.0000 T

****************
TIME= 3.25000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55759E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 7.93457E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 7.93457E-04

T     10 =  209.7476 T     99 = -200.0000 T
```

```
*****************
TIME= 3.30000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55756E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 7.32422E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 7.32422E-04

T     10 =  209.7513 T     99 = -200.0000 T

*****************
TIME= 3.35000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55753E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 5.49316E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 5.49316E-04

T     10 =  209.7543 T     99 = -200.0000 T

*****************
TIME= 3.40000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55750E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 4.88281E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 4.88281E-04

T     10 =  209.7569 T     99 = -200.0000 T

*****************
TIME= 3.45000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55748E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.66211E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 3.66211E-04

T     10 =  209.7591 T     99 = -200.0000 T

*****************
TIME= 3.50000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55746E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.66211E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 3.66211E-04

T     10 =  209.7611 T     99 = -200.0000 T
```



```
*****************
TIME= 3.55000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55744E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.66211E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 3.66211E-04

T     10 =  209.7631 T     99 = -200.0000 T

*****************
TIME= 3.60000E+02, DTIMEU= 1.00000E+00, CSGMIN(     10)= 5.55743E+01, ATMPCC(      0)= 0.00000E+00, DTMPCC(     10)= 3.05176E-04
    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     10)= 3.05176E-04

T     10 =  209.7645 T     99 = -200.0000 T
```

B. Generation of an Alternate (Exact) Solution:

For the transient case, we may perform an energy balance on the segment, assuming that energy is transferred to the segment by way of a uniform surface flux and lost only through convection. Radiative losses are considered negligible. We may write

$$\Sigma Q = \Sigma \dot{q} = \Sigma \dot{q}_{in} - \Sigma \dot{q}_{out} = \rho V C_p \frac{dT}{dt} \tag{1}$$

or

$$100 J/sec - hA_s(T - T_\infty) = \rho V C_p \frac{dT}{dt} \tag{2}$$

where T denotes the temperature of the segment. The temperature of the segment is assumed to be uniform, for all t. Substitution of the given expression for h into (2) yields

$$100 - \{[0.6532\ T_{film} + 188.06]\ A_s(T - T_\infty)\} = \rho V C_p \frac{dT}{dt} \tag{3}$$

Defining T_{film} as the mean temperature, $(T + T_\infty)/2$, equation (3) becomes

$$100 - \left\{\left[0.6532\ \frac{(T + T_\infty)}{2} + 188.06\right] A_s(T - T_s)\right\} = \rho V C_p \frac{dT}{dt} \tag{4}$$

Simplifying (4) gives

$$100 - \{[0.3266\ T + 122.7]\ A_s\ (T + 200)\} = \rho V C_p \frac{dT}{dt} \tag{5}$$

or

$$100 - \{[0.3266\ T^2 + 188.06\ T + 24540]\ A_s\} = \rho V C_p \frac{dT}{dt} \tag{6}$$

A_s denotes the total <u>exposed</u> surface area of the segment and is given by the sum of the upper, lower, inner, and outer surface areas (the two ends of the segment are neglected because they are insulated). The exposed surface area is easily calculated.

$$A_s = A_u + A_l + A_i + A_o$$

$$= \frac{1}{8}\left[\pi\left[(40mm)^2 - (25mm)^2\right]\right] + \frac{1}{8}\left[\pi\left[(40mm)^2 - (25mm)^2\right]\right]$$

$$+ \frac{1}{8}[2\pi(40mm)(10mm)] + \frac{1}{8}[2\pi(25mm)(10mm)]$$

$$= 1276 mm^2 = 1.276 \times 10^{-3}\ m^2$$

The volume of the segment is easily obtained, as well.

$$V = \frac{1}{8}\left[\pi\left[(40\,mm)^2 - (25\,mm)^2\right]\right](10\,mm)$$

$$3828.8\,mm^3 = 3.83 \times 10^{-6}\ m^3$$

Substitution of available values for A_s, V, ρ , and C_p into equation (6) yields

$$-4.17 \times 10^{-4}\ T^2 - 0.24\ T - 31.31 + 100 = 13.56\frac{dT}{dt} \tag{7}$$

or

$$-\ 3.07 \times 10^{-5}\ T^2 - 1.77 \times 10^{-2}\ T + 5.064 = \frac{dT}{dt} \tag{8}$$

Separation of variaoles gives

$$\frac{dT}{-3.07 \times 10^{-5}\ T^2 - 1.77 \times 10^{-2} + 5.064} = dt \tag{9}$$

which may be written in the alternate form of equation (10).

$$\frac{dT}{\left(-3.07 \times 10^{-5}\right)\left(T - 209.8\right)\left(T + 786.5\right)} = dt \tag{11}$$

The left-hand side of (11) may be integrated using partial fractions. Integration of the left-hand side, on the interval from T_o to T, and the right-hand side, on the interval from t_o to t gives

$$-32.7\ \ln\frac{\left|(T - 209.8)\right|}{\left|(T + 786.5)\right|} - 18.65 = t \tag{12}$$

Although (12) specifies t as a function of T, such does not really pose a problem as (12) still defines a relationship between the dependent and independent variables. The values given in Table 1 are obtained from equation (12). From the table, we find that the steady state temperature of the segment is 209.8 °C and that this temperature is reached after 335.04 sec. This result compares quite favorably with that obtained using SINDA (209.75 °C after 340 sec). The two sets of results are compared in Figure 4.

V. Closing Comments:

Most one-node problems (excluding those involving radiation) are similar to the present example. While the mass of the system, boundary conditions, and material properties will affect the transient results, the closed-form solution to such problems will always be similar to that included in this section. The thermal analyst should be familiar with closed-form solutions of this type as they are often useful for estimating system transient responses. Also, simple hand calculations of this type can provide the analyst with added

insight into whether numerical (SINDA) results are reasonable. While network analyses may include many discrete nodes, the analyst, through knowledge of the system mass and boundary conditions can determine approximate "order-of-magnitude" response times.

VI. References:

None

t (sec)	T (°C)
0	-150.0
3.62	-125.0
7.37	-100.0
11.29	-75.0
15.42	-50.0
19.82	-25.0
24.56	0.0
29.73	25.0
35.48	50.0
42.00	75.0
59.00	125.0
71.31	150.0
132.16	200.0
335.04	209.8

Table 1. Exact Solution

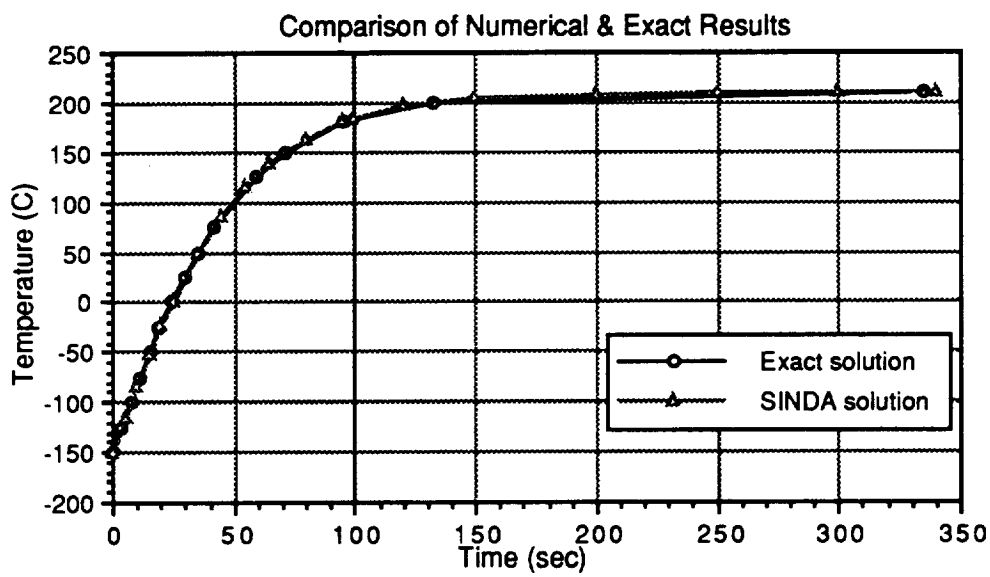

Figure 4. Comparison of exact solution with that obtained using SINDA; while both predict a steady state temperature of about 210 °C, reached within approximately 340 sec.

CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 6: Transient Conduction Through a Multi-material Body with Convection.

ANALYSIS CODE: SINDA (Gaski Version)/PATRAN

I. Identification of the Problem:

A. State of the Problem:

Consider a ground junction Chromel-Alumel type K thermocouple shown in figure 1. The thermocouple has a sheath diameter of 0.04 inch and a height of 0.0624 inch. The metal case is inconel 600 and the insulation is magnesia (MgO). The chromel and alumel wires both have the same diameter of 0.001 inch. The material properties of the elements in the thermocouple are listed in table 1 for convenient reference. According to the manufacture's specification, the thermocouple time constant (time constant will be defined later) is 0.25 seconds in a convective environment of air at room temperature and atmospheric pressure, moving with a velocity of 65.0 feet per second. For this problem first, verify the manufacture's time constant value and then determine the temperature of the thermocouple at one time constant. Second, if the thermocouple is installed on the turbine inlet of a HPFTP where hot gas temperature is assumed to be 3575.0°R and heat transfer coefficient is 0.028 Btu/sec-in^2-R, find the time constant for the thermocouple.

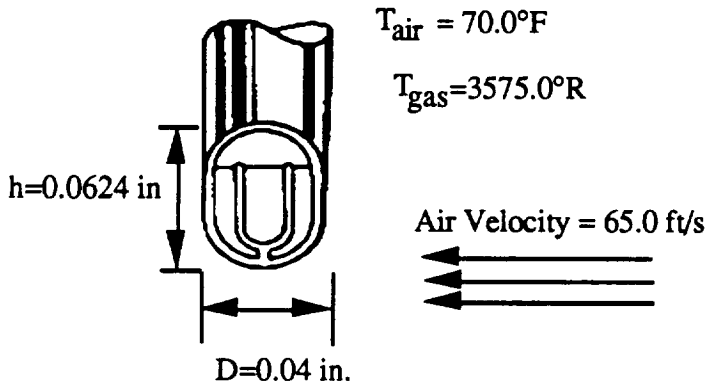

Figure 1. A ground junction thermocouple

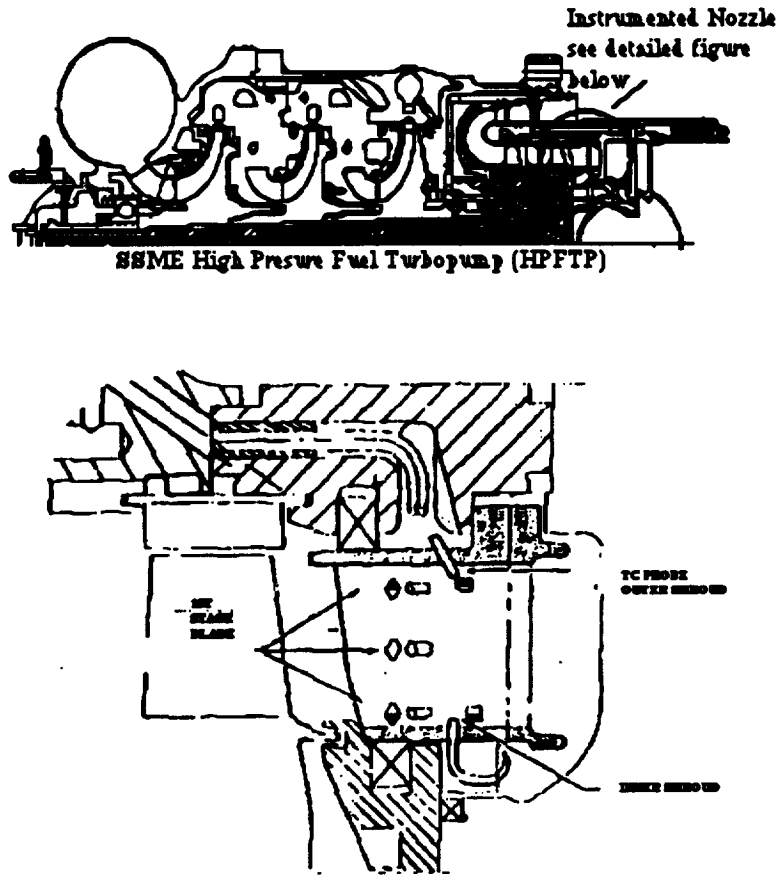

Figure 2. A HPFTP Instrumented Nozzle

B. Given

The following data is given for this problem:

1. Air temperature is 70.0°F
2. Air velocity is 65.0 ft/s
3. Hot gas temperature is 3575.0°R
4. Heat transfer coefficient between the thermocouple and hot gas is 0.0028 Btu/sec-in^2-R
5. Thermocouple case thickness is 0.001 inch
6. Chromel/Alumel wire diameter is 0.001 inch
7. Thermocouple diameter is 0.04 inch
8. Thermocouple height is 0.0624 inch
9. All material properties are listed in table 1 below:

Material	Inconel-600	Magnesia	Chromel	Alumel
Density, p, (lb/in3)	3.040E-01	9.7E-03	3.154E-01	3.107E-01
Specific Heat, Cp, (Btu/lb-R)	1.06E-01	2.22E-01	5.5E-02	5.5E-02
Conductivity, k, (Btu/in-R)	3.703E-04	1.066E-05	1.111E-03	1.111E-03

Table 1. Material Property

C. Find:

1. Verify the manufacturer's specified time constant value.
2. Determine temperature of the thermocouple at one time constant in the hot gas environment.

II. Analysis

A. Lumped Capacitance Method:

1. Verify the time constant of Thermocouple (Tc) probe:

The lumped capacitance method may expected to give good estimates when the Biot number is less than 0.1

$$\text{Biot number} = (h\ V/A)/k \qquad (1)$$

where,

h: heat transfer coefficient from the body to environment
V: volume of the solid body
A: convective area of the solid body
k: thermal conductivity of the solid

The heat transfer coefficient for air at room temperature with velocity of 65.0 ft/s is calculated as follows:

$$Reyd = (\rho * v * d)/\mu$$

where,

Reyd: Reynolds number
ρ: density of air
v: velocity of air
μ: dynamic viscosity of air
d: diameter of tc probe

Substitute given values from table 1

$$Reyd = (0.0735*65.0*3600.0*0.04)/0.04467*12.0$$
$$= 1283.0$$

Nussett number:

$$Nu = hd/k = C\ Reyd^{m}\ Pr^{1/3}$$

where,

$$C = 0.683;\ m = 0.466;\ \text{for } 40.0 < Reyd < 4000.0$$

Pr: Prandtl number of air = 0.709

$$Nu = 0.863*1283.0^{0.466} * 0.709^{1/3}$$
$$= 17.10$$

Heat transfer coefficient h:

$$h = Nu*k/d$$
$$= 17.10*0.01516*12.0/0.04$$
$$= 77.78\ Btu/hr\text{-}ft^2\text{-}R = 1.5E\text{-}04\ Btu/sec\text{-}in^2\text{-}R$$

Volume of the tc probe:

$$V = 1/2 \text{ solid sphere} + \text{solid cylinder}$$
$$= (1/2)(4/3)(0.02^3)\ \pi + (0.02^2)(0.0425)\pi$$
$$= 7.0157E\text{-}05\ in^3$$

Convective area:

$$A = 1/2 \text{ sphere surface} + \text{cylinder surface}$$
$$= (1/2)4(0.02^2) + (0.04)(0.0425)\pi$$
$$= 7.851E\text{-}03\ in^2$$

Equation (1) become

$$Biot = [1.5E\text{-}04(7.015E\text{-}05/7.851E\text{-}03)]/3.703E\text{-}04$$
$$= 0.0036 < 0.1$$

So the condition of the Biot number is satisfied.

The convection heat loss from the tc probe is assumed to be equal to a decrease in its internal energy:

$$q = hA(T-Te) = -\rho CpV\, dT/dt \qquad (2)$$

where

V: volume the solid
A: convective area of solid
ρ: density of solid
Cp: specific heat of solid
T: temperature of solid
Te: temperature of environment
t: time

The initial condition is:

$$T = Ti \quad \text{at} \quad t=0$$

Solution is:

$$(T-Te)/(Ti-Te) = e^{-(hA/\rho CpV)t} \qquad (3)$$

The term (ρCpV)/(hA) has the dimensions of time and it is called the time constant.

when time equals to one time constant:

$$t = (\rho CpV)/(hA) \qquad (4)$$

or

$$t = (0.3*0.139*7.015E\text{-}05)/(1.5E\text{-}04*7.851E\text{-}03)$$
$$= 2.5 \text{ seconds}$$

This time constant value of the probe agrees with the Omega manufacturer's time constant chart.

2. Temperature of Tc probe in hot gas environment at one time constant

a. Hand calculation:

Verify the Biot number condition requirement

$$\text{Biot number} = h(V/A)/k$$
$$= 0.0028(7.0157E\text{-}5/7.851E\text{-}3)/3.703E\text{-}4$$
$$= .0672 < 0.1$$

when time equals to one time constant:

$$t = (\rho CpV)/(hA)$$
$$= 0.3*0.139*7.015E\text{-}5/(0.0028*7.851E\text{-}3)$$
$$= 0.134 \text{ seconds}$$

So that equation (3) become

$$(T-Te)/(Ti-Te) = e^{-1/1}$$
$$= 0.368$$

$$T = Te + 0.368(Ti-Te)$$
$$= 3675.0 \text{ R} + 0.368(450.0 \text{ R} - 3675.0 \text{ R})$$
$$= 2488.0 \text{ R}$$

b. SINDA simple one-node model:

```
C TCSIMP.SIN THIS IS SIMPLE CASE OF TCPROBE
C SOLID TIP/CYL THERMOCOUPLE
C APRIL 2/91
C USING THE INPUT
C H VARY WITH SPECIES MASS FLOWRATES DURING START
       BCD 3THERMAL LPCS
       BCD 9TCPROBE SIMPLE CASE
       BCD 9
       BCD 2
       END
       BCD 3NODE DATA
           -1 ,3675.0  , 1.0    $ BOUNDARY NODE
       CAL 2  , 450.0  , 0.30,0.14,7.0157E-05,1.0 $ SOLID TIP/CYL
       CAL 49 , 450.0  , 0.30,0.14,7.0E-04,1.0    $ THERMAL SINK
       END
       BCD 3SOURCE DATA
       END
       BCD 3CONDUCTOR DATA
       CAL 1,  2,  1,  7.851E-03,.0028,1.,1.  $H*A
       CAL 2,  2, 49,  1.0E-01,3.7E-04,5.260E-04,0.0625  $KA/L
       END
       BCD 3CONSTANTS DATA
           NDIM=4000
           TIMEO=0.0
           TIMEND=.3
           OUTPUT=0.005
           DRLXCA=0.001
           ARLXCA=0.001
           NLOOP=500
           DAMPA=0.003
           DAMPD=0.003
           DTIMEI=0.0001
       END
       BCD 3ARRAY DATA
       END
       BCD 3EXECUTION
M      OPEN(UNIT=10,FILE='TCSIMP.XL',STATUS='UNKNOWN')
M          CALL FWDBKL
CM         CALL  SNDUFR
C
       END
       BCD 3VARIABLES 1
       END
       BCD 3VARIABLES 2
CM          IF(TIMEO.LE.0.1) OUTPUT=0.05
       END
       BCD 3OUTPUT CALLS
           TPRINT
M      WRITE(10,100)TIMEO,T1,T2,T49
M 100  FORMAT(F6.3,3X,F8.2,3X,F8.2,3X,F8.2)
C           TDUMP
       END
       BCD 3END OF DATA
       END
```

c. SINDA simple model output:

```
(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      1
    TCPROBE SIMPLE CASE
 *** NOTE *** FWDBKL REQUIRES     15 DYNAMIC STORAGE LOCATIONS OUT OF   3995 AVAILABLE ***
```

```
          TIMEND = 0.30000    , CSGFAC = 1.0000    ,  DTIMEI = 0.10000E-03, NLOOP  =          500
          IMEO   = 0.00000E+00, OUTPUT = 0.50000E-02, DTIMEH = 0.10000E+09, DTIMEL = 0.00000E+00
          ARLXCA = 0.10000E-02, ATMPCA = 0.00000E+00, DRLXCA = 0.10000E-02, DTMPCA = 0.10000E+09
          EXTLIM =  50.000

 ****************
TIME = 0.00000E+00, DTIMEU = 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
     LOOPCT =      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

 SINPAT_TIME =  0.0000E+00
 T      2 =  450.0000 T     49 =  450.0000 T      1 = 3675.0000 T

 ****************
 TIME= 5.00003E-02, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 8.24219E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  5.0000E-02
 T      2 = 1451.5625 T     49 =  450.2759 T      1 = 3675.0000 T

 ****************
 TIME= 1.00001E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 5.64697E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.0000E-01
 T      2 = 2137.7146 T     49 =  450.9931 T      1 = 3675.0000 T

 ****************
 TIME= 1.05001E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 5.43701E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.0500E-01
 T      2 = 2193.1162 T     49 =  451.0808 T      1 = 3675.0000 T

 ****************
 TIME= 1.10001E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 5.23438E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.1000E-01
 T      2 = 2246.4604 T     49 =  451.1772 T      1 = 3675.0000 T
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     TCPROBE SIMPLE CASE

 ****************
 TIME= 1.15001E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 5.04395E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.1500E-01
 T      2 = 2297.8235 T     49 =  451.2735 T      1 = 3675.0000 T

 ****************
 TIME= 1.20001E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 4.85596E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.2000E-01
 T      2 = 2347.2808 T     49 =  451.3697 T      1 = 3675.0000 T

 ****************
 TIME= 1.25002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 4.67285E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.2500E-01
 T      2 = 2394.9021 T     49 =  451.4680 T      1 = 3675.0000 T

 ****************
 TIME= 1.30002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 4.50195E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.3000E-01
 T      2 = 2440.7559 T     49 =  451.5720 T      1 = 3675.0000 T

 ****************
 TIME= 1.35002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 4.33350E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.3500E-01
 T      2 = 2484.9070 T     49 =  451.6765 T      1 = 3675.0000 T

 ****************
 TIME= 1.40002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 4.17236E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.4000E-01
 T      2 = 2527.4187 T     49 =  451.7809 T      1 = 3675.0000 T

 ****************
 TIME= 1.45002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 4.01855E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.4500E-01
 T      2 = 2568.3523 T     49 =  451.8853 T      1 = 3675.0000 T

 ****************
 TIME= 1.50002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 3.86963E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.5000E-01
 T      2 = 2607.7654 T     49 =  452.0002 T      1 = 3675.0000 T
1(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      5

     TCPROBE SIMPLE CASE

 ****************
 TIME= 1.55002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 3.72559E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

 SINPAT_TIME =  1.5500E-01
 T      2 = 2645.7151 T     49 =  452.1185 T      1 = 3675.0000 T
```
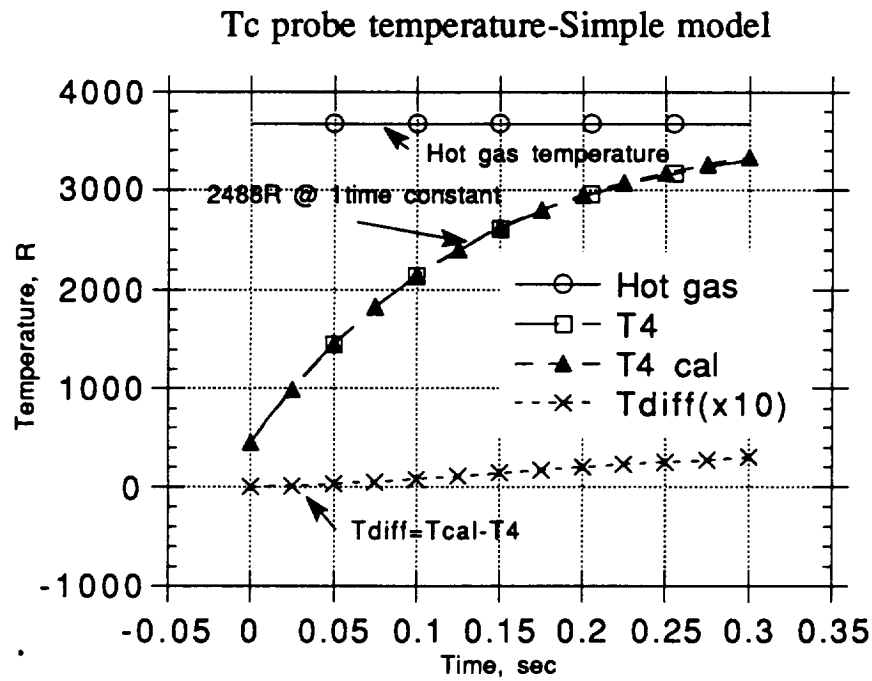

```
****************
TIME= 1.60002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 3.58887E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  1.6000E-01
T      2 = 2682.2563 T     49 =  452.2368 T      1 = 3675.0000 T

****************
TIME= 1.65002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 3.45459E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  1.6500E-01
T      2 = 2717.4421 T     49 =  452.3551 T      1 = 3675.0000 T

****************
TIME= 1.70002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 3.32520E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  1.7000E-01
T      2 = 2751.3208 T     49 =  452.4735 T      1 = 3675.0000 T

****************
TIME= 1.80002E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 3.08105E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  1.8000E-01
T      2 = 2815.3508 T     49 =  452.7216 T      1 = 3675.0000 T

****************
TIME= 2.00003E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 2.65137E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  2.0000E-01
T      2 = 2929.7559 T     49 =  453.2306 T      1 = 3675.0000 T

****************
TIME= 2.05003E-01, DTIMEU= 5.00004E-05, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 2.55127E-01
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  2.0500E-01
T      2 = 2955.7529 T     49 =  453.3577 T      1 = 3675.0000 T

****************
TIME= 3.00000E-01, DTIMEU= 3.01003E-06, CSGMIN(      2)= 1.32169E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)= 7.56836E-03
    LOOPCT=     2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      2)= 0.00000E+00

SINPAT_TIME =  3.0000E-01
T      2 = 3301.4229 T     49 =  456.0718 T      1 = 3675.0000 T
```

Comparison of simple model and hand calculation results:

Time: (sec)	Tgas: (R)	T4 : (R)	Tcal: (R)	Tdiff: (R)
0.0000	3675.0	450.00	450.00	0.0000
0.0050	3675.0	568.05		
0.0100	3675.0	681.72		
0.0150	3675.0	791.16		
0.0200	3675.0	896.54		
0.0250	3675.0	998.01	990.00	2.000
0.0300	3675.0	1095.7		
0.0350	3675.0	1189.8		
0.0400	3675.0	1280.4		
0.0450	3675.0	1367.6		
0.0500	3675.0	1451.6	1454.0	3.000
0.055000	3675.0	1532.4		
0.060000	3675.0	1610.3		
0.065000	3675.0	1685.2		
0.070000	3675.0	1757.4		
0.075000	3675.0	1827.0	1832.0	5.000
0.080000	3675.0	1893.9		
0.085000	3675.0	1958.4		
0.090000	3675.0	2020.4		
0.095000	3675.0	2080.2		
0.10000	3675.0	2137.7	2145.0	8.000
0.10500	3675.0	2193.1		
0.11000	3675.0	2246.5		
0.11500	3675.0	2297.8		
0.12000	3675.0	2347.3		
0.12500	3675.0	2394.9	2406.0	11.00
0.13000	3675.0	2440.8		
0.13500	3675.0	2484.9		
0.14000	3675.0	2527.4		

0.14500	3675.0	2568.4		
0.15000	3675.0	2607.8	2622.0	14.00
0.15500	3675.0	2645.7		
0.16000	3675.0	2682.3		
0.16500	3675.0	2717.4		
0.17000	3675.0	2751.3		
0.17500	3675.0	2783.9	2801.0	17.00
0.18000	3675.0	2815.4		
0.18500	3675.0	2845.6		
0.19000	3675.0	2874.7		
0.19500	3675.0	2902.8		
0.20000	3675.0	2929.8	2950.0	20.00
0.20500	3675.0	2955.7		
0.21000	3675.0	2980.8		
0.21500	3675.0	3004.9		
0.22000	3675.0	3028.1		
0.22500	3675.0	3050.4	3073.0	23.00
0.23000	3675.0	3072.0		
0.23500	3675.0	3092.7		
0.24000	3675.0	3112.6		
0.24500	3675.0	3131.8		
0.25000	3675.0	3150.3	3175.0	25.00
0.25500	3675.0	3168.1		
0.26000	3675.0	3185.3		
0.26500	3675.0	3201.8		
0.27000	3675.0	3217.7		
0.27500	3675.0	3233.0	3260.0	27.00
0.28000	3675.0	3247.7		
0.28500	3675.0	3261.9		
0.29000	3675.0	3275.6		
0.29500	3675.0	3288.8		
0.30000	3675.0	3301.4	3331.0	30.00



* Temperature differences (Tdiff) between the hand calculation and SINDA model in the above plot were multiplied by 10 for easy visual comparison purpose.

B. Spatial effects:

1. Assumptions:

The spatial effects are modeled utilizing a 2-Dimensional analysis model built with PATRAN/SINDA to define the tc probe temperature at one time constant based on the following assumptions:

Heat transfer from hot gas to thermocouple occurs through the leading edge and sides through the metal casing of inconel and magnesia insulation.

Conduction is modeled from the thermocouple surface to the distinct wires (chromel and alumel) inside the probe.

Conduction through the probe base to a thermal sink is included.

2. Patran model listing:

```
$ patran file for the TC grounded junction Chromel/Alumel type K thermocouple
$  mar 20/91
GO
1
1
$ H=0.0028 BTU/SEC IN2 R for later input
SET,LABEL,OFF
SET,TOL,5.000E-7
GR,#,,-.018,-.002
GR,2,,-.014,-.002
GR,3,,-.007,-.002
GR,4,,-.003,-.002
WI
4
PL
LI,#,2G,,1,2
LI,#,2G,,2,3
LI,3,2G,,3,4
LI,4T6,TR,0/.004/0,1T3
WI
4
PL
PA,#,2L,,1,4
PA,#,2L,,2,5
PA,#,2L,,3,6
LI,3#,RO,0/.002/0/0/0/1/-30,4T6
LI,3#,RO,0/.002/0/0/0/1/-30,7T9
LI,3#,RO,0/.002/0/0/0/1/-30,10T12
LI,3#,TR,.008/0/0,13T15
LI,3#,TR,.016/0/0,16T18
LI,3#,TR,.0205/0/0,19T21
PA,6#,2L,,4T19B3,7T22B3
PA,6#,2L,,6T21B3,9T24B3
PA,12#,MIRROR,Y,4T15
PA,6#,2L,,5T20B3,8T23B3
PA,6#,MIRROR,Y,28T33
PA,#,QU,,8/4/45/12
PA,#,QU,,12/45/47/16
PA,#,QU,,16/47/49/20
PA,#,QU,,20/49/51/24
PA,#,QU,,24/51/53/28
PA,#,QU,,28/53/55/32
SET,BEAMINP,OFF
GR,1001,,-.025
GR,1002,,-.025,.0001
LI,1000,2G,,1001,1002
GF,1000L
CF,1000L,BAR//1
DF,1000L,TEMP/E,3675.0/-1,-100
GF,P1T45,,2/2
CF,P1T45,QU//1
$ RHO:LB/IN3 CP:BTU/LB.F  K:BTU/SEC IN2 F
$ CHROMEL
PMAT,1,ANI,2,.3154,.055,,,2,0.001111
$ ALUMEL
PMAT,2,ANI,2,.3107,.055,,,2,0.001111
$ INCONEL
PMAT,3,ANI,2,.3040,.106,,,2,0.0003703
$ MAGNESIA MgO
PMAT,4,ANI,2,.0097,.222,,,2,0.000001064
DF,P1,CONV/E,0.0028/-2,-100,ED1
```

```
DF,P4T8,CONV/E,0.0028/-2,-100,ED1
DF,P16T20,CONV/E,0.0028/-2,-100,ED4
$ CHROMEL
PF,P2T3,QU//1,1/7.004
PF,P10T15,QU//1,1//.004
PA,2T3,COLOR,12
PA,10T15,COLOR,12
$ ALUMEL
PF,P22T27,QU//1,2//.004
PA,22T27,COLOR,8
$ INCONEL
PF,P1,QU//1,3//.004
PF,P4T9,QU//1,3//.004
PF,P16T21,QU//1,3//.004
PA,1,COLOR,4
PA,4T9,COLOR,4
PA,16T21,COLOR,4
$ MAGNESIA MgO HIGH TEMPERATURE INSULATION
PF,P28T45,QU//1,4//.004
PA,28T45,COLOR,10
$ INITIAL TEMPERATURE
DF,P1T45,TEMP/E,450.0/1
$
$
```

3. SINDA 2-D model listing:

```
C PATRAN GENERATED NEUTRAL FILE WHOSE TITLE WAS: patran.out.4
C from tcmar20.sin added thermal sink node 49 of5.15E-05
C conductivity of magnesia=1.066E-05
C
C TC4A1MAR20
C         CREATED ON: 20-Mar-91     AT 10:40:39
C WAS USED BY *** P A T S I N *** VERSION 3.0 TO CREATE THIS
C SINDA INPUT FILE: tcmar20.sin.1
C         CREATED ON: 20-Mar-91     AT 10:49:38
C
C BEGIN TRANSLATION PARAMETERS
C
C END TRANSLATION PARAMETERS
       BCD 3THERMAL LPCS
       BCD 9TC4A1MAR20
       BCD 9
       BCD 2
       END
C
       BCD 3NODE DATA
C             Node,    Init Temp,  Density    *  Spec Heat  *   Volume          $   Typ Cfg
Pid  Mid   Cord Typ User_note...
                -1,   3675.0    ,   1.0000    *   1.0000    *  0.00000E+00      $
                 2,   450.00    ,  0.30400    *  0.10600    *  6.40000E-08      $
                 3,   450.00    ,  0.31540    *  5.50000E-02*  1.12000E-07      $
                 4,   450.00    ,  0.31540    *  5.50000E-02*  6.40000E-08      $
                 5,   450.00    ,  0.30400    *  0.10600    *  1.28000E-07      $
                 6,   450.00    ,  0.30400    *  0.10600    *  1.28000E-07      $
                 7,   450.00    ,  0.30400    *  0.10600    *  1.28000E-07      $
                 8,   450.00    ,  0.30400    *  0.10600    *  1.28000E-07      $
                 9,   450.00    ,  0.30400    *  0.10600    *  2.56000E-07      $
                10,   450.00    ,  0.30400    *  0.10600    *  3.28000E-07      $
                11,   450.00    ,  0.31540    *  5.50000E-02*  3.99999E-08      $
                12,   450.00    ,  0.31540    *  5.50000E-02*  4.00001E-08      $
                13,   450.00    ,  0.31540    *  5.50000E-02*  4.00002E-08      $
                14,   450.00    ,  0.31540    *  5.50000E-02*  1.28001E-07      $
```

```
          15,   450.00    ,  0.31540     *  5.50000E-02*  2.56001E-07      $
          16,   450.00    ,  0.31540     *  5.50000E-02*  3.28002E-07      $
          17,   450.00    ,  0.30400     *  0.10600     *  1.28000E-07      $
          18,   450.00    ,  0.30400     *  0.10600     *  1.28000E-07      $
          19,   450.00    ,  0.30400     *  0.10600     *  1.28000E-07      $
          20,   450.00    ,  0.30400     *  0.10600     *  1.28000E-07      $
          21,   450.00    ,  0.30400     *  0.10600     *  2.56000E-07      $
          22,   450.00    ,  0.30400     *  0.10600     *  3.28000E-07      $
          23,   450.00    ,  0.31070     *  5.50000E-02*  3.99999E-08      $
          24,   450.00    ,  0.31070     *  5.50000E-02*  4.00002E-08      $
          25,   450.00    ,  0.31070     *  5.50000E-02*  4.00002E-08      $
          26,   450.00    ,  0.31070     *  5.50000E-02*  1.28001E-07      $
          27,   450.00    ,  0.31070     *  5.50000E-02*  2.56001E-07      $
          28,   450.00    ,  0.31070     *  5.50000E-02*  3.28002E-07      $
          29,   450.00    ,  9.70000E-03*  0.22200     *  1.47000E-07      $
          30,   450.00    ,  9.70000E-03*  0.22200     *  1.47000E-07      $
          31,   450.00    ,  9.70000E-03*  0.22200     *  1.47000E-07      $
          32,   450.00    ,  9.70000E-03*  0.22200     *  2.24000E-07      $
          33,   450.00    ,  9.70000E-03*  0.22200     *  4.48000E-07      $
          34,   450.00    ,  9.70000E-03*  0.22200     *  5.74000E-07      $
          35,   450.00    ,  9.70000E-03*  0.22200     *  1.47000E-07      $
          36,   450.00    ,  9.70000E-03*  0.22200     *  1.47000E-07      $
          37,   450.00    ,  9.70000E-03*  0.22200     *  1.47000E-07      $
          38,   450.00    ,  9.70000E-03*  0.22200     *  2.24000E-07      $
          39,   450.00    ,  9.70000E-03*  0.22200     *  4.48000E-07      $
          40,   450.00    ,  9.70000E-03*  0.22200     *  5.74000E-07      $
          41,   450.00    ,  9.70000E-03*  0.22200     *  8.84233E-09      $
          42,   450.00    ,  9.70000E-03*  0.22200     *  3.55692E-08      $
          43,   450.00    ,  9.70000E-03*  0.22200     *  5.75884E-08      $
          44,   450.00    ,  9.70000E-03*  0.22200     *  3.20000E-07      $
          45,   450.00    ,  9.70000E-03*  0.22200     *  6.39999E-07      $
          46,   450.00    ,  9.70000E-03*  0.22200     *  8.19999E-07      $
          47,   450.00    ,9.141E-06
          48,   450.00    ,9.100E-06
          49,   450.00    ,0.3*0.14*7.0E-04
     END
C
     BCD 3SOURCE DATA
C          NODE,   LoAoV     *   HEAT/LoAoV                                $
     END
C
     BCD 3CONDUCTOR DATA
C      Conductor, NodeI, NodeJ, Conductivity* Effective A / Length    L    $
          1,      2,      3,  6.43174E-04*  1.60000E-05/  5.50000E-03      $
          2,      2,      5,  3.70300E-04*  1.56538E-05/  6.14189E-03      $
          3,      2,     17,  3.70300E-04*  1.56538E-05/  6.14189E-03      $
          4,      2,      1,  4.41326E-08                                  $
          5,      3,      4,  1.11100E-03*  1.60000E-05/  5.50000E-03      $
          6,      3,     29,  1.81076E-05*  2.75781E-05/  4.74344E-03      $
          7,      3,     35,  1.81076E-05*  2.75781E-05/  4.74344E-03      $
          8,      4,     11,  1.11100E-03*  1.58185E-05/  3.31948E-03      $
          9,      4,     23,  1.11100E-03*  1.58186E-05/  3.31948E-03      $
         10,      4,     41,  1.14690E-04*  1.62597E-05/  2.21923E-03      $
         11,      5,      6,  3.70300E-04*  1.54920E-05/  8.28377E-03      $
         12,      5,     29,  1.62855E-05*  2.75750E-05/  5.01745E-03      $
         13,      5,      1,  1.02834E-07                                  $
         14,      6,      7,  3.70300E-04*  1.54919E-05/  8.28377E-03      $
         15,      6,     30,  1.62855E-05*  2.75750E-05/  5.01745E-03      $
         16,      6,      1,  1.02834E-07                                  $
         17,      7,      8,  3.70300E-04*  1.57373E-05/  8.14189E-03      $
         18,      7,     31,  1.62856E-05*  2.75750E-05/  5.01745E-03      $
         19,      7,      1,  1.02834E-07                                  $
         20,      8,      9,  3.70300E-04*  1.60000E-05/  1.20000E-02      $
         21,      8,     32,  1.64803E-05*  3.20000E-05/  5.50000E-03      $
```

```
22,     8,     1,  8.82651E-08                                          $
23,     9,    10,  3.70300E-04*  1.60000E-05/  1.82500E-02             $
24,     9,    33,  1.64803E-05*  6.40000E-05/  5.50000E-03             $
25,     9,     1,  1.76530E-07                                          $
26,    10,    34,  1.64803E-05*  8.20000E-05/  5.50000E-03             $
27,    11,    12,  1.11100E-03*  1.55513E-05/  2.63896E-03             $
28,    11,    29,  1.74168E-05*  1.60269E-05/  5.43065E-03             $
29,    11,    41,  1.22978E-05*  2.52990E-06/  4.93949E-03             $
30,    12,    13,  1.11100E-03*  1.55513E-05/  2.63896E-03             $
31,    12,    30,  1.74167E-05*  1.60270E-05/  5.43065E-03             $
32,    12,    42,  1.36677E-05*  5.27968E-06/  6.23855E-03             $
33,    13,    14,  1.11100E-03*  1.58864E-05/  5.31948E-03             $
34,    13,    31,  1.74168E-05*  1.60270E-05/  5.43066E-03             $
35,    13,    43,  1.41156E-05*  6.57955E-06/  6.98848E-03             $
36,    14,    15,  1.11100E-03*  1.60001E-05/  1.20000E-02             $
37,    14,    32,  1.66601E-05*  3.20000E-05/  5.50001E-03             $
38,    14,    44,  1.48670E-05*  3.20000E-05/  7.00000E-03             $
39,    15,    16,  1.11100E-03*  1.60001E-05/  1.82500E-02             $
40,    15,    33,  1.66601E-05*  6.40000E-05/  5.50001E-03             $
41,    15,    45,  1.48670E-05*  6.40000E-05/  7.00000E-03             $
42,    16,    34,  1.66601E-05*  8.20000E-05/  5.50001E-03             $
43,    16,    46,  1.48670E-05*  8.20000E-05/  7.00000E-03             $
44,    17,    18,  3.70300E-04*  1.54919E-05/  8.28377E-03             $
45,    17,    35,  1.62855E-05*  2.75750E-05/  5.01745E-03             $
46,    17,     1,  1.02834E-07                                          $
47,    18,    19,  3.70300E-04*  1.54917E-05/  8.28377E-03             $
48,    18,    36,  1.62855E-05*  2.75750E-05/  5.01745E-03             $
49,    18,     1,  1.02834E-07                                          $
50,    19,    20,  3.70300E-04*  1.57375E-05/  8.14189E-03             $
51,    19,    37,  1.62856E-05*  2.75750E-05/  5.01745E-03             $
52,    19,     1,  1.02834E-07                                          $
53,    20,    21,  3.70300E-04*  1.60000E-05/  1.20000E-02             $
54,    20,    38,  1.64803E-05*  3.20000E-05/  5.50000E-03             $
55,    20,     1,  8.82651E-08                                          $
56,    21,    22,  3.70300E-04*  1.60000E-05/  1.82500E-02             $
57,    21,    39,  1.64803E-05*  6.40000E-05/  5.50000E-03             $
58,    21,     1,  1.76530E-07                                          $
59,    22,    40,  1.64803E-05*  8.20000E-05/  5.50000E-03             $
60,    23,    24,  1.11100E-03*  1.55513E-05/  2.63896E-03             $
61,    23,    35,  1.74168E-05*  1.60269E-05/  5.43065E-03             $
62,    23,    41,  1.22978E-05*  2.52990E-06/  4.93949E-03             $
63,    24,    25,  1.11100E-03*  1.55513E-05/  2.63896E-03             $
64,    24,    36,  1.74167E-05*  1.60270E-05/  5.43065E-03             $
65,    24,    42,  1.36677E-05*  5.27966E-06/  6.23854E-03             $
66,    25,    26,  1.11100E-03*  1.58864E-05/  5.31948E-03             $
67,    25,    37,  1.74168E-05*  1.60270E-05/  5.43066E-03             $
68,    25,    43,  1.41154E-05*  6.57915E-06/  6.98848E-03             $
69,    26,    27,  1.11100E-03*  1.60001E-05/  1.20000E-02             $
70,    26,    38,  1.66601E-05*  3.20000E-05/  5.50001E-03             $
71,    26,    44,  1.48670E-05*  3.20000E-05/  7.00000E-03             $
72,    27,    28,  1.11100E-03*  1.60001E-05/  1.82500E-02             $
73,    27,    39,  1.66601E-05*  6.40000E-05/  5.50001E-03             $
74,    27,    45,  1.48670E-05*  6.40000E-05/  7.00000E-03             $
75,    28,    40,  1.66601E-05*  8.20000E-05/  5.50001E-03             $
76,    28,    46,  1.48670E-05*  8.20000E-05/  7.00000E-03             $
77,    29,    30,  1.06600E-05*  2.72784E-05/  5.48688E-03             $
78,    30,    31,  1.06600E-05*  2.72784E-05/  5.48688E-03             $
79,    31,    32,  1.06600E-05*  2.77019E-05/  6.74344E-03             $
80,    32,    33,  1.06600E-05*  2.80000E-05/  1.20000E-02             $
81,    33,    34,  1.06600E-05*  2.80000E-05/  1.82500E-02             $
82,    35,    36,  1.06600E-05*  2.72784E-05/  5.48688E-03             $
83,    36,    37,  1.06600E-05*  2.72784E-05/  5.48688E-03             $
84,    37,    38,  1.06600E-05*  2.77019E-05/  6.74344E-03             $
85,    38,    39,  1.06600E-05*  2.80000E-05/  1.20000E-02             $
```

```
                86,     39,     40,  1.06600E-05*  2.80000E-05/  1.82500E-02       $
                87,     41,     42,  1.06600E-05*  2.88368E-05/  7.56547E-04       $
                88,     42,     43,  1.06600E-05*  3.63320E-05/  1.28469E-03       $
                89,     43,     44,  1.06600E-05*  3.98733E-05/  4.73953E-03       $
                90,     44,     45,  1.06600E-05*  4.00000E-05/  1.20000E-02       $
                91,     45,     46,  1.06600E-05*  4.00000E-05/  1.82500E-02       $
                92,     16,47,0.00111*0.0000126/21.0
                93,     28,48,0.00111*0.0000126/21.0
                94,     10,49,3.703E-04*1.06E-05/2.15E-02
                95,     22,49,3.703E-04*1.06E-05/2.15E-02
                96,     34,49,2.8E-05*1.06E-05/2.15E-02
                97,     40,49,2.8E-05*1.06E-05/2.15E-02
                98,     46,49,4.0E-05*1.06E-05/2.15E-02
        END
C
        BCD 3CONSTANTS DATA
M           NDIM=4000
M           TIMEO=0.0
M           TIMEND=.250
M           OUTPUT=.005
M           DRLXCA=0.01
M           ARLXCA=0.01
M           NLOOP=1000
M           DAMPA=0.03
M           DAMPD=0.03
M           DTIMEI=0.0001
        END
        BCD 3ARRAY DATA
        END
C APPEND ALL FROM HERE...
        BCD 3EXECUTION
CM       CALL CSGDMP
M       OPEN(UNIT=10,FILE='TC.XL',STATUS='UNKNOWN')
M       CALL FWDBKL
CM       CALL SNDUFR
        END
        BCD 3VARIABLES 1
        END
        BCD 3VARIABLES 2
CM       IF(TIMEO.LE.5.) OUTPUT=1.0
        END
        BCD 3OUTPUT CALLS
M       CALL TPRINT
CM       CALL QNPRNT
C             TDUMP
M          WRITE(10,100)TIMEO,T1,T2,T4,T47,T48,T49
M 100   FORMAT(F6.3,3X,F8.2,3X,F8.2,3X,F8.2,3X,F8.2,3X,F8.2,3X,F8.2)
        END
        BCD 3END OF DATA
        END
```

4. SINDA 2-D model output :

```
C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      1

    TC4A1MAR20

 *** NOTE *** FWDBKL REQUIRES     337 DYNAMIC STORAGE LOCATIONS OUT OF    3853 AVAILABLE ***
              TIMEND= 0.25000     , CSGFAC=  1.0000     , DTIMEI= 0.10000E-03, NLOOP =         1000
              TIMEO = 0.00000E+00, OUTPUT= 0.50000E-02, DTIMEH= 0.10000E+09, DTIMEL= 0.00000E+00
              ARLXCA= 0.10000E-01, ATMPCA= 0.00000E+00, DRLXCA= 0.10000E-01, DTMPCA= 0.10000E+09
              EXTLIM=  50.000

 ****************
 TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
     LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

 SINPAT_TIME =  0.0000E+00
 T      2 =  450.0000 T      3 =  450.0000 T      4 =  450.0000 T      5 =  450.0000 T      6 =  450.0000 T      7 =  450.0000
 T      8 =  450.0000 T      9 =  450.0000 T     10 =  450.0000 T     11 =  450.0000 T     12 =  450.0000 T     13 =  450.0000
 T     14 =  450.0000 T     15 =  450.0000 T     16 =  450.0000 T     17 =  450.0000 T     18 =  450.0000 T     19 =  450.0000
```

```
T     20 =  450.0000 T     21 =  450.0000 T     22 =  450.0000 T     23 =  450.0000 T     24 =  450.0000 T     25 =  450.0000
T     26 =  450.0000 T     27 =  450.0000 T     28 =  450.0000 T     29 =  450.0000 T     30 =  450.0000 T     31 =  450.0000
T     32 =  450.0000 T     33 =  450.0000 T     34 =  450.0000 T     35 =  450.0000 T     36 =  450.0000 T     37 =  450.0000
T     38 =  450.0000 T     39 =  450.0000 T     40 =  450.0000 T     41 =  450.0000 T     42 =  450.0000 T     43 =  450.0000
T     44 =  450.0000 T     45 =  450.0000 T     46 =  450.0000 T     47 =  450.0000 T     48 =  450.0000 T     49 =  450.0000
T      1 = 3675.0000 T

****************
TIME= 5.00000E-03, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     19)= 3.11328E+00
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     23)=-2.13623E-03

SIMPAT_TIME =  5.0000E-03
T      2 =  684.7109 T      3 =  570.8774 T      4 =  521.0691 T      5 =  772.7166 T      6 =  803.4513 T      7 =  801.2020
T      8 =  771.0339 T      9 =  739.8029 T     10 =  471.0560 T     11 =  508.5410 T     12 =  499.7735 T     13 =  492.0585
T     14 =  470.5490 T     15 =  462.2131 T     16 =  452.5291 T     17 =  772.7158 T     18 =  803.4526 T     19 =  801.2039
T     20 =  771.0364 T     21 =  739.8052 T     22 =  471.0572 T     23 =  508.6463 T     24 =  499.9374 T     25 =  492.2595
T     26 =  470.7887 T     27 =  462.3958 T     28 =  452.5960 T     29 =  586.6420 T     30 =  595.2043 T     31 =  589.3755
T     32 =  551.8918 T     33 =  535.9839 T     34 =  456.3477 T     35 =  586.6594 T     36 =  595.2366 T     37 =  589.4160
T     38 =  551.9481 T     39 =  536.0223 T     40 =  456.3594 T     41 =  514.1885 T     42 =  501.0494 T     43 =  487.7741
T     44 =  461.4180 T     45 =  452.8857 T     46 =  450.4867 T     47 =  450.0000 T     48 =  450.0001 T     49 =  449.9998
T      1 = 3675.0000 T

****************
TIME= 1.00001E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 5.60303E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     11)=-1.22070E-03

SIMPAT_TIME =  1.0000E-01
T      2 = 2402.1287 T      3 = 2247.1902 T      4 = 2157.7454 T      5 = 2535.1335 T      6 = 2619.3254 T      7 = 2618.3389
T      8 = 2534.3193 T      9 = 2315.9326 T     10 = 1544.5817 T     11 = 2132.2827 T     12 = 2111.1831 T     13 = 2088.9492
T     14 = 2042.7131 T     15 = 1941.3247 T     16 = 1812.4709 T     17 = 2535.2021 T     18 = 2619.5039 T     19 = 2618.6270
T     20 = 2534.7288 T     21 = 2316.5098 T     22 = 1545.3395 T     23 = 2132.5613 T     24 = 2111.6719 T     25 = 2089.6343
T     26 = 2043.7588 T     27 = 1943.0015 T     28 = 1814.6467 T     29 = 2329.2112 T     30 = 2388.4094 T     31 = 2376.9700
T     32 = 2268.0701 T     33 = 2096.8689 T     34 = 1638.8259 T     35 = 2329.3318 T     36 = 2388.7043 T     37 = 2377.4326
T     38 = 2268.8047 T     39 = 2098.0088 T     40 = 1640.2751 T     41 = 2145.7283 T     42 = 2121.7512 T     43 = 2092.7756
T     44 = 2010.5308 T     45 = 1885.7419 T     46 = 1700.0654 T     47 =  450.0000 T     48 =  450.0001 T     49 =  450.7715
T      1 = 3675.0000 T

****************
TIME= 1.20001E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 4.44336E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     11)=-9.76563E-04

SIMPAT_TIME =  1.2000E-01
T      2 = 2552.1807 T      3 = 2413.0645 T      4 = 2332.1135 T      5 = 2671.0554 T      6 = 2743.5366 T      7 = 2736.8711
T      8 = 2652.2749 T      9 = 2434.8501 T     10 = 1668.9211 T     11 = 2308.9385 T     12 = 2289.6150 T     13 = 2269.1563
T     14 = 2226.4717 T     15 = 2131.3733 T     16 = 2006.7654 T     17 = 2671.1177 T     18 = 2743.6973 T     19 = 2737.1301
T     20 = 2652.6477 T     21 = 2435.3607 T     22 = 1669.6069 T     23 = 2309.1631 T     24 = 2290.0098 T     25 = 2269.7097
T     26 = 2227.3169 T     27 = 2132.7297 T     28 = 2008.5281 T     29 = 2487.1860 T     30 = 2538.5667 T     31 = 2524.9282
T     32 = 2422.7764 T     33 = 2256.0049 T     34 = 1798.5305 T     35 = 2487.2878 T     36 = 2538.8159 T     37 = 2525.3188
T     38 = 2423.3918 T     39 = 2256.9561 T     40 = 1799.7439 T     41 = 2321.5608 T     42 = 2300.4905 T     43 = 2274.9255
T     44 = 2201.7874 T     45 = 2085.7629 T     46 = 1894.8188 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.0955
T      1 = 3675.0000 T

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TIME= 1.25002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 4.19189E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     12)=-7.32422E-04

SIMPAT_TIME =  1.2500E-01
T      2 = 2584.4302 T      3 = 2448.7568 T      4 = 2369.6587 T      5 = 2700.2271 T      6 = 2770.1509 T      7 = 2762.2424
T      8 = 2677.5264 T      9 = 2460.3308 T     10 = 1695.6343 T     11 = 2346.9824 T     12 = 2328.0461 T     13 = 2307.9744
T     14 = 2266.0654 T     15 = 2172.3450 T     16 = 2048.6819 T     17 = 2700.2886 T     18 = 2770.3079 T     19 = 2762.4958
T     20 = 2677.8850 T     21 = 2460.8313 T     22 = 1696.2981 T     23 = 2347.1948 T     24 = 2328.4194 T     25 = 2308.4973
T     26 = 2266.8640 T     27 = 2173.6274 T     28 = 2050.3496 T     29 = 2521.1487 T     30 = 2570.8167 T     31 = 2556.6956
T     32 = 2456.0193 T     33 = 2290.2317 T     34 = 1832.9348 T     35 = 2521.2466 T     36 = 2571.0554 T     37 = 2557.0710
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    TC4A1MAR20
T     38 = 2456.6053 T     39 = 2291.1372 T     40 = 1834.0911 T     41 = 2359.4246 T     42 = 2338.9868 T     43 = 2314.1633
T     44 = 2243.0063 T     45 = 2128.9136 T     46 = 1936.8728 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.1882
T      1 = 3675.0000 T

****************
TIME= 1.30002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 3.95020E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     11)=-9.76563E-04

SIMPAT_TIME =  1.3000E-01
T      2 = 2614.8159 T      3 = 2482.3931 T      4 = 2405.0422 T      5 = 2727.7075 T      6 = 2795.2139 T      7 = 2786.1284
T      8 = 2701.2966 T      9 = 2484.3237 T     10 = 1720.7988 T     11 = 2382.8374 T     12 = 2364.2683 T     13 = 2344.5632
T     14 = 2303.3892 T     15 = 2210.9775 T     16 = 2088.2131 T     17 = 2727.7671 T     18 = 2795.3660 T     19 = 2786.3740
T     20 = 2701.6438 T     21 = 2484.8064 T     22 = 1721.4387 T     23 = 2383.0383 T     24 = 2364.6211 T     25 = 2345.0581
T     26 = 2304.1458 T     27 = 2212.1917 T     28 = 2089.7908 T     29 = 2553.1519 T     30 = 2601.2024 T     31 = 2586.6238
T     32 = 2487.3401 T     33 = 2322.4883 T     34 = 1865.3713 T     35 = 2553.2446 T     36 = 2601.4309 T     37 = 2586.9817
T     38 = 2487.9081 T     39 = 2323.3513 T     40 = 1866.4717 T     41 = 2395.1089 T     42 = 2375.2693 T     43 = 2351.1489
T     44 = 2281.8708 T     45 = 2169.6028 T     46 = 1976.5381 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.2838
T      1 = 3675.0000 T

****************
TIME= 1.35002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 3.72559E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     11)=-9.76563E-04

SIMPAT_TIME =  1.3500E-01
T      2 = 2643.4468 T      3 = 2514.0913 T      4 = 2438.3909 T      5 = 2753.5962 T      6 = 2818.8203 T      7 = 2808.6221
T      8 = 2723.6004 T      9 = 2506.9185 T     10 = 1744.5117 T     11 = 2416.6318 T     12 = 2398.4089 T     13 = 2379.0515
T     14 = 2338.5735 T     15 = 2247.4001 T     16 = 2125.4878 T     17 = 2753.6531 T     18 = 2818.9651 T     19 = 2808.8591
T     20 = 2724.0129 T     21 = 2507.3831 T     22 = 1745.1252 T     23 = 2416.8215 T     24 = 2398.7427 T     25 = 2379.5188
T     26 = 2339.2078 T     27 = 2248.5479 T     28 = 2126.9800 T     29 = 2583.3049 T     30 = 2629.8279 T     31 = 2614.8191
T     32 = 2516.8513 T     33 = 2352.8875 T     34 = 1895.9475 T     35 = 2583.3958 T     36 = 2630.0459 T     37 = 2615.1611
T     38 = 2517.3843 T     39 = 2353.7078 T     40 = 1896.9917 T     41 = 2428.7427 T     42 = 2409.4670 T     43 = 2386.0100
T     44 = 2318.5081 T     45 = 2207.9744 T     46 = 2013.9460 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.3871
T      1 = 3675.0000 T

****************
TIME= 1.40002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 3.51563E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     11)=-9.76563E-04

SIMPAT_TIME =  1.4000E-01
T      2 = 2670.4260 T      3 = 2543.9646 T      4 = 2469.8228 T      5 = 2777.9883 T      6 = 2841.0571 T      7 = 2829.8098
T      8 = 2744.7625 T      9 = 2528.2002 T     10 = 1766.8513 T     11 = 2448.4839 T     12 = 2430.5881 T     13 = 2411.5579
T     14 = 2371.7363 T     15 = 2281.7344 T     16 = 2160.6292 T     17 = 2778.0413 T     18 = 2841.1965 T     19 = 2830.0371
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T     20 = 2745.0815 T     21 = 2528.6465 T     22 = 1767.4385 T     23 = 2440.6636 T     24 = 2430.9038 T     25 = 2412.0005
T     26 = 2372.4116 T     27 = 2282.8191 T     28 = 2162.0410 T     29 = 2611.7234 T     30 = 2656.8018 T     31 = 2641.3855
T     32 = 2544.6599 T     33 = 2381.5352 T     34 = 1924.7683 T     35 = 2611.8074 T     36 = 2657.0098 T     37 = 2641.7117
T     38 = 2545.1660 T     39 = 2382.3137 T     40 = 1925.7610 T     41 = 2460.4424 T     42 = 2441.7002 T     43 = 2418.8694
T     44 = 2353.0430 T     45 = 2244.1470 T     46 = 2049.2209 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.4904
T      1 = 3675.0000 T

****************
TIME= 1.45002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 3.31543E-01
    LOOPCT=     4                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     11)=-7.32422E-04

SINPAT_TIME =  1.4500E-01
T      2 = 2695.8486 T      3 = 2572.1187 T      4 = 2499.4453 T      5 = 2800.9695 T      6 = 2862.0046 T      7 = 2849.7676
T      8 = 2764.6194 T      9 = 2548.2471 T     10 = 1787.9001 T     11 = 2478.5039 T     12 = 2460.9175 T     13 = 2442.1973
T     14 = 2402.9961 T     15 = 2314.1013 T     16 = 2193.7595 T     17 = 2801.0208 T     18 = 2862.1355 T     19 = 2849.9836
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    TC4A1MAR20
T     20 = 2764.9250 T     21 = 2548.6746 T     22 = 1788.4626 T     23 = 2478.6731 T     24 = 2461.2148 T     25 = 2442.6140
T     26 = 2403.6338 T     27 = 2315.1252 T     28 = 2195.0938 T     29 = 2638.5017 T     30 = 2682.2192 T     31 = 2666.4180
T     32 = 2570.8657 T     33 = 2408.5322 T     34 = 1951.9329 T     35 = 2638.5815 T     36 = 2682.4150 T     37 = 2666.7241
T     38 = 2571.3447 T     39 = 2409.2712 T     40 = 1952.8748 T     41 = 2490.3191 T     42 = 2472.0806 T     43 = 2449.8416
T     44 = 2385.5964 T     45 = 2278.2502 T     46 = 2082.4807 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.5938
T      1 = 3675.0000 T

****************
TIME= 1.50002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 3.12012E-01
    LOOPCT=     3                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     41)= 9.76563E-03

SINPAT_TIME =  1.5000E-01
T      2 = 2719.8042 T      3 = 2598.6487 T      4 = 2527.3604 T      5 = 2822.6216 T      6 = 2881.7375 T      7 = 2868.5681
T      8 = 2783.3269 T      9 = 2567.1389 T     10 = 1807.7361 T     11 = 2506.7937 T     12 = 2489.5007 T     13 = 2471.0730
T     14 = 2432.4578 T     15 = 2344.6064 T     16 = 2224.9866 T     17 = 2822.6714 T     18 = 2881.8660 T     19 = 2868.7739
T     20 = 2783.6187 T     21 = 2567.5476 T     22 = 1808.2734 T     23 = 2506.9539 T     24 = 2489.7817 T     25 = 2471.4670
T     26 = 2433.0601 T     27 = 2345.5742 T     28 = 2226.2485 T     29 = 2663.7356 T     30 = 2706.1682 T     31 = 2690.0037
T     32 = 2595.5581 T     33 = 2433.9763 T     34 = 1977.5352 T     35 = 2663.8120 T     36 = 2706.3547 T     37 = 2690.2959
T     38 = 2596.0129 T     39 = 2434.6768 T     40 = 1978.4282 T     41 = 2518.4739 T     42 = 2500.7117 T     43 = 2479.0305
T     44 = 2416.2793 T     45 = 2310.3945 T     46 = 2113.8313 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.6972
T      1 = 3675.0000 T

****************
TIME= 1.55002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 2.94189E-01
    LOOPCT=     3                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     41)= 9.27734E-03

SINPAT_TIME =  1.5500E-01
T      2 = 2742.3799 T      3 = 2623.6538 T      4 = 2553.6741 T      5 = 2843.0266 T      6 = 2900.3289 T      7 = 2886.2820
T      8 = 2800.9536 T      9 = 2584.9373 T     10 = 1826.4268 T     11 = 2533.4607 T     12 = 2516.4419 T     13 = 2498.2893
T     14 = 2460.2263 T     15 = 2373.3601 T     16 = 2254.4238 T     17 = 2843.0723 T     18 = 2900.4526 T     19 = 2886.4795
T     20 = 2801.2322 T     21 = 2585.3235 T     22 = 1826.9380 T     23 = 2533.6113 T     24 = 2516.7075 T     25 = 2498.6624
T     26 = 2460.7961 T     27 = 2374.2747 T     28 = 2255.6143 T     29 = 2687.5171 T     30 = 2728.7356 T     31 = 2712.2290
T     32 = 2618.8279 T     33 = 2457.9541 T     34 = 2001.6675 T     35 = 2687.5884 T     36 = 2728.9131 T     37 = 2712.5083
T     38 = 2619.2600 T     39 = 2458.6172 T     40 = 2002.5142 T     41 = 2545.0127 T     42 = 2527.6973 T     43 = 2506.5422
T     44 = 2445.1985 T     45 = 2340.6931 T     46 = 2143.3835 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.8057
T      1 = 3675.0000 T

****************
TIME= 1.60002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 2.77100E-01
    LOOPCT=     3                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     41)= 8.54492E-03

SINPAT_TIME =  1.6000E-01
T      2 = 2763.6543 T      3 = 2647.2178 T      4 = 2578.4714 T      5 = 2862.2539 T      6 = 2917.8535 T      7 = 2902.9739
T      8 = 2817.5583 T      9 = 2601.7068 T     10 = 1844.0417 T     11 = 2558.5916 T     12 = 2541.8328 T     13 = 2523.9404
T     14 = 2486.3987 T     15 = 2400.4619 T     16 = 2282.1697 T     17 = 2862.2971 T     18 = 2917.9666 T     19 = 2903.1572
T     20 = 2817.8240 T     21 = 2602.0747 T     22 = 1844.5269 T     23 = 2558.7339 T     24 = 2542.0825 T     25 = 2524.2910
T     26 = 2486.9343 T     27 = 2401.3240 T     28 = 2283.2935 T     29 = 2709.9280 T     30 = 2750.0044 T     31 = 2733.1755
T     32 = 2640.7566 T     33 = 2480.5508 T     34 = 2024.4131 T     35 = 2709.9954 T     36 = 2750.1709 T     37 = 2733.4373
T     38 = 2641.1648 T     39 = 2481.1770 T     40 = 2025.2151 T     41 = 2570.0227 T     42 = 2553.1294 T     43 = 2532.4707
T     44 = 2472.4536 T     45 = 2369.2520 T     46 = 2171.2439 T     47 =  450.0000 T     48 =  450.0001 T     49 =  451.9138
T      1 = 3675.0000 T

TIME= 1.80002E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 2.18994E-01
    LOOPCT=     3                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     41)= 7.08008E-03

SINPAT_TIME =  1.8000E-01
T      2 = 2837.1841 T      3 = 2728.6699 T      4 = 2664.1895 T      5 = 2928.6992 T      6 = 2978.3896 T      7 = 2960.6343
T      8 = 2874.9314 T      9 = 2659.6396 T     10 = 1904.9146 T     11 = 2645.4624 T     12 = 2629.6006 T     13 = 2612.6072
T     14 = 2576.8677 T     15 = 2494.1504 T     16 = 2378.0920 T     17 = 2928.7346 T     18 = 2978.4844 T     19 = 2960.7856
T     20 = 2875.1504 T     21 = 2659.9404 T     22 = 1905.3145 T     23 = 2645.5747 T     24 = 2629.7983 T     25 = 2612.8848
T     26 = 2577.2917 T     27 = 2494.8318 T     28 = 2378.9797 T     29 = 2787.3843 T     30 = 2823.5044 T     31 = 2805.5571
T     32 = 2716.5427 T     33 = 2558.6504 T     34 = 2103.0334 T     35 = 2787.4392 T     36 = 2823.6377 T     37 = 2805.7659
T     38 = 2716.8701 T     39 = 2559.1519 T     40 = 2103.6729 T     41 = 2656.4761 T     42 = 2641.0420 T     43 = 2622.0989
T     44 = 2566.6775 T     45 = 2467.9868 T     46 = 2267.5640 T     47 =  450.0000 T     48 =  450.0001 T     49 =  452.3480
T      1 = 3675.0000 T
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TIME= 2.00003E-01, DTIMEU= 5.00004E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 1.72607E-01
    LOOPCT=     3                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     41)= 5.61523E-03

SINPAT_TIME =  2.0000E-01
T      2 = 2895.1809 T      3 = 2792.9192 T      4 = 2731.8069 T      5 = 2981.1042 T      6 = 3026.1323 T      7 = 3006.1042
T      8 = 2920.1721 T      9 = 2705.3281 T     10 = 1952.9536 T     11 = 2713.9893 T     12 = 2698.8362 T     13 = 2682.5522
T     14 = 2648.2363 T     15 = 2568.0623 T     16 = 2453.7666 T     17 = 2981.1353 T     18 = 3026.2102 T     19 = 3006.2295
T     20 = 2920.3496 T     21 = 2705.5718 T     22 = 1953.2742 T     23 = 2714.0779 T     24 = 2698.9922 T     25 = 2682.7712
T     26 = 2648.5710 T     27 = 2568.6018 T     28 = 2454.4712 T     29 = 2848.4800 T     30 = 2881.4741 T     31 = 2862.6453
T     32 = 2776.3181 T     33 = 2620.2539 T     34 = 2165.0681 T     35 = 2848.5239 T     36 = 2881.5828 T     37 = 2862.8142
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    TC4A1MAR20
T     38 = 2776.5808 T     39 = 2620.6553 T     40 = 2165.5786 T     41 = 2724.6733 T     42 = 2710.3914 T     43 = 2692.8022
T     44 = 2641.0095 T     45 = 2545.8767 T     46 = 2343.5632 T     47 =  450.0000 T     48 =  450.0001 T     49 =  452.7856
T      1 = 3675.0000 T

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TIME= 2.50000E-01, DTIMEU= 4.67002E-05, CSGMIN(     41)= 1.51213E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(     45)= 8.93555E-02
    LOOPCT=     3                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(     41)= 2.68555E-03
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SINPAT_TIME =  2.5000E-01
T      2 = 2992.0896 T      3 = 2900.2842 T      4 = 2844.8040 T      5 = 3068.6697 T      6 = 3105.8997 T      7 = 3082.0757
T      8 = 2995.7688 T      9 = 2781.6931 T     10 = 2033.3259 T     11 = 2828.5078 T     12 = 2814.5396 T     13 = 2799.4434
T     14 = 2767.5090 T     15 = 2691.5920 T     16 = 2580.2639 T     17 = 3068.6826 T     18 = 3105.9419 T     19 = 3082.1472
T     20 = 2995.8706 T     21 = 2781.8330 T     22 = 2033.5054 T     23 = 2828.5569 T     24 = 2814.6257 T     25 = 2799.5645
T     26 = 2767.6948 T     27 = 2691.8911 T     28 = 2580.6538 T     29 = 2950.5710 T     30 = 2978.3416 T     31 = 2958.0371
T     32 = 2876.2087 T     33 = 2723.2151 T     34 = 2268.8064 T     35 = 2950.5955 T     36 = 2978.4019 T     37 = 2958.1321
T     38 = 2876.3538 T     39 = 2723.4397 T     40 = 2269.0894 T     41 = 2838.6401 T     42 = 2826.2834 T     43 = 2810.9580
T     44 = 2765.2290 T     45 = 2676.0613 T     46 = 2470.6101 T     47 =  450.0000 T     48 =  450.0000 T     49 =  453.9207
T      1 = 3675.0000 T
```
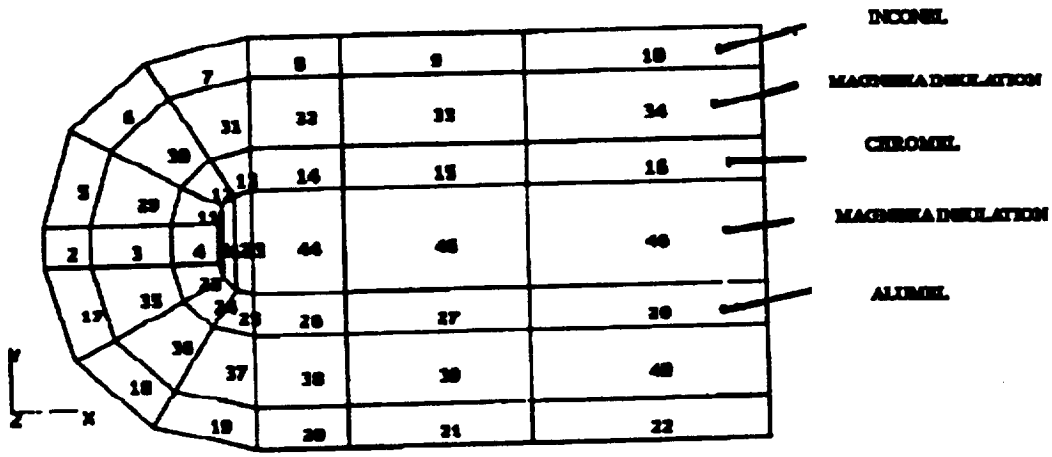
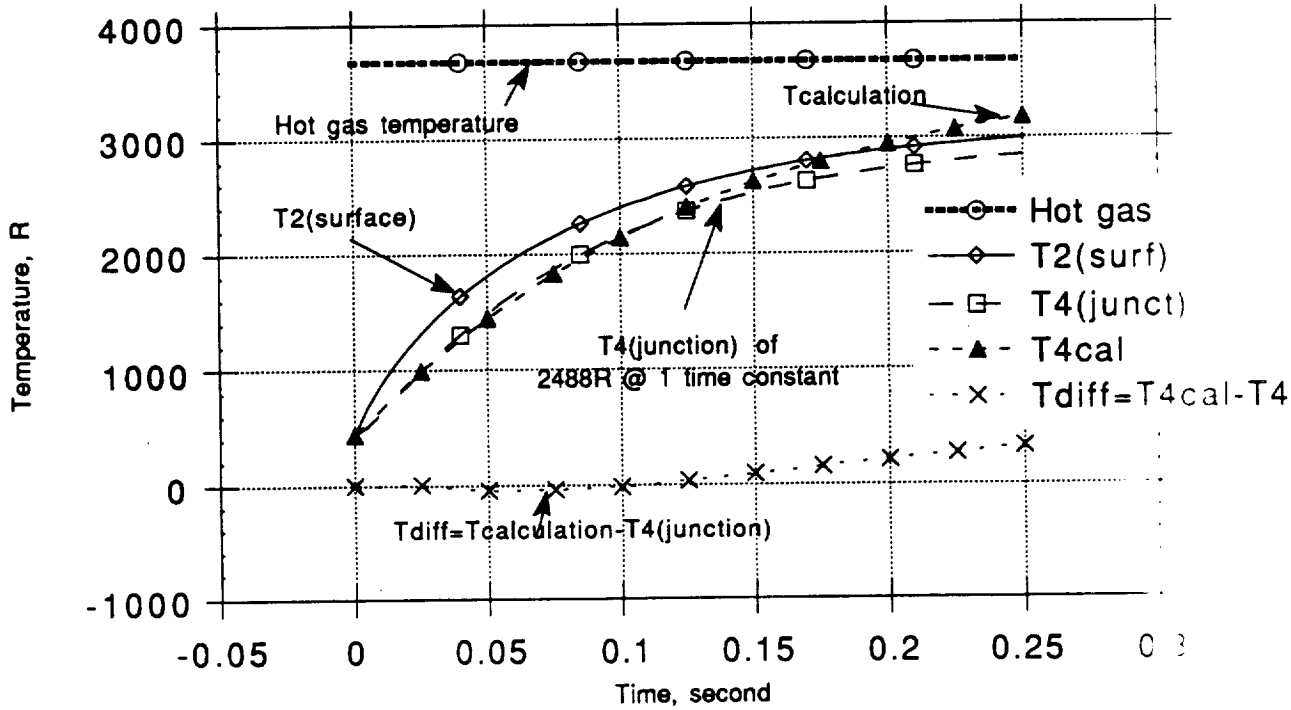

Comparison of 2-D model and hand calculation results:

Time: (sec)	Tgas (R)	T2 (R)	T4 (R)	Tcal (R)	Tdiff (R)
0.0000	3675.0	450.00	450.00	450.00	0.0000
0.0050	3675.0	684.86	520.58		
0.0100	3675.0	875.83	635.19		
0.0150	3675.0	1042.0	756.93		
0.0200	3675.0	1188.8	877.21		
0.0250	3675.0	1319.9	993.27	999.00	6.0000
0.0300	3675.0	1437.9	1104.2		
0.0350	3675.0	1545.1	1209.7		
0.0400	3675.0	1643.1	1309.8		
0.0450	3675.0	1733.2	1404.6		
0.0500	3675.0	1816.6	1494.3	1454.0	-44.000
0.0550	3675.0	1894.0	1579.1		
0.0600	3675.0	1966.1	1659.2		
0.0650	3675.0	2033.5	1734.9		
0.0700	3675.0	2096.6	1806.4		
0.0750	3675.0	2155.8	1873.9	1832.0	-41.000
0.0800	3675.0	2211.4	1937.6		
0.0850	3675.0	2263.6	1997.6		
0.0900	3675.0	2312.7	2054.3		
0.0950	3675.0	2358.9	2107.8		
0.1000	3675.0	2402.4	2158.1	2145.0	-13.000
0.10500	3675.0	2443.3	2205.7		
0.11000	3675.0	2481.9	2250.5		
0.11500	3675.0	2518.2	2292.7		
0.12000	3675.0	2552.4	2332.5		
0.12500	3675.0	2584.7	2370.1	2406.0	36.000
0.13000	3675.0	2615.1	2405.4		
0.13500	3675.0	2643.7	2438.8		
0.14000	3675.0	2670.7	2470.2		
0.14500	3675.0	2696.1	2499.9		
0.15000	3675.0	2720.1	2527.8	2622.0	95.000
0.15500	3675.0	2742.7	2554.1		
0.16000	3675.0	2763.9	2578.9		
0.16500	3675.0	2784.0	2602.3		
0.17000	3675.0	2802.9	2624.3		
0.17500	3675.0	2820.7	2645.1	2801.0	156.00
0.18000	3675.0	2837.5	2664.6		
0.18500	3675.0	2853.3	2683.1		
0.19000	3675.0	2868.2	2700.4		
0.19500	3675.0	2882.3	2716.8		
0.20000	3675.0	2895.5	2732.2	2950.0	218.00
0.20500	3675.0	2908.0	2746.8		
0.21000	3675.0	2919.7	2760.5		
0.21500	3675.0	2930.8	2773.4		
0.22000	3675.0	2941.3	2785.6		
0.22500	3675.0	2951.1	2797.1	3073.0	276.00
0.23000	3675.0	2960.4	2807.9		
0.23500	3675.0	2969.1	2818.1		
0.24000	3675.0	2977.4	2827.7		
0.24500	3675.0	2985.1	2836.7		
0.25000	3675.0	2992.4	2845.3	3175.0	330.00

Tc probe - nodal layout



Tc probe temperature-2D model



* Temperature differences (Tdiff) between the hand calculation and 2-D model results are plotted for easy comparison.

IV. Comments:

The temperature differences between both the simple model, 2D model, and hand calculation results are wider as the time gets larger. The hand calculation temperatures are higher than the simple output since there is a thermal sink included in the thermal network, therefore heat is allowed to conduct away from the tc probe base. In the case of the 2-D model, the thermal node representing a the thermocouple junction is heated up quicker than a whole lumped node assumed for the hand calculation during the early part of the measurement time. However, in the later part of the measurement, the temperatures of tc probe are lower than the hand calculation results since, like in the previous case, heat is allowed to conduct to the thermal sink.

The hot gas temperature and heat transfer coefficient in this problem are estimates. Efforts are in progress to extend this study to define a spike temperature during start incorporating the computational fluid dynamics study, a calculation of the heat transfer rates from the hot gas to probe as functions of species mass flow rates, and possible data from a future instrumented HPFTP engine test.

V. References:

1. The Temperature Handbook, 1990/91 by Omega Engineering Inc., USA.
2. Holman J.P.: "Heat transfer," Mcgraw-Hill Book Co., New York, 1981

CHAPTER 1: **STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION**

SECTION 7: **SSME HPOTP First Disc Seal Pilot Rib Cracking Thermal Analysis.**

ANALYSIS CODE: ANSYS

I. ANSYS Description

The finite element method is an analytical procedure whose active development has been pursued for a relatively short period of time. The basic concept of the method, when applied to problems of structural analysis, is that a continuum (the total structure) can be modeled analytically by its subdivision into regions (the finite element) in each of which the behavior is describe by a separate set of assumed functions representing the stresses or displacements in that region. The finite element method is a numerical procedure for solving a continuum mechanics problem with an accuracy acceptable to engineers. Classical methods describe the problem with partial differential equations but yield no answers because the geometry and loading are too complicated. In practice, most problems are too complicated for a closed-form mathematical solution. A numerical solution is required, and the most versatile method that provides it is the finite element method. The method also has disadvantages. A specific numerical result may be found for a specific problem but there is no closed-form expression that permits parametric study and verification of the results can only be done through additional numerical solutions. A computer and a reliable program are essential. Experience and good engineering sense are needed to construct a good representative model with appropiate boundary conditions.

The finite element method is not restricted to problems of structural mechanics, versatility is an outstanding feature of the finite element method. Steady state and transient heat transfer problems may be solved by finite element techniques analogous to those used for structural analysis. Table 1 describes the analogy between boundary condition concepts.

Boundary Condition

Thermal	Structural
specified nodal temperature	specified nodal displacement
specified nodal heat flow	specified nodal force
specified convection	specified pressure
note: convection also affects the effective thermal conductivity matrix	
internal heat generation	body force (gravity)

Table 1. Boundary condition analogy

A finite element analysis of an engineering system requires the creation of a finite element model. The model is a mathematical idealization of the real system. Nodes, elements, and boundary conditions are used to describe the basic concept of the method: the transformation of an engineering system with an infinite number of unknowns (the response at every location in a system) to one that has a finite number of unknowns related to each other by elements of finite size.

The unknowns, called degrees of freedom (DOF), see figure 1, represent the responses to applied actions. Table 2 shows the various types of degrees of freedom and their engineering use.

Application	Action	Type of DOF
structural	force	displacement
heat transfer	heat flow rate	temperature
electrical	current	volt
magnetics	current	magnetic potential
fluid flow	fluid flow rate	pressure

Table 2. Degree of freedom and their engineering use.

The degrees of freedom and the actions are related by a set of basic equations. The purpose of the finite element method is to determine the solution to these equations across the entire engineering system being analyzed. The simplest form of a basic equation is:

$$[K]\{d\} = \{A\}$$

where $\{d\}$ is the degree of freedom vector, $\{A\}$ is the action vector, and $[K]$ is the matrix relating $\{d\}$ to $\{A\}$ (often called the stiffness or coefficient matrix). In general, $[K]$ and $\{A\}$ are known, and $\{d\}$ is initially unknown.

The actual form of a basic equation is determined by the type of analysis being performed. For instance, for a steady-state thermal analysis, the equation is:

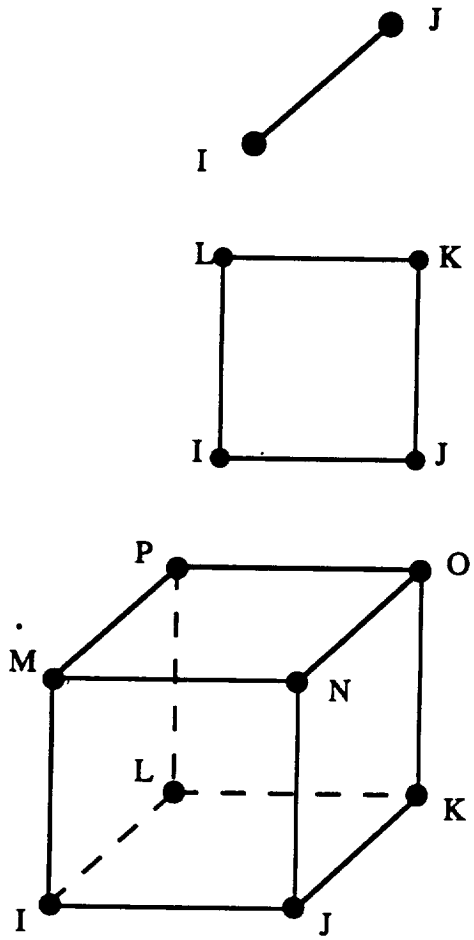
$$[K]\{T\} = \{Q\}$$

where

$[K]$ is the thermal conductivity matrix,
$\{T\}$ is the temperature vector, and
$\{Q\}$ is the heat flow rate vector.

In order to solve the basic equation across an entire engineering system, the system must be represented (modeled) by discrete, interconnected pieces (elements). Once $[K]$ is determined for each element, all of the individual $[K]$ matrices are assembled to form the set of simultaneous equations, $[K]\{d\} = \{A\}$. Solution of the simultaneous equations gives response values at every degree of freedom across the entire system.

The number of degrees of freedom (DOF) at a node and their meaning (temperature) are determined by the element type.



Some examples follow:

3-D Thermal Bar
STIF33 2 nodes 3-D space
No. of DOFs: 1
DOF: Temperature

2-D Multi-Field Solid
STIF13 4 nodes 2-D space
No. of DOFs:4
DOFs: Displacement in X and Y directions. Temperature and Magnetic Potential.

3-D Thermal Solid
STIF70 8 nodes 3-D space
No. of DOFs:1
DOF: Temperature

Figure 1. Element Descriptions

The element is the critical part of the finite element method. The element interconnects degrees of freedom, establishes how they act together, and determines how they respond to applied actions.

Every element has one or more nodes that lie along its boundary. Information is passed from element to element only at common (shared) nodes: See figure 2.

Node A coordinate location in space where degrees of freedom (displacement, flux potentials, temperature, etc.) and actions (forces, flux densities, heat flow, etc.) of the engineering system are considered to exist.

Element A mathematical, matrix representation (called a stiffness or coefficient matrix) of the interaction between the degrees of freedom of the set of nodes. Elements may be lines, areas, or solids and can be two or three dimensional.

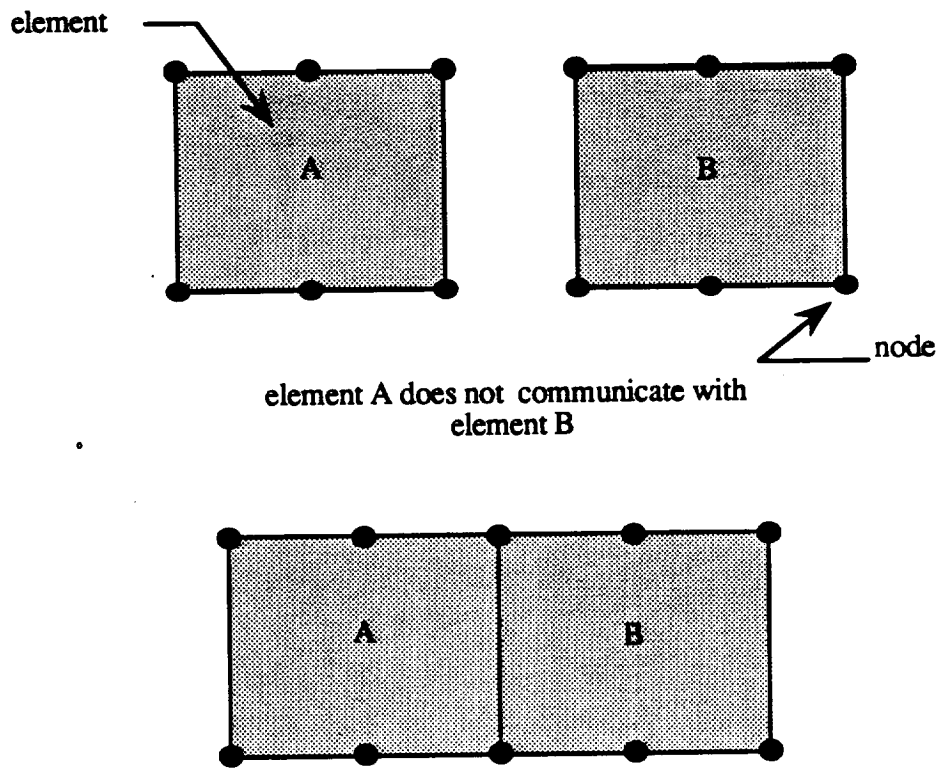


Figure 2. Element Connectivity

To obtain solution data for the entire system being analyzed, the [K] matrices for the individual elements are assembled into a global [K] matrix. This is straightforward since the elements are mathematically connected to each other by their nodes. The resulting global set of simultaneous equations can then be solved for the unknowns (degrees of freedom).

The **ANSYS** code is a large-scale, general purpose computer program for the solution of several classes of engineering analyses. Analysis capabilities include static and dynamic; elastic, plastic, creep and swelling; buckling; small and large deflections; steady state and transient heat transfer, electrostatics, magnetostatics, and fluid flow. The matrix displacement method of analysis based upon finite element idealization is employed throughout the program. The library of finite elements available is over twenty for heat transfer analyses. Loading for heat transfer analyses include internal heat generation, convection and radiation boundaries, and specified temperatures or heat flows.

ANSYS uses a frontal equation solver which performs the assembly and solution steps simultaneously. The frontal (also called wavefront) equation solver simultaneously assembles and solves the global set of simultaneous equations. The number of degrees of freedom in the global matrix at any given time constitutes the wavefront. The wavefront swells and shrinks as the elements are processed. Large wavefronts require more computer resources than small wavefronts. The wavefront is smallest if degrees of freedom can be removed as soon as possible from the global matrix after the degrees of freedom are added. Since degrees of freedom are added based on the element order, adjustment of the element order can be used to reduce the wavefront. Once the degrees of freedom are determined, derived results (if any) are calculated within each element using its shape functions. Thermal flux and thermal gradient are examples of derived results for a thermal element.

HEAT TRANSFER ANALYSIS (KAN=-1)

Steady-state thermal analysis is used to determine the steady-state temperature distribution in a structure or component that is subjected to thermal loading. "Steady state" means the temperature distribution is not function of time. That is, transient effects are not considered. The steady-state thermal analysis solves the following equation:

$$[K]\{T\} = \{Q\}$$

where

$[K]$ is the conductivity matrix.
$\{T\}$ is the nodal temperature vector, and
$\{Q\}$ is the nodal heat flow rate vector.

The "conductivity" matrix [K] includes not only terms involving conduction, but also those involving convection and radiation. {Q} includes convection, radiation as well as internal heat generation rate terms.

Transient thermal analysis is used to determine the transient temperature distribution in a structure or component that is subjected to thermal loading. "Transient" means that the thermal loads, and hence the temperature distribution, are functions of time. The transient thermal analysis solves the following equation:

$$[C]\{\dot{T}\} + [K]\{T\} = \{Q\}$$

where

$[C]$ is the specific heat matrix,
$[K]$ is the conductivity matrix,
$\{T\}$ is the nodal temperature vector
$\{\dot{T}\}$ is the time-derivative of $\{T\}$, and
$\{Q\}$ is the nodal heat flow rate vector.

The "conductivity" matrix [K] includes not only terms involving conduction, but also those involving convection and radiation. {Q} includes convection, radiation as well as internal heat generation rate terms.

Steady-State Thermal Analysis (KAN=-1) Procedure Summaries

Preprocessing:

The preprocessing phase is where all relevant data, such as material properties, geometry, and boundary conditions, are entered into the database in preparation for solution.

1. Set Up: To define the analysis type, analysis options, element types, element geometric properties, and material properties.

   Analysis type (KAN,-1).
   Element types (ET).
   Geometric Properties (R, RMODIF, etc.).
   Material properties (MP).

2. Model: To build the finite element model (nodes and elements) either by solid modeling or by direct generation.

   Solid Modeling (K, L, A, V, etc.), or
   Direct Generation (N, NGEN, E, EGEN, etc.).
   Reordering (WSORT, WAVES).

3. Load Data: To specify boundary condition (constraints and loads) and load options.

   Boundary Conditions
   on the solid model (KNT, KHFLOW, LCVSF, etc.), or
   on nodes and elements (NT, HFLOW, CVSF, etc.).
   Load options (ITER, etc.).
   Load Step (LWRITE, etc.).

4. Wrap Up: To write all appropriate information in a form suitable for the solution phase of the analysis.

   Write analysis file (AFWRITE).

Solution:

The solution phase is the most computationally intensive phase of the analysis. In the solution phase, the solver is used to solve the basic equation of the analysis type and to compute the results.

1. Divert output to a file if desired (/OUTPUT).

2. Submit analysis file (File27) for solution (/INPUT,27).

Postprocessing:

The postprocessing phase is where you review the results of the analysis by obtaining graphics displays and tabular reports of temperatures, heat fluxes, thermal gradient, etc.

POST1, the general postprocessor, allows you to review the results of any load step and iteration for the entire model.

POST26, the time-history postprocessor, allows you to review the variation of a result item, such as temperature at a specific point in the model, with respect to time or with respect to another result item. POST26 is typically used in a transient analysis.

1. Read results data from the postdata file (File12) into the POST1 database (SET).

2. Perform desired operations-contour displays, results, results tabulation, etc.

Transient Thermal Analysis (KAN=-1) Procedure Summaries

The procedure for transient thermal analysis is essentially the same as that for a steady-state thermal analysis. The only difference is that one or all of the boundary conditions are functions of time. Therefore, multiple load steps are usually required.

II. Problem Statement

Cracks were found in the Seal Pilot Rib fillet radius of the first stage turbine disc in the High Pressure Oxygen Turbopump on the Space Shuttle Main Engine. The disc experiences high thermal gradients at the surface during shutdown of the engine when the disc coolant temperature drops from approximately 1000°R to cryogenic temperatures. The combination of thermal gradients and stress concentration at the fillet radius is enough to cause cracks to develop after a short number of cycles. The purpose of this study is to characterize disc temperatures during the shutdown transient. One dimensional ANSYS and SINDA models were created to evaluate results from the large, 3-D, 20,000 element model of the turbine disc.

HPOTP FIRST STAGE TURBINE DISC

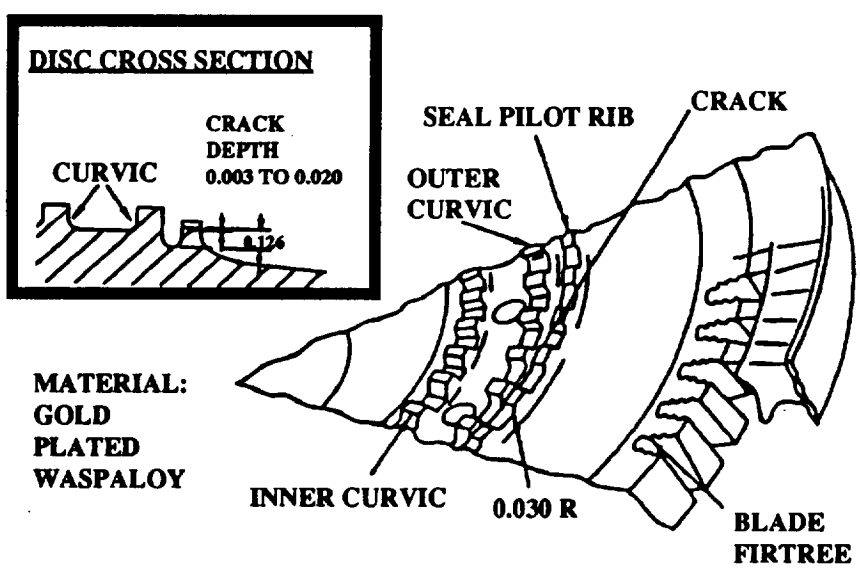


Figure 3.

III. Presentation and Discussion of Results

The finite difference solution (SINDA) and finite element solution (ANSYS) compared well, as shown in figure 4. The SINDA and ANSYS results are compared during the shut down with a drop in gas temperature from 915.5°R to 218.1°R

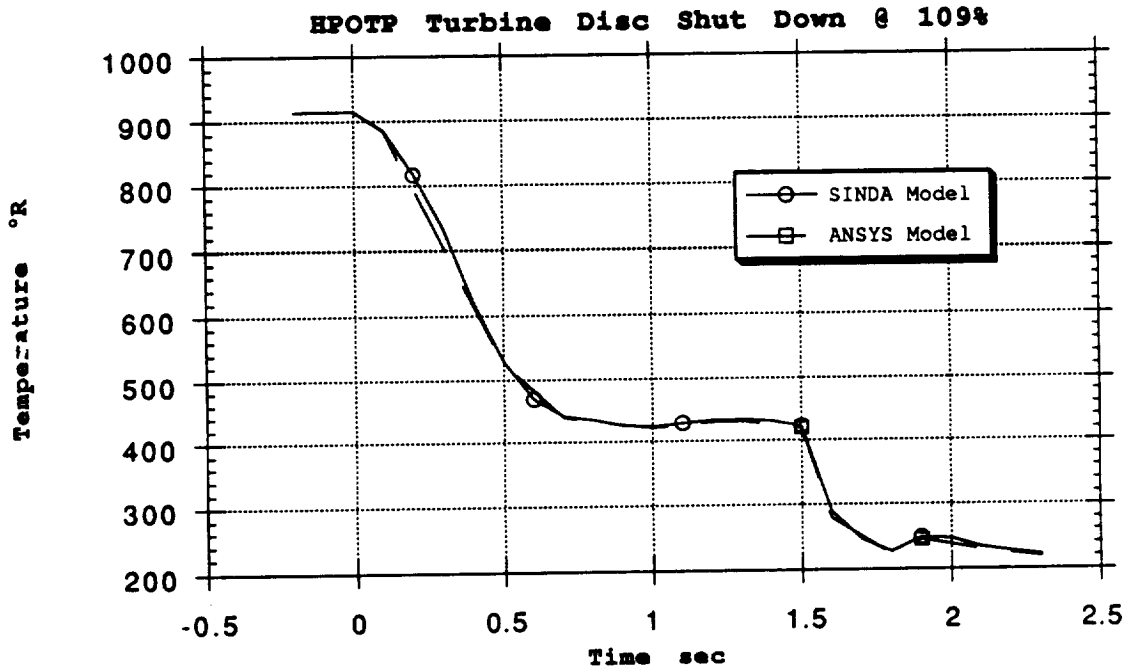


Figure 4. SINDA and ANSYS Comparison

IV. ANSYS Model

ANSYS MODEL INPUT LISTING

This section is included to explain how information given in the statement of the problem is conveyed to ANSYS and to present a corresponding input deck. The input deck includes three major phases or routines, one for each processor. These include, 1) preprocessing, 2) solution, 3) postprocessing. The preprocessing phase is where all relevant data, such as material properties, geometry, and boundary conditions, are entered into the database in preparation for solution. The solution phase is the most computationally intensive phase of the analysis. In the solution phase, the solver is used to solve the basic equation of the analysis type and to compute the results. The postprocessing phase is where you review the result of the analysis by obtaining graphics displays and tabular report of temperatures, heat fluxes, thermal gradient, etc.

```
C*** HPOTP TURBINE DISC SIN1D SD109%, 5/23/91
/CORE,6000000
C*** BEGIN PREPOCESSING ROUTINE
/PREP7
/TITLE,HPOTP TURBINE DISC SIN1D SD109%, 5/23/91
C***
C***
KAN , -1
```

```
KRF ,  0
KSE ,  0
TREF   ,916.
TUNIF  ,916.
C*** DEFINE MATERIAL PROPERTIES FOR STIFF6
MPTEMP,1,60.,2460.
MPDATA,C,2,1,0.,0.
MPDATA,EX,2,1,.01,.01
R,1,0.,0.,0.,0.,0.,0.
RSIZE,12
RMORE,0,0.
C*** DEFINE MATERIAL PROPERTIES FOR STIFF70
MPDATA,KXX,1,1,8.796E-5,3.565E-4
MPDATA,KYY,1,1,8.796E-5,3.565E-4
MPDATA,KZZ,1,1,8.796E-5,3.565E-4
MPDATA,C,1,1,.03864,.23409
MPDATA,DENS,1,1,.296,.296
C***
C*** NODAL COORDINATE DEFINITION
/NOLIS
/NOPR
N ,      1 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.4000000
N ,      2 ,  0.3999999E-02 ,  0.0000000E+00 ,  0.4000000
N ,      3 ,  0.0000000E+00 ,  0.3999999E-02 ,  0.4000000
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N ,      6 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.3995000
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N ,     45 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.3895000
N ,     46 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.3895000
```

N ,	47 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3895000
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N ,	69 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3835000
N ,	70 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3835000
N ,	71 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3835000
N ,	72 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3835000
N ,	73 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3825000
N ,	74 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3825000
N ,	75 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3825000
N ,	76 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3825000
N ,	77 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3815000
N ,	78 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3815000
N ,	79 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3815000
N ,	80 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3815000
N ,	81 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3805000
N ,	82 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3805000
N ,	83 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3805000
N ,	84 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3805000
N ,	85 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3795000
N ,	86 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3795000
N ,	87 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3795000
N ,	88 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3795000
N ,	89 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3785000
N ,	90 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3785000
N ,	91 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3785000
N ,	92 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3785000
N ,	93 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3775000
N ,	94 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3775000
N ,	95 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3775000
N ,	96 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3775000
N ,	97 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3765000
N ,	98 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3765000
N ,	99 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3765000
N ,	100 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3765000
N ,	101 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3755000
N ,	102 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3755000
N ,	103 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3755000
N ,	104 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3755000
N ,	105 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3745000
N ,	106 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3745000
N ,	107 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3745000
N ,	108 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3745000
N ,	109 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3735000
N ,	110 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3735000
N ,	111 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3735000
N ,	112 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3735000
N ,	113 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3725000

N ,	114 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3725000
N ,	115 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3725000
N ,	116 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3725000
N ,	117 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3715000
N ,	118 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3715000
N ,	119 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3715000
N ,	120 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3715000
N ,	121 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3705000
N ,	122 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3705000
N ,	123 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3705000
N ,	124 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3705000
N ,	125 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3695000
N ,	126 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3695000
N ,	127 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3695000
N ,	128 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3695000
N ,	129 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3685000
N ,	130 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3685000
N ,	131 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3685000
N ,	132 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3685000
N ,	133 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3674999
N ,	134 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3674999
N ,	135 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3674999
N ,	136 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3674999
N ,	137 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3665000
N ,	138 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3665000
N ,	139 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3665000
N ,	140 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3665000
N ,	141 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3655000
N ,	142 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3655000
N ,	143 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3655000
N ,	144 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3655000
N ,	145 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3645000
N ,	146 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3645000
N ,	147 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3645000
N ,	148 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3645000
N ,	149 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3635000
N ,	150 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3635000
N ,	151 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3635000
N ,	152 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3635000
N ,	153 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3625000
N ,	154 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3625000
N ,	155 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3625000
N ,	156 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3625000
N ,	157 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3615000
N ,	158 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3615000
N ,	159 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3615000
N ,	160 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3615000
N ,	161 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3604999
N ,	162 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3604999
N ,	163 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3604999
N ,	164 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3604999
N ,	165 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3595000
N ,	166 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3595000
N ,	167 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3595000
N ,	168 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3595000
N ,	169 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3584999
N ,	170 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3584999
N ,	171 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3584999
N ,	172 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3584999
N ,	173 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3575000
N ,	174 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3575000
N ,	175 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3575000
N ,	176 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3575000
N ,	177 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3565000
N ,	178 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3565000
N ,	179 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3565000
N ,	180 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3565000

N ,	181 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3555000
N ,	182 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3555000
N ,	183 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3555000
N ,	184 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3555000
N ,	185 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3545000
N ,	186 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3545000
N ,	187 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3545000
N ,	188 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3545000
N ,	189 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3535000
N ,	190 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3535000
N ,	191 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3535000
N ,	192 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3535000
N ,	193 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3525000
N ,	194 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3525000
N ,	195 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3525000
N ,	196 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3525000
N ,	197 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3515000
N ,	198 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3515000
N ,	199 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3515000
N ,	200 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3515000
N ,	201 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3505000
N ,	202 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3505000
N ,	203 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3505000
N ,	204 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3505000
N ,	205 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3490000
N ,	206 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3490000
N ,	207 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3490000
N ,	208 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3490000
N ,	209 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3470000
N ,	210 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3470000
N ,	211 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3470000
N ,	212 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3470000
N ,	213 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3450000
N ,	214 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3450000
N ,	215 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3450000
N ,	216 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3450000
N ,	217 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3430000
N ,	218 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3430000
N ,	219 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3430000
N ,	220 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3430000
N ,	221 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3410000
N ,	222 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3410000
N ,	223 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3410000
N ,	224 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3410000
N ,	225 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3390000
N ,	226 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3390000
N ,	227 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3390000
N ,	228 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3390000
N ,	229 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3370000
N ,	230 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3370000
N ,	231 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3370000
N ,	232 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3370000
N ,	233 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3350000
N ,	234 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3350000
N ,	235 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3350000
N ,	236 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3350000
N ,	237 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3330000
N ,	238 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3330000
N ,	239 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3330000
N ,	240 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3330000
N ,	241 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3310000
N ,	242 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3310000
N ,	243 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3310000
N ,	244 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3310000
N ,	245 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3275000
N ,	246 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3275000
N ,	247 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3275000

N ,	248 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3275000
N ,	249 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3225000
N ,	250 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3225000
N ,	251 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3225000
N ,	252 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3225000
N ,	253 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3175000
N ,	254 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3175000
N ,	255 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3175000
N ,	256 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3175000
N ,	257 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3125000
N ,	258 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3125000
N ,	259 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3125000
N ,	260 ,	0.4000000E-02	0.4000000E-02 ,	0.3125000
N ,	261 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3075000
N ,	262 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3075000
N ,	263 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3075000
N ,	264 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3075000
N ,	265 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.3024999
N ,	266 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.3024999
N ,	267 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.3024999
N ,	268 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.3024999
N ,	269 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2975000
N ,	270 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2975000
N ,	271 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2975000
N ,	272 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2975000
N ,	273 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2925000
N ,	274 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2925000
N ,	275 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2925000
N ,	276 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2925000
N ,	277 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2875000
N ,	278 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2875000
N ,	279 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2875000
N ,	280 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2875000
N ,	281 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2825000
N ,	282 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2825000
N ,	283 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2825000
N ,	284 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2825000
N ,	285 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2750001
N ,	286 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2750001
N ,	287 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2750001
N ,	288 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2750001
N ,	289 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2650000
N ,	290 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2650000
N ,	291 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2650000
N ,	292 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2650000
N ,	293 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2550000
N ,	294 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2550000
N ,	295 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2550000
N ,	296 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2550000
N ,	297 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2450000
N ,	298 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2450000
N ,	299 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2450000
N ,	300 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2450000
N ,	301 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2350000
N ,	302 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2350000
N ,	303 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2350000
N ,	304 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2350000
N ,	305 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2250000
N ,	306 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2250000
N ,	307 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2250000
N ,	308 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2250000
N ,	309 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2150000
N ,	310 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2150000
N ,	311 ,	0.4000000E-02 ,	0.0000000E+00 ,	0.2150000
N ,	312 ,	0.4000000E-02 ,	0.4000000E-02 ,	0.2150000
N ,	313 ,	0.0000000E+00 ,	0.0000000E+00 ,	0.2050000
N ,	314 ,	0.0000000E+00 ,	0.4000000E-02 ,	0.2050000

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N ,     315 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.2050000
N ,     316 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.2050000
N ,     317 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.1900000
N ,     318 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.1900000
N ,     319 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.1900000
N ,     320 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.1900000
N ,     321 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.1700000
N ,     322 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.1700000
N ,     323 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.1700000
N ,     324 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.1700000
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N ,     326 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.1500000
N ,     327 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.1500000
N ,     328 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.1500000
N ,     329 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.1300000
N ,     330 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.1300000
N ,     331 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.1300000
N ,     332 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.1300000
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N ,     334 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.1100000
N ,     335 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.1100000
N ,     336 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.1100000
N ,     337 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.8999998E-01
N ,     338 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.8999998E-01
N ,     339 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.8999998E-01
N ,     340 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.8999998E-01
N ,     341 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.6999999E-01
N ,     342 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.6999999E-01
N ,     343 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.6999999E-01
N ,     344 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.6999999E-01
N ,     345 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.4999997E-01
N ,     346 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.4999997E-01
N ,     347 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.4999997E-01
N ,     348 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.4999997E-01
N ,     349 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.2999997E-01
N ,     350 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.2999997E-01
N ,     351 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.2999997E-01
N ,     352 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.2999997E-01
N ,     353 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.9999961E-02
N ,     354 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.9999961E-02
N ,     355 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.9999961E-02
N ,     356 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.9999961E-02
N ,     357 ,  0.0000000E+00 ,  0.0000000E+00 ,  0.0000000E+00
N ,     358 ,  0.0000000E+00 ,  0.4000000E-02 ,  0.0000000E+00
N ,     359 ,  0.4000000E-02 ,  0.0000000E+00 ,  0.0000000E+00
N ,     360 ,  0.4000000E-02 ,  0.4000000E-02 ,  0.0000000E+00
C*** ELEMENT LIBRARY DEFINITION
ET ,     1,     6,     8,     0,     0,     0,     0,     0
ET ,     2,    70,     0,     0,     0,     0,     0,     0
C*** ELEMENT CONNECTIVITY DEFINITION
TYPE ,     1  $MAT ,     2  $REAL ,     1
EN ,     1,     1,     2,     4,     3
TYPE ,     2  $MAT ,     1  $REAL ,     1
EN ,     2,     1,     3,     4,     2,     5,     6,     8,     7
EN ,     3,     5,     6,     8,     7,     9,    10,    12,    11
EN ,     4,     9,    10,    12,    11,    13,    14,    16,    15
EN ,     5,    13,    14,    16,    15,    17,    18,    20,    19
EN ,     6,    17,    18,    20,    19,    21,    22,    24,    23
EN ,     7,    21,    22,    24,    23,    25,    26,    28,    27
EN ,     8,    25,    26,    28,    27,    29,    30,    32,    31
EN ,     9,    29,    30,    32,    31,    33,    34,    36,    35
EN ,    10,    33,    34,    36,    35,    37,    38,    40,    39
EN ,    11,    37,    38,    40,    39,    41,    42,    44,    43
EN ,    12,    41,    42,    44,    43,    45,    46,    48,    47
EN ,    13,    45,    46,    48,    47,    49,    50,    52,    51
EN ,    14,    49,    50,    52,    51,    53,    54,    56,    55
EN ,    15,    53,    54,    56,    55,    57,    58,    60,    59
```

EN ,	16,	57,	58,	60,	59,	61,	62,	64,	63
EN ,	17,	61,	62,	64,	63,	65,	66,	68,	67
EN ,	18,	65,	66,	68,	67,	69,	70,	72,	71
EN ,	19,	69,	70,	72,	71,	73,	74,	76,	75
EN ,	20,	73,	74,	76,	75,	77,	78,	80,	79
EN ,	21,	77,	78,	80,	79,	81,	82,	84,	83
EN ,	22,	81,	82,	84,	83,	85,	86,	88,	87
EN ,	23,	85,	86,	88,	87,	89,	90,	92,	91
EN ,	24,	89,	90,	92,	91,	93,	94,	96,	95
EN ,	25,	93,	94,	96,	95,	97,	98,	100,	99
EN ,	26,	97,	98,	100,	99,	101,	102,	104,	103
EN ,	27,	101,	102,	104,	103,	105,	106,	108,	107
EN ,	28,	105,	106,	108,	107,	109,	110,	112,	111
EN ,	29,	109,	110,	112,	111,	113,	114,	116,	115
EN ,	30,	113,	114,	116,	115,	117,	118,	120,	119
EN ,	31,	117,	118,	120,	119,	121,	122,	124,	123
EN ,	32,	121,	122,	124,	123,	125,	126,	128,	127
EN ,	33,	125,	126,	128,	127,	129,	130,	132,	131
EN ,	34,	129,	130,	132,	131,	133,	134,	136,	135
EN ,	35,	133,	134,	136,	135,	137,	138,	140,	139
EN ,	36,	137,	138,	140,	139,	141,	142,	144,	143
EN ,	37,	141,	142,	144,	143,	145,	146,	148,	147
EN ,	38,	145,	146,	148,	147,	149,	150,	152,	151
EN ,	39,	149,	150,	152,	151,	153,	154,	156,	155
EN ,	40,	153,	154,	156,	155,	157,	158,	160,	159
EN ,	41,	157,	158,	160,	159,	161,	162,	164,	163
EN ,	42,	161,	162,	164,	163,	165,	166,	168,	167
EN ,	43,	165,	166,	168,	167,	169,	170,	172,	171
EN ,	44,	169,	170,	172,	171,	173,	174,	176,	175
EN ,	45,	173,	174,	176,	175,	177,	178,	180,	179
EN ,	46,	177,	178,	180,	179,	181,	182,	184,	183
EN ,	47,	181,	182,	184,	183,	185,	186,	188,	187
EN ,	48,	185,	186,	188,	187,	189,	190,	192,	191
EN ,	49,	189,	190,	192,	191,	193,	194,	196,	195
EN ,	50,	193,	194,	196,	195,	197,	198,	200,	199
EN ,	51,	197,	198,	200,	199,	201,	202,	204,	203
EN ,	52,	201,	202,	204,	203,	205,	206,	208,	207
EN ,	53,	205,	206,	208,	207,	209,	210,	212,	211
EN ,	54,	209,	210,	212,	211,	213,	214,	216,	215
EN ,	55,	213,	214,	216,	215,	217,	218,	220,	219
EN ,	56,	217,	218,	220,	219,	221,	222,	224,	223
EN ,	57,	221,	222,	224,	223,	225,	226,	228,	227
EN ,	58,	225,	226,	228,	227,	229,	230,	232,	231
EN ,	59,	229,	230,	232,	231,	233,	234,	236,	235
EN ,	60,	233,	234,	236,	235,	237,	238,	240,	239
EN ,	61,	237,	238,	240,	239,	241,	242,	244,	243
EN ,	62,	241,	242,	244,	243,	245,	246,	248,	247
EN ,	63,	245,	246,	248,	247,	249,	250,	252,	251
EN ,	64,	249,	250,	252,	251,	253,	254,	256,	255
EN ,	65,	253,	254,	256,	255,	257,	258,	260,	259
EN ,	66,	257,	258,	260,	259,	261,	262,	264,	263
EN ,	67,	261,	262,	264,	263,	265,	266,	268,	267
EN ,	68,	265,	266,	268,	267,	269,	270,	272,	271
EN ,	69,	269,	270,	272,	271,	273,	274,	276,	275
EN ,	70,	273,	274,	276,	275,	277,	278,	280,	279
EN ,	71,	277,	278,	280,	279,	281,	282,	284,	283
EN ,	72,	281,	282,	284,	283,	285,	286,	288,	287
EN ,	73,	285,	286,	288,	287,	289,	290,	292,	291
EN ,	74,	289,	290,	292,	291,	293,	294,	296,	295
EN ,	75,	293,	294,	296,	295,	297,	298,	300,	299
EN ,	76,	297,	298,	300,	299,	301,	302,	304,	303
EN ,	77,	301,	302,	304,	303,	305,	306,	308,	307
EN ,	78,	305,	306,	308,	307,	309,	310,	312,	311
EN ,	79,	309,	310,	312,	311,	313,	314,	316,	315
EN ,	80,	313,	314,	316,	315,	317,	318,	320,	319
EN ,	81,	317,	318,	320,	319,	321,	322,	324,	323
EN ,	82,	321,	322,	324,	323,	325,	326,	328,	327

```
EN ,    83,   325,   326,   328,   327,   329,   330,   332,   331
EN ,    84,   329,   330,   332,   331,   333,   334,   336,   335
EN ,    85,   333,   334,   336,   335,   337,   338,   340,   339
EN ,    86,   337,   338,   340,   339,   341,   342,   344,   343
EN ,    87,   341,   342,   344,   343,   345,   346,   348,   347
EN ,    88,   345,   346,   348,   347,   349,   350,   352,   351
EN ,    89,   349,   350,   352,   351,   353,   354,   356,   355
EN ,    90,   353,   354,   356,   355,   357,   358,   360,   359
/GOLIS
/GOPR
nall
eall
WSORT,Z
SAVE
C*** END OF THE ELEMENT AND NODE GENERATION
C***
C*** BEGIN LOAD STEP 1 DEFINITION SS TIME= 0.
ITER,1,0,1
TIME,0.
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.328E-01
EC,ALL,6,,915.5
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 2 DEFINITION SS TIME= 0.1
ITER,10,0,10
TIME,0.1
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.328E-01
EC,ALL,6,,876.7
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 3 DEFINITION SS TIME= 0.5
ITER,10,0,10
TIME,0.5
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.242E-01
EC,ALL,6,,467.7
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 4 DEFINITION SS TIME= 0.7
ITER,10,0,10
TIME,0.7
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.184E-01
EC,ALL,6,,380.3
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 5 DEFINITION SS TIME= 0.8
ITER,10,0,10
TIME,0.8
```

```
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.162E-01
EC,ALL,6,,377.9
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 6 DEFINITION SS TIME= 1.0
ITER,10,0,10
TIME,1.0
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.142E-01
EC,ALL,6,,370.6
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 7 DEFINITION SS TIME= 1.2
ITER,10,0,10
TIME,1.2
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.127E-01
EC,ALL,6,,384.7
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 8 DEFINITION SS TIME= 1.3
ITER,10,0,10
TIME,1.3
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.125E-01
EC,ALL,6,,386.3
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 9 DEFINITION SS TIME= 1.5
ITER,10,0,10
TIME,1.5
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.123E-01
EC,ALL,6,,373.8
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 10 DEFINITION SS TIME= 1.6
ITER,10,0,10
TIME,1.6
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.145E-01
EC,ALL,6,,187.1
EALL
NALL
```

```
LWRITE
C***
C*** BEGIN LOAD STEP 11 DEFINITION SS TIME= 1.8
ITER,10,0,10
TIME,1.8
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.146E-01
EC,ALL,6,,161.6
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 12 DEFINITION SS TIME= 1.9
ITER,10,0,10
TIME,1.9
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.120E-01
EC,ALL,6,,191.4
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 13 DEFINITION SS TIME= 2.1
ITER,10,0,10
TIME,2.1
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.143E-01
EC,ALL,6,,180.5
EALL
NALL
LWRITE
C***
C*** BEGIN LOAD STEP 14 DEFINITION SS TIME= 2.3
ITER,10,0,10
TIME,2.3
KBC,0
C***   *** ****   ***ZONE 2
ESEL,STIF,6
EC,ALL,5,0.146E-01
EC,ALL,6,,174.6
EALL
NALL
LWRITE
C***
AFWRITE
FINISH
C*** BEGIN SOLUTION ROUTINE
/INPUT,27
FINISH
C*** BEGIN POSTPROCESSING ROUTINE
/POST1
SET,1     $PRTEMP
SET,2     $PRTEMP
SET,3     $PRTEMP
SET,4     $PRTEMP
SET,5     $PRTEMP
SET,6     $PRTEMP
SET,7     $PRTEMP
SET,8     $PRTEMP
SET,9     $PRTEMP
SET,10     $PRTEMP
```

```
SET,11     $PRTEMP
SET,12     $PRTEMP
SET,13     $PRTEMP
SET,14     $PRTEMP
FINISH
/EOF
```

ANSYS OUTPUT LISTING

The output data consists of the temperature results for the first ten nodes. The first 4 nodes represent the surface of the disc. This output data list is printed at every interval of ten nodes specified in the input file for the postprocessor POST1 using the node selection command (NSEL) and the print command (PRTEMP) that list nodal temperatures at selected nodes.

```
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 IF RUNNING INTERACTIVELY, ENTER  /INTER
1
                    **********  ANSYS INPUT DATA LISTING (FILE18)  **********

      1   /POST1
      2   nall
      3   SET,1
      4   NSEL,NODE,1,10
      5   $PRTEMP
      6   SET,2
      7   NSEL,NODE,1,10
      8   $PRTEMP
      9   SET,3
     10   NSEL,NODE,1,10
     11   $PRTEMP
     12   SET,4
     13   NSEL,NODE,1,10
     14   $PRTEMP
     15   SET,5
     16   NSEL,NODE,1,10
     17   $PRTEMP
     18   SET,6
     19   NSEL,NODE,1,10
     20   $PRTEMP
     21   SET,7
     22   NSEL,NODE,1,10
     23   $PRTEMP
     24   SET,8
     25   NSEL,NODE,1,10
     26   $PRTEMP
     27   SET,9
     28   NSEL,NODE,1,10
     29   $PRTEMP
     30   SET,10
     31   NSEL,NODE,1,10
     32   $PRTEMP
     33   SET,11
     34   NSEL,NODE,1,10
     35   $PRTEMP
     36   SET,12
     37   NSEL,NODE,1,10
     38   $PRTEMP
     39   SET,13
     40   NSEL,NODE,1,10
     41   $PRTEMP
     42   SET,14
     43   NSEL,NODE,1,10
     44   $PRTEMP
     45   SET,15
     46   NSEL,NODE,1,10
     47   $PRTEMP
     48   FINI
     49   /EOF
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
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                                                                                    9.7151  JUL 12,1991 CP=     12.520

            ***** ANSYS RESULTS INTERPRETATION (POST1) *****

        0  NODES (OF      0  DEFINED) SELECTED BY  NALL  COMMAND.

      USE LOAD STEP     1  ITERATION     0  SECTION   1  FOR LOAD CASE     1


      GEOMETRY STORED FOR    360  NODES     90  ELEMENTS
       TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

      DISPLACEMENT STORED FOR  360 NODES

      ITERATION SUMMARY INFORMATION STORED

      NODAL FORCES STORED FOR   90 ELEMENTS
```

```
***WARNING ***                                CP=     14.990   TIME=   9.71635
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =      1.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     1  ITERATION=     1  SECTION=   1
 TIME=  0.000000E+00   LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
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HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7164  JUL 12,1991 CP=     15.200

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     1  ITERATION=     1  SECTION=  1
 TIME=   0.00000E+00     LOAD CASE=  1

   NODE      TEMP
     1    915.50000
     2    915.50000
     3    915.50000
     4    915.50000
     5    915.50000
     6    915.50000
     7    915.50000
     8    915.50000
     9    915.50000
    10    915.50000

MAXIMUMS
NODE         10
VALUE     915.50000

USE LOAD STEP     2  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                CP=     16.010   TIME=   9.71672
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     11.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     2  ITERATION=    10  SECTION=   1
 TIME=  0.100000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
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HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7168  JUL 12,1991 CP=     16.200

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     2  ITERATION=    10  SECTION=  1
 TIME=   0.10000         LOAD CASE=  1

   NODE      TEMP
     1    885.01413
     2    885.01413
     3    885.01413
     4    885.01413
     5    885.76293
     6    885.76293
     7    885.76293
     8    885.76293
     9    887.21580
    10    887.21580

MAXIMUMS
NODE         10
VALUE     887.21580

USE LOAD STEP     3  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                CP=     17.000   TIME=   9.71710
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     21.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     3  ITERATION=    10  SECTION=   1
 TIME=  0.500000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.
```

```
PRINT NODAL TEMPERATURES
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
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     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                    9.7172  JUL 12,1991 CP=     17.200

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     3  ITERATION=    10  SECTION=  1
 TIME=   0.50000          LOAD CASE=  1

   NODE       TEMP
     1     524.07226
     2     524.07226
     3     524.07227
     4     524.07227
     5     528.92003
     6     528.92004
     7     528.92004
     8     528.92004
     9     538.44803
    10     538.44804

MAXIMUMS
NODE          10
VALUE      538.44804

USE LOAD STEP     4  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                              CP=     17.990   TIME=   9.71749
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     31.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     4  ITERATION=    10  SECTION=   1
 TIME=  0.700000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
     ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS        SYSTEMS, INC. AS
UNPUBLISHED WORK.
     PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                    9.7175  JUL 12,1991 CP=     18.180

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     4  ITERATION=    10  SECTION=  1
 TIME=   0.70000          LOAD CASE=  1

   NODE       TEMP
     1     439.53705
     2     439.53705
     3     439.53706
     4     439.53706
     5     443.70121
     6     443.70122
     7     443.70121
     8     443.70122
     9     451.94184
    10     451.94185

MAXIMUMS
NODE          10
VALUE      451.94185

USE LOAD STEP     5  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                              CP=     18.960   TIME=   9.71781
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     41.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     5  ITERATION=    10  SECTION=   1
 TIME=  0.800000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
     ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS        SYSTEMS, INC. AS
UNPUBLISHED WORK.
     PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                    9.7179  JUL 12,1991 CP=     19.160

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     5  ITERATION=    10  SECTION=  1
```

```
TIME=   0.80000          LOAD CASE=  1

  NODE       TEMP
    1     432.28073
    2     432.28074
    3     432.28074
    4     432.28074
    5     435.67371
    6     435.67372
    7     435.67372
    8     435.67372
    9     442.42609
   10     442.42609

MAXIMUMS
NODE          10
VALUE      442.42609

USE LOAD STEP     6  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                  CP=     19.980   TIME=   9.71823
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     51.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     6  ITERATION=    10  SECTION=   1
 TIME=   1.00000        LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
      ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
      PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL             RIGHTS RESERVED.
      FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7183  JUL 12,1991 CP=     20.200

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     6  ITERATION=    10  SECTION=  1
 TIME=    1.0000          LOAD CASE=  1

  NODE       TEMP
    1     422.49019
    2     422.49020
    3     422.49020
    4     422.49020
    5     425.35261
    6     425.35261
    7     425.35261
    8     425.35261
    9     431.05141
   10     431.05141

MAXIMUMS
NODE          10
VALUE      431.05141

USE LOAD STEP     7  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                  CP=     21.040   TIME=   9.71864
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     61.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     7  ITERATION=    10  SECTION=   1
 TIME=   1.20000        LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
      ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
      PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
      FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7187  JUL 12,1991 CP=     21.230

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     7  ITERATION=    10  SECTION=  1
 TIME=    1.2000          LOAD CASE=  1

  NODE       TEMP
    1     430.71814
    2     430.71814
    3     430.71814
    4     430.71814
    5     432.97459
    6     432.97460
    7     432.97460
    8     432.97460
    9     437.48052
```

```
    10    437.48052

MAXIMUMS
NODE        10
VALUE     437.48052

USE LOAD STEP     8  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                              CP=     22.020   TIME=   9.71898
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     71.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     8  ITERATION=    10  SECTION=   1
 TIME=   1.30000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD1094, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
     ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
     PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD1094, 5/23/91                                          9.7190  JUL 12,1991 CP=     22.210

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     8  ITERATION=    10  SECTION=  1
 TIME=    1.3000         LOAD CASE=  1

   NODE       TEMP
     1    431.49173
     2    431.49174
     3    431.49174
     4    431.49174
     5    433.67034
     6    433.67034
     7    433.67034
     8    433.67034
     9    438.01544
    10    438.01544

MAXIMUMS
NODE        10
VALUE     438.01544

USE LOAD STEP     9  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                              CP=     23.010   TIME=   9.71929
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     81.
     SEE FILE19 OR FILE06

FOR LOAD STEP=     9  ITERATION=    10  SECTION=   1
 TIME=   1.50000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD1094, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
     ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
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     PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD1094, 5/23/91                                          9.7193  JUL 12,1991 CP=     23.220

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP     9  ITERATION=    10  SECTION=  1
 TIME=    1.5000         LOAD CASE=  1

   NODE       TEMP
     1    419.87429
     2    419.87430
     3    419.87430
     4    419.87430
     5    422.08069
     6    422.08069
     7    422.08069
     8    422.08069
     9    426.47318
    10    426.47318

MAXIMUMS
NODE        10
VALUE     426.47318

USE LOAD STEP    10  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED
```

```
NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                CP=     23.990   TIME=   9.72001
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     91.
     SEE FILE19 OR FILE06

FOR LOAD STEP=    10  ITERATION=    10  SECTION=   1
 TIME=   1.60000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
     ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
     PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7201  JUL 12,1991 CP=     24.180

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP    10  ITERATION=    10  SECTION=  1
 TIME=    1.6000          LOAD CASE=  1

   NODE       TEMP
     1     278.17924
     2     278.17925
     3     278.17925
     4     278.17926
     5     284.00478
     6     284.00479
     7     284.00478
     8     284.00479
     9     295.36984
    10     295.36985

MAXIMUMS
NODE          10
VALUE      295.36985

USE LOAD STEP    11  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                CP=     24.980   TIME=   9.72034
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =    101.
     SEE FILE19 OR FILE06

FOR LOAD STEP=    11  ITERATION=    10  SECTION=   1
 TIME=   1.80000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
     ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
     PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
     FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7204  JUL 12,1991 CP=     25.180

          ***** POST1 NODAL TEMPERATURE LISTING *****

 LOAD STEP    11  ITERATION=    10  SECTION=  1
 TIME=    1.8000          LOAD CASE=  1

   NODE       TEMP
     1     221.99981
     2     221.99982
     3     221.99982
     4     221.99982
     5     226.14442
     6     226.14442
     7     226.14442
     8     226.14443
     9     234.36152
    10     234.36152

MAXIMUMS
NODE          10
VALUE      234.36152

USE LOAD STEP    12  ITERATION     0  SECTION   1  FOR LOAD CASE     1

DISPLACEMENT STORED FOR  360 NODES

ITERATION SUMMARY INFORMATION STORED

NODAL FORCES STORED FOR   90 ELEMENTS

***WARNING ***                                CP=     25.960   TIME=   9.72067
ACCUMULATED SOLUTION PHASE WARNING MESSAGES =    111.
     SEE FILE19 OR FILE06

FOR LOAD STEP=    12  ITERATION=    10  SECTION=   1
 TIME=   1.90000       LOAD CASE=  1
 TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1
```

```
    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

 PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
      ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
      PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
      FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

 HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7207  JUL 12,1991 CP=     26.150

          ***** POST1 NODAL TEMPERATURE LISTING *****

  LOAD STEP    12  ITERATION=    10  SECTION=  1
  TIME=    1.9000          LOAD CASE=  1

    NODE       TEMP
      1    245.06086
      2    245.06087
      3    245.06087
      4    245.06087
      5    248.02458
      6    248.02459
      7    248.02458
      8    248.02459
      9    253.95540
     10    253.95540

 MAXIMUMS
 NODE          10
 VALUE     253.95540

 USE LOAD STEP    13  ITERATION     0  SECTION   1  FOR LOAD CASE     1

 DISPLACEMENT STORED FOR  360 NODES

 ITERATION SUMMARY INFORMATION STORED

 NODAL FORCES STORED FOR   90 ELEMENTS

 ***WARNING ***                                  CP=     26.930   TIME=   9.72103
 ACCUMULATED SOLUTION PHASE WARNING MESSAGES =    121.
      SEE FILE19 OR FILE06

 FOR LOAD STEP=    13  ITERATION=    10  SECTION=   1
  TIME=   2.10000       LOAD CASE=  1
  TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

 NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

     10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

 PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
      ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
      PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
      FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

 HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7211  JUL 12,1991 CP=     27.130

          ***** POST1 NODAL TEMPERATURE LISTING *****

  LOAD STEP    13  ITERATION=    10  SECTION=  1
  TIME=    2.1000          LOAD CASE=  1

    NODE       TEMP
      1    228.76088
      2    228.76088
      3    228.76088
      4    228.76088
      5    231.98329
      6    231.98330
      7    231.98330
      8    231.98330
      9    238.38483
     10    238.38484

 MAXIMUMS
 NODE          10
 VALUE     238.38484

 USE LOAD STEP    14  ITERATION     0  SECTION   1  FOR LOAD CASE     1

 DISPLACEMENT STORED FOR  360 NODES

 ITERATION SUMMARY INFORMATION STORED

 NODAL FORCES STORED FOR   90 ELEMENTS

 ***WARNING ***                                  CP=     27.890   TIME=   9.72136
 ACCUMULATED SOLUTION PHASE WARNING MESSAGES =    131.
      SEE FILE19 OR FILE06

 FOR LOAD STEP=    14  ITERATION=    10  SECTION=   1
  TIME=   2.30000       LOAD CASE=  1
  TITLE= HPOTP TURBINE DISC SIN1D SD109%, 5/23/91

 NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

     10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

 PRINT NODAL TEMPERATURES
1            ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A 10   (MARSHALL SPACE) MAY 1,1990
      ANSYS(R)  COPYRIGHT(C) 1971, 1978, 1982, 1983, 1985, 1987, 1989, 1990   SWANSON ANALYSIS          SYSTEMS, INC. AS
UNPUBLISHED WORK.
      PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL   RIGHTS RESERVED.
      FOR SUPPORT CALL RAFIQ AHMED       PHONE (205) 544-2217    TWX

 HPOTP TURBINE DISC SIN1D SD109%, 5/23/91                                          9.7214  JUL 12,1991 CP=     28.090

          ***** POST1 NODAL TEMPERATURE LISTING *****
```

```
LOAD STEP    14  ITERATION=    10  SECTION=  1
TIME=    2.3000          LOAD CASE=  1

  NODE      TEMP
    1    218.18240
    2    218.18240
    3    218.18241
    4    218.18241
    5    221.18791
    6    221.18791
    7    221.18791
    8    221.18791
    9    227.16531
   10    227.16532

MAXIMUMS
NODE          10
VALUE     227.16532

USE LOAD STEP    15  ITERATION     0  SECTION   1  FOR LOAD CASE     1

 END OF FILE DETECTED ON FILE12

***  NOTE  ***
LOAD STEP   15.  ITER    0.  DISPLACEMENTS (GROUP 3.) NOT ON FILE12.

 END OF FILE DETECTED ON FILE12

***  NOTE  ***
LOAD STEP   15.  ITER    0.  ELEM STRESSES (GROUP 4.) NOT ON FILE12.

 END OF FILE DETECTED ON FILE12

***  NOTE  ***
LOAD STEP   15.  ITER    0.  REACT. FORCES (GROUP 5.) NOT ON FILE12.

***WARNING ***                          CP=     38.140   TIME=   9.72795
NO DATA STORED FOR LOAD STEP   15.  ITERATION    0.  TIME      0.0000

NSEL  FOR LABEL= NODE  FROM     1 TO    10 BY    1

    10  NODES (OF    360  DEFINED) SELECTED BY  NSEL  COMMAND.

PRINT NODAL TEMPERATURES

***WARNING ***                          CP=     38.320   TIME=   9.72800
NO DISPLACEMENTS FOR LOAD CASE =    1.

***** ROUTINE COMPLETED *****  CP =        38.380

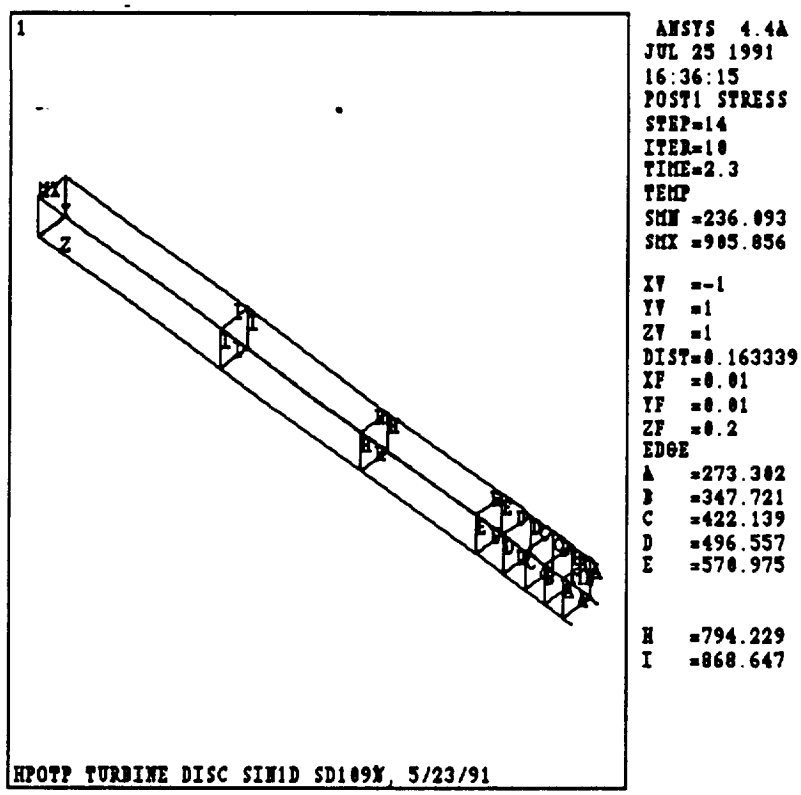
/EOF ENCOUNTERED ON FILE10

          ***** RUN COMPLETED *****  CP=       38.6100   TIME=    9.7281
```

Review of the results

The postprocessing phase is where the results of the analysis are reviewed by graphics displays or tabular reports of temperature, heat flux and thermal gradient. A temperature contour of the model is a quick way to locate the high temperature region. ANSYS has two postprocessors, POST1, the general postprocessor, allows you to review the results of any load step and iteration for the entire model, and POST26, the time-history postprocessor, allows you to review the variation of a result item, such as temperature at specific point in the model, with respect to time or with respect to another result item. This is very helpful with transient analysis.

The following example illustrates some uses of the POST1 and POST26 commands. It is assumed that the FILE12.DAT (or FILE10), containing the solution data is available. See your reference manual for details about POST1 and POST26. For a complete command statement description see the ANSYS User's Manuals, volumen 1 & 2.

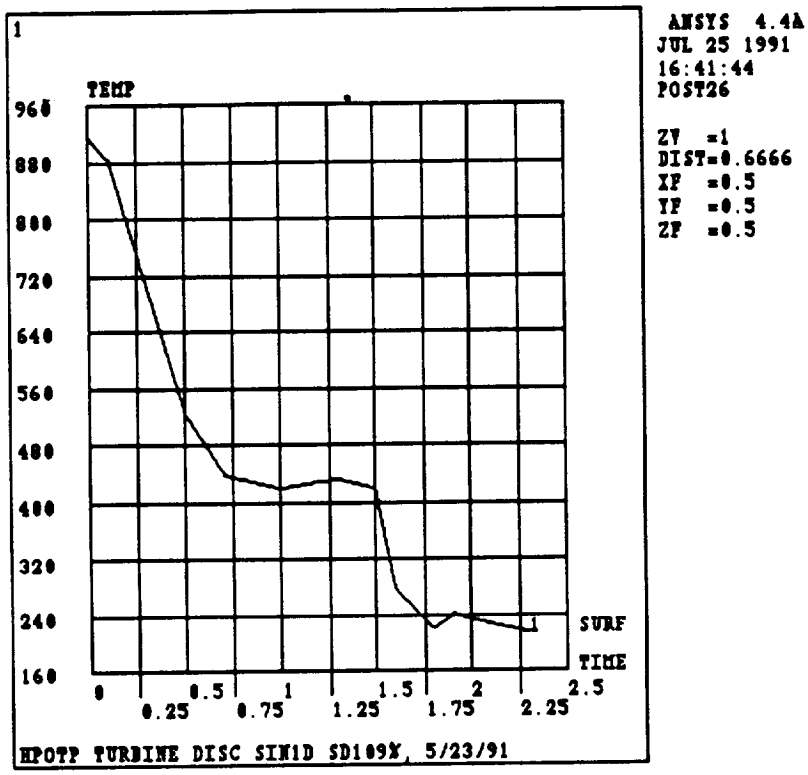


POST1 General Database Postprocessor

This routine is a database postprocessor for sorting, printing, and displaying selected results from any ANSYS analysis. Geometry, node, and element data may be stored for a specified iteration and load step. Next is a sample input and printout of the figure above, a section of the first stage turbine disc model of the HPOTP in the SSME.

/SHOW,4105M,,1	*Command for graphics valid device the output will be on the screen , 4105 for Tektronix terminal, M for pointing device, and 1 for vector mode (lines instead of color contour areas).

```
/POST1
/VIEW,1,-1,1,1
SET,14
/EDGE,1
PLNSTR,TEMP
FINISH
/EOF
```



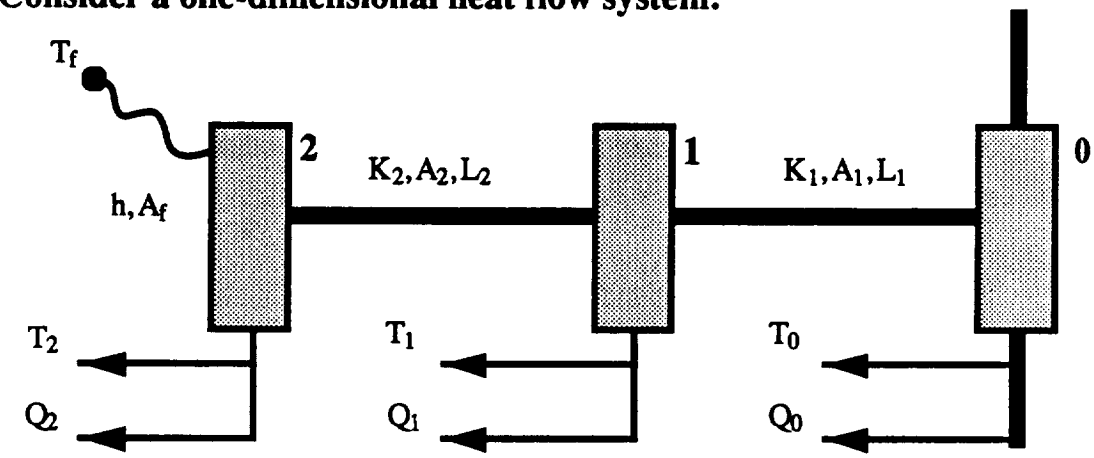
POST26 Time History Results Postprocessor

The POST26 routine allows the cross-displaying or listing of any variable for an element or nodal point against any other variable for an element or nodal point. For example, the /POST26 command began the routine. The next input listing is to build the graph above that represents the temperature variation during the shutdown of the engine, when the disc coolant temperature drops from approximately 1000°R to cryogenic temperatures.

/POST 26	
FILE,12	
DISP,2,1,TEMP,SURF	*This command defines nodal temperature data to be stored, 2 Is a arbitrary reference number assigned to this particular variable, 1 Node for which data are to stored, TEMP Displacement label associated with node, SURF Four character name on the printout and display.
/GRAPH,LABX,TIME	*Determines the style of a graph plot, and X axis labeling can applied to a graph
/GRAPH,LABY,TEMP	*Determines the style of a graph plot, and Y axis labeling can applied to a graph
GRID,1	*Grid lines for the graph
PLVAR,2	*Define which variables are to be displayed. Up to nine variables may be displayed on a frame
FINISH	
/EOF	

V. Derivation of Equation:

Consider a one-dimensional heat flow system:



h = convection coefficient

A_f = convection area

Q= positive for heat flow into a node

For a 1-d conducting bar

$$Q = \frac{KA}{L}(T_2 - T_1)$$

For a lumped mass

$$Q = \rho C_p V \dot{T} = C \dot{T}$$

For a convection element

$$Q = hA(T_f - T_2)$$

Summing the heat flow rates into mass 2 and equating to the heat storage at the node gives:

$$hA_f(T_f - T_2) + \frac{K_2A_2}{L_2}(T_1 - T_2) + Q_2 = C_2\dot{T}_2$$

For Mass 1

$$\frac{K_2A_2}{L_2}(T_2 - T_1) + \frac{K_1A_1}{L_1}(T_0 - T_1) + Q_1 = C_1\dot{T}_1$$

For the final temperature mass

$$\frac{K_1A_1}{L_1}(T_1 - T_0) + Q_0 = C_0\dot{T}_0$$

Rearranging terms:

$$C_0\dot{T}_0 + \frac{K_1A_1}{L_1}T_0 - \frac{K_1A_1}{L_1}T_1 = Q_0$$

$$C_1\dot{T}_1 + \frac{K_1A_1}{L_1}T_1 - \frac{K_1A_1}{L_1}T_0 + \frac{K_2A_2}{L_2}T_1 - \frac{K_2A_2}{L_2}T_2 = Q_1$$

$$C_2\dot{T}_2 + \frac{K_2A_2}{L_2}T_2 - \frac{K_2A_2}{L_2}T_1 + hA_fT_2 = Q_2 + hA_fT_f$$

Expressing this set of equations in matrix form gives:

$$\begin{bmatrix} C_0 & 0 & 0 \\ 0 & C_1 & 0 \\ 0 & 0 & C_2 \end{bmatrix}\begin{Bmatrix} \dot{T}_0 \\ \dot{T}_1 \\ \dot{T}_2 \end{Bmatrix} + \begin{bmatrix} \frac{K_1A_1}{L_1} & -\frac{K_1A_1}{L_1} & 0 \\ -\frac{K_1A_1}{L_1} & \frac{K_1A_1}{L_1} + \frac{K_2A_2}{L_2} & \frac{K_2A_2}{L_2} \\ 0 & -\frac{K_2A_2}{L_2} & \frac{K_2A_2}{L_2} + hA_f \end{bmatrix}\begin{Bmatrix} T_0 \\ T_1 \\ T_2 \end{Bmatrix} = \begin{Bmatrix} Q_0 \\ Q_1 \\ Q_2 + hA_fT_f \end{Bmatrix}$$

This matrix equation can be written more concisely as:

$$[C]\{\dot{T}\} + [K]\{T\} = \{Q\}$$

For a steady-stated thermal solution, the equation becomes:

$$[K]\{T\} = \{Q\}$$

If the properties (K, h_f) are not function of temperature, then this is a set of simultaneous linear equations and can be solved by a standard equation solution techniques.

If the properties are temperature dependent, then an iterative solution is appropriate, that is:

$$[K_i]\{T_{i+1}\} = \{Q_i\}$$

VI. Closing Comments

In this section, two methods are used to solve a one-dimensional, steady state and transient heat transfer problem. In this particular problem the purpose was to determine the most likely thermal environment that drives rib cracking. Two solutions, obtained using a finite difference method (SINDA), and a finite element method (ANSYS), were found to compare favorably during engine shutdown.

VII. References

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CHAPTER 1: STEADY STATE AND TRANSIENT CONDUCTION WITH CONVECTION

SECTION 8: - Investigation of Time Step and Node Size Sensitivity, 1-Dimensional Solution

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A thermal modeler is faced with the task of constructing a model and selecting a solution technique which will yield a good, stable solution for the least cost. To do so, the modeler must define appropriate values for the grid size and time step. Criteria for determining these values are presented in this chapter. A simple problem, for which a high heat flux is imposed on one surface of a plane wall, is used to illustrate the influence of these parameters on a transient solution. The following is a list of objectives for this section:

1. Develop an exact solution to the problem (solve for the transient temperature profile across the wall).

2. Develop criteria for determining the grid size and time step.

3. Develop a SINDA model of the problem. Perform parametric analysis using the criteria developed in item 2 for determining the grid size and time step. Compare the (temperature) results with those of the exact solution.

A. Statement of the Problem:

Consider a homogeneous, semi-infinite wall which is 0.2m thick. The thermal conductivity, k, of the wall is 3.98 W/m°K. The specific heat and the density are 808 J/kg°K and 2600 kg/m^3, respectively. The wall temperature is 300°K. A high heat flux is imposed on one surface such that the surface temperature, at time zero, is fixed at 3300°K. Determine the transient temperature distribution across the wall.

B. Schematic:

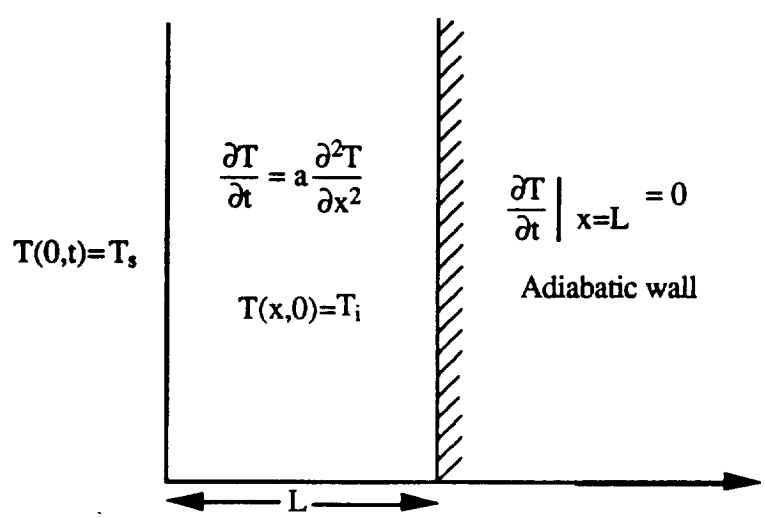


Figure 1: Schematic of semi-infinite wall, insulated on one side with high heat flux imposed on the other surface.

C. Given:

1. Wall has constant cross section area and is homogeneous.
2. Wall thickness = 0.2 m
3. $k = 3.98$ W/m°K
4. $C_p = 808$ J/kg°K
5. $\rho = 2600$ kg/m^3
6. $T_i = 300$°K
7. $(T_s)_{t=0.} = 3300$°K

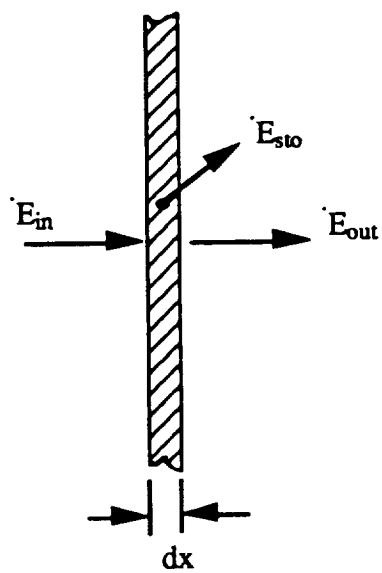
D. Find:

1. The transient temperature distribution across the wall.

III. Exact Solution to the Problem:

Consider a differential strip of the plane wall. Conservation of energy requires that

$$\dot{E}_{in} = \dot{E}_{out} + \dot{E}_{sto} \tag{1}$$



From which

$$q_x = q_{x+dx} + \rho C_p A dx \frac{\partial T}{\partial t} \tag{2}$$

From Fourier's law,

$$q_x = -kA\frac{\partial T}{\partial x} \tag{3}$$

where A is the cross sectional area of the "strip". Similarly,

$$q_{x+dx} = q_x + \left(\frac{\partial q_x}{\partial x}\right)dx$$

or

$$q_{x+dx} = -kA\frac{\partial T}{\partial x} + \left[\frac{\partial}{\partial x}\left(-kA\frac{\partial T}{\partial x}\right)\right]dx$$

or

$$q_{x+dx} = -kA\frac{\partial T}{\partial x} - \left(kA\frac{\partial^2 T}{\partial x^2}\right)dx \tag{4}$$

Substitution of (3) and (4) into (2) gives

$$-kA\frac{\partial T}{\partial x} = -kA\frac{\partial T}{\partial x} - \left(kA\frac{\partial^2 T}{\partial x^2}\right)dx + \rho C_p A dx\frac{\partial T}{\partial t}$$

or

$$kA\frac{\partial^2 T}{\partial x^2}dx = \rho C_p A dx\frac{\partial T}{\partial t}$$

or

$$k\frac{\partial^2 T}{\partial x^2} = \rho C_p\frac{\partial T}{\partial t} \tag{5}$$

Dividing both sides of (5) by k yeilds

$$\frac{\partial^2 T}{\partial x^2} = \frac{\rho C_p}{k}\frac{\partial T}{\partial t} \tag{6}$$

Setting $\frac{\rho C_p}{k} = \frac{1}{\beta}$ then gives

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\beta}\frac{\partial T}{\partial t} \tag{7}$$

From the problem statement, we may write the following boundary conditions.

$$T(0,t) = T_s = 3300°K$$

$$\frac{\partial T(x=L,t)}{\partial t} = 0 \quad \text{(Adiabatic boundary)}$$

The initial condition is

$$T(x,0) = T_i = 300°K$$

So then, the temperature distribution is obtained by solving

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\beta}\frac{\partial T}{\partial t} \tag{8}$$

subject to the following boundary/initial conditions:

$$T(0,t) = T_s \qquad t \geq 0 \tag{9}$$

$$\frac{\partial T(L,t)}{\partial x} = 0 \qquad t \geq 0 \tag{10}$$

$$T(x,0) = T_i \qquad 0 \langle x \langle L \tag{11}$$

Suppose now that T(x,t), the general solution to (8), is expressed as the sum of its steady state and transient parts; that is,

$$T(x,t) = w(x,t) + v(x)$$

where w(x,t) is the transient part of the solution and v(x) denotes the steady state part. It is easily shown that the steady state solution is given by

$$v(x) = T_S$$

Hence, $\quad T(x,t) = w(x,t) + T_S \qquad (12)$

and we are left only to obtain the transient part of the solution. The transient part must satisfy the original partial differential equation as well as the boundary and initial conditions. From (12), we have

$$w(x,t) = T(x,t) - Ts$$

and

$$\frac{\partial w}{\partial x} = \frac{\partial T(x,t)}{\partial x} - \cancelto{0}{\frac{\partial}{\partial x} T_s} \tag{13}$$

and

$$\frac{\partial^2 w}{\partial x^2} = \frac{\partial^2 T(x,t)}{\partial x^2} \tag{14}$$

Similarly,

$$\frac{\partial w}{\partial t} = \frac{\partial T(x,t)}{\partial t} + \cancelto{0}{\frac{\partial}{\partial t} T_s} \tag{15}$$

The boundary conditions become

$$\begin{aligned} w(0,t) &= T(0,t) - T_s \\ &= T_s - T_s = 0. \end{aligned} \tag{16}$$

and

$$\left.\frac{\partial w}{\partial x}\right|_{x=0} = \frac{\partial T(L,t)}{\partial x} + \cancelto{0}{\frac{\partial}{\partial x} T_s} = 0 \tag{17}$$

The initial condition is

$$w(x,0) = T(x,0) - T_s = T_i - T_s\,. \tag{18}$$

substitution of (14) and (15) into (8) gives

$$\frac{\partial^2 w}{\partial x^2} = \frac{1}{\beta}\frac{\partial w}{\partial t} \tag{19}$$

where the (new) boundary conditions are

$$w(0,t) = 0$$

$$\frac{\partial w}{\partial x}(L,t) = 0$$

$$w(x,0) = T_i - T_s$$

Suppose now that w(x,t) is expressed as the product of two functions, one of x and one of t. w(x,t) may be expressed as

$$w(x,t) = \phi(x)\,\gamma(t)$$

such that

$$\frac{\partial^2 w}{\partial x^2} = \phi''(x)\,\gamma(t)$$

and

$$\frac{\partial w}{\partial t} = \phi(x)\,\gamma'(t) \tag{20}$$

(21)

Substitution of (20) and (21) into (19) gives

$$\phi''(x)\,\gamma(t) = \frac{1}{\beta}\,\phi(x)\,\gamma'(t) \tag{22}$$

from which

$$\frac{\phi''(x)}{\phi(x)} = \frac{1}{\beta}\frac{\gamma'(t)}{\gamma(t)} \tag{23}$$

Since the left side of (23) is a function of x and the right side is a function of only t, the only way to satisfy (23) is to set both sides equal to the same non-zero constant, C. We then have

$$\frac{\phi''(x)}{\phi(x)} = C \;\Rightarrow\; \phi''(x) - C\phi(x) = 0 \tag{24}$$

and

$$\frac{1}{\beta}\frac{\gamma'(t)}{\gamma(t)} = C \;\Rightarrow\; \gamma'(t) - C\beta\gamma(t) = 0 \tag{25}$$

which are both homogeneous differential equations. Let us now define a negative constant, $-\lambda^2 = C$, such that (24) becomes

$$\phi''(x) + \lambda^2\phi(x) = 0\,, \tag{26}$$

where

$$w(0,t) = \phi(0)\,\gamma(t) = 0$$

and

$$\left.\frac{\partial w}{\partial x}\right|_{x=L} = \phi'(L)\,\gamma(t) = 0$$

from which

$$\phi(0) = 0 \tag{27}$$

and

$$\phi'(L) = 0 \tag{28}$$

The general solution to (26) is

$$A_1\cos\lambda x + A_2\sin\lambda x = \phi(x) \tag{29}$$

Applying the boundary condition, (27), gives

$$A_1\cos 0 + A_2\sin 0 = 0$$

or

$$A_1 = 0.$$

Then

$$\phi(x) = A_2 \sin \lambda x \tag{30}$$

and

$$\phi'(x) = A_2 \lambda \cos \lambda x \tag{31}$$

Applying the second boundary condition, we find that

$$\phi'(L) = A_2 \lambda \cos \lambda L = 0.$$

We can not allow $A_2 \equiv 0$ or $\lambda \equiv 0$,as this leads to a correct but trivial solution. The only alternative is for

$$\cos \lambda L \equiv 0.$$

which means that λ must be an odd integer multiple of $\frac{\pi}{2L}$.
Thus,

$$\lambda_n = \frac{(2n-1)\pi}{2L} \quad \text{where} \quad 1 \le n \le \infty$$

and

$$\phi_n(x) = A_2 \sin \frac{(2n-1)\pi}{2L} x \tag{32}$$

Recognizing that (26), (27), and (28) are homogeneous, A_2 may be droped from (32) because any constant multiple of a solution to (26) is also a solution. Therefore,

$$\phi_n(x) = \sin \frac{(2n-1)\pi}{2L} x \tag{33}$$

Considering, now, equation (25), we have

$$\gamma'(t) - C\beta\gamma(t) = 0$$

or, upon substitution of λ into (25),

$$\gamma'(t) + \beta\lambda^2\gamma(t) = 0. \tag{34}$$

The general form of the solution to (34) is

$$\gamma(t) = A_3 \exp(-\beta\lambda^2 t) \tag{35}$$

Noting, again, that (25) is homogeneous, we may re-write (35) without the constant. Hence,

$$\gamma_n(t) = \exp(-\beta\lambda_n^2 t)$$

So then,

$$w_n(x,t) = \phi_n(x)\,\gamma_n(t)$$
$$= \sin \lambda_n x \exp(-\beta\lambda_n^2 t) \tag{36}$$

It is now possible to apply the principle of superposition and to form the following linear combination of the solution.

$$w(x,t) = \sum_{n=1}^{\infty} b_n \sin \lambda_n x \exp(-\beta\lambda_n^2 t)$$

where

$$\lambda_n = \frac{2(n-1)\pi}{2L}$$

The general solution to the original problem then has the form

$$T(x,t) = w(x,t) + v(x)$$
$$= \sum_{n=1}^{\infty} b_n \sin \lambda_n x \exp(-\beta\lambda_n^2 t) + T_s$$

where

$$\lambda_n = \frac{(2n-1)\pi}{2L} \quad \text{and } L, \beta, T_s \text{ are constants.}$$

The initial condition has yet to be satisfied, and requires that

$$w(x,0) = \sum_{n=1}^{\infty} b_n \sin \lambda_n x \exp(-\beta\lambda_n^2(0))$$

$$= \sum_{n=1}^{\infty} b_n \sin \lambda_n x = g(x) = \text{constant} = T_i - T_s \tag{37}$$

$$\text{where } 0 \le x \le L$$

Because λ_n has the form, $(2n-1)\pi/2L$, (37) is not a routine Fourier series. It may be shown, however, that the series in (37) represents the function, g(x) (a constant in this case), as long as g is sectionally smooth and the coefficients are chosen according to

$$b_n = \frac{2}{L}\int_0^L g(x) \sin \frac{(2n-1)\pi x}{2L}\, dx \tag{38}$$

The completed general solution is given by

$$T(x,t) = \sum_{n=1}^{\infty} b_n \sin \lambda_n x \exp(-\beta\lambda_n^2 t) + T_s$$

where

$$\lambda_n = \frac{(2n-1)\pi}{2L} \quad ; \quad b_n = \frac{2}{L}\int_0^L (T_i - T_s) \sin \frac{(2n-1)\pi x}{2L}\, dx$$

and

$$0 \le x \le L$$

In this case, $L = 0.2$m, $T_i = 300$ K, $T_s = 3300$ K, $\beta = k/\rho C_p$,
$k = 3.98$ W/mK, $\rho = 2600$ Kg/m^3, $C_p = 808$ J/KgK .
We have

$$b_n = \frac{2}{0.2}\int_0^{.2} -3000 \sin \frac{(2n-1)\pi}{2(.2)} x\, dx$$

$$= (10)(-3000)\int_0^{.2} \sin \frac{(2n-1)\pi}{.4} x\, dx$$

$$= 30000\left(\frac{.4}{(2n-1)\pi}\right) \cos \frac{(2n-1)\pi}{.4} x \Big|_0^{.2}$$

$$= \frac{12000}{(2n-1)\pi} \cos \frac{(2n-1)\pi\, x}{(.2)\, 2} \Big|_0^{.2}$$

$$= \frac{12000}{(2n-1)\pi}\left[\cancelto{0}{\cos \frac{(2n-1)\pi}{2}} - 1\right] = -\frac{12000}{(2n-1)\pi}$$

where

$$\beta = \frac{k}{\rho C_p} = \frac{3.98\ \text{J}}{\text{sec m K}}\ \frac{\text{m}^3}{2600\ \text{Kg}}\ \frac{\text{Kg K}}{808\ \text{J}} = 1.8945\ \text{E}^{-6}\ \text{m}^2/\text{sec}$$

So,

$$\boxed{T(x,t) = \sum_{n=1}^{\infty}\left[\frac{-12000}{(2n-1)\pi}\right]\left[\sin\frac{(2n-1)\pi x}{.4}\right]\left\{\exp\left[-1.8945\text{E}^{-6}\left[\frac{(2n-1)\pi}{.4}\right]^2 t\right]\right\} + 3300}$$

where x is in meters, t in seconds, and T in degrees K.

II. Mathematical Approximation for Grid Size & Time Step

Consider, again, the geometry represented in Figure 1. The

accuracy of the (temperature) predictions, obtained from a finite element heat transfer analyzer such as FAHT (thermal analyzer part of Fantastic), are highly dependent on correctly defining the grid size and the time step. Temperature results from several FAHT solutions are shown in Table 1.

RUN NO.	X = .01 meter	.02	.03	.04	No. of Elements	Time Step (Seconds)
FE-1	489.4K	179.9	324.6	297.6	20	2
FE-2	561.1	175.8	320.3	299.6	20	0.2
FE-3	572.0	301.0	300.0	300.0	80	2

Table 1.FAHT Temperature prediction for various grid sizes and time steps at time = 10. seconds

Figure 2. Depicts the short time transient solutions to the problem

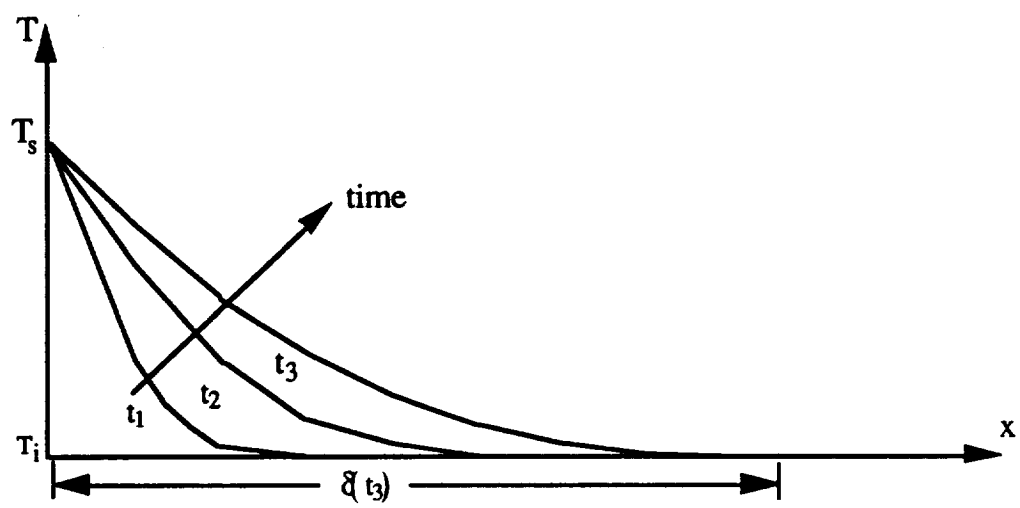


Figure 2: Short time transient in a domain.

where $\delta(t_i)$ is the Penetration Depth, PD, at each time step. Physically, the PD is the maximum depth, in the wall, to which the effect of heat addition is currently felt. In order to obtain a realistic answer, the PD, for the first time step, should be large enough to cover a number of elements.

Notice the fluctuation in temperature across the wall for the first 2 runs in table 1. It is obvious that these predictions are in error since the wall temperature at X=.02m

is significantly below the initial wall temperature of 300°K; such is illustrated by upper most curve in figure 3. This error is attributed to the grid sizes being larger than the PD.

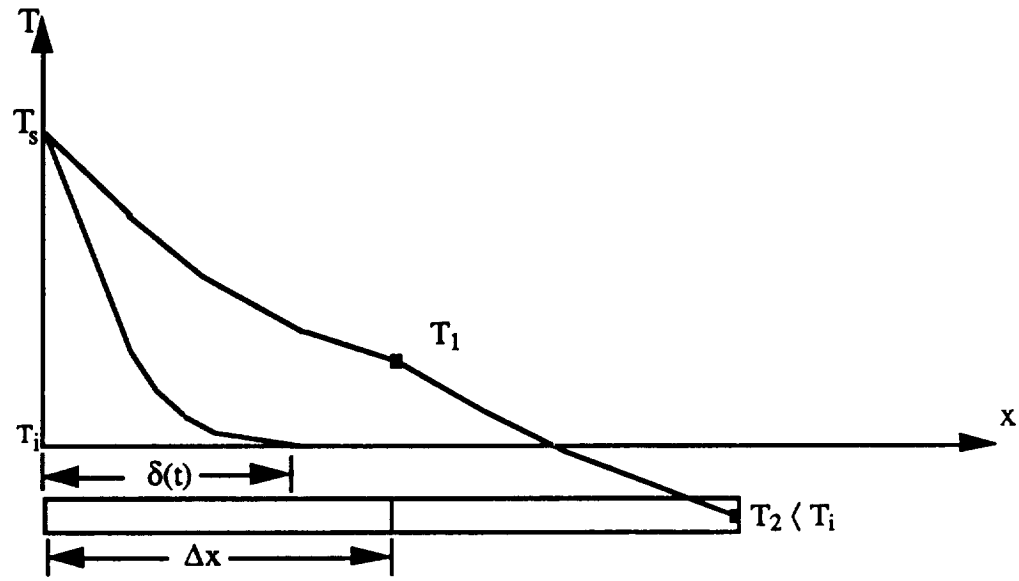


Figure 3. Effect of large grid size in FAHT solution

A. Approximate Solution:

Consider a general solution to the problem, of the following form.

$$\theta(x,t) = \frac{T(x,t) - T_i}{T_s - T_i} = 1 - 2(x/\delta) + (x/\delta)^2 \tag{39}$$

This equation is an approximate temperature profile which satisfies the boundary condition. The energy equation, (7), in terms of $\theta(x,t)$ is

$$\frac{\partial^2\theta}{\partial x^2} = \frac{1}{\beta}\frac{\partial\theta}{\partial t} \tag{40}$$

Substituting (39) into (40), and integrating from 0 to δ, gives

$$\left[\frac{\partial\theta}{\partial x}\right]_0^\delta = \frac{1}{\beta}\frac{d}{dt}\left[\int_0^\delta \left(1 - 2x/\delta + x^2/\delta^2\right) dx\right] \tag{41}$$

where

$$\frac{\partial\theta}{\partial x} = -\frac{2}{\delta} + \frac{2x}{\delta^2}$$

The left side of the equation (41) is then equal to $2/\delta$. and

$$\int_0^{\delta}\left(1-\frac{2x}{\delta}+\frac{x^2}{\delta^2}\right)dx = x-\frac{x^2}{\delta}+\frac{x^3}{3\delta^2}\Bigg|_0^{\delta}=\frac{\delta}{3}$$

Then

$$\frac{2}{\delta}=\frac{1}{\beta}\frac{d}{dt}\left[\frac{\delta}{3}\right]$$

or

$$6\beta dt = \delta d\delta$$

Integration from 0 to t (with $\delta(0) = 0$) gives

$$\frac{\delta^2}{2}=6\beta t \quad \Rightarrow \quad \boxed{\delta=\sqrt{12\beta t}} \tag{42}$$

Equation (42) approximates the Penetration Depth (PD) of a thermal front into an isothermal semi-infinite domain. In order to obtain a realistic answer, the PD (for the first time step) should be large enough to cover a number of elements i.e.,

$$\delta(\Delta t)=\sqrt{12\beta\,\Delta t} \;\rangle\; 2\Delta x \tag{43}$$

or

$$\sqrt{3\beta\Delta t} \;\rangle\; \Delta x$$

The stability criterion for the explicit solution scheme is given by,

$$\Delta x \;\rangle\; \sqrt{2\beta\,\Delta t} \tag{44}$$

Equation (44) describes an inter-dependence between the time step and the element size. In implicit solution routines this equation has no bearing on stability.

The following relation which satisfies equation (43) (and does not result in the gross violation of equation (44)) is proposed for estimating inter-dependence between the time step and the element size.

$$\boxed{\sqrt{\beta\,\Delta t} \;\langle\; \Delta x \;\langle\; \sqrt{3\beta\,\Delta t}} \tag{45}$$

B. Suggested Procedure for Obtaining Accurate Transient Results:

The following approach is suggested where accurate transient solutions, requiring minimal CPU time, are sought;

1. Choose a reasonable time step.

2. Select Δx by calculating the acceptable limits Acceptable limits are determined by applying

$$\sqrt{\beta \Delta t} \langle \Delta x \langle \sqrt{3\beta \Delta t} \tag{46}$$

3. Reduce Δx by a factor of two and select Δt using the following relation

$$\frac{\Delta x^2}{3\beta} \langle \Delta t \langle \frac{\Delta x^2}{\beta} \tag{47}$$

4. Compare the two results. If the change in the temperature field exceeds an "acceptable variation", repeat step 3. Obviously, the degree of the accuracy depends upon the selected criterion for the " acceptable variation".

NOTE: This procedure is recommended for the <u>implicit</u> solution scheme.

IV. Numerical SINDA Solution to the Problem

A. General Approach:

The above procedure was used to estimate the grid size and time step interdependence in an implicit SINDA solution. The "Forwad-back-long" differencing scheme (FWDBKL) was selected. A time step of 10. seconds was chosen for the first run. From the given material properties;

$$\beta = \frac{K}{\rho C_p} = \frac{3.98}{2600.*808.} = 1.8945E\text{-}6 \ \frac{m^2}{sec}$$

and

$$\sqrt{\beta \Delta t} = .0043 \text{ m} \quad \& \quad \sqrt{3\beta \Delta t} = .007 \text{ m}$$

From equation (45)

$$.0043 \langle \Delta x \langle .007$$

An element size of .005 was chosen for the first run. The element size was reduced by 50% and the corresponding time step was estimated using equation (46). The SINDA model included in this section was run for each combination of time step and element size.

B. Discretization

The SINDA model consisted of a 0.2m thick homogeneous semi-infinite wall with a surface area of 1.0 m^2. The number of nodes within the wall thickness was varied between runs, starting with 80 and increasing to 160 and 320 nodes. The initial wall temperature was set at 300°K. A boundary

node with a fixed temperature of 3300°K was placed on the surface (NODE 1000).

C. Presentation of Numerical Results

Predicted temperatures, together with the results of the exact solution, are tabulated in Table 2. Also included in this table are the % absolute temperature errors, for each case. The temperature result of the first run, at location X= 0.01, is unexpectedly good. The temperature predictions should get closer to the exact solution, as the grids become finer and/or time steps are decreased. This trend is better illustrated by the results obtained at X= 0.02.

RUN NO.	X=.01	0.02	0.03	NO. OF ELEMENTS	TIME STEP SECONDS
EXACT	612.8	303.5	300.	-	-
SINDA1	608.2	315.8	300.8	40	10
%ERROR	-0.75	4.	-		
SINDA2	658.9	313.6	300.3	40	4
%ERROR	7.53	3.4	-		
SINDA3	623.0	306.2	300.05	80	2
%ERROR	1.67	0.9	-		
SINDA4	615.6	304.2	300.	160	0.5
%ERROR	0.46	0.21	0.		
SINDA5	614.3	303.7	300.	320	0.1
%ERROR	0.25	0.05	0.		

TABLE 2: SINDA Temperature results at 10 seconds.

SINDA INPUT LISTING

```
BCD 3THERMAL LPGS
BCD 9INVESTIGATION OF TIME STEP & NODE SIZE
END
BCD 3NODE DATA
GEN 1,80,1,300.,2600.,808.,.2,1.25E-2
        -1000,3300,0.                    $BOUNDARY SURFACE NODE
END
BCD 3 CONDUCTOR DATA
GEN 1,79,1,1,1,2,1,3.98,1.,80.,.2
CAL 80.,1000,1,3.98,2.,80.,.2
END
BCD 3CONSTANTS DATA
       NDIM = 1500, NLOOP =10
       ARLXCA = .01, DRLXCA = .01
       DTIMEI = 2., OUTPUT = 2.,  TIMEND = 10.
END
BCD 3ARRAY DATA
END
BCD 3EXECUTION
       CALL STATUS
       CALL FWDBKL
END
BCD 3VARIABLES 1
END
BCD 3VARIABLES 2
END
BCD 3OUTPUT CALLS
       CALL TPRINT
END
BCD 3END OF DATA
```

D. Recommendation for model generation

Because SINDA uses the finite differencing solution schemes, it is not as sensitive to the Grid size and time step as the finite element analyzers such as FAHT. As a model grows in complexity, so does the calculation of interdependence between the grid size and time step. In general the SINDA user should nodalize the model with consideration factors such as: (1) the points where temperatures are desired, (2) the expected temperature distribution, (3) physical reasonableness, and (4) the ease of computation. The actual size of the node is dependent on other considerations: (1) accuracy desired, (2) structural design, (3) computer storage capability, and (4) computer time required. Each factor, however embodies other considerations. For example, to anticipate the expected temperature distribution, one must draw heavily on Engineering Judgement as to the effects of the expected boundary condition and associated material properties.

A SINDA user however does not have to figure out the interdependence between the grid size and time step for the problem. The explicit solution routines within SINDA such as, SNFRDL, will calculate the time step necessary to insure a stable solution. The stability criteria of each diffusion node is calculated as the capacitance divided by the sum of the conductors attached to it. The lowest value is then placed in control constant CSGMIN. The time step, DTIMEU, is then calculated as 95% of CSGMIN. The implicit solution routines such as, FWDBKL, on the other hand are unconditionally stable. The user however is cautioned in selecting computational time steps significantly larger than the explicit stability criteria, CSGMIN. For the implicit solution routines the value of CSGMIN is calculated at each time step for information only. The user should compare the time step specified, DTIMEI, with CSGMIN. IF the DTIMEI is 5 to 10 times larger than CSGMIN, the user should halve the time step and repeat the run to check the accuracy of the results.

Introduction to Chapter 2

Steady State and Transient Radiation

Chapter two includes radiation heat transfer examples, vitally important to spacecraft thermal design. Because radiation is nonlinear with temperature, additional analytical techniques are required and are illustrated here. In network analyzers, these techniques are usually transparent to the code user. But it is important that even casual code users understand the underlying assumptions and techniques employed.

Also, because several of these nonlinear problems have no closed- form solution, differencing approaches and techniques for linearization of nonlinear terms are introduced in this chapter. Again, this is important because analysts must understand numerical assumptions and constraints to produce accurate analytical results.

Additionally, because radiation interchange is a complex function of geometry and surface properties, an introductory example is given for the TRASYS program. Numerical techniques for calculating geometric form factors are illustrated and graybody exchange between surfaces is discussed.

Finally, the beginning analysts are advised to examine the closed- form solution given in section one. This simple hand calculation can be useful for problem bounding estimates, especially during thermal vacuum testing. The thermal analyst may find this useful several times during his or her career.

CHAPTER 2: STEADY STATE AND TRANSIENT RADIATION

SECTION 1: Radiation Heat Transfer Examples

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

Radiative heat transfer is an important consideration in the design and development of spacecraft. The radiative exchange process for simple geometries like parallel plates, concentric cylinders, and concentric spheres is easy to model and understand. These cases are of practical importance in predicting the performance of radiation shields, Dewar vessels, and cryogenic insulation. A box wrapped in multi-layer insulation (MLI) undergoing thermal vacuum testing is analyzed in this section to show as an example of simple radiative exchange.

A. Statement of the Problem:

Consider a 100 pound box wrapped in multi-layer insulation undergoing a thermal vacuum test. The thermal vacuum test commences at time $\tau = 0$ hours. The initial temperature of the box is 70 °F. The total surface area of the box is 10 square feet. The cold case begins when the temperature of the box is 0 °F. The sink temperature of liquid Nitrogen (TLN_2) is -320 °F.

Find:

1) The transient temperature drop of the box
2) The time required for the box to reach 0 °F (from 70 °F)
3) The time required for the box to reach 140 °F (from 0 °F), following the cold case and assuming a 50 Watt heater is utilized

B. Schematic:

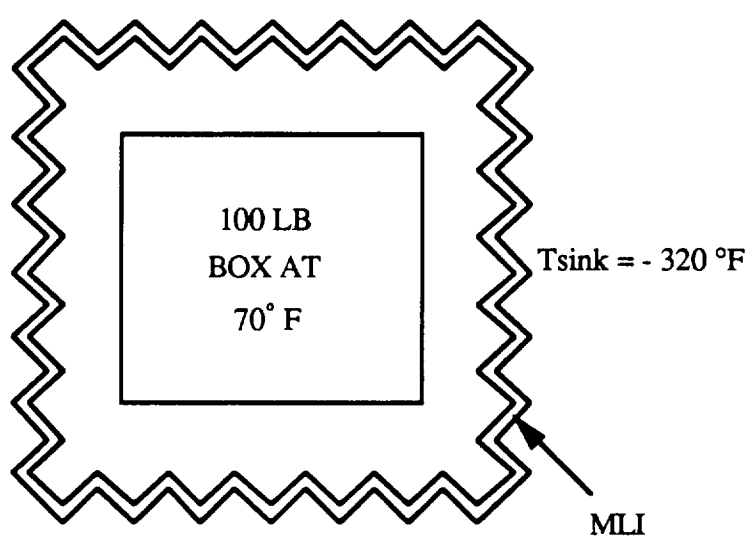


Figure 1. Schematic of 100 lbm box wrapped in MLI

C. Given:

1) $T_0 = 70\ °F = 70 + 460 = 530\ °R$
2) $m = \rho v = 100$ lbm
3) Surface Area = 10 sq. ft.
4) $T = 0\ °F = 460\ °R$

D. Find:

1) Transient temperature drop of the box
2) Time required for box to reach 0 °F (from 70 °F)
3) Time required for box to reach 140 °F (from 0 °F), following the cold case and assuming a 50 Watt heater is utilized

II. Formulation of the Problem:

A. Simplifying Assumptions:

1) Specific heat (c_p) of the box is 0.20 Btu/lbm °F
2) Emissivity (ε) of MLI is 0.03
3) Sink temperature (TLN_2) is - 320 °F (140 °R)
4) View Factor is 1.0

B. Initial and/or Boundary Conditions:

1) Initial box temperature is 70 °F (530 °R)
2) Final box temperature is 0 °F (460 °R)
3) Sink temperature is - 320 °F (140 °R)

III. Analysis:

A. Closed Form Solution:

1. Cold Case:

If the heat transfer process is determined only by radiation, then the net heat flow during the time interval is given by

$$-\rho c_p v \frac{dT}{d\tau} = \sigma \varepsilon F A [T(\tau)^4 - T_\infty^4]$$

Separating the variables of the equation gives

$$\frac{dT}{T^4 - T_\infty^4} = -\frac{\sigma \varepsilon F A}{\rho c_p V} d\tau$$

Integration of the equation gives

$$\int_{T_0}^{T} \frac{dT}{T^4 - T_\infty^4} = -\frac{\sigma\varepsilon FA}{\rho c_p V} \int_0^{\tau} d\tau$$

Expressing $T^4 - T_\infty^4$ as the product of three binomials leads to

$$T^4 - T_\infty^4 = (T^2 + T_\infty^2)(T + T_\infty)(T - T_\infty)$$

$$\frac{1}{T^4 - T_\infty^4} = \frac{AT + B}{T^2 + T_\infty^2} + \frac{C}{T + T_\infty} + \frac{D}{T - T_\infty} \tag{1}$$

Simplifying the equation gives

$$(A + C + D)\,T^3 + (B - CT_\infty + DT_\infty)\,T^2 + (-AT_\infty^2 + CT_\infty^2 + DT_\infty^2)T + DT_\infty^3 - C\,T_\infty^3 - B\,T_\infty^2 = 1$$

Comparing the coefficients, we obtain

$$A + C + D = 0$$

$$B - C\,T_\infty + D\,T_\infty = 0$$

$$-A\,T_\infty^2 + C\,T_\infty^2 + D\,T_\infty^2 = 0$$

$$D\,T_\infty^3 - C\,T_\infty^3 - B\,T_\infty^2 = 1$$

Solving for A, B, C, and D gives

$$A = 0 \tag{2}$$

$$B = -\frac{1}{2T_\infty^2} \tag{3}$$

$$C = -\frac{1}{4\,T_\infty^3} \tag{4}$$

$$D = \frac{1}{4\,T_\infty^3} \tag{5}$$

By substitution of equations (2), (3), (4), and (5) into (1), the resulting equation becomes

$$\int \frac{dT}{T^4 - T_\infty^4} = -\frac{1}{2T_\infty^2}\int \frac{dT}{T^2+T_\infty^2} - \frac{1}{4T_\infty^3}\int \frac{dT}{T+T_\infty} + \frac{1}{4T_\infty^3}\int \frac{dT}{T-T_\infty}$$

$$= \int_0^\tau -\frac{\sigma\varepsilon AF}{\rho c_p v}\, d\tau$$

Integration of the equation gives

$$-\frac{1}{2T_\infty^2}\left(\frac{1}{T_\infty}\right)\tan^{-1}\left(\frac{T}{T_\infty}\right)\Bigg|_{To}^{T} - \frac{1}{4T_\infty^3}\ln\left(T+T_\infty\right)\Bigg|_{To}^{T} + \frac{1}{4T_\infty^3}\ln\left(T-T_\infty\right)\Bigg|_{To}^{T}$$

$$= -\frac{\sigma\varepsilon AF}{\rho c_p v}\,\tau\Bigg|_0^\tau$$

Evaluating the limits of the equation gives

$$-\frac{1}{2T_\infty^3}\left[\tan^{-1}\frac{T}{T_\infty} - \tan^{-1}\frac{T_0}{T_\infty}\right] - \frac{1}{4T_\infty^3}\ln\frac{T+T_\infty}{T_0+T_\infty} + \frac{1}{4T_\infty^3}\ln\frac{T-T_\infty}{T_0-T_\infty} \qquad (6)$$

$$= -\frac{\sigma\varepsilon AF}{\rho c_p v}\,\tau$$

Substituting the following values:

T = Final box temperature = 0 °F = 460 °R
T_0 = Initial box temperature = 70 °F = 530 °R
T_∞ = Sink Temperature = - 320 °F = 140 °R
$m = \rho v$ = 100 lbm
$c_p = 0.20$, $\varepsilon = 0.03$, $F = 1.0$

into equation (6) and solving for the time, τ, we obtain

$$\tau = 47.13 \text{ hrs}$$

2. Hot Case:

For the hot case T_∞ becomes the steady state (s.s.) temperature

$$q_{s.s.} = \sigma\varepsilon AF\left(T_{s.s}^4 - T_{sink}^4\right)$$

Given that $q_{s.s.}$ = 50 Watts and T_{sink} = 140 °R, then

$$q_{s.s.} = (50\text{ W})(3.413\text{ Btu/hrW}) = 170.65\text{ Btu/hr}$$

$$= (0.1714E\ 10^{-8})(0.03)(1.0)(10.0)(T_{s.s.}^4 - 140^4)$$

Solving for $T_{s.s.}$ gives

$$T_{s.s.} = T_{\infty} = 759.22°R$$

Substituting the following values:

$$T = 600° R$$
$$T_0 = 460° R$$
$$T_{\infty} = 759° R$$

into equation (6) and solving for the time, τ, we obtain

$$\tau = 21.98 \text{ hrs.}$$

B. Numerical (SINDA) Solution

1. Cold Case:

The "NODE DATA" block for this problem includes two nodes. One node is the box, which has an initial temperature of 70°F (530°R) and a thermal capacitance of 20 Btu/°F. The other node is a boundary node at -320 °F (140°R).

The next block, "CONDUCTOR DATA", contains the conductance values between the nodes. The negative sign in front of the conductor number indicates radiation heat transfer. The conductance value is 5.142E -10.

The "EXECUTION" block calls SNFRDL, which is an explicit forward differencing subroutine used for transient analyses. For this case, the LPCS option is required and the control constants, TIMEND and OUTPUT, must be specified.

The SINDA input listing for the cold case is given on the following pages.

2. Hot Case

The hot case is similar to the cold case, except that heater power is added (to node 1) in the "VARIABLES 1" data block. In the node data block, the initial temperature of node 1 is 0°F The SINDA input listing for the hot case is given on the following pages.

IV. Presentation and Discussion of Results:

A. Presentation of Results:

For the cold case, the closed form solution indicated that 47.13 hours was required for the box to reach 0°F, while the SINDA solution predicted 46.50 hours (Figure 2), a difference of less than 2%. For the hot case, the closed-form solution indicated that 21.98 hours was required for the box to reach 140 °F (600 °R), while the SINDA solution predicted 22.00 hours (Figure 3). The output files for the cold and hot cases are given following the SINDA input listings.

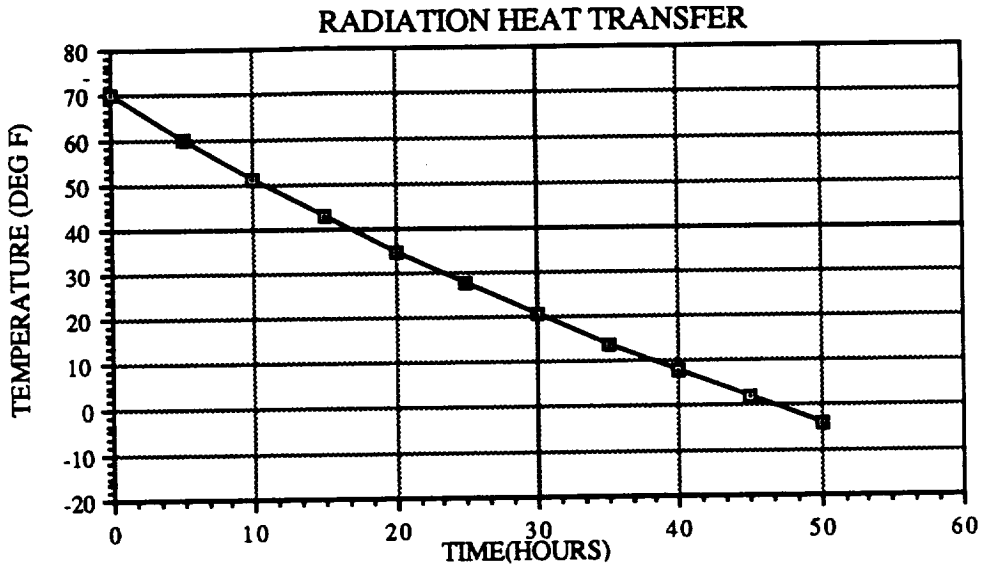


Figure 2. Transient Temperature of the Box (Cold Case)

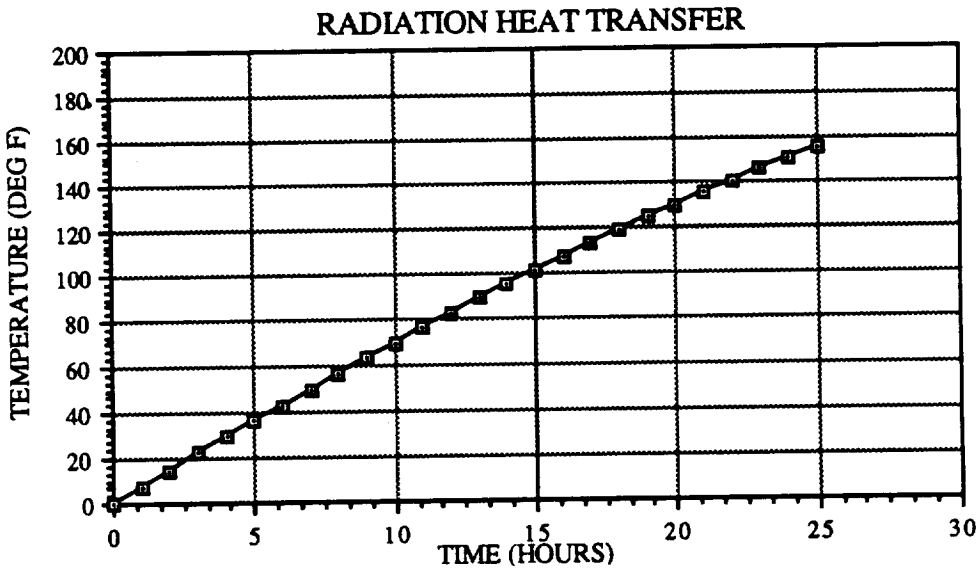


Figure 3. Transient Temperature of the Box (Hot Case)

V. Closing Comments:

The simple closed-form solution for this example is useful for obtaining quick answers to transient problems which arise, for example, during thermal vacuum testing. Many instances occur when a digital computer is not available or a numerical solution may not be practical. In such cases, the closed-form solution provides valuable insight into determining the expected system response.

VI. References:

Robert Siegel and John R. Howell, Thermal Radiation Heat Transfer, 1972, McGraw-Hill Inc.,New York, pp. 278-281

SINDA INPUT LISTING
(COLD CASE)

```
      BCD 3THERMAL LPCS
      BCD 3TEST.PC-SINDA
      END
C
      BCD 3NODE DATA
C
          1,70.0,20.0
          -99,-320.,1.0
C
      END
C
      BCD 3CONDUCTOR DATA
          -1,1,99,5.142E-10
      END
C
      BCD 3CONSTANTS DATA
          DTIMEI,0.1
          DTIMEH,0.1
          NLOOP,100
C
          TIMEND,50.0
          OUTPUT,1.0
C
          ARLXCA,.01
          DRLXCA,.01
          TIMEO,0.0
          DAMPA,0.5
          DAMPD,0.5
          NDIM,1000
C
      END
C
      BCD 3ARRAY DATA
      END
C
      BCD 3EXECUTION
C
F     OPEN(3,FILE="EMLFLT.PLT",STATUS="UNKNOWN")
F     WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F   2 FORMAT(I6/,250(I6,31X,I6/))
C
F     CALL SNFRDL
C
      END
      BCD 3VARIABLES 1
      END
C
      BCD 3VARIABLES 2
      END
C
      BCD 3OUTPUT CALLS
C
F     DATA HT/4HT   /
C
F     WRITE(3,1)TIMEO,(T(I),I=1,NNT)
F   1 FORMAT(E10.3/,250(7F9.3/))
C
C
CF          CALL TPRINT
CF          CALL TDUMP
```

```
C
C     THREE COLUMN OUTPUT ROUTINE,STNDRD
C
CF      IF(LNODE.EQ.0)CALL NNREAD(1)
F      IF(ABS(AMOD(TIMEN+0.001,5.0)).GT.1.0)RETURN
F      IF(NPAGE.EQ.0.OR.NLINE.GE.56)CALL TPLIN
F      J=LNODE+NCSGMN
F      I1=NX(J)
F      IF(J.LE.LNODE)I1=0
F      J=LNODE+NDTMPC
F      I2=NX(J)
F      IF(J.LE.LNODE)I2=0
F      J=LNODE+NARLXC
F      I3=NX(J)
F      IF(J.LE.LNODE)I3=0
F      WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F    9 FORMAT(/,11H,**********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F    $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F    $          8H RELXCC(I6,2H)=1PE12.5)
F      NLINE=NLINE+4
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F      WRITE(6,100)
F 100  FORMAT(1H )
F      NLINE=NLINE+1
F      J=1
F      L=3
F    5 IF(L.LT.NNT)GO TO 10
F      L=NNT
F   10 WRITE(6,101) (HT,NX(I+LNODE),T(I),I=J,L)
F  101 FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F      IF(NLINE.LE.56)GO TO 15
F      CALL TPLIN
F      WRITE(6,100)
F   15 NLINE=NLINE+1
F      IF(L.EQ.NNT)RETURN
F      J=L+1
F      L=L+3
F      GO TO 5
F      END
C
C  THREE COLUMN OUTPUT PAGE ROUTINE
C
F      SUBROUTINE TPLIN
F      WRITE(6,100)
F 100  FORMAT(//////////,1X,'GASKI PC-SINDA, THREE COLUMN OUTPUT',/)
F      CALL TOPLIN
C      RETURN
       END
       BCD 3END OF DATA
```

SINDA OUTPUT LISTING
(COLD CASE)

```
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     TEST.PC-SINDA

 *** NOTE *** SNFRDL REQUIRES       3 DYNAMIC STORAGE LOCATIONS OUT OF     997 AVAILABLE ***
              TIMEND=  50.000     , CSGFAC=  1.0000     , DTIMEI=  0.10000     , NLOOP =          100
              TIMEO = 0.00000     , OUTPUT=  1.0000     , DTIMEH=  0.10000     , DTIMEL=  0.00000
              ARLXCA= 0.10000E-01, ATMPCA= 0.10000E+09, DRLXCA=  0.10000E-01, DTMPCA= 0.10000E+09

,**********
 TIME=     0.00000          DTIMEU= 0.00000E+00 CSGMIN(      0)=  0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)=  0.00000E+00

 T     1=    70.00000  T    99=  -320.00000

,**********
 TIME=     5.00000          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.02742E+02
                     TEMPCC(      1)=-1.87656E-01 RELXCC(      0)=  0.00000E+00

 T     1=    60.26929  T    99=  -320.00000

,**********
 TIME=    10.00000          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.12401E+02
                     TEMPCC(      1)=-1.74855E-01 RELXCC(      0)=  0.00000E+00

 T     1=    51.21939  T    99=  -320.00000

,**********
 TIME=    15.00002          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.21970E+02
                     TEMPCC(      1)=-1.63506E-01 RELXCC(      0)=  0.00000E+00

 T     1=    42.77158  T    99=  -320.00000

,**********
 TIME=    20.00004          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.31454E+02
                     TEMPCC(      1)=-1.53384E-01 RELXCC(      0)=  0.00000E+00

 T     1=    34.85910  T    99=  -320.00000

,**********
 TIME=    25.00006          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.40855E+02
                     TEMPCC(      1)=-1.44307E-01 RELXCC(      0)=  0.00000E+00

 T     1=    27.42548  T    99=  -320.00000

,**********
 TIME=    30.00008          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.50175E+02
                     TEMPCC(      1)=-1.36128E-01 RELXCC(      0)=  0.00000E+00

 T     1=    20.42215  T    99=  -320.00000

,**********
 TIME=    35.00004          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.59419E+02
                     TEMPCC(      1)=-1.28725E-01 RELXCC(      0)=  0.00000E+00

 T     1=    13.80765  T    99=  -320.00000
```

```
GASKI PC-SINDA, THREE COLUMN OUTPUT

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     TEST.PC-SINDA

,**********
 TIME=    39.99996          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.68586E+02
                   TEMPCC(      1)=-1.21997E-01 RELXCC(      0)=  0.00000E+00

 T     1=      7.54559  T     99=  -320.00000

,**********
 TIME=    44.99989          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.77681E+02
                   TEMPCC(      1)=-1.15859E-01 RELXCC(      0)=  0.00000E+00

 T     1=      1.60455  T     99=  -320.00000

,**********
 TIME=    49.99981          DTIMEU= 1.00000E-01 CSGMIN(      1)=  2.86705E+02
                   TEMPCC(      1)=-1.10241E-01 RELXCC(      0)=  0.00000E+00

 T     1=     -4.04315  T     99=  -320.00000

,**********
 TIME=    50.00000          DTIMEU= 1.90735E-04 CSGMIN(      1)=  2.86885E+02
                   TEMPCC(      1)=-2.10063E-04 RELXCC(      0)=  0.00000E+00

 T     1=     -4.04337  T     99=  -320.00000
```

SINDA INPUT LISTING
(HOT CASE)

```
      BCD 3THERMAL LPCS
      BCD 3TEST.PC-SINDA
      END
C
      BCD 3NODE DATA
C
          1,0.0,20.0
          -99,-320.,1.0
C
      END
C
      BCD 3CONDUCTOR DATA
          -1,1,99,5.142E-10
      END
C
      BCD 3CONSTANTS DATA
          DTIMEI,0.1
          DTIMEH,0.1
          NLOOP,100
C
          TIMEND,25.0
          OUTPUT,1.0
C
          ARLXCA,.01
          DRLXCA,.01
          TIMEO,0.0
          DAMPA,0.5
          DAMPD,0.5
          NDIM,1000
C
      END
C
      BCD 3ARRAY DATA
      END
C
      BCD 3EXECUTION
C
F     OPEN(3,FILE="EMLFLT.PLT",STATUS="UNKNOWN")
F     WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F   2 FORMAT(I6/,250(I6,31X,I6/))
C
F     CALL SNFRDL
C
      END
      BCD 3VARIABLES 1
C
C INPUT NODE 1 HEAT LOAD
C
M     Q(1)=50.0*3.413
C
      END
C
      BCD 3VARIABLES 2
      END
C
      BCD 3OUTPUT CALLS
C
F     DATA HT/4HT   /
C
F     WRITE(3,1)TIMEO,(T(I),I=1,NNT)
```

```
F    1 FORMAT(E10.3/,250(7F9.3/))
C
C
C
CF          CALL TPRINT
CF          CALL TDUMP
C
C     THREE COLUMN OUTPUT ROUTINE,STNDRD
C
CF       IF(LNODE.EQ.0)CALL NNREAD(1)
CF       IF(ABS(AMOD(TIMEN+0.001,5.0)).GT.1.0)RETURN
F       IF(NPAGE.EQ.0.OR.NLINE.GE.56)CALL TPLIN
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXC(
F    9  FORMAT(/,11H,**********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $          8H RELXCC(I6,2H)=1PE12.5)
F       NLINE=NLINE+4
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       NLINE=NLINE+1
F       J=1
F       L=3
F    5  IF(L.LT.NNT)GO TO 10
F       L=NNT
F   10  WRITE(6,101)  (HT,NX(I+LNODE),T(I),I=J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F       IF(NLINE.LE.56)GO TO 15
F       CALL TPLIN
F       WRITE(6,100)
F   15  NLINE=NLINE+1
F       IF(L.EQ.NNT)RETURN
F       J=L+1
F       L=L+3
F       GO TO 5
F       END
C
C  THREE COLUMN OUTPUT PAGE ROUTINE
C
F       SUBROUTINE TPLIN
F       WRITE(6,100)
F 100   FORMAT(//////////,1X,'GASKI PC-SINDA, THREE COLUMN OUTPUT',/)
F       CALL TOPLIN
C       RETURN
        END
        BCD 3END OF DATA
```

SINDA OUTPUT LISTING
(HOT CASE)

```
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  TEST.PC-SINDA

*** NOTE *** SNFRDL REQUIRES    3 DYNAMIC STORAGE LOCATIONS OUT OF   997 AVAILABLE ***
      TIMEND= 25.000   , CSGFAC= 1.0000   , DTIMEI= 0.10000   , NLOOP =      100
      TIMEO = 0.00000  , OUTPUT= 1.0000   , DTIMEH= 0.10000   , DTIMEL= 0.00000
      ARLXCA= 0.10000E-01, ATMPCA= 0.10000E+09, DRLXCA= 0.10000E-01, DTMPCA= 0.10000E+09

,**********
TIME=   0.00000      DTIMEU= 0.00000E+00 CSGMIN(   0)= 0.00000E+00
         TEMPCC(   0)= 0.00000E+00 RELXCC(   0)= 0.00000E+00

T   1=   0.00000 T   99= -320.00000

,**********
TIME=   1.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.70152E+02
         TEMPCC(   1)= 7.32346E-01 RELXCC(   0)= 0.00000E+00

T   1=   7.35751 T   99= -320.00000

,**********
TIME=   2.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.59451E+02
         TEMPCC(   1)= 7.24550E-01 RELXCC(   0)= 0.00000E+00

T   1=  14.63831 T   99= -320.00000

,**********
TIME=   3.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.49407E+02
         TEMPCC(   1)= 7.16476E-01 RELXCC(   0)= 0.00000E+00

T   1=  21.83960 T   99= -320.00000

,**********

TIME=   4.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.39974E+02
         TEMPCC(   1)= 7.08130E-01 RELXCC(   0)= 0.00000E+00

T   1=  28.95868 T   99= -320.00000

,**********
TIME=   5.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.31109E+02
         TEMPCC(   1)= 6.99516E-01 RELXCC(   0)= 0.00000E+00

T   1=  35.99280 T   99= -320.00000

,**********
TIME=   6.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.22771E+02
         TEMPCC(   1)= 6.90640E-01 RELXCC(   0)= 0.00000E+00

T   1=  42.93930 T   99= -320.00000

,**********
TIME=   7.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.14926E+02
         TEMPCC(   1)= 6.81509E-01 RELXCC(   0)= 0.00000E+00

T   1=  49.79565 T   99= -320.00000
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

1(C) COPYRIGHT 1982,1983,1984,1985,1986,1987 J.D.GASKI
SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE 2

TEST.PC-SINDA

```
,**********
TIME=   7.99999      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.07538E+02
         TEMPCC(   1)= 6.72133E-01 RELXCC(   0)= 0.00000E+00

T   1=  56.55939 T   99= -320.00000

,**********
TIME=   9.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 2.00578E+02
         TEMPCC(   1)= 6.62518E-01 RELXCC(   0)= 0.00000E+00

T   1=  63.22809 T   99= -320.00000

,**********
TIME=  10.00000      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.94017E+02
         TEMPCC(   1)= 6.52676E-01 RELXCC(   0)= 0.00000E+00

T   1=  69.79938 T   99= -320.00000

,**********
TIME=  11.00001      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.87829E+02
         TEMPCC(   1)= 6.42618E-01 RELXCC(   0)= 0.00000E+00

T   1=  76.27094 T   99= -320.00000

,**********
TIME=  12.00001      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.81990E+02
         TEMPCC(   1)= 6.32353E-01 RELXCC(   0)= 0.00000E+00

T   1=  82.64075 T   99= -320.00000

,**********

TIME=  13.00001      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.76476E+02
         TEMPCC(   1)= 6.21896E-01 RELXCC(   0)= 0.00000E+00

T   1=  88.90680 T   99= -320.00000

,**********
TIME=  14.00002      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.71268E+02
         TEMPCC(   1)= 6.11257E-01 RELXCC(   0)= 0.00000E+00

T   1=  95.06738 T   99= -320.00000

,**********
TIME=  15.00002      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.66346E+02
         TEMPCC(   1)= 6.00452E-01 RELXCC(   0)= 0.00000E+00

T   1= 101.12070 T   99= -320.00000

,**********
TIME=  16.00002      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.61693E+02
         TEMPCC(   1)= 5.89493E-01 RELXCC(   0)= 0.00000E+00

T   1= 107.06490 T   99= -320.00000
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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TEST.PC-SINDA

```
,**********
TIME=  17.00003      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.57291E+02
          TEMPCC(   1)= 5.78396E-01 RELXCC(   0)= 0.00000E+00

T   1= 112.89890 T   99= -320.00000

,**********
TIME=  18.00003      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.53126E+02
          TEMPCC(   1)= 5.67175E-01 RELXCC(   0)= 0.00000E+00

T   1= 118.62120 T   99= -320.00000

,**********
TIME=  19.00004      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.49183E+02
          TEMPCC(   1)= 5.55846E-01 RELXCC(   0)=
0.00000E+00

T   1= 124.23080 T   99= -320.00000

,**********
TIME=  20.00004      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.45448E+02
          TEMPCC(   1)= 5.44424E-01 RELXCC(   0)= 0.00000E+00

T   1= 129.72650 T   99= -320.00000

,**********
TIME=  21.00004      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.41911E+02
          TEMPCC(   1)= 5.32925E-01 RELXCC(   0)= 0.00000E+00

T   1= 135.10750 T   99= -320.00000

,**********

TIME=  22.00005      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.38558E+02
          TEMPCC(   1)= 5.21365E-01 RELXCC(   0)= 0.00000E+00

T   1= 140.37330 T   99= -320.00000

,**********
TIME=  23.00005      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.35379E+02
          TEMPCC(   1)= 5.09759E-01 RELXCC(   0)= 0.00000E+00

T   1= 145.52310 T   99= -320.00000

,**********
TIME=  24.00006      DTIMEU= 1.00000E-01 CSGMIN(   1)= 1.32364E+02
          TEMPCC(   1)= 4.98124E-01 RELXCC(   0)= 0.00000E+00

T   1= 150.55680 T   99= -320.00000

,**********
TIME=  25.00000      DTIMEU= 9.99413E-02 CSGMIN(   1)= 1.29504E+02
          TEMPCC(   1)= 4.86190E-01 RELXCC(   0)= 0.00000E+00

T   1= 155.47370 T   99= -320.00000
```

CHAPTER 2: STEADY STATE AND TRANSIENT RADIATION

SECTION 2: Simplified Spacecraft Orbiting the Earth.

ANALYSIS CODE: TRASYS

I TRASYS Description

TRASYS is a program based in FORTRAN that is used for radiation thermal analysis. It is useful for predicting radiation form factors between geometrically complicated surfaces. With the form factors and surface areas that TRASYS calculates and surface property data that is input to the program, it will calculate gray body factors and radiation conductors called RADKs, that are directly input to SINDA to solve for temperatures. For orbiting spacecraft TRASYS calculates direct incident and absorbed heat rates. The following example demonstrates many TRASYS capabilities.

II. Problem Statement

Calculate radiation conductors and absorbed heat fluxes for a simple spacecraft in a circular earth orbit at an altitude of 200 nautical miles. The spacecraft is oriented toward the sun at all orbital positions. The Beta angle, or the angle between the sun vector and the orbit plane is 52 degrees. Figure 1 shows the simplified spacecraft geometry and node numbers associated with each surface. Figure 2 shows the orientation of the spacecraft and orbit description.

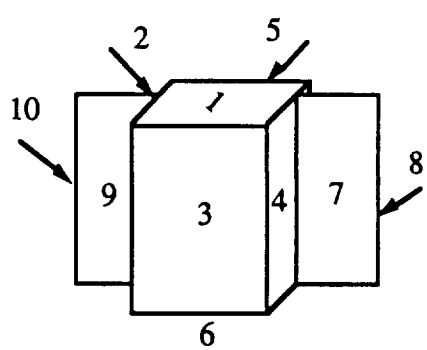

Figure 1. Spacecraft Description

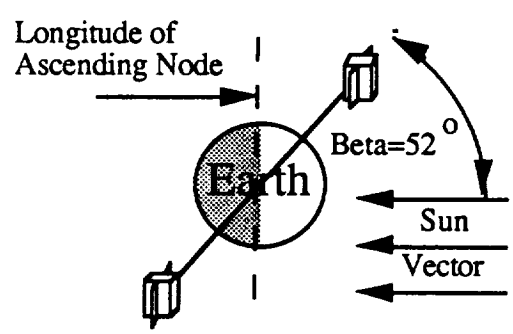

Figure 2. Orbit Description

The body of the spacecraft is a 1 ft x 1 ft x 2 ft box with two solar arrays each 1 ft x 2 ft. Surface properties are given in table 1.

Surface Description	Node	Absorptivity	Emissivity
Body, Top Face	1	0.2	0.6
Body, Strbrd Face	2	0.2	0.6
Body, Front Face	3	0.2	0.6
Body, Port Face	4	0.2	0.6
Body, Back Face	5	0.2	0.6
Body, Bottom Face	6	0.2	0.6
Port Solar Array, Front Face	7	0.8	0.8
Port Solar Array, Back Face	8	0.8	0.8
Strbrd Solar Array, Front Face	9	0.8	0.8
Strbrd Solar Array, Back Face	10	0.8	0.8

Table 1. Spacecraft Surface Properties

III. TRASYS Model

Given the statement of the problem, a TRASYS model was written to determine form factors, radiation conductors, and orbital heating rates. The model consists of the Options, Surface, and Operations data blocks. The options data block consists primarily of input and output information. All the geometry and surface property information is contained in the surface data block. In the operations data block, calls are made to the solution subroutines. The model includes calls to subroutines that generate a node plot file, calculates form factors, gray body factors, RADKs, describes the orbit of the spacecraft, and calculates absorbed heating rates. A listing of the TRASYS input deck which will run on the EADS IBM/CRAY is shown below. The file name for the input deck is HBKG197.TRASYS.DATA(NOTEBK) .

TRASYS MODEL LISTING

```
HEADER OPTIONS DATA
TITLE SPACECRAFT THERMAL RADIATION MODEL
      MODEL=SCRAFT
      BCDOU
      INFO=N
      RSO
      RSI
HEADER SURFACE DATA
S     SURFN=1
      ACTIVE=OUT
      PROP=.2,.6
      TYPE =BOX6
      TZ=0.0
      TX=0.0
      TY=0.0
      P1=1.,1.,2.
      NNX=1
      NNY=1
S     SURFN=7
      ACTIVE=BOTH
      PROP=.8,.8
      TYPE=RECT
      ROTY=-90.
      TZ=0.
      TX=.5
      TY=1.
```

```
      P1=2.,1.,0.
      NNX=1
      NNY=1
S     SURFN=9
      ACTIVE=BOTH
      PROP=.8,.8
      TYPE=RECT
      ROTY=-90.
      TZ=0.
      TX=.5
      TY=-1.
      P1=2.,1.,0.
      NNX=1
      NNY=1
HEADER CORRESPONDENCE DATA
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL NDATAS(1,'ALL',0.2,'NO','NO')
L     NPLOT
      CALL FFDATA(.05,.1,'SHAD',15.,1.E-6,'YES','TAPE','NO',0.,0.)
L     FFCAL
      CALL GBDATA('BOTH',0,'FF')
L     GBCAL
      CALL RKDATA(0,'NO',.001,1,'SPACE',9999,0.,1.,'TAPE',0)
L     RKCAL
      CALL ORBIT1('EAR',90.,0.,52.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT('SUN',1,2,3,0.,0.,0.)
ORBGEN INER,0.,360.,8,AQ,NO,0.,1
      CALL QODATA(0,1,'YES',0,1.,1.,1.,'BOTH',0)
L     QOCAL
      END FILE NUSER1
      END FILE NBCDOU
END OF DATA
```

The data that is used directly in SINDA is written in the BCD file. The RADKs, absorbed heat rate arrays, and interpolation subroutine calls for absorbed heat rates are all listed in the output file HBKG197.TRASYS.OUT(BCD). The data is in SINDA format and may be directly inserted into the SINDA model. The following is a listing of the BCD file.

TRASYS BCD OUTPUT LISTING

```
          -      1,      2,      9, 2.75738E-10$
          -      2,      2,     10, 2.75738E-10$
          -      3,      4,      7, 2.75738E-10$
          -      4,      4,      8, 2.75738E-10$
          -      5,      7,      8, 2.45485E-11$
          -      6,      9,     10, 2.45485E-11$
          -      7,      1,   9999, 1.02780E-09$
          -      8,      2,   9999, 1.49031E-09$
          -      9,      3,   9999, 2.05560E-09$
          -     10,      4,   9999, 1.49031E-09$
          -     11,      5,   9999, 2.05560E-09$
          -     12,      6,   9999, 1.02780E-09$
          -     13,      7,   9999, 2.41596E-09$
          -     14,      8,   9999, 2.41596E-09$
          -     15,      9,   9999, 2.41596E-09$
          -     16,     10,   9999, 2.41596E-09$
C$END
          1$ TIME ARRAY
  0.00000E+00, 1.35999E-01, 1.36849E-01, 1.91341E-01, 3.82682E-01
  5.74022E-01, 6.28514E-01, 6.29364E-01, 7.65363E-01, 9.56704E-01
  1.14804E+00, 1.33939E+00, 1.53060E+00
 END$
          2$ HEAT RATE ARRAY FOR NODE        1
  1.36318E+01, 5.70977E+00, 5.70977E+00, 3.64319E+00, 8.08929E-01
  3.64319E+00, 5.70977E+00, 5.70977E+00, 1.36318E+01, 3.38409E+01
  4.51486E+01, 3.38409E+01, 1.36318E+01
 END$
          3$ HEAT RATE ARRAY FOR NODE        2
  3.09967E+01, 2.56680E+01, 2.27777E+01, 2.01222E+01, 1.01752E+01
  6.53735E-01, 5.17392E-01, 3.40764E+00, 3.30913E+00, 5.69426E+00
  1.66761E+01, 3.21602E+01, 3.09967E+01
 END$
          4$ HEAT RATE ARRAY FOR NODE        3
```

```
 9.93421E+01, 1.06621E+02, 2.08211E+01, 2.37082E+01, 2.85956E+01
 2.37082E+01, 2.08211E+01, 1.06621E+02, 9.93421E+01, 9.29197E+01
 8.97315E+01, 9.29197E+01, 9.93421E+01
END$
     5$ HEAT RATE ARRAY FOR NODE        4
 3.30913E+00, 3.40764E+00, 5.17392E-01, 6.53735E-01, 1.01752E+01
 2.01222E+01, 2.27777E+01, 2.56680E+01, 3.09967E+01, 3.21602E+01
 1.66761E+01, 5.69426E+00, 3.30913E+00
END$
     6$ HEAT RATE ARRAY FOR NODE        5
 1.29556E+01, 7.19193E+00, 7.19193E+00, 5.47404E+00, 2.80176E+00
 5.47404E+00, 7.19193E+00, 7.19193E+00, 1.29556E+01, 2.89228E+01
 3.80415E+01, 2.89228E+01, 1.29556E+01
END$
     7$ HEAT RATE ARRAY FOR NODE        6
 1.36318E+01, 2.32236E+01, 2.32236E+01, 2.69509E+01, 3.30542E+01
 2.69509E+01, 2.32236E+01, 2.32236E+01, 1.36318E+01, 4.46827E+00
 1.03095E+00, 4.46827E+00, 1.36318E+01
END$
     8$ HEAT RATE ARRAY FOR NODE        7
 3.54313E+02, 3.62014E+02, 1.72706E+01, 2.26450E+01, 3.39721E+01
 3.29420E+01, 2.97325E+01, 3.74476E+02, 3.66962E+02, 3.63871E+02
 3.55089E+02, 3.51386E+02, 3.54313E+02
END$
     9$ HEAT RATE ARRAY FOR NODE        8
 9.67260E+00, 4.93665E+00, 3.39277E+00, 3.26185E+00, 4.29780E+00
 9.09015E+00, 1.16171E+01, 1.31610E+01, 2.14162E+01, 5.85251E+01
 7.01351E+01, 3.90266E+01, 9.67260E+00
END$
    10$ HEAT RATE ARRAY FOR NODE        9
 3.66962E+02, 3.74476E+02, 2.97325E+01, 3.29420E+01, 3.39721E+01
 2.26450E+01, 1.72706E+01, 3.62014E+02, 3.54313E+02, 3.51386E+02
 3.55089E+02, 3.63871E+02, 3.66962E+02
END$
    11$ HEAT RATE ARRAY FOR NODE       10
 2.14162E+01, 1.31610E+01, 1.16171E+01, 9.09015E+00, 4.29780E+00
 3.26185E+00, 3.39277E+00, 4.93665E+00, 9.67260E+00, 3.90266E+01
 7.01351E+01, 5.85251E+01, 2.14162E+01
END$
CSEND
        DA11MC(1.5306037E+00,TIMEM,A    1,A    2, 1.0000E+00,Q     1)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    3, 2.0000E+00,Q     2)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    4, 2.0000E+00,Q     3)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    5, 2.0000E+00,Q     4)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    6, 2.0000E+00,Q     5)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    7, 1.0000E+00,Q     6)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    8, 2.0000E+00,Q     7)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    9, 2.0000E+00,Q     8)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A   10, 2.0000E+00,Q     9)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A   11, 2.0000E+00,Q    10)$
CSEND
M       Q     1= 1.84215973E+01* 1.00000000E+00
M       Q     2= 1.51440683E+01* 2.00000000E+00
M       Q     3= 7.33552320E+01* 2.00000000E+00
M       Q     4= 1.51462344E+01* 2.00000000E+00
M       Q     5= 1.68884121E+01* 2.00000000E+00
M       Q     6= 1.55374595E+01* 1.00000000E+00
M       Q     7= 2.53387710E+02* 2.00000000E+00
M       Q     8= 2.68945613E+01* 2.00000000E+00
M       Q     9= 2.53386705E+02* 2.00000000E+00
M       Q    10= 2.68933116E+01*-2.00000000E+00
CSEND
```

The geometry may be verified by plotting the nodes using the plot file created with calls to NDATAS and NPLOT. Figure 4 shows the 3-D view of the node plot.

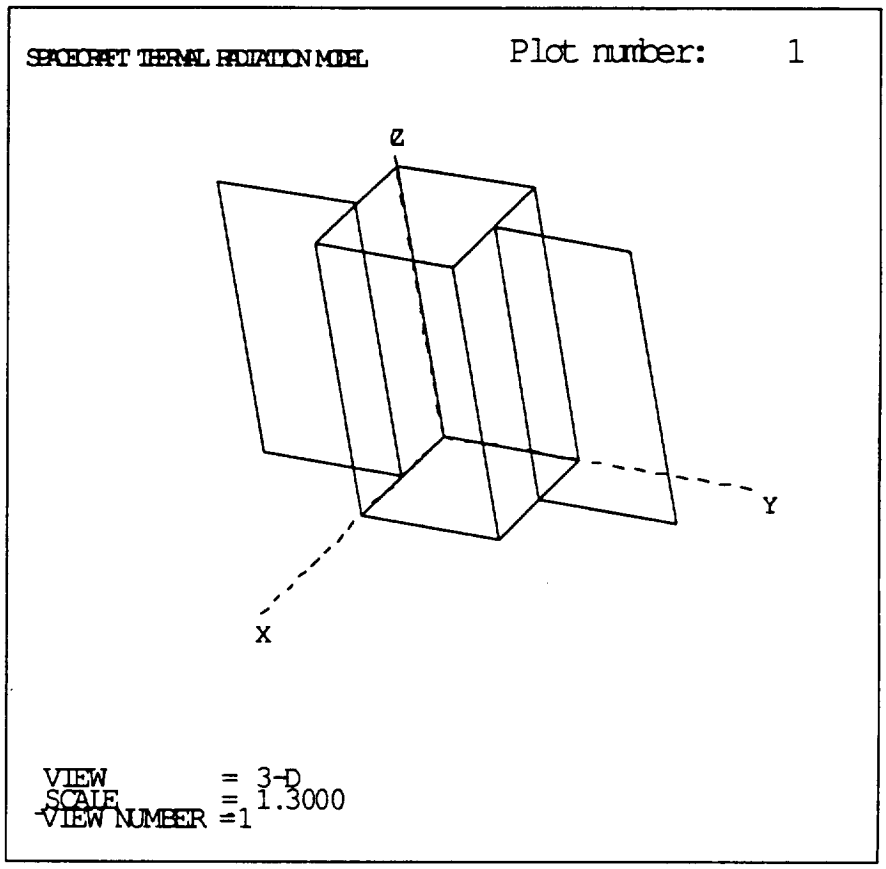

Figure 4. TRASYS Node Plot

IV. FORM FACTOR CALCULATIONS

The Form Factor, F_{ij} is defined as the fraction of radiation leaving surface i and is intercepted by surface j. The Form Factor between surfaces 7 and 4, for example, is estimated as follows.

For two areas A_j and A_i the Form Factor between them is given by

$$F_{ij} = \frac{1}{A_i} \int_{A_i} \int_{A_j} \frac{\cos\theta_i \cos\theta_j}{\pi R^2} dA_i dA_j \tag{1}$$

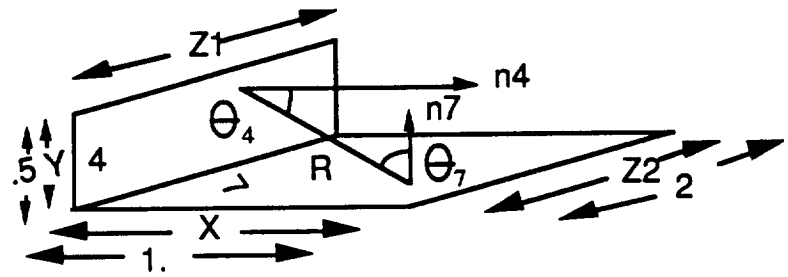

Figure 5. Form Factor Nomenclature

$$\cos\theta_7 = \frac{y}{\sqrt{x^2 + y^2 + (z_1 - z_2)^2}} \tag{2}$$

$$\cos\theta_4 = \frac{x}{\sqrt{x^2 + y^2 + (z_1 - z_2)^2}} \tag{3}$$

$$R^2 = x^2 + y^2 + (z_1 - z_2)^2 \tag{4}$$

Substitution of (2), (3) and (4) into (1) gives:

$$F_{7,4} = \frac{1}{A_7\pi}\int_x\int_y\int_{z1}\int_{z2}\frac{xy}{(x^2 + y^2 + (z_1 - z_2)^2)^2}dxdydz_1dz_2$$

On the following pages this integral has been solved numerically with a FORTRAN program called FFAC.

FORTRAN CODE LISTING

```
      PROGRAM FFAC
C
      REAL*8 X,Y,Z1,Z2,DX,DY,DZ1,DZ2,TI
      REAL*8 XI,YI,Z1I,Z2I,XF,YF,Z1F,Z2F,FF,FF1,FFIJ,FFJI
      INTEGER NODEX,NODEY,NODEZ1,NODEZ2,II,IJ,IK,IL
C
C     INPUT VALUES OF CONSTANTS
      XI=0.
      YI=0.
      Z1I=0.
      Z2I=0.
      XF=.5
      YF=1.
      Z1F=2.
      Z2F=2.
      NODEX=60
      NODEY=60
      NODEZ1=90
      NODEZ2=90
C
C     CALCULATE DELTA X,Y,Z
      DX=(XF-XI)/FLOAT(NODEX)
      DY=(YF-YI)/FLOAT(NODEY)
      DZ1=(Z1F-Z1I)/FLOAT(NODEZ1)
      DZ2=(Z2F-Z2I)/FLOAT(NODEZ2)
C
C     PERFORM INTEGRATION
      FF=0.
      FF1=0.
      TI=0.
      Z2=Z2I+DZ2/2.
      DO 4 II=1,NODEZ2
      Y=YI+DY/2.
       DO 3 IJ=1,NODEY
       Z1=Z1I+DZ1/2.
        DO 2 IK=1,NODEZ1
        X=XI+DX/2.
         DO 1 IL=1,NODEX
         DUM=ABS(Z1-Z2)
         FF1=X*Y*DX*DY*DZ1*DZ2/((X**2.+Y**2.+DUM**2.)**2.)
         FF=FF+FF1
 1       X=X+DX
 2      Z1=Z1+DZ1
 3     Y=Y+DY
 4    Z2=Z2+DZ2
      X=X-DX
      Y=Y-DY
      Z1=Z1-DZ1
      Z2=Z2-DZ2
      FFIJ=FF/(3.1415*(Z1F-Z1I)*(XF-XI))
      FFJI=FF/(3.1415*(Z2F-Z2I)*(YF-YI))
C
C     OUTPUT RESULTS
      OPEN (6,FILE='FFAC.OUT')
      WRITE(6,101)XI,XF,Z1I,Z1F,YI,YF,Z2I,Z2F
      WRITE(6,102)NODEX,NODEZ1,NODEY,NODEZ2
      WRITE(6,103)X,Y,Z1,Z2
      WRITE(6,104)FFIJ,FFJI
 101  FORMAT(10X,'DOUBLE PRECISION',//,10X,'INITIAL,FINAL VALUES',/,
     *10X,'SURFACE I     XI,XF    = ',F10.2,',',5X,F10.2,/,
     *10X,'              Z1I,Z1F  = ',F10.2,',',5X,F10.2,/,
     *10X,'SURFACE J     YI,YF    = ',F10.2,',',5X,F10.2,/,
```

```
     *10X,'              Z2I,Z2F = ',F10.2,',',5X,F10.2)
 102  FORMAT(/,10X,'GRID INFORMATION',/,
     *10X,'SURFACE I     NODEX  = ',I4,' NODEZ1 = ',I4,/,
     *10X,'SURFACE J     NODEY  = ',I4,' NODEZ2 = ',I4)
 103  FORMAT(/,10X,'CURRENT VALUES AFTER INTEGRATION',/,
     *10X,'SURFACE I     X   = ',F10.2,/,
     *10X,'              Z1  = ',F10.2,/,
     *10X,'SURFACE J     Y   = ',F10.2,/,
     *10X,'              Z2  = ',F10.2)
 104  FORMAT(/,10X,'FORM FACTORS     FF(I,J) = ',F10.6,
     */,'                          FF(J,I) = ',F10.6)
C
      CLOSE(UNIT=6)
      STOP
      END
```

FORTRAN CODE OUTPUT (40 By 60 Nodes)

```
DOUBLE PRECISION

INITIAL,FINAL VALUES
SURFACE I     XI,XF    =        .00,          .50
              Z1I,Z1F  =        .00,         2.00
SURFACE J     YI,YF    =        .00,         1.00
              Z2I,Z2F  =        .00,         2.00

GRID INFORMATION
SURFACE I     NODEX  =   40 NODEZ1 =   60
SURFACE J     NODEY  =   40 NODEZ2 =   60

CURRENT VALUES AFTER INTEGRATION
SURFACE I     X   =        .49
              Z1  =        .99
SURFACE J     Y   =       1.98
              Z2  =       1.98

FORM FACTORS     FF(I,J) =    .341843
                 FF(J,I) =    .170921
```

FORTRAN CODE OUTPUT (60 By 90 Nodes)

```
DOUBLE PRECISION

INITIAL,FINAL VALUES
SURFACE I     XI,XF    =        .00,          .50
              Z1I,Z1F  =        .00,         2.00
SURFACE J     YI,YF    =        .00,         1.00
              Z2I,Z2F  =        .00,         2.00

GRID INFORMATION
SURFACE I     NODEX  =   60 NODEZ1 =   90
SURFACE J     NODEY  =   60 NODEZ2 =   90

CURRENT VALUES AFTER INTEGRATION
SURFACE I     X   =        .50
              Z1  =        .99
SURFACE J     Y   =       1.99
              Z2  =       1.99

FORM FACTORS     FF(I,J) =    .339128
                 FF(J,I) =    .169564
```

V. ALTERNATE SOLUTION OF FORM FACTORS

The integral on the left hand side of (1) has also been solved in a number of heat transfer text books as follows:

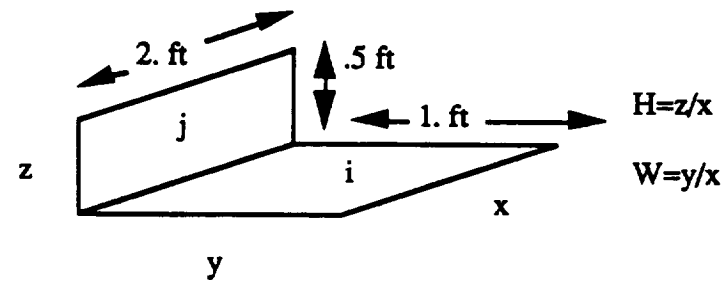

Figure 6. Surface Orientation

$$F_{ij}=\frac{1}{\pi W}\left(W\tan^{-1}\frac{1}{W}+H\tan^{-1}\frac{1}{H}-\left(H^2+W^2\right)^{0.5}\tan^{-1}\frac{1}{\left(H^2+W^2\right)^{0.5}}\right)$$
$$+\frac{1}{\pi W}\left(\frac{1}{4}\ln\left\{\frac{\left(1+W^2\right)\left(1+H^2\right)}{1+W^2+H^2}\left[\frac{W^2\left(1+W^2+H^2\right)}{\left(1+W^2\right)\left(W^2+H^2\right)}\right]^{W^2}\left[\frac{H^2\left(1+H^2+W^2\right)}{\left(1+H^2\right)\left(H^2+W^2\right)}\right]^{H^2}\right\}\right) \tag{5}$$

For the spacecraft,

$$F_{74}=\frac{1}{\pi .5}\left(.5\tan^{-1}\frac{1}{.5}+.25\tan^{-1}\frac{1}{.25}-\left(.25^2+.5^2\right)^{\frac{1}{2}}\tan^{-1}\frac{1}{\left(.25^2+.5^2\right)^{\frac{1}{2}}}\right)$$
$$+\frac{1}{\pi .5}\left(\frac{1}{4}\ln\left\{\frac{\left(1+.5^2\right)\left(1+.25^2\right)}{1+.5^2+.25^2}\left[\frac{.5^2\left(1+.5^2+.25^2\right)}{\left(1+.5^2\right)\left(.5^2+.25^2\right)}\right]^{.5^2}\left[\frac{.25^2\left(1+.25^2+.5^2\right)}{\left(1+.25^2\right)\left(.25^2+.5^2\right)}\right]^{.25^2}\right\}\right)$$
$$=\frac{1}{\pi .5}\left(0.5536+0.3315-0.5590*1.0611+\frac{1}{4}\ln\left\{\frac{1.3281}{1.3125}\left[\frac{0.3281}{0.3906}\right]^{0.25}\left[\frac{0.082}{0.332}\right]^{0.0625}\right\}\right)$$

$F_{74}=0.1669$

Form factors were calculated in a number of different ways. Table 2 lists the methods used, the calculated form factors and the percent error assuming the exact solution has no error.

Description	Form Factor	% Error
IBM PC FORTRAN Single Precision Nodes 20x30	.1750	4.849
IBM PC FORTRAN Single Precision Nodes 40x60	.1693	1.470
IBM PC FORTRAN Single Precision Nodes 60x90	.1565	-6.236
IBM PC FORTRAN Double Precision Nodes 40x60	.1709	2.415
IBM PC FORTRAN Double Precision Nodes 60x90	.1696	1.602
VAX TRASYS	.1813	8.621
CRAY TRASYS	.1669	0.023
Exact Solution	.1669	0.0

Table 2. Summary of Form Factor Results

VI. RADK HAND CALCULATION

Radiation exchange between two surfaces is given by the following equation:

$$q_{74} = \frac{\sigma\left(T_7^4 - T_4^4\right)}{\frac{1-\varepsilon_4}{\varepsilon_4 A_4} + \frac{1}{A_7 F_{74}} + \frac{1-\varepsilon_7}{\varepsilon_7 A_7}}$$

SINDA cannot numerically solve this nonlinear equation; consequently, the radiation exchange is written as:

$$q_{74} = G(T_7 - T_4)$$

where:

$$G = \sigma\varepsilon_4\varepsilon_7 F_{74} A_7 (T_7 + T_4)\left(T_7^2 + T_4^2\right),$$

In SINDA,

$$RADK = \sigma\varepsilon_4\varepsilon_7 F_{74} A_7$$

and RADK, between surfaces 4 and 7, in the spacecraft model, is given by

and RADK, between surfaces 4 and 7, in the spacecraft model, is given by

$$RADK = \sigma\varepsilon_4\varepsilon_7F_{74}A_7 = (0.1713E\text{-}8)(0.6)(0.8)(0.16693)(2.)$$

or

$$RADK = 2.745\ E\text{-}10.$$

VII. DETERMINATION OF FLUXES AND HEAT RATES

Defaults for the flux constants are as follows:

Planet Albedo	PALB = 0.3
Planetary Diffuse Emissive Power	WDS $= 75.1 \frac{Btu}{hr\text{-}ft^2\text{-}F}$
Planetary Specular Emissive Power	WSS $= 75.1 \frac{Btu}{hr\text{-}ft^2\text{-}F}$
Solar Constant	SOL $= 429. \frac{Btu}{hr\text{-}ft^2\text{-}F}$

Since the spacecraft is sun-oriented the solar flux is equal to the solar constant on the sun-facing sides 3, 7 and 9. Figure 7 shows the direct incident fluxes on surface 3 with a longitude of ascending node equal to 90° and a sun oriented spacecraft. Figure 8 shows fluxes for an earth oriented spacecraft and figure 9 shows fluxes for an earth oriented spacecraft and longitude of ascending node equal to 180°.

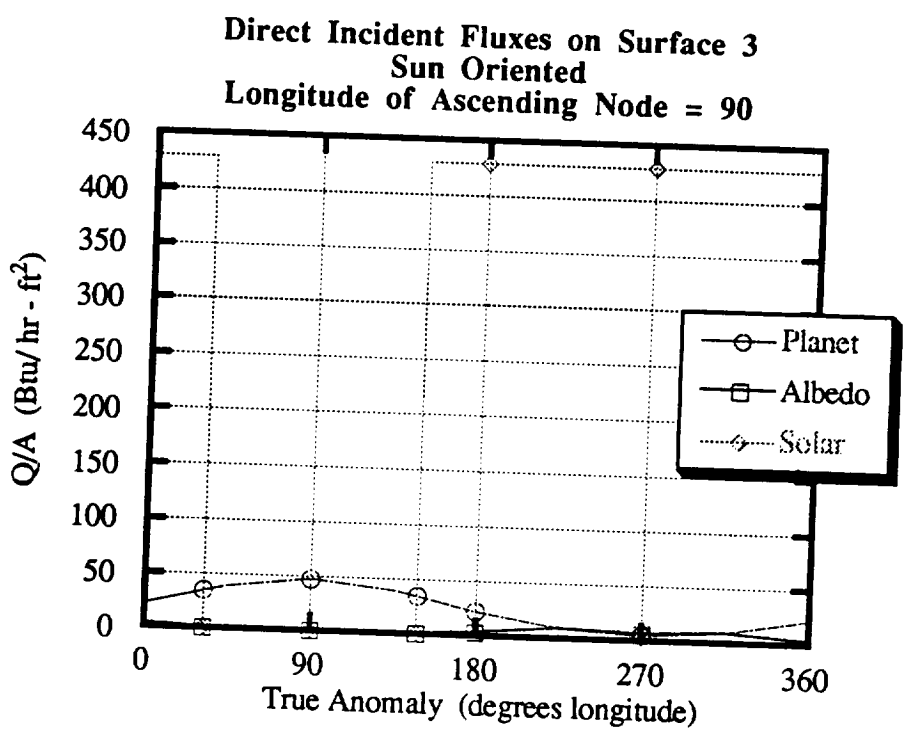

Figure 7. Orbital Heating Rates For Sun Oriented Spacecraft

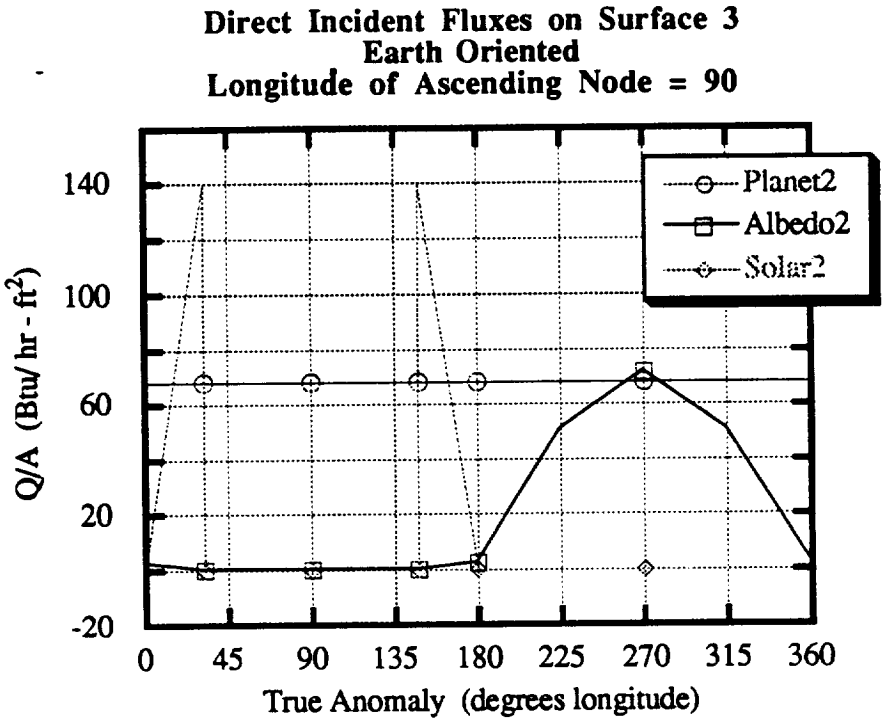

Figure 8. Orbital Heating Rates For Earth Oriented Spacecraft

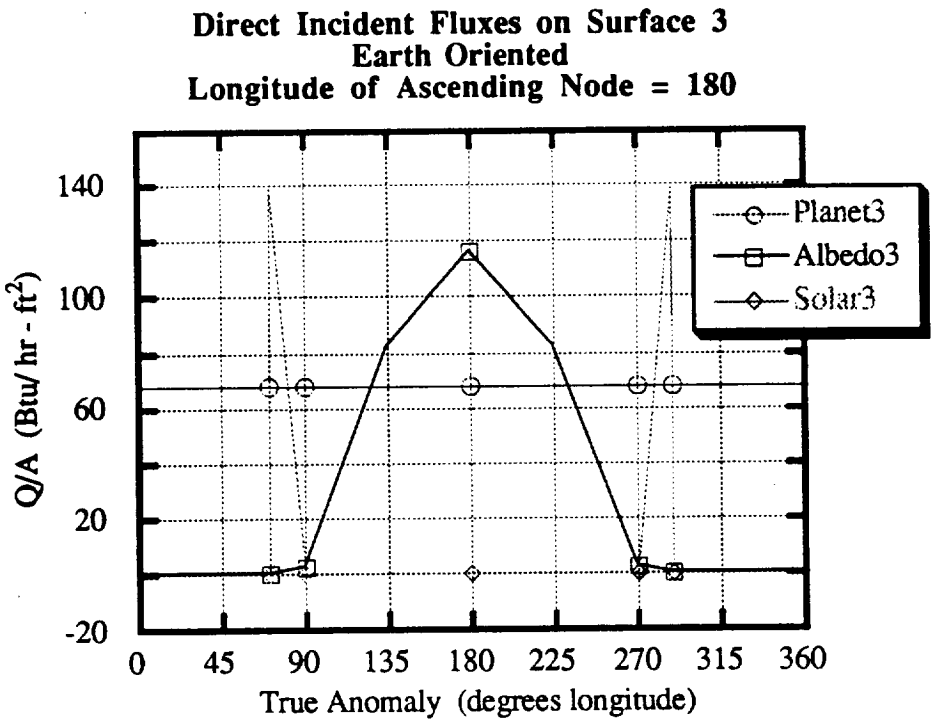

Figure 9. Orbital Heating Rates For Earth Oriented Spacecraft with ALAN=180°

VIII. CONCLUSIONS

This spacecraft model demonstrates a few of the capabilities inherent in the TRASYS program. For complex thermal problems that involve radiation exchange and orbital heating, TRASYS has become the standard for creating SINDA compatible radiation conductors and orbital heating rates. The program resides on the VAX and the IBM/CRAY systems here at MSFC. The closed form solutions such as the textbook equations for form factors or numerical solutions may be used to verify TRASYS results. The IBM/CRAY system appears to have the most accuracy and shortest run time of the different versions as shown in table 2.

The following is a listing of the processor output that is written to HBKG197.TRASYS.OUT(POUT) for this example. It includes the information that will help determine if the correct values were passed in the subroutine calls as well as listing the results.

TRASYS MODEL OUTPUT LISTING

```
1
                    T H E R M A L   R A D I A T I O N   A N A L Y S I S   S Y S T E M
                                F O R T R A N - 7 7   V E R S I O N
0    TTTTTTTTTTTTT
     TTTTTTTTTTTTT
     TT   TTT   TT
          TTT
          TTT
          TTT                                                          T R A S Y S   I I
          TTT          RRRRRRRRR
          TTT          RRRRRRRRRR
        TTTTTTT        RRR     RRR
                       RRR     RRR
                       RRRRRRRRRR
                  .    RRR  RRR
                       RRR   RRR          AAAAAAA
                       RRR    RRR        AAAAAAAAA
                       RRR     RRRR      AAAAAAAAAAA
                                         AAA     AAA
                                         AAA     AAA
                                         AAAAAAAAAAA
                                         AAA     AAA
                                         AAA     AAA        SSSSSSSSSS
                                         AAA     AAA       SSSSSSSSSSSS
                                        AAAAA   AAAAA      SSS      SS
                                                           SSS
                                                            SSSSSSSSSS
                                                                  SSS
                                                            SS      SSS       YYYY     YYYY
                                                            SSSSSSSSSSSS      YYY      YYY
                                                             SSSSSSSSSS        YYY   YYY
                                                                               YYY YYY
                                                                                YYYYY
                                                                                 YYY
                                                                                 YYY            SSSSSSSSSS
                                                                                 YYY           SSSSSSSSSSSS
                                                                                YYYYYYY        SSS      SS
                                                                                               SSS
                                                                                                SSSSSSSSSS
                                                                                                        SSS
                                                                                                SS      SSS
                                                                                                SSSSSSSSSSSS
                                                                                                 SSSSSSSSSS
     P R O C E S S O R   E X E C U T I O N

     VERSION.MODIFICATION ... P22P
     MODIFICATION DATE ...... 080190

     DATE OF RUN ............ 071691
     TIME OF RUN ............ 190850
     JOB NUMBER ............. CRAYJOB
1
 DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE    1

 MODEL-SCRAFT CONFIG-SCRAFT STEP-NONE              SPACECRAFT THERMAL RADIATION MODEL
 TRASYS PROC-INITIALIZATION

 END-OF-FILE ENCOUNTERED ATTEMPTING TO READ 1st RECORD ON 2nd FILE OF -RSI-

 ++NOTE++  THE 1st RECORD ON 2nd FILE OF THE -RSI- TAPE IS NOT A VALID RECORD OR NO DATA ON FILE

 ASSUMING NO DATA ON RSI. CONTINUING PER USER REQUEST

1
 DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE    2

 MODEL-SCRAFT CONFIG-SCRAFT STEP--1                SPACECRAFT THERMAL RADIATION MODEL
 PROCESSING OPERATIONS DATA

  SEQUENCE  NODE   BCS        AREA       ALPH  EMISS  SURF. TYPE  ACTIVE  --------COMMENTS--------------

        1        1  ALLBLK   1.00000      0.200  0.600  RECTANGLE   TOP
```

2	2	ALLBLK	2.00000	0.200	0.600	RECTANGLE	TOP
3	3	ALLBLK	2.00000	0.200	0.600	RECTANGLE	TOP
4	4	ALLBLK	2.00000	0.200	0.600	RECTANGLE	TOP
5	5	ALLBLK	2.00000	0.200	0.600	RECTANGLE	TOP
6	6	ALLBLK	1.00000	0.200	0.600	RECTANGLE	TOP
7	7	ALLBLK	2.00000	0.800	0.800	RECTANGLE	BOTTOM
8	8	ALLBLK	2.00000	0.800	0.800	RECTANGLE	TOP
9	9	ALLBLK	2.00000	0.800	0.800	RECTANGLE	BOTTOM
10	10	ALLBLK	2.00000	0.800	0.800	RECTANGLE	TOP

NODE, AREA, AND PROPERTIES ARRAYS HAVE BEEN WRITTEN ON THE -RSO- TAPE
BY -BUILDC- (ACCESS NUMBER = 1)

1
DATE 071691 TIME 190850 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 3

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1 SPACECRAFT THERMAL RADIATION MODEL
NODE PLOTTER DATA OUTPUT

NODE PLOTTER

PARAMETER	DESCRIPTION	OPTION *	DEFAULT
NV	VIEW NUMBER	1-6	1
IVU	VIEW	'ALL' '3-D' 'X' 'Y' 'Z' 'GEN'	'ALL'
SCL	SCALE FACTOR (3.15/LARGEST DISTANCE FROM CCS ORIGIN IN USERS UNITS)		AUTOMATIC SCALE
NACT	ACTIVE SIDE ARROW FLAG	YES, NO	NO
ISHO	SHADOWER-ONLY SURFACE PLOT FLAG	YES, NO	NO
ISELN	ARRAY NAME CONTAINING NUMBER OF NODES TO BE SELECTIVELY PLOTTED	ARRAY NAME	PLOTS ALL NODES
ITIT	ARRAY NAME OF PLOT TITLE	ARRAY NAME	USES JOB TITLE
ROTX, ROTY, ROTZ,	VIEW ROTATIONS (FOR IVU = 'GEN')	0 : ANG : 360	0.0 0.0 0.0
IROTX, IROTY, IROTZ	ORDER OF ROTATIONS (FOR IVU = 'GEN')	1,2,3 (ANY ORDER)	1,2,3

*INPUT ZERO FOR DEFAULT ACTION

CALLING SEQUENCE-

CALL NDATA (NV, IVU, SCL, NACT, ISHO, ISELN, ITIT, ROTX, ROTY, ROTZ, IROTX, IROTY, IROTZ)

OR

CALL NDATAS (NV, IVU, SCL)

NOTE- IF NO CALLS TO NDATA/NDATAS ARE MADE, A CALL TO NPLOT WILL
RESULT IN ALL VIEWS BEING AUTOMATICALLY SCALED AND GENERATED FOR ALL NODES.

1
DATE 071691 TIME 190850 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 4

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1 SPACECRAFT THERMAL RADIATION MODEL
NODE PLOTTER DATA OUTPUT

VIEW= 3-D SCALE= 1.5491 VIEW NUMBER= 1

VIEW= Z-AXIS SCALE= 1.5491 VIEW NUMBER= 1

VIEW= X-AXIS SCALE= 1.5491 VIEW NUMBER= 1

VIEW= Y-AXIS SCALE= 1.5491 VIEW NUMBER= 1

1
DATE 071691 TIME 190850 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 5

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1 SPACECRAFT THERMAL RADIATION MODEL
FORM FACTOR CALCULATION LINK.

FORM FACTORS AND COMBINED FORM FACTORS - USER INPUT AND DEFAULT PARAMETERS

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
FFACC	0.0500	0.0500	ORIENTATION ACCURACY PARAMETER	N/A
FFACCS	0.1000	0.1000	SHADOWING ACCURACY PARAMETER	N/A
FFNOSH	SHAD	SHAD	OVERRIDE SHADOWING PARAMETER	(SHAD,NOSH)
FFRATL	15.0	15.0	RATIO FOR USING UNIT-SPHERE TECHNIQUE	N/A
FFMIN	0.1E-05	0.1E-05	PARAMETER TO ELIMINATE SMALL FORM FACTORS	N/A
FFPRNT	YES	YES	FLAG FOR COMPREHENSIVE FF AND CM PRINT	(YES,NO,FF,CM,RB)
+FFPNCH	TAPE	NO	PARAMETER TO PUNCH FORM FACTORS	(YES,NO)
FFNAC	NO	YES	FLAG TO CHECK NODE ARRAY AGAINST -RSI-	(YES,NO)
IFFSPC	0	N/A	SPACE NODE NO. FOR CALC. OF FORM FACTOR TO SPACE	(INTEGER NO.)
IFFDT	SCRAFT	CONF. NAME	CONFIG. NAME FOR FF DATA BLOCK ACCESS	(ANY CONFIG. NAME)

```
    IFFSHO    YES          YES       FLAG TO CALCULATE FORM FACTOR TO SHADE ONLY NODES                    (YES,NO)

   + -FFPNCH WILL DEFAULT TO -YES- ON CALCULATED VALUES IF THE -RSO- FILE IS NOT SPECIFIED IN THE OPTIONS DATA BLOCK
1
 DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE    6

 MODEL-SCRAFT CONFIG-SCRAFT STEP--1                SPACECRAFT THERMAL RADIATION MODEL
 FORM FACTOR CALCULATION LINK.


 NODE DATA--

                                                                                  SPECULAR   SPECULAR
 SEQUENCE   NODE     AREA          ALPH        EMISS     TRAN(SOL)  TRAN(IR)   REFL(SOL)  REFL(IR)

     1         1   1.00000      0.200E+00  0.600E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     2         2   2.00000      0.200E+00  0.600E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     3         3   2.00000      0.200E+00  0.600E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     4         4   2.00000      0.200E+00  0.600E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     5         5   2.00000      0.200E+00  0.600E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     6         6   1.00000      0.200E+00  0.600E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     7         7   2.00000      0.800E+00  0.800E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     8         8   2.00000      0.800E+00  0.800E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
     9         9   2.00000      0.800E+00  0.800E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
    10        10   2.00000      0.800E+00  0.800E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00

  NUMBER OF NODES =   10  NUMBER OF SURFACES =    8
1
 DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE    7

 MODEL-SCRAFT CONFIG-SCRAFT STEP--1                SPACECRAFT THERMAL RADIATION MODEL
 FORM FACTOR CALCULATION LINK.

          (* -INDICATES FF CALCULATED BY UNIT-SPHERE TECHNIQUE)
          (R -INDICATES FF CALCULATED FROM NODE J TO NODE I BECAUSE NODE J IS SMALLER IN AREA)
          (UN-INDICATES UNKNOWN CALCULATION MODE BECAUSE OF RSI, RTI, OR CARD INPUT)
          (9.999999 -INDICATES UNKNOWN DATA VALUE BECAUSE OF INSUFFICIENT CARD INPUT)
          (DEV -DEVIATION OF SUM FROM 1.0 DUE TO FFMIN CONSIDERATIONS AND COMPUTATIONAL INACCURACIES)

 NODE I  NODE J  COMPUTATION  FIR(I,J)  FIR(J,I)  FSOL(I,J)  FSOL(J,I)   FF(I,J)  SHAD.IR  SHAD.SOL  CP TIME   NEI   NEJ
                               W/SHAD    W/SHAD    W/SHAD     W/SHAD    WO/SHAD  FACTOR    FACTOR    (SEC)

     1   FF SUM =  0.0000     ROW CP TIME =     0.006

1
 DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE    8

 MODEL-SCRAFT CONFIG-SCRAFT STEP--1                SPACECRAFT THERMAL RADIATION MODEL
 FORM FACTOR CALCULATION LINK.

          (* -INDICATES FF CALCULATED BY UNIT-SPHERE TECHNIQUE)
          (R -INDICATES FF CALCULATED FROM NODE J TO NODE I BECAUSE NODE J IS SMALLER IN AREA)
          (UN-INDICATES UNKNOWN CALCULATION MODE BECAUSE OF RSI, RTI, OR CARD INPUT)
          (9.999999 -INDICATES UNKNOWN DATA VALUE BECAUSE OF INSUFFICIENT CARD INPUT)
          (DEV -DEVIATION OF SUM FROM 1.0 DUE TO FFMIN CONSIDERATIONS AND COMPUTATIONAL INACCURACIES)

 NODE I  NODE J  COMPUTATION  FIR(I,J)  FIR(J,I)  FSOL(I,J)  FSOL(J,I)  FF(I,J)  SHAD.IR  SHAD.SOL  CP TIME   NEI   NEJ
                               W/SHAD    W/SHAD    W/SHAD     W/SHAD    WO/SHAD  FACTOR    FACTOR    (SEC)

     2       9   CAL         0.166928  0.166928   0.166928   0.166928 0.166928 1.000000  1.000000    0.051    28   195  *
     2      10   CAL         0.166928  0.166928   0.166928   0.166928 0.166928 1.000000  1.000000    0.050    28   195  *
     2   FF SUM =  0.3339     ROW CP TIME =     0.103

     3   FF SUM =  0.0000     ROW CP TIME =     0.003

     4       7   CAL         0.166928  0.166928   0.166928   0.166928 0.166928 1.000000  1.000000    0.050    28   195  *
     4       8   CAL         0.166928  0.166928   0.166928   0.166928 0.166928 1.000000  1.000000    0.050    28   195  *
     4   FF SUM =  0.3339     ROW CP TIME =     0.102

     5   FF SUM =  0.0000     ROW CP TIME =     0.002

     6   FF SUM =  0.0000     ROW CP TIME =     0.002

     7   FF SUM =  0.1669     ROW CP TIME =     0.001

     8   FF SUM =  0.1669     ROW CP TIME =     0.001

     9   FF SUM =  0.1669     ROW CP TIME =     0.001

    10   FF SUM =  0.1669     ROW CP TIME =     0.000

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

FF FORM FACTORS FOR CONFIGURATION SCRAFT HAVE BEEN STORED ON RSO.
LAST RESTART RECORD WRITTEN =     24

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

1
 DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE    9

 MODEL-SCRAFT CONFIG-SCRAFT STEP--1                SPACECRAFT THERMAL RADIATION MODEL
 FORM FACTOR CALCULATION LINK.


                                   IR FORM FACTOR SUMS TABLE

   NODE I- FF SUM     NODE I- FF SUM     NODE I- FF SUM     NODE I- FF SUM     NODE I- FF SUM     NODE I- FF SUM

        1- 0.0000          2- 0.3339          3- 0.0000          4- 0.3339          5- 0.0000          6- 0.0000
        7- 0.1669          8- 0.1669          9- 0.1669         10- 0.1669
```

```
TOTAL TIME FOR FORM FACTOR SEGMENT =      0.236

TOTAL TIME SINCE START OF RUN      =      0.461
1
DATE 071691 TIME 190850       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   10

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1                SPACECRAFT THERMAL RADIATION MODEL
GRAY BODIES COMPUTATION LINK.

                                                  GRAY BODIES
   VARIABLE  CURRENT  DEFAULT            DEFINITION                                                OPTIONS
     NAME     VALUE

    GBWBND    BOTH      BOTH             WAVEBAND DEFINITION PARAMETER                           (IR,SOL,BOTH)
    NFIGFF    SCRAFT    CONF. NAME       CURRENT CONF. NAME FOR FORM FACTOR ACCESS               (ANY CONF. NAME)
    NFFTYP    FF        LAST TYPE        FORM FACTOR TYPE FLAG                                   (FF,IF,CM)
                        CALCULATED
                        UNDER NFIGFF

SCRIPT-FS TO SPACE CALCULATED IMPLICITLY.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

IR     GRAY BODIES FOR CONFIGURATION SCRAFT HAVE BEEN COMPUTED AND STORED ON RSO.
LAST RESTART RECORD WRITTEN =    36
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

SCRIPT-FS TO SPACE CALCULATED IMPLICITLY.

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

SOL    GRAY BODIES FOR CONFIGURATION SCRAFT HAVE BEEN COMPUTED AND STORED ON RSO.
LAST RESTART RECORD WRITTEN =    48
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TOTAL TIME TO COMPUTE GRAY BODIES        0.02
1
DATE 071691 TIME 190851       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   11

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1                SPACECRAFT THERMAL RADIATION MODEL
RADIATION CONDUCTOR GENERATION LINK.

                                                  RADIATION CONDUCTORS
   VARIABLE  CURRENT  DEFAULT            DEFINITION                                                OPTIONS
     NAME     VALUE

    NFIGGB    SCRAFT   CONF. NAME  CURRENT CONF. NAME FOR GRAY BODY FACTOR ACCESS                  (CONFIG. NAME)
    RKPNCH    NO          YES      PUNCH/NO PUNCH PARAMETER FOR RADKS                             (YES,NO)
    RKMIN   0.10E-02   0.0001      PARAMETER TO ELIMINATE SMALL RADKS                                N/A
    IRKCN       1        1         INITIAL RADIATION CONDUCTOR ID NUMBER                             N/A
    RKSP      SPACE      NO        MNEMONIC FLAG FOR COMPUTATION OF RADKS TO SPACE                (SPACE,NO)
    IRKNSP     9999    32767       SPACE NODE ID NUMBER                                              N/A
    SIGMA   0.17E-08  0.17E-08     STEFAN-BOLTZMANN CONSTANT                                         N/A
    RKAMPF     1.00     1.00       AREA MULTIPLYING FACTOR                                           N/A
    RKTAPE    TAPE      NO         PARAMETER TO OUTPUT TO BCD TAPE                                (YES,TAPE,NO)
    NFIGCO    SCRAFT   CONF. NAME  CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS               (CONFIG. NAME)
    RFRAC   0.7E+00   0.7E+00      SIGNIFICANT RADIATION FRACTION                                 (0. TO 1.)
    RTOL    0.990     0.990        DECIMAL FRACTION OF LAST RADK SAVED                               N/A
    NERN        0        0         EFFECTIVE RADIATION NODE (ERN) NUMBER                             N/A
1
DATE 071691 TIME 190851       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   12

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1                SPACECRAFT THERMAL RADIATION MODEL
RADIATION CONDUCTOR GENERATION LINK.

  SPECIAL RADIATION NODES

        NONE

   MESS SPECIAL NODES

   PRIMARY  SECONDARY

        NONE
1
DATE 071691 TIME 190851       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   13

MODEL=SCRAFT CONFIG=SCRAFT STEP=-1                SPACECRAFT THERMAL RADIATION MODEL
RADIATION CONDUCTOR GENERATION LINK.

     RADIATION CONDUCTORS (RADKS) WRITTEN ON NRADK, NBCDOU, AND/OR PUNCH FILE(S)

            AREA UNITS = INPUT UNITS * AMPF, WHERE AMPF =   1.00000
```

```
-      1,      2,      9, 2.75738E-10$
-      2,      2,     10, 2.75738E-10$
-      3,      4,      7, 2.75738E-10$
-      4,      4,      8, 2.75738E-10$
-      5,    - 7,      8, 2.45485E-11$
-      6,      9,     10, 2.45485E-11$
-      7,      1,   9999, 1.02780E-09$
-      8,      2,   9999, 1.49031E-09$
-      9,      3,   9999, 2.05560E-09$
-     10,      4,   9999, 1.49031E-09$
-     11,      5,   9999, 2.05560E-09$
-     12,      6,   9999, 1.02780E-09$
-     13,      7,   9999, 2.41596E-09$
-     14,      8,   9999, 2.41596E-09$
-     15,      9,   9999, 2.41596E-09$
-     16,     10,   9999, 2.41596E-09$

RADKS STORED ON MITAS/SINDA BCD OUTPUT TAPE IN FILE    1

1
DATE 071691 TIME 190851        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   14

MODEL-SCRAFT CONFIG-SCRAFT STEP--1              SPACECRAFT THERMAL RADIATION MODEL
RADIATION CONDUCTOR GENERATION LINK.


                                        CONSERVATION CHECKS
                                RADIATIONS SUMS FOR EACH NODE BEFORE RKMIN SCREENING

     1- 0.10000E+01        2- 0.10000E+01        3- 0.10000E+01        4- 0.10000E+01        5- 0.10000E+01        6- 0.10000E+
01
     7- 0.10000E+01        8- 0.10000E+01        9- 0.10000E+01       10- 0.10000E+01
1
DATE 071691 TIME 190851        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   15

MODEL-SCRAFT CONFIG-SCRAFT STEP--1              SPACECRAFT THERMAL RADIATION MODEL
RADIATION CONDUCTOR GENERATION LINK.


                                        CONSERVATION CHECKS
                                RADIATIONS SUMS FOR EACH NODE AFTER RKMIN SCREENING

     1- 0.10000E+01        2- 0.10000E+01        3- 0.10000E+01        4- 0.10000E+01        5- 0.10000E+01        6- 0.10000E+
01
     7- 0.10000E+01        8- 0.10000E+01        9- 0.10000E+01       10- 0.10000E+01

   TOTAL TIME TO COMPUTE AND CONDENSE RADKS =   0.01
1
DATE 071691 TIME 190851        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   16

MODEL-SCRAFT CONFIG-SCRAFT STEP-1               SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE  CURRENT     DEFAULT        DEFINITION                                    OPTIONS
  NAME     VALUE
                                     ++++ BASIC CONTROL PARAMETERS ++++

DINOSH      SHAD      SHAD           SHADOWING OVERRIDE FLAG                       SHAD,NOSH
DIACC       0.250     0.250          PLANETARY ACCURACY FACTOR
DIACCS      0.100     0.100          SHADOWING ACCURACY FACTOR
NSPFF           0     0              STEP NO. FOR PLANETARY FORM FACTORS
TRUEAN      0.000     0.000          TRUE ANOMALY ANGLE, DEGREES
TIMEST      0.000     0.000          INITIAL TIME ( AT PERIAPSIS )
ISOLFL          0     N/A            BACK REFERENCE FOR SOLAR FLUXES               STEP NO.
IALBFL          0     N/A            BACK REFERENCE FOR ALBEDO FLUXES              STEP NO.
IPLAFL          0     N/A            BACK REFERENCE FOR PLANETARY FLUXES           STEP NO.
DIPNCH     NO         NO             DIRECT INCIDENT FLUX PUNCH FLAG               YES,NO,TAPE
ISFAC      NO         YES            FLAG TO WRITE SHADOW FACTORS ON RSO           YES,NO

                                     ++++ BASIC ORBIT DATA ++++

ALAN         90.000  0.000            LONGITUDE OF ASCENDING NODE, DEGREES
APER          0.000  0.000            ARGUMENT OF PERIFOCUS, DEGREES
OINC         52.000  0.000            ORBIT INCLINATION, DEGREES
HP      0.12160E+07  0.000            ORBIT ALTITUDE AT PERIAPSIS
HA      0.12160E+07  0.000            ORBIT ALTITUDE AT APOAPSIS
ECC           0.000  0.000            ORBIT ECCENTRICITY
SUNRA         0.000  0.000            SUN RA ANGLE, DEGREES
SUNDEC        0.000  0.000            SUN DEC ANGLE, DEGREES
STRRA         0.000  0.000            REFERENCE STAR RA ANGLE, DEGREES
STRDEC        0.000  0.000            REFERENCE STAR DEC ANGLE, DEGREES

                                     ++++ SUN   -ORIENTED, ORIENTATION DATA ++++

ROTX          0.000  0.000            ROTATION ABOUT VCS X-AXIS TO CCS
ROTY          0.000  0.000            ROTATION ABOUT VCS Y-AXIS TO CCS
ROTZ          0.000  0.000            ROTATION ABOUT VCS Z-AXIS TO CCS
              1 2 3  1 2 3            ROTATION ORDER -- IROTX,IROTY,IROTZ
SUNCL         0.000  0.000            SUN LOOK ANGLE - CLOCK, DEGREES
SUNCO        90.000  0.000            SUN LOOK ANGLE - CONE , DEGREES
PLCL        270.000  0.000            PLANET LOOK ANGLE - CLOCK, DEGREES
PLCO         90.000  0.000            PLANET LOOK ANGLE - CONE , DEGREES
1
DATE 071691 TIME 190851        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   17

MODEL-SCRAFT CONFIG-SCRAFT STEP-1               SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.
```

++++ SPIN DATA ++++

CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)
CONE	0.000	0.000	CONE ANGLE, DEGREES
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE
TIMSP	0.000	0.000	TIME SPIN BEGINS

++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 1

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 18

MODEL=SCRAFT CONFIG=SCRAFT STEP=1 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 1 TRUE ANOMALY = 0.00000 TIME = 0.00000
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	CALC	0.00000E+00	0.00000E+00	0.0000	0.000	9	0
2	CALC	0.00000E+00	0.00000E+00	0.0000	0.001	8	0
3	CALC	0.42900E+03	0.42900E+03	1.0000	0.006	78	7
4	CALC	0.00000E+00	0.00000E+00	0.0000	0.007	8	0
5	CALC	0.00000E+00	0.00000E+00	0.0000	0.007	8	0
6	CALC	0.00000E+00	0.00000E+00	0.0000	0.008	9	0
7	CALC	0.42900E+03	0.42900E+03	1.0000	0.013	78	7
8	CALC	0.00000E+00	0.00000E+00	0.0000	0.014	8	0
9	CALC	0.42900E+03	0.42900E+03	1.0000	0.019	78	7
10	CALC	0.00000E+00	0.00000E+00	0.0000	0.019	8	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 0.523 SECONDS

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 19

MODEL=SCRAFT CONFIG=SCRAFT STEP=1 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 1 TRUE ANOMALY = 0.00000 TIME = 0.00000
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.931E+00	0.224E+02	0.931E+00	0.224E+02	1.000	1.000	0.000	58	9	6
2	CALC	0.970E+00	0.448E+02	0.245E+01	0.681E+02	0.395	0.658	0.094	98	18	7
3	CALC	0.293E+01	0.216E+02	0.293E+01	0.216E+02	1.000	1.000	0.117	58	8	7
4	CALC	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000	0.000	0.119	58	8	0
5	CALC	0.000E+00	0.216E+02	0.000E+00	0.216E+02	0.000	1.000	0.141	58	8	7
6	CALC	0.931E+00	0.224E+02	0.931E+00	0.224E+02	1.000	1.000	0.164	58	9	6
7	CALC	0.180E+01	0.101E+02	0.293E+01	0.216E+02	0.614	0.468	0.182	58	8	7
8	CALC	0.000E+00	0.101E+02	0.000E+00	0.216E+02	0.000	0.468	0.200	58	8	7
9	CALC	0.293E+01	0.216E+02	0.293E+01	0.216E+02	1.000	1.000	0.222	58	8	7
10	CALC	0.000E+00	0.216E+02	0.000E+00	0.216E+02	0.000	1.000	0.244	58	8	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 0.790 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 56

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 20

MODEL=SCRAFT CONFIG=SCRAFT STEP=1 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT -	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 1

TOTAL TIME TO COMPUTE ABSORBED Q = 0.00

STEP 2

ABSORBED HEATS FROM STEP 1 PUT IN CURRENT STEP DATA STORAGE.

INPUT ARGUMENTS--- TRUE ANOMALY = 360.000 TIME = 0.15306E+01

STORED ARGUMENTS-- TRUE ANOMALY = 360.000 TIME = 0.15306E+01

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 21

MODEL=SCRAFT CONFIG=SCRAFT STEP=3 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	45.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	301.619	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	123.863	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 22

MODEL=SCRAFT CONFIG=SCRAFT STEP=3 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

			++++ SPIN DATA ++++	
CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW=POSITIVE)	
CONE	0.000	0.000	CONE ANGLE, DEGREES	
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE	
TIMSP	0.000	0.000	TIME SPIN BEGINS	
			++++ SHADOW FACTOR APPLICATION DATA ++++	
TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 3

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 23

MODEL=SCRAFT CONFIG=SCRAFT STEP=3 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 3 TRUE ANOMALY = 45.00000 TIME = 0.19134
++++ IN THE SHADE ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 0.818 SECONDS

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 24

MODEL=SCRAFT CONFIG=SCRAFT STEP=3 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 3 TRUE ANOMALY = 45.00000 TIME = 0.19134
++++ IN THE SHADE ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.000E+00	0.607E+01	0.000E+00	0.607E+01	0.000	1.000	0.000	58	1	6
2	CALC	0.000E+00	0.318E+02	0.000E+00	0.521E+02	0.000	0.611	0.061	82	18	7
3	CALC	0.000E+00	0.395E+02	0.000E+00	0.395E+02	0.000	1.000	0.119	70	18	7
4	CALC	0.000E+00	0.841E-02	0.000E+00	0.276E+01	0.000	0.003	0.127	58	1	7
5	CALC	0.000E+00	0.912E+01	0.000E+00	0.912E+01	0.000	1.000	0.137	58	3	7
6	CALC	0.000E+00	0.449E+02	0.000E+00	0.449E+02	0.000	1.000	0.190	74	16	6
7	CALC	0.000E+00	0.282E+02	0.000E+00	0.395E+02	0.000	0.715	0.239	70	18	7
8	CALC	0.000E+00	0.400E+01	0.000E+00	0.912E+01	0.000	0.439	0.248	58	3	7
9	CALC	0.000E+00	0.389E+02	0.000E+00	0.395E+02	0.000	0.985	0.305	70	18	7
10	CALC	0.000E+00	0.912E+01	0.000E+00	0.912E+01	0.000	1.000	0.316	58	3	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 1.142 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 82

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 25

MODEL=SCRAFT CONFIG=SCRAFT STEP=3 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 3

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

MODEL-SCRAFT CONFIG-SCRAFT STEP-4 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	90.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	0.000	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	142.000	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

MODEL-SCRAFT CONFIG-SCRAFT STEP-4 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

			++++ SPIN DATA ++++	
CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)	
CONE	0.000	0.000	CONE ANGLE, DEGREES	
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE	
TIMSP	0.000	0.000	TIME SPIN BEGINS	
			++++ SHADOW FACTOR APPLICATION DATA ++++	
TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 4

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

MODEL-SCRAFT CONFIG-SCRAFT STEP-4 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 4 TRUE ANOMALY = 90.00000 TIME = 0.38268
++++ IN THE SHADE ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES

1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 1.165 SECONDS

1
DATE 071691 TIME 190851 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 29

MODEL=SCRAFT CONFIG=SCRAFT STEP=4 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 4 TRUE ANOMALY = 90.00000 TIME = 0.38268
++++ IN THE SHADE ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.000E+00	0.135E+01	0.000E+00	0.135E+01	0.000	1.000	0.000	58	1	6
2	CALC	0.000E+00	0.154E+02	0.000E+00	0.224E+02	0.000	0.685	0.021	58	8	7
3	CALC	0.000E+00	0.477E+02	0.000E+00	0.477E+02	0.000	1.000	0.094	82	18	7
4	CALC	0.000E+00	0.154E+02	0.000E+00	0.224E+02	0.000	0.685	0.114	58	8	7
5	CALC	0.000E+00	0.467E+01	0.000E+00	0.467E+01	0.000	1.000	0.123	58	2	7
6	CALC	0.000E+00	0.551E+02	0.000E+00	0.551E+02	0.000	1.000	0.201	94	16	6
7	CALC	0.000E+00	0.413E+02	0.000E+00	0.477E+02	0.000	0.867	0.266	82	18	7
8	CALC	0.000E+00	0.424E+01	0.000E+00	0.467E+01	0.000	0.908	0.275	58	2	7
9	CALC	0.000E+00	0.413E+02	0.000E+00	0.477E+02	0.000	0.867	0.339	82	18	7
10	CALC	0.000E+00	0.424E+01	0.000E+00	0.467E+01	0.000	0.908	0.348	58	2	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 1.521 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 96

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 30

MODEL=SCRAFT CONFIG=SCRAFT STEP=4 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 4

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 31

MODEL=SCRAFT CONFIG=SCRAFT STEP=5 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	135.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	

```
ECC          0.000  0.000        ORBIT ECCENTRICITY
SUNRA        0.000  0.000        SUN RA ANGLE, DEGREES
SUNDEC       0.000  0.000        SUN DEC ANGLE, DEGREES
STRRA        0.000  0.000        REFERENCE STAR RA ANGLE, DEGREES
STRDEC       0.000  0.000        REFERENCE STAR DEC ANGLE, DEGREES

                                 ++++ SUN   -ORIENTED, ORIENTATION DATA ++++

ROTX         0.000  0.000        ROTATION ABOUT VCS X-AXIS TO CCS
ROTY         0.000  0.000        ROTATION ABOUT VCS Y-AXIS TO CCS
ROTZ         0.000  0.000        ROTATION ABOUT VCS Z-AXIS TO CCS
             1 2 3  1 2 3        ROTATION ORDER -- IROTX,IROTY,IROTZ
SUNCL        0.000  0.000        SUN LOOK ANGLE - CLOCK, DEGREES
SUNCO       90.000  0.000        SUN LOOK ANGLE - CONE , DEGREES
PLCL        58.381  0.000        PLANET LOOK ANGLE - CLOCK, DEGREES
PLCO       123.863  0.000        PLANET LOOK ANGLE - CONE , DEGREES
1
DATE 071691 TIME 190852      THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   32

MODEL=SCRAFT CONFIG=SCRAFT STEP=5              SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.


                                 ++++ SPIN DATA ++++

CLOCK        0.000  0.000        CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW=POSITIVE)
CONE         0.000  0.000        CONE ANGLE, DEGREES
RATE         0.000  0.000        ROTATION RATE - CCW POSITIVE
TIMSP        0.000  0.000        TIME SPIN BEGINS


                                 ++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS         0.500  0.500        TOLERANCE FOR SOLAR FLUX CALCULATIONS                  REAL NO.
TOLP         0.750  0.750        TOLERANCE FOR PLANETARY FLUX CALCULATIONS              REAL NO.
NSAR           N/A  NONE         NAME OF SOLAR NODE NUMBER ARRAY                        ARRAY NAME
NPAR           N/A  NONE         NAME OF PLANETARY NODE NUMBER ARRAY                    ARRAY NAME
ISFL         YES    YES          FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS      YES,NO
IPFL         YES    YES          FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS  YES,NO


                                 ++++++++ STEP NO =        5

                                 ++++ COMPUTED OR INPUT ORBIT DATA ++++

        VALUE          VARIABLE DESCRIPTION          ***          VALUE          VARIABLE DESCRIPTION

       38.000       SUN  BETA  ANGLE, DEGREES                    270.000       SUN  CIGMA  ANGLE, DEGREES
       38.000       STAR BETAS ANGLE, DEGREES                    270.000       STAR CIGMAS ANGLE, DEGREES


                                 ++++ PLANET -- EARTH  -- DATA ++++

        VALUE          DESCRIPTION          NAME   ***      VALUE          DESCRIPTION          NAME

        0.300     PLANET ALBEDO             PALB          0.75073E+02    PLANET DS EMISS POWER    WDS
   0.20900E+08    PLANET RADIUS             PRAD          0.75073E+02    PLANET SS EMISS POWER    WSS
   0.15306E+01    ORBIT PERIOD              PERIOD
   0.41731E+09    PLANET GRAV CONSTANT      GRAV          0.42900E+03    SOLAR CONSTANT AT PSD    SOL
1
DATE 071691 TIME 190852      THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   33

MODEL=SCRAFT CONFIG=SCRAFT STEP=5              SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

                 SOLAR DIRECT INCIDENT FLUX FOR STEP NO.     5 TRUE ANOMALY =    135.00000    TIME =      0.57402
                                        ++++  IN THE SHADE   ++++

   NODE     COMPUTATION        DIRECT        UNSHADOWED     SHADOW        CP TIME      SURFACE     SHADOWING
  NUMBERS                     FLUX(QDS)        FLUX        FACTOR       (SECONDS)    ELEMENTS     SURFACES

      1       ++++++         0.00000E+00   0.00000E+00    0.0000          0.000          0           0
      2       ++++++         0.00000E+00   0.00000E+00    0.0000          0.001          0           0
      3       ++++++         0.00000E+00   0.00000E+00    0.0000          0.001          0           0
      4       ++++++         0.00000E+00   0.00000E+00    0.0000          0.001          0           0
      5       ++++++         0.00000E+00   0.00000E+00    0.0000          0.002          0           0
      6       ++++++         0.00000E+00   0.00000E+00    0.0000          0.002          0           0
      7       ++++++         0.00000E+00   0.00000E+00    0.0000          0.002          0           0
      8       ++++++         0.00000E+00   0.00000E+00    0.0000          0.002          0           0
      9       ++++++         0.00000E+00   0.00000E+00    0.0000          0.002          0           0
     10       ++++++         0.00000E+00   0.00000E+00    0.0000          0.003          0           0

 NOTE--

    FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
                                 STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.


                 TOTAL ELAPSED TIME IN PROBLEM =          1.545 SECONDS
1
DATE 071691 TIME 190852      THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   34

MODEL=SCRAFT CONFIG=SCRAFT STEP=5              SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

    ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. =     5   TRUE ANOMALY =    135.00000    TIME =  0.57402
                                        ++++  IN THE SHADE   ++++

  NODE   COMPUT   ---DIRECT INCID. FLUX--    ---UNSHADOWED  FLUX---    --SHADOW FACTORS--    CP TIME    --ELEMENTS--    SHAD
 NUMBER             ALBEDO      PLANETARY     ALBEDO      PLANETARY     ALBEDO      PLAN     (SECONDS)  PLAN     SURF    SURF
```

1	CALC	0.000E+00	0.607E+01	0.000E+00	0.607E+01	0.000	1.000	0.000	58	1	6
2	CALC	0.000E+00	0.841E-02	0.000E+00	0.276E+01	0.000	0.003	0.009	58	1	7
3	CALC	0.000E+00	0.395E+02	0.000E+00	0.395E+02	0.000	1.000	0.067	70	18	7
4	CALC	0.000E+00	0.318E+02	0.000E+00	0.521E+02	0.000	0.611	0.128	82	18	7
5	CALC	0.000E+00	0.912E+01	0.000E+00	0.912E+01	0.000	1.000	0.139	58	3	7
6	CALC	0.000E+00	0.449E+02	0.000E+00	0.449E+02	0.000	1.000	0.193	74	16	6
7	CALC	0.000E+00	0.389E+02	0.000E+00	0.395E+02	0.000	0.985	0.250	70	18	7
8	CALC	0.000E+00	0.912E+01	0.000E+00	0.912E+01	0.000	1.000	0.260	58	3	7
9	CALC	0.000E+00	0.282E+02	0.000E+00	0.395E+02	0.000	0.715	0.309	70	18	7
10	CALC	0.000E+00	0.400E+01	0.000E+00	0.912E+01	0.000	0.439	0.318	58	3	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK, STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 1.872 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 110

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 35

MODEL=SCRAFT CONFIG=SCRAFT STEP=5 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 5

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 36

MODEL=SCRAFT CONFIG=SCRAFT STEP=6 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	180.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	90.000	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	90.000	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 37

MODEL=SCRAFT CONFIG=SCRAFT STEP=6 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

++++ SPIN DATA ++++

CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)
CONE	0.000	0.000	CONE ANGLE, DEGREES
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE
TIMSP	0.000	0.000	TIME SPIN BEGINS

++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES, NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES, NO

++++++++ STEP NO = 6

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1

DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 38

MODEL=SCRAFT CONFIG=SCRAFT STEP=6 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 6 TRUE ANOMALY = 180.00000 TIME = 0.76536
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.42900E+03	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 1.897 SECONDS

1

DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 39

MODEL=SCRAFT CONFIG=SCRAFT STEP=6 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 6 TRUE ANOMALY = 180.00000 TIME = 0.76536
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.931E+00	0.224E+02	0.931E+00	0.224E+02	1.000	1.000	0.000	58	9	6
2	CALC	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000	0.000	0.004	58	8	0
3	CALC	0.293E+01	0.216E+02	0.293E+01	0.216E+02	1.000	1.000	0.026	58	8	7
4	CALC	0.970E+00	0.448E+02	0.245E+01	0.681E+02	0.395	0.658	0.119	98	18	7
5	CALC	0.000E+00	0.216E+02	0.000E+00	0.216E+02	0.000	1.000	0.141	58	8	7
6	CALC	0.931E+00	0.224E+02	0.931E+00	0.224E+02	1.000	1.000	0.163	58	9	6
7	CALC	0.293E+01	0.216E+02	0.293E+01	0.216E+02	1.000	1.000	0.185	58	8	7
8	CALC	0.000E+00	0.216E+02	0.000E+00	0.216E+02	0.000	1.000	0.207	58	8	7
9	CALC	0.180E+01	0.101E+02	0.293E+01	0.216E+02	0.614	0.468	0.225	58	8	7
10	CALC	0.000E+00	0.101E+02	0.000E+00	0.216E+02	0.000	0.468	0.243	58	8	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 2.162 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE. LAST RESTART RECORD WRITTEN = 124

1

DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 40

MODEL=SCRAFT CONFIG=SCRAFT STEP=6 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS

IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 6

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 41

MODEL-SCRAFT CONFIG-SCRAFT STEP-7 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD, NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	225.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES, NO, TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES, NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX, IROTY, IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	121.619	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	56.137	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

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DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 42

MODEL-SCRAFT CONFIG-SCRAFT STEP-7 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

			++++ SPIN DATA ++++	
CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)	
CONE	0.000	0.000	CONE ANGLE, DEGREES	
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE	
TIMSP	0.000	0.000	TIME SPIN BEGINS	
			++++ SHADOW FACTOR APPLICATION DATA ++++	
TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES, NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES, NO

++++++++ STEP NO = 7

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				

0.41731E+09 PLANET GRAV CONSTANT GRAV 0.42900E+03 SOLAR CONSTANT AT PSD SOL

1
DATE 071691 TIME 190852 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 43

MODEL=SCRAFT CONFIG=SCRAFT STEP=7 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 7 TRUE ANOMALY = 225.00000 TIME = 0.95670
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.42900E+03	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 2.189 SECONDS

1
DATE 071691 TIME 190853 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 44

MODEL=SCRAFT CONFIG=SCRAFT STEP=7 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 7 TRUE ANOMALY = 225.00000 TIME = 0.95670
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.345E+02	0.449E+02	0.345E+02	0.449E+02	1.000	1.000	0.000	74	16	6
2	CALC	0.174E+01	0.275E+01	0.174E+01	0.276E+01	0.995	0.997	0.009	58	1	7
3	CALC	0.823E+01	0.912E+01	0.823E+01	0.912E+01	1.000	1.000	0.020	58	3	7
4	CALC	0.283E+02	0.371E+02	0.402E+02	0.521E+02	0.703	0.713	0.083	82	18	7
5	CALC	0.261E+02	0.395E+02	0.261E+02	0.395E+02	1.000	1.000	0.142	70	18	7
6	CALC	0.413E+01	0.607E+01	0.413E+01	0.607E+01	1.000	1.000	0.151	58	1	6
7	CALC	0.823E+01	0.912E+01	0.823E+01	0.912E+01	1.000	1.000	0.162	58	3	7
8	CALC	0.257E+02	0.389E+02	0.261E+02	0.395E+02	0.987	0.985	0.220	70	18	7
9	CALC	0.371E+01	0.400E+01	0.823E+01	0.912E+01	0.451	0.439	0.230	58	3	7
10	CALC	0.180E+02	0.282E+02	0.261E+02	0.395E+02	0.692	0.715	0.278	70	18	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 2.522 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 138

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DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 45

MODEL=SCRAFT CONFIG=SCRAFT STEP=7 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 7

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

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DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 46

MODEL=SCRAFT CONFIG=SCRAFT STEP=8 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	270.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.

IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO

++++ BASIC ORBIT DATA ++++

ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS
ECC	0.000	0.000	ORBIT ECCENTRICITY
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES

++++ SUN -ORIENTED, ORIENTATION DATA ++++

ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES
PLCL	180.000	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES
PLCO	30.000	0.000	PLANET LOOK ANGLE - CONE , DEGREES

++++ SPIN DATA ++++

CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)
CONE	0.000	0.000	CONE ANGLE, DEGREES
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE
TIMSP	0.000	0.000	TIME SPIN BEGINS

++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 0

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
30.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
30.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 0 TRUE ANOMALY = 270.00000 TIME = 1.14804
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.42900E+03	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK, STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 2.550 SECONDS

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MODEL-SCRAFT CONFIG-SCRAFT STEP-8 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. - 8 TRUE ANOMALY - 270.00000 TIME - 1.14804
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.605E+02	0.551E+02	0.605E+02	0.551E+02	1.000	1.000	0.000	94	16	6
2	CALC	0.164E+02	0.154E+02	0.235E+02	0.224E+02	0.696	0.685	0.021	58	8	7
3	CALC	0.565E+01	0.467E+01	0.565E+01	0.467E+01	1.000	1.000	0.031	58	2	7
4	CALC	0.164E+02	0.154E+02	0.235E+02	0.224E+02	0.696	0.685	0.051	58	8	7
5	CALC	0.472E+02	0.477E+02	0.472E+02	0.477E+02	1.000	1.000	0.125	82	18	7
6	CALC	0.111E+01	0.135E+01	0.111E+01	0.135E+01	1.000	1.000	0.133	58	1	6
7	CALC	0.515E+01	0.424E+01	0.565E+01	0.467E+01	0.911	0.908	0.142	58	2	7
8	CALC	0.409E+02	0.413E+02	0.472E+02	0.477E+02	0.865	0.867	0.208	82	18	7
9	CALC	0.515E+01	0.424E+01	0.565E+01	0.467E+01	0.911	0.908	0.217	58	2	7
10	CALC	0.409E+02	0.413E+02	0.472E+02	0.477E+02	0.865	0.867	0.282	82	18	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 2.910 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 152

1

DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 50

MODEL-SCRAFT CONFIG-SCRAFT STEP-8 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 8

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

1

DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 51

MODEL-SCRAFT CONFIG-SCRAFT STEP-9 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	315.000	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	238.381	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	56.137	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

1

DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 52

MODEL-SCRAFT CONFIG-SCRAFT STEP-9 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

++++ SPIN DATA ++++

CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)
CONE	0.000	0.000	CONE ANGLE, DEGREES
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE
TIMSP	0.000	0.000	TIME SPIN BEGINS

++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 9

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1
DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 53

MODEL-SCRAFT CONFIG-SCRAFT STEP-9 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 9 TRUE ANOMALY = 315.00000 TIME = 1.33939
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.42900E+03	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 2.939 SECONDS

1
DATE 071691 TIME 190854 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 54

MODEL-SCRAFT CONFIG-SCRAFT STEP-9 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 9 TRUE ANOMALY = 315.00000 TIME = 1.33939
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.345E+02	0.449E+02	0.345E+02	0.449E+02	1.000	1.000	0.000	74	16	6
2	CALC	0.283E+02	0.371E+02	0.402E+02	0.521E+02	0.703	0.713	0.064	82	18	7
3	CALC	0.823E+01	0.912E+01	0.823E+01	0.912E+01	1.000	1.000	0.075	58	3	7
4	CALC	0.174E+01	0.275E+01	0.174E+01	0.276E+01	0.995	0.997	0.083	58	1	7
5	CALC	0.261E+02	0.395E+02	0.261E+02	0.395E+02	1.000	1.000	0.142	70	18	7
6	CALC	0.413E+01	0.607E+01	0.413E+01	0.607E+01	1.000	1.000	0.151	58	1	6
7	CALC	0.37[illegible]E+01	0.400E+01	0.823E+01	0.912E+01	0.451	0.439	0.161	58	3	7
8	CALC	0.180E+02	0.282E+02	0.261E+02	0.395E+02	0.692	0.715	0.210	70	18	7
9	CALC	0.823E+01	0.912E+01	0.823E+01	0.912E+01	1.000	1.000	0.221	58	3	7
10	CALC	0.257E+02	0.389E+02	0.261E+02	0.395E+02	0.987	0.985	0.278	70	18	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

```
                    TOTAL ELAPSED TIME IN PROBLEM =          3.271 SECONDS
     S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN =   166

1
DATE 071691 TIME 190855        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   55

MODEL=SCRAFT CONFIG=SCRAFT STEP=9                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

                                                 ABSORBED HEAT
   VARIABLE  CURRENT  DEFAULT            DEFINITION                                                OPTIONS
     NAME     VALUE

    IAQGBI    SCRAFT  CONF. NAME   CURRENT CONF. NAME FOR IR GRAY BODY FACTORS                  (ANY CONF. NAME)
    IAQGBS    SCRAFT  CONF. NAME   CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS                (ANY CONF. NAME)
    RSOLAR    1.000   1.000        SOLAR HEAT MULTIPLIER                                            REAL NO.
    RALB      1.000   1.000        ALBEDO HEAT MULTIPLIER                                           REAL NO.
    RPLAN     1.000   1.000        PLANETARY HEAT MULTIPLIER                                        REAL NO.
    NFIGCO    SCRAFT  CONF. NAME   CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS             (ANY CONF. NAME)

ABSORBED Q STORED IN STEP  9


TOTAL TIME TO COMPUTE ABSORBED Q =   0.01
1
DATE 071691 TIME 190856        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   56

MODEL=SCRAFT CONFIG=SCRAFT STEP=10               SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE  CURRENT     DEFAULT        DEFINITION                                          OPTIONS
  NAME     VALUE
                                      ++++ BASIC CONTROL PARAMETERS ++++


DINOSH      SHAD      SHAD           SHADOWING OVERRIDE FLAG                             SHAD,NOSH
DIACC       0.250     0.250          PLANETARY ACCURACY FACTOR
DIACCS      0.100     0.100          SHADOWING ACCURACY FACTOR
NSPFF           0     0              STEP NO. FOR PLANETARY FORM FACTORS
TRUEAN     31.985     0.000          TRUE ANOMALY ANGLE, DEGREES
TIMEST      0.000     0.000          INITIAL TIME ( AT PERIAPSIS )
ISOLFL          1     N/A            BACK REFERENCE FOR SOLAR FLUXES                     STEP NO.
IALBFL          0     N/A            BACK REFERENCE FOR ALBEDO FLUXES                    STEP NO.
IPLAFL          0     N/A            BACK REFERENCE FOR PLANETARY FLUXES                 STEP NO.
DIPNCH     NO         NO             DIRECT INCIDENT FLUX PUNCH FLAG                     YES,NO,TAPE
ISFAC      NO         YES            FLAG TO WRITE SHADOW FACTORS ON RSO                 YES,NO

                                      ++++ BASIC ORBIT DATA ++++

ALAN          90.000  0.000          LONGITUDE OF ASCENDING NODE, DEGREES
APER           0.000  0.000          ARGUMENT OF PERIFOCUS, DEGREES
OINC          52.000  0.000          ORBIT INCLINATION, DEGREES
HP       0.12160E+07  0.000          ORBIT ALTITUDE AT PERIAPSIS
HA       0.12160E+07  0.000          ORBIT ALTITUDE AT APOAPSIS
ECC            0.000  0.000          ORBIT ECCENTRICITY
SUNRA          0.000  0.000          SUN RA ANGLE, DEGREES
SUNDEC         0.000  0.000          SUN DEC ANGLE, DEGREES
STRRA          0.000  0.000          REFERENCE STAR RA ANGLE, DEGREES
STRDEC         0.000  0.000          REFERENCE STAR DEC ANGLE, DEGREES

                                      ++++ SUN   -ORIENTED, ORIENTATION DATA ++++

ROTX           0.000  0.000          ROTATION ABOUT VCS X-AXIS TO CCS
ROTY           0.000  0.000          ROTATION ABOUT VCS Y-AXIS TO CCS
ROTZ           0.000  0.000          ROTATION ABOUT VCS Z-AXIS TO CCS
               1 2 3  1 2 3          ROTATION ORDER -- IROTX,IROTY,IROTZ
SUNCL          0.000  0.000          SUN LOOK ANGLE - CLOCK, DEGREES
SUNCO         90.000  0.000          SUN LOOK ANGLE - CONE , DEGREES
PLCL         291.031  0.000          PLANET LOOK ANGLE - CLOCK, DEGREES
PLCO         114.671  0.000          PLANET LOOK ANGLE - CONE , DEGREES
1
DATE 071691 TIME 190856        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   57

MODEL=SCRAFT CONFIG=SCRAFT STEP=10               SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.


                                      ++++ SPIN DATA ++++

CLOCK          0.000  0.000          CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)
CONE           0.000  0.000          CONE ANGLE, DEGREES
RATE           0.000  0.000          ROTATION RATE - CCW POSITIVE
TIMSP          0.000  0.000          TIME SPIN BEGINS


                                      ++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS           0.500  0.500          TOLERANCE FOR SOLAR FLUX CALCULATIONS                REAL NO.
TOLP           0.750  0.750          TOLERANCE FOR PLANETARY FLUX CALCULATIONS            REAL NO.
NSAR             N/A  NONE           NAME OF SOLAR NODE NUMBER ARRAY                      ARRAY NAME
NPAR             N/A  NONE           NAME OF PLANETARY NODE NUMBER ARRAY                  ARRAY NAME
ISFL       YES        YES            FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS    YES,NO
IPFL       YES        YES            FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS YES,NO


                                      ++++++++ STEP NO =        10

                                      ++++ COMPUTED OR INPUT ORBIT DATA ++++

        VALUE          VARIABLE DESCRIPTION            ***            VALUE          VARIABLE DESCRIPTION
```

38.000	SUN BETA ANGLE, DEGREES	270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES	270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1
DATE 071691 TIME 190856 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 58

MODEL=SCRAFT CONFIG=SCRAFT STEP=10 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 10 TRUE ANOMALY = 31.98454 TIME = 0.13600
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.42900E+03	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 3.301 SECONDS

1
DATE 071691 TIME 190856 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 59

MODEL=SCRAFT CONFIG=SCRAFT STEP=10 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 10 TRUE ANOMALY = 31.98454 TIME = 0.13600
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.000E+00	0.952E+01	0.000E+00	0.952E+01	0.000	1.000	0.000	58	4	6
2	CALC	0.000E+00	0.362E+02	0.000E+00	0.584E+02	0.000	0.621	0.082	98	18	7
3	CALC	0.000E+00	0.347E+02	0.000E+00	0.347E+02	0.000	1.000	0.131	68	15	7
4	CALC	0.000E+00	0.000E+00	0.000E+00	0.575E+00	0.000	0.000	0.138	58	1	7
5	CALC	0.000E+00	0.120E+02	0.000E+00	0.120E+02	0.000	1.000	0.154	58	6	7
6	CALC	0.000E+00	0.387E+02	0.000E+00	0.387E+02	0.000	1.000	0.203	70	16	6
7	CALC	0.000E+00	0.215E+02	0.000E+00	0.347E+02	0.000	0.620	0.243	68	15	7
8	CALC	0.000E+00	0.418E+01	0.000E+00	0.120E+02	0.000	0.349	0.255	58	6	7
9	CALC	0.000E+00	0.346E+02	0.000E+00	0.347E+02	0.000	0.998	0.304	68	15	7
10	CALC	0.000E+00	0.120E+02	0.000E+00	0.120E+02	0.000	1.000	0.319	58	6	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 3.633 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 180

1
DATE 071691 TIME 190856 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 60

MODEL=SCRAFT CONFIG=SCRAFT STEP=10 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT VALUE	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 10

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

1
DATE 071691 TIME 190856 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 61

MODEL=SCRAFT CONFIG=SCRAFT STEP=11 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	32.185	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	ZERO	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	ZERO	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	10	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	291.180	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	114.818	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

1

			++++ SPIN DATA ++++	
CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW=POSITIVE)	
CONE	0.000	0.000	CONE ANGLE, DEGREES	
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE	
TIMSP	0.000	0.000	TIME SPIN BEGINS	
			++++ SHADOW FACTOR APPLICATION DATA ++++	
TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 11

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 11 TRUE ANOMALY = 32.18454 TIME = 0.13685
++++ IN THE SHADE ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0

8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK, STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 3.669 SECONDS

1
DATE 071691 TIME 190856 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 64

MODEL=SCRAFT CONFIG=SCRAFT STEP=11 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 11 TRUE ANOMALY = 32.18454 TIME = 0.13685
++++ IN THE SHADE ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	++++++	0.000E+00	0.952E+01	0.000E+00	0.000E+00	0.000	0.000	0.000	0	0	0
2	++++++	0.000E+00	0.362E+02	0.000E+00	0.000E+00	0.000	0.000	0.001	0	0	0
3	++++++	0.000E+00	0.347E+02	0.000E+00	0.000E+00	0.000	0.000	0.001	0	0	0
4	++++++	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
5	++++++	0.000E+00	0.120E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
6	++++++	0.000E+00	0.387E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
7	++++++	0.000E+00	0.215E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
8	++++++	0.000E+00	0.418E+01	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
9	++++++	0.000E+00	0.346E+02	0.000E+00	0.000E+00	0.000	0.000	0.003	0	0	0
10	++++++	0.000E+00	0.120E+02	0.000E+00	0.000E+00	0.000	0.000	0.003	0	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK, STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 3.672 SECONDS
S.A.P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 194

1
DATE 071691 TIME 190856 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 65

MODEL=SCRAFT CONFIG=SCRAFT STEP=11 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 11

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

1
DATE 071691 TIME 190857 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 66

MODEL=SCRAFT CONFIG=SCRAFT STEP=12 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	148.015	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	1	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	0	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	0	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	

ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES
PLCL	68.969	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES
PLCO	114.671	0.000	PLANET LOOK ANGLE - CONE , DEGREES

1

MODEL-SCRAFT CONFIG-SCRAFT STEP-12 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

++++ SPIN DATA ++++

CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)
CONE	0.000	0.000	CONE ANGLE, DEGREES
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE
TIMSP	0.000	0.000	TIME SPIN BEGINS

++++ SHADOW FACTOR APPLICATION DATA ++++

TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME
ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS	YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS	YES,NO

++++++++ STEP NO = 12

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1

MODEL-SCRAFT CONFIG-SCRAFT STEP-12 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 12 TRUE ANOMALY = 148.01546 TIME = 0.62936
++++ IN THE SUN ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.42900E+03	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.42900E+03	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 3.705 SECONDS

1

MODEL-SCRAFT CONFIG-SCRAFT STEP-12 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 12 TRUE ANOMALY = 148.01546 TIME = 0.62936
++++ IN THE SUN ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	CALC	0.000E+00	0.952E+01	0.000E+00	0.952E+01	0.000	1.000	0.000	58	4	6
2	CALC	0.000E+00	0.000E+00	0.000E+00	0.575E+00	0.000	0.000	0.009	58	1	7
3	CALC	0.000E+00	0.347E+02	0.000E+00	0.347E+02	0.000	1.000	0.057	68	15	7
4	CALC	0.000E+00	0.362E+02	0.000E+00	0.584E+02	0.000	0.621	0.137	98	18	7
5	CALC	0.000E+00	0.120E+02	0.000E+00	0.120E+02	0.000	1.000	0.153	58	6	7
6	CALC	0.000E+00	0.387E+02	0.000E+00	0.387E+02	0.000	1.000	0.202	70	16	6
7	CALC	0.000E+00	0.346E+02	0.000E+00	0.347E+02	0.000	0.998	0.250	68	15	7

8	CALC	0.000E+00	0.120E+02	0.000E+00	0.120E+02	0.000	1.000	0.266	58	6	7
9	CALC	0.000E+00	0.215E+02	0.000E+00	0.347E+02	0.000	0.620	0.305	68	15	7
10	CALC	0.000E+00	0.418E+01	0.000E+00	0.120E+02	0.000	0.349	0.318	58	6	7

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK, STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 4.035 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 208

MODEL-SCRAFT CONFIG-SCRAFT STEP-12 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

ABSORBED Q STORED IN STEP 12

TOTAL TIME TO COMPUTE ABSORBED Q = 0.01

MODEL-SCRAFT CONFIG-SCRAFT STEP-13 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
			++++ BASIC CONTROL PARAMETERS ++++	
DINOSH	SHAD	SHAD	SHADOWING OVERRIDE FLAG	SHAD,NOSH
DIACC	0.250	0.250	PLANETARY ACCURACY FACTOR	
DIACCS	0.100	0.100	SHADOWING ACCURACY FACTOR	
NSPFF	0	0	STEP NO. FOR PLANETARY FORM FACTORS	
TRUEAN	147.815	0.000	TRUE ANOMALY ANGLE, DEGREES	
TIMEST	0.000	0.000	INITIAL TIME (AT PERIAPSIS)	
ISOLFL	ZERO	N/A	BACK REFERENCE FOR SOLAR FLUXES	STEP NO.
IALBFL	ZERO	N/A	BACK REFERENCE FOR ALBEDO FLUXES	STEP NO.
IPLAFL	12	N/A	BACK REFERENCE FOR PLANETARY FLUXES	STEP NO.
DIPNCH	NO	NO	DIRECT INCIDENT FLUX PUNCH FLAG	YES,NO,TAPE
ISFAC	NO	YES	FLAG TO WRITE SHADOW FACTORS ON RSO	YES,NO
			++++ BASIC ORBIT DATA ++++	
ALAN	90.000	0.000	LONGITUDE OF ASCENDING NODE, DEGREES	
APER	0.000	0.000	ARGUMENT OF PERIFOCUS, DEGREES	
OINC	52.000	0.000	ORBIT INCLINATION, DEGREES	
HP	0.12160E+07	0.000	ORBIT ALTITUDE AT PERIAPSIS	
HA	0.12160E+07	0.000	ORBIT ALTITUDE AT APOAPSIS	
ECC	0.000	0.000	ORBIT ECCENTRICITY	
SUNRA	0.000	0.000	SUN RA ANGLE, DEGREES	
SUNDEC	0.000	0.000	SUN DEC ANGLE, DEGREES	
STRRA	0.000	0.000	REFERENCE STAR RA ANGLE, DEGREES	
STRDEC	0.000	0.000	REFERENCE STAR DEC ANGLE, DEGREES	
			++++ SUN -ORIENTED, ORIENTATION DATA ++++	
ROTX	0.000	0.000	ROTATION ABOUT VCS X-AXIS TO CCS	
ROTY	0.000	0.000	ROTATION ABOUT VCS Y-AXIS TO CCS	
ROTZ	0.000	0.000	ROTATION ABOUT VCS Z-AXIS TO CCS	
	1 2 3	1 2 3	ROTATION ORDER -- IROTX,IROTY,IROTZ	
SUNCL	0.000	0.000	SUN LOOK ANGLE - CLOCK, DEGREES	
SUNCO	90.000	0.000	SUN LOOK ANGLE - CONE , DEGREES	
PLCL	68.820	0.000	PLANET LOOK ANGLE - CLOCK, DEGREES	
PLCO	114.818	0.000	PLANET LOOK ANGLE - CONE , DEGREES	

MODEL-SCRAFT CONFIG-SCRAFT STEP-13 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

			++++ SPIN DATA ++++	
CLOCK	0.000	0.000	CLOCK ANGLE, DEGREES(ABOUT CCS Z-AXIS CCW-POSITIVE)	
CONE	0.000	0.000	CONE ANGLE, DEGREES	
RATE	0.000	0.000	ROTATION RATE - CCW POSITIVE	
TIMSP	0.000	0.000	TIME SPIN BEGINS	
			++++ SHADOW FACTOR APPLICATION DATA ++++	
TOLS	0.500	0.500	TOLERANCE FOR SOLAR FLUX CALCULATIONS	REAL NO.
TOLP	0.750	0.750	TOLERANCE FOR PLANETARY FLUX CALCULATIONS	REAL NO.
NSAR	N/A	NONE	NAME OF SOLAR NODE NUMBER ARRAY	ARRAY NAME
NPAR	N/A	NONE	NAME OF PLANETARY NODE NUMBER ARRAY	ARRAY NAME

ISFL	YES	YES	FLAG TO SPECIFY METHOD OF SOLAR FLUX CALCULATIONS — YES,NO
IPFL	YES	YES	FLAG TO SPECIFY METHOD OF PLANETARY FLUX CALCULATIONS — YES,NO

++++++++ STEP NO = 13

++++ COMPUTED OR INPUT ORBIT DATA ++++

VALUE	VARIABLE DESCRIPTION	***	VALUE	VARIABLE DESCRIPTION
38.000	SUN BETA ANGLE, DEGREES		270.000	SUN CIGMA ANGLE, DEGREES
38.000	STAR BETAS ANGLE, DEGREES		270.000	STAR CIGMAS ANGLE, DEGREES

++++ PLANET -- EARTH -- DATA ++++

VALUE	DESCRIPTION	NAME	***	VALUE	DESCRIPTION	NAME
0.300	PLANET ALBEDO	PALB		0.75073E+02	PLANET DS EMISS POWER	WDS
0.20900E+08	PLANET RADIUS	PRAD		0.75073E+02	PLANET SS EMISS POWER	WSS
0.15306E+01	ORBIT PERIOD	PERIOD				
0.41731E+09	PLANET GRAV CONSTANT	GRAV		0.42900E+03	SOLAR CONSTANT AT PSD	SOL

1
DATE 071691 TIME 190857 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 73

MODEL=SCRAFT CONFIG=SCRAFT STEP=13 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

SOLAR DIRECT INCIDENT FLUX FOR STEP NO. 13 TRUE ANOMALY = 147.81546 TIME = 0.62851
++++ IN THE SHADE ++++

NODE NUMBERS	COMPUTATION	DIRECT FLUX(QDS)	UNSHADOWED FLUX	SHADOW FACTOR	CP TIME (SECONDS)	SURFACE ELEMENTS	SHADOWING SURFACES
1	++++++	0.00000E+00	0.00000E+00	0.0000	0.000	0	0
2	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
3	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
4	++++++	0.00000E+00	0.00000E+00	0.0000	0.001	0	0
5	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
6	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
7	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
8	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
9	++++++	0.00000E+00	0.00000E+00	0.0000	0.002	0	0
10	++++++	0.00000E+00	0.00000E+00	0.0000	0.003	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 4.075 SECONDS

1
DATE 071691 TIME 190857 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 74

MODEL=SCRAFT CONFIG=SCRAFT STEP=13 SPACECRAFT THERMAL RADIATION MODEL
DIRECT IRRADIATION CALCULATION LINK.

ALBEDO AND PLANETARY DIRECT INCIDENT FLUXES FOR STEP NO. = 13 TRUE ANOMALY = 147.81546 TIME = 0.62851
++++ IN THE SHADE ++++

NODE NUMBER	COMPUT	---DIRECT INCID. FLUX-- ALBEDO	PLANETARY	---UNSHADOWED FLUX--- ALBEDO	PLANETARY	--SHADOW FACTORS-- ALBEDO	PLAN	CP TIME (SECONDS)	--ELEMENTS-- PLAN	SURF	SHAD SURF
1	++++++	0.000E+00	0.952E+01	0.000E+00	0.000E+00	0.000	0.000	0.000	0	0	0
2	++++++	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000	0.000	0.001	0	0	0
3	++++++	0.000E+00	0.347E+02	0.000E+00	0.000E+00	0.000	0.000	0.001	0	0	0
4	++++++	0.000E+00	0.362E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
5	++++++	0.000E+00	0.120E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
6	++++++	0.000E+00	0.387E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
7	++++++	0.000E+00	0.346E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
8	++++++	0.000E+00	0.120E+02	0.000E+00	0.000E+00	0.000	0.000	0.002	0	0	0
9	++++++	0.000E+00	0.215E+02	0.000E+00	0.000E+00	0.000	0.000	0.003	0	0	0
10	++++++	0.000E+00	0.418E+01	0.000E+00	0.000E+00	0.000	0.000	0.003	0	0	0

NOTE--

FLUX VALUES FLAGGED (++++++) MAY HAVE COME FROM RTI, THE FLUX DATA BLOCK,
STUFFED FROM ANOTHER STEP, OR FORCED TO ZERO IN DICOMP.

TOTAL ELAPSED TIME IN PROBLEM = 4.078 SECONDS
S,A,P FLUXES HAVE BEEN WRITTEN TO RSO TAPE, LAST RESTART RECORD WRITTEN = 222

1
DATE 071691 TIME 190857 THERMAL RADIATION ANALYSIS SYSTEM (TRASYS) FORTRAN 77 VERSION PAGE 75

MODEL=SCRAFT CONFIG=SCRAFT STEP=13 SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q COMPUTATION LINK.

ABSORBED HEAT

VARIABLE NAME	CURRENT VALUE	DEFAULT	DEFINITION	OPTIONS
IAQGBI	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR IR GRAY BODY FACTORS	(ANY CONF. NAME)
IAQGBS	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR SOLAR GRAY BODY FACTORS	(ANY CONF. NAME)
RSOLAR	1.000	1.000	SOLAR HEAT MULTIPLIER	REAL NO.
RALB	1.000	1.000	ALBEDO HEAT MULTIPLIER	REAL NO.
RPLAN	1.000	1.000	PLANETARY HEAT MULTIPLIER	REAL NO.
NFIGCO	SCRAFT	CONF. NAME	CURRENT CONF. NAME FOR CORRESPONDENCE DATA ACCESS	(ANY CONF. NAME)

```
ABSORBED Q STORED IN STEP  13


TOTAL TIME TO COMPUTE ABSORBED Q =   0.01
1
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MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                                                  ABSORBED Q OUT
   VARIABLE  CURRENT  DEFAULT            DEFINITION                                                  OPTIONS
     NAME     VALUE

    NSARRY   ALL       ALL        STEP NO. ARRAY DIRECTIVE                                          (ALL,ARRAY NAME)
    NTHARY       1       1        TIME ARRAY ID NUMBER FLUX TABLES START AT IQOTME + 1                  N/A
    QOTAPE   NO        NO         PARAMETER TO OUTPUT TO BCD TAPE                                   (YES,NO)
    QOPNCH   PUN       PUN        PUNCH/NO PUNCH PARAMETER FOR OUTPUT                               (PUN,NO)
    QOAMPF   1.0000    1.0000     AREA MULTIPLYING FACTOR                                           N/A
    QOFMPF   1.0000    1.0000     FLUX MULTIPLYING FACTOR                                           N/A
    QOTMPF   1.0000    1.0000     TIME MULTIPLYING FACTOR                                           N/A
    QOTYPE   BOTH      BOTH       PARAMETER TO DETERMINE TYPE OF OUTPUT                             (TAB,AV,BOTH,TASI,AVSI,BOS
I)
    NFIGCO   SCRAFT CONFIG. NAME CURRENT CONFIGURATION NAME FOR CORRESPONDENCE DATA ACCESS            (ANY CONFIG. NAME)
1
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MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                                ABSORBED HEAT FLUX TABLES

                        Q    = INPUT * FMPF  WHERE FMPF =   0.10000E+01
                        TIME = INPUT * TMPF  WHERE TMPF =   0.10000E+01
                        AREA IS ON SUBROUTINE CALLS

                     1$ TIME ARRAY
                 0.00000E+00, 1.35999E-01, 1.36849E-01, 1.91341E-01, 3.82682E-01
                 5.74022E-01, 6.28514E-01, 6.29364E-01, 7.65363E-01, 9.56704E-01
                 1.14804E+00, 1.33939E+00, 1.53060E+00
                END$
                     2$ HEAT RATE ARRAY FOR NODE        1
                 1.36318E+01, 5.70977E+00, 5.70977E+00, 3.64319E+00, 8.08929E-01
                 3.64319E+00, 5.70977E+00, 5.70977E+00, 1.36318E+01, 3.38409E+01
                 4.51486E+01, 3.38409E+01, 1.36318E+01
                END$
                     3$ HEAT RATE ARRAY FOR NODE        2
                 3.09967E+01, 2.56680E+01, 2.27777E+01, 2.01222E+01, 1.01752E+01
                 6.53735E-01, 5.17392E-01, 3.40764E+00, 3.30913E+00, 5.69426E+00
                 1.66761E+01, 3.21602E+01, 3.09967E+01
                END$
                     4$ HEAT RATE ARRAY FOR NODE        3
                 9.93421E+01, 1.06621E+02, 2.08211E+01, 2.37082E+01, 2.85956E+01
                 2.37082E+01, 2.08211E+01, 1.06621E+02, 9.93421E+01, 9.29197E+01
                 8.97315E+01, 9.29197E+01, 9.93421E+01
                END$
                     5$ HEAT RATE ARRAY FOR NODE        4
                 3.30913E+00, 3.40764E+00, 5.17392E-01, 6.53735E-01, 1.01752E+01
                 2.01222E+01, 2.27777E+01, 2.56680E+01, 3.09967E+01, 3.21602E+01
                 1.66761E+01, 5.69426E+00, 3.30913E+00
                END$
                     6$ HEAT RATE ARRAY FOR NODE        5
                 1.29556E+01, 7.19193E+00, 7.19193E+00, 5.47404E+00, 2.80176E+00
                 5.47404E+00, 7.19193E+00, 7.19193E+00, 1.29556E+01, 2.89228E+01
                 3.80415E+01, 2.89228E+01, 1.29556E+01
                END$
                     7$ HEAT RATE ARRAY FOR NODE        6
                 1.36318E+01, 2.32236E+01, 2.32236E+01, 2.69509E+01, 3.30542E+01
                 2.69509E+01, 2.32236E+01, 2.32236E+01, 1.36318E+01, 4.46827E+00
                 1.03095E+00, 4.46827E+00, 1.36318E+01
                END$
                     8$ HEAT RATE ARRAY FOR NODE        7
                 3.54313E+02, 3.62014E+02, 1.72706E+01, 2.26450E+01, 3.39721E+01
                 3.29420E+01, 2.97325E+01, 3.74476E+02, 3.66962E+02, 3.63871E+02
                 3.55089E+02, 3.51386E+02, 3.54313E+02
                END$
                     9$ HEAT RATE ARRAY FOR NODE        8
                 9.67260E+00, 4.93665E+00, 3.39277E+00, 3.26185E+00, 4.29780E+00
                 9.09015E+00, 1.16171E+01, 1.31610E+01, 2.14162E+01, 5.85251E+01
                 7.01351E+01, 3.90266E+01, 9.67260E+00
                END$
1
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MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                                ABSORBED HEAT FLUX TABLES

                        Q    = INPUT * FMPF  WHERE FMPF =   0.10000E+01
                        TIME = INPUT * TMPF  WHERE TMPF =   0.10000E+01
                        AREA IS ON SUBROUTINE CALLS

                    10$ HEAT RATE ARRAY FOR NODE        9
                 3.66962E+02, 3.74476E+02, 2.97325E+01, 3.29420E+01, 3.39721E+01
                 2.26450E+01, 1.72706E+01, 3.62014E+02, 3.54313E+02, 3.51386E+02
                 3.55089E+02, 3.63871E+02, 3.66962E+02
                END$
                    11$ HEAT RATE ARRAY FOR NODE       10
                 2.14162E+01, 1.31610E+01, 1.16171E+01, 9.09015E+00, 4.29780E+00
                 3.26185E+00, 3.39277E+00, 4.93665E+00, 9.67260E+00, 3.90266E+01
                 7.01351E+01, 5.85251E+01, 2.14162E+01
                END$
1
DATE 071691 TIME 190857        THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   79
```

```
MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                          DA11MC SUBROUTINE CALLS

            AREA = INPUT (UNITS) * AMPF  WHERE AMPF =  0.10000E+01
        DA11MC(1.5306037E+00,TIMEM,A    1,A    2, 1.0000E+00,Q      1)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    3, 2.0000E+00,Q      2)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    4, 2.0000E+00,Q      3)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    5, 2.0000E+00,Q      4)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    6, 2.0000E+00,Q      5)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    7, 1.0000E+00,Q      6)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    8, 2.0000E+00,Q      7)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A    9, 2.0000E+00,Q      8)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A   10, 2.0000E+00,Q      9)$
        DA11MC(1.5306037E+00,TIMEM,A    1,A   11, 2.0000E+00,Q     10)$
1
 DATE 071691 TIME 190857       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   80

MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                          AVERAGE ORBITAL HEATING RATES

          VALUES ARE    RATE - INPUT (UNITS) * RMPF,  WHERE RMPF =  0.10000E+01
          VALUES ARE    AREA - INPUT (UNITS) * AMPF,  WHERE AMPF =  0.10000E+01

M         Q     1- 1.84215973E+01* 1.00000000E+00
M         Q     2- 1.51440683E+01* 2.00000000E+00
M         Q     3- 7.33552320E+01* 2.00000000E+00
M         Q     4- 1.51462344E+01* 2.00000000E+00
M         Q     5- 1.68884121E+01* 2.00000000E+00
M         Q     6- 1.55374595E+01* 1.00000000E+00
M         Q     7- 2.53387710E+02* 2.00000000E+00
M         Q     8- 2.68945613E+01* 2.00000000E+00
M         Q     9- 2.53386705E+02* 2.00000000E+00
M         Q    10- 2.68933116E+01* 2.00000000E+00


 TOTAL TIME TO COMPUTE ABSORBED Q OUT  0.06
1
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MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                                                  ABSORBED Q OUT
   VARIABLE  CURRENT  DEFAULT            DEFINITION                                          OPTIONS
     NAME     VALUE

    NSARRY   ALL       ALL       STEP NO. ARRAY DIRECTIVE                                  (ALL,ARRAY NAME)
    NTMARY       1       1       TIME ARRAY ID NUMBER FLUX TABLES START AT IQOTME + 1          N/A
    QOTAPE   YES       NO        PARAMETER TO OUTPUT TO BCD TAPE                           (YES,NO)
    QOPNCH   PUN       PUN       PUNCH/NO PUNCH PARAMETER FOR OUTPUT                       (PUN,NO)
    QOAMPF   1.0000    1.0000    AREA MULTIPLYING FACTOR                                   N/A
    QOFMPF   1.0000    1.0000    FLUX MULTIPLYING FACTOR                                   N/A
    QOTMPF   1.0000    1.0000    TIME MULTIPLYING FACTOR                                   N/A
    QOTYPE   BOTH      BOTH      PARAMETER TO DETERMINE TYPE OF OUTPUT                     (TAB,AV,BOTH,TASI,AVSI,BOS
I)
    NFIGCO   SCRAFT CONFIG. NAME CURRENT CONFIGURATION NAME FOR CORRESPONDENCE DATA ACCESS  (ANY CONFIG. NAME)
1
 DATE 071691 TIME 190857       THERMAL RADIATION ANALYSIS SYSTEM (TRASYS)  FORTRAN 77  VERSION          PAGE   82

MODEL-SCRAFT CONFIG-SCRAFT STEP-13                SPACECRAFT THERMAL RADIATION MODEL
ABSORBED Q OUTPUT COMPUTATION LINK.

                          ABSORBED HEAT FLUX TABLES

                Q    = INPUT * FMPF  WHERE FMPF =   0.10000E+01
                TIME = INPUT * TMPF  WHERE TMPF =   0.10000E+01
                AREA IS ON SUBROUTINE CALLS

            1$ TIME ARRAY
         0.00000E+00, 1.35999E-01, 1.36849E-01, 1.91341E-01, 3.82682E-01
         5.74022E-01, 6.28514E-01, 6.29364E-01, 7.65363E-01, 9.56704E-01
         1.14804E+00, 1.33939E+00, 1.53060E+00
        END$
            2$ HEAT RATE ARRAY FOR NODE        1
         1.36318E+01, 5.70977E+00, 5.70977E+00, 3.64319E+00, 8.08929E-01
         3.64319E+00, 5.70977E+00, 5.70977E+00, 1.36318E+01, 3.38409E+01
         4.51486E+01, 3.38409E+01, 1.36318E+01
        END$
            3$ HEAT RATE ARRAY FOR NODE        2
         3.09967E+01, 2.56680E+01, 2.27777E+01, 2.01222E+01, 1.01752E+01
         6.53735E-01, 5.17392E-01, 3.40764E+00, 3.30913E+00, 5.69426E+00
         1.66761E+01, 3.21602E+01, 3.09967E+01
        END$
            4$ HEAT RATE ARRAY FOR NODE        3
         9.93421E+01, 1.06621E+02, 2.08211E+01, 2.37082E+01, 2.85956E+01
         2.37082E+01, 2.08211E+01, 1.06621E+02, 9.93421E+01, 9.29197E+01
         8.97315E+01, 9.29197E+01, 9.93421E+01
        END$
            5$ HEAT RATE ARRAY FOR NODE        4
         3.30913E+00, 3.40764E+00, 5.17392E-01, 6.53735E-01, 1.01752E+01
         2.01222E+01, 2.27777E+01, 2.56680E+01, 3.09967E+01, 3.21602E+01
         1.66761E+01, 5.69426E+00, 3.30913E+00
        END$
            6$ HEAT RATE ARRAY FOR NODE        5
         1.29556E+01, 7.19193E+00, 7.19193E+00, 5.47404E+00, 2.80176E+00
         5.47404E+00, 7.19193E+00, 7.19193E+00, 1.29556E+01, 2.89228E+01
         3.80415E+01, 2.89228E+01, 1.29556E+01
        END$
            7$ HEAT RATE ARRAY FOR NODE        6
         1.36318E+01, 2.32236E+01, 2.32236E+01, 2.69509E+01, 3.30542E+01
         2.69509E+01, 2.32236E+01, 2.32236E+01, 1.36318E+01, 4.46827E+00
         1.03095E+00, 4.46827E+00, 1.36318E+01
        END$
```

```
        8$ HEAT RATE ARRAY FOR NODE        7
 3.54313E+02, 3.62014E+02, 1.72706E+01, 2.26450E+01, 3.39721E+01
 3.29420E+01, 2.97325E+01, 3.74476E+02, 3.66962E+02, 3.63871E+02
 3.55089E+02, 3.51386E+02, 3.54313E+02
END$
        9$ HEAT RATE ARRAY FOR NODE        8
 9.67260E+00, 4.93665E+00, 3.39277E+00, 3.26185E+00, 4.29780E+00
 9.09015E+00, 1.16171E+01, 1.31610E+01, 2.14162E+01, 5.85251E+01
 7.01351E+01, 3.90266E+01, 9.67260E+00
END$
```


ABSORBED HEAT FLUX TABLES

```
Q    = INPUT * FMPF  WHERE FMPF =   0.10000E+01
TIME = INPUT * TMPF  WHERE TMPF =   0.10000E+01
AREA IS ON SUBROUTINE CALLS

       10$ HEAT RATE ARRAY FOR NODE        9
 3.66962E+02, 3.74476E+02, 2.97325E+01, 3.29420E+01, 3.39721E+01
 2.26450E+01, 1.72706E+01, 3.62014E+02, 3.54313E+02, 3.51386E+02
 3.55089E+02, 3.63871E+02, 3.66962E+02
END$
       11$ HEAT RATE ARRAY FOR NODE       10
 2.14162E+01, 1.31610E+01, 1.16171E+01, 9.09015E+00, 4.29780E+00
 3.26185E+00, 3.39277E+00, 4.93665E+00, 9.67260E+00, 3.90266E+01
 7.01351E+01, 5.85251E+01, 2.14162E+01
END$
```

TIME AND HEAT FLUX ARRAYS STORED ON MITAS/SINDABCD OUTPUT TAPE IN FILE 2

DA11MC SUBROUTINE CALLS

```
AREA = INPUT (UNITS) * AMPF  WHERE AMPF =  0.10000E+01
DA11MC(1.5306037E+00,TIMEM,A    1,A    2, 1.0000E+00,Q     1)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    3, 2.0000E+00,Q     2)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    4, 2.0000E+00,Q     3)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    5, 2.0000E+00,Q     4)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    6, 2.0000E+00,Q     5)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    7, 1.0000E+00,Q     6)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    8, 2.0000E+00,Q     7)$
DA11MC(1.5306037E+00,TIMEM,A    1,A    9, 2.0000E+00,Q     8)$
DA11MC(1.5306037E+00,TIMEM,A    1,A   10, 2.0000E+00,Q     9)$
DA11MC(1.5306037E+00,TIMEM,A    1,A   11, 2.0000E+00,Q    10)$
```

SUBROUTINE CALL CARDS STORED ON MITAS/SINDA BCD OUTPUT TAPE IN FILE 3

TIME AND CONDUCTOR ARRAYS STORED ON MITAS/SINDA BCD OUTPUT TAPE IN FILE 3

AVERAGE ORBITAL HEATING RATES

```
VALUES ARE    RATE = INPUT (UNITS) * RMPF,  WHERE RMPF =  0.10000E+01
VALUES ARE    AREA = INPUT (UNITS) * AMPF,  WHERE AMPF =  0.10000E+01

M        Q     1= 1.84215973E+01* 1.00000000E+00
M        Q     2= 1.51440683E+01* 2.00000000E+00
M        Q     3= 7.33552320E+01* 2.00000000E+00
M        Q     4= 1.51462344E+01* 2.00000000E+00
M        Q     5= 1.68884121E+01* 2.00000000E+00
M        Q     6= 1.55374595E+01* 1.00000000E+00
M        Q     7= 2.53387710E+02* 2.00000000E+00
M        Q     8= 2.68945613E+01* 2.00000000E+00
M        Q     9= 2.53386705E+02* 2.00000000E+00
M        Q    10= 2.68933116E+01* 2.00000000E+00
```

AVERAGE Q VALUES STORED ON MITAS/SINDA BCD OUTPUT TAPE IN FILE 4

TOTAL TIME TO COMPUTE ABSORBED Q OUT 0.07

0NORMAL TERMINATION BY PROCESSOR

CHAPTER 2: STEADY STATE AND TRANSIENT RADIATION

SECTION 3: Radiation with Convection; Linearization of a Transient Case

ANALYSIS CODE: SINDA (Gaski Version)

I. Preface to the Problem:

This section is included to illustrate the solution to a problem which involves combined radiation and convection. The complete problem has no closed-form solution. The following analysis illustrates the development of user defined differencing equations and incorporation of these equations into SINDA's execution block.

The analysis is performed using several approaches. The problem is first solved using SINDA, in which case an intrinsic differencing scheme is selected and the original form of the problem is solved. Next, a mathematical representation of the physical problem is developed and the radiation conductor is linearized. A differencing formulation of the linearized problem is described. The linearized problem is then modeled using SINDA. Results obtained using SINDA are compared with those obtained by solving the original problem. Next, the problem is formulated without linearizing the radiation conductor. The differencing equation is written in its quartic form and the non-linearized problem is solved using a Newton-Raphson technique. The non-linearized differencing equation is incorporated into SINDA and the resulting solution is compared with previous solutions to the original problem and the linearized problem.

II. Identification of the Problem:

A. Statement of the Problem:

Consider a tank into which fluid has just been introduced. The tank resides in an unspecified environment, at a temperature of -320°F, to which the tank transfers heat via radiative exchange. Initially, the walls of the tank have been heated to a temperature of 300°F. The temperature of the fluid is 100°F. Wall thickness is 0.1ft. The density of the wall material is 170 lbm/ft^3 and the corresponding specific heat is 0.2 Btu/lbm°F. The emissivity of the external surfaces of the tank is 0.8 and the form factor is unity (indicating that the tank is emitting to a hemisphere). The convective heat transfer coefficient between the fluid and the inside surfaces of the tank is 1 Btu/ft^2 hr°F. Find the transient temperature change, T(t), in the walls of the vessel. The tank is depicted in Figure 1.

B. Schematic:

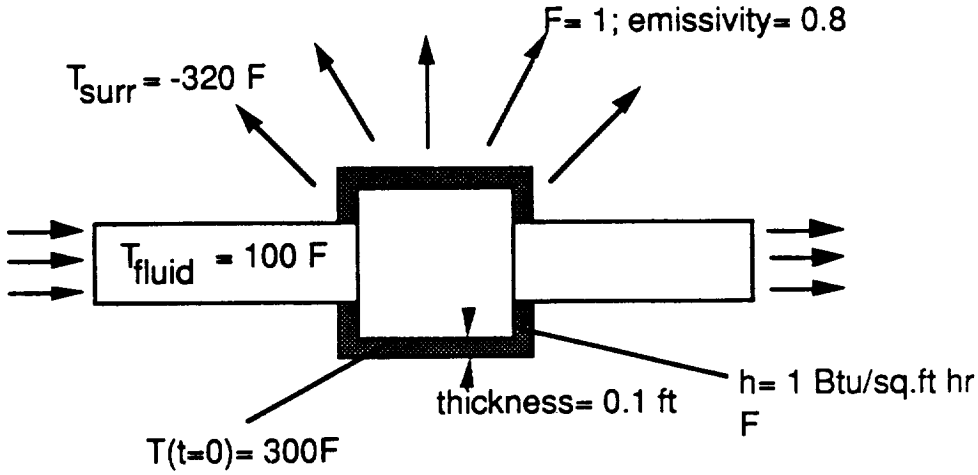

Figure 1. Flow through a pre-heated tank which radiates to its surroundings

C. Given:

1. A vessel with known wall thickness and thermophysical properties
2. Ambient temperature is -320°F.
3. Fluid temperature is 100°F.
4. Emissivity of external tank surfaces is 0.8.
5. View factor is unity (all exposed surfaces).
6. h= 1 Btu/ft^2 hr°F
7. Wall thickness of tank is 0.1 ft.
8. Wall density and specific heat are 170 lbm/ft^3 and 0.2 Btu/lbm°F, respectively.

D. Find:

1. Transient temperature change, T(t), in the tank wall

III. Formulation of the Problem:

A. Assumptions:

1. The wall is assumed to be a sufficiently good conductor of heat such that the temperature is uniform, throughout its thickness, at any instant in time.
2. The desired information may be obtained by considering the tank to be a homogeneous entity which exchanges heat with its surroundings and with the fluid that flows through it.
3. The inside and outside surface areas of the tank are assumed to be the same.
4. Radiative heat loss to the fluid is neglected.
5. The wall is assumed to radiate (or absorb incident radiation) as a graybody, following the Stefan-Boltzmann law of radiation, where the proportionallity constant is the emissivity.

B. Initial/Boundary Conditions:

1. Initial tank temperature is 300°F; i.e. $T(t=0)= 300°F$
2. Fluid temperature is 100°F; i.e. T_f= constant = 100°F
3. Ambient temperature is -320°F.

C. Discretization:

As previously indicated, the analysis is performed by considering the tank as a single entity. Hence, the first law of thermodynamics requires that heat transferred to the tank, via convection, must be balanced by that transferred from the tank, by way of radiation. This statement only holds, of course, once steady state conditions have been reached. For the transient case, the difference between the incoming and outgoing heat fluxes is equal to the energy stored in the walls of the tank.

The physical system is divided into three parts; these include the fluid, the tank wall, and the surroundings. Each part is represented by a node to which is assigned a characteristic thermal capacitance (where applicable) that is proportional to its mass and specific heat. The node which represents the tank is linked to the fluid by a single convection conductor. Similarly, the tank is linked to its external environment by a single radiation conductor. The circuit that represents the physical system is shown in Figure 2.

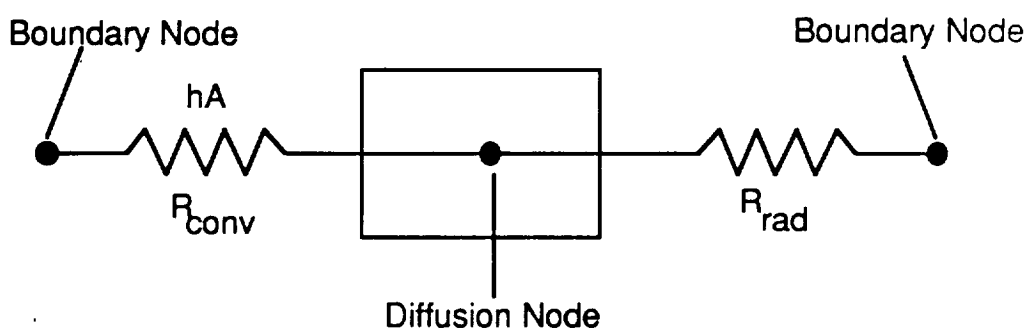

Figure 2. Simple circuit representing the physical system

IV. Analysis:

A. SINDA Solution to the Original Problem:

A SINDA input listing corresponding to the simple three-node model shown in Figure 2 has been included. The subroutine, SNFRDL, has been specified in the EXECUTION block and signals the use of an intrinsic forward differencing form of the diffusion equation. The complete input listing appears on page 2-3-5. Results of the first analysis follow the input listing.

B. Construction of a Linearized Model:

We begin by performing an energy balance on the tank. Where T denotes the temperature of the tank, the heat transferred from the tank to the flowing fluid is given by

$$\dot{q}_{conv} = hA(T_f - T). \tag{1}$$

The heat lost to the surroundings is given by

$$\dot{q}_{rad} = \sigma\varepsilon FA(T_\infty^4 - T^4) \tag{2}$$

and that stored within the walls of the tank is given by

$$\dot{q}_{sto} = \rho V C_p \frac{dT}{dt} \tag{3}$$

Conservation of energy requires that

$$\dot{q}_{sto} = \dot{q}_{conv} + \dot{q}_{rad}$$

from which

$$\rho V C_p \frac{dT}{dt} = hA(T_f - T) + \sigma\varepsilon FA(T_\infty^4 - T^4) \tag{4}$$

Equation (4) defines a first-order, non-linear, ordinary differential equation. The function, T(t), which satisfies (4) is the solution we seek. Suppose that the radiative heat loss is expressed as

$$\sigma\varepsilon FA(T_\infty^4 - T^4) = \sigma\varepsilon FA(T_\infty^2 + T^2)(T_\infty + T)(T_\infty - T) \tag{5}$$

Defining R equal to

$$\sigma\varepsilon AF(T_\infty^2 + T^2)(T_\infty + T)$$

we may re-write (4) in the form of equation (6).

SINDA INPUT LISTING FOR THE ORIGINAL PROBLEM

```
        BCD 3THERMAL LPCS
        END
        BCD 3NODE DATA
            1,300.0,3.4
            -99,-320.0,1.0
            -100,100.0,1.0
        END
        BCD 3CONDUCTOR DATA
            1,1,100,1.0
            -2,1,99,1.3712E-9
        END
        BCD 3CONSTANTS DATA
            DTIMEI=0.01
            DTIMEH=0.01
            NLOOP=100
            TIMEND=10.0
            OUTPUT=0.1
            ARLXCA=0.01
            DRLXCA =0.01
            TIMEO=0.0
            DAMPA=0.5
            DAMPD=0.5
            NDIM=1000
        END
        BCD 3ARRAY DATA
        END
        BCD 3EXECUTION
            SNFRDL
        END
        BCD 3VARIABLES 1
        END
        BCD 3VARIABLES 2
        END
        BCD 3OUTPUT CALLS
F       CALL TPRINT
        END
        BCD 3END OF DATA
```

SINDA OUTPUT LISTING FOR THE ORIGINAL PROBLEM

```
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*** NOTE *** SNFRDL REQUIRES       4 DYNAMIC STORAGE LOCATIONS OUT OF     995 AVAILABLE ***
             TIMEND=  10.000     , CSGFAC=  1.0000     , DTIMEI= 0.10000E-01, NLOOP =          100
             TIMEO = 0.00000     , OUTPUT= 0.10000     , DTIMEH= 0.10000E-01, DTIMEL= 0.00000
             ARLXCA= 0.10000E-01, ATMPCA= 0.10000E+09, DRLXCA= 0.10000E-01, DTMPCA= 0.10000E+09

****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  300.0000 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.01114E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.80002E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  281.5175 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.06312E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.01385E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  264.7260 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.11088E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.32822E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  249.4023 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.15483E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.72561E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  235.3640 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.19536E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.19233E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  222.4591 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.23278E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.71751E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  210.5605 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.26739E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.29244E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  199.5603 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 8.00000E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.29945E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.91005E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  189.3663 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 8.99999E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.32918E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.56455E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  179.8989 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 9.99999E-01, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.35679E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.25115E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  171.0898 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.10000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.38247E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.96584E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  162.8786 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.20000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.40638E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.70525E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  155.2125 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.30000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.42866E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.46655E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  148.0453 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.40000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.44945E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.24730E-01
    LOOPCT=      0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  141.3356 T     99 = -320.0000 T    100 =  100.0000 T
```

```
****************
TIME= 1.50000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.46886E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.04542E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  135.0466 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.60000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.48701E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.85909E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  129.1455 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 1.70000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.50400E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.68678E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  123.6027 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.80000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.51991E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.52711E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  118.3917 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 1.90000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.53482E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.37890E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  113.4882 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.00000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.54881E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.24110E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  108.8705 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.10000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.56194E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.11277E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  104.5187 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.20000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.57427E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.99310E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =  100.4149 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.30000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.58587E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.88136E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   96.5423 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.40000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.59678E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.77690E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   92.8857 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.50000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.60705E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.67912E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   89.4313 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 2.60000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.61673E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.58752E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   86.1660 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.70000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.62584E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.50160E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   83.0782 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.80000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.63444E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.42095E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   80.1569 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 2.90000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.64255E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.34518E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   77.3919 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.00000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.65020E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.27392E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   74.7739 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.10000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.65743E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.20688E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   72.2941 T     99 = -320.0000 T    100 =  100.0000 T
```

```
****************
TIME= 3.20000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.66426E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.14374E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   69.9444 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.30000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.67071E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.08425E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   67.7173 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.40000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.67681E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.02815E-01
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   65.6057 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 3.50000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.68258E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-9.75227E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   63.6031 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.60000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.68805E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-9.25270E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   61.7034 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.70000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.69321E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.78089E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   59.9008 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.80000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.69811E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.33503E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   58.1898 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 3.90000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.70274E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.91356E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   56.5656 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.00000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.70713E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.51496E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   55.0234 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.10000E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.71129E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.13782E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   53.5587 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.20001E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.71524E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.78086E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   52.1674 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.30001E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.71898E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.44284E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   50.8454 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 4.40001E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.72253E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.12268E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   49.5893 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.50001E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.72589E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.81934E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   48.3955 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.60002E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.72909E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.53183E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   47.2608 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.70002E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.73212E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.25926E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   46.1820 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 4.80002E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.73499E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.00078E-
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E-

T      1 =   45.1564 T     99 = -320.0000 T    100 =  100.0000 T
```

```
****************
TIME= 4.90002E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.73773E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.75559E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   44.1811 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.00002E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.74032E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.52295E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   43.2535 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.10003E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.74278E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.30218E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   42.3713 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.20003E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.74512E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.09263E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   41.5321 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 5.30003E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.74735E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.89366E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   40.7337 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.40003E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.74946E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.70473E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   39.9742 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.50004E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.75147E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.52528E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   39.2514 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.60004E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.75338E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.35481E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   38.5636 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.70004E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.75519E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.19284E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   37.9091 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.80004E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.75692E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.03894E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   37.2862 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 5.90004E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.75856E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.89266E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   36.6932 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.00005E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76012E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.75360E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   36.1288 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.10005E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76160E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.62142E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   35.5914 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 6.20005E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76301E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.49572E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   35.0799 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.30005E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76436E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.37619E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   34.5928 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.40006E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76563E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.26252E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   34.1291 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.50006E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76685E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.15442E-02
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   33.6876 T     99 = -320.0000 T    100 =  100.0000 T
```

```
****************
TIME= 6.60006E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76801E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-2.05158E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   33.2671 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.70006E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.76911E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.95374E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   32.8667 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.80007E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77015E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.86066E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   32.4854 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 6.90007E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77115E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.77208E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   32.1223 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.00007E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77210E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.68779E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   31.7764 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 7.10007E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77300E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.60758E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   31.4470 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.20007E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77386E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.53122E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   31.1331 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.30008E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77468E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.45855E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   30.8342 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.40008E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77546E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.38938E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   30.5495 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.50008E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77620E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.32353E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   30.2783 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.60008E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77691E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.26085E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   30.0200 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.70009E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77758E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.20117E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   29.7738 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.80009E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77822E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.14435E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   29.5394 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 7.90009E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77883E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.09024E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   29.3160 T     99 = -320.0000 T    100 =  100.0000 T
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****************
TIME= 8.00009E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77941E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-1.03873E-02
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   29.1032 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 8.10009E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.77997E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-9.89668E-03
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   28.9005 T     99 = -320.0000 T    100 =  100.0000 T

****************
TIME= 8.20010E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78050E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-9.42936E-03
    LOOPCT=     0                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   28.7072 T     99 = -320.0000 T    100 =  100.0000 T
```

```
*****************
TIME= 8.30010E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78100E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.98426E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   28.5231 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 8.40010E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78148E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.56046E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   28.3477 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 8.50010E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78193E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-8.15676E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   28.1806 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 8.60011E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78237E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.77226E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   28.0213 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 8.70011E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78278E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.40605E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.8696 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 8.80011E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78317E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-7.05717E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.7250 T     99 = -320.0000 T    100 =  100.0000 T
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*****************
TIME= 8.90011E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78355E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.72491E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.5872 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.00012E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78391E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.40847E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.4560 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.10012E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78425E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-6.10687E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.3308 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.20012E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78457E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.81961E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.2116 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.30012E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78488E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.54591E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   27.0980 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.40012E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78517E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.28505E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.9897 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.50013E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78546E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-5.03663E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.8865 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.60013E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78572E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.79993E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.7882 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.70013E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78598E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.57450E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.6945 T     99 = -320.0000 T    100 =  100.0000 T
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*****************
TIME= 9.80013E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78622E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.35957E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.6052 T     99 = -320.0000 T    100 =  100.0000 T

*****************
TIME= 9.90014E+00, DTIMEU= 5.00000E-03, CSGMIN(      1)= 2.78645E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-4.15481E-03
    LOOPCT=     0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.5201 T     99 = -320.0000 T    100 =  100.0000 T
```

```
****************
TIME= 1.00000E+01, DTIMEU= 4.86183E-03, CSGMIN(      1)= 2.78667E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=-3.85034E-03
    LOOPCT=      0                                                  , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T      1 =   26.4391 T     99 = -320.0000 T    100 =  100.0000 T
```

$$\rho V C_p \frac{dT}{dt} = \frac{1}{\rho V C_p}\left[hA(T_f - T) + R(T_\infty - T)\right] \tag{6}$$

Multiplying both sides of (6) by the reciprocal of the capacitance then gives

$$\frac{dT}{dt} = \frac{1}{\rho V C_p}\left[hA(T_f - T) + R(T_\infty - T)\right] \tag{7}$$

which is now a linear differential equation, in T, that describes the transient cool down of the tank.

C. The Linearized Difference Formulation:

The difference form of equation (7) is easily written. The change in temperature, with respect to the change in time, is expressed as a function of (T + delta T), where T denotes the temperature of the tank, prior to the time step, delta-t.

$$\frac{\Delta T}{\Delta t} = \frac{1}{\rho V C_p}\left\{hA\left[T_f - (T + \Delta T)\right] + R\left[T_\infty - (T + \Delta T)\right]\right\} \tag{8}$$

Multiplying both sides of (8) by delta-t and expanding the result gives

$$\Delta T = \frac{\Delta t}{\rho V C_p}\left[hA(T_f - T) + R(T_\infty - T)\right] - \frac{\Delta t}{\rho V C_p}(hA + R)\Delta T \tag{9}$$

from which

$$\Delta T + \frac{\Delta t}{\rho V C_p}(hA + R)\Delta T = \frac{\Delta t}{\rho V C_p}\left[hA(T_f - T) + R(T_\infty - T)\right] \tag{10}$$

or

$$\Delta T\left[1 + \frac{\Delta t}{\rho V C_p}(hA + R)\right] = \frac{\Delta t}{\rho V C_p}\left[hA(T_f - T) + R(T_\infty - T)\right] \tag{11}$$

Isolating delta-T on the left side of the equation gives

$$\Delta T = \frac{\frac{\Delta t}{\rho V C_p}\left[hA(T_f - T) + R(T_\infty - T)\right]}{\left[1 + \frac{\Delta t}{\rho V C_p}(hA + R)\right]} \tag{12}$$

So then, equation (12), referred to as the linearized differencing form, may be used to determine delta-T provided that we have a known temperature preceding a given time step. Thus, we may determine the temperature history of the tank.

D. Solution to the Linearized Problem:

The SINDA input file that is used to analyze the linearized problem appears on pages 2-3-15 through 2-3-17. The file is not particularly complex and contains only two sections which warrant special discussion. First, the preceding differencing equation has been coded in the execution block. It is important to note that SINDA is nothing more than a finite difference based thermal solver that employs a number of intrinsic differencing schemes. The user may chose from the available options or may elect to write and implement any particular differencing equation. The ability to implement ones own equation adds a great deal of flexibility to SINDA. The second section of the file which warrants brief mention is the output block, in which three-column output has been specified. The short segments of code contained therein were user supplied and were included for the purpose of formatting the output, as desired.

Results obtained using SINDA are listed on pages 2-3-18 through 2-3-24 and have been graphically represented in Figure 3.

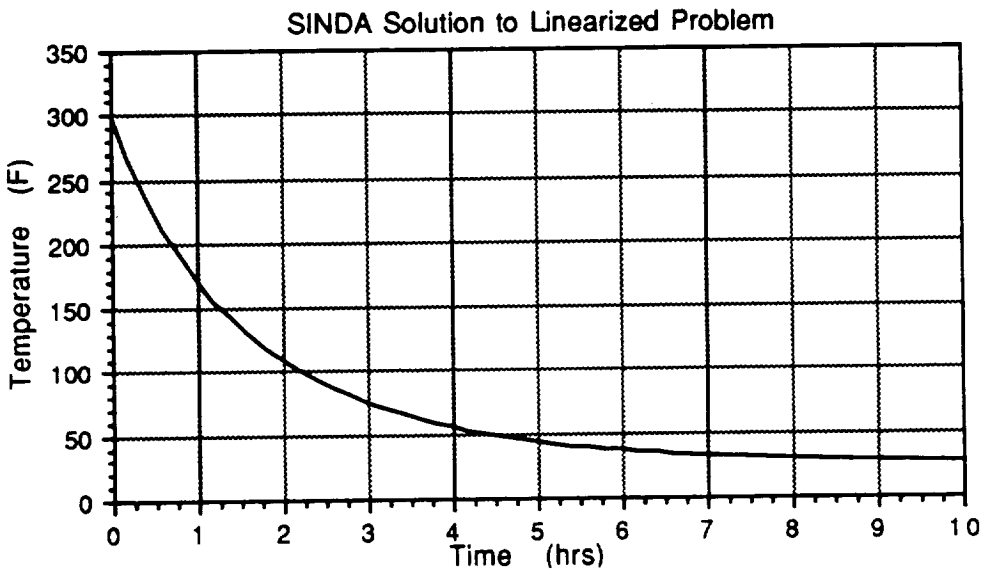

Figure 3. SINDA solution to the linearized problem

SINDA INPUT FILE, LINEARIZED CASE

```
          BCD 3THERMAL LPCS
          BCD 3TEST. PC-SINDA
          END
C
          BCD 3NODE DATA
              1, 300.0, 3.4
              -99, -320.0, 1.0
              -100, 100.0, 1.0
C
          END
C
          BCD 3CONDUCTOR DATA
C
              1, 1, 100, 1.0
              -2, 1, 99, 1.3712E-9
C
          END
C
          BCD 3CONSTANTS DATA
              DTIMEI,0.01
              DTIMEH,0.01
              NLOOP,100
C
              TIMEND,10.0
              OUTPUT,0.1
C
              ARLXCA,.01
              DRLXCA,.01
              TIMEO,0.0
              DAMPA,0.5
              DAMPD,0.5
              NDIM,1000
C
          END
C
          BCD 3ARRAY DATA
          END
C
          BCD 3EXECUTION
C
F         OPEN(3,FILE="EMLFLT.PLT",STATUS="UNKNOWN")
F         WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F       2 FORMAT(I6/,250(I6,31X,I6/))
C
CF        CALL SNFRDL
C
CF        GO TO 500
C
C BEGIN DIFFERENCING SOLUTION
C
F         SIGMA=0.1714E-8
F         AREA=1.0
F         EM=0.8
F         VF=1.0
F         XH=1.0
F         RHO=170.0
F         VOL=0.1
F         CP=0.2
C
M         T(1)=760.0
M         T99=140.0
```

```
M       T100=560.0
F       TIME=0.0
F       DTIMEU=0.01
M       TEMP=T(1)-460.0
F       WRITE(6,25)TIME,TEMP
F 25    FORMAT(1X,2(F12.4,2X))
C
F       GX=XH*AREA
F       CAP=RHO*VOL*CP
F       R=SIGMA*EM*VF*AREA
M       TS1=T1
M       TS2=T99
M       TS3=T100
M       T1=T1-460.
M       T99=T99-460.
M       T100=T100-460.
F       TIMEN=TIME
F       CALL OUTCAL
M       T1=TS1
M       T99=TS2
M       T100=TS3
F 1     TIME=TIME+DTIMEU
M       RX=R*(T(99)**2+T(1)**2)*(T(99)+T(1))
M       DELT=(DTIMEU/CAP)*(GX*(T100-T1)+RX*(T99-T1))
M       DELT=DELT/(1.+(DTIMEU/CAP)*(GX+RX))
M       T1=T1+DELT
CM       ANSWR=T1-460.
CM       WRITE(6,25)TIME,ANSWR
M       TS1=T1
M       TS2=T99
M       TS3=T100
M       T1=T1-460.
M       T99=T99-460.
M       T100=T100-460.
F       TIMEN=TIME
F       IF(AMOD(TIME,0.1).LT.0.01)CALL OUTCAL
M       T1=TS1
M       T99=TS2
M       T100=TS3
F       IF(TIME.GT.10.0)GO TO 500
F       GO TO 1
F 500   CONTINUE
C
        END
        BCD 3VARIABLES 1
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
F       WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F    1 FORMAT(E10.3/,250(7F9.3/))
C
CF       CALL TPRINT
CF       CALL TDUMP
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
CF       IF(LNODE.EQ.0)CALL NNREAD(1)
F       IF(NPAGE.EQ.0 .OR. NLINE.GE.56)CALL TPLIN
```

```
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F  9    FORMAT(/,11H **********/6H TIME=F12.5,8X,
F     $          8H DTIMEU=1PE12.6,
F     $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,
F     $          8H TEMPCC(I6,2H)=1PE12.5,
F     $          8H RELXCC(I6,2H)=1PE12.5)
F       NLINE=NLINE+4
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       NLINE=NLINE+1
F       J=1
F       L=3
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F       IF(NLINE.LE.56)GO TO 15
F       CALL TPLIN
F       WRITE(6,100)
F  15   NLINE=NLINE+1
F       IF(L.EQ.NNT)RETURN
F       J=L+1
F       L=L+3
F       GO TO 5
F       END
C
C THREE COLUMN OUTPUT PAGE ROUTINE
C
F       SUBROUTINE TPLIN
F       WRITE(6,100)
F 100   FORMAT(//////,1X,'GASKI PC-SINDA, THREE COLUMN',
F     $         ' OUTPUT',/)
F       CALL TOPLIN
CF       RETURN
        END
        BCD 3END OF DATA
```

SINDA OUTPUT LISTING, LINEARIZED CASE

```
(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      1

    TEST. PC-SINDA
      0.0000       300.0000

**********
TIME=      0.00000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   300.00000  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.11000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   279.85830  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.20000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   264.87800  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.31000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   248.15420  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.41000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   234.27800  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.51000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   221.51320  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.61000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   209.73610  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.71000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   198.84170  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.81000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   188.74050  T    99=  -320.00000  T   100=   100.00000


 GASKI PC-SINDA, THREE COLUMN OUTPUT
1(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      2

    TEST. PC-SINDA

 **********
 TIME=      0.91000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

 T     1=   179.35480  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=      1.01000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

 T     1=   170.61760  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=      1.11000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

 T     1=   162.47000  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=      1.21000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

 T     1=   154.86040  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=      1.31000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

 T     1=   147.74330  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=      1.41000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00
```

```
T     1=   141.07820  T    99= -320.00000  T   100=   100.00000

**********
TIME=     1.51000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   134.82890  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     1.61000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   128.96310  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     1.71000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   123.45200  T    99=  -320.00000  T   100=   100.00000
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

```
1(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      3

    TEST. PC-SINDA

**********
TIME=     1.81000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   118.26900  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     1.91000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   113.39090  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.01000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   108.79570  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.11000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   104.46420  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.21000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=   100.37830  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.31000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    96.52179  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.41000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    92.87946  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.51000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    89.43774  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.61000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    86.18402  T    99=  -320.00000  T   100=   100.00000
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

```
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    TEST. PC-SINDA

**********
TIME=     2.71000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    83.10626  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.81000          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    80.19379  T    99=  -320.00000  T   100=   100.00000
```

```
**********
TIME=      2.91000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     77.43671  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.01000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     74.82556  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.11000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     72.35181  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.21000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     70.00745  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.31000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     67.78491  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.41000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     65.67731  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.51000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     63.67804  T     99=  -320.00000  T   100=   100.00000
```



```
**********
TIME=      3.61000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     61.78113  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.71000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     59.98083  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.81000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     58.27185  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      3.91000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     56.64911  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      4.01000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     55.10803  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      4.11000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     53.64410  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      4.20000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     52.38916  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      4.30000          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     51.06082  T     99=  -320.00000  T   100=   100.00000

**********
TIME=      4.40001          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=     49.79837  T     99=  -320.00000  T   100=   100.00000
```

TEST. PC-SINDA

```
**********
TIME=     4.50001          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    48.59836  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.60001          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    47.45758  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.70001          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    46.37292  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.80001          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    45.34146  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.90002          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    44.36047  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.00002          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    43.42740  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.10002          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    42.53973  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.20002          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    41.69519  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.30003          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    40.89169  T    99=  -320.00000  T   100=   100.00000
```


TEST. PC-SINDA

```
**********
TIME=     5.40003          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    40.12708  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.50003          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    39.39938  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.60003          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    38.70685  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.70004          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    38.04767  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.80004          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    37.42017  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.90004          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00
```

```
T     1=    36.82285  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.00004          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    36.25409  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.10004          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    35.71259  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.20005          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    35.19696  T    99=  -320.00000  T   100=   100.00000
```



```
**********
TIME=     6.30005          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    34.70602  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.40005          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    34.23846  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.50005          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    33.79324  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.60006          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    33.36920  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.70006          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    32.96527  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.80006          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    32.58060  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     6.90006          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    32.21417  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     7.00007          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    31.86514  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     7.10007          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    31.53262  T    99=  -320.00000  T   100=   100.00000
```



```
**********
TIME=     7.20007          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    31.21591  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     7.30007          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                  TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    30.91412  T    99=  -320.00000  T   100=   100.00000
```

```
**********
TIME=      7.40007          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    30.62659  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      7.50008          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    30.35269  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      7.60008          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    30.09167  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      7.70008          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    29.84296  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      7.80008          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    29.60602  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      7.90009          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    29.38025  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.00009          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    29.16513  T    99=  -320.00000  T   100=   100.00000
```



```
**********
TIME=      8.10009          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    28.96014  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.20009          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    28.76480  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.30009          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    28.57864  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.40010          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    28.40125  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.50010          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    28.23218  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.60010          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    28.07104  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.70010          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    27.91748  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.80011          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    27.77115  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      8.90011          DTIMEU=1.000000E-02 CSGMIN(      0)= 0.00000E+00
                   TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=    27.63165  T    99=  -320.00000  T   100=   100.00000
```

```
GASKI PC-SINDA, THREE COLUMN OUTPUT
1(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE     11
    TEST. PC-SINDA
**********
TIME=     9.00011          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    27.49872  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.10011          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    27.37207  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.20012          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    27.25131  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.30012          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    27.13620  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.40012          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    27.02649  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.50012          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    26.92194  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.60012          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    26.82227  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.70013          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    26.72723  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     9.80013          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    26.63669  T    99=  -320.00000  T   100=   100.00000


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    TEST. PC-SINDA
**********
TIME=     9.90013          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    26.55038  T    99=  -320.00000  T   100=   100.00000

**********
TIME=    10.00013          DTIMEU=1.000000E-02 CSGMIN(     0)= 0.00000E+00
                   TEMPCC(     0)= 0.00000E+00 RELXCC(     0)= 0.00000E+00

T     1=    26.46814  T    99=  -320.00000  T   100=   100.00000
```

E. The Non-linearized Difference Formulation:

We begin, once again, with the general form of the differential equation, (4) In this case, however, we will maintain the radiation term in its original form. Instead of expanding the radiation term, as was done in equation (5), the convection and radiation terms are expanded to obtain equation (13).

$$\rho V C_p \frac{dT}{dt} = hAT_f - hAT + \sigma\varepsilon AFT_\infty^4 - \sigma\varepsilon AFT^4 \tag{13}$$

Equation (13) may be re-written in the alternate form of (14)

$$\rho V C_p \frac{dT}{dt} = \sigma\varepsilon AF\left[\frac{hAT_f}{\sigma\varepsilon AF} - \frac{hAT}{\sigma\varepsilon AF} + T_\infty^4 - T^4\right] \tag{14}$$

Multiplying both sides of (14) by the reciprocal of the thermal capacitance and re-ordering terms yields

$$\frac{dT}{dt} = \frac{-\sigma\varepsilon AF}{\rho V C_p}\left[\frac{hA}{\sigma\varepsilon AF}T - \frac{hA}{\sigma\varepsilon AF}T_f + T^4 - T_\infty^4\right] \tag{15}$$

or

$$\frac{dT}{dt} = \frac{-\sigma\varepsilon AF}{\rho V C_p}\left[T^4 + \frac{hA}{\rho V C_p}T - \frac{hA}{\rho V C_p}T_f - T_\infty^4\right] \tag{16}$$

Defining the constant, C_1, by

$$C_1 = \frac{hA}{\sigma\varepsilon AF} \tag{17}$$

and C_2 by

$$C_2 = \frac{-hA}{\sigma\varepsilon AF}T_f - T_\infty^4 \tag{18}$$

and k by

$$k = \frac{-\sigma\varepsilon AF}{\rho V C_p} \tag{19}$$

we may write (19) in the form of equation (20).

$$\frac{dT}{dt} = k\left[T^4 + C_1 T + C_2\right] \tag{20}$$

The differencing form of (20) becomes

$$\frac{\Delta T}{\Delta t} = k\left[(T + \Delta T)^4 + C_1(T + \Delta T) + C_2\right]$$

or

$$\frac{\Delta T}{\Delta t} = k\left[T^4 + 4T^3\Delta T + 6T^2\Delta T^2 + 4T\Delta T^3 + \Delta T^4 + C_1T + C_1\Delta T + C_2\right]$$

or

$$\frac{1}{k}\frac{\Delta T}{\Delta t} = \left[\Delta T^4 + 4T\Delta T^3 + 6T^2\Delta T^2 + (4T^3 + C_1)\Delta T + (C_1T + C_2 + T^4)\right]$$

or

$$0 = \Delta T^4 + 4T\Delta T^3 + 6T^2\Delta T^2$$

$$+ (4T^3 + C_1 - 1/k\Delta t)\Delta T + (C_1T + C_2 + T^4) \qquad (21)$$

Suppose that we now define p,q,r, and s using equations (22),(23),(24), and (25), respectively.

$$p = 4T \qquad (22)$$

$$q = 6T^2 \qquad (23)$$

$$r = 4T^3 + C_1 - 1/k\Delta t \qquad (24)$$

$$s = C_1T + C_2 + T^4 \qquad (25)$$

Substitution of the aforementioned equations into (21) gives

$$0 = \Delta T^4 + p\Delta T^3 + q\Delta T^2 + r\Delta T + s \qquad (26)$$

which is easily recognized as a bi-quadratic equation, in T. While we do not have delta-T as an explicit function of delta-t, as in the linearized case, we have produced an equation that defines four values of delta-T for each value of delta-t. Presumably, we will find that only one of the four values is physically possible.

One approach to solving (26) is to apply a Newton-Raphson technique. This approach requires iteration to determine when the "new" and "old" values of delta-T are sufficiently close to one another. Values of delta-T are updated using

$$\Delta T_{new} = \Delta T_{old} - \frac{f(\Delta T)}{f'(\Delta T)} \qquad (27)$$

The function, f, is defined by (26), from which f ' is given by

$$f'(\Delta T) = 4\Delta T^3 + 3p\Delta T^2 + 2q\Delta T + r \qquad (28)$$

While the technique may be cumbersome to apply, it is straight-forward and generally converges quickly.

F. Solution to the Non-linearized Problem:

As was done for the linearized problem, a SINDA input file was generated for the non-linearized problem. Once again, a user defined differencing equation has been coded in the execution block. In this case, however, the differencing equation is non-linear and is somewhat more complex than it was in the previous case.

Results obtained appear on the following pages and have been plotted in Figure 4. All solutions to the problem have been plotted in Figure 5, from which it is clear that agreement is acceptable.

V. Presentation of Results:

A. SINDA Results:

Presented in part IV

B. Exact Solution:

None Available for this problem

SINDA INPUT LISTING FOR THE NON-LINEARIZED CASE

```
      BCD 3THERMAL LPCS
      BCD 9TEST, PC-SINDA
      END
C
      BCD 3NODE DATA
C
          1, 300.0, 3.4
          -99, -320.0, 1.0
          -100, 100.0, 1.0
C
      END
C
      BCD 3CONDUCTOR DATA
C
          1, 1, 100, 1.0
          -2, 1, 99, 1.3712E-9
C
      END
C
      BCD 3CONSTANTS DATA
          DTIMEI,0.01
          DTIMEH,0.01
          NLOOP,100
C
          TIMEND,10.0
          OUTPUT,0.1
C
          ARLXCA,.01
          DRLXCA,.01
          TIMEO,0.0
          DAMPA,0.5
          DAMPD,0.5
          NDIM,1000
C
      END
C
      BCD 3ARRAY DATA
      END
C
      BCD 3EXECUTION
C
F     OPEN(3,FILE="EMLFLT.PLT",STATUS="UNKNOWN")
F     WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F   2 FORMAT(I6/,250(I6,31X,I6/))
C
CF      CALL SNFRDL
C
CF      GO TO 500
C
C BEGIN BIQUADRATIC SOLUTION
C
F       SIGMA=0.1714E-8
F       AREA=1.0
F       EM=0.8
F       VF=1.0
F       XH=1.0
F       RHO=170.0
F       VOL=0.1
F       CP=0.2
```

```
C
C
C
C
C
C
C
C
M       T(1)=760.0
M       T99=140.0
M       T100=560.0
F       TIMEO=0.0
F       DTIMEU=0.01
F       TIME=0.0
M       TS1=T1
M       TS2=T99
M       TS3=T100
M       T1=T1-460.
M       T99=T99-460.
M       T100=T100-460.
F       TIMEN=TIME
F       CALL OUTCAL
M       T1=TS1
M       T99=TS2
M       T100=TS3
C
F 1     TIME=TIME+DTIMEU
F       CK1=XH*AREA/(SIGMA*VF*EM*AREA)
M       CK2=-1.0*XH*AREA*T100/(SIGMA*EM*VF*AREA)
M       CK2=CK2-T99**4
F       ZK=-1.0*SIGMA*EM*VF*AREA/(RHO*VOL*CP)
M       XP=4.0*T1
M       XQ=6.0*T1**2
M       XR=4.0*T1**3+CK1-1.0/(ZK*DTIMEU)
M       XS=T1**4+CK1*T1+CK2
F       DELT=0.0
F 55    DERIV=4.0*DELT**3+3*XP*DELT**2+2.*XQ*DELT+XR
F       VALUE=DELT**4+XP*DELT**3+XQ*DELT**2+XR*DELT+XS
F       DTLAST=DELT
F       DELT=DELT-VALUE/DERIV
F       ERROR=DELT-DTLAST
F       IF(ERROR.LT.1.E-6)GO TO 60
F       GO TO 55
M 60    T(1)=T(1)+DELT
M       TS1=T1
M       TS2=T99
M       TS3=T100
M       T1=T1-460.
M       T99=T99-460.
M       T100=T100-460.
F       TIMEN=TIME
F       IF(AMOD(TIMEN,0.1).LT.0.01)CALL OUTCAL
M       T1=TS1
M       T99=TS2
M       T100=TS3
F       IF(TIME.GT.10.0)GO TO 500
F       GO TO 1
F 500   CONTINUE
C
        END
        BCD 3VARIABLES 1
        END
C
        BCD 3VARIABLES 2
```

```
      END
C
C
C
C
C
C
C
C
C
C
C
C
C
C
      BCD 3OUTPUT CALLS
C
F     DATA HT/4HT   /
C
F     WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F   1 FORMAT(E10.3/,250(7F9.3/))
C
CF     CALL TPRINT
CF     CALL TDUMP
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
CF     IF(LNODE.EQ.0)CALL NNREAD(1)
F     IF(NPAGE.EQ.0 .OR. NLINE.GE.56)CALL TPLIN
F     J=LNODE+NCSGMN
F     I1=NX(J)
F     IF(J.LE.LNODE)I1=0
F     J=LNODE+NDTMPC
F     I2=NX(J)
F     IF(J.LE.LNODE)I2=0
F     J=LNODE+NARLXC
F     I3=NX(J)
F     IF(J.LE.LNODE)I3=0
F     WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F  9  FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F    $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F    $          8H RELXCC(I6,2H)=1PE12.5)
F     NLINE=NLINE+4
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F     WRITE(6,100)
F 100 FORMAT(1H )
F     NLINE=NLINE+1
F     J=1
F     L=3
F   5 IF(L.LT.NNT)GO TO 10
F     L=NNT
F  10 WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101 FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F     IF(NLINE.LE.56)GO TO 15
F     CALL TPLIN
F     WRITE(6,100)
F  15 NLINE=NLINE+1
F     IF(L.EQ.NNT)RETURN
F     J=L+1
F     L=L+3
F     GO TO 5
F     END
C
```

```
C THREE COLUMN OUTPUT PAGE ROUTINE
C
F       SUBROUTINE TPLIN
F       WRITE(6,100)
F 100   FORMAT(//////,1X,'GASKI PC-SINDA, THREE COLUMN OUTPUT',/)
F       CALL TOPLIN
C       RETURN
        END
        BCD 3END OF DATA
```

SINDA OUTPUT LISTING, NON-LINEARIZED CASE

```
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    TEST. PC-SINDA

*** NOTE *** SNFRDL REQUIRES      4 DYNAMIC STORAGE LOCATIONS OUT OF    995 AVAILABLE ***
             TIMEND=  10.000    , CSGFAC=  1.0000    , DTIMEI= 0.10000E-01, NLOOP =          100
             TIMEO = 0.00000    , OUTPUT= 0.10000    , DTIMEH= 0.10000E-01, DTIMEL= 0.00000
             ARLXCA= 0.10000E-01, ATMPCA= 0.10000E+09, DRLXCA= 0.10000E-01, DTMPCA= 0.10000E+09

**********
TIME=      0.00000          DTIMEU=0.000000E+00 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T     1=   300.00000  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.10000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.01114E+00
                     TEMPCC(      1)=-8.80002E-01 RELXCC(      0)= 0.00000E+00

T     1=   281.51750  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.20000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.06312E+00
                     TEMPCC(      1)=-8.01385E-01 RELXCC(      0)= 0.00000E+00

T     1=   264.72600  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.30000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.11088E+00
                     TEMPCC(      1)=-7.32822E-01 RELXCC(      0)= 0.00000E+00

T     1=   249.40230  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.40000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.15483E+00
                     TEMPCC(      1)=-6.72561E-01 RELXCC(      0)= 0.00000E+00

T     1=   235.36400  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.50000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.19536E+00
                     TEMPCC(      1)=-6.19233E-01 RELXCC(      0)= 0.00000E+00

T     1=   222.45910  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.60000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.23278E+00
                     TEMPCC(      1)=-5.71751E-01 RELXCC(      0)= 0.00000E+00

T     1=   210.56050  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.70000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.26739E+00
                     TEMPCC(      1)=-5.29244E-01 RELXCC(      0)= 0.00000E+00

T     1=   199.56030  T    99=  -320.00000  T   100=   100.00000
```

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    TEST. PC-SINDA

**********
TIME=      0.80000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.29945E+00
                     TEMPCC(      1)=-4.91005E-01 RELXCC(      0)= 0.00000E+00

T     1=   189.36630  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      0.90000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.32918E+00
                     TEMPCC(      1)=-4.56455E-01 RELXCC(      0)= 0.00000E+00

T     1=   179.89890  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.00000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.35679E+00
                     TEMPCC(      1)=-4.25115E-01 RELXCC(      0)= 0.00000E+00

T     1=   171.08980  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.10000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.38247E+00
                     TEMPCC(      1)=-3.96584E-01 RELXCC(      0)= 0.00000E+00

T     1=   162.87860  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.20000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.40638E+00
                     TEMPCC(      1)=-3.70525E-01 RELXCC(      0)= 0.00000E+00

T     1=   155.21250  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.30000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.42866E+00
                     TEMPCC(      1)=-3.46655E-01 RELXCC(      0)= 0.00000E+00

T     1=   148.04530  T    99=  -320.00000  T   100=   100.00000

**********
```

```
TIME=      1.40000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.44945E+00
                   TEMPCC(      1)=-3.24730E-01 RELXCC(      0)= 0.00000E+00

T     1=   141.33560  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.50000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.46886E+00
                   TEMPCC(      1)=-3.04542E-01 RELXCC(      0)= 0.00000E+00

T     1=   135.04660  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.60000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.48701E+00
                   TEMPCC(      1)=-2.85909E-01 RELXCC(      0)= 0.00000E+00

T     1=   129.14550  T    99=  -320.00000  T   100=   100.00000
```

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    TEST. PC-SINDA

**********
TIME=      1.70000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.50400E+00
                   TEMPCC(      1)=-2.68678E-01 RELXCC(      0)= 0.00000E+00

T     1=   123.60270  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.80000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.51991E+00
                   TEMPCC(      1)=-2.52711E-01 RELXCC(      0)= 0.00000E+00

T     1=   118.39170  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      1.90000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.53482E+00
                   TEMPCC(      1)=-2.37890E-01 RELXCC(      0)= 0.00000E+00

T     1=   113.48820  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.00000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.54881E+00
                   TEMPCC(      1)=-2.24110E-01 RELXCC(      0)= 0.00000E+00

T     1=   108.87050  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.10000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.56194E+00
                   TEMPCC(      1)=-2.11277E-01 RELXCC(      0)= 0.00000E+00

T     1=   104.51870  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.20000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.57427E+00
                   TEMPCC(      1)=-1.99310E-01 RELXCC(      0)= 0.00000E+00

T     1=   100.41490  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.30000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.58587E+00
                   TEMPCC(      1)=-1.88136E-01 RELXCC(      0)= 0.00000E+00

T     1=    96.54230  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.40000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.59678E+00
                   TEMPCC(      1)=-1.77690E-01 RELXCC(      0)= 0.00000E+00

T     1=    92.88574  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.50000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.60705E+00
                   TEMPCC(      1)=-1.67912E-01 RELXCC(      0)= 0.00000E+00

T     1=    89.43127  T    99=  -320.00000  T   100=   100.00000
```

```
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    TEST. PC-SINDA

**********
TIME=      2.60000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.61673E+00
                   TEMPCC(      1)=-1.58752E-01 RELXCC(      0)= 0.00000E+00

T     1=    86.16602  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.70000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.62584E+00
                   TEMPCC(      1)=-1.50160E-01 RELXCC(      0)= 0.00000E+00

T     1=    83.07825  T    99=  -320.00000  T   100=   100.00000

**********
TIME=      2.80000          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.63444E+00
                   TEMPCC(      1)=-1.42095E-01 RELXCC(      0)= 0.00000E+00
```

```
T     1=    80.15692  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     2.90000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.64255E+00
                  TEMPCC(     1)=-1.34518E-01 RELXCC(     0)= 0.00000E+00

T     1=    77.39191  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.00000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.65020E+00
                  TEMPCC(     1)=-1.27392E-01 RELXCC(     0)= 0.00000E+00

T     1=    74.77386  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.10000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.65743E+00
                  TEMPCC(     1)=-1.20688E-01 RELXCC(     0)= 0.00000E+00

T     1=    72.29407  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.20000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.66426E+00
                  TEMPCC(     1)=-1.14374E-01 RELXCC(     0)= 0.00000E+00

T     1=    69.94440  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.30000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.67071E+00
                  TEMPCC(     1)=-1.08425E-01 RELXCC(     0)= 0.00000E+00

T     1=    67.71729  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.40000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.67681E+00
                  TEMPCC(     1)=-1.02815E-01 RELXCC(     0)= 0.00000E+00

T     1=    65.60571  T    99=  -320.00000  T   100=   100.00000
```



```
**********
TIME=     3.50000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.68258E+00
                  TEMPCC(     1)=-9.75227E-02 RELXCC(     0)= 0.00000E+00

T     1=    63.60315  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.60000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.68805E+00
                  TEMPCC(     1)=-9.25270E-02 RELXCC(     0)= 0.00000E+00

T     1=    61.70343  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.70000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.69321E+00
                  TEMPCC(     1)=-8.78089E-02 RELXCC(     0)= 0.00000E+00

T     1=    59.90082  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.80000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.69811E+00
                  TEMPCC(     1)=-8.33503E-02 RELXCC(     0)= 0.00000E+00

T     1=    58.18982  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     3.90000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.70274E+00
                  TEMPCC(     1)=-7.91356E-02 RELXCC(     0)= 0.00000E+00

T     1=    56.56555  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.00000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.70713E+00
                  TEMPCC(     1)=-7.51496E-02 RELXCC(     0)= 0.00000E+00

T     1=    55.02338  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.10000          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.71129E+00
                  TEMPCC(     1)=-7.13782E-02 RELXCC(     0)= 0.00000E+00

T     1=    53.55872  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.20001          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.71524E+00
                  TEMPCC(     1)=-6.78086E-02 RELXCC(     0)= 0.00000E+00

T     1=    52.16736  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.30001          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.71898E+00
                  TEMPCC(     1)=-6.44284E-02 RELXCC(     0)= 0.00000E+00

T     1=    50.84543  T    99=  -320.00000  T   100=   100.00000
```

```
**********
TIME=     4.40001          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.72253E+00
                   TEMPCC(     1)=-6.12268E-02 RELXCC(     0)= 0.00000E+00

T     1=    49.58929  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.50001          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.72589E+00
                   TEMPCC(     1)=-5.81934E-02 RELXCC(     0)= 0.00000E+00

T     1=    48.39551  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.60002          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.72909E+00
                   TEMPCC(     1)=-5.53183E-02 RELXCC(     0)= 0.00000E+00

T     1=    47.26077  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.70002          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.73212E+00
                   TEMPCC(     1)=-5.25926E-02 RELXCC(     0)= 0.00000E+00

T     1=    46.18204  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.80002          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.73499E+00
                   TEMPCC(     1)=-5.00078E-02 RELXCC(     0)= 0.00000E+00

T     1=    45.15637  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     4.90002          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.73773E+00
                   TEMPCC(     1)=-4.75559E-02 RELXCC(     0)= 0.00000E+00

T     1=    44.18109  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.00002          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.74032E+00
                   TEMPCC(     1)=-4.52295E-02 RELXCC(     0)= 0.00000E+00

T     1=    43.25351  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.10003          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.74278E+00
                   TEMPCC(     1)=-4.30218E-02 RELXCC(     0)= 0.00000E+00

T     1=    42.37128  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.20003          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.74512E+00
                   TEMPCC(     1)=-4.09263E-02 RELXCC(     0)= 0.00000E+00

T     1=    41.53214  T    99=  -320.00000  T   100=   100.00000
```



```
**********
TIME=     5.30003          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.74735E+00
                   TEMPCC(     1)=-3.89366E-02 RELXCC(     0)= 0.00000E+00

T     1=    40.73373  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.40003          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.74946E+00
                   TEMPCC(     1)=-3.70473E-02 RELXCC(     0)= 0.00000E+00

T     1=    39.97415  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.50004          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.75147E+00
                   TEMPCC(     1)=-3.52528E-02 RELXCC(     0)= 0.00000E+00

T     1=    39.25140  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.60004          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.75338E+00
                   TEMPCC(     1)=-3.35481E-02 RELXCC(     0)= 0.00000E+00

T     1=    38.56363  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.70004          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.75519E+00
                   TEMPCC(     1)=-3.19284E-02 RELXCC(     0)= 0.00000E+00

T     1=    37.90909  T    99=  -320.00000  T   100=   100.00000

**********
TIME=     5.80004          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.75692E+00
                   TEMPCC(     1)=-3.03894E-02 RELXCC(     0)= 0.00000E+00

T     1=    37.28616  T    99=  -320.00000  T   100=   100.00000
```

```
**********
TIME=      5.90004          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.75856E+00
                   TEMPCC(      1)=-2.89266E-02 RELXCC(      0)= 0.00000E+00

T     1=     36.69321  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.00005          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76012E+00
                   TEMPCC(      1)=-2.75360E-02 RELXCC(      0)= 0.00000E+00

T     1=     36.12875  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.10005          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76160E+00
                   TEMPCC(      1)=-2.62142E-02 RELXCC(      0)= 0.00000E+00

T     1=     35.59143  T     99=  -320.00000  T    100=   100.00000
```

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```
**********
TIME=      6.20005          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76301E+00
                   TEMPCC(      1)=-2.49572E-02 RELXCC(      0)= 0.00000E+00

T     1=     35.07986  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.30005          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76436E+00
                   TEMPCC(      1)=-2.37619E-02 RELXCC(      0)= 0.00000E+00

T     1=     34.59277  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.40006          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76563E+00
                   TEMPCC(      1)=-2.26252E-02 RELXCC(      0)= 0.00000E+00

T     1=     34.12909  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.50006          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76685E+00
                   TEMPCC(      1)=-2.15442E-02 RELXCC(      0)= 0.00000E+00

T     1=     33.68756  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.60006          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76801E+00
                   TEMPCC(      1)=-2.05158E-02 RELXCC(      0)= 0.00000E+00

T     1=     33.26712  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.70006          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.76911E+00
                   TEMPCC(      1)=-1.95374E-02 RELXCC(      0)= 0.00000E+00

T     1=     32.86673  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.80007          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.77015E+00
                   TEMPCC(      1)=-1.86066E-02 RELXCC(      0)= 0.00000E+00

T     1=     32.48544  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      6.90007          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.77115E+00
                   TEMPCC(      1)=-1.77208E-02 RELXCC(      0)= 0.00000E+00

T     1=     32.12225  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      7.00007          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.77210E+00
                   TEMPCC(      1)=-1.68779E-02 RELXCC(      0)= 0.00000E+00

T     1=     31.77637  T     99=  -320.00000  T    100=   100.00000
```

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```
**********
TIME=      7.10007          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.77300E+00
                   TEMPCC(      1)=-1.60758E-02 RELXCC(      0)= 0.00000E+00

T     1=     31.44696  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      7.20007          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.77386E+00
                   TEMPCC(      1)=-1.53122E-02 RELXCC(      0)= 0.00000E+00

T     1=     31.13312  T     99=  -320.00000  T    100=   100.00000

**********
TIME=      7.30008          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.77468E+00
```

```
                    TEMPCC(     1)=-1.45855E-02 RELXCC(     0)= 0.00000E+00

 T     1=    30.83423  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     7.40008          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77546E+00
                    TEMPCC(     1)=-1.38938E-02 RELXCC(     0)= 0.00000E+00

 T     1=    30.54953  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     7.50008          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77620E+00
                    TEMPCC(     1)=-1.32353E-02 RELXCC(     0)= 0.00000E+00

 T     1=    30.27829  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     7.60008          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77691E+00
                    TEMPCC(     1)=-1.26085E-02 RELXCC(     0)= 0.00000E+00

 T     1=    30.01996  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     7.70009          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77758E+00
                    TEMPCC(     1)=-1.20117E-02 RELXCC(     0)= 0.00000E+00

 T     1=    29.77383  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     7.80009          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77822E+00
                    TEMPCC(     1)=-1.14435E-02 RELXCC(     0)= 0.00000E+00

 T     1=    29.53940  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     7.90009          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77883E+00
                    TEMPCC(     1)=-1.09024E-02 RELXCC(     0)= 0.00000E+00

 T     1=    29.31601  T    99=  -320.00000  T   100=   100.00000


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     TEST. PC-SINDA

 **********
 TIME=     8.00009          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77941E+00
                    TEMPCC(     1)=-1.03873E-02 RELXCC(     0)= 0.00000E+00

 T     1=    29.10321  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.10009          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.77997E+00
                    TEMPCC(     1)=-9.89668E-03 RELXCC(     0)= 0.00000E+00

 T     1=    28.90045  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.20010          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78050E+00
                    TEMPCC(     1)=-9.42936E-03 RELXCC(     0)= 0.00000E+00

 T     1=    28.70721  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.30010          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78100E+00
                    TEMPCC(     1)=-8.98426E-03 RELXCC(     0)= 0.00000E+00

 T     1=    28.52310  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.40010          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78148E+00
                    TEMPCC(     1)=-8.56046E-03 RELXCC(     0)= 0.00000E+00

 T     1=    28.34769  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.50010          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78193E+00
                    TEMPCC(     1)=-8.15676E-03 RELXCC(     0)= 0.00000E+00

 T     1=    28.18057  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.60011          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78237E+00
                    TEMPCC(     1)=-7.77226E-03 RELXCC(     0)= 0.00000E+00

 T     1=    28.02130  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.70011          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78278E+00
                    TEMPCC(     1)=-7.40605E-03 RELXCC(     0)= 0.00000E+00

 T     1=    27.86957  T    99=  -320.00000  T   100=   100.00000

 **********
 TIME=     8.80011          DTIMEU=5.000003E-03 CSGMIN(     1)= 2.78317E+00
                    TEMPCC(     1)=-7.05717E-03 RELXCC(     0)= 0.00000E+00

 T     1=    27.72498  T    99=  -320.00000  T   100=   100.00000
```

```
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    TEST. PC-SINDA

**********
TIME=      8.90011          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78355E+00
                   TEMPCC(      1)=-6.72491E-03 RELXCC(      0)= 0.00000E+00

T     1=     27.58722  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.00012          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78391E+00
                   TEMPCC(      1)=-6.40847E-03 RELXCC(      0)= 0.00000E+00

T     1=     27.45596  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.10012          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78425E+00
                   TEMPCC(      1)=-6.10687E-03 RELXCC(      0)= 0.00000E+00

T     1=     27.33084  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.20012          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78457E+00
                   TEMPCC(      1)=-5.81961E-03 RELXCC(      0)= 0.00000E+00

T     1=     27.21161  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.30012          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78488E+00
                   TEMPCC(      1)=-5.54591E-03 RELXCC(      0)= 0.00000E+00

T     1=     27.09799  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.40012          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78517E+00
                   TEMPCC(      1)=-5.28505E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.98969  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.50013          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78546E+00
                   TEMPCC(      1)=-5.03663E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.88651  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.60013          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78572E+00
                   TEMPCC(      1)=-4.79993E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.78818  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.70013          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78598E+00
                   TEMPCC(      1)=-4.57450E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.69449  T     99=  -320.00000  T    100=    100.00000
```

```
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    TEST. PC-SINDA

**********
TIME=      9.80013          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78622E+00
                   TEMPCC(      1)=-4.35957E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.60516  T     99=  -320.00000  T    100=    100.00000

**********
TIME=      9.90014          DTIMEU=5.000003E-03 CSGMIN(      1)= 2.78645E+00
                   TEMPCC(      1)=-4.15481E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.52005  T     99=  -320.00000  T    100=    100.00000

**********
TIME=     10.00000          DTIMEU=4.861832E-03 CSGMIN(      1)= 2.78667E+00
                   TEMPCC(      1)=-3.85034E-03 RELXCC(      0)= 0.00000E+00

T     1=     26.43906  T     99=  -320.00000  T    100=    100.00000
```

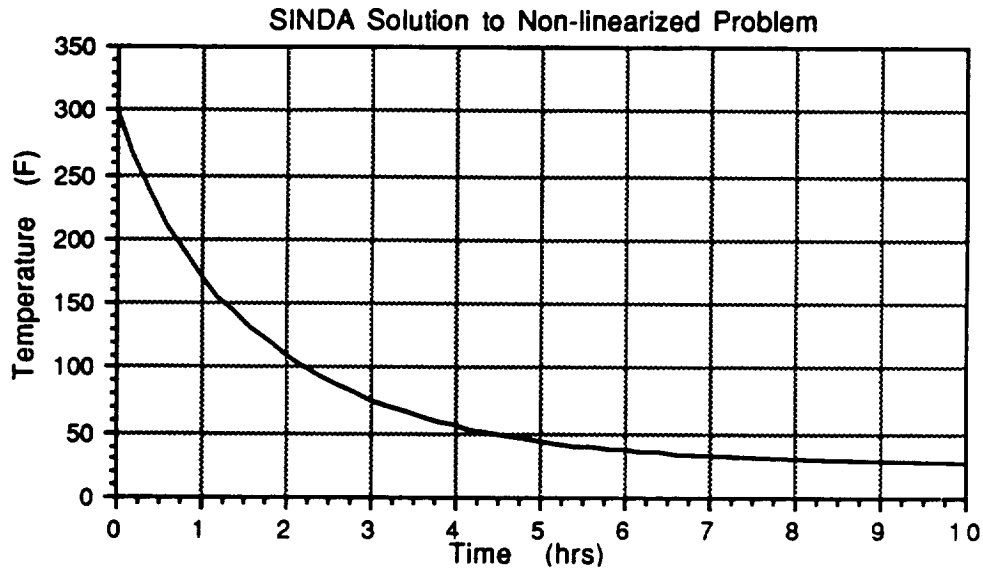

Figure 4. SINDA solution to the non-linearized transient problem

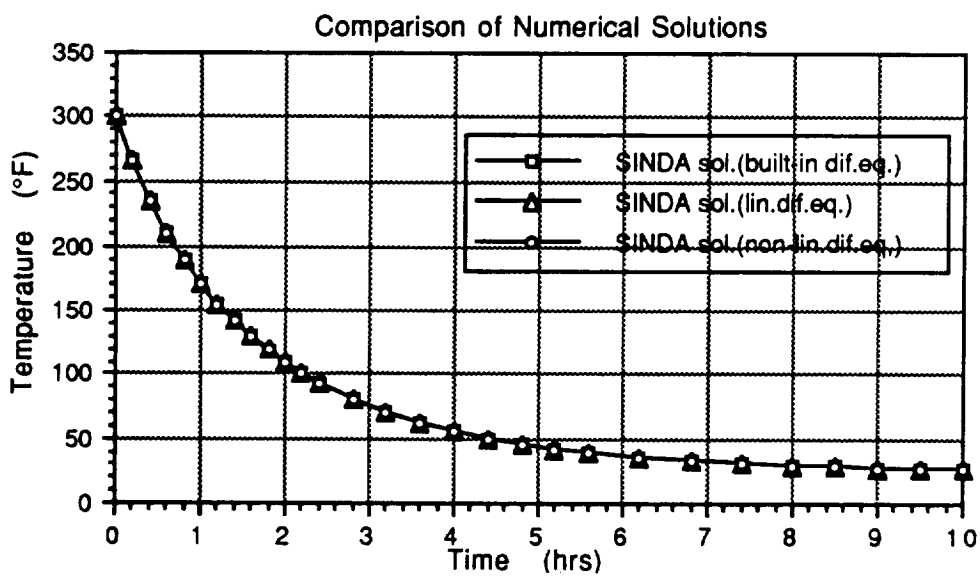

Figure 5. Comparison of solutions obtained using three differencing equations (intrinsic, linearized user-defined, and non-linearized user defined)

VI. Closing Comments:

This example is particularly important because it illustrates both the power and flexibility of SINDA, as an analysis tool. Writing one's own differencing equation is not only a useful option when solving certain problems but adds to the users insight into what calculations are performed within the code. The reader is invited to select another method for finding the zeros of a fourth order polynomial and to develop his/her own differencing scheme for solving the non-linearized problem.

This example illustrates several numerical techniques which are sometimes used in network analysis codes, but are not readily apparent to the thermal analyst. These techniques include linearization of the radiation term, formulation of the diffusion equation in a differencing form, and use of a Newton-Raphson numerical convergence technique. These techniques are simple, as illustrated here, but become powerful when impemented in a network analyzer. By studying the present example, the analyst will gain an appreciation for the terms and techniques discussed in the code instruction manuals.

SECTION 4: TRASYS Model Example of Space Transportation System (STS) Prelaunch Model

ANALYSIS CODE: TRASYS

I. Identification of the Problem:

A. Statement of the Problem:

This model was created to aid in the analyzing of the ice potential on the STS External Tank (ET). TRASYS provides radiation conductors and heat rate arrays that are input into a SINDA model (see Chapter 3.3).

B. Given:

TRASYS involves building the model parts to be analyzed. The parts are constructed by inputting the type of shape desired (i.e., rectangle, circle, sphere, arc, ect..) and the size of the shape along with the translations of the object, which sides are active and other parameters pertaining to radiation transfer. The model includes the major components (relative to heat transfer) related to launching the Space Shuttle : the ET, the Solid Rocket Boosters (SRB's), the Orbiter, the Fixed Service Structure (FSS), the Mobile Launch Pad (MLP), the ground and the concrete pad.

TRASYS INPUT LISTING

```
HEADER OPTIONS DATA
TITLE  STS 30 PRELAUNCH THERMAL MODEL
      MODEL= STACK
      INFO = N
      BCDOU
      USER1
HEADER DOCUMENTATION DATA
            COMMENTS,  WORDS, ETC..........
HEADER SURFACE DATA
BCS   LH2BAR
D     1./12.
S     SURFN=1001 $ NODES 1001 THRU 1016
      TYPE=CYL
      R= 165.6
      ZMIN=0.
      ZMAX=912.
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=4
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   IT
S     SURFN=1017 $ NODES 1017 THRU 1020
      TYPE=CYL
      R= 165.6
      ZMIN=0.
      ZMAX=297.9
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   LOXBAR
S     SURFN=1021 $ NODES 1021 THRU 1024
      TYPE=CYL
      R= 165.6
      ZMIN=0.
      ZMAX=98.7
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   AOGIV
S     SURFN=1025 $ NODES 1025 THRU 1029
      TYPE=CONE
      R=165.6
      ZMIN=584.87
      ZMAX=787.87
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   FOGIV
S     SURFN=1029 $ NODES 1029 THRU 1032
      TYPE=CONE
      R=122.83
      ZMIN=42.83
      ZMAX=208.58
```

```
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   AFTDOME
S     SURFN=1033 $ NODES 1033 THRU 1036
      TYPE=SPHERE
      R= 172.4
      ZMIN=48.
      ZMAX=172.4
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   NOSECAP
S     SURFN=1037 $ NODE 1037
      TYPE=CONE
      R= 25.22
      ZMIN=0.
      ZMAX=34.
      AXMIN=0.
      AXMAX=360.
      NNAX=1
      NNZ=1
      ACTIVE=OUT,ALPHA=.8,EMISS=.94
BCS   RHSRB
S     SURFN=12001 $ NODES 12001 THRU 12004 (NOSE CONE)
      TYPE=CONE
      R= 73.0
      ZMIN=0.
      ZMAX=201.
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=0.25,EMISS=0.9
S     SURFN=12005 $ NODES 12005 THRU 12032 (SRM)
      TYPE=CYL
      R= 73.0
      ZMIN=201.
      ZMAX=1290.3
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=7
      ACTIVE=OUT,ALPHA=.50,EMISS=.9
S     SURFN=12033 $ NODES 12033 THRU 12040 (REAR ASSM)
      TYPE=CYL
      R= 73.0
      ZMIN=1290.3
      ZMAX=1639.
      AXMIN=0.
      AXMAX=360.
      NNAX=4
      NNZ=2
      ACTIVE=OUT,ALPHA=.5,EMISS=.9
BCS   LHSRB
S     SURFN=12045 $ NODES 12045 THRU 12048 (NOSE CONE)
      IDUPSF=12001
S     SURFN=12049 $ NODES 12049 THRU 12076 (SRM)
      IDUPSF=12005
S     SURFN=12077  $ NODES 12077 THRU 12084 (REAR ASSM)
```

```
      IDUPSF=12033
BCS   LASKRT
S     SURFN=12085    $ LEFT AFT SKIRT
      TYPE=CONE
      R=107.57
      ZMIN=189.88
      ZMAX=279.88
      AXMAX=360.
      AXMIN=0.
      NNAX=4
      NNZ=1
      ACTIVE=OUT,ALPHA=.5,EMISS=.9
BCS   RASKRT
S     SURFN=12041 $ RIGHT AFT SKIRT
      IDUPSF=12085
BCS   MLP
S     SURFN=500    $ MLP DECK
      TYPE=RECT
      P1=1920.,1620.,0.
      NNX=2
      NNY=2
      ACTIVE=TOP,ALPHA=.6,EMISS=.8
BCS   ORBITER
S     SURFN=8000 $ FUSELAGE
      TYPE=TRAP
      P1=205.,-105.,1823.04
      P2=205.,-209.6,1306.44
      P3=205.,209.6,1306.44
      P4=205.,105.,1823.04
      NNAX=1
      NNY=1
      ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S     SURFN=8005   $ FWD WINGS
      TYPE=TRAP
      P1=205.,-209.6,1306.44
      P2=205.,-441.72,1029.48
      P3=205.,441.72,1029.48
      P4=205.,209.6,1306.44
      NNY=1
      NNAX=1
      ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S     SURFN=8010   $ PORT AFT WING
      TYPE=POLY
      P1=205.,-441.72,1029.48
      P2=205.,-457.,887.25
      P3=205.,-142.20,834.81
      P4=205.,-104.76,1029.48
      ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S     SURFN=8015   $ STARBOARD AFT WING
      TYPE=POLY
      IMAGSF=8010
      IREFSF=101
R     REFNO=101
      P1=0.,0.,0.
      P2=0.0,0.,1.
      P3=1.,0.,1.
      NNAX=1
      NNY=1
      ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S     SURFN=8020      $ TAIL
      TYPE=TRAP
      P1=205.,-104.76,1029.48
      P2=205.,-142.2,834.81
      P3=205.,142.2,834.81
```

```
        P4=205.,104.76,1029.48
        NNAX=1
        NNY=1
        ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S       SURFN=8025    $ BODY FLAP
        TYPE=TRAP
        P1=205.,119.78,715.03
        P2=205.,142.2,834.81
        P3=205.,-142.2,834.81
        P4=205.,-119.78,715.03
        NNAX=1
        NNY=1
        ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S       SURFN=8030    $ AFT NOSE
        TYPE=TRAP
        P1=205.,-71.87,1947.84
        P2=205.,-105.0,1823.04
        P3=205.,105.0,1823.04
        P4=205.,71.87,1947.84
        NNAX=1
        NNY=1
        ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
S       SURFN=8035    $ FWD NOSE
        TYPE=TRAP
        P1=205.,-17.64,2072.64
        P2=205.,-71.87,1947.84
        P3=205.,71.87,1947.84
        P4=205.,17.64,2072.64
        NNAX=1
        NNY=1
        ACTIVE=BOTTOM,ALPHA=.85,EMISS=.85
D       1.         $ RESETTING THE DIMENSIONS TO FEET
BCS     FSS
S       SURFN=6000    $ FSS LV 115
        TYPE=RECT
        P1= 20.,20.,115.
        P2=-20.,20.,115.
        P3=-20.,-20.,115.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
S       SURFN=6010    $ FSS LV 135
        TYPE=RECT
        P1= 20.,20.,135.
        P2=-20.,20.,135.
        P3=-20.,-20.,135.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
S       SURFN=6020    $ FSS LV 155
        TYPE=RECT
        P1= 20.,20.,155.
        P2=-20.,20.,155.
        P3=-20.,-20.,155.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
S       SURFN=6030    $ FSS LV 175
        TYPE=RECT
        P1= 20.,20.,175.
        P2=-20.,20.,175.
        P3=-20.,-20.,175.
        NNAX=1
        NNY=1
```

```
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
 S      SURFN=6040    $ FSS LV 195
        TYPE=RECT
        P1= 20.,20.,195.
        P2=-20.,20.,195.
        P3=-20.,-20.,195.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
 S      SURFN=6050    $ FSS LV 215
        TYPE=RECT
        P1= 20.,20.,215.
        P2=-20.,20.,215.
        P3=-20.,-20.,215.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
 S      SURFN=6060    $ FSS LV 235
        TYPE=RECT
        P1= 20.,20.,235.
        P2=-20.,20.,235.
        P3=-20.,-20.,235.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
 S      SURFN=6070    $ FSS LV 255
        TYPE=RECT
        P1= 20.,20.,255.
        P2=-20.,20.,255.
        P3=-20.,-20.,255.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
 S      SURFN=6080    $ FSS LV 275
        TYPE=RECT
        P1= 20.,20.,275.
        P2=-20.,20.,275.
        P3=-20.,-20.,275.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
 S      SURFN=6090    $ FSS LV 295
        TYPE=RECT
        P1= 20.,20.,295.
        P2=-20.,20.,295.
        P3=-20.,-20.,295.
        NNAX=1
        NNY=1
        ACTIVE=BOTH,ALPHA=.80,EMISS=.60
BCS     GROUND
 S      SURFN=9000     $  GROUND NODES
        TYPE=DISK
        DIMENSIONS=0.,0.,250.,0.,360.
        NNAX=4
        NNR=1
        ACTIVE=TOP,PROP=.60,.90
 C      SURFN=9001     $  BUBBLE
 C      TYPE=BOX6
 C      P1=251.,251.,320.
 C      P2=-251.,251.,320.
 C      P3=-251.,-251.,320.
 C      P4=-251.,-251.,-10.
 C      ACTIVE=IN,PROP=.3,.3
HEADER BCS DATA
```

```
B     LH2BAR,0.,0.,992.8/12.,0.,0.,45.
B     IT,0.,0.,1904.8/12.,0.,0.,45.
B     AFTDOME,0.,0.,1040.8/12.,180.,0.,45.
B     LOXBAR,0.,0.,2202.7/12.,0.,0.,45.
B     AOGIV,0.,0.,3087.87/12.,180.,0.,45.
B     FOGIV,0.,0.,2713.59/12.,180.,0.,45.
B     NOSECAP,0.,0.,2704.76/12.,180.,0.,90.
B     RHSRB,250.9/12.,0.,2295./12.,180.,0.,45.
B     LHSRB,-250.9/12.,0.,2295./12.,180.,0.,45.
B     LASKRT,-250.9/12.,0.,845.98/12.,180.,0.,45.
B     RASKRT,250.9/12.,0.,845.98/12.,180.,0.,45.
B     MLP,-67.5,100.,47.0,0.,0.,-90.
B     ORBITER,0.,0.,0.,0.,0.,-90.
B     FSS,-97.5,0.,0.,0.,0.,0.
B     GROUND,0.,0.,0.,0.,0.,0.
HEADER CORRESPONDENCE DATA
HEADER OPERATIONS DATA
BUILD STACK,ORBITER,LOXBAR,LH2BAR,IT,AFTDOME,AOGIV,NOSECAP,
     *LHSRB,RHSRB,LASKRT,RASKRT,MLP,FOGIV,FSS,GROUND
      CALL NDATAS(1,3HALL,0,3HYES,2HNO)
L     NPLOT
      CALL FFDATA(.05,0.1,4HSHAD,15.0,1.E-6,3HYES,4HTAPE,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,2HFF)
L     GBCAL
      CALL RKDATA(0,2HNO,.005,10001,5HSPACE,9999,1.713E-9,1.,4HTAPE,0)
L     RKCAL
C  124 = MAY.4, 1989
      CALL SURFP(3HEAR,28.5,124.,0.0)
      CALL DIDT3S(0000,2HNO)
STEP     1
      TIMEPR=00.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
L     AQCAL
STEP     2
      TIMEPR=01.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
L     AQCAL
STEP     3
      TIMEPR=02.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
L     AQCAL
STEP     4
      TIMEPR=03.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
L     AQCAL
STEP     5
      TIMEPR=04.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
L     AQCAL
STEP     6
      TIMEPR=05.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
L     AQCAL
STEP     7
      TIMEPR=06.00
L     DICAL
      CALL AQDATA(0,0,1.,1.,1.)
```

```
L       AQCAL
STEP      8
        TIMEPR=07.00
        SOLO=53.56
L       DICAL
        CALL AQDATA(0,0,1.,1.,1.)
L       AQCAL
STEP      9
        TIMEPR=08.00
        SOLO=155.49
L       DICAL
        CALL AQDATA(0,0,1.,1.,1.)
L       AQCAL
STEP      10
        TIMEPR=09.00
        SOLO=207.6
L       DICAL
        CALL AQDATA(0,0,1.,1.,1.)
L       AQCAL
STEP      11
        TIMEPR=10.00
        SOLO=189.1
L       DICAL
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      END FILE NUSER1
END OF DATA
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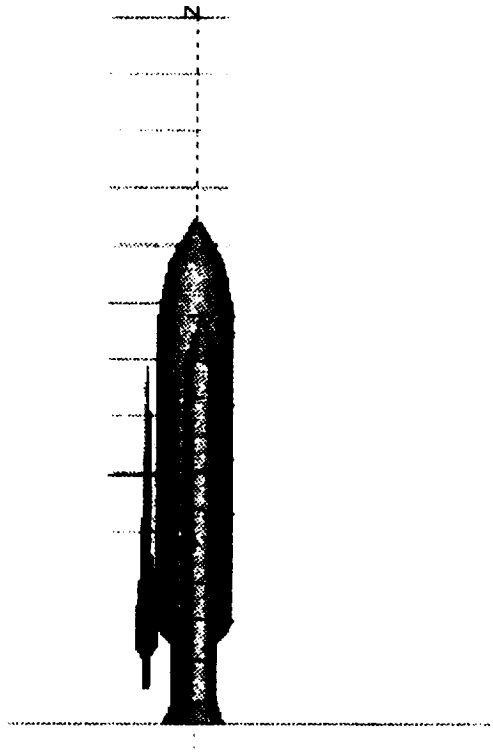

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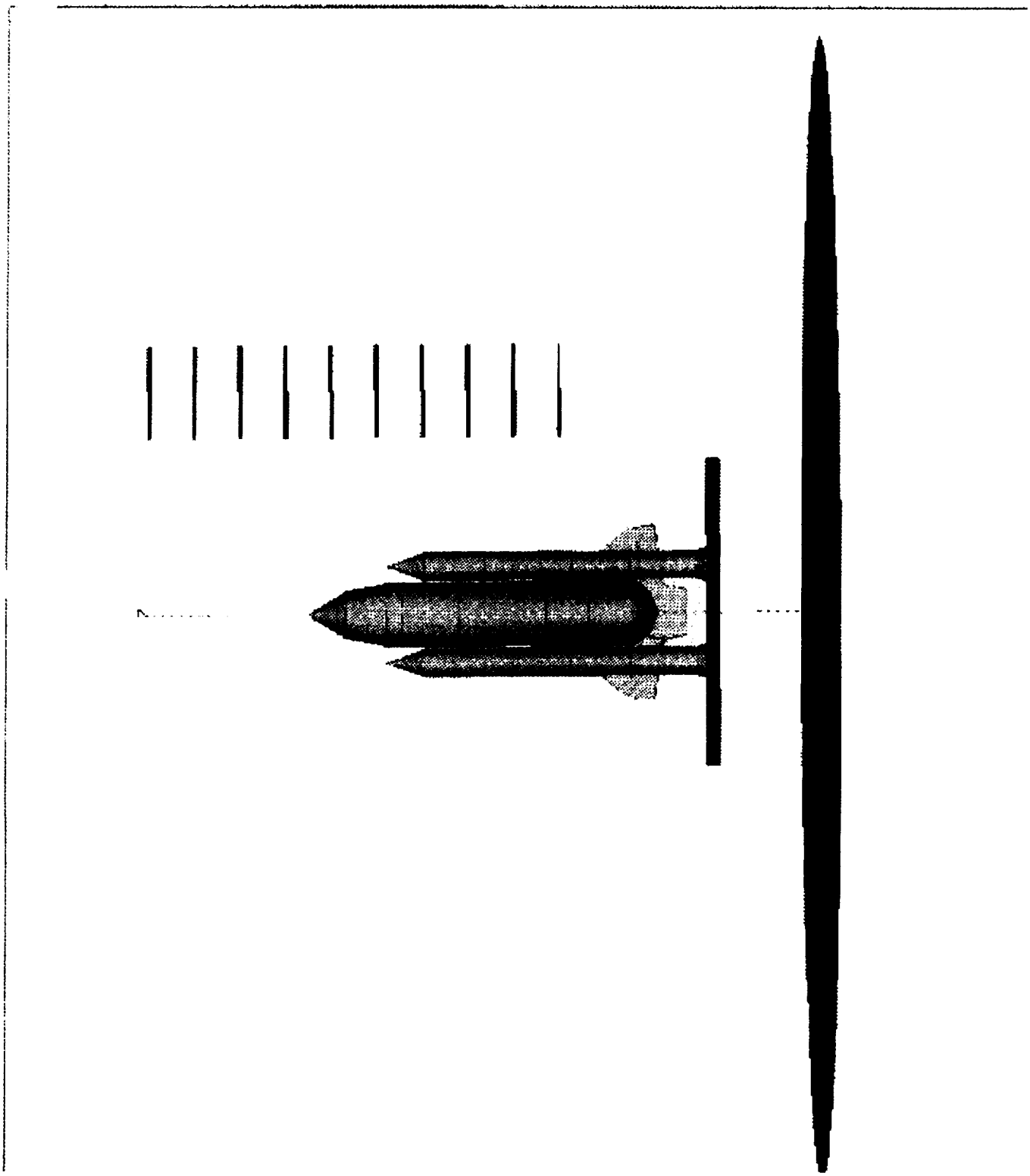

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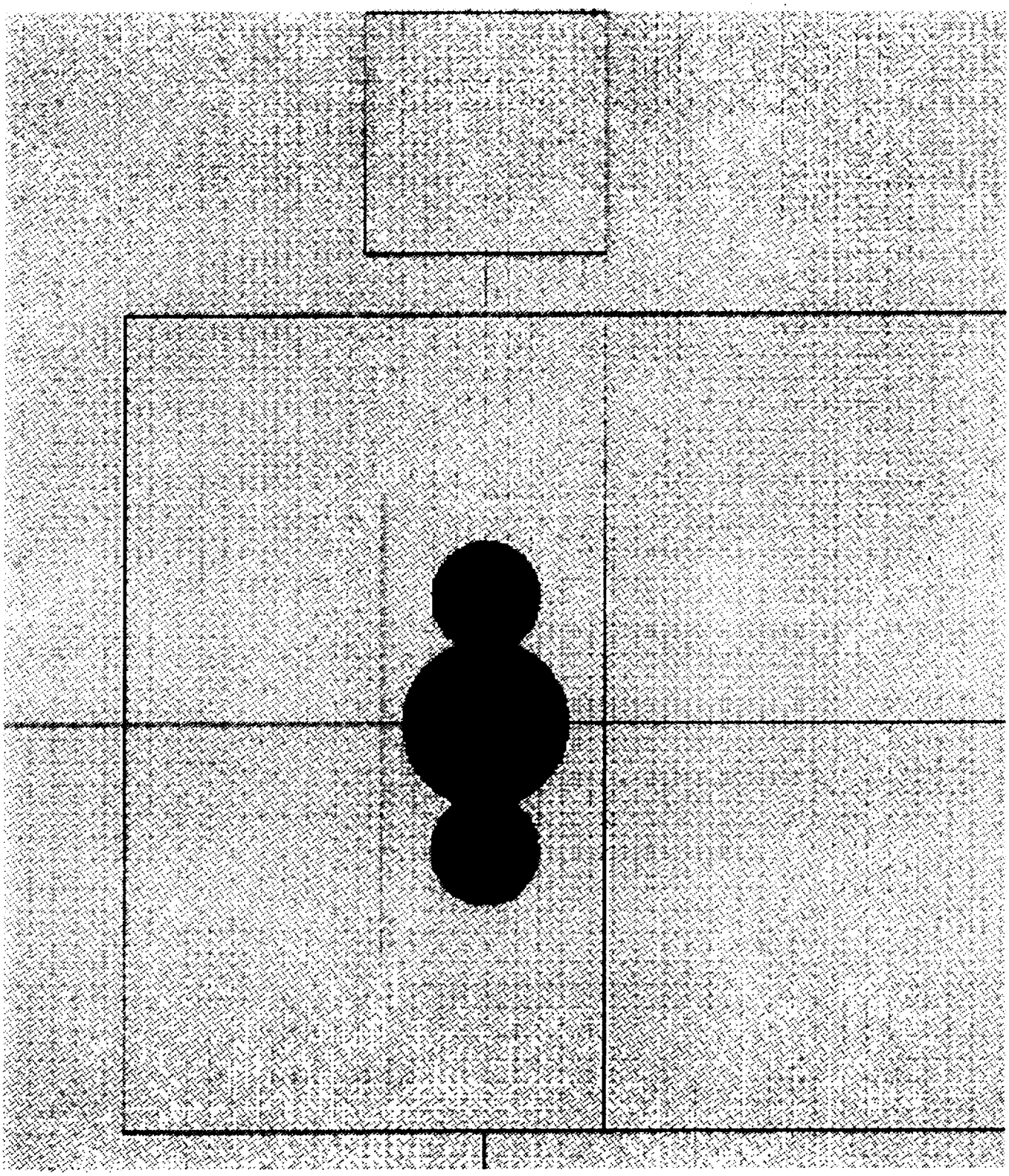

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ORIGINAL PAGE
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SAMPLE TRASYS OUTPUT LISTING FOR SINDA

RADIATION CONDUCTORS

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- 11411,  12003,   9999, 8.72225E-08$
- 11412,  12004,   9999, 9.86438E-08$
- 11413,  12005,   9999, 1.04109E-07$
- 11414,  12006,   9999, 1.03575E-07$
- 11415,  12007,   9999, 1.04336E-07$
- 11416,  12008,   9999, 9.55326E-08$
- 11417,  12009,   9999, 8.05967E-08$
- 11418,  12010,   9999, 6.66439E-08$
- 11419,  12011,   9999, 4.06986E-08$
- 11420,  12012,   9999, 3.39110E-08$
- 11421,  12013,   9999, 2.79366E-08$
- 11422,  12014,   9999, 2.93201E-08$
- 11423,  12015,   9999, 2.44923E-08$
- 11424,  12016,   9999, 1.92401E-08$
- 11425,  12017,   9999, 2.23314E-08$
- 11426,  12018,   9999, 2.61965E-08$
- 11427,  12019,   9999, 1.13294E-07$
- 11428,  12020,   9999, 1.12200E-07$
- 11429,  12021,   9999, 1.09356E-07$
- 11430,  12022,   9999, 1.07065E-07$
- 11431,  12023,   9999, 1.04726E-07$
- 11432,  12024,   9999, 1.03526E-07$
- 11433,  12025,   9999, 1.03012E-07$
- 11434,  12026,   9999, 1.15780E-07$
- 11435,  12027,   9999, 1.16320E-07$
- 11436,  12028,   9999, 1.15136E-07$
- 11437,  12029,   9999, 1.14342E-07$
- 11438,  12030,   9999, 1.11985E-07$
- 11439,  12031,   9999, 1.11120E-07$
- 11440,  12032,   9999, 1.07872E-07$
- 11441,  12033,   9999, 4.31136E-08$
- 11442,  12034,   9999, 8.73098E-08$
- 11443,  12035,   9999, 3.38638E-08$
- 11444,  12036,   9999, 7.01038E-08$
- 11445,  12037,   9999, 1.18102E-07$
- 11446,  12038,   9999, 1.24298E-07$
- 11447,  12039,   9999, 1.14837E-07$
- 11448,  12040,   9999, 1.21920E-07$
- 11449,  43006,   9999, 3.88466E-09$
- 11450,  43013,   9999, 1.16064E-09$
- 11451,  43020,   9999, 4.23570E-09$
- 11452,  43027,   9999, 4.66378E-09$
- 11453,  43008,   9999, 3.51608E-09$
- 11454,  43015,   9999, 8.24931E-10$
- 11455,  43022,   9999, 4.03099E-09$
- 11456,  43029,   9999, 4.37187E-09$
- 11457,  43010,   9999, 2.09008E-09$
- 11458,  43017,   9999, 8.18065E-10$
- 11459,  43024,   9999, 3.87880E-09$
- 11460,  43031,   9999, 4.23041E-09$
- 11461,  12045,   9999, 8.26543E-08$
- 11462,  12046,   9999, 8.22954E-08$
- 11463,  12047,   9999, 8.35973E-08$
- 11464,  12048,   9999, 4.20576E-08$
- 11465,  12049,   9999, 1.02350E-07$
- 11466,  12050,   9999, 1.01737E-07$
- 11467,  12051,   9999, 1.01575E-07$
- 11468,  12052,   9999, 9.29073E-08$
- 11469,  12053,   9999, 7.77609E-08$
- 11470,  12054,   9999, 6.37379E-08$
- 11471,  12055,   9999, 3.79128E-08$
- 11472,  12056,   9999, 1.01532E-07$
- 11473,  12057,   9999, 1.02443E-07$
- 11474,  12058,   9999, 9.95482E-08$
- 11475,  12059,   9999, 9.84763E-08$
- 11476,  12060,   9999, 9.59663E-08$
- 11477,  12061,   9999, 9.43600E-08$
- 11478,  12062,   9999, 9.19944E-08$
- 11479,  12063,   9999, 1.11544E-07$
- 11480,  12064,   9999, 1.10373E-07$
- 11481,  12065,   9999, 1.06608E-07$
- 11482,  12066,   9999, 1.04447E-07$
- 11483,  12067,   9999, 1.01893E-07$
- 11484,  12068,   9999, 1.00618E-07$
- 11485,  12069,   9999, 1.00329E-07$
- 11486,  12070,   9999, 3.37103E-08$
- 11487,  12071,   9999, 2.79330E-08$
- 11488,  12072,   9999, 2.93720E-08$
- 11489,  12073,   9999, 2.45253E-08$
- 11490,  12074,   9999, 1.92435E-08$
- 11491,  12075,   9999, 2.23263E-08$
- 11492,  12076,   9999, 2.61852E-08$
- 11493,  12077,   9999, 4.03175E-08$
- 11494,  12078,   9999, 8.56524E-08$
- 11495,  12079,   9999, 1.01257E-07$
- 11496,  12080,   9999, 1.10520E-07$
- 11497,  12081,   9999, 1.15601E-07$
- 11498,  12082,   9999, 1.22780E-07$
- 11499,  12083,   9999, 3.39103E-08$
```

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- 11500,  12084,   9999, 7.01165E-08$
- 11501,  43050,   9999, 3.78448E-09$
- 11502,  43057,   9999, 4.19564E-09$
- 11503,  43064,   9999, 4.13605E-09$
- 11504,  43071,   9999, 1.16295E-09$
- 11505,  43052,   9999, 3.40185E-09$
- 11506,  43059,   9999, 3.73963E-09$
- 11507,  43066,   9999, 3.91710E-09$
- 11508,  43073,   9999, 8.26110E-10$
- 11509,  43054,   9999, 1.98333E-09$
- 11510,  43061,   9999, 3.61112E-09$
- 11511,  43068,   9999, 3.77234E-09$
- 11512,  43075,   9999, 8.17813E-10$
- 11513,  12085,   9999, 9.31425E-08$
- 11514,  12086,   9999, 1.10239E-07$
- 11515,  12087,   9999, 1.05881E-07$
- 11516,  12080,   9999, 7.70442E-08$
- 11517,  12041,   9999, 9.53576E-08$
- 11518,  12042,   9999, 7.71229E-08$
- 11519,  12043,   9999, 1.08058E-07$
- 11520,  12044,   9999, 1.18376E-07$
- 11521,    500,   9999, 6.44032E-06$
- 11522,    501,   9999, 6.48011E-06$
- 11523,    502,   9999, 6.34811E-06$
- 11524,    503,   9999, 6.52374E-06$
- 11525,   8000,   9999, 1.24330E-07$
- 11526,   8005,   9999, 3.25876E-07$
- 11527,   8010,   9999, 1.56292E-07$
- 11528,   8015,   9999, 1.65680E-07$
- 11529,   8020,   9999, 1.04383E-07$
- 11530,   8025,   9999, 9.49144E-08$
- 11531,   8030,   9999, 3.07597E-08$
- 11532,   8035,   9999, 1.01002E-08$
- 11533,   6000,   9999, 2.17026E-07$
- 11534,   6001,   9999, 9.69449E-07$
- 11535,   6010,   9999, 3.02201E-07$
- 11536,   6011,   9999, 9.73354E-07$
- 11537,   6020,   9999, 3.01580E-07$
- 11538,   6021,   9999, 9.76792E-07$
- 11539,   6030,   9999, 2.81845E-07$
- 11540,   6031,   9999, 9.89442E-07$
- 11541,   6040,   9999, 3.11121E-07$
- 11542,   6041,   9999, 9.94824E-07$
- 11543,   6050,   9999, 3.02520E-07$
- 11544,   6051,   9999, 9.97456E-07$
- 11545,   6060,   9999, 3.01171E-07$
- 11546,   6061,   9999, 9.98594E-07$
- 11547,   6070,   9999, 3.07021E-07$
- 11548,   6071,   9999, 1.00000E-06$
- 11549,   6080,   9999, 3.15305E-07$
- 11550,   6081,   9999, 9.99466E-07$
- 11551,   6090,   9999, 3.12156E-07$
- 11552,   6091,   9999, 1.64448E-06$
- 11553,   9000,   9999, 4.36742E-03$
- 11554,   9001,   9999, 4.36466E-03$
- 11555,   9002,   9999, 4.36529E-03$
- 11556,   9003,   9999, 4.36791E-03$
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HEAT RATE ARRAYS FOR EACH SURFACE

```
     1$ TIME ARRAY
 0.00000E+00, 1.00000E+00, 2.00000E+00, 3.00000E+00, 4.00000E+00
 5.00000E+00, 6.00000E+00, 7.00000E+00, 8.00000E+00, 9.00000E+00
 1.00000E+01, 1.10000E+01, 1.20000E+01, 1.30000E+01, 1.40000E+01
 1.50000E+01, 1.60000E+01, 1.70000E+01, 1.80000E+01, 1.90000E+01
 2.00000E+01, 2.10000E+01, 2.20000E+01, 2.30000E+01, 2.40000E+01
ENDS
     2$ HEAT RATE ARRAY FOR NODE    1001
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.09821E-01, 1.70126E+01, 2.84869E+01, 3.18196E+01
 2.89202E+01, 3.25380E+01, 3.43436E+01, 2.77422E+01, 2.13386E+01
 1.88975E+01, 1.25804E+01, 9.10502E+00, 1.09821E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
     3$ HEAT RATE ARRAY FOR NODE    1002
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.09650E-01, 1.69328E+01, 2.82457E+01, 3.15403E+01
 2.88799E+01, 3.29014E+01, 3.46543E+01, 2.96201E+01, 2.37080E+01
 1.97013E+01, 1.25415E+01, 8.67481E+00, 1.09652E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
     4$ HEAT RATE ARRAY FOR NODE    1003
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.09136E-01, 1.65769E+01, 2.71059E+01, 2.96614E+01
 2.65822E+01, 3.04851E+01, 3.20682E+01, 2.82384E+01, 2.30521E+01
 1.85628E+01, 1.15403E+01, 7.95204E+00, 1.03624E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
     5$ HEAT RATE ARRAY FOR NODE    1004
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.08791E-01, 1.63356E+01, 2.63347E+01, 2.83913E+01
 2.50221E+01, 2.88332E+01, 3.02972E+01, 2.72705E+01, 2.25768E+01
 1.77826E+01, 1.08695E+01, 8.76399E+00, 1.08804E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
     6$ HEAT RATE ARRAY FOR NODE    1005
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.33517E-03, 1.69929E+00, 5.29870E+00, 8.77931E+00
 1.12447E+01, 1.30290E+01, 2.08988E+01, 4.81359E+01, 5.71136E+01
 4.77144E+01, 1.06416E+01, 1.06876E+01, 1.55402E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
     7$ HEAT RATE ARRAY FOR NODE    1006
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.65623E-03, 1.81182E+00, 5.80481E+00, 9.86286E+00
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 1.27903E+01, 1.52181E+01, 2.84722E+01, 5.29849E+01, 5.87072E+01
 4.86781E+01, 1.24193E+01, 9.24655E+00, 1.36053E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
     8$ HEAT RATE ARRAY FOR NODE     1007
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.27658E-03, 2.01675E+00, 6.48475E+00, 1.10979E+01
 1.47601E+01, 2.06441E+01, 3.60987E+01, 5.56608E+01, 6.09178E+01
 5.01118E+01, 1.17578E+01, 1.09630E+01, 1.35564E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
     9$ HEAT RATE ARRAY FOR NODE     1008
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.07466E-03, 2.15187E+00, 6.93417E+00, 1.19094E+01
 1.65029E+01, 2.37080E+01, 3.76464E+01, 5.74230E+01, 6.24271E+01
 5.10770E+01, 1.23541E+01, 1.11681E+01, 1.21875E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    10$ HEAT RATE ARRAY FOR NODE     1009
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.39542E-02, 1.35900E+01, 3.20359E+01, 2.77378E+01
 1.28591E+01, 4.58678E+00, 5.07943E+00, 4.47910E+00, 1.26706E+01
 2.75993E+01, 3.16981E+01, 5.60682E+00, 6.37180E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    11$ HEAT RATE ARRAY FOR NODE     1010
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.39467E-02, 1.37533E+01, 3.26506E+01, 3.80720E+01
 2.80626E+01, 1.22120E+01, 6.50313E+00, 1.21821E+01, 2.80079E+01
 3.80237E+01, 3.08326E+01, 5.39078E+00, 5.93282E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    12$ HEAT RATE ARRAY FOR NODE     1011
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.35040E-02, 1.38923E+01, 3.31513E+01, 4.47329E+01
 3.65617E+01, 2.33658E+01, 1.10574E+01, 2.33552E+01, 3.65405E+01
 4.47184E+01, 3.29955E+01, 5.17324E+00, 5.53460E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    13$ HEAT RATE ARRAY FOR NODE     1012
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.25630E-02, 1.42273E+01, 3.43061E+01, 5.03447E+01
 5.04760E+01, 4.09691E+01, 3.85647E+01, 4.09558E+01, 5.04448E+01
 5.03239E+01, 3.26356E+01, 6.59534E+00, 5.09321E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    14$ HEAT RATE ARRAY FOR NODE     1013
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.55658E-01, 2.56114E+01, 4.86092E+01, 4.88328E+01
 5.93657E+01, 5.06595E+01, 2.08829E+01, 1.27535E+01, 8.98644E+00
 7.53520E+00, 4.90066E+00, 1.66459E+00, 4.27799E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    15$ HEAT RATE ARRAY FOR NODE     1014
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.54971E-01, 2.56866E+01, 4.89159E+01, 4.94292E+01
 6.02660E+01, 5.48870E+01, 2.84656E+01, 1.50336E+01, 1.10658E+01
 8.92628E+00, 5.56422E+00, 1.78297E+00, 3.55866E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    16$ HEAT RATE ARRAY FOR NODE     1015
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.54802E-01, 2.59595E+01, 4.97994E+01, 5.09505E+01
 6.23342E+01, 5.73309E+01, 3.64749E+01, 2.08638E+01, 1.38888E+01
 1.06848E+01, 6.47031E+00, 2.04306E+00, 3.25800E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    17$ HEAT RATE ARRAY FOR NODE     1016
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.54784E-01, 2.61765E+01, 5.04371E+01, 5.20512E+01
 6.37790E+01, 5.89861E+01, 3.83258E+01, 2.42497E+01, 1.62398E+01
 1.18717E+01, 7.07988E+00, 2.21994E+00, 3.14623E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    18$ HEAT RATE ARRAY FOR NODE     1017
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.09516E-01, 1.66291E+01, 2.70395E+01, 2.85169E+01
 2.71716E+01, 2.92741E+01, 3.07279E+01, 2.82142E+01, 2.55255E+01
 1.82675E+01, 1.09969E+01, 8.86876E+00, 1.09539E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    19$ HEAT RATE ARRAY FOR NODE     1018
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.96136E-03, 2.20045E+00, 7.11001E+00, 1.22202E+01
 1.77591E+01, 2.75210E+01, 4.14775E+01, 6.48617E+01, 7.95621E+01
 5.97389E+01, 1.37669E+01, 1.93838E+01, 1.56525E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    20$ HEAT RATE ARRAY FOR NODE     1019
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.25707E-02, 1.58557E+01, 3.90349E+01, 5.86565E+01
 7.37271E+01, 8.39173E+01, 8.79341E+01, 8.39055E+01, 7.36961E+01
 5.86363E+01, 3.90462E+01, 8.12371E+00, 5.27801E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    21$ HEAT RATE ARRAY FOR NODE     1020
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.70733E-01, 3.61800E+01, 6.36548E+01, 7.57775E+01
 8.05505E+01, 6.60311E+01, 4.20888E+01, 2.80262E+01, 1.77010E+01
 1.22617E+01, 7.24022E+00, 2.25522E+00, 3.03466E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    22$ HEAT RATE ARRAY FOR NODE     1021
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.08969E-01, 1.64757E+01, 2.68820E+01, 2.87511E+01
 2.75657E+01, 2.92013E+01, 3.06298E+01, 2.84043E+01, 2.63367E+01
 1.83179E+01, 1.09432E+01, 3.39991E+00, 1.08989E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
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END$
    23$ HEAT RATE ARRAY FOR NODE    1022
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.65398E-03, 2.69987E+00, 8.85694E+00, 1.52874E+01
 2.19356E+01, 2.96355E+01, 4.43540E+01, 7.56553E+01, 1.11187E+02
 8.37494E+01, 1.13796E+01, 3.15216E+00, 2.32197E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    24$ HEAT RATE ARRAY FOR NODE    1023
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.20187E-02, 1.67120E+01, 4.23094E+01, 6.43951E+01
 8.15708E+01, 9.54039E+01, 1.01065E+02, 9.53903E+01, 8.15346E+01
 6.43662E+01, 4.23088E+01, 3.74537E+00, 4.77932E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    25$ HEAT RATE ARRAY FOR NODE    1024
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.46998E-01, 6.25130E+01, 1.15440E+02, 1.30538E+02
 1.13161E+02, 7.82164E+01, 4.67781E+01, 3.17889E+01, 2.32740E+01
 1.62312E+01, 9.49661E+00, 2.93768E+00, 3.92946E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    26$ HEAT RATE ARRAY FOR NODE    1025
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.07727E-02, 1.79528E+01, 4.79214E+01, 7.72842E+01
 1.05111E+02, 1.25608E+02, 1.32723E+02, 1.25606E+02, 1.05104E+02
 7.72792E+01, 4.27778E+01, 9.68713E+00, 6.07918E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    27$ HEAT RATE ARRAY FOR NODE    1026
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.50893E-03, 2.58958E+00, 8.58100E+00, 1.47707E+01
 1.98225E+01, 3.16763E+01, 6.56173E+01, 1.09259E+02, 1.40080E+02
 1.10365E+02, 1.18531E+01, 3.30536E+01, 3.50174E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    28$ HEAT RATE ARRAY FOR NODE    1027
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.09378E-01, 1.79230E+01, 3.08696E+01, 3.44985E+01
 3.10561E+01, 2.72061E+01, 2.54820E+01, 2.69632E+01, 3.07014E+01
 1.54006E+01, 9.05602E+00, 9.63831E+00, 1.09397E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    29$ HEAT RATE ARRAY FOR NODE    1028
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.82922E-01, 6.94265E+01, 1.29624E+02, 1.50260E+02
 1.41203E+02, 1.10915E+02, 6.74951E+01, 3.32726E+01, 2.07893E+01
 1.53335E+01, 8.91984E+00, 2.74727E+00, 3.66966E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    30$ HEAT RATE ARRAY FOR NODE    1029
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 5.71281E-02, 1.88632E+01, 5.57950E+01, 9.94894E+01
 1.38696E+02, 1.64387E+02, 1.73290E+02, 1.64387E+02, 1.38696E+02
 9.94895E+01, 1.93483E+01, 1.01186E+01, 4.48447E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    31$ HEAT RATE ARRAY FOR NODE    1030
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.31557E-03, 1.73196E+00, 5.70426E+00, 9.73382E+00
 2.50585E+01, 6.95124E+01, 1.16503E+02, 1.52828E+02, 1.71937E+02
 1.67854E+02, 5.83881E+00, 3.10467E+01, 2.99713E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    32$ HEAT RATE ARRAY FOR NODE    1031
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.00149E-01, 1.89883E+01, 3.77525E+01, 4.78308E+01
 5.19009E+01, 5.62386E+01, 5.81849E+01, 5.62385E+01, 5.19185E+01
 1.37543E+01, 5.23535E+00, 1.01823E+01, 8.77180E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    33$ HEAT RATE ARRAY FOR NODE    1032
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.45274E-01, 6.72806E+01, 1.34255E+02, 1.66944E+02
 1.70865E+02, 1.51822E+02, 1.15577E+02, 6.85068E+01, 2.40047E+01
 8.82967E+00, 5.12446E+00, 1.57552E+00, 2.10415E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    34$ HEAT RATE ARRAY FOR NODE    1033
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.56191E-02, 7.51089E+00, 1.59682E+01, 2.07109E+01
 2.17598E+01, 2.62619E+01, 2.80884E+01, 2.52301E+01, 1.96571E+01
 1.92377E+01, 1.49645E+01, 7.15089E+00, 3.56061E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    35$ HEAT RATE ARRAY FOR NODE    1034
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.32138E-02, 4.61847E+00, 1.45437E+01, 2.30924E+01
 2.90116E+01, 3.47887E+01, 3.97713E+01, 3.31533E+01, 3.29988E+01
 3.40551E+01, 1.77835E+01, 1.18198E+01, 8.21525E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    36$ HEAT RATE ARRAY FOR NODE    1035
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.46594E-02, 1.09752E+01, 2.34446E+01, 3.58039E+01
 4.55899E+01, 5.19342E+01, 5.51890E+01, 4.31553E+01, 3.13373E+01
 2.89158E+01, 1.99664E+01, 1.06151E+01, 7.46444E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    37$ HEAT RATE ARRAY FOR NODE    1036
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.21672E-02, 1.18877E+01, 2.78105E+01, 3.76362E+01
 3.98774E+01, 3.90036E+01, 3.97342E+01, 3.30999E+01, 2.30598E+01
 1.97473E+01, 1.27508E+01, 4.59899E+00, 1.31992E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    38$ HEAT RATE ARRAY FOR NODE    1037
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
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 0.00000E+00, 1.19474E-01, 2.58498E+01, 5.88139E+01, 8.46267E+01
 1.06072E+02, 1.23593E+02, 1.29615E+02, 1.23592E+02, 1.06076E+02
 8.46267E+01, 3.97777E+00, 1.22481E+00, 1.19496E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    39$ HEAT RATE ARRAY FOR NODE   12001
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.04887E-02, 6.03011E+00, 1.63949E+01, 2.73201E+01
 3.81478E+01, 4.51281E+01, 4.74097E+01, 4.48155E+01, 3.07275E+01
 3.87403E+00, 2.24800E+00, 6.88700E-01, 9.39569E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    40$ HEAT RATE ARRAY FOR NODE   12002
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.01499E-03, 1.91156E+00, 3.67638E+00, 4.60228E+00
 5.54199E+00, 1.13336E+01, 2.45609E+01, 2.61865E+01, 4.19161E+00
 1.48495E+00, 8.69118E-01, 2.67655E-01, 3.60019E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    41$ HEAT RATE ARRAY FOR NODE   12003
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.45631E-02, 6.06830E+00, 1.10961E+01, 1.28579E+01
 1.23381E+01, 1.02885E+01, 8.13471E+00, 9.12297E+00, 5.40536E+00
 3.85039E+00, 2.25684E+00, 6.95261E-01, 9.40405E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    42$ HEAT RATE ARRAY FOR NODE   12004
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.16292E-01, 2.17494E+01, 4.18345E+01, 5.00990E+01
 4.90576E+01, 4.10140E+01, 2.81010E+01, 1.35754E+01, 6.24755E+00
 4.15783E+00, 2.41442E+00, 7.42492E-01, 9.91673E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    43$ HEAT RATE ARRAY FOR NODE   12005
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.05343E-02, 1.05956E+01, 2.56911E+01, 3.91933E+01
 4.93464E+01, 5.74352E+01, 6.05394E+01, 5.69620E+01, 3.91225E+01
 1.12315E+01, 6.52132E+00, 2.01380E+00, 2.87250E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    44$ HEAT RATE ARRAY FOR NODE   12006
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.03919E-02, 1.03240E+01, 2.49262E+01, 3.78498E+01
 4.76407E+01, 5.55276E+01, 5.85498E+01, 5.50475E+01, 3.74725E+01
 1.00109E+01, 5.81557E+00, 1.80202E+00, 2.78113E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    45$ HEAT RATE ARRAY FOR NODE   12007
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.02717E-02, 1.00866E+01, 2.41932E+01, 3.65689E+01
 4.59495E+01, 5.35847E+01, 5.65131E+01, 5.30886E+01, 2.90465E+01
 8.76397E+00, 5.09336E+00, 1.58398E+00, 2.65293E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    46$ HEAT RATE ARRAY FOR NODE   12008
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.05073E-02, 9.96825E+00, 2.37951E+01, 3.58678E+01
 4.49945E+01, 5.24702E+01, 5.53440E+01, 5.19758E+01, 1.09352E+01
 8.09912E+00, 4.70485E+00, 1.45979E+00, 2.84633E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    47$ HEAT RATE ARRAY FOR NODE   12009
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.09618E-02, 9.92697E+00, 2.36394E+01, 3.55736E+01
 4.45801E+01, 5.19823E+01, 5.48068E+01, 3.83234E+01, 1.04564E+01
 7.81896E+00, 4.53749E+00, 1.40847E+00, 3.27629E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    48$' HEAT RATE ARRAY FOR NODE   12010
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.12042E-02, 9.35401E+00, 2.17229E+01, 3.22200E+01
 4.00399E+01, 4.66727E+01, 4.92725E+01, 1.98344E+01, 5.95394E+00
 4.50533E+00, 2.60507E+00, 8.16653E-01, 3.51709E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    49$ HEAT RATE ARRAY FOR NODE   12011
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.21490E-02, 9.29470E+00, 2.14716E+01, 3.17335E+01
 3.92943E+01, 4.57252E+01, 4.81918E+01, 8.60487E+00, 4.54711E+00
 3.42699E+00, 2.02223E+00, 7.06133E-01, 4.13418E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    50$ HEAT RATE ARRAY FOR NODE   12012
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.67930E-02, 3.93669E+00, 7.72982E+00, 1.01295E+01
 1.15970E+01, 1.08947E+01, 1.75546E+01, 2.18192E+01, 5.52771E+00
 4.09026E+00, 2.42090E+00, 7.51736E-01, 1.01167E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    51$ HEAT RATE ARRAY FOR NODE   12013
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.58608E-02, 3.17849E+00, 6.59103E+00, 8.08046E+00
 9.88582E+00, 9.76011E+00, 1.66086E+01, 2.08839E+01, 4.84694E+00
 3.65709E+00, 2.18052E+00, 6.76963E-01, 1.12726E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    52$ HEAT RATE ARRAY FOR NODE   12014
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.52450E-02, 2.85774E+00, 6.05552E+00, 7.19118E+00
 9.04611E+00, 9.09223E+00, 1.60263E+01, 2.02710E+01, 4.36762E+00
 3.35455E+00, 2.01821E+00, 6.28967E-01, 1.14117E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    53$ HEAT RATE ARRAY FOR NODE   12015
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.53785E-02, 2.79862E+00, 5.86236E+00, 6.84958E+00
 8.57692E+00, 8.53792E+00, 1.54258E+01, 1.46958E+01, 3.77534E+00
 2.98015E+00, 1.81824E+00, 5.69832E-01, 1.26614E-03, 0.00000E+00
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 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    54$ HEAT RATE ARRAY FOR NODE   12016
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.55241E-02, 2.70537E+00, 5.55413E+00, 6.30504E+00
 7.82851E+00, 7.64650E+00, 1.40704E+01, 3.76058E+00, 2.87782E+00
 2.37552E+00, 1.49090E+00, 4.73438E-01, 1.40801E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    55$ HEAT RATE ARRAY FOR NODE   12017
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.54334E-02, 2.66918E+00, 5.43733E+00, 6.09880E+00
 7.54809E+00, 7.19954E+00, 1.33967E+01, 3.26736E+00, 2.42378E+00
 2.08086E+00, 1.34478E+00, 4.38842E-01, 1.36869E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    56$ HEAT RATE ARRAY FOR NODE   12018
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.51488E-02, 2.63255E+00, 5.37779E+00, 6.05405E+00
 7.49500E+00, 7.01057E+00, 1.30640E+01, 3.18393E+00, 2.25853E+00
 2.00695E+00, 1.34117E+00, 4.48659E-01, 1.37013E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    57$ HEAT RATE ARRAY FOR NODE   12019
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.00974E-02, 1.06078E+01, 1.70126E+01, 1.76248E+01
 1.65175E+01, 1.74765E+01, 1.79825E+01, 1.63327E+01, 1.34509E+01
 1.04285E+01, 6.29784E+00, 1.96688E+00, 2.65713E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    58$ HEAT RATE ARRAY FOR NODE   12020
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.00517E-02, 1.05659E+01, 1.70083E+01, 1.75921E+01
 1.65377E+01, 1.75728E+01, 1.80792E+01, 1.62601E+01, 1.32790E+01
 1.04146E+01, 6.34863E+00, 1.99125E+00, 2.69221E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    59$ HEAT RATE ARRAY FOR NODE   12021
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.01557E-02, 1.06306E+01, 1.72662E+01, 1.80200E+01
 1.71407E+01, 1.82441E+01, 1.87544E+01, 1.66920E+01, 1.34933E+01
 1.07198E+01, 6.60261E+00, 2.08075E+00, 2.81972E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    60$ HEAT RATE ARRAY FOR NODE   12022
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.02779E-02, 1.07104E+01, 1.75284E+01, 1.84535E+01
 1.76828E+01, 1.88175E+01, 1.92955E+01, 1.69387E+01, 1.34844E+01
 1.09002E+01, 6.80802E+00, 2.15998E+00, 2.93724E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    61$ HEAT RATE ARRAY FOR NODE   12023
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.04133E-02, 1.07959E+01, 1.78063E+01, 1.89107E+01
 1.82469E+01, 1.94013E+01, 1.97782E+01, 1.70859E+01, 1.33160E+01
 1.10138E+01, 7.00541E+00, 2.24298E+00, 3.06440E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    62$ HEAT RATE ARRAY FOR NODE   12024
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.05116E-02, 1.08524E+01, 1.79881E+01, 1.92008E+01
 1.85811E+01, 1.96958E+01, 1.99243E+01, 1.68512E+01, 1.26891E+01
 1.08470E+01, 7.07672E+00, 2.29630E+00, 3.15351E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    63$ HEAT RATE ARRAY FOR NODE   12025
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.05128E-02, 1.09040E+01, 1.81769E+01, 1.95212E+01
 1.89370E+01, 2.00318E+01, 2.01151E+01, 1.65518E+01, 1.18430E+01
 1.06002E+01, 7.16049E+00, 2.36744E+00, 3.27509E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    64$ HEAT RATE ARRAY FOR NODE   12026
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41398E-01, 4.20720E+01, 7.54211E+01, 8.33099E+01
 7.31732E+01, 5.11089E+01, 3.03791E+01, 2.05691E+01, 1.73701E+01
 1.29879E+01, 7.59476E+00, 2.35528E+00, 3.14470E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    65$ HEAT RATE ARRAY FOR NODE   12027
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41385E-01, 4.20571E+01, 7.53702E+01, 8.32196E+01
 7.30492E+01, 5.09600E+01, 3.01968E+01, 2.03621E+01, 1.71306E+01
 1.28306E+01, 7.51906E+00, 2.33831E+00, 3.12178E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    66$ HEAT RATE ARRAY FOR NODE   12028
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41447E-01, 4.20968E+01, 7.54961E+01, 8.34327E+01
 7.33315E+01, 5.12828E+01, 3.04997E+01, 2.06049E+01, 1.72526E+01
 1.29485E+01, 7.60853E+00, 2.37478E+00, 3.17012E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    67$ HEAT RATE ARRAY FOR NODE   12029
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41498E-01, 4.21242E+01, 7.55805E+01, 8.35728E+01
 7.35145E+01, 5.14876E+01, 3.06666E+01, 2.07020E+01, 1.72208E+01
 1.29619E+01, 7.64456E+00, 2.39785E+00, 3.20117E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    68$ HEAT RATE ARRAY FOR NODE   12030
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41619E-01, 4.21789E+01, 7.57492E+01, 8.38529E+01
 7.38802E+01, 5.18992E+01, 3.10292E+01, 2.09525E+01, 1.72629E+01
 1.30400E+01, 7.72957E+00, 2.44409E+00, 3.28399E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
    69$ HEAT RATE ARRAY FOR NODE   12031
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 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41647E-01, 4.21072E+01, 7.55053E+01, 8.34236E+01
 7.32955E+01, 5.12077E+01, 3.02313E+01, 2.01028E+01, 1.63739E+01
 1.24573E+01, 7.43809E+00, 2.36622E+00, 3.27826E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    70$ HEAT RATE ARRAY FOR NODE   12032
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.41830E-01, 4.19978E+01, 7.51032E+01, 8.26890E+01
 7.22656E+01, 4.99590E+01, 2.87710E+01, 1.84750E+01, 1.45906E+01
 1.11932E+01, 6.70212E+00, 2.22089E+00, 3.26437E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    71$ HEAT RATE ARRAY FOR NODE   12033
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.21730E-02, 9.62547E+00, 2.38404E+01, 3.60334E+01
 4.48909E+01, 5.22575E+01, 4.07755E+01, 1.18949E+01, 9.24634E+00
 6.80031E+00, 4.06723E+00, 1.46657E+00, 4.44952E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    72$ HEAT RATE ARRAY FOR NODE   12034
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.09028E-02, 1.03886E+01, 2.63831E+01, 4.04105E+01
 5.07850E+01, 4.00647E+01, 2.17985E+01, 1.88966E+01, 1.46175E+01
 1.06334E+01, 1.09316E+01, 2.34028E+00, 3.99840E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    73$ HEAT RATE ARRAY FOR NODE   12035
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.90109E-03, 2.35300E+00, 6.82267E+00, 1.05104E+01
 1.27745E+01, 1.46122E+01, 1.78654E+01, 1.30602E+01, 1.02834E+01
 8.54392E+00, 5.64929E+00, 1.90637E+00, 1.65440E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    74$ HEAT RATE ARRAY FOR NODE   12036
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.07369E-03, 2.40802E+00, 7.68969E+00, 1.23498E+01
 1.51969E+01, 1.80091E+01, 1.94715E+01, 1.67029E+01, 1.30031E+01
 1.45686E+01, 8.46884E+00, 2.39670E+00, 7.35442E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    75$ HEAT RATE ARRAY FOR NODE   12037
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.86717E-02, 1.05509E+01, 1.79561E+01, 1.99643E+01
 1.94401E+01, 2.07008E+01, 2.08098E+01, 1.66777E+01, 1.11245E+01
 1.04791E+01, 7.37104E+00, 2.51450E+00, 2.28970E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    76$ HEAT RATE ARRAY FOR NODE   12038
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.85705E-02, 1.04850E+01, 1.77627E+01, 1.96395E+01
 1.90186E+01, 2.02950E+01, 2.00630E+01, 1.59912E+01, 9.85661E+00
 9.37057E+00, 6.75440E+00, 2.46814E+00, 6.79492E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    77$ HEAT RATE ARRAY FOR NODE   12039
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.42374E-01, 4.22093E+01, 7.57016E+01, 8.36374E+01
 7.34567E+01, 5.11092E+01, 2.98929E+01, 1.92060E+01, 1.46414E+01
 1.12514E+01, 6.91192E+00, 2.35701E+00, 3.38991E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    78$ HEAT RATE ARRAY FOR NODE   12040
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.42767E-01, 4.23780E+01, 7.60889E+01, 8.41598E+01
 7.40142E+01, 5.15978E+01, 2.63125E+01, 1.91352E+01, 1.40557E+01
 1.06544E+01, 6.59841E+00, 2.38969E+00, 3.16130E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    79$ HEAT RATE ARRAY FOR NODE   43006
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.42132E-02, 6.13342E+00, 1.50378E+01, 2.24635E+01
 2.82444E+01, 3.28979E+01, 3.46953E+01, 3.25985E+01, 2.02573E+01
 5.77688E+00, 3.35981E+00, 1.04058E+00, 1.69178E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    80$ HEAT RATE ARRAY FOR NODE   43013
 0.00000E+00, 0,00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.12041E-03, 1.72440E+00, 3.66860E+00, 4.37870E+00
 5.50324E+00, 5.70183E+00, 9.66790E+00, 1.01430E+01, 2.70796E+00
 2.07809E+00, 1.25188E+00, 3.89495E-01, 6.83932E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    81$ HEAT RATE ARRAY FOR NODE   43020
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.20476E-02, 6.32359E+00, 1.01918E+01, 1.06830E+01
 1.01273E+01, 1.05282E+01, 1.08270E+01, 9.66806E+00, 7.85377E+00
 6.20712E+00, 3.80716E+00, 1.20117E+00, 1.69879E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    82$ HEAT RATE ARRAY FOR NODE   43027
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.44498E-01, 2.51113E+01, 4.48766E+01, 4.93788E+01
 4.31196E+01, 2.98623E+01, 1.72509E+01, 1.15914E+01, 9.57410E+00
 7.18511E+00, 4.22062E+00, 1.31602E+00, 1.75702E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    83$ HEAT RATE ARRAY FOR NODE   43008
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.43294E-02, 5.93324E+00, 1.43734E+01, 2.12975E+01
 2.66595E+01, 3.10460E+01, 3.27399E+01, 2.85725E+01, 6.17363E+00
 4.61872E+00, 2.68944E+00, 8.33607E-01, 1.76572E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    84$ HEAT RATE ARRAY FOR NODE   43015
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.28403E-03, 1.68925E+00, 3.55164E+00, 4.16292E+00
 5.19489E+00, 5.32492E+00, 9.24189E+00, 2.94114E+00, 2.24723E+00
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 1.81503E+00, 1.12419E+00, 3.53226E-01, 8.28452E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    85$ HEAT RATE ARRAY FOR NODE   43022
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.22108E-02, 6.43285E+00, 1.05498E+01, 1.12804E+01
 1.08803E+01, 1.13379E+01, 1.16045E+01, 1.00835E+01, 7.95259E+00
 6.50725E+00, 4.10281E+00, 1.31042E+00, 1.85607E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    86$ HEAT RATE ARRAY FOR NODE   43029
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.44710E-01, 2.52566E+01, 4.53450E+01, 5.01785E+01
 4.41870E+01, 3.10950E+01, 1.84864E+01, 1.26914E+01, 1.03746E+01
 7.82474E+00, 4.62637E+00, 1.45572E+00, 1.94384E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    87$ HEAT RATE ARRAY FOR NODE   43010
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.48830E-02, 5.47932E+00, 1.20382E+01, 1.85869E+01
 2.29757E+01, 2.67300E+01, 2.82306E+01, 7.51912E+00, 2.49742E+00
 1.92408E+00, 1.12191E+00, 3.56173E-01, 2.28657E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    88$ HEAT RATE ARRAY FOR NODE   43017
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.31491E-03, 1.64918E+00, 3.41823E+00, 3.91742E+00
 4.83543E+00, 4.70261E+00, 8.16063E+00, 2.13936E+00, 1.60238E+00
 1.43080E+00, 9.49187E-01, 3.12145E-01, 8.97568E-04, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    89$ HEAT RATE ARRAY FOR NODE   43024
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.23642E-02, 6.52975E+00, 1.08643E+01, 1.17962E+01
 1.15091E+01, 1.19577E+01, 1.20473E+01, 1.00759E+01, 7.44581E+00
 6.48188E+00, 4.28610E+00, 1.40434E+00, 2.00403E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    90$ HEAT RATE ARRAY FOR NODE   43031
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.44801E-01, 2.51931E+01, 4.51198E+01, 4.97732E+01
 4.36262E+01, 3.04219E+01, 1.76832E+01, 1.17925E+01, 9.37235E+00
 7.16545E+00, 4.30342E+00, 1.37958E+00, 1.97167E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    91$ HEAT RATE ARRAY FOR NODE   12045
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.55357E-04, 6.96557E-01, 2.27673E+00, 3.92096E+00
 3.07805E+01, 4.48551E+01, 4.74407E+01, 4.51640E+01, 3.81949E+01
 2.64579E+01, 2.32147E+00, 3.24523E+00, 1.95515E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    92$ HEAT RATE ARRAY FOR NODE   12046
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.01892E-03, 7.46244E-01, 2.47695E+00, 4.29314E+00
 6.35874E+00, 1.35790E+01, 2.80380E+01, 4.10111E+01, 4.91648E+01
 2.17917E+01, 2.59153E+00, 1.01113E+01, 1.12795E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    93$ HEAT RATE ARRAY FOR NODE   12047
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.42260E-04, 6.96009E-01, 2.25969E+00, 3.90040E+00
 5.48878E+00, 9.15597E+00, 8.10339E+00, 1.02064E+01, 1.22535E+01
 4.27833E+00, 2.30799E+00, 3.26071E+00, 3.34072E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    94$ HEAT RATE ARRAY FOR NODE   12048
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.55123E-04, 2.63654E-01, 8.58458E-01, 1.47828E+00
 4.19213E+00, 2.61668E+01, 2.45174E+01, 1.12728E+01, 5.47946E+00
 3.62795E+00, 1.07670E+00, 8.07759E-01, 7.46145E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    95$ HEAT RATE ARRAY FOR NODE   12049
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.82656E-03, 1.95379E+00, 6.34889E+00, 1.09241E+01
 3.86817E+01, 5.63896E+01, 5.99111E+01, 5.68316E+01, 4.88328E+01
 3.86714E+01, 6.51254E+00, 5.23479E+00, 3.51642E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    96$ HEAT RATE ARRAY FOR NODE   12050
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.77428E-03, 1.76028E+00, 5.69297E+00, 9.77464E+00
 3.71327E+01, 5.45988E+01, 5.80553E+01, 5.50363E+01, 4.72025E+01
 3.74939E+01, 5.85515E+00, 3.95639E+00, 3.12081E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    97$ HEAT RATE ARRAY FOR NODE   12051
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.71771E-03, 1.58151E+00, 5.08789E+00, 8.71270E+00
 2.89596E+01, 5.29446E+01, 5.63439E+01, 5.33886E+01, 4.57446E+01
 3.64254E+01, 5.24210E+00, 6.82197E+00, 3.98739E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    98$ HEAT RATE ARRAY FOR NODE   12052
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.97438E-03, 1.47751E+00, 4.73506E+00, 8.09575E+00
 1.09199E+01, 5.19245E+01, 5.52777E+01, 5.23684E+01, 4.48716E+01
 3.57836E+01, 4.85315E+00, 3.62273E+00, 2.99431E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
    99$ HEAT RATE ARRAY FOR NODE   12053
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.44487E-03, 1.45194E+00, 4.62963E+00, 7.89505E+00
 1.05519E+01, 3.84027E+01, 5.48787E+01, 5.20030E+01, 4.45599E+01
 3.55629E+01, 4.72157E+00, 4.03687E+00, 3.55064E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
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  100$ HEAT RATE ARRAY FOR NODE   12054
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.66396E-03, 8.82006E-01, 2.74786E+00, 4.61309E+00
 6.09707E+00, 1.99547E+01, 4.93756E+01, 4.67185E+01, 4.00554E+01
 3.22343E+01, 2.75175E+00, 6.05724E+00, 3.58610E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  101$ HEAT RATE ARRAY FOR NODE   12055
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.24763E-03, 7.74661E-01, 2.24991E+00, 3.59089E+00
 4.75687E+00, 8.76167E+00, 4.83015E+01, 4.56335E+01, 3.90015E+01
 3.15060E+01, 2.41996E+00, 2.81607E+00, 4.20618E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  102$ HEAT RATE ARRAY FOR NODE   12056
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.84432E-03, 2.08034E+00, 6.85640E+00, 1.19132E+01
 1.58267E+01, 1.81953E+01, 2.77244E+01, 4.84398E+01, 7.11569E+01
 4.13201E+01, 7.23172E+00, 1.81232E+01, 1.93620E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  103$ HEAT RATE ARRAY FOR NODE   12057
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.88653E-03, 2.11980E+00, 6.94254E+00, 1.20413E+01
 1.60279E+01, 1.84882E+01, 2.80967E+01, 4.87096E+01, 7.13421E+01
 3.74942E+01, 7.29312E+00, 1.01979E+01, 1.93647E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  104$ HEAT RATE ARRAY FOR NODE   12058
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.05673E-03, 2.25947E+00, 7.34896E+00, 1.27029E+01
 1.69304E+01, 1.96210E+01, 2.93719E+01, 4.98126E+01, 7.22277E+01
 3.21358E+01, 7.65492E+00, 2.61878E+01, 2.41443E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  105$ HEAT RATE ARRAY FOR NODE   12059
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.18375E-03, 2.36742E+00, 7.64872E+00, 1.31734E+01
 1.75649E+01, 2.04454E+01, 3.03434E+01, 5.05976E+01, 7.28367E+01
 4.45856E+01, 7.90713E+00, 1.64987E+01, 1.93909E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  106$ HEAT RATE ARRAY FOR NODE   12060
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.35827E-03, 2.49289E+00, 7.99752E+00, 1.37171E+01
 1.82808E+01, 2.13692E+01, 3.14448E+01, 5.14788E+01, 7.35358E+01
 3.71815E+01, 8.24153E+00, 1.23026E+01, 2.17912E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  107$ HEAT RATE ARRAY FOR NODE   12061
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.37775E-03, 2.43599E+00, 7.79566E+00, 1.33388E+01
 1.77226E+01, 2.06852E+01, 3.08302E+01, 5.07046E+01, 7.28864E+01
 3.47494E+01, 8.03117E+00, 2.63013E+01, 2.17953E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  108$ HEAT RATE ARRAY FOR NODE   12062
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.36741E-03, 2.29387E+00, 7.23048E+00, 1.22330E+01
 1.62052E+01, 1.90680E+01, 2.93814E+01, 4.90833E+01, 7.14432E+01
 4.28274E+01, 7.59293E+00, 1.34214E+01, 2.41950E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  109$ HEAT RATE ARRAY FOR NODE   12063
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.58087E-03, 1.90309E+00, 6.17524E+00, 1.06387E+01
 1.41070E+01, 1.63296E+01, 1.73533E+01, 1.60673E+01, 1.49801E+01
 1.07388E+01, 6.26834E+00, 5.20845E+00, 5.52910E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  110$ HEAT RATE ARRAY FOR NODE   12064
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.63324E-03, 1.94100E+00, 6.29221E+00, 1.08235E+01
 1.43088E+01, 1.65030E+01, 1.75836E+01, 1.60650E+01, 1.48481E+01
 1.07766E+01, 6.36136E+00, 4.15585E+00, 5.51256E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  111$ HEAT RATE ARRAY FOR NODE   12065
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.80504E-03, 2.06560E+00, 6.69044E+00, 1.14829E+01
 1.51314E+01, 1.73904E+01, 1.85840E+01, 1.67450E+01, 1.53335E+01
 1.12850E+01, 6.72804E+00, 7.35313E+00, 6.98369E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  112$ HEAT RATE ARRAY FOR NODE   12066
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.93484E-03, 2.15622E+00, 6.97336E+00, 1.19381E+01
 1.56571E+01, 1.79125E+01, 1.92288E+01, 1.70131E+01, 1.54898E+01
 1.15803E+01, 6.98443E+00, 4.33522E+00, 5.54837E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  113$ HEAT RATE ARRAY FOR NODE   12067
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.08013E-03, 2.25471E+00, 7.28104E+00, 1.24246E+01
 1.61956E+01, 1.84002E+01, 1.98502E+01, 1.71862E+01, 1.55679E+01
 1.18721E+01, 7.27820E+00, 4.89232E+00, 6.29301E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  114$ HEAT RATE ARRAY FOR NODE   12068
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.17347E-03, 2.31210E+00, 7.45560E+00, 1.26619E+01
 1.63615E+01, 1.84214E+01, 2.00290E+01, 1.67872E+01, 1.51825E+01
 1.18835E+01, 7.43340E+00, 7.58042E+00, 6.31146E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
  115$ HEAT RATE ARRAY FOR NODE   12069
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.29496E-03, 2.38419E+00, 7.66709E+00, 1.29306E+01
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1.65229E+01, 1.84036E+01, 2.02195E+01, 1.61748E+01, 1.45718E+01
1.18142E+01, 7.60105E+00, 4.43441E+00, 7.05188E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
116$ HEAT RATE ARRAY FOR NODE   12070
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.00506E-03, 7.46873E-01, 2.42216E+00, 4.15948E+00
5.69321E+00, 2.18711E+01, 1.74969E+01, 1.06767E+01, 1.13380E+01
8.55328E+00, 3.03821E+00, 2.35374E+00, 1.54281E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
117$ HEAT RATE ARRAY FOR NODE   12071
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.15314E-03, 6.76706E-01, 2.18700E+00, 3.74875E+00
5.06485E+00, 2.09530E+01, 1.65460E+01, 9.49028E+00, 9.57336E+00
7.54876E+00, 2.70470E+00, 1.71266E+00, 1.31575E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
118$ HEAT RATE ARRAY FOR NODE   12072
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.17887E-03, 6.31451E-01, 2.03555E+00, 3.48143E+00
4.65523E+00, 2.03724E+01, 1.59721E+01, 8.77623E+00, 8.67934E+00
6.99620E+00, 2.50647E+00, 1.45827E+00, 1.25483E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
119$ HEAT RATE ARRAY FOR NODE   12073
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.33420E-03, 5.79809E-01, 1.85741E+00, 3.16099E+00
4.16320E+00, 1.48433E+01, 1.53913E+01, 8.16510E+00, 8.14763E+00
6.64081E+00, 2.31246E+00, 1.39425E+00, 1.35223E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
120$ HEAT RATE ARRAY FOR NODE   12074
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.50584E-03, 4.93151E-01, 1.56296E+00, 2.63449E+00
3.40661E+00, 3.96364E+00, 1.40651E+01, 7.18782E+00, 7.31530E+00
6.07459E+00, 2.11035E+00, 1.18757E+00, 1.36799E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
121$ HEAT RATE ARRAY FOR NODE   12075
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.41729E-03, 4.56651E-01, 1.44208E+00, 2.40968E+00
3.08007E+00, 3.49973E+00, 1.33979E+01, 6.61963E+00, 6.92015E+00
5.82252E+00, 1.95645E+00, 1.18775E+00, 1.43242E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
122$ HEAT RATE ARRAY FOR NODE   12076
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.39102E-03, 4.62461E-01, 1.46004E+00, 2.42317E+00
3.06743E+00, 3.43321E+00, 1.30658E+01, 6.27301E+00, 6.73125E+00
5.72218E+00, 1.88187E+00, 1.27041E+00, 1.51022E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
123$ HEAT RATE ARRAY FOR NODE   12077
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 4.49536E-03, 1.50157E+00, 4.38600E+00, 7.03475E+00
9.51961E+00, 1.20793E+01, 4.08864E+01, 5.19137E+01, 4.40120E+01
3.53434E+01, 4.98205E+00, 9.55881E+00, 4.21566E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
124$ HEAT RATE ARRAY FOR NODE   12078
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 4.00960E-03, 2.35137E+00, 1.71478E+01, 1.09908E+01
1.49567E+01, 1.90573E+01, 2.18339E+01, 3.95226E+01, 4.94121E+01
3.93217E+01, 1.47983E+01, 1.03705E+01, 4.08980E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
125$ HEAT RATE ARRAY FOR NODE   12079
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 3.47114E-03, 2.41598E+00, 7.44435E+00, 1.23923E+01
1.64303E+01, 1.96966E+01, 3.03987E+01, 4.96786E+01, 7.19540E+01
3.51836E+01, 8.07651E+00, 4.22595E+01, 2.42469E-01, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
126$ HEAT RATE ARRAY FOR NODE   12080
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 3.23737E-03, 2.44602E+00, 7.25338E+00, 1.17743E+01
1.57426E+01, 1.96127E+01, 2.68137E+01, 5.00525E+01, 7.20342E+01
3.51381E+01, 4.32205E+01, 4.24273E+01, 2.42859E-01, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
127$ HEAT RATE ARRAY FOR NODE   12081
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 2.29151E-02, 2.53122E+00, 8.05673E+00, 1.34338E+01
1.69531E+01, 1.87350E+01, 2.09037E+01, 1.56404E+01, 1.39257E+01
1.17800E+01, 7.95768E+00, 1.05250E+01, 6.86824E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
128$ HEAT RATE ARRAY FOR NODE   12082
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 6.79565E-02, 2.47691E+00, 7.56468E+00, 1.23401E+01
1.55057E+01, 1.74847E+01, 2.00893E+01, 1.47443E+01, 1.32669E+01
1.12283E+01, 1.17781E+01, 1.04729E+01, 6.85667E-02, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
129$ HEAT RATE ARRAY FOR NODE   12083
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 1.65507E-02, 1.91857E+00, 5.96343E+00, 9.87118E+00
1.28897E+01, 1.49818E+01, 1.78610E+01, 1.35193E+01, 1.12931E+01
9.16586E+00, 5.51386E+00, 2.23327E+00, 9.89214E-03, 0.00000E+00
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
130$ HEAT RATE ARRAY FOR NODE   12084
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
0.00000E+00, 7.35505E-02, 2.41195E+00, [illegible], [illegible]
1.55399E+01, 1.84847E+01, 1.94701E+01, [illegible], [illegible]
1.08309E+01, 6.73380E+00, 2.39345E+00, [illegible], [illegible]
0.00000E+00, 0.00000E+00, 0.00000E+00, [illegible], [illegible]
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END$
   131$ HEAT RATE ARRAY FOR NODE   43050
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.71989E-03, 1.03597E+00, 3.33291E+00, 5.70847E+00
 2.01527E+01, 3.24468E+01, 3.45230E+01, 3.27164E+01, 2.80715E+01
 2.23396E+01, 3.43113E+00, 1.10593E+00, 2.15085E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   132$ HEAT RATE ARRAY FOR NODE   43057
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.58259E-03, 1.16318E+00, 3.80165E+00, 6.58303E+00
 8.75845E+00, 1.02782E+01, 1.57964E+01, 2.82850E+01, 4.18773E+01
 3.19958E+01, 3.99388E+00, 1.23640E+00, 1.44401E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   133$ HEAT RATE ARRAY FOR NODE   43064
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.68131E-03, 1.19025E+00, 3.83631E+00, 6.57988E+00
 8.67450E+00, 9.98665E+00, 1.06539E+01, 9.66391E+00, 9.09498E+00
 6.50058E+00, 3.85797E+00, 1.26176E+00, 2.70430E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   134$ HEAT RATE ARRAY FOR NODE   43071
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.01678E-04, 3.89965E-01, 1.25802E+00, 2.15397E+00
 2.89466E+00, 1.02424E+01, 9.63025E+00, 5.52379E+00, 5.25409E+00
 4.23929E+00, 1.53799E+00, 8.87137E-01, 7.28078E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   135$ HEAT RATE ARRAY FOR NODE   43052
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.86109E-03, 8.57959E-01, 2.73004E+00, 4.64762E+00
 6.20594E+00, 2.85910E+01, 3.27526E+01, 3.10292E+01, 2.66166E+01
 2.12689E+01, 2.80395E+00, 5.80733E+00, 2.41135E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   136$ HEAT RATE ARRAY FOR NODE   43059
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.94719E-03, 1.45060E+00, 4.67322E+00, 8.03439E+00
 1.07090E+01, 1.26557E+01, 1.84159E+01, 3.06150E+01, 4.38021E+01
 1.03251E+01, 4.82107E+00, 2.52735E+01, 1.44750E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   137$ HEAT RATE ARRAY FOR NODE   43066
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.86404E-03, 1.32017E+00, 4.24760E+00, 7.24832E+00
 9.47098E+00, 1.08026E+01, 1.16169E+01, 1.01705E+01, 9.43051E+00
 6.96736E+00, 4.23488E+00, 6.32138E+00, 4.20820E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   138$ HEAT RATE ARRAY FOR NODE   43073
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.74162E-04, 3.60791E-01, 1.15346E+00, 1.95949E+00
 2.57357E+00, 3.12777E+00, 9.22300E+00, 5.07832E+00, 4.83932E+00
 3.98811E+00, 1.41896E+00, 8.40294E-01, 8.17337E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   139$ HEAT RATE ARRAY FOR NODE   43054
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.36844E-03, 4.05869E-01, 1.22321E+00, 1.99641E+00
 2.59496E+00, 7.59680E+00, 2.82923E+01, 2.67455E+01, 2.29661E+01
 1.85806E+01, 1.21191E+00, 4.35762E-01, 2.48037E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   140$ HEAT RATE ARRAY FOR NODE   43061
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.03237E-03, 1.42240E+00, 4.53476E+00, 7.73514E+00
 1.02584E+01, 1.21516E+01, 1.80420E+01, 3.00244E+01, 4.32818E+01
 1.96446E+01, 4.68736E+00, 1.44913E+00, 1.44874E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   141$ HEAT RATE ARRAY FOR NODE   43068
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.01593E-03, 1.41973E+00, 4.55476E+00, 7.70317E+00
 9.90222E+00, 1.11019E+01, 1.21099E+01, 9.98139E+00, 9.21992E+00
 7.15978E+00, 4.52267E+00, 1.48144E+00, 4.23546E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   142$ HEAT RATE ARRAY FOR NODE   43075
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 9.12748E-04, 3.21916E-01, 1.01818E+00, 1.69955E+00
 2.17856E+00, 2.45985E+00, 8.16153E+00, 4.29499E+00, 4.25736E+00
 3.64709E+00, 1.26359E+00, 8.10973E-01, 9.26057E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   143$ HEAT RATE ARRAY FOR NODE   12085
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.26561E-03, 8.24895E+00, 3.15813E+01, 5.67278E+00
 7.77295E+00, 1.03203E+01, 1.68067E+01, 1.84874E+01, 5.81732E+01
 5.37875E+01, 3.22584E+01, 1.16635E+01, 3.93963E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   144$ HEAT RATE ARRAY FOR NODE   12086
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.38898E-03, 1.03543E+00, 2.96394E+00, 4.70119E+00
 6.35692E+00, 8.23148E+00, 2.25341E+01, 7.29118E+01, 9.52652E+01
 5.32253E+01, 8.25863E+01, 4.31392E+01, 2.31349E-01, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   145$ HEAT RATE ARRAY FOR NODE   12087
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.68396E-02, 8.34898E+00, 3.92094E+00, 6.20809E+00
 7.99401E+00, 9.69083E+00, 1.12448E+01, 1.65128E+01, 2.09781E+01
 6.39343E+00, 2.12453E+01, 1.17480E+01, 6.75879E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   146$ HEAT RATE ARRAY FOR NODE   12088
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
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 0.00000E+00, 7.10933E-02, 1.51553E+00, 3.37121E+01, 6.90386E+01
 8.96820E+00, 1.12482E+01, 1.22267E+01, 1.09148E+01, 8.99585E+00
 7.37065E+00, 4.45424E+00, 1.53279E+00, 5.47917E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   147$ HEAT RATE ARRAY FOR NODE   12041
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 3.93847E-02, 1.16690E+01, 3.24443E+01, 5.45429E+01
 5.91386E+01, 1.88013E+01, 1.66775E+01, 1.01408E+01, 7.53399E+00
 5.41628E+00, 2.40300E+01, 8.22896E+00, 2.24026E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   148$ HEAT RATE ARRAY FOR NODE   12042
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 5.48426E-03, 1.54499E+00, 5.17667E+00, 8.36260E+00
 1.04969E+01, 1.15746E+01, 1.22162E+01, 1.06312E+01, 8.01999E+00
 6.84193E+01, 6.09026E+00, 1.50218E+00, 7.10877E-02, 0.00000E+00
END$
   148$ HEAT RATE ARRAY FOR NODE   12042
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 5.48426E-03, 1.54499E+00, 5.17667E+00, 8.36260E+00
 1.04969E+01, 1.15746E+01, 1.22162E+01, 1.06312E+01, 8.01999E+00
 6.84193E+01, 6.09026E+00, 1.50218E+00, 7.10877E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   149$ HEAT RATE ARRAY FOR NODE   12043
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.75714E-02, 1.17495E+01, 2.14117E+01, 2.49350E+01
 2.35446E+01, 1.88130E+01, 1.11193E+01, 9.13092E+00, 5.74458E+00
 4.93561E+00, 3.41966E+00, 8.33203E+00, 6.68207E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   150$ HEAT RATE ARRAY FOR NODE   12044
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.31263E-01, 4.30924E+01, 8.26028E+01, 9.85279E+01
 9.59769E+01, 7.32442E+01, 2.20675E+01, 7.78514E+00, 5.56065E+00
 4.12186E+00, 2.55725E+00, 9.83115E-01, 1.31661E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   151$ HEAT RATE ARRAY FOR NODE     500
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.29019E-02, 1.63853E+01, 5.33028E+01, 8.59298E+01
 9.55193E+01, 8.81795E+01, 1.22430E+02, 5.09398E+01, 5.60524E+01
 7.00955E+01, 5.32555E+01, 1.65052E+01, 2.43430E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   152$ HEAT RATE ARRAY FOR NODE     501
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.44335E-02, 1.66367E+01, 5.37130E+01, 9.19815E+01
 1.23264E+02, 1.41669E+02, 1.22333E+02, 8.80267E+01, 1.90103E+01
 4.37301E+01, 4.25926E+01, 1.63322E+01, 2.28712E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   153$ HEAT RATE ARRAY FOR NODE     502
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.72509E-02, 1.38914E+01, 3.76306E+01, 5.77028E+01
 8.03991E+01, 1.11513E+02, 1.26553E+02, 1.19246E+02, 9.51938E+01
 7.19049E+01, 4.83957E+01, 1.54934E+01, 2.44702E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   154$ HEAT RATE ARRAY FOR NODE     503
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.44847E-02, 1.55653E+01, 4.90714E+01, 8.25923E+01
 1.08818E+02, 1.24404E+02, 1.26272E+02, 1.11212E+02, 8.00820E+01
 5.63417E+01, 3.40800E+01, 1.38572E+01, 1.72116E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   155$ HEAT RATE ARRAY FOR NODE     8000
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.91924E-02, 3.39379E+00, 8.20920E+00, 1.17421E+01
 1.29665E+01, 1.40268E+01, 1.42469E+01, 1.39712E+01, 1.28595E+01
 1.16647E+01, 6.68678E+00, 1.81976E+00, 5.98731E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   156$ HEAT RATE ARRAY FOR NODE     8005
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.69943E-02, 3.66244E+00, 8.92668E+00, 1.21927E+01
 1.38900E+01, 1.55138E+01, 1.85499E+01, 1.51318E+01, 1.32450E+01
 1.15729E+01, 6.17685E+00, 2.26066E+00, 6.46943E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   157$ HEAT RATE ARRAY FOR NODE     8020
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.68395E-02, 3.21824E+00, 9.13010E+00, 1.34340E+01
 1.56641E+01, 1.73255E+01, 1.90296E+01, 1.51463E+01, 1.21137E+01
 1.17210E+01, 7.56259E+00, 2.81721E+00, 6.68102E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   158$ HEAT RATE ARRAY FOR NODE     8025
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.78445E-02, 4.21468E+00, 1.31199E+01, 2.02790E+01
 2.48584E+01, 2.83351E+01, 3.01920E+01, 2.56573E+01, 2.02949E+01
 1.78665E+01, 1.09704E+01, 4.15874E+00, 6.78330E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   159$ HEAT RATE ARRAY FOR NODE     8030
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.81613E-02, 3.30390E+00, 8.10796E+00, 1.24062E+01
 1.51366E+01, 1.61179E+01, 1.64780E+01, 1.61032E+01, 1.51023E+01
 1.23781E+01, 7.38167E+00, 1.88636E+00, 6.62339E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   160$ HEAT RATE ARRAY FOR NODE     8035
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 6.90683E-02, 3.70391E+00, 9.18725E+00, 1.41864E+01
 1.90214E+01, 2.22570E+01, 2.33393E+01, 2.22444E+01, 1.89899E+01
 1.41526E+01, 8.42541E+00, 2.08469E+00, 5.25373E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
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END$
   161$ HEAT RATE ARRAY FOR NODE     6000
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.10303E-02, 8.18065E+00, 2.61187E+01, 4.46293E+01
 5.94426E+01, 6.96123E+01, 7.43479E+01, 6.86714E+01, 5.87841E+01
 4.47879E+01, 2.69140E+01, 8.53886E+00, 1.34109E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   162$ HEAT RATE ARRAY FOR NODE     6001
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.51066E-02, 5.24619E+00, 3.10993E+01, 6.55640E+01
 8.20269E+01, 6.26059E+01, 4.84622E+01, 6.28137E+01, 8.24435E+01
 7.63454E+01, 6.52468E+01, 2.22592E+01, 3.13695E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   163$ HEAT RATE ARRAY FOR NODE     6010
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.49781E-03, 5.00867E+00, 1.72893E+01, 3.06888E+01
 4.05127E+01, 4.45498E+01, 4.56828E+01, 4.41334E+01, 4.01143E+01
 3.15557E+01, 2.04339E+01, 6.67877E+00, 1.09688E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   164$ HEAT RATE ARRAY FOR NODE     6011
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.50795E-02, 5.23873E+00, 3.19624E+01, 7.15798E+01
 8.20199E+01, 6.25868E+01, 4.84408E+01, 6.27849E+01, 8.23958E+01
 7.63226E+01, 6.52217E+01, 2.22294E+01, 3.10945E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   165$ HEAT RATE ARRAY FOR NODE     6020
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.52760E-03, 5.00903E+00, 1.74607E+01, 3.14599E+01
 4.08300E+01, 4.47051E+01, 4.57070E+01, 4.42086E+01, 4.02809E+01
 3.16344E+01, 2.03506E+01, 6.65018E+00, 1.09996E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   166$ HEAT RATE ARRAY FOR NODE     6021
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.50633E-02, 5.23922E+00, 3.89686E+01, 7.61106E+01
 8.20346E+01, 6.26103E+01, 4.84490E+01, 6.27501E+01, 8.22935E+01
 7.62885E+01, 6.52228E+01, 2.21988E+01, 3.05883E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   167$ HEAT RATE ARRAY FOR NODE     6030
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.67176E-03, 5.12582E+00, 1.84333E+01, 3.24987E+01
 4.17426E+01, 4.58063E+01, 4.68199E+01, 4.53066E+01, 4.11800E+01
 3.22911E+01, 2.06823E+01, 6.73860E+00, 1.10828E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   168$ HEAT RATE ARRAY FOR NODE     6031
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.50143E-02, 1.00381E+01, 6.42774E+01, 7.60007E+01
 8.18965E+01, 6.24509E+01, 4.82180E+01, 6.25337E+01, 8.20341E+01
 7.61079E+01, 6.51493E+01, 2.21358E+01, 3.00278E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   169$ HEAT RATE ARRAY FOR NODE     6040
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.41217E-03, 5.36114E+00, 2.00531E+01, 3.16732E+01
 4.08541E+01, 4.49645E+01, 4.56350E+01, 4.49168E+01, 4.07987E+01
 3.16580E+01, 2.01068E+01, 6.53485E+00, 1.07197E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   170$ HEAT RATE ARRAY FOR NODE     6041
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 1.50003E-02, 2.07525E+01, 6.51478E+01, 7.59945E+01
 8.18860E+01, 6.24286E+01, 4.81697E+01, 6.24524E+01, 8.19265E+01
 7.60355E+01, 6.51448E+01, 2.21123E+01, 2.97266E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   171$ HEAT RATE ARRAY FOR NODE     6050
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 7.44723E-03, 6.30240E+00, 2.02312E+01, 3.18515E+01
 4.11050E+01, 4.52749E+01, 4.59878E+01, 4.52719E+01, 4.11105E+01
 3.18968E+01, 2.02171E+01, 6.55867E+00, 1.06433E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   172$ HEAT RATE ARRAY FOR NODE     6051
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.58430E-02, 2.20919E+01, 6.51488E+01, 7.59965E+01
 8.18871E+01, 6.24226E+01, 4.81518E+01, 6.24200E+01, 8.18821E+01
 7.60000E+01, 6.51462E+01, 2.21013E+01, 2.95915E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   173$ HEAT RATE ARRAY FOR NODE     6060
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.38936E-03, 6.43778E+00, 2.03064E+01, 3.19767E+01
 4.12684E+01, 4.54607E+01, 4.61750E+01, 4.54196E+01, 4.11897E+01
 3.19976E+01, 2.02803E+01, 6.54577E+00, 1.02178E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   174$ HEAT RATE ARRAY FOR NODE     6061
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.94582E-02, 2.20927E+01, 6.51520E+01, 7.60023E+01
 8.18944E+01, 6.24296E+01, 4.81574E+01, 6.24218E+01, 8.18798E+01
 7.60003E+01, 6.51496E+01, 2.20993E+01, 2.95497E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   175$ HEAT RATE ARRAY FOR NODE     6070
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.69494E-03, 6.44934E+00, 2.03501E+01, 3.20521E+01
 4.13657E+01, 4.55623E+01, 4.62668E+01, 4.54705E+01, 4.11939E+01
 3.20284E+01, 2.03220E+01, 6.52741E+00, 9.77297E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
END$
   176$ HEAT RATE ARRAY FOR NODE     6071
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
```

```
 0.00000E+00, 2.94545E-02, 2.20918E+01, 6.51498E+01, 7.59991E+01
 8.18903E+01, 6.24250E+01, 4.81578E+01, 6.24269E+01, 8.18964E+01
 7.60070E+01, 6.51522E+01, 2.20961E+01, 2.95124E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   177$ HEAT RATE ARRAY FOR NODE    6080
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.65151E-03, 6.43847E+00, 2.03241E+01, 3.20146E+01
 4.13183E+01, 4.55086E+01, 4.62716E+01, 4.55314E+01, 4.13896E+01
 3.21076E+01, 2.03519E+01, 6.48870E+00, 9.33274E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   178$ HEAT RATE ARRAY FOR NODE    6081
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.94587E-02, 2.20961E+01, 6.51642E+01, 7.60239E+01
 8.19234E+01, 6.24624E+01, 4.81955E+01, 6.24606E+01, 8.19226E+01
 7.60266E+01, 6.51669E+01, 2.20987E+01, 2.94943E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   179$ HEAT RATE ARRAY FOR NODE    6090
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.70106E-03, 6.48870E+00, 2.04933E+01, 3.23076E+01
 4.17074E+01, 4.59493E+01, 4.67160E+01, 4.59276E+01, 4.16984E+01
 3.23384E+01, 2.05249E+01, 6.52006E+00, 9.11965E-03, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   180$ HEAT RATE ARRAY FOR NODE    6091
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.87201E-02, 2.15452E+01, 7.03751E+01, 1.21138E+02
 1.62795E+02, 1.89740E+02, 1.99034E+02, 1.89740E+02, 1.62795E+02
 1.21138E+02, 7.03751E+01, 2.15452E+01, 2.87201E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   181$ HEAT RATE ARRAY FOR NODE    9000
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.15609E-02, 1.61627E+01, 5.27888E+01, 9.08630E+01
 1.22106E+02, 1.42314E+02, 1.49283E+02, 1.42311E+02, 1.21254E+02
 8.99566E+01, 5.23125E+01, 1.61039E+01, 2.15462E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   182$ HEAT RATE ARRAY FOR NODE    9001
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.15472E-02, 1.61049E+01, 5.16872E+01, 8.99608E+01
 1.20895E+02, 1.42317E+02, 1.49288E+02, 1.42318E+02, 1.22110E+02
 9.08634E+01, 5.27862E+01, 1.61617E+01, 2.15595E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   183$ HEAT RATE ARRAY FOR NODE    9002
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.15437E-02, 1.61606E+01, 5.26293E+01, 9.08621E+01
 1.22107E+02, 1.42318E+02, 1.49290E+02, 1.42321E+02, 1.22111E+02
 9.08645E+01, 5.27863E+01, 1.61616E+01, 2.15561E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   184$ HEAT RATE ARRAY FOR NODE    9003
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 2.15575E-02, 1.61625E+01, 5.27889E+01, 9.08636E+01
 1.22107E+02, 1.42316E+02, 1.49285E+02, 1.42313E+02, 1.22103E+02
 9.08586E+01, 5.26268E+01, 1.61598E+01, 2.15428E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   185$ HEAT RATE ARRAY FOR NODE    8010
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 4.95320E-02, 3.23241E+00, 9.89772E+00, 1.54820E+01
 1.98669E+01, 2.34123E+01, 3.10451E+01, 3.00492E+01, 2.69865E+01
 2.17880E+01, 1.03574E+01, 5.83804E+00, 8.16748E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
   186$ HEAT RATE ARRAY FOR NODE    8015
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
 0.00000E+00, 8.18218E-02, 6.81398E+00, 1.70317E+01, 2.53060E+01
 3.07039E+01, 3.29555E+01, 3.07924E+01, 2.17261E+01, 1.60217E+01
 1.34269E+01, 8.99239E+00, 3.03710E+00, 4.94755E-02, 0.00000E+00
 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
ENDS
```

INTERPOLATION CALLS TO INPUT HEAT RATES TO APPROPIATE NODE AT APPROPIATE TIME

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D11MDA(TIMEM,A    1,A    2, 4.1186E+02,Q  1001)$
D11MDA(TIMEM,A    1,A    3, 4.1186E+02,Q  1002)$
D11MDA(TIMEM,A    1,A    4, 4.1186E+02,Q  1003)$
D11MDA(TIMEM,A    1,A    5, 4.1186E+02,Q  1004)$
D11MDA(TIMEM,A    1,A    6, 4.1186E+02,Q  1005)$
D11MDA(TIMEM,A    1,A    7, 4.1186E+02,Q  1006)$
D11MDA(TIMEM,A    1,A    8, 4.1186E+02,Q  1007)$
D11MDA(TIMEM,A    1,A    9, 4.1186E+02,Q  1008)$
D11MDA(TIMEM,A    1,A   10, 4.1186E+02,Q  1009)$
D11MDA(TIMEM,A    1,A   11, 4.1186E+02,Q  1010)$
D11MDA(TIMEM,A    1,A   12, 4.1186E+02,Q  1011)$
D11MDA(TIMEM,A    1,A   13, 4.1186E+02,Q  1012)$
D11MDA(TIMEM,A    1,A   14, 4.1186E+02,Q  1013)$
D11MDA(TIMEM,A    1,A   15, 4.1186E+02,Q  1014)$
D11MDA(TIMEM,A    1,A   16, 4.1186E+02,Q  1015)$
D11MDA(TIMEM,A    1,A   17, 4.1186E+02,Q  1016)$
D11MDA(TIMEM,A    1,A   18, 5.3813E+02,Q  1017)$
D11MDA(TIMEM,A    1,A   19, 5.3813E+02,Q  1018)$
D11MDA(TIMEM,A    1,A   20, 5.3813E+02,Q  1019)$
D11MDA(TIMEM,A    1,A   21, 5.3813E+02,Q  1020)$
D11MDA(TIMEM,A    1,A   22, 1.7829E+02,Q  1021)$
D11MDA(TIMEM,A    1,A   23, 1.7829E+02,Q  1022)$
D11MDA(TIMEM,A    1,A   24, 1.7829E+02,Q  1023)$
D11MDA(TIMEM,A    1,A   25, 1.7829E+02,Q  1024)$
D11MDA(TIMEM,A    1,A   26, 3.2644E+02,Q  1025)$
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D11MDA(TIMEM,A     1,A    27,  3.2644E+02,Q   1026)$
D11MDA(TIMEM,A     1,A    28,  3.2644E+02,Q   1027)$
D11MDA(TIMEM,A     1,A    29,  3.2644E+02,Q   1028)$
D11MDA(TIMEM,A     1,A    30,  1.5533E+02,Q   1029)$
D11MDA(TIMEM,A     1,A    31,  1.5533E+02,Q   1030)$
D11MDA(TIMEM,A     1,A    32,  1.5533E+02,Q   1031)$
D11MDA(TIMEM,A     1,A    33,  1.5533E+02,Q   1032)$
D11MDA(TIMEM,A     1,A    34,  2.3395E+02,Q   1033)$
D11MDA(TIMEM,A     1,A    35,  2.3395E+02,Q   1034)$
D11MDA(TIMEM,A     1,A    36,  2.3395E+02,Q   1035)$
D11MDA(TIMEM,A     1,A    37,  2.3395E+02,Q   1036)$
D11MDA(TIMEM,A     1,A    38,  2.3292E+01,Q   1037)$
D11MDA(TIMEM,A     1,A    39,  8.5143E+01,Q  12001)$
D11MDA(TIMEM,A     1,A    40,  8.5143E+01,Q  12002)$
D11MDA(TIMEM,A     1,A    41,  8.5143E+01,Q  12003)$
D11MDA(TIMEM,A     1,A    42,  8.5143E+01,Q  12004)$
D11MDA(TIMEM,A     1,A    43,  1.2392E+02,Q  12005)$
D11MDA(TIMEM,A     1,A    44,  1.2392E+02,Q  12006)$
D11MDA(TIMEM,A     1,A    45,  1.2392E+02,Q  12007)$
D11MDA(TIMEM,A     1,A    46,  1.2392E+02,Q  12008)$
D11MDA(TIMEM,A     1,A    47,  1.2392E+02,Q  12009)$
D11MDA(TIMEM,A     1,A    48,  1.2392E+02,Q  12010)$
D11MDA(TIMEM,A     1,A    49,  1.2392E+02,Q  12011)$
D11MDA(TIMEM,A     1,A    50,  1.2392E+02,Q  12012)$
D11MDA(TIMEM,A     1,A    51,  1.2392E+02,Q  12013)$
D11MDA(TIMEM,A     1,A    52,  1.2392E+02,Q  12014)$
D11MDA(TIMEM,A     1,A    53,  1.2392E+02,Q  12015)$
D11MDA(TIMEM,A     1,A    54,  1.2392E+02,Q  12016)$
D11MDA(TIMEM,A     1,A    55,  1.2392E+02,Q  12017)$
D11MDA(TIMEM,A     1,A    56,  1.2392E+02,Q  12018)$
D11MDA(TIMEM,A     1,A    57,  1.2392E+02,Q  12019)$
D11MDA(TIMEM,A     1,A    58,  1.2392E+02,Q  12020)$
D11MDA(TIMEM,A     1,A    59,  1.2392E+02,Q  12021)$
D11MDA(TIMEM,A     1,A    60,  1.2392E+02,Q  12022)$
D11MDA(TIMEM,A     1,A    61,  1.2392E+02,Q  12023)$
D11MDA(TIMEM,A     1,A    62,  1.2392E+02,Q  12024)$
D11MDA(TIMEM,A     1,A    63,  1.2392E+02,Q  12025)$
D11MDA(TIMEM,A     1,A    64,  1.2392E+02,Q  12026)$
D11MDA(TIMEM,A     1,A    65,  1.2392E+02,Q  12027)$
D11MDA(TIMEM,A     1,A    66,  1.2392E+02,Q  12028)$
D11MDA(TIMEM,A     1,A    67,  1.2392E+02,Q  12029)$
D11MDA(TIMEM,A     1,A    68,  1.2392E+02,Q  12030)$
D11MDA(TIMEM,A     1,A    69,  1.2392E+02,Q  12031)$
D11MDA(TIMEM,A     1,A    70,  1.2392E+02,Q  12032)$
D11MDA(TIMEM,A     1,A    71,  1.3884E+02,Q  12033)$
D11MDA(TIMEM,A     1,A    72,  1.3884E+02,Q  12034)$
D11MDA(TIMEM,A     1,A    73,  1.3884E+02,Q  12035)$
D11MDA(TIMEM,A     1,A    74,  1.3884E+02,Q  12036)$
D11MDA(TIMEM,A     1,A    75,  1.3884E+02,Q  12037)$
D11MDA(TIMEM,A     1,A    76,  1.3884E+02,Q  12038)$
D11MDA(TIMEM,A     1,A    77,  1.3884E+02,Q  12039)$
D11MDA(TIMEM,A     1,A    78,  1.3884E+02,Q  12040)$
D11MDA(TIMEM,A     1,A    79,  4.7778E+00,Q  43006)$
D11MDA(TIMEM,A     1,A    80,  4.7778E+00,Q  43013)$
D11MDA(TIMEM,A     1,A    81,  4.7778E+00,Q  43020)$
D11MDA(TIMEM,A     1,A    82,  4.7778E+00,Q  43027)$
D11MDA(TIMEM,A     1,A    83,  4.7778E+00,Q  43008)$
D11MDA(TIMEM,A     1,A    84,  4.7778E+00,Q  43015)$
D11MDA(TIMEM,A     1,A    85,  4.7778E+00,Q  43022)$
D11MDA(TIMEM,A     1,A    86,  4.7778E+00,Q  43029)$
D11MDA(TIMEM,A     1,A    87,  4.7778E+00,Q  43010)$
D11MDA(TIMEM,A     1,A    88,  4.7778E+00,Q  43017)$
D11MDA(TIMEM,A     1,A    89,  4.7778E+00,Q  43024)$
D11MDA(TIMEM,A     1,A    90,  4.7778E+00,Q  43031)$
D11MDA(TIMEM,A     1,A    91,  8.5143E+01,Q  12045)$
D11MDA(TIMEM,A     1,A    92,  8.5143E+01,Q  12046)$
D11MDA(TIMEM,A     1,A    93,  8.5143E+01,Q  12047)$
D11MDA(TIMEM,A     1,A    94,  8.5143E+01,Q  12048)$
D11MDA(TIMEM,A     1,A    95,  1.2392E+02,Q  12049)$
D11MDA(TIMEM,A     1,A    96,  1.2392E+02,Q  12050)$
D11MDA(TIMEM,A     1,A    97,  1.2392E+02,Q  12051)$
D11MDA(TIMEM,A     1,A    98,  1.2392E+02,Q  12052)$
D11MDA(TIMEM,A     1,A    99,  1.2392E+02,Q  12053)$
D11MDA(TIMEM,A     1,A   100,  1.2392E+02,Q  12054)$
D11MDA(TIMEM,A     1,A   101,  1.2392E+02,Q  12055)$
D11MDA(TIMEM,A     1,A   102,  1.2392E+02,Q  12056)$
D11MDA(TIMEM,A     1,A   103,  1.2392E+02,Q  12057)$
D11MDA(TIMEM,A     1,A   104,  1.2392E+02,Q  12058)$
D11MDA(TIMEM,A     1,A   105,  1.2392E+02,Q  12059)$
D11MDA(TIMEM,A     1,A   106,  1.2392E+02,Q  12060)$
D11MDA(TIMEM,A     1,A   107,  1.2392E+02,Q  12061)$
D11MDA(TIMEM,A     1,A   108,  1.2392E+02,Q  12062)$
D11MDA(TIMEM,A     1,A   109,  1.2392E+02,Q  12063)$
D11MDA(TIMEM,A     1,A   110,  1.2392E+02,Q  12064)$
D11MDA(TIMEM,A     1,A   111,  1.2392E+02,Q  12065)$
D11MDA(TIMEM,A     1,A   112,  1.2392E+02,Q  12066)$
D11MDA(TIMEM,A     1,A   113,  1.2392E+02,Q  12067)$
D11MDA(TIMEM,A     1,A   114,  1.2392E+02,Q  12068)$
D11MDA(TIMEM,A     1,A   115,  1.2392E+02,Q  12069)$
D11MDA(TIMEM,A     1,A   116,  1.2392E+02,Q  12070)$
D11MDA(TIMEM,A     1,A   117,  1.2392E+02,Q  12071)$
D11MDA(TIMEM,A     1,A   118,  1.2392E+02,Q  12072)$
D11MDA(TIMEM,A     1,A   119,  1.2392E+02,Q  12073)$
D11MDA(TIMEM,A     1,A   120,  1.2392E+02,Q  12074)$
D11MDA(TIMEM,A     1,A   121,  1.2392E+02,Q  12075)$
D11MDA(TIMEM,A     1,A   122,  1.2392E+02,Q  12076)$
D11MDA(TIMEM,A     1,A   123,  1.3884E+02,Q  12077)$
D11MDA(TIMEM,A     1,A   124,  1.3884E+02,Q  12078)$
D11MDA(TIMEM,A     1,A   125,  1.3884E+02,Q  12079)$
D11MDA(TIMEM,A     1,A   126,  1.3884E+02,Q  12080)$
D11MDA(TIMEM,A     1,A   127,  1.3884E+02,Q  12081)$
D11MDA(TIMEM,A     1,A   128,  1.3884E+02,Q  12082)$
D11MDA(TIMEM,A     1,A   129,  1.3884E+02,Q  12083)$
D11MDA(TIMEM,A     1,A   130,  1.3884E+02,Q  12084)$
D11MDA(TIMEM,A     1,A   131,  4.7778E+00,Q  43050)$
D11MDA(TIMEM,A     1,A   132,  4.7778E+00,Q  43057)$
D11MDA(TIMEM,A     1,A   133,  4.7778E+00,Q  43064)$
D11MDA(TIMEM,A     1,A   134,  4.7778E+00,Q  43071)$
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D11MDA(TIMEM,A     1,A  135,  4.7778E+00,Q 43052)$
D11MDA(TIMEM,A     1,A  136,  4.7778E+00,Q 43059)$
D11MDA(TIMEM,A     1,A  137,  4.7778E+00,Q 43066)$
D11MDA(TIMEM,A     1,A  138,  4.7778E+00,Q 43073)$
D11MDA(TIMEM,A     1,A  139,  4.7778E+00,Q 43054)$
D11MDA(TIMEM,A     1,A  140,  4.7778E+00,Q 43061)$
D11MDA(TIMEM,A     1,A  141,  4.7778E+00,Q 43068)$
D11MDA(TIMEM,A     1,A  142,  4.7778E+00,Q 43075)$
D11MDA(TIMEM,A     1,A  143,  9.4947E+01,Q 12085)$
D11MDA(TIMEM,A     1,A  144,  9.4947E+01,Q 12086)$
D11MDA(TIMEM,A     1,A  145,  9.4947E+01,Q 12087)$
D11MDA(TIMEM,A     1,A  146,  9.4947E+01,Q 12088)$
D11MDA(TIMEM,A     1,A  147,  9.4947E+01,Q 12041)$
D11MDA(TIMEM,A     1,A  148,  9.4947E+01,Q 12042)$
D11MDA(TIMEM,A     1,A  149,  9.4947E+01,Q 12043)$
D11MDA(TIMEM,A     1,A  150,  9.4947E+01,Q 12044)$
D11MDA(TIMEM,A     1,A  151,  5.4000E+03,Q   500)$
D11MDA(TIMEM,A     1,A  152,  5.4000E+03,Q   501)$
D11MDA(TIMEM,A     1,A  153,  5.4000E+03,Q   502)$
D11MDA(TIMEM,A     1,A  154,  5.4000E+03,Q   503)$
D11MDA(TIMEM,A     1,A  155,  1.1286E+03,Q  8000)$
D11MDA(TIMEM,A     1,A  156,  1.2527E+03,Q  8005)$
D11MDA(TIMEM,A     1,A  185,  3.8601E+02,Q  8010)$
D11MDA(TIMEM,A     1,A  186,  3.8601E+02,Q  8015)$
D11MDA(TIMEM,A     1,A  157,  3.3386E+02,Q  8020)$
D11MDA(TIMEM,A     1,A  158,  2.1792E+02,Q  8025)$
D11MDA(TIMEM,A     1,A  159,  1.5329E+02,Q  8030)$
D11MDA(TIMEM,A     1,A  160,  7.7575E+01,Q  8035)$
D11MDA(TIMEM,A     1,A  161,  1.6000E+03,Q  6000)$
D11MDA(TIMEM,A     1,A  162,  1.6000E+03,Q  6001)$
D11MDA(TIMEM,A     1,A  163,  1.6000E+03,Q  6010)$
D11MDA(TIMEM,A     1,A  164,  1.6000E+03,Q  6011)$
D11MDA(TIMEM,A     1,A  165,  1.6000E+03,Q  6020)$
D11MDA(TIMEM,A     1,A  166,  1.6000E+03,Q  6021)$
D11MDA(TIMEM,A     1,A  167,  1.6000E+03,Q  6030)$
D11MDA(TIMEM,A     1,A  168,  1.6000E+03,Q  6031)$
D11MDA(TIMEM,A     1,A  169,  1.6000E+03,Q  6040)$
D11MDA(TIMEM,A     1,A  170,  1.6000E+03,Q  6041)$
D11MDA(TIMEM,A     1,A  171,  1.6000E+03,Q  6050)$
D11MDA(TIMEM,A     1,A  172,  1.6000E+03,Q  6051)$
D11MDA(TIMEM,A     1,A  173,  1.6000E+03,Q  6060)$
D11MDA(TIMEM,A     1,A  174,  1.6000E+03,Q  6061)$
D11MDA(TIMEM,A     1,A  175,  1.6000E+03,Q  6070)$
D11MDA(TIMEM,A     1,A  176,  1.6000E+03,Q  6071)$
D11MDA(TIMEM,A     1,A  177,  1.6000E+03,Q  6080)$
D11MDA(TIMEM,A     1,A  178,  1.6000E+03,Q  6081)$
D11MDA(TIMEM,A     1,A  179,  1.6000E+03,Q  6090)$
D11MDA(TIMEM,A     1,A  180,  1.6000E+03,Q  6091)$
D11MDA(TIMEM,A     1,A  181,  2.8353E+06,Q  9000)$
D11MDA(TIMEM,A     1,A  182,  2.8353E+06,Q  9001)$
D11MDA(TIMEM,A     1,A  183,  2.8353E+06,Q  9002)$
D11MDA(TIMEM,A     1,A  184,  2.8353E+06,Q  9003)$
```

Introduction to Chapter 3

Change of Phase

Because many engineering problems related to heat transfer and thermodynamics involve a change of phase (solid/liquid or liquid/ vapor), chapter three section one is included to illustrate a simple technique, in SINDA, to account for a phase change. This chapter also illustrates the versatility of the SINDA code, through use of so-called working arrays. These arrays are useful ways of storing and summing variables during transient analyses.

Section two is included as a more detailed example, extending the techniques discussed in chapter three, section one. This example also includes a specific application to an engineering problem, related to the Shuttle program. Also included in this example is a method for grid recession and for modeling temperature dependent rate reactions. While this example has much detail and background information, it illustrates the fundamental versatility of the analysis techniques, and codes.

Section 3 illustrates the analytical procedures used to calculate ice/frost formation on ET surfaces. Early in the Shuttle program, engineering at MSFC recognized that excessive formation of ice on the cryogenic External Tank (ET), represented a potential debris hazard to the Orbiter tiles. Prior to launch of STS-1, precautions were taken through design, to minimize formation of ice or frost on the ET. Along with this, analyses were undertaken to quantify the potential for ice formation on tank surfaces. Because weight restrictions prohibit preclusion of all ice formation on the tank, a finite probability of excessive ice formation exists during severe weather in winter months. The example includes a very conservative representation of potential ice formation, and also describes a procedure for calculating condensate or frost formation in a humid atmospheric environment. The energy balance described in the analysis includes both sensible and latent heat storage, and the three modes of heat transfer. The example includes the same analytical procedure used for prelaunch calculations for each Shuttle launch.

CHAPTER 3: CHANGE OF PHASE

SECTION 1: Phase Change of a Metal

ANALYSIS CODE: SINDA (Gaski Version)

I. Preface to the Problem:

Following is a simple approach for modeling phase changes in physical systems. This approach may be taken when analyzing spacecraft systems that utilize phase change materials, such as those used in thermal capacitors. The included example involves a metal with high heat flux and a quick response.

The principle objectives of this section are to understand a physical modeling technique, the use of "working arrays" and the use of specific user-supplied subroutines, in SINDA.

II. Identification of the Problem:

A. Statement of the Problem:

Consider a 440C Stainless Steel specimen of length, 0.1", width, 0.1", and thickness, 0.0025". The specimen is shown in Figure 1. If the specimen is initially at a temperature of 2400 ^{o}F and heat is added to the upper surface such that Q(t) = 1.0 BTU/ft^2-sec, for a duration of 0.0005 seconds, determine the transient temperature distribution in the plate for a 0.001 seconds period. Define when and where melting/vaporization occurs (if at all). The lower side of the plate is insulated.

B. Schematic:

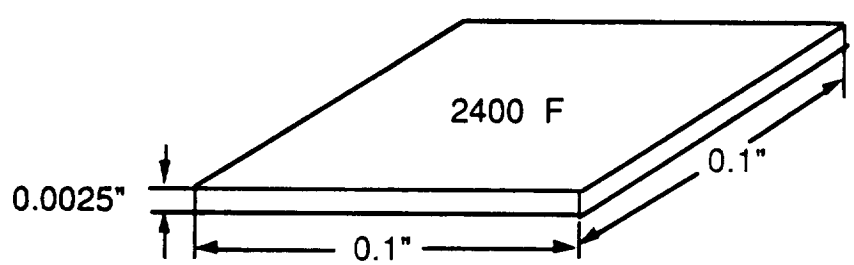

Figure 1. Schematic of Stainless Steel Specimen

C. Given:

1. Thermal properties of 440C Stainless Steel.
2. Uniform initial temperature of 2400°F.
3. Melting temperature of 2600 °F.
4. Vaporization temperature of 5000 °F.
5. Time dependent heat input.
6. Heat of fusion, 86.4 BTU/lbm.
7. Heat of vaporization, 2900 BTU/lbm.

D. Find:

1.Transient temperature distribution through the specimen.

III. Formulation of the Problem:

A simple approach to modeling solid-to-liquid phase changes is to consider the specimen as a 1-D stack of nodes, with an impressed heat load at the surface. Such a nodal network is depicted in Figure 2.

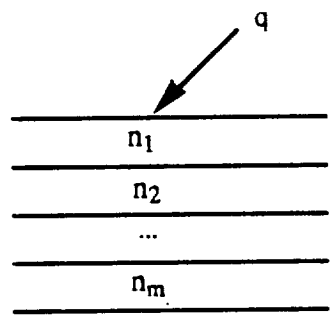

Figure 2. One Dimensional Node Stack

Assuming an R-C network connecting the lumped masses (nodes), the energy required to induce a phase change in node 1 is given by equation (1).

$$Q = (\text{mass})*(\text{heat of fusion}). \qquad (1)$$

For a transient (SINDA) solution, equation (2) applies at each time step.

$$Q = (\text{mass})*(\text{specific heat})*(\text{delta T}). \qquad (2)$$

However, a phase change occurs at constant temperature; hence there should be no "delta T" during this process. If such information is not conveyed to SINDA, the phase change must be modeled, separately, with user-defined subroutines. While there are versions of SINDA which have intrinsic routines that model a change of phase, this chapter is intended to illustrate the use of "working arrays" and user-written subroutines; consequently, these versions are not addressed here.

The model must be constructed with adequate information about the (phase change) material. Time steps must also be sufficiently small such that node melting and solidification occurs over several steps. Furthermore, the accuracy of the energy balance is strongly dependent upon the time step. It

should be noted that this constraint on the time step has nothing to do with the numerical stability of the solution, but rather, with the accuracy of the results.

One possible approch is as follows:

1. Check nodal temperatures, with respect to the phase change temperature (T_{pc}).
2. If a phase change is occuring, calculate m·cp·ΔT for the surface node, and store this value in the Q_{sum} location.
3. Compare Q_{sum} with the product, (mass)*(heat of fusion) to determine whether the node has melted or solidified.
4. If the node is fully melted/solidified, cease checking for a phase change in future time steps, for the surface node.
5. If the node continues to change phase, reset the temperature to T_{pc} and continue stepping through the calculations.

This approach may be used on successive nodes in the 1-D stack. As nodes are vaporized, they are disconnected from the network, and the active surface moves through the network.

A convenient method of recording node status and energy is through use of "working arrays". For each node, an array is established, in the array data block, as follows:

ARRAY LOCATION	DESCRIPTION	
1	record melt status	0 - unmelted 1 - melting 2 - melted
2	record mass	
3	store heat of fusion	
4	sum energy input	

As the transient solution progresses, the melt status location is used to select an appropriate calculation procedure.

IV. Analysis:

A. The Input Deck:

This section is included to describe how the (SINDA) input deck, presented on the following pages, was developed. The "Gaski" deck comprises nine major parts or "blocks". As many of these parts have been described in previous chapters, emphasis will be placed upon the "working arrays" and the user-written subroutines.

The Stainless Steel specimen has dimensions 0.1"x0.1"x0.0025" and is modeled as a 1-D stack of 25 nodes. Heating is applied to the 0.1"x 0.1" surface area of this 1-D stack. The thickness of each element is 1.0E-4

inch. It is assumed that the initial and melt temperatures of the stack are 2400 °F and 2600 °F, respectively.

1. Working Arrays

Array numbers 1 through 25 correspond to nodes 1 through 25. Each array has 12 entries which are addressed and used in VARIABLES 1 and VARIABLES 2. Location 2 is used to store the mass of each node. The melt status of each node is stored as an integer in location 7. The heat of fusion is stored in location 8. The energy stored in each node (i.e. Q_{sum}) is stored in location 9. The vaporization status of each node is retained in locations 10, 11 and 12. The node number corresponding to the active surface is determined in VARIABLES 1, by checking the value in location 10. Locations 1, 3, 4, 5, 6, and 7 are initially set to zero.

2. User Subroutines

Calls to the user-supplied subroutines are made in VARIABLES 2. This block also contains the user subroutines entitled "QVAP" and "QMELT". While these subroutines use basically the same logic, one checks for vaporization of the surface node and the other for melting. Working arrays, used in these subroutines check or reset the melt/vaporization status, retrive thermal properties, and store the summed heat load for each node. Note that, through the use of this technique, a phase change may be modeled in either "direction" (i.e. melting or solidification), depending upon the energy balance.

SINDA INPUT LISTING

```
        BCD 3THERMAL LPCS
        BCD 9PHASE CHANGE (SOLID/LIQUID) IN THERMAL NETWORKS
        END
C
        BCD 3NODE DATA
C
C ONE D STACK, 1.E-4 IN THICK NODES, 0.1" X 0.1" AREA
C CAPACITANCES ARE CALCULATED IN EXECUTIONS AND VARIABLES 1
C
        GEN 1, 25, 1, 2400.0, 2.894E-8
C
C CONVECTION BOUNDARY
C
            -9998, -230., 1.0 $ LOX BULK TEMP
C
C BOUNDARY FOR BULK BALL TEMP, CAN BE TIME VARYING FOR WHITE
C SANDS 0.05" TC
C
            -9999, 2400.0, 1.0 $ BULK BALL TEMP
C
        END
C
        BCD 3CONDUCTOR DATA
C
C VARIABLE CONDUCTIVITY CONDUCTORS
C
        SIV 1,  1,  2,  A4000, K1
        SIV 2,  2,  3,  A4000, K2
        SIV 3,  3,  4,  A4000, K3
        SIV 4,  4,  5,  A4000, K4
        SIV 5,  5,  6,  A4000, K5
        SIV 6,  6,  7,  A4000, K6
        SIV 7,  7,  8,  A4000, K7
        SIV 8,  8,  9,  A4000, K8
        SIV 9,  9,  10, A4000, K9
        SIV 10, 10, 11, A4000, K10
        SIV 11, 11, 12, A4000, K11
        SIV 12, 12, 13, A4000, K12
        SIV 13, 13, 14, A4000, K13
        SIV 14, 14, 15, A4000, K14
        SIV 15, 15, 16, A4000, K15
        SIV 16, 16, 17, A4000, K16
        SIV 17, 17, 18, A4000, K17
        SIV 18, 18, 19, A4000, K18
        SIV 19, 19, 20, A4000, K19
        SIV 20, 20, 21, A4000, K20
        SIV 21, 21, 22, A4000, K21
        SIV 22, 22, 23, A4000, K22
        SIV 23, 23, 24, A4000, K23
        SIV 24, 24, 25, A4000, K24
C
        SIV 25, 25, 9999, A4000, K25
C
C CONVECTION CONDUCTORS
C CALCULATED IN VARIABLES 1 FOR FIRST AVAILABLE SURFACE
C CAN BE SET FOR MOLTEN PARTICLES WHICH LEAVE SURFACE
C
        GEN 1001, 25, 1, 1, 1, 9998, 0, 0.0
C
        END
C
        BCD 3CONSTANTS DATA
```

```
            NDIM,    1500
            DTIMEI,  5.E-7
            DTIMEH,  5.E-7
            NLOOP,   1000
C
C MODEL RUNS IN MICROSECOND RANGE
C
            TIMEND,  1000.E-6
            OUTPUT,  10.E-6
C
C MAX TIME STEP IS 5.E-7 BASED ON C/GSUM
C MAY NEED TO BE SMALLER TO GO THROUGH HEAT OF FUSION
C ACCURATELY
C
            BALENG,  0.0001
            ARLXCA,  0.001
            DRLXCA,  0.001
            TIMEO,   0.0
            DAMPA,   0.5
            DAMPD,   0.5
C
C CONSTANTS FOR CONDUCTORS
C THESE ARE RESET WHEN SURFACE CONSUMES ITSELF
C CAN BE DISCONNECTED WHEN SURFACE MELTS (FOR ROTATING CASES)
C
        GEN 1, 25, 1, 8.33
C
C Q LOCATION POINTER
C
            1001,0
            1002,0.
C
C RHO*VOL
C
            5000,    2.8935E-7
C
C CONVECTION H*A FOR QUENCH OF MOLTEN PARTICLES AFTER LEAVING
C SURFACE
C
            5001,  4.E-4
            8000,  0.0
C
        END
C
        BCD 3ARRAY DATA
C
C WORKING ARRAYS
C
C  +1 NOT USED IN THIS MODEL
C
C  +2 MASS (LB)
C
C  +3 NOT USED IN THIS MODEL
C
C  +4 NOT USED IN THIS MODEL
C
C  +5 NOT USED IN THIS MODEL
C
C  +6 NOT USED IN THIS MODEL
C
C  +7 MELT STATUS          0 - UNMELTED
C                          1 - MELTING
C                          2 - MELTED
C
```

```
C  +8 HEAT OF FUSION (BTU/LB)
C
C  +9 MELT QSUM (BTU)
C
C +10 VAPORIZATION STATUS  0 - UNVAPORIZED
C                          1 - VAPORIZING
C                          2 - VAPORIZED
C
C +11 HEAT OF VAPORIZATION (BTU/LB)
C
C +12 VAPORIZATION QSUM (BTU)
C
          1,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          2,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          3,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          4,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          5,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          6,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          7,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          8,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
          9,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         10,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         11,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         12,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         13,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         14,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         15,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         16,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         17,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         18,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         19,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         20,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         21,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         22,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         23,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         24,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
         25,  0, 2.894E-7, 0.,0.,0.,0.,0, 86.4, 0., 0, 2900., 0., END
C
C VARIABLE CONDUCTIVITY
C
         4000 $ THERMAL COND VS TEMP (440C) BTU/SEC-FT-F
         -300.,    3.108E-3
            0.,    3.756E-3
          700.,    4.332E-3
         1400.,    5.724E-3
         2000.,    6.948E-3
         END
C
C VARIABLE CAPACITANCE
C
         5000 $ THERMAL CAPACITANCE VS TEMP (440C) BTU/LBM-DEG F
         -300.,      0.0948
          200.,      0.1138
         1400.,      0.1801
         2100.,      0.2275
         END
C
         5001 $ DUMMY
         0.0,        0.0
         0.0,        0.0
         END
C
C CYCLIC HAETING ARRAY FOR ROLLING BALL
C CAN BE CONSTANT FOR WHITE SANDS OR FOR NBS
```

```
C
          2000
          0.0,        1.0
          500.0E-6,   1.0
          500.1E-6,   0.0
          1000.0E-6,  0.0
          END
C
C CYCLIC CONVECTION ARRAY FOR ROLLING BALL
C
          3000
          0.0,        0.0
          10.E-6,     0.0
          10.01E-6,   0.0E-4
          338.E-6,    0.0E-4
          END
C
      END
C
      BCD 3EXECUTION
C
F     OPEN(3,FILE="SAB.PLT",STATUS="UNKNOWN")
F     WRITE(3,2) NX(1),(NX(I),I=5,25,5)
F   2 FORMAT(/,3X,'TIME',4X,6('   NODE   '),/,
F    *         3X,'SEC ',5X,6(I5,5X),/)
C
C
C CALCULATE CAPACITANCE
C
F     DO 4 I=1,25
F     TEMP=T(I)
M     CALL D1DEG1(TEMP,A5000,CAP)
M     CAP=CAP*XK5000
F     C(I)=CAP
F   4 CONTINUE
C

F          DTIMEI = 5.E-7
F          DTIMEH = 5.E-7
F          NLOOP  = 1000
F          TIMEND = 1000.E-6
F          OUTPUT = 10.E-6
F          ARLXCA = 0.001
F          DRLXCA = 0.001
F          TIMEO  = 0.0
F          DAMPA  = 0.5
F          DAMPD  = 0.5
C
F     CALL FWDBKL
      END
C
      BCD 3VARIABLES 1
C
C DETERMINE FRICTIONAL HEATING
C
M 1   CALL D1DEG1(TIMEN,A2000,FQ)
C
C DETERMINE CYCLIC CONVECTION
C
M     CALL D11CYL(338.E-6,TIMEN,A3000,GCONV)
C
C CALCULATE CAPACITANCE
C
F     DO 4 I=1,25
```

```
C
F       TEMP=T(I)
M       CALL D1DEG1(TEMP,A5000,CAP)
M       CAP=CAP*XK5000
F       C(I)=CAP
C
C SET CONVECTION TO 0 UNTIL FIRST ACTIVE SURFACE IS DETERMINED BELOW
C
M       G(1001+I-1)=0.
C
F    4  CONTINUE
C
C SET POINTER FOR FIRST ACTIVE SURFACE
C
F       DO 15 I=1,25
F       IF (IA(11+13*(I-1)).NE.2)GO TO 18
F 15    CONTINUE
C
C IMPOSE FRICTIONAL Q
C
F 18    CONTINUE
F       Q(I)=Q(I)+FQ
F       STQ=Q(I)
F 19    CONTINUE
C
C SET CONVECTION
C
M       G(1001+I-1)=GCONV
C
C STORE POINTER
C
M       K1001=I
M       XK1002=STQ
C
F1000   CONTINUE
C
        END
C
        BCD 3VARIABLES 2
C

C DETERMINE MELTING
C
F       DO 5 I=1,25
F       CALL QMELT(T(I),A(1+13*(I-1)),IA(1+13*(I-1)),XK(I))
F    5  CONTINUE
C
C DETERMINE VAPORIZATION
C
F       DO 6 I=1,25
F       CALL QVAP(T(I),A(1+13*(I-1)),IA(1+13*(I-1)),XK(I))
F    6  CONTINUE
C
F       RETURN
F       END
C
C VAPORIZATION ROUTINE
C
F       SUBROUTINE QVAP(TEMP,CA,ICA,GCOND)
F       DIMENSION CA(1),ICA(1)
C
C DETERMINE IF NODE IS COMPLETELY CONSUMED
C
F       IF(ICA(2).EQ.3)RETURN
```

```
C
C DOES NODE MEET VAPORIZATION TEMPERATURE REQUIREMENTS
C
F       IF(TEMP.LT.5000.0)RETURN
C
C IS NODE COMPLETELY VAPORIZED
C
F       IF(ICA(11).EQ.2)RETURN
C
C CALCULATE M*CP*DELTA-T FOR LAST TIME STEP
C
F       CA(13)=CA(13)+CA(3)*.2275*(TEMP-5000.)
C
C CHECK FOR COMPLETE VAPORIZATION
C
F       IF(CA(13).GE.CA(12)*CA(3))GO TO 25
C
C RESET TEMPERATURE TO VAPORIZATION TEMPERATURE
C SET VAPORIZATION STATUS TO VAPORIZING
C
F       TEMP=5000.
F       ICA(11)=1
F       RETURN
C
C SET VAPORIZATION STATUS TO VAPORIZED
C DISCONNECT FROM NETWORK
C
F  25   ICA(11)=2
F       GCOND=1.E-8
F       RETURN
F       END
C
C MELTING ROUTINE
C
F       SUBROUTINE QMELT(TEMP,CA,ICA,GCOND)
F       DIMENSION CA(1),ICA(1)
C
C IS NODE COMPLETELY CONSUMED
C
F       IF(ICA(2).EQ.3)RETURN
C

C DOES NODE MEET MELT TEMPERATURE REQUIREMENTS
C
F       IF(TEMP.LT.2600.0)GO TO 100
C
C IS NODE ALREADY MELTED
C
F       IF(ICA(8).EQ.2)RETURN
C
C CALCULATED M*CP*DEL-T FOR LAST TIME STEP
C
F       CA(10)=CA(10)+CA(3)*.2275*(TEMP-2600.)
C
C CHECK FOR COMPLETELY MELTED
C
F       IF(CA(10).GE.CA(9)*CA(3))GO TO 25
C
C RESET TEMPERATURE TO MELT TEMPERATURE
C SET MELT STATUS TO MELTING
C
F       TEMP=2600.
F       ICA(8)=1
F       RETURN
```

```
C
C SET MELT STATUS TO MELTED
C
F  25  ICA(8)=2
F      TEMP=2600.
C
C REMOVE LIQUID NODE FROM MODEL FOR ROTATING CASES
C MAY WANT TO CHANGE TO A CONVECTIVE G TO SIMULATE COMBUSTION
C PRODUCTS INTERFACING WITH NEXT LAYER OR MAY USE A LIQUID
C CONDUCTIVITY
C
F      GCOND=8.33
F      RETURN
C
C ALLOW FOR RESOLIDIFICATION
C
F 100  IF(ICA(8).EQ.2 .OR. ICA(8).EQ.1)GO TO 110
F      RETURN
F 110  CA(10)=CA(10)-CA(3)*.2275*(2600.-TEMP)
F      IF(CA(10).LE.0.0)GO TO 120
F      TEMP=2600.
F      ICA(8)=1
F      RETURN
F 120  ICA(8)=0
F      CA(10)=0.
F      GCOND=8.33
C
       END
C
       BCD 3OUTPUT CALLS
C
F      WRITE(3,1)TIMEO,T(1),(T(I),I=5,25,5)
F    1 FORMAT(E10.3,(6F10.3))
C
F      CALL STNDRD
F      WRITE(6,99)
F   99 FORMAT(/,' NODE TEMP STATUS  QCOMB  GCOND    GCONV  Q-LOC',
F     * ' M-STAT Q-MLT V-STAT QSURF',/)
C
F      DO 200 I=1,25
M      GCONV=G(1001+I-1)
M      IQ=K(1001)
M      STQ=XK1002
F      WRITE(6,100)I,T(I),IA(2+(I-1)*13),A(7+(I-1)*13),G(I),GCONV,IQ,
F     * IA(8+(I-1)*13),A(10+(I-1)*13),IA(11+(I-1)*13),STQ
F 100 FORMAT(1X,I3,1X,F7.1,1X,I2,1X,E8.3,1X,E8.3,1X,E8.3,1X,I3,2X,I2,
F     * 2X,E8.3,2X,I2,2X,E8.3)
F 200  CONTINUE
C
       END
       BCD 3END OF DATA
```

V. Presentation and Discussion of Results:

A. SINDA Output File:

The output file corresponding to the example in Section IV.A is presented on the following pages. Output was generated using user-supplied FORTRAN statements in the OUTPUT CALLS block. The title heading for each column is given below:

TITLE	STORED VALUE
NODE	Node number
TEMP	Node temperatue, °F
STATUS	Not used in this chapter
QCOMB	Not used in this section
GCOND	Conduction conductor
GCONV	Convection Conductor
Q-LOC	Active surface node number
M-STAT	Node melting status
Q-MLT	Summed phase change energy
V-STAT	Node vapor status
QSURF	Summed vaporization energy

As seen from this output file, node 1 is melting at TIME = 2.00E-4 seconds, at which time it's temperature is 2600 °F and the melt status is 1. At the next print time, nodes 1 and 2 have a melt status of 2, indicating that these nodes have already melted. Node 3 is in the process of melting as evidenced by the fact that M-STAT = 1. At this print interval, the active surface is still node 1 and the temperatures of nodes 1 and 2 are greater than the 2600 °F melt temperature. It should be noted that the actual print time used for this analysis was 10.E-6 seconds. However a, longer print interval was used to generate the SINDA output file presented, here. This action was taken to reduce the amount of printout.

SINDA OUTPUT LISTING

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     PHASE CHANGE (SOLID/LIQUID) IN THERMAL NETWORKS

 *** NOTE *** FWDBKL REQUIRES     177 DYNAMIC STORAGE LOCATIONS OUT OF    1333 AVAILABLE ***
              TIMEND= 0.10000E-02, CSGFAC=  1.0000      , DTIMEI= 0.50000E-06, NLOOP =          1000
              TIMEO = 0.00000      , OUTPUT= 0.10000E-03, DTIMEH= 0.50000E-06, DTIMEL= 0.00000
              ARLXCA= 0.10000E-02, ATMPCA= 0.00000      , DRLXCA= 0.10000E-02, DTMPCA= 0.10000E+09
              EXTLIN=  50.000

 ****************
 TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(       0)= 0.00000E+00, ATMPCC(       0)= 0.00000E+00, DTMPCC(       0)=
0.00000E+00
     LOOPCT=      0
0.00000E+00                                                                 , ARLXCC(       0)= 0.00000E+00, DRLXCC(       0)=

 NODE TEMP STATUS  QCOMB  GCOND    GCONV  Q-LOC M-STAT Q-MLT V-STAT QSURF

   1  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   2  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   3  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   4  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   5  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   6  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   7  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   8  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   9  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  10  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  11  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  12  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  13  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  14  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  15  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  16  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  17  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  18  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  19  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  20  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  21  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  22  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  23  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  24  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  25  2400.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01

 ****************
 TIME= 1.00000E-04, DTIMEU= 2.50118E-07, CSGMIN(       2)= 5.68683E-07, ATMPCC(       0)= 0.00000E+00, DTMPCC(       1)=
2.28516E-01
     LOOPCT=      4
2.44141E-04                                                                 , ARLXCC(       0)= 0.00000E+00, DRLXCC(       2)=

 NODE TEMP STATUS  QCOMB  GCOND    GCONV  Q-LOC M-STAT Q-MLT V-STAT QSURF

   1  2574.3  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   2  2558.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   3  2542.8  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   4  2528.6  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   5  2515.4  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   6  2503.2  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   7  2492.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   8  2481.6  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   9  2472.2  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  10  2463.6  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  11  2455.7  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  12  2448.7  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  13  2442.3  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  14  2436.6  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  15  2431.5  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  16  2426.9  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  17  2422.8  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  18  2419.2  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  19  2415.9  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  20  2413.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  21  2410.4  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  22  2408.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  23  2405.9  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  24  2403.8  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  25  2401.9  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01

 ****************
 TIME= 2.00001E-04, DTIMEU= 2.50118E-07, CSGMIN(       2)= 5.68683E-07, ATMPCC(       0)= 0.00000E+00, DTMPCC(       1)=
1.63940E+00
     LOOPCT=      3
7.32422E-04                                                                 , ARLXCC(       0)= 0.00000E+00, DRLXCC(      11)=

 NODE TEMP STATUS  QCOMB  GCOND    GCONV  Q-LOC M-STAT Q-MLT V-STAT QSURF

   1  2600.0  0 .000E+00 .579E-01 .000E+00   1   1  .203E-04   0  .100E+01
   2  2591.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   3  2580.8  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   4  2570.6  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   5  2560.5  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   6  2550.6  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   7  2540.8  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   8  2531.2  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
   9  2521.8  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  10  2512.7  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  11  2503.9  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  12  2495.3  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
  13  2487.0  0 .000E+00 .579E-01 .000E+00   1   0  .000E+00   0  .100E+01
```

14	2478.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
15	2471.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
16	2463.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
17	2456.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
18	2449.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
19	2442.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
20	2436.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
21	2430.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
22	2423.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
23	2417.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
24	2411.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
25	2405.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01

```
****************
TIME= 3.00002E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      3)=
1.68115E+00
    LOOPCT=      4                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      5)=
2.44141E-04
```

NODE	TEMP	STATUS	QCOMB	QCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2635.8	0	.000E+00	.579E-01	.000E+00	1	2	.251E-04	0	.100E+01
2	2618.5	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.100E+01
3	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.427E-05	0	.100E+01
4	2590.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
5	2580.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
6	2570.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
7	2560.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
8	2550.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
9	2540.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
10	2531.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
11	2522.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
12	2513.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
13	2504.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
14	2495.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
15	2487.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
16	2478.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
17	2470.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
18	2462.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
19	2454.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
20	2446.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
21	2438.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
22	2430.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
23	2423.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
24	2415.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
25	2407.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01

```
****************
TIME= 4.00003E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      4)=
1.87256E+00
    LOOPCT=      5                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
0.00000E+00
```

NODE	TEMP	STATUS	QCOMB	QCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2653.4	0	.000E+00	.579E-01	.000E+00	1	2	.251E-04	0	.100E+01
2	2636.1	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.100E+01
3	2618.7	0	.000E+00	.579E-01	.000E+00	1	2	.252E-04	0	.100E+01
4	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.162E-04	0	.100E+01
5	2591.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
6	2582.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
7	2572.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
8	2562.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
9	2552.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
10	2543.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
11	2533.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
12	2524.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
13	2515.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
14	2505.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
15	2496.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
16	2487.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
17	2478.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
18	2469.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
19	2460.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
20	2451.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
21	2443.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
22	2434.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
23	2425.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
24	2417.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01
25	2408.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.100E+01

```
****************
TIME= 5.00004E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      5)=
3.95020E-01
    LOOPCT=      4                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
4.88281E-04
```

NODE	TEMP	STATUS	QCOMB	QCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2670.6	0	.000E+00	.579E-01	.000E+00	1	2	.251E-04	0	.964E+00
2	2653.6	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.964E+00
3	2636.9	0	.000E+00	.579E-01	.000E+00	1	2	.252E-04	0	.964E+00
4	2621.0	0	.000E+00	.579E-01	.000E+00	1	2	.251E-04	0	.964E+00
5	2606.6	0	.000E+00	.579E-01	.000E+00	1	2	.251E-04	0	.964E+00
6	2593.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
7	2582.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
8	2572.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
9	2562.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
10	2552.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
11	2542.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
12	2532.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
13	2522.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
14	2513.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
15	2503.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
16	2494.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00

17	2484.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
18	2474.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
19	2465.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
20	2456.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
21	2446.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
22	2437.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
23	2427.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
24	2418.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00
25	2409.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.964E+00

```
****************
 TIME= 6.00005E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      4)=
1.75220E+00
     LOOPCT=      5                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
0.00000E+00
```

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.250E-04	0	.000E+00
2	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.248E-04	0	.000E+00
3	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.234E-04	0	.000E+00
4	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.132E-04	0	.000E+00
5	2590.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
6	2581.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
7	2573.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
8	2565.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
9	2556.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
10	2548.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
11	2539.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
12	2530.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
13	2521.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
14	2512.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
15	2503.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
16	2494.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
17	2484.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
18	2475.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
19	2466.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
20	2456.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
21	2447.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
22	2437.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
23	2428.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
24	2418.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
25	2409.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00

```
****************
 TIME= 7.00006E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      2)=
1.42529E+00
     LOOPCT=      3                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
7.32422E-04
```

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.238E-04	0	.000E+00
2	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.182E-04	0	.000E+00
3	2592.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
4	2585.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
5	2578.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
6	2571.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
7	2563.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
8	2555.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
9	2547.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
10	2539.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
11	2531.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
12	2523.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
13	2514.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
14	2506.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
15	2497.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
16	2488.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
17	2480.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
18	2471.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
19	2462.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
20	2453.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
21	2444.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
22	2435.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
23	2426.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
24	2417.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
25	2409.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00

```
****************
 TIME= 8.00007E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=
1.73682E+00
     LOOPCT=      3                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
2.44141E-04
```

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.114E-05	0	.000E+00
2	2591.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
3	2583.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
4	2576.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
5	2568.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
6	2561.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
7	2554.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
8	2546.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
9	2538.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
10	2531.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
11	2523.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
12	2515.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
13	2507.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
14	2499.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
15	2491.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
16	2483.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
17	2475.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
18	2467.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
19	2458.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00

20	2450.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
21	2442.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
22	2433.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
23	2425.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
24	2416.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
25	2408.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00

```
****************
TIME= 9.00008E-04, DTIMEU= 2.50118E-07, CSGMIN(      2)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=
1.07422E-01
    LOOPCT=     3                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
9.76563E-04
```

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2521.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
2	2521.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
3	2520.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
4	2519.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
5	2517.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
6	2514.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
7	2511.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
8	2508.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
9	2504.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
10	2500.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
11	2496.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
12	2491.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
13	2486.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
14	2480.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
15	2475.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
16	2469.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
17	2462.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
18	2456.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
19	2449.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
20	2443.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
21	2436.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
22	2428.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
23	2421.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
24	2414.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
25	2407.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00

```
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     PHASE CHANGE (SOLID/LIQUID) IN THERMAL NETWORKS

****************
TIME= 1.00000E-03, DTIMEU= 2.41562E-07, CSGMIN(     25)= 5.68683E-07, ATMPCC(      0)= 0.00000E+00, DTMPCC(      1)=
7.00684E-02
    LOOPCT=     3                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      1)=
7.32422E-04
```

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2486.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
2	2486.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
3	2485.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
4	2484.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
5	2483.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
6	2481.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
7	2479.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
8	2477.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
9	2475.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
10	2472.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
11	2469.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
12	2465.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
13	2462.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
14	2458.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
15	2454.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
16	2450.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
17	2445.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
18	2441.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
19	2436.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
20	2431.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
21	2426.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
22	2421.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
23	2415.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
24	2410.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00
25	2405.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.000E+00

B. PLOTS

While the transient temperature distribution across the thickness of the plate can be inferred from the tabulated output, it is often difficult to interpret results which are presented in tabular form. For this reason, a FORTRAN statement was added to the OUTPUT CALLS block. The write statement printed the temperature of nodes 1, 5, 10, 15, 20 and 25 to file 3, as a function of time. This file was then used to generate a graphical representation of the results. Figure 3 shows the results of this analysis. This figure indicates melting of nodes 1 through 5 and further shows that the 1-D stack resolidifies upon reducing the heat addition to zero.

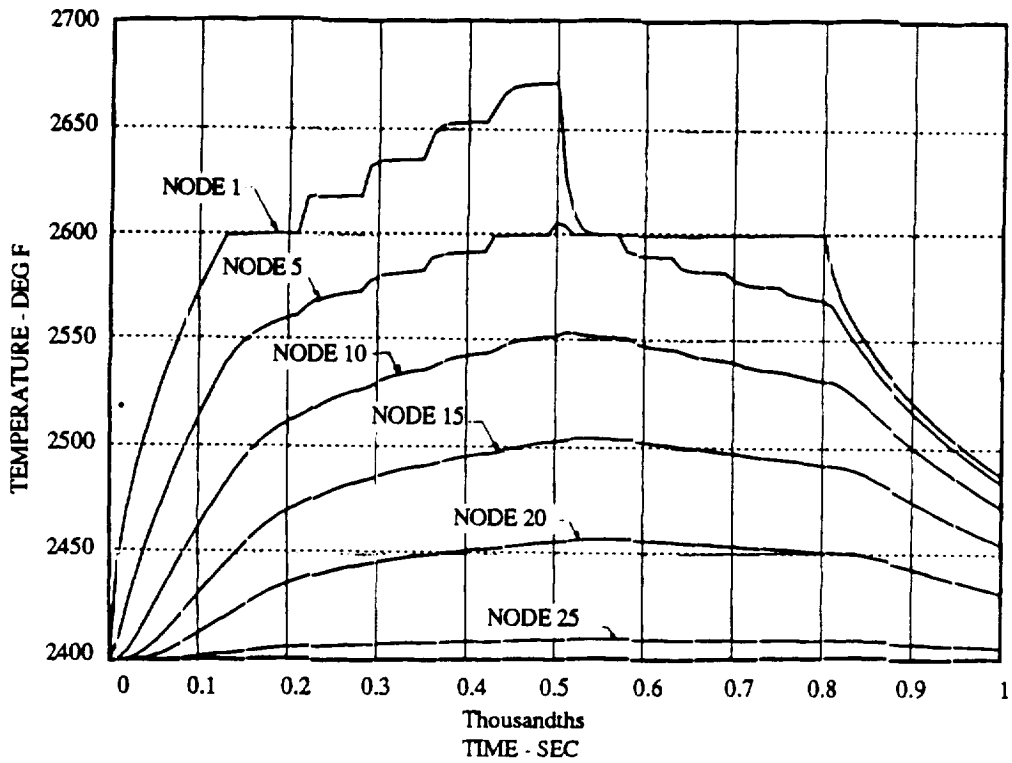

Figure 3. Phase Change (Solid/Liquid/Solid) in a 25 Node 1-D Stack

CHAPTER 3: CHANGE OF PHASE

SECTION 2: Oxidation of Metals at High Temperatures

ANALYSIS CODE: SINDA (Gaski)

Following is an extension of the previous technique. In this example the oxidation characteristics of a metal (stainless steel 440C) are simulated. The motivation for this work relates to the ignition potential of metals operating at high temperature in oxygen environments. The application of the work to a physical problem is discussed below. The reasons for including this example in the workbook are to illustrate the versatility of the SINDA code, the utility of the working array concept discussed in the previous example, the modeling of melting/resolidification and vaporization, and the modeling of temperature dependent rate reactions. A one-dimensional model is illustrated with surface recession based upon surface oxidation conditions.

Background:

The Space Shuttle Main Engine (SSME) High Pressure Oxidizer Turbopump (HPOTP) contains two duplex sets of liquid oxygen cooled ball bearings which support the rotating parts. The pump cross section is shown in Figure 1. Coolant for the turbine end bearings is provided through a hollow shaft, through the bearings, discharging to the main pump impeller inlet. Coolant for the preburner pump end bearings is provided by the preburner pump through a hub labyrinth,through the bearings,discharging to the main pump impeller inlet. Because the bearings are cryogenically cooled, they are poorly lubricated, and heat generation and bearing life are of concern. The SSME bearings are considered to be the life limiting element in the pump design, and additionally have been studied as a safety critical item during pump operation.

During SSME development several pump failures were attributed to bearing failures. These failures typically resulted in a fire which consumes much of the pump. Because of NASA's return to flight safety assessment following the Challenger accident, a thorough investigation of bearing thermal and mechanical behavior was initiated. This analysis discusses the coolant heat transfer characteristics, the bearing geometry, materials, and thermal response to loads, the ignition characteristics of bearing materials, and an assessment of ignition potential for normally operating bearing systems.

Typically, high mechanical loads which can lead to high bearing temperatures have been thought to be a contributor to accelerated bearing wear, leading to a relatively short bearing life. Bearing failures which result in a combustion event have been attributed to cage fractures, severe rotor or bearing displacement, or extreme loss of bearing internal clearance. Because disassembly of some pumps revealed discolored bearing surfaces (attributed to oxidation at high surface temperatures) but no evidence of ignition or combustion, and no mechanical failure, NASA endeavored to quantify the thermal characteristics of the HPOTP bearings prior to the successful 1988 return to flight of the Space Transportation System (STS).

HPOTP-PHASE II DESIGN CHANGES

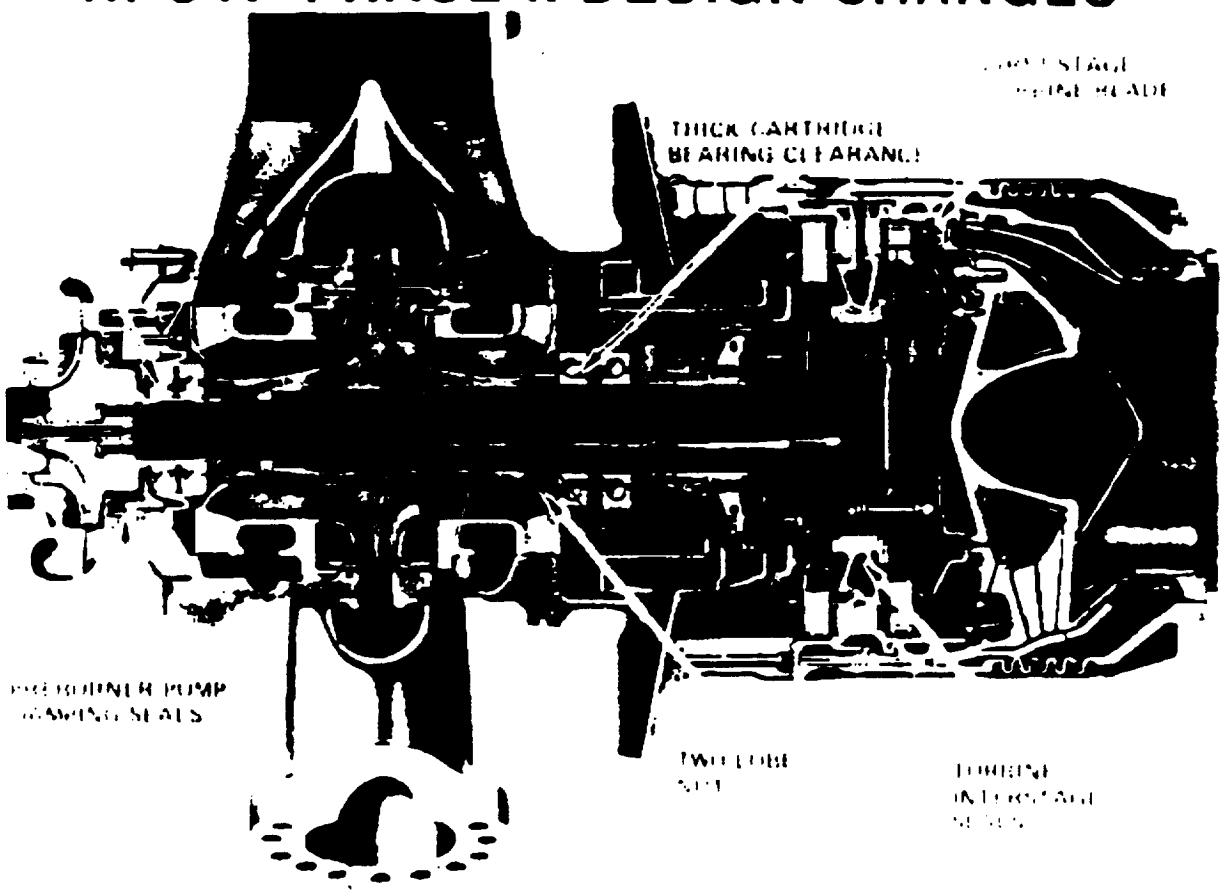

Figure 1. SSME High Pressure Oxidizer Turbopump

I. Identification of the Problem:

A. Statement of the Problem:

Consider a one-dimensional node stack as shown in Figure 2. The surface is exposed to a periodic frictional heat flux of a known magnitude. Depending upon surface temperature, an additional flux is imposed due to oxidation of the material. The rate of oxidation versus temperature is given. The node stack conducts heat to a constant temperature boundary condition. This boundary can be physically related to bulk ball temperature or average rolling path temperature in the bearing. Based upon the frictional heating, boundary temperature, and resulting surface temperature, simulate the transient response of the material and predict the potential for a sustained combustion event.

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OF POOR QUALITY

B. Schematic:

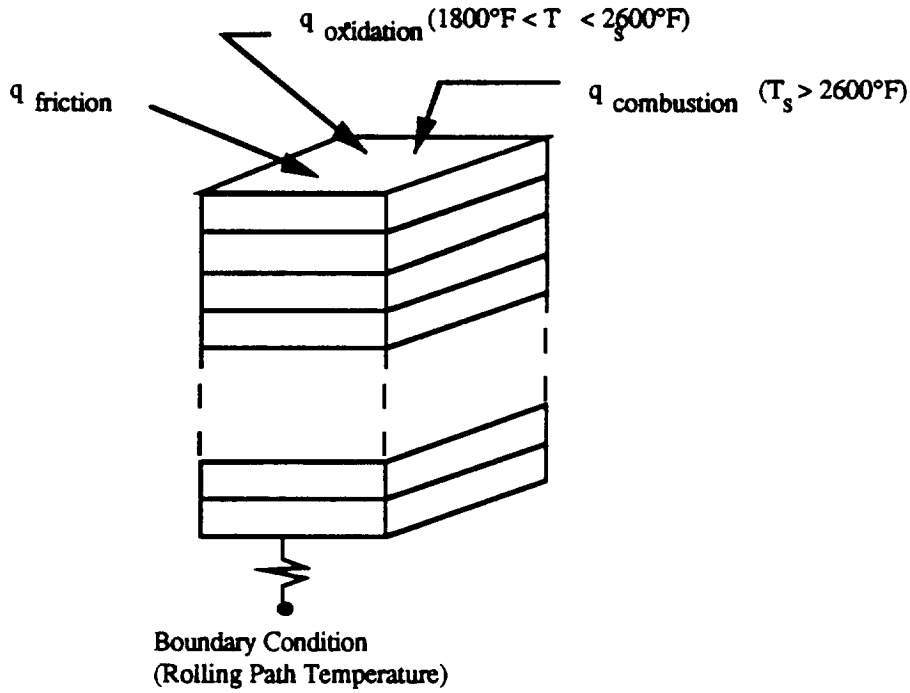

Figure 2. One-Dimensional Network

C. Given:

(1) Boundary temperature
(2) Frictional heating with time (see Figure 3)
(3) Material oxidation characteristic (see Figure 4)
(4) Material combustion characteristic (see Figure 5)

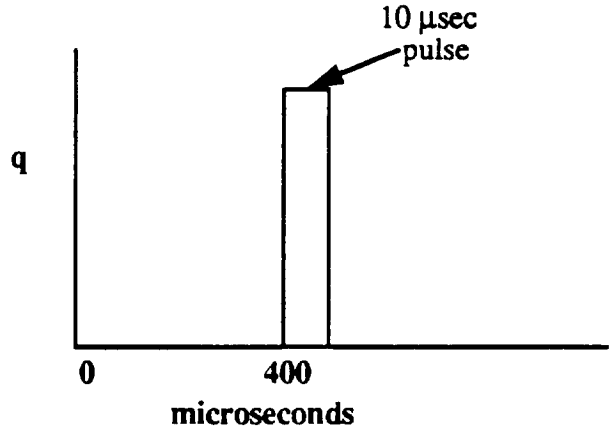

Figure 3. Frictional Heat Flux versus Time

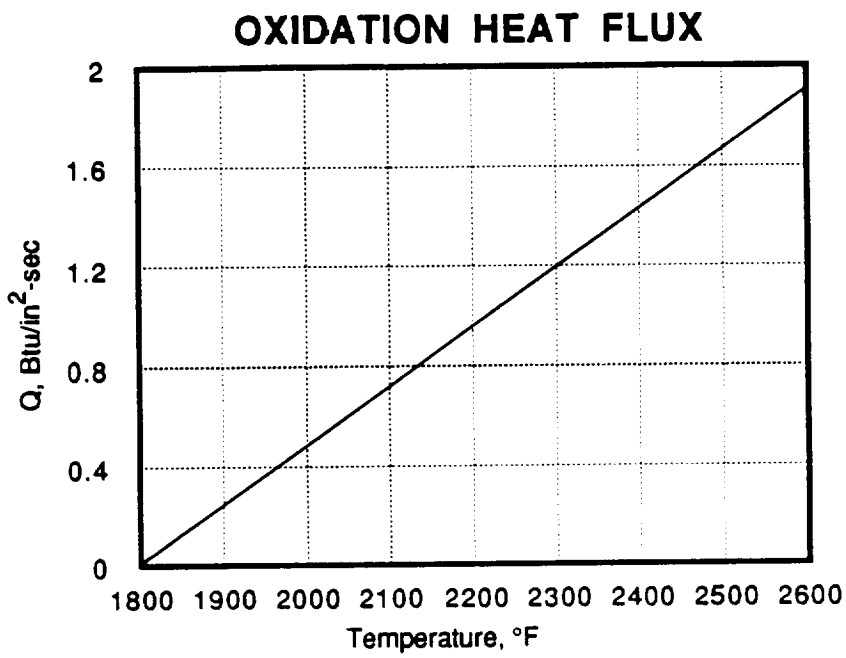

Figure 4. Oxidation Rate versus Temperature

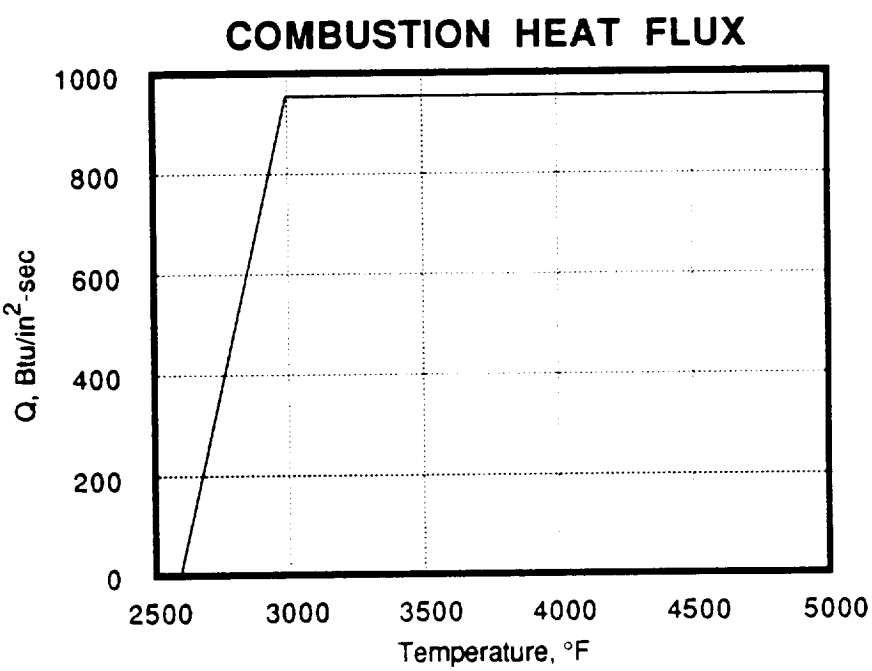

Figure 5. Combustion Rate versus Temperature

D. Find:

(1) The transient thermal response of the material
(2) The potential for propagation to a combustion event

II. Formulation of the Problem:

A. Simplifying Assumptions:

For analytical conservatism the following assumptions were used in the analysis.

(1) No convective cooling at the surface
(2) No radiation at the surface
(3) Energy of oxidation or combustion imposed to surface node (no energy lost to the surrounding convective environment)
(4) Consumption of material through the oxidation process can be modeled as shown in Figure 6, based upon the material heat of combustion (3437 BTU/lb)

B. Initial/Boundary Conditions:

(1) Known frictional (cyclic) heat flux
(2) Known conduction boundary temperature (average steady state rolling path temperature)
(3) Initial temperatures generated from steady state with time averaged heat flux (see input deck, EXECUTION block)

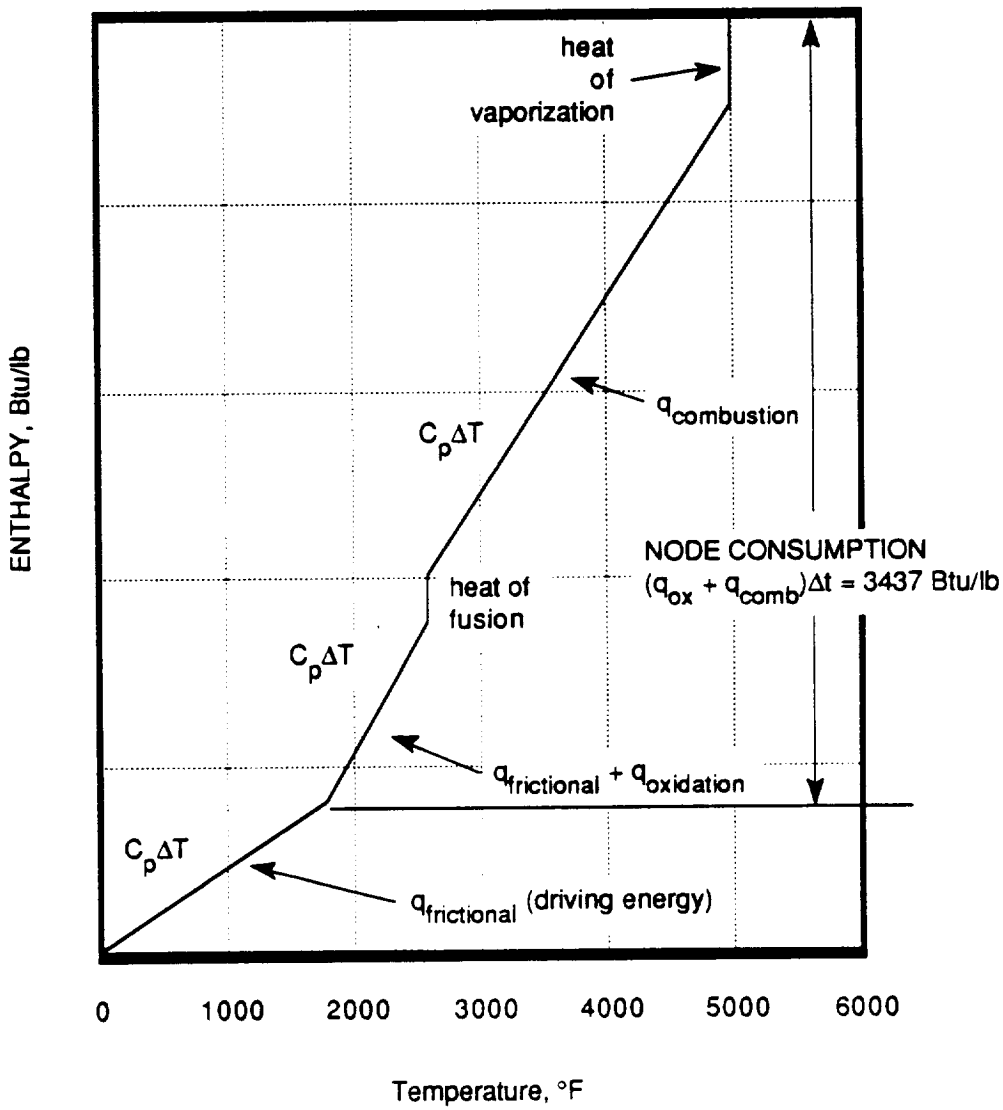

Figure 6. Node Consumption Methodology

C. Discretization:

The one-dimensional network is divided into 100 equally spaced diffusion nodes. To model the rolling path transient condition extremely small node sizes and time

steps were required. Two and three dimensional parametric analyses were performed (not presented here, see reference), to assure that the one-dimensional conduction approach adequately (and conservatively) bounded the problem at hand, and that the boundary condition, node size, and number of nodes accurately simulated the surface temperature transient response.

II. Analysis:

A. The Input Deck:

The input deck shown on the following pages is a Gaski SINDA input deck. As discussed in earlier examples, the input deck consists of the standard nine blocks of data required by SINDA. These will not be discussed in detail here, but specific and unique features of the analysis will be described.

A key feature of this simulation involves the summation over time of several mass and energy terms. The complex set of variables used for the simulation are described in the ARRAY data block. One working array is defined for each diffusion node in the model. Several status conditions are tracked in the working arrays including combustion, melting, and vaporization status. The reader is referred to the listing for complete description of the working array contents. This programming technique in SINDA has proven to be a very efficient method of defining and tracking information related to each node in the network.

Note that in the EXECUTION block, the time averaged heat flux is used in a steady state solution to provide the initial temperature distribution for the transient simulation.

SINDA MODEL LISTING

```
      BCD 3THERMAL LPCS
      BCD 9FUNDAMENTAL COMBUSTION ANALYSIS
      END
C
      BCD 3NODE DATA
C
C ONE D STACK, 1.E-4 IN THICK NODES, 0.1" X 0.1' AREA
C CAPACITANCES ARE CALCULATED IN ECECUTIONS AND VARIABLES 1
C
      GEN 1,100,1,2400.0, 2.894E-8
          -999, 2400.0, 1.0 $ ACTIVE SURF TEMP
C
C CONVECTION BOUNDARY
C
          -9998, -230., 1.0 $ LOX BULK TEMP (UNUSED)
C
C BOUNDARY FOR BULK BALL TEMP, CAN BE TIME VARYING FOR WHITE
C SANDS 0.05" TC
C
          -9999,2400.0, 1.0 $ AVG SURF TEMP (BOUNDARY)
C
      END
C
      BCD 3CONDUCTOR DATA
C
C VARIABLE CONDUCTIVITY CONDUCTORS
C
      SIV 1, 1, 2, A4000, K1
      SIV 2, 2, 3, A4000, K2
      SIV 3, 3, 4, A4000, K3
      SIV 4, 4, 5, A4000, K4
      SIV 5, 5, 6, A4000, K5
      SIV 6, 6, 7, A4000, K6
      SIV 7, 7, 8, A4000, K7
      SIV 8, 8, 9, A4000, K8
      SIV 9, 9, 10, A4000, K9
      SIV 10, 10, 11, A4000, K10
      SIV 11, 11, 12, A4000, K11
      SIV 12, 12, 13, A4000, K12
      SIV 13, 13, 14, A4000, K13
      SIV 14, 14, 15, A4000, K14
      SIV 15, 15, 16, A4000, K15
      SIV 16, 16, 17, A4000, K16
      SIV 17, 17, 18, A4000, K17
      SIV 18, 18, 19, A4000, K18
      SIV 19, 19, 20, A4000, K19
      SIV 20, 20, 21, A4000, K20
      SIV 21, 21, 22, A4000, K21
      SIV 22, 22, 23, A4000, K22
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      SIV 26, 26, 27, A4000, K26
      SIV 27, 27, 28, A4000, K27
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SIV 98, 98, 99, A4000, K98
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```
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        SIV 100, 100, 9999, A4000, K100
C
C CONVECTION CONDUCTORS
C CALCULATED IN VARIABLES 1 FOR FIRST AVAILABLE SURFACE
C CAN BE SET FOR MOLTEN PARTICLES WHICH LEAVE SURFACE
C
        GEN 1001,100,1, 1,1, 9998,0, 0.0
C
        END
C
        BCD 3CONSTANTS DATA
            NDIM,2000
            DTIMEI,2.E-7
            DTIMEH,2.E-7
            NLOOP,500
C
C MODEL RUNS IN MICROSECOND RANGE
C
            TIMEND,33800.E-6
            OUTPUT,2.E-7
C
C MAX TIME STEP IS 5.E-7 BASED ON C/GSUM
C MAY NEED TO BE SMALLER TO GO THROUGH HEAT OF FUSION
C ACCURATELY
C
C            BALENG,4.75E-4
            ARLXCA,.1
            DRLXCA,.1
            TIMEO,0.0
            DAMPA;0.5
            DAMPD,0.5
C
C CONSTANTS FOR CONDUCTORS
C THESE ARE RESET WHEN SURFACE CONSUMES ITSELF
C CAN BE DISCONNECTED WHEN SURFACE MELTS (FOR ROTATING CASES)
C
        GEN 1,100,1, 8.33
C
C Q LOCATION POINTER
C
            1001,0
            1002,0.
C
C RHO*VOL
C
            5000,2.8935E-7
C
C CONVECTION H*A FOR QUENCH OF MOLTEN PARTICLES AFTER LEAVING
C SURFACE
C
            5001,4.E-4
            8000,0.0
C
        END
C
        BCD 3ARRAY DATA
C
C WORKING ARRAYS
C
C  +1 COMBUSTION STATUS    0 - UNOXIDIZED/UNBURNED
C                          1 - OXIDIZING
C                          2 - BURNING
C                          3 - COMPLETELY CONSUMED
```

```
C
C  +2 MASS (LB)
C
C  +3 HEAT OF COMBUSTION (BTU/LB)
C
C  +4 RATE OF OXIDATION, SOLID (SEC) DETERMINES THE RATE OF
C                                    OXIDATION WHEN SOLID, .053 SEC
C                                    CORRESPONDS TO 1980 W/SQ-IN
C                                    [MASS*HEAT-OF-COMBUSTION/RATE]
C
C  +5 RATE OF OXIDATION, LIQUID (SEC) DETERMINES THE RATE OF
C                                     OXIDATION WHEN LIQUID, 1.E-4 SEC
C                                     CORRESPONDS TO 1.05E+6 W/SQ-IN
C                                     [MASS*HEAT-OF-COMBUSTION/RATE]
C
C  +6 OXIDATION/COMBUSTION QSUM (BTU)
C
C  +7 MELT STATUS        0 - UNMELTED
C                        1 - MELTING
C                        2 - MELTED
C
C  +8 HEAT OF FUSION (BTU/LB)
C
C  +9 MELT QSUM (BTU)
C
C +10 VAPORIZATION STATUS  0 - UNVAPORIZED
C                          1 - VAPORIZING
C                          2 - VAPORIZED
C
C +11 HEAT OF VAPORIZATION (BTU/LB)
C
C +12 VAPORIZATION QSUM (BTU)
C
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88,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
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90,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
91,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
92,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
93,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
94,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
95,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
```

```
            96,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
            97,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
            98,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
            99,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
            100,0,2.894E-7,3437.,.053,1.E-4,0.,0,86.4,0.,0,2900.,0.,END
C
C VARIABLE CONDUCTIVITY
C
            4000 $ THERMAL COND VS TEMP (440C) BTU/SEC-FT-F
            -300.,3.108E-3, 0.,3.756E-3, 700.,4.332E-3, 1400.,5.724E-3
            2000.,6.948E-3
            END
C
C VARIABLE CAPACITANCE
C
            5000 $ CAP
            -300.0,0.0948, 200.0,0.1138, 1400.,0.1801, 2100.,0.24
            END
C
            5001 $ DUMMY
            0.0,0.0, 0.0,0.0
            END
C
C CYCLIC HAETING ARRAY FOR ROLLING BALL
C CAN BE CONSTANT FOR WHITE SANDS OR FOR NBS
C
            2000
            0.0,0.0
            389.99E-6,0.0
            390.E-6,9.5
            400.E-6,9.5
            END
C
C CYCLIC CONVECTION ARRAY FOR ROLLING BALL
C
            3000
            0.0,0.0
            10.E-6,0.0
            10.01E-6,0.0E-4
            400.E-6,0.0E-4
            END
C
        END
C
        BCD 3EXECUTION
C
F       DATA TAB/1H    /
C
F       OPEN(3,FILE="OXIDE.PCP",STATUS="UNKNOWN")
F       WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F 2     FORMAT(I6/,250(I6,31X,I6/))
C
C
F       OPEN(10,FILE="OXIDE.MCP",STATUS="UNKNOWN")
F       WRITE(10,32)(NX(LNODE+I),TAB,I=1,NNT)
F 32    FORMAT(250(I6,A1))
C
C CALCULATE CAPACITANCE
C
F       DO 4 I=1,100
F       TEMP=T(I)
M       CALL D1DEG1(TEMP,A5000,CAP)
M       CAP=CAP*XK5000
F       C(I)=CAP
```

```
F    4  CONTINUE
C
F       TIMEO=0.0
F       OUTPUT=10.E-6
F       TIMEND=0.0
M       CALL D1DEG1(395.E-6,A2000,QAVG)
CF       BALENG=0.0005*QAVG
F       QAVG=(QAVG*10.)/400.
M       XK8000=QAVG
F       JTEST=0
F       CALL STDSTL
C
F            DTIMEI=2.E-7
F            DTIMEH=2.E-7
F            NLOOP=500
F            TIMEND=1000.E-6
F            OUTPUT=10.E-6
F            ARLXCA=.1
F            DRLXCA=.1
F            TIMEO=0.0
F            DAMPA=0.5
F            DAMPD=0.5
F            JTEST=1
C
F       CALL SNFRDL
C
        END
C
        BCD 3VARIABLES 1
C
F       IF(JTEST.EQ.1)GO TO 1
M       QAVG=XK8000
F       Q(1)=QAVG
F       GO TO 1000
C
C DETERMINE FRICTIONAL HEATING
C
M 1     CALL D11CYL(400.E-6,TIMEN,A2000,FQ)
C
C DETERMINE CYCLIC CONVECTION
C
M       CALL D11CYL(400.E-6,TIMEN,A3000,GCONV)
C
C CALCULATE CAPACITANCE
C
F       DO 4 I=1,100
C
F       TEMP=T(I)
M       CALL D1DEG1(TEMP,A5000,CAP)
M       CAP=CAP*XK5000
F       C(I)=CAP
C
C SET CONVECTION TO 0 UNTIL FIRST ACTIVE SURFACE IS DETERMINED BELOW
C
M       G(1001+I-1)=0.
C
F    4  CONTINUE
C
C DETERMINE OXIDATION
C
F       DO 3 I=1,100
C
F       CALL QOX(T(I),A(1+13*(I-1)),IA(1+13*(I-1)),Q(I),XK(I),DTIMEU)
C
```

```
C ONLY ALLOW FIRST OXIDIZING OR BURNING SURFACE TO RELEASE ENERGY
C
F       IF(IA(2+13*(I-1)).EQ.1 .OR. IA(2+13*(I-1)).EQ.2)GO TO 5
C
F   3   CONTINUE
C
F   5   CONTINUE
C
C DETERMINE COMBUSTION
C
F       DO 10 I=1,100
C
F       CALL QCOMB(T(I),A(1+13*(I-1)),IA(1+13*(I-1)),Q(I),XK(I),DTIMEU)
C
C ONLY ALLOW THE FIRST BURNING NODE TO RELEASE ENERGY AND STOP FRICTION
C
F       IF(IA(2+13*(I-1)).EQ.1 .OR. IA(2+13*(I-1)).EQ.2)GO TO 13
C
F 10    CONTINUE
C
F 13    CONTINUE
C
C SET POINTER FOR FIRST ACTIVE SURFACE
C
F       DO 15 I=1,100
F       ISTORE=I
F       IF (IA(2+13*(I-1)).NE.3)GO TO 18
F       T(I)=6000.0
F 15    CONTINUE
C
C IMPOSE FRICTIONAL Q
C
F 18    CONTINUE
CF 18    IF(IA(8+13*(ISTORE-1)).EQ.2)GO TO 19
F       Q(I)=Q(I)+FQ
F       STQ=Q(I)
F       TACT=T(I)
M       T999=TACT
F 19    CONTINUE
C
C SET CONVECTION.
C
M       G(1001+I-1)=GCONV
C
C STORE POINTER
C
M       K1001=I
M       XK1002=STQ
C
F1000   CONTINUE
C
F       RETURN
F       END
C
C OXIDATION ROUTINE
C
F       SUBROUTINE QOX(TEMP,CA,ICA,QLOC,GCOND,DTIMEU)
F       DIMENSION CA(1),ICA(1)
C
C IS NODE COMPLETELY COMSUMED
C
F       IF(ICA(2).EQ.3)RETURN
C
C DOES NODE MEET TEMPERATURE REQUIREMENT FOR OXIDATION
```

```
C
F       IF(TEMP.LT.1800.0)RETURN
F       IF(TEMP.GE.2600.0)RETURN
C
C CALCULATE HEAT RATE FOR OXIDATION
C
F       QADD=CA(3)*CA(4)/CA(5)
F       QADD=QADD*((TEMP-1800.)/800.)
C
C SUM OXIDATION/COMBUSTION ENERGY
C
F       CA(7)=QADD*DTIMEU+CA(7)
C
C CHECK FOR TOTAL ENERGY TO SEE IF NODE IS COMPLETELY CONSUMED
C
F       IF(CA(7).GT.CA(3)*CA(4)*1.0001)GO TO 20
C
C ADD OXIDATION HEATING TO NODE
C
F       QLOC=QADD+QLOC
C
C SET STATUS TO OXIDIZING
C
F       ICA(2)=1
F       RETURN
C
C DISCONNECT NODE FROM NETWORK
C
F 20    GCOND=1.0E-8
C
C SET STATUS TO COMPLETELY CONSUMED
C
F       ICA(2)=3
F       RETURN
F       END
C
C COMBUSTION ROUTINE
C
F       SUBROUTINE QCOMB(TEMP,CA,ICA,QLOC,GCOND,DTIMEU)
F       DIMENSION CA(1),ICA(1)
C
C IS NODE COMPLETELY CONSUMED
C
F       IF(ICA(2).EQ.3)RETURN
C
C DOES NODE MEET TEMPERATURE REQUIREMENTS FOR COMBUSTION
C
F       IF(TEMP.LT.2600.0)RETURN
C
C CALCULATE HEATING RATE FOR COMBUSTION
C
F       QMIN=CA(3)*CA(4)/CA(5)
F       QMAX=CA(3)*CA(4)/CA(6)
F       QDELTA=QMAX-QMIN
F       QMULT=((TEMP-2600.)/350.)
F       IF(QMULT.GT.1.)QMULT=1.
F       QADD=QMIN+QMULT*QDELTA
C
C STORE QSUM FOR OXIDATION/COMBUSTIN
C
F       CA(7)=QADD*DTIMEU+CA(7)
C
C DETERMINE IF NODE IS COMPLETELY CONSUMED
C
```

```
F       IF(CA(7).GT.CA(3)*CA(4)*1.0001)GO TO 30
C
C ADD COMBUSTION HEATING TO NODE
C
F       QLOC=QADD+QLOC
C
C SET STATUS TO BURNING
C
F       ICA(2)=2
F       RETURN
C
C DISCONNECT NODE FROM NETWORK
C SET STATUS TO COMPLETELY CONSUMED
C
F 30    GCOND=1.0E-8
F       ICA(2)=3
        END
C
        BCD 3VARIABLES 2
C
F       IF(JTEST.EQ.0)RETURN
C
C DETERMINE MELTING
C
F       DO 5 I=1,100
F       CALL QMELT(T(I),A(1+13*(I-1)),IA(1+13*(I-1)),Q(I),XK(I),DTIMEU)
F    5  CONTINUE
C
C DETERMINE VAPORIZATION
C
F       DO 6 I=1,100
F       CALL QVAP(T(I),A(1+13*(I-1)),IA(1+13*(I-1)),Q(I),XK(I),DTIMEU)
F    6  CONTINUE
C
F       RETURN
F       END
C
C VAPORIZATION ROUTINE
C
F       SUBROUTINE QVAP(TEMP,CA,ICA,QLOC,GCOND,DTIMEU)
F       DIMENSION CA(1),ICA(1)
C
C DETERMINE IF NODE IS COMPLETELY CONSUMED
C
F       IF(ICA(2).EQ.3)RETURN
C
C DOES NODE MEET VAPORIZATION TEMPERATURE REQUIREMENTS
C
F       IF(TEMP.LT.5000.0)RETURN
C
C IS NODE COMPLETELY VAPORIZED
C
F       IF(ICA(11).EQ.2)RETURN
C
C CALCULATE M*CP*DELTA-T FOR LAST TIME STEP
C
F       CA(13)=CA(13)+CA(3)*.24*(TEMP-5000.)
C
C CHECK FOR COMPLETE VAPORIZATION
C
F       IF(CA(13).GE.CA(12)*CA(3))GO TO 25
C
C RESET TEMPERATURE TO VAPORIZATION TEMPERATURE
C SET VAPORIZATION STATUS TO VAPORIZING
```

```
C
F       TEMP=5000.
F       ICA(11)=1
F       RETURN
C
C SET VAPORIZATION STATUS TO VAPORIZED
C DISCONNECT FROM NETWORK
C
F  25   ICA(11)=2
F       GCOND=1.E-8
F       RETURN
F       END
C
C MELTING ROUTINE
C
F       SUBROUTINE QMELT(TEMP,CA,ICA,QLOC,GCOND,DTIMEU)
F       DIMENSION CA(1),ICA(1)
C
C IS NODE COMPLETELY CONSUMED
C
F       IF(ICA(2).EQ.3)RETURN
C
C DETERMINE CURRENT HEAT OF FUSION BASED ON MASS
C
F       CA(9)=(1.-(CA(7)/(CA(3)*CA(4))))*86.4
C
C DOES NODE MEET MELT TEMPERATURE REQUIREMENTS
C
F       IF(TEMP.LT.2600.0)GO TO 100
C
C IS NODE ALREADY MELTED
C
F       IF(ICA(8).EQ.2)RETURN
C
C CALCULATED M*CP*DEL-T FOR LAST TIME STEP
C
F       CA(10)=CA(10)+CA(3)*.24*(TEMP-2600.)
C
C CHECK FOR COMPLETELY MELTED
C
F       IF(CA(10).GE.CA(9)*CA(3))GO TO 25
C
C RESET TEMPERATURE TO MELT TEMPERATURE
C SET MELT STATUS TO MELTING
C
F       TEMP=2600.
F       ICA(8)=1
F       RETURN
C
C SET MELT STATUS TO MELTED
C
F  25   ICA(8)=2
F       TEMP=2600.
C
C REMOVE LIQUID NODE FROM MODEL FOR ROTATING CASES
C MAY WANT TO CHANGE TO A CONVECTIVE G TO SIMULATE COMBUSTION
C PRODUCTS INTERFACING WITH NEXT LAYER OR MAY USE A LIQUID
C CONDUCTIVITY
C
F       GCOND=8.33
F       RETURN
C
C ALLOW FOR RESOLIDIFICATION
C
```

```
F 100  IF(ICA(8).EQ.2 .OR. ICA(8).EQ.1)GO TO 110
F      RETURN
F 110  CA(10)=CA(10)-CA(3)*.24*(2600.-TEMP)
F      IF(CA(10).LE.0.0)GO TO 120
F      TEMP=2600.
F      ICA(8)=1
F      RETURN
F 120  ICA(8)=0
F      CA(10)=0.
F      GCOND=8.33
C
       END
C
       BCD 3OUTPUT CALLS
C
F      DATA TAB/1H    /
C
F       WRITE(3,1)TIMEO,(T(I),I=1,NNT)
F  1    FORMAT(E10.3/,250(7F12.3/))
C
C
F      WRITE(10,32)TIMEO,TAB,(T(I),TAB,I=1,NNT)
F 32   FORMAT(E10.3,A1,250(F12.3,A1))
C
CF      IF(TIMEN.GT.33124.E-6)CALL TDUMP
CF      IF(ABS(AMOD(TIMEN,338.E-6)).GT.3.9E-7)RETURN
C
F      CALL STNDRD
F      WRITE(6,99)
F  99 FORMAT(/," NODE TEMP STATUS  QCOMB  GCOND    GCONV  Q-LOC M-STAT',
F    * ' Q-MLT V-STAT QSURF',/)
C
F      DO 200 I=1,100
M      GCONV=G(1001+I-1)
M      IQ=K(1001)
M      STQ=XK1002
F      WRITE(6,100)I,T(I),IA(2+(I-1)*13),A(7+(I-1)*13),G(I),GCONV,IQ,
F    * IA(8+(I-1)*13),A(10+(I-1)*13),IA(11+(I-1)*13),STQ
F 100 FORMAT(1X,I3,1X,F7.1,1X,I2,1X,E8.3,1X,E8.3,1X,E8.3,1X,I3,2X,I2,
F    * 2X,E8.3,2X,I2,2X,E8.3)
F 200  CONTINUE
C
CF      CALL TDUMP
C
       END
       BCD 3END OF DATA
```

In the VARIABLES 1 block, the network is examined to determine appropriate oxidation heat fluxes, and the active surface (oxidized surfaces are also disconnected here). The frictional heat flux with respect to time is also imposed here. The key to determining node status and oxidation is controlled in VARIABLES 1 and the subroutines QOX and QCOMB. In these routines key status variables are set, and summation of energy is accomplished. In these routines, a check to see if the node has completely oxidized is made. If so the node is disconnected from the network, and the succeeding node becomes the first active surface. Note also, the powerful programming techniques employed by passing working arrays to the subroutines for data storage and manipulation. Also note that the arrays are used for mixed mode storage of variables, and therefore must be addressable as either real or integer.

In VARIABLES 2, the network is again examined, but this time to account for any change of phase which may occur. This is accomplished with subroutines QMELT and QVAP. Again, manipulation of variables in the working arrays is the key to the simulation. Note also, that the software allows for resolidification of melted nodes, if the energy balance dictates.

The working array variables are displayed as output through the OUTPUT CALLS block. Files for plotting are also generated here.

IV. Presentation and Discussion of Results:

A. Presentation of Unprocessed Results:

Plotted results which illustrate three potential temperature response characteristics are shown in Figures 7,8,9, and 10. Figure 7 shows typical thermal response of the first ten nodes when the network energy balance results in temperatures in the oxidation temperature regime. Figure 8, shows similar transient response but the frictional heat flux is now of sufficient magnitude to cause surface melting (this is illustrated by the constant node 1 surface temperature at 2600 °F). Also note that when the surface periodic heat flux is removed, the node resolidifies. Figure 9 shows a case where the energy balance propagates to a combustion event in the second cycle. Figure 10 is a comparison of the node 1 temperature response for the three cases above.

Figure 11 illustrates the potential grid recession with time for a combustion event. Note that when the surface node is fully consumed (has released 3437 BTU/lb) it is disconnected from the network and arbitrarily given a temperature value of 6000 °F. Figure 12 is a plot of the active surface temperature derived from Figure 11. Note here that the combustion temperature is 5000 °F. This indicates that the rate of reaction is sufficient to cause simultaneous combustion and material vaporization. While the analytical assumptions and numerical results are very interesting, material properties are not characterized well enough to fully describe the transient combustion characteristics (high temperature characteristics). For this example, the material characteristics prior to melting (oxidation regime) were characterized well enough to predict the thermal conditions required for the onset of a combustion event (see reference for further details). Also shown in the following is limited printed output, which illustrates the progression of the transient response predicted by the model.

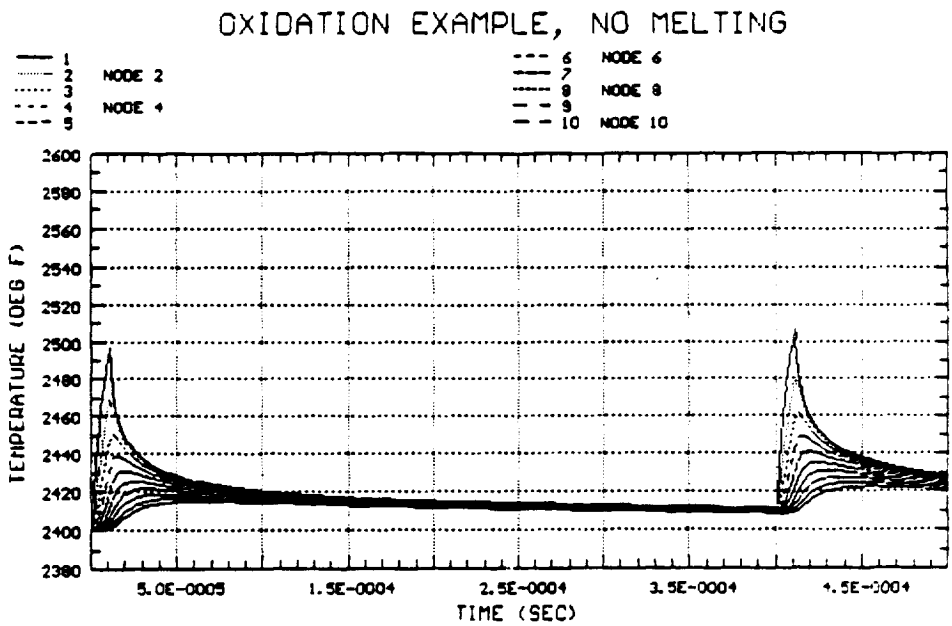

Figure 7. Oxidation with no Melting

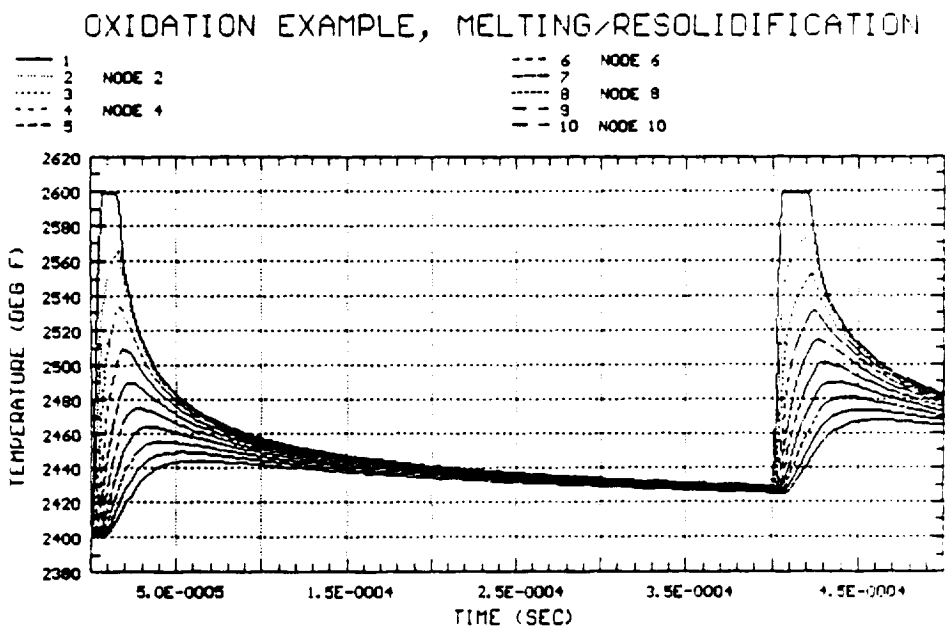

Figure 8. Surface Melting, Resolidification

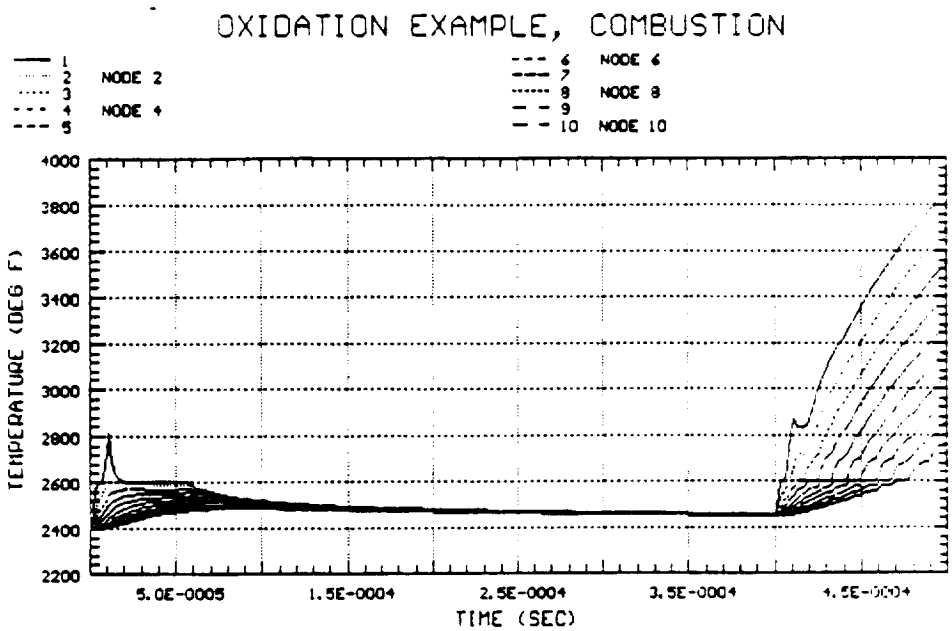

Figure 9. Combustion Example

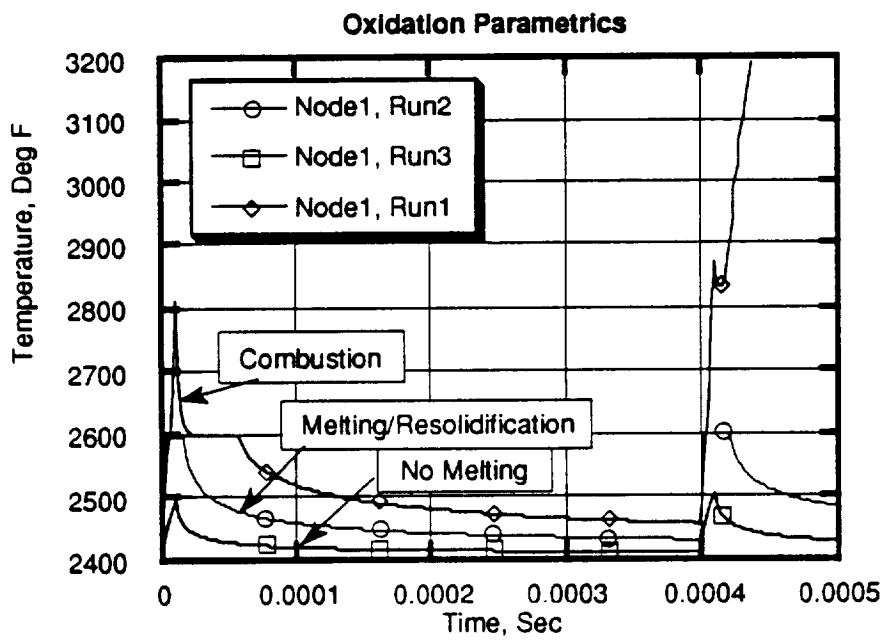

Figure 10. Comparison of Oxidation Parametrics

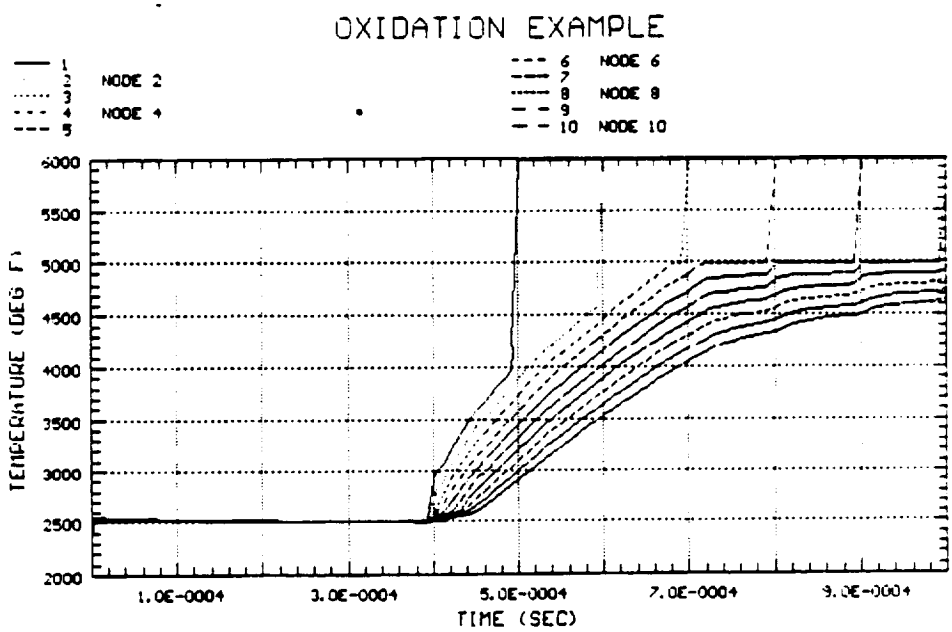

Figure 11. Grid Recession During Combustion

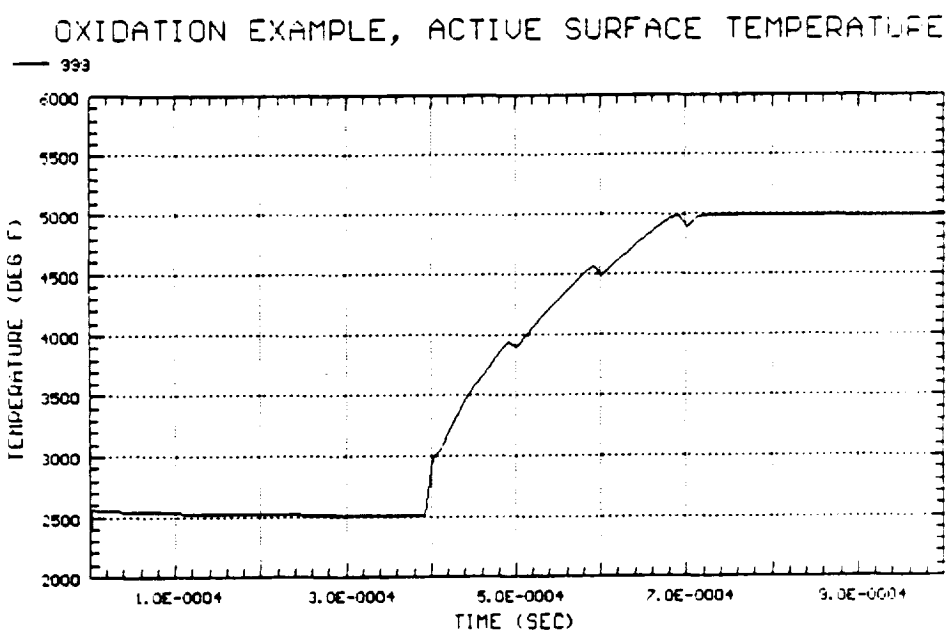

Figure 12. Active (Burning) Surface Temperature

V. Closing Comments:

While this example is quite involved, and deals with a specific and unique problem, the techniques used and integrated into the SINDA code are powerful analytical techniques. These can be utilized for many problems where change of phase must be simulated or where specific chemical processes (rate reactions) or thermodynamic processes must be simulated. The analysis shown here is only a minor portion of the effort to characterize bearing ignition potential. The reader is referred to the reference AIAA paper for a full description of analysis and testing done to characterize the oxidation phenomena.

VI. References:

Page, A., Goode, B., and Owen, J.; AIAA 90-1753, Liquid Oxygen Cooled Bearing Ignition Potential Assessment; AIAA/ASME 5th Joint Thermophysics and Heat Transfer Conference; June 18- 20, 1990; Seattle, WA.

EXAMPLE PRINTED OUTPUT

```
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     FUNDAMENTAL COMBUSTION ANALYSIS

 *** NOTE *** SNFRDL REQUIRES    203 DYNAMIC STORAGE LOCATIONS OUT OF   1382 AVAILABLE ***
              TIMEND= 0.50000E-03, CSGFAC=  1.0000     , DTIMEI= 0.20000E-06, NLOOP =          500
              TIMEO = 0.00000     , OUTPUT= 0.10000E-04, DTIMEH= 0.20000E-06, DTIMEL= 0.00000
              ARLXCA= 0.10000     , ATMPCA= 0.10000E+09, DRLXCA= 0.10000     , DTMPCA= 0.10000E+09

*****************
TIME= 4.00003E-04, DTIMEU= 2.00000E-07, CSGMIN(     100)= 5.99929E-07, ATMPCC(       0)= 0.00000E+00, DTMPCC(       3)= 2.11548E+01
    LOOPCT=      0                                                     , ARLXCC(       0)= 0.00000E+00, DRLXCC(       0)= 0.00000E+00
```

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	2977.1	2	.388E-04	.579E-01	.000E+00	1	2	.262E-04	0	.995E+01
2	2770.8	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
3	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.565E-05	0	.995E+01
4	2568.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
5	2543.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
6	2527.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
7	2516.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
8	2509.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
9	2504.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
10	2501.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
11	2499.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
12	2497.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
13	2496.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
14	2495.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
15	2494.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
16	2493.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
17	2492.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
18	2490.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
19	2489.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
20	2488.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
21	2487.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
22	2485.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
23	2484.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
24	2483.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
25	2481.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
26	2480.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
27	2478.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
28	2477.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
29	2476.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
30	2474.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
31	2473.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
32	2471.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
33	2470.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
34	2468.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
35	2467.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
36	2465.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
37	2464.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
38	2462.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
39	2460.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
40	2459.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
41	2458.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
42	2456.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
43	2455.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
44	2453.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
45	2452.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
46	2450.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
47	2449.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
48	2447.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
49	2446.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
50	2445.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
51	2443.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
52	2442.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
53	2441.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
54	2439.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
55	2438.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
56	2437.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
57	2436.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
58	2434.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
59	2433.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
60	2432.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
61	2431.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
62	2430.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
63	2429.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
64	2428.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
65	2427.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
66	2426.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
67	2425.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
68	2424.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
69	2423.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
70	2422.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
71	2421.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
72	2420.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
73	2419.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
74	2418.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
75	2417.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
76	2417.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
77	2416.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
78	2415.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
79	2414.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
80	2413.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
81	2413.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
82	2412.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
83	2411.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
84	2410.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
85	2410.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
86	2409.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

87	2408.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
88	2408.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
89	2407.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
90	2406.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
91	2406.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
92	2405.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
93	2404.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
94	2404.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
95	2403.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
96	2403.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
97	2402.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
98	2401.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
99	2401.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
100	2400.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

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TIME= 4.10003E-04, DTIMEU= 2.00000E-07, CSGMIN(100)= 5.99929E-07, ATMPCC(0)= 0.00000E+00, DTMPCC(5)= 8.03255E+00
LOOPCT= 0 , ARLXCC(0)= 0.00000E+00, DRLXCC(0)= 0.00000E+00

NODE	TEMP	STATUS	QCONB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	3064.1	2	.138E-03	.579E-01	.000E+00	1	2	.262E-04	0	.995E+01
2	2911.4	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
3	2782.2	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
4	2680.6	0	.000E+00	.579E-01	.000E+00	1	2	.261E-04	0	.995E+01
5	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.165E-05	0	.995E+01
6	2572.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
7	2551.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
8	2535.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
9	2524.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
10	2515.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
11	2509.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
12	2504.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
13	2500.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
14	2497.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
15	2495.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
16	2493.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
17	2492.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
18	2490.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
19	2489.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
20	2488.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
21	2486.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
22	2485.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
23	2484.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
24	2482.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
25	2481.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
26	2480.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
27	2478.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
28	2477.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
29	2475.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
30	2474.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
31	2472.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
32	2471.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
33	2470.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
34	2468.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
35	2467.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
36	2465.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
37	2464.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
38	2462.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
39	2461.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
40	2459.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
41	2458.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
42	2456.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
43	2455.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
44	2453.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
45	2452.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
46	2450.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
47	2449.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
48	2448.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
49	2446.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
50	2445.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
51	2443.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
52	2442.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
53	2441.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
54	2440.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
55	2438.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
56	2437.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
57	2436.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
58	2435.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
59	2433.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
60	2432.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
61	2431.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
62	2430.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
63	2429.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
64	2428.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
65	2427.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
66	2426.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
67	2425.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
68	2424.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
69	2423.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
70	2422.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
71	2421.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
72	2420.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
73	2419.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
74	2418.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
75	2418.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
76	2417.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
77	2416.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
78	2415.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
79	2414.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
80	2413.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
81	2413.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
82	2412.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
83	2411.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
84	2411.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
85	2410.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
86	2409.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

87	2408.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
88	2408.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
89	2407.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
90	2406.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
91	2406.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
92	2405.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
93	2404.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
94	2404.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
95	2403.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
96	2403.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
97	2402.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
98	2401.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
99	2401.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
100	2400.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

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TIME= 4.20003E-04, DTIMEU= 2.00000E-07, CSGMIN(100)= 5.99929E-07, ATMPCC(0)= 0.00000E+00, DTMPCC(6)= 1.34910E+01
LOOPCT= 0 , ARLXCC(0)= 0.00000E+00, DRLXCC(0)= 0.00000E+00

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	3218.7	2	.238E-03	.579E-01	.000E+00	1	2	.262E-04	0	.995E+01
2	3065.1	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
3	2929.0	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
4	2808.8	0	.000E+00	.579E-01	.000E+00	1	2	.261E-04	0	.995E+01
5	2701.0	0	.000E+00	.579E-01	.000E+00	1	2	.259E-04	0	.995E+01
6	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.137E-04	0	.995E+01
7	2581.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
8	2563.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
9	2548.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
10	2535.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
11	2525.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
12	2516.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
13	2510.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
14	2504.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
15	2500.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
16	2497.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
17	2494.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
18	2492.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
19	2490.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
20	2488.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
21	2487.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
22	2485.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
23	2484.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
24	2482.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
25	2481.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
26	2480.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
27	2478.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
28	2477.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
29	2475.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
30	2474.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
31	2472.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
32	2471.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
33	2469.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
34	2468.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
35	2467.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
36	2465.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
37	2464.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
38	2462.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
39	2461.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
40	2459.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
41	2458.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
42	2456.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
43	2455.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
44	2453.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
45	2452.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
46	2450.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
47	2449.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
48	2448.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
49	2446.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
50	2445.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
51	2444.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
52	2442.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
53	2441.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
54	2440.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
55	2438.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
56	2437.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
57	2436.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
58	2435.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
59	2434.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
60	2433.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
61	2431.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
62	2430.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
63	2429.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
64	2428.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
65	2427.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
66	2426.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
67	2425.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
68	2424.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
69	2423.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
70	2422.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
71	2421.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
72	2420.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
73	2419.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
74	2419.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
75	2418.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
76	2417.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
77	2416.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
78	2415.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
79	2414.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
80	2414.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
81	2413.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
82	2412.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
83	2411.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
84	2411.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
85	2410.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
86	2409.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

87	2409.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
88	2408.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
89	2407.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
90	2406.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
91	2406.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
92	2405.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
93	2405.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
94	2404.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
95	2403.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
96	2403.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
97	2402.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
98	2401.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
99	2401.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
100	2400.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

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TIME= 4.30003E-04, DTIMEU= 2.00000E-07, CSGMIN(100)= 5.99929E-07, ATMPCC(0)= 0.00000E+00, DTMPCC(7)= 1.45079E+01
LOOPCT= 0 , ARLXCC(0)= 0.00000E+00, DRLXCC(0)= 0.00000E+00

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	3354.1	2	.337E-03	.579E-01	.000E+00	1	2	.262E-04	0	.995E+01
2	3197.8	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
3	3056.3	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
4	2928.4	0	.000E+00	.579E-01	.000E+00	1	2	.261E-04	0	.995E+01
5	2811.9	0	.000E+00	.579E-01	.000E+00	1	2	.259E-04	0	.995E+01
6	2703.8	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
7	2600.0	0	.000E+00	.579E-01	.000E+00	1	2	.253E-04	0	.995E+01
8	2584.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
9	2568.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
10	2554.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
11	2542.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
12	2531.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
13	2522.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
14	2515.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
15	2508.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
16	2503.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
17	2499.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
18	2496.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
19	2493.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
20	2490.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
21	2488.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
22	2486.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
23	2484.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
24	2483.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
25	2481.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
26	2480.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
27	2478.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
28	2477.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
29	2475.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
30	2474.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
31	2472.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
32	2471.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
33	2469.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
34	2468.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
35	2466.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
36	2465.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
37	2464.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
38	2462.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
39	2461.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
40	2459.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
41	2458.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
42	2456.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
43	2455.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
44	2453.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
45	2452.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
46	2451.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
47	2449.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
48	2448.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
49	2446.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
50	2445.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
51	2444.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
52	2442.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
53	2441.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
54	2440.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
55	2439.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
56	2437.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
57	2436.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
58	2435.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
59	2434.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
60	2433.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
61	2432.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
62	2430.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
63	2429.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
64	2428.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
65	2427.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
66	2426.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
67	2425.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
68	2424.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
69	2423.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
70	2422.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
71	2421.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
72	2420.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
73	2420.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
74	2419.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
75	2418.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
76	2417.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
77	2416.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
78	2415.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
79	2415.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
80	2414.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
81	2413.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
82	2412.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
83	2411.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
84	2411.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
85	2410.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
86	2409.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

87	2409.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
88	2408.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
89	2407.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
90	2407.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
91	2406.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
92	2405.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
93	2405.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
94	2404.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
95	2403.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
96	2403.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
97	2402.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
98	2401.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
99	2401.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
100	2400.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

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TIME= 4.40003E-04, DTIMEU= 2.00000E-07, CSGMIN(100)= 5.99929E-07, ATMPCC(0)= 0.00000E+00, DTMPCC(9)= 4.35337E+00
LOOPCT= 0 , ARLXCC(0)= 0.00000E+00, DRLXCC(0)= 0.00000E+00

NODE	TEMP	STATUS	QCONB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	3475.4	2	.437E-03	.579E-01	.000E+00	1	2	.262E-04	0	.995E+01
2	3317.4	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
3	3172.8	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
4	3040.9	0	.000E+00	.579E-01	.000E+00	1	2	.261E-04	0	.995E+01
5	2921.1	0	.000E+00	.579E-01	.000E+00	1	2	.259E-04	0	.995E+01
6	2814.2	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
7	2723.5	0	.000E+00	.579E-01	.000E+00	1	2	.253E-04	0	.995E+01
8	2653.2	0	.000E+00	.579E-01	.000E+00	1	2	.258E-04	0	.995E+01
9	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.581E-06	0	.995E+01
10	2577.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
11	2560.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
12	2546.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
13	2536.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
14	2526.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
15	2518.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
16	2512.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
17	2506.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
18	2501.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
19	2497.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
20	2494.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
21	2491.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
22	2488.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
23	2486.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
24	2484.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
25	2482.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
26	2480.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
27	2478.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
28	2477.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
29	2475.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
30	2474.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
31	2472.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
32	2471.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
33	2469.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
34	2468.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
35	2466.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
36	2465.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
37	2464.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
38	2462.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
39	2461.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
40	2459.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
41	2458.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
42	2456.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
43	2455.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
44	2453.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
45	2452.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
46	2451.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
47	2449.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
48	2448.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
49	2447.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
50	2445.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
51	2444.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
52	2443.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
53	2441.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
54	2440.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
55	2439.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
56	2438.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
57	2436.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
58	2435.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
59	2434.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
60	2433.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
61	2432.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
62	2431.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
63	2430.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
64	2428.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
65	2427.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
66	2426.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
67	2425.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
68	2424.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
69	2423.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
70	2422.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
71	2421.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
72	2421.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
73	2420.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
74	2419.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
75	2418.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
76	2417.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
77	2416.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
78	2415.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
79	2415.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
80	2414.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
81	2413.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
82	2412.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
83	2412.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
84	2411.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
85	2410.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
86	2409.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

87	2409.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
88	2408.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
89	2407.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
90	2407.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
91	2406.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
92	2405.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
93	2405.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
94	2404.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
95	2403.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
96	2403.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
97	2402.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
98	2401.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
99	2401.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
100	2400.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

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TIME= 4.50003E-04, DTIMEU= 2.00000E-07, CSGMIN(100)= 5.99929E-07, ATMPCC(0)= 0.00000E+00, DTMPCC(10)= 6.90331E+00
LOOPCT= 0 , ARLXCC(0)= 0.00000E+00, DRLXCC(0)= 0.00000E+00

NODE	TEMP	STATUS	QCOMB	GCOND	GCONV	Q-LOC	M-STAT	Q-MLT	V-STAT	QSURF
1	3586.3	2	.536E-03	.579E-01	.000E+00	1	2	.262E-04	0	.995E+01
2	3427.2	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
3	3280.6	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
4	3146.1	0	.000E+00	.579E-01	.000E+00	1	2	.261E-04	0	.995E+01
5	3023.5	0	.000E+00	.579E-01	.000E+00	1	2	.259E-04	0	.995E+01
6	2913.0	0	.000E+00	.579E-01	.000E+00	1	2	.250E-04	0	.995E+01
7	2815.5	0	.000E+00	.579E-01	.000E+00	1	2	.253E-04	0	.995E+01
8	2732.1	0	.000E+00	.579E-01	.000E+00	1	2	.258E-04	0	.995E+01
9	2661.9	0	.000E+00	.579E-01	.000E+00	1	2	.255E-04	0	.995E+01
10	2600.0	0	.000E+00	.579E-01	.000E+00	1	1	.295E-05	0	.995E+01
11	2581.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
12	2564.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
13	2550.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
14	2539.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
15	2529.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
16	2521.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
17	2514.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
18	2508.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
19	2503.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
20	2498.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
21	2494.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
22	2491.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
23	2488.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
24	2486.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
25	2483.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
26	2481.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
27	2479.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
28	2477.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
29	2476.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
30	2474.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
31	2473.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
32	2471.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
33	2470.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
34	2468.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
35	2467.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
36	2465.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
37	2464.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
38	2462.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
39	2461.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
40	2459.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
41	2458.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
42	2456.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
43	2455.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
44	2454.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
45	2452.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
46	2451.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
47	2449.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
48	2448.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
49	2447.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
50	2445.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
51	2444.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
52	2443.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
53	2441.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
54	2440.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
55	2439.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
56	2438.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
57	2437.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
58	2435.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
59	2434.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
60	2433.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
61	2432.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
62	2431.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
63	2430.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
64	2429.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
65	2428.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
66	2427.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
67	2426.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
68	2425.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
69	2424.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
70	2423.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
71	2422.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
72	2421.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
73	2420.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
74	2419.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
75	2418.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
76	2417.7	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
77	2416.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
78	2416.0	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
79	2415.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
80	2414.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
81	2413.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
82	2412.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
83	2412.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
84	2411.4	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
85	2410.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
86	2409.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

87	2409.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
88	2408.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
89	2407.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
90	2407.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
91	2406.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
92	2405.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
93	2405.1	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
94	2404.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
95	2403.8	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
96	2403.2	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
97	2402.5	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
98	2401.9	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
99	2401.3	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01
100	2400.6	0	.000E+00	.579E-01	.000E+00	1	0	.000E+00	0	.995E+01

CHAPTER 3: CHANGE OF PHASE

SECTION 3: Condensation and Frost Formation on the External Tank

ANALYSIS CODE: SINDA (Gaski Version)

Background:

There has always been the concern of ice and frost build-up on the Space Shuttle External Tank (ET) during propellant loading prior to every mission. If the right environmental conditions exist, ice/frost can form on the tank surface and can potentially damage the Orbiter heat tiles during lift-off when the ice breaks loose. This is especially a problem during the winter months. Since the start of the Shuttle program, the Marshall Center and the maker of the ET, Martin Marietta, have been working on the analytical tools to help predict the amount of ice/frost and water formation to aid them in making better engineering judgements concerning the flight readiness of the tank (on the standpoint of a debris hazard) before liftoff. The following analytical routine is the current approach used by NASA to analyze the above problem:

I. Identification of the Problem:

A. Statement of the Problem:

To determine the amount of ice/frost and water condensate on the tank's foam surface, it is necessary to do a heat balance on the surface.

The total heat balance equation is as follows:

$$Q_{cond}+Q_{conv}+Q_{rad\text{-}sky}+Q_{rad\text{-}grnd}+Q_{lat} = 0.$$

B. Schematic

Figure 1 along wuth the above equation , depicts what is called a conservative approach to the heat transfer on the tank surface. Notice that solar heat was left out, in addition to radiation between the different segments of the launch vehicle (orbiter, SRB's, launch pad structure). The greatest potential for ice accumulation occurs during the late-night/early morning hours so the solar impact is zero. The more conservative approach yields a *worst case* scenario which provides a larger factor of safety

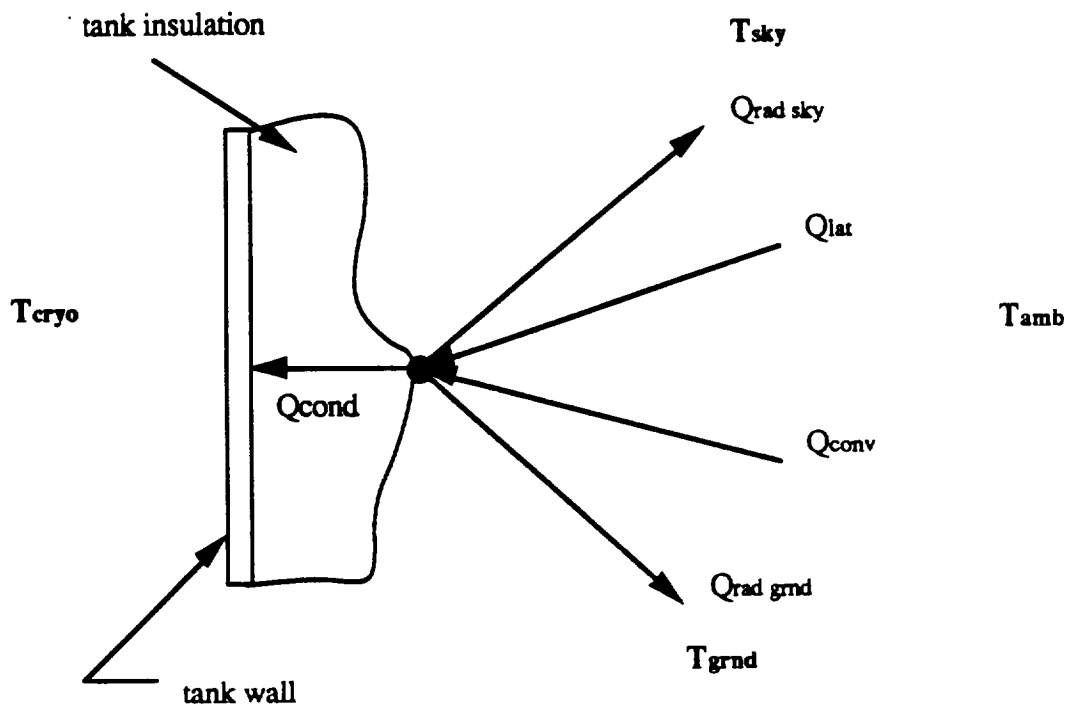

Figure 1. Schematic of heat flow into tank foam and wall

II. Steady State Formulation of the Problem

The above modes of heat transfer on the foam surface will be discussed below in detail and how are calculated within the model:

A. Conduction

$$Q_{cond} = \frac{k_{sofi} A_{sofi}}{\Delta x}(T_{cryo} - T_{surf})$$

k = thermal conductivity at a given temperature (btu/hr-ft^2-°F)
A = surface area of sofi (ft^2)
Δx = thickness of sofi (ft.)

B. Convection

$$Q_{conv} = h_c\,(T_{amb} - T_{surf})$$

h_c = natural or forced heat transfer convection coefficient (btu/hr-ft^2-°R). The larger heat transfer coefficient is used is used for h_c

B.1 Natural Convection

$$h_{nat} = 0.1\ Ra^{1/3}\ \frac{k_{air}}{dia}$$

Ra = Rayleigh Number
k_{air} = thermal conductivity of air (btu/hr-ft^2-°F)
dia = diameter (ft.)

The Raleigh Number

$$Ra = Gr\ Pr\ (T_{amb} - T_{surf})\ dia^{\ 3}$$

The Grashof Number

$$Gr = -32{,}500.\ T_{film} + 42.0\ E\text{-}5$$

$$T_{film} \leq 32\ °F$$

or

$$Gr = -20{,}538.2359\ T_{film} + 3828823.529$$

$$T_{film} > 32\ °F$$

$$T_{film} = \frac{T_{surf} + T_{amb}}{2.}$$

$$k_{air} = 0.133 + 2.1\ E\text{-}5\ T_{film}$$

B.2 Forced Convection

$$h_{nat} = (.46Re^{1/3} + .00128\ Re)\frac{k_{air}}{dia}$$

Re = Reynolds Number

The Reynolds Number

$$Re = \frac{1.688\ dia\ v_l}{\gamma}$$

v_l = wind velocity (knots)
γ = dynamic viscosity (ft^2/sec)

$$\gamma = 5.0E\text{-}7\ T_{film} + 1.3E\text{-}4$$

$$T_{film} \leq 32\ °F$$

or

$$\gamma = 5.1471E\text{-}7\ T_{film} + 1.28529E\text{-}4$$

$$T_{film} > 32\ °F$$

The local wind is determined by multiplying the free-stream wind by a "wind factor" that scales the free-stream wind to the local wind velocity. These factors were detremined by a PHOENIX model of the STS system , which detrermined local wind velocities around each part of the tank and SRB's. From these velocities the "wind factors" were determined and were input into the SINDA model in the ARRAY DATA block to be multiplied by the free-stream wind to calculate a local wind velocity for each SRB and ET nodal segment for whatever case(s) are being considered.

C. Radiation

$$q_{rad\ sky} = f_{sky}\sigma\ \varepsilon\ (T^4_{sky} - T^4_{surf})$$

$$q_{rad\ grnd} = (1-f_{sky})\ \sigma\ \varepsilon\ (T^4_{amb} - T^4_{surf})$$

f_{sky} = view factor from tank segment to sky

LOx Ogive - 0.8
LOx Barrell - 0.65
LH_2 Tank - 0.5

σ = Stephan - Bolztman Constant
.1714E-8 (btu/hr-ft^2-°R^4)

ε = surface emissivity

$$T_{sky} = (0.0019111\ T_{dp} - 0.137)^{1/4}\ T_{amb}$$

T_{dp} = dew point temperature

C.1 Dew Point Temperature Calculation

First, we must calculate the specific ambient humidity:

$$W_{amb} = a\ (T_{amb})^b\ \frac{RH}{100.}$$

$T_{amb} \leq 493.771$ °R

or

$$W_{amb} = c\ (T_{amb})^d\ \frac{RH}{100.}$$

$T_{amb} > 493.771$ °R

RH = ambient relative humidity (%)

a = 2.6317601 E-19
b = 23.35631703

$$c = 4.0942242\ E\text{-}16$$
$$d = 18.75385414$$

Then, the dew point temperature can be determined

$$T_{dp} = 100. \left(\frac{W_{amb}}{a}\right)^{\frac{1}{b}}$$

if $T_{dp} - 460. > 33.771$, then

$$T_{dp} = 100. \left(\frac{W_{amb}}{c}\right)^{\frac{1}{d}}$$

Note: T_{sky}, T_{surf}, T_{amb}, and T_{dp} must be in °R for radiation calculations.

D. Latent Heat

Latent heat of soilidification and/or condensation only becomes factor if $T_{dp} \geq T_{surf}$. The below equation determines the magnitude of this heat.

$$q_{lat} = 1.1\ h_{lat}\ \dot{m}$$

$\dot{m}$ = condensate rate (in./hr.)
h_{lat} = latent heat of solidification and/or condensation

$$h_{lat} = h_{fs} + h_{fg}$$

$$T_{surf} \leq 32\ °F$$

or

$$h_{lat} = h_{fg}$$

$$T_{surf} > 32\ °F$$

h_{fs} = latent heat of solidification (143.3 btu/lbm.)
h_{fg} = latent heat of condensation

$$h_{fg} = -0.565294118\ T_{surf} + 1093.249412$$

D.1 Calculation of Condensate Rate

$$\dot{m}\ (\text{lbm/hr.}) = \frac{h_c\ (W_{amb} - W_{surf})\ A}{Cp_{air}}$$

h_c = convective heat transfer coefficient (greater of natural/forced)
Cp = specific heat of air (.24 btu/lbm - °R)
W_{surf} = surface specific humidity (lbm_{h2o}/lbm_{air})

$$W_{surf} = a\ (T_{surf})^b$$

$$T_{surf} \leq 493.771\ °R$$

$$W_{surf} = c\ (T_{surf})^d$$

$$T_{surf} > 493.771\ °R$$

Heat Balance & Ice Rate Calculations

$$Q_{cond}+Q_{conv}+Q_{rad\text{-}sky}+Q_{rad\text{-}grnd}+Q_{lat} = Q_{ice}$$

Thus, the total ice rate can be calculated by the following:

$$I\ (\text{in./hr.}) = \frac{Q_{ice}}{\rho h_{fs}}$$

ρ = ice density (57lbm/ft.^{3})

The program logic can accumulate ice only if Tsurf $\leq$ 32 °F and thus if Tsurf drops below 32 °F, any accumulated ice can melt.

Environmental Conditions

The input environment(s) were taken from the STS - 30 launch scrub on April 30, 1989 from 6:00 a.m. until 2:30 p.m. EDT.

TIME OF DAY	TEMP. (°F)	REL. HUM. (%)	WIND SPEED (knots)	WIND DIR (deg.)	CLOUDS (%)
06:00	65.	99.	7.5	275	0.0
06:30	66.	99.	7.8	272	0.0
07:00	66.5	99.	10.0	270	0.0
07:30	67.5	98.	8.7	275	0.0
08:00	68.	92.5	8.7	290	0.0
08:30	70.5	90.	8.5	308	0.0
09:00	72.	83.5	7.3	315	0.0
09:30	74.5	73.	8.8	308	0.0
10:00	76.5	64.	7.5	302	0.0
10:30	78.5	56.	6.1	275	0.0
11:00	80.	50.	4.75	235	0.0
11:30	80.	45.	6.0	280	0.0
12:00	80.	55.	7.1	450	0.0
12:30	81.8	53.5	6.8	460	0.0
13:00	83.	48.	8.0	455	0.0
13:30	86.	40.	9.8	210	0.0
14:00	84.	48.	9.8	160	0.0
14:30	84.3	50.	8.3	150	0.0

SINDA INPUT LISTING

```
A       BCD 3THERMAL LPCS
        BCD 9STS 30 PRE-LAUNCH SURFACE ENVIRONMENT MODEL
        END
        BCD 3NODE DATA
C==========================
C    ET  SURFACE NODES
C==========================
        SIV 1001,36.,A202,K501
        SIV 1002,36.,A202,K502
        SIV 1003,36.,A202,K503
        SIV 1004,36.,A202,K504
        SIV 1005,36.,A202,K505
        SIV 1006,36.,A202,K506
        SIV 1007,36.,A202,K507
        SIV 1008,36.,A202,K508
        SIV 1009,36.,A202,K509
        SIV 1010,36.,A202,K510
        SIV 1011,36.,A202,K511
        SIV 1012,36.,A202,K512
        SIV 1013,36.,A202,K513
        SIV 1014,36.,A202,K514
        SIV 1015,36.,A202,K515
        SIV 1016,36.,A202,K516
        SIV 1017,36.,A202,K517
        SIV 1018,36.,A202,K518
        SIV 1019,36.,A202,K519
        SIV 1020,36.,A202,K520
        SIV 1021,36.,A202,K521
        SIV 1022,36.,A202,K522
        SIV 1023,36.,A202,K523
        SIV 1024,36.,A202,K524
        SIV 1025,36.,A202,K525
        SIV 1026,36.,A202,K526
        SIV 1027,36.,A202,K527
        SIV 1028,36.,A202,K528
        SIV 1029,36.,A202,K529
        SIV 1030,36.,A202,K530
        SIV 1031,36.,A202,K531
        SIV 1032,36.,A202,K532
        SIV 1033,36.,A202,K533
        SIV 1034,36.,A202,K534
        SIV 1035,36.,A202,K535
        SIV 1036,36.,A202,K536
        SIV 1037,36.,A202,K537
C
C==============================
C    ET                 *** NOTE **  EACH THOUSAND SERIES OF ET NODES
C============================== IS .25 THICKNESS OF SOFI DEEP
C  LH2 BARREL
C
        SIM 2001,4,1000,36.0,A202,K501
        SIM 2002,4,1000,36.0,A202,K502
        SIM 2003,4,1000,36.0,A202,K503
        SIM 2004,4,1000,36.0,A202,K504
        SIM 2005,4,1000,36.0,A202,K505
        SIM 2006,4,1000,36.0,A202,K506
        SIM 2007,4,1000,36.0,A202,K507
        SIM 2008,4,1000,36.0,A202,K508
        SIM 2009,4,1000,36.0,A202,K509
        SIM 2010,4,1000,36.0,A202,K510
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      SIM 2011,4,1000,36.0,A202,K511
      SIM 2012,4,1000,36.0,A202,K512
      SIM 2013,4,1000,36.0,A202,K513
      SIM 2014,4,1000,36.0,A202,K514
      SIM 2015,4,1000,36.0,A202,K515
      SIM 2016,4,1000,36.0,A202,K516
C
C   INTERTANK
C
      SIM 2017,4,1000,50.0,A202,K517
      SIM 2018,4,1000,50.0,A202,K518
      SIM 2019,4,1000,50.0,A202,K519
      SIM 2020,4,1000,50.0,A202,K520
C
C   LOX BARREL
C
      SIM 2021,4,1000,36.0,A202,K521
      SIM 2022,4,1000,36.0,A202,K522
      SIM 2023,4,1000,36.0,A202,K523
      SIM 2024,4,1000,36.0,A202,K524
C
C    AFT OGIVE
C
      SIM 2025,4,1000,50.0,A202,K525
      SIM 2026,4,1000,50.0,A202,K526
      SIM 2027,4,1000,50.0,A202,K527
      SIM 2028,4,1000,50.0,A202,K528
C
C     FWD OGIVE
C
      SIM 2029,4,1000,50.0,A202,K529
      SIM 2030,4,1000,50.0,A202,K530
      SIM 2031,4,1000,50.0,A202,K531
      SIM 2032,4,1000,36.0,A202,K532
C
C    AFTDOME
C
      SIM 2033,4,1000,50.0,A203,K533
      SIM 2034,4,1000,50.0,A203,K534
      SIM 2035,4,1000,50.0,A203,K535
      SIM 2036,4,1000,50.0,A202,K536
C
C    NOSE CAP
C
      SIM 2037,4,1000,50.0,A201,K537
C
C       ET ALUMINUM SKIN NODES
C
      SIM 21001,3,1,50.,A204,966.5
      SIM 21005,3,1,50.,A204,966.5
      SIM 21009,3,1,50.,A204,966.5
      SIM 21013,3,1,50.,A204,966.5
      SIM 21004,4,4,50.,A204,1570.6
C
      SIM 21017,4,1,50.,A204,1551.6
C
      SIM 21021,4,1,50.,A204,312.76
C
      SIM 21025,4,1,50.,A204,525.28
C
      SIM 21029,4,1,50.,A204,341.70
C
      SIM 21033,4,1,50.,A204,548.99
C
```

```
      SIV 21037,50.,A204,26.86
C
C==============================
C    SRB'S - SOFI NODES
C==============================
C
C   RHSRB
C
      GEN 12001,4,1,50.,3.6782          $  NOSECONE AND FRUSTRUM
      GEN 12041,4,1,50.,39.62           $  AFT SKIRT
C  LHSRB
C
      GEN 12045,4,1,50.,3.6782          $  NOSECONE AND FRUSTRUM
      GEN 12085,4,1,50.,39.62           $  AFT SKIRT
C==============================
C      SRB'S STEEL SKIN
C==============================
C
C   RHSRB
C
      GEN 12005,4,7,70.,272.98           $  SRM
      GEN 12006,4,7,70.,272.98
      GEN 12007,4,7,70.,272.98
      GEN 12008,4,7,70.,272.98
      GEN 12009,4,7,70.,272.98
      GEN 12010,4,7,70.,272.98
      GEN 12011,4,7,70.,272.98
      GEN 12033,8,1,70.,305.71            $  REAR ASSEMBLY
C
      GEN 22001,4,1,70.,187.44           $  NOSECONE
      GEN 22041,4,1,70.,209.08           $  AFT SKIRT
C
C  LHSRB
C
      GEN 12049,4,7,70.,272.98           $  SRM
      GEN 12050,4,7,70.,272.98
      GEN 12051,4,7,70.,272.98
      GEN 12052,4,7,70.,272.98
      GEN 12053,4,7,70.,272.98
      GEN 12054,4,7,70.,272.98
      GEN 12055,4,7,70.,272.98
      GEN 12077,8,1,70.,305.71            $  REAR ASSEMBLY
C
      GEN 22045,4,1,70.,187.44           $  NOSECONE
      GEN 22085,4,1,70.,209.08           $  AFT SKIRT
C
C=====================================
C    SRB'S INSULATION(ABESTOS SILICA-NBR
C=====================================
      GEN 22005,28,1,70.,16.20           $SRM
      GEN 22049,28,1,70.,16.20
      GEN 22033,8,1,70.,18.15            $ REAR ASSEMBLY
      GEN 22077,8,1,70.,18.15
C
C============================
C    PROPELLANT(TP-H-1148)
C============================
      GEN 31005,28,1,82.,3016.
      GEN 31033,8,1,82.,3372.
      GEN 31049,28,1,82.,3016.
      GEN 31077,8,1,82.,3372.
C
      GEN 32005,28,1,82.,2558.
      GEN 32033,8,1,82.,2860.
```

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        GEN 32049,28,1,82.,2558.
        GEN 32077,8,1,82.,2860.
C
        GEN 33005,28,1,82.,2115.
        GEN 33033,8,1,82.,2365.
        GEN 33049,28,1,82.,2115.
        GEN 33077,8,1,82.,2365.
C
        GEN 34005,28,1,82.,1665.
        GEN 34033,8,1,82.,1862.
        GEN 34049,28,1,82.,1665.
        GEN 34077,8,1,82.,1862.
C================================
C    ORBITER
C================================
        SIV 8000,50.,A200,K300
        SIV 8005,50.,A200,K301
        SIV 8010,50.,A200,K302
        SIV 8011,50.,A200,K303
        SIV 8015,50.,A200,K302
        SIV 8016,50.,A200,K303
        SIV 8020,50.,A200,K304
        SIV 8025,50.,A200,K305
        SIV 8030,50.,A200,K306
        SIV 8035,50.,A200,K307
C================================
C    FSS STRUCTURE
C================================
        GEN 6000,10,10,50.,2500.0          $  TOP OF PLATES
        GEN 6001,10,10,50.,2500.0          $  BOTTOM OF PLATES
C================================
C  MISC CONDITIONS
C
C       GEN 500,4,1,50.,117936.0           $   MLP
C       GEN 9000,4,1,50.,1720071.0         $  GROUND
        GEN 500,4,1,50.,27832.7            $   MLP(T=1IN)
        GEN 9000,4,1,50.,1072071.0         $  GROUND(T=1IN)
            -40,    55.,   0.              $  ISS GAS NODE
            -9999,55.,1.0                  $  SKY TEMP
            -7000,-423.,1.                 $  LH2 CRYOGEN TEMP
            -7001,-297.,1.                 $  LOX     "       "
            -7002,55.,1.                   $  INTERTANK TEMP
            -7003,80.,1.                   $  NOSE CONE TEMP
        GEN -8888,5,1,1.0,1.0              $  TAMB,RELHUM,CLOUD
        GEN -13001,37,1,1.,1.              $  SOLAR  HEAT
        GEN -16001,37,1,1.,1.              $  LATENT HEAT
C==================================
C
        GEN -101,37,1,1.,1.                $ LOCAL WIND(FT/S)
        GEN -151,37,1,1.,1.                $ WIND FACTOR
        GEN -201,37,1,1.,1.                $ COND. RATE(IN/HR)
        GEN -401,37,1,0.,0.                $ COND. RATE(IN/OUTPUT)
        GEN -701,37,1,1.,1.                $ ICE RATE(IN/HR)
        GEN -801,37,1,0.,0.                $ ICE ACCUM.(IN)
        GEN -901,37,1,0.,0.                $ ICE ACCUM.(LBS/H2O)
C
        END
        BCD 3CONDUCTOR DATA
C
C
C================================
C     ORBITER
C================================
        SIV 1,8035,8030,A300,0.10
```

```
      SIV 2,8030,8000,A300,0.0612
      SIV 3,8000,8005,A300,0.0762
      SIM 4,2,1,8005,0,8011,5,A300,0.0912
      SIM 6,2,1,8011,5,8010,5,A300,0.186
      SIV 8,8005,8020,A300,0.075
      SIV 9,8020,8025,A300,0.158
C
C================================
C       ET
C     CONDUCTION THROUGH SOFI
C================================
C    LH2 BARREL
      SIM 1001,3,1000,2001,1000,3001,1000,A302,K451
      SIM 1002,3,1000,2002,1000,3002,1000,A302,K452
      SIM 1003,3,1000,2003,1000,3003,1000,A302,K453
      SIM 1004,3,1000,2004,1000,3004,1000,A302,K454
      SIM 1005,3,1000,2005,1000,3005,1000,A302,K455
      SIM 1006,3,1000,2006,1000,3006,1000,A302,K456
      SIM 1007,3,1000,2007,1000,3007,1000,A302,K457
      SIM 1008,3,1000,2008,1000,3008,1000,A302,K458
      SIM 1009,3,1000,2009,1000,3009,1000,A302,K459
      SIM 1010,3,1000,2010,1000,3010,1000,A302,K460
      SIM 1011,3,1000,2011,1000,3011,1000,A302,K461
      SIM 1012,3,1000,2012,1000,3012,1000,A302,K462
      SIM 1013,3,1000,2013,1000,3013,1000,A302,K463
      SIM 1014,3,1000,2014,1000,3014,1000,A302,K464
      SIM 1015,3,1000,2015,1000,3015,1000,A302,K465
      SIM 1016,3,1000,2016,1000,3016,1000,A302,K466
C
C     SOFI TO ALUMINUM SKIN
C
      DIV 4001,5001,21001,A302,K651,A304,61.93E3
      DIV 4002,5002,21002,A302,K652,A304,61.93E3
      DIV 4003,5003,21003,A302,K653,A304,61.93E3
      DIV 4004,5004,21004,A302,K654,A304,61.93E3
      DIV 4005,5005,21005,A302,K655,A304,61.93E3
      DIV 4006,5006,21006,A302,K656,A304,61.93E3
      DIV 4007,5007,21007,A302,K657,A304,61.93E3
      DIV 4008,5008,21008,A302,K658,A304,61.93E3
      DIV 4009,5009,21009,A302,K659,A304,61.93E3
      DIV 4010,5010,21010,A302,K660,A304,61.93E3
      DIV 4011,5011,21011,A302,K661,A304,61.93E3
      DIV 4012,5012,21012,A302,K662,A304,61.93E3
      DIV 4013,5013,21013,A302,K663,A304,61.93E3
      DIV 4014,5014,21014,A302,K664,A304,61.93E3
      DIV 4015,5015,21015,A302,K665,A304,61.93E3
      DIV 4016,5016,21016,A302,K666,A304,61.93E3
C
C
C     INTERTANK
C
      SIM 1017,3,1000,2017,1000,3017,1000,A302,K467
      SIM 1018,3,1000,2018,1000,3018,1000,A302,K468
      SIM 1019,3,1000,2019,1000,3019,1000,A302,K469
      SIM 1020,3,1000,2020,1000,3020,1000,A302,K470
C
      DIV 4017,5017,21017,A302,K667,A305,64.45E3
      DIV 4018,5018,21018,A302,K668,A305,64.45E3
      DIV 4019,5019,21019,A302,K669,A305,64.45E3
      DIV 4020,5020,21020,A302,K670,A305,64.45E3
C
C     LOX BARREL
C
      SIM 1021,3,1000,2021,1000,3021,1000,A302,K471
```

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C
      DIV 4025,5025,21025,A302,K675,A304,38.20E3
      DIV 4026,5026,21026,A302,K676,A304,38.20E3
      DIV 4027,5027,21027,A302,K677,A304,38.20E3
      DIV 4028,5028,21028,A302,K678,A304,38.20E3
C
C     FWD OGIVE
C
      SIM 1029,3,1000,2029,1000,3029,1000,A302,K479
      SIM 1030,3,1000,2030,1000,3030,1000,A302,K480
      SIM 1031,3,1000,2031,1000,3031,1000,A302,K481
      SIM 1032,3,1000,2032,1000,3032,1000,A302,K482
C
      DIV 4029,5029,21029,A302,K679,A304,24.85E3
      DIV 4030,5030,21030,A302,K680,A304,24.85E3
      DIV 4031,5031,21031,A302,K681,A304,24.85E3
      DIV 4032,5032,21032,A302,K682,A304,24.85E3
C
C      AFTDOME
C
      SIM 1033,3,1000,2033,1000,3033,1000,A303,K483
      SIM 1034,3,1000,2034,1000,3034,1000,A303,K484
      SIM 1035,3,1000,2035,1000,3035,1000,A303,K485
      SIM 1036,3,1000,2036,1000,3036,1000,A303,K486
C
      DIV 4033,5033,21033,A303,K683,A304,35.18E3
      DIV 4034,5034,21034,A303,K684,A304,35.18E3
      DIV 4035,5035,21035,A303,K685,A304,35.18E3
      DIV 4036,5036,21036,A303,K686,A304,35.18E3
C
C       NOSECAP
C
      SIM 1037,3,1000,2037,1000,3037,1000,A301,K487
C
      DIV 4037,5037,21037,A301,K687,A305,6.95E3
C
C
      SIV 5001,1001,2001,A302,K651
      SIV 5002,1002,2002,A302,K652
      SIV 5003,1003,2003,A302,K653
      SIV 5004,1004,2004,A302,K654
      SIV 5005,1005,2005,A302,K655
      SIV 5006,1006,2006,A302,K656
      SIV 5007,1007,2007,A302,K657
      SIV 5008,1008,2008,A302,K658
      SIV 5009,1009,2009,A302,K659
      SIV 5010,1010,2010,A302,K660
      SIV 5011,1011,2011,A302,K661
      SIV 5012,1012,2012,A302,K662
      SIV 5013,1013,2013,A302,K663
      SIV 5014,1014,2014,A302,K664
      SIV 5015,1015,2015,A302,K665
      SIV 5016,1016,2016,A302,K666
      SIV 5017,1017,2017,A302,K667
      SIV 5018,1018,2018,A302,K668
      SIV 5019,1019,2019,A302,K669
      SIV 5020,1020,2020,A302,K670
      SIV 5021,1021,2021,A302,K671
      SIV 5022,1022,2022,A302,K672
      SIV 5023,1023,2023,A302,K673
      SIV 5024,1024,2024,A302,K674
      SIV 5025,1025,2025,A302,K675
      SIV 5026,1026,2026,A302,K676
      SIV 5027,1027,2027,A302,K677
      SIV 5028,1028,2028,A302,K678
      SIV 5029,1029,2029,A302,K679
      SIV 5030,1030,2030,A302,K680
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      SIV 5031,1031,2031,A302,K681
      SIV 5032,1032,2032,A302,K682
      SIV 5033,1033,2033,A303,K683
      SIV 5034,1034,2034,A303,K684
      SIV 5035,1035,2035,A303,K685
      SIV 5036,1036,2036,A303,K686
      SIV 5037,1037,2037,A301,K687
C=========================================
C    ET- CIRCUMFERENTIAL  SOFI CONDUCTORS
C=========================================
C         LH2 TANK
      SIM 6001,3,1,2001,4,2005,4,A302,.0176
      SIM 6005,3,1,2002,4,2006,4,A302,.0176
      SIM 6009,3,1,2003,4,2007,4,A302,.0176
      SIM 6013,3,1,2004,4,2008,4,A302,.0176
C
      SIV 6016,2001,2013,A302,.0176
      SIV 6017,2002,2014,A302,.0176
      SIV 6018,2003,2015,A302,.0176
      SIV 6019,2004,2016,A302,.0176
C
C          INTERTANK
C
      SIM 6020,3,1,2017,1,2018,1,A302,.036
      SIV 6023,2017,2020,A302,.036
C
C         LOX BARREL
C
      SIM 6030,3,1,2021,1,2022,1,A302,0.006
      SIV 6033,2024,2021,A302,0.006
C
C         AFT OGIVE
C
      SIM 6040,3,1,2025,1,2026,1,A302,0.0197
      SIV 6043,2028,2025,A302,.0197
C
C            FWD OGIVE
C
      SIM 6050,3,1,2029,1,2030,1,A302,.0131
      SIV 6053,2029,2032,A302,.0131
C
C            LH2 AFT DOME
C
      SIM 6060,3,1,2033,1,2034,1,A302,0.0198
      SIV 6063,2036,2033,A302,0.0198
C
C=========================================
C         LH2 TANK
      SIM 6101,3,1,3001,4,3005,4,A302,.0176
      SIM 6105,3,1,3002,4,3006,4,A302,.0176
      SIM 6109,3,1,3003,4,3007,4,A302,.0176
      SIM 6113,3,1,3004,4,3008,4,A302,.0176
C
      SIV 6116,3001,3013,A302,.0176
      SIV 6117,3002,3014,A302,.0176
      SIV 6118,3003,3015,A302,.0176
      SIV 6119,3004,3016,A302,.0176
C
C          INTERTANK
C
      SIM 6120,3,1,3017,1,3018,1,A302,.036
      SIV 6123,3017,3020,A302,.036
C
C         LOX BARREL
C
      SIM 6130,3,1,3021,1,3022,1,A302,0.006
      SIV 6133,3024,3021,A302,0.006
```

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C==========================================
C          LH2 TANK
       SIM 6101,3,1,3001,4,3005,4,A302,.0176
       SIM 6105,3,1,3002,4,3006,4,A302,.0176
       SIM 6109,3,1,3003,4,3007,4,A302,.0176
       SIM 6113,3,1,3004,4,3008,4,A302,.0176
C
       SIV 6116,3001,3013,A302,.0176
       SIV 6117,3002,3014,A302,.0176
       SIV 6118,3003,3015,A302,.0176
       SIV 6119,3004,3016,A302,.0176
C
C           INTERTANK
C
       SIM 6120,3,1,3017,1,3018,1,A302,.036
       SIV 6123,3017,3020,A302,.036
C
C          LOX BARREL
C
       SIM 6130,3,1,3021,1,3022,1,A302,0.006
       SIV 6133,3024,3021,A302,0.006
C
C          AFT OGIVE
C
       SIM 6140,3,1,3025,1,3026,1,A302,0.0197
       SIV 6143,3028,3025,A302,.0197
C
C             FWD OGIVE
C
       SIM 6150,3,1,3029,1,3030,1,A302,.0131
       SIV 6153,3029,3032,A302,.0131
C
C             LH2 AFT DOME
C
       SIM 6160,3,1,3033,1,3034,1,A302,0.0198
       SIV 6163,3036,3033,A302,0.0198
C==========================================
C          LH2 TANK
       SIM 6201,3,1,4001,4,4005,4,A302,.0176
       SIM 6205,3,1,4002,4,4006,4,A302,.0176
       SIM 6209,3,1,4003,4,4007,4,A302,.0176
       SIM 6213,3,1,4004,4,4008,4,A302,.0176
C
       SIV 6216,4001,4013,A302,.0176
       SIV 6217,4002,4014,A302,.0176
       SIV 6218,4003,4015,A302,.0176
       SIV 6219,4004,4016,A302,.0176
C
C           INTERTANK
C
       SIM 6220,3,1,4017,1,4018,1,A302,.036
       SIV 6223,4017,4020,A302,.036
C
C          LOX BARREL
C
       SIM 6230,3,1,4021,1,4022,1,A302,0.006
       SIV 6233,4024,4021,A302,0.006
C
C          AFT OGIVE
C
       SIM 6240,3,1,4025,1,4026,1,A302,0.0197
       SIV 6243,4028,4025,A302,.0197
C
C             FWD OGIVE
```

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C
      SIM 6250,3,1,4029,1,4030,1,A302,.0131
      SIV 6253,4029,4032,A302,.0131
C
C           LH2 AFT DOME
C
      SIM 6260,3,1,4033,1,4034,1,A302,0.0198
      SIV 6263,4036,4033,A302,0.0198
C
C==========================================
C         LH2 TANK
      SIM 6301,3,1,5001,4,5005,4,A302,.0176
      SIM 6305,3,1,5002,4,5006,4,A302,.0176
      SIM 6309,3,1,5003,4,5007,4,A302,.0176
      SIM 6313,3,1,5004,4,5008,4,A302,.0176
C
      SIV 6316,5001,5013,A302,.0176
      SIV 6317,5002,5014,A302,.0176
      SIV 6318,5003,5015,A302,.0176
      SIV 6319,5004,5016,A302,.0176
C
C          INTERTANK
C
      SIM 6320,3,1,5017,1,5018,1,A302,.036
      SIV 6323,5017,5020,A302,.036
C
C         LOX BARREL
C
      SIM 6330,3,1,5021,1,5022,1,A302,0.006
      SIV 6333,5024,5021,A302,0.006
C
C         AFT OGIVE
C
      SIM 6340,3,1,5025,1,5026,1,A302,0.0197
      SIV 6343,5028,5025,A302,.0197
C
C           FWD OGIVE
C
      SIM 6350,3,1,5029,1,5030,1,A302,.0131
      SIV 6353,5029,5032,A302,.0131
C
C           LH2 AFT DOME
C
      SIM 6360,3,1,5033,1,5034,1,A302,0.0198
      SIV 6363,5036,5033,A302,0.0198
C
C==========================================
C     ET- LONGITUDINAL  SOFI CONDUCTORS
C==========================================
C
C           LH2 TANK
C
      SIM 7001,4,1,2001,4,2002,4,A302,.0227
      SIM 7005,4,1,2002,4,2003,4,A302,.0227
      SIM 7009,4,1,2003,4,2004,4,A302,.0227
C
C           LH2 & IT
C
      SIM 7013,4,1,2004,4,2017,1,A302,.0197
C
C           IT & LOX
C
      SIM 7020,4,1,2017,1,2021,1,A302,.0276
C
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C           LOX & AFT OGIVE
C
C
      SIM 7025,4,1,2021,1,2027,1,A302,.0343
C
C           LH2 & AFT DOME
C
C
      SIV 7030,2001,2035,A302,.0215
      SIV 7031,2005,2034,A302,.0215
      SIV 7032,2009,2033,A302,.0215
      SIV 7033,2013,2036,A302,.0215
C
C
C           LH2 TANK
C
      SIM 7101,4,1,3001,4,3002,4,A302,.0227
      SIM 7105,4,1,3002,4,3003,4,A302,.0227
      SIM 7109,4,1,3003,4,3004,4,A302,.0227
C
C           LH2 & IT
C
      SIM 7113,4,1,3004,4,3017,1,A302,.0197
C
C           IT & LOX
C
      SIM 7120,4,1,3017,1,3021,1,A302,.0276
C
C           LOX & AFT OGIVE
C
C
      SIM 7125,4,1,3021,1,3027,1,A302,.0343
C
C           LH2 & AFT DOME
C
C
      SIV 7130,3001,3035,A302,.0215
      SIV 7131,3005,3034,A302,.0215
      SIV 7132,3009,3033,A302,.0215
      SIV 7133,3013,3036,A302,.0215
C
C
C           LH2 TANK
C
      SIM 7201,4,1,4001,4,4002,4,A302,.0227
      SIM 7205,4,1,4002,4,4003,4,A302,.0227
      SIM 7209,4,1,4003,4,4004,4,A302,.0227
C
C           LH2 & IT
C
      SIM 7213,4,1,4004,4,4017,1,A302,.0197
C
C           IT & LOX
C
      SIM 7220,4,1,4017,1,4021,1,A302,.0276
C
C           LOX & AFT OGIVE
C
C
      SIM 7225,4,1,4021,1,4027,1,A302,.0343
C
C           LH2 & AFT DOME
C
C
```

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      SIV 7230,4001,4035,A302,.0215
      SIV 7231,4005,4034,A302,.0215
      SIV 7232,4009,4033,A302,.0215
      SIV 7233,4013,4036,A302,.0215
C
C
C           LH2 TANK
C
      SIM 7301,4,1,5001,4,5002,4,A302,.0227
      SIM 7305,4,1,5002,4,5003,4,A302,.0227
      SIM 7309,4,1,5003,4,5004,4,A302,.0227
C
C           LH2 & IT
C
      SIM 7313,4,1,5004,4,5017,1,A302,.0197
C
C           IT & LOX
C
      SIM 7320,4,1,5017,1,5021,1,A302,.0276
C
C           LOX & AFT OGIVE
C
C
      SIM 7325,4,1,5021,1,5027,1,A302,.0343
C
C           LH2 & AFT DOME
C
C
      SIV 7330,5001,5035,A302,.0215
      SIV 7331,5005,5034,A302,.0215
      SIV 7332,5009,5033,A302,.0215
      SIV 7333,5013,5036,A302,.0215
C
C          LONGITUDINAL SOFI SURFACE CONDUCTORS
C          LH2
C
      SIM 7401,4,1,1001,4,1002,4,A302,.0011
      SIM 7405,4,1,1002,4,1003,4,A302,.0011
      SIM 7409,4,1,1003,4,1004,4,A302,.0011
C
C          LH2 & IT
      SIM 7413,4,1,1004,4,1017,1,A302,.001
C
C          IT  & LOX
      SIM 7420,4,1,1017,1,1021,1,A302,.00138
C
C          LOX & AFT OGIVE
      SIM 7425,4,1,1021,1,1027,1,A302,.0017
C
C          LH2 & AFT DOME
C
      SIV 7430,1001,1035,A302,.001
      SIV 7431,1005,1034,A302,.001
      SIV 7432,1009,1033,A302,.001
      SIV 7433,1013,1036,A302,.001
C
C=================================================
C        ALUMINUM SKIN TO CYOGENIC BOUNDARY
C=================================================
C
      SIM 11301,16,1,21001,1,7000,0,A304,61.93E3
      SIM 11317,4,1,21017,1,7002,0,A305,64.45E3
      SIM 11321,4,1,21021,1,7001,0,A304,22.75E3
      SIM 11325,4,1,21025,1,7001,0,A304,38.2E3
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C
      SIM 12050,3,1,21029,1,21030,1,A304,.0177
      SIV 12053,21029,21032,A304,.0177
C
C           LH2 AFT DOME
C
      SIM 12060,3,1,21033,1,21034,1,A304,0.023
      SIV 12063,21036,21033,A304,0.023
C
C   LONGITUDINAL ET SKIN CONDUCTORS
C
C          LH2 TANK
C
      SIM 13001,2,1,21001,1,21002,1,A304,.0152
      SIM 13005,2,1,21005,1,21006,1,A304,.0152
      SIM 13009,2,1,21009,1,21010,1,A304,.0152
      SIM 13013,2,1,21013,1,21014,1,A304,.0152
C
      DIM 13015,4,1,21003,4,21004,4,A304,.0304,A304,.0494
C
C
C
      SIV 13020,21021,21027,A304,.0215
      SIV 13021,21022,21026,A304,.0215
      SIV 13022,21023,21025,A304,.0215
      SIV 13023,21024,21028,A304,.0215
      SIM 13025,4,1,21025,1,21029,1,A304,.0126
C
C
C
      DIM 13030,4,1,21029,1,21037,0,A304,.0058,A305,.0150
C
C            LOX BARREL &  IT
C
      DIM 13040,4,1,21017,1,21021,1,A305,.0291,A304,.0827
C
C             LH2 BARREL &  IT
C
      DIM 13050,4,1,21017,1,21004,4,A305,.0291,A304,.0494
C
C
C
      SIV 13060,21001,21035,A304,.0063
      SIV 13061,21034,21005,A304,.0063
      SIV 13062,21013,21036,A304,.0063
      SIV 13063,21009,21033,A304,.0063
C
C=================================
C    SRB SKIN CONDUCTION
C=================================
C  RHSRB
C        CIRCUMFERENCIAL CONDUCTORS
C
      GEN 201,3,1,22001,1,22002,1,4.257          $ NOSECONE
          204,22004,22001,4.257
C
      GEN 205,3,1,12005,7,12012,7,1.65             $ SRM
      GEN 209,3,1,12006,7,12013,7,1.65             $ SRM
      GEN 213,3,1,12007,7,12014,7,1.65             $ SRM
      GEN 217,3,1,12008,7,12015,7,1.65             $ SRM
      GEN 221,3,1,12009,7,12016,7,1.65             $ SRM
      GEN 225,3,1,12010,7,12017,7,1.65             $ SRM
      GEN 229,3,1,12011,7,12018,7,1.65             $ SRM
C
          233,12005,12026,1.65
          234,12006,12027,1.65
          235,12007,12028,1.65
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          236,12008,12029,1.65
          237,12009,12030,1.65
          238,12010,12031,1.65
          239,12011,12032,1.65
C
      GEN 240,6,1,12033,1,12035,1,1.65                    $ REAR ASSEMBLY
          246,12039,12033,1.65
          247,12040,12034,1.65
C
      GEN 260,3,1,22041,1,22042,1,2.866                   $  AFT SKIRT
C
C     LONGITUDINAL  SKIN CONDUCTORS
C
      GEN 270,4,1,22001,1,12005,7,1.478
      GEN 275,4,1,12005,7,12006,7,0.895
      GEN 280,4,1,12006,7,12007,7,0.895
      GEN 285,4,1,12007,7,12008,7,0.895
      GEN 290,4,1,12008,7,12009,7,0.895
      GEN 295,4,1,12009,7,12010,7,0.895
      GEN 300,4,1,12010,7,12011,7,0.895
C
          315,12011,12033,12013,12035,12025,12037,12032,12039,0.895
C
      GEN 320,4,1,12033,2,12034,2,0.895
      GEN 325,4,1,12034,2,22041,1,2.83
C
C  LHSRB - CIRCUMFERENCIAL  SKIN CONDUCTORS
C
C
      GEN 401,3,1,22045,1,22046,1,4.257              $ NOSECONE
          404,22048,22045,4.257
C
      GEN 405,3,1,12049,7,12056,7,1.65                 $ SRM
      GEN 409,3,1,12050,7,12057,7,1.65                 $ SRM
      GEN 413,3,1,12051,7,12058,7,1.65                 $ SRM
      GEN 417,3,1,12052,7,12059,7,1.65                 $ SRM
      GEN 421,3,1,12053,7,12060,7,1.65                 $ SRM
      GEN 425,3,1,12054,7,12061,7,1.65                 $ SRM
      GEN 429,3,1,12055,7,12062,7,1.65                 $ SRM
C
          433,12049,12070,1.65
          434,12050,12071,1.65
          435,12051,12072,1.65
          436,12052,12073,1.65
          437,12053,12074,1.65
          438,12054,12075,1.65
          439,12055,12076,1.65
C
      GEN 440,6,1,12077,1,12079,1,1.65                    $ REAR ASSEMBLY
          446,12083,12077,1.65
          447,12084,12078,1.65
C
      GEN 460,3,1,22085,1,22086,1,2.866                   $  AFT SKIRT
C
C     LONGITUDINAL  SKIN CONDUCTORS
C
      GEN 470,4,1,22045,1,12049,7,1.478
      GEN 475,4,1,12049,7,12050,7,0.895
      GEN 480,4,1,12050,7,12051,7,0.895
      GEN 485,4,1,12051,7,12052,7,0.895
      GEN 490,4,1,12052,7,12053,7,0.895
      GEN 495,4,1,12053,7,12054,7,0.895
      GEN 500,4,1,12054,7,12055,7,0.895
C
          515,12055,12077,12062,12079,12069,12081,12076,12083,0.895
C
      GEN 520,4,1,12077,2,12078,2,0.895
```

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C
       GEN 401,3,1,22045,1,22046,1,4.257          $ NOSECONE
           404,22048,22045,4.257
C
       GEN 405,3,1,12049,7,12056,7,1.65             $ SRM
       GEN 409,3,1,12050,7,12057,7,1.65             $ SRM
       GEN 413,3,1,12051,7,12058,7,1.65             $ SRM
       GEN 417,3,1,12052,7,12059,7,1.65             $ SRM
       GEN 421,3,1,12053,7,12060,7,1.65             $ SRM
       GEN 425,3,1,12054,7,12061,7,1.65             $ SRM
       GEN 429,3,1,12055,7,12062,7,1.65             $ SRM
C
           433,12049,12070,1.65
           434,12050,12071,1.65
           435,12051,12072,1.65
           436,12052,12073,1.65
           437,12053,12074,1.65
           438,12054,12075,1.65
           439,12055,12076,1.65
C
       GEN 440,6,1,12077,1,12079,1,1.65                $ REAR ASSEMBLY
           446,12083,12077,1.65
           447,12084,12078,1.65
C
       GEN 460,3,1,22085,1,22086,1,2.866               $  AFT SKIRT
C
C     LONGITUDINAL  SKIN CONDUCTORS
C
       GEN 470,4,1,22045,1,12049,7,1.478
       GEN 475,4,1,12049,7,12050,7,0.895
       GEN 480,4,1,12050,7,12051,7,0.895
       GEN 485,4,1,12051,7,12052,7,0.895
       GEN 490,4,1,12052,7,12053,7,0.895
       GEN 495,4,1,12053,7,12054,7,0.895
       GEN 500,4,1,12054,7,12055,7,0.895
C
           515,12055,12077,12062,12079,12069,12081,12076,12083,0.895
C
       GEN 520,4,1,12077,2,12078,2,0.895
       GEN 525,4,1,12078,2,12085,1,2.83
C
C    SRB SOFI TO STEEL CASE
C
       GEN 600,4,1,12001,1,22001,1,71.283
       GEN 605,4,1,12045,1,22045,1,71.283
C
C
       GEN 690,4,1,12041,1,22041,1,73.04
       GEN 695,4,1,12085,1,22085,1,73.04
C
C        STEEL CASE TO INSULATION
C RSRB
       GEN 9001,28,1,12005,1,22005,1,64248.
       GEN 9051,8,1,12033,1,22033,1,71970.
C
C LSRB
       GEN 9101,28,1,12049,1,22049,1,64248.
       GEN 9151,8,1,12077,1,22077,1,71970.
C
C        INSULATION TO PROPELLANT
C RSRB
       GEN 9201,28,1,22005,1,31005,1,41.99
       GEN 9251,8,1,22033,1,31033,1,47.20
C
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C LSRB
      GEN 9301,28,1,22049,1,31049,1,41.99
      GEN 9351,8,1,22077,1,31077,1,47.20
C
C        PROPELLANT CONDUCTORS
C RSRB
      GEN 9401,28,1,31005,1,32005,1,30.26
      GEN 9451,8,1,31033,1,32033,1,33.82
C
C LSRB
      GEN 9501,28,1,31049,1,32049,1,30.26
      GEN 9551,8,1,31077,1,32077,1,33.82
C
C RSRB
      GEN 9601,28,1,32005,1,33005,1,25.55
      GEN 9651,8,1,32033,1,33033,1,28.56
C
C LSRB
      GEN 9701,28,1,32049,1,33049,1,25.55
      GEN 9751,8,1,32077,1,33077,1,28.56
C
C RSRB
      GEN 9801,28,1,33005,1,34005,1,21.06
      GEN 9851,8,1,33033,1,34033,1,23.55
C
C LSRB
      GEN 9901,28,1,33049,1,34049,1,21.06
      GEN 9951,8,1,33077,1,34077,1,23.55
C
C================================
C      ET
C    CONVECTION TO ISS GAS
C================================
C   LH2 BARREL
           8001,1001,40, 1.0
           8002,1002,40, 1.0
           8003,1003,40, 1.0
           8004,1004,40, 1.0
           8005,1005,40, 1.0
           8006,1006,40, 1.0
           8007,1007,40, 1.0
           8008,1008,40, 1.0
           8009,1009,40, 1.0
           8010,1010,40, 1.0
           8011,1011,40, 1.0
           8012,1012,40, 1.0
           8013,1013,40, 1.0
           8014,1014,40, 1.0
           8015,1015,40, 1.0
           8016,1016,40, 1.0
C
C   INTERTANK
           8017,1017,40, 1.0
           8018,1018,40, 1.0
           8019,1019,40, 1.0
           8020,1020,40, 1.0
C
C   LOX BARREL
C
           8021,1021,40, 1.0
           8022,1022,40, 1.0
           8023,1023,40, 1.0
           8024,1024,40, 1.0
C
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-  10013,   8000,  12050, 0.74914E-08$
-  10014,   8000,  12051, 0.14741E-07$
-  10015,   8000,  12052, 0.25210E-07$
-  10016,   8000,  12053, 0.26787E-07$
-  10017,   8000,  12054, 0.11742E-07$
-  10018,   8000,  12055, 0.27002E-08$
-  10019,   8000,  12071, 0.64580E-08$
-  10020,   8000,  12072, 0.10516E-07$
-  10021,   8000,  12073, 0.12995E-07$
-  10022,   8000,  12074, 0.17076E-07$
-  10023,   8000,  12075, 0.50461E-08$
-  10024,   8000,  12077, 0.11997E-08$
-  10025,   8000,  12005, 0.21766E-08$
-  10026,   8000,  12006, 0.74894E-08$
-  10027,   8000,  12007, 0.14739E-07$
-  10028,   8000,  12008, 0.25208E-07$
-  10029,   8000,  12009, 0.26785E-07$
-  10030,   8000,  12010, 0.11740E-07$
-  10031,   8000,  12011, 0.26992E-08$
-  10032,   8000,  12013, 0.64580E-08$
-  10033,   8000,  12014, 0.10516E-07$
-  10034,   8000,  12015, 0.12995E-07$
-  10035,   8000,  12016, 0.17076E-07$
-  10036,   8000,  12017, 0.50461E-08$
-  10037,   8000,  12033, 0.11989E-08$
-  10038,   8000,    502, 0.93027E-08$
-  10039,   8000,    503, 0.93012E-08$
-  10040,   8000,   9000, 0.14397E-07$
-  10041,   8000,   9001, 0.14627E-07$
-  10042,   8005,   8010, 0.29698E-08$
-  10043,   8005,   8015, 0.29640E-08$
-  10044,   8005,   8020, 0.34570E-08$
-  10045,   8005,   1005, 0.70359E-07$
-  10046,   8005,   1006, 0.34868E-07$
-  10047,   8005,   1009, 0.39574E-06$
-  10048,   8005,   1010, 0.18774E-06$
-  10049,   8005,   1011, 0.40981E-08$
-  10050,   8005,   1013, 0.70359E-07$
-  10051,   8005,   1014, 0.34868E-07$
-  10052,   8005,   1033, 0.46406E-08$
-  10053,   8005,   1034, 0.33504E-08$
-  10054,   8005,   1036, 0.33501E-08$
-  10055,   8005,  12052, 0.26592E-08$
-  10056,   8005,  12053, 0.15483E-07$
-  10057,   8005,  12054, 0.56407E-07$
-  10058,   8005,  12055, 0.65812E-07$
-  10059,   8005,  12061, 0.27455E-08$
-  10060,   8005,  12062, 0.53430E-08$
-  10061,   8005,  12073, 0.15336E-08$
-  10062,   8005,  12074, 0.44827E-08$
-  10063,   8005,  12075, 0.14054E-07$
-  10064,   8005,  12076, 0.13062E-07$
-  10065,   8005,  12077, 0.20399E-07$
-  10066,   8005,  12078, 0.21241E-08$
-  10067,   8005,  12079, 0.23158E-08$
-  10068,   8005,  12083, 0.44247E-08$
-  10069,   8005,  12084, 0.12579E-08$
-  10070,   8005,  12008, 0.26577E-08$
-  10071,   8005,  12009, 0.15481E-07$
-  10072,   8005,  12010, 0.56405E-07$
-  10073,   8005,  12011, 0.65810E-07$
-  10074,   8005,  12015, 0.15336E-08$
-  10075,   8005,  12016, 0.44827E-08$
-  10076,   8005,  12017, 0.14054E-07$
-  10077,   8005,  12018, 0.13062E-07$
-  10078,   8005,  12031, 0.27351E-08$
-  10079,   8005,  12032, 0.53333E-08$
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- 10080,   8005,  12033, 0.20398E-07$
- 10081,   8005,  12034, 0.21230E-08$
- 10082,   8005,  12035, 0.44248E-08$
- 10083,   8005,  12036, 0.12579E-08$
- 10084,   8005,  12039, 0.23077E-08$
- 10085,   8005,  12085, 0.19933E-08$
- 10086,   8005,  12088, 0.12336E-08$
- 10087,   8005,  12041, 0.19920E-08$
- 10088,   8005,  12042, 0.12335E-08$
- 10089,   8005,    502, 0.18908E-07$
- 10090,   8005,    503, 0.18793E-07$
- 10091,   8005,   9000, 0.24983E-07$
- 10092,   8005,   9001, 0.25593E-07$
- 10093,   8010,   1005, 0.29941E-07$
- 10094,   8010,   1006, 0.38697E-08$
- 10095,   8010,   1009, 0.17072E-07$
- 10096,   8010,   1033, 0.15806E-07$
- 10097,   8010,   1034, 0.21191E-07$
- 10098,   8010,  12053, 0.10323E-08$
- 10099,   8010,  12054, 0.47546E-08$
- 10100,   8010,  12055, 0.28445E-07$
- 10101,   8010,  12061, 0.13080E-08$
- 10102,   8010,  12062, 0.57466E-08$
- 10103,   8010,  12076, 0.36182E-08$
- 10104,   8010,  12077, 0.61620E-07$
- 10105,   8010,  12078, 0.16722E-07$
- 10106,   8010,  12079, 0.10594E-07$
- 10107,   8010,  12080, 0.34499E-08$
- 10108,   8010,  12083, 0.65042E-08$
- 10109,   8010,  12084, 0.19734E-08$
- 10110,   8010,  12036, 0.32645E-08$
- 10111,   8010,  12085, 0.35441E-08$
- 10112,   8010,  12086, 0.15079E-08$
- 10113,   8010,  12088, 0.89031E-09$
- 10114,   8010,  12042, 0.18072E-08$
- 10115,   8010,    500, 0.24233E-07$
- 10116,   8010,    501, 0.11536E-07$
- 10117,   8010,    502, 0.28042E-07$
- 10118,   8010,    503, 0.10191E-07$
- 10119,   8010,   9001, 0.15246E-07$
- 10120,   8015,   1009, 0.17070E-07$
- 10121,   8015,   1013, 0.29940E-07$
- 10122,   8015,   1014, 0.38696E-08$
- 10123,   8015,   1033, 0.15805E-07$
- 10124,   8015,   1036, 0.21190E-07$
- 10125,   8015,  12084, 0.32643E-08$
- 10126,   8015,  12009, 0.10315E-08$
- 10127,   8015,  12010, 0.47535E-08$
- 10128,   8015,  12011, 0.28443E-07$
- 10129,   8015,  12018, 0.36182E-08$
- 10130,   8015,  12031, 0.13016E-08$
- 10131,   8015,  12032, 0.57394E-08$
- 10132,   8015,  12033, 0.61619E-07$
- 10133,   8015,  12034, 0.16721E-07$
- 10134,   8015,  12035, 0.65041E-08$
- 10135,   8015,  12036, 0.19732E-08$
- 10136,   8015,  12039, 0.10588E-07$
- 10137,   8015,  12040, 0.34440E-08$
- 10138,   8015,  12088, 0.18071E-08$
- 10139,   8015,  12041, 0.35426E-08$
- 10140,   8015,  12042, 0.89019E-09$
- 10141,   8015,  12044, 0.15033E-08$
- 10142,   8015,    500, 0.11496E-07$
- 10143,   8015,    501, 0.24110E-07$
- 10144,   8015,    502, 0.10184E-07$
- 10145,   8015,    503, 0.27886E-07$
- 10146,   8015,   9000, 0.14588E-07$
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- 10096,   8010,   1033, 0.15806E-07$
- 10097,   8010,   1034, 0.21191E-07$
- 10098,   8010,  12053, 0.10323E-08$
- 10099,   8010,  12054, 0.47546E-08$
- 10100,   8010,  12055, 0.28445E-07$
- 10101,   8010,  12061, 0.13080E-08$
- 10102,   8010,  12062, 0.57466E-08$
- 10103,   8010,  12076, 0.36182E-08$
- 10104,   8010,  12077, 0.61620E-07$
- 10105,   8010,  12078, 0.16722E-07$
- 10106,   8010,  12079, 0.10594E-07$
- 10107,   8010,  12080, 0.34499E-08$
- 10108,   8010,  12083, 0.65042E-08$
- 10109,   8010,  12084, 0.19734E-08$
- 10110,   8010,  12036, 0.32645E-08$
- 10111,   8010,  12085, 0.35441E-08$
- 10112,   8010,  12086, 0.15079E-08$
- 10113,   8010,  12088, 0.89031E-09$
- 10114,   8010,  12042, 0.18072E-08$
- 10115,   8010,    500, 0.24233E-07$
- 10116,   8010,    501, 0.11536E-07$
- 10117,   8010,    502, 0.28042E-07$
- 10118,   8010,    503, 0.10191E-07$
- 10119,   8010,   9001, 0.15246E-07$
- 10120,   8015,   1009, 0.17070E-07$
- 10121,   8015,   1013, 0.29940E-07$
- 10122,   8015,   1014, 0.38696E-08$
- 10123,   8015,   1033, 0.15805E-07$
- 10124,   8015,   1036, 0.21190E-07$
- 10125,   8015,  12084, 0.32643E-08$
- 10126,   8015,  12009, 0.10315E-08$
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           DAMPD=0.02
C          BALENG=.01
C
           3 ,85.76       $---- AMB RELATIVE HUMIDITY - PERCENT
           8 ,180.        $---- WIND DIRECTION
           9 ,0.          $---- CLOUD FACTOR 0=CLEAR  1=OVERCAST
           10,32.         $---- START FREEZING TEMP
           11,0.          $---- CONDUCTION HEAT OF ET
           12,0.          $---- HEAT BALANCE
           13,0.          $---- ICE RATE
           14,0.          $---- LATENT HEAT
       GEN 15,5,1,0.      $---- ICE ACCUMULATION
           20,0.0         $---- FIXED HEAT TRANSFER COEFFICIENT
           21,0.0         $---- ORBITER VIEW FACTOR
           22,1.          $----DEW POINT TEMP.
           23,0.          $----T SKY
           28,0.          $----FREE CONV. COEF.
           29,0.          $----FORCE CONV. COEF.
           32,0.
           33,0.
           34,0.
           35,0.
           36,0.
           37,1.
           38,1.
           39,0.
           40,0.
           41,0.
           42,0.
           46,0.0         $---- ISS TEMPERATURE BOOST
           47,49.         $---- AMBIENT TEMPERATURE
           57,40.0        $---- BACK FACE TEMP OTHER THAN LH2 OR LO2
           66,100.
           ITEST,3        $---- NAT=1, FOR=2, NAT/FOR=3                  /FORCED
           KTEST,1
           RTEST,0
C
           71,0.0         $ WIND SPEED (KNOTS)
       GEN 80,9,1,0.0     $ T AVERAGE
           89,0.0         $ QTEST
           91,0.
           92,0.
           93,0.
C    RADIATION OF ET(FOR ICE)
       GEN 171,7,1,0.
       GEN 181,7,1,0.
C
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           262,1.0
C****************
C     ORBITER
C****************
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          300, 1128.63              $ MAIN FUSELAGE
          301, 1252.71              $ UPPER WING
          302, 158.248              $ PORT AND STARBOARD REAR WING
          303, 277.764              $   "   "     "      UPPER WING
          304, 333.859              $ TAIL
          305, 217.916              $ BODY FLAP
          306, 153.287              $ AFT NOSE
          307, 77.5753              $ FWD NOSE
C*********************************
C    SOFI THICKNESS NODES
C*********************************
       GEN 401,37,1,1.0
C
C  A/L OF ET
       GEN 451,16,1,1.0
       GEN 467,4,1,1.0
       GEN 471,4,1,1.0
       GEN 475,4,1,1.0
       GEN 479,4,1,1.0
       GEN 483,4,1,1.0
           487,1.0
C  VOLUME OF ET
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       GEN 525,4,1,1.0
       GEN 529,4,1,1.0
       GEN 533,4,1,1.0
           537,1.0
C  VOLUME OF ET SURFACE NODES
       GEN 551,16,1,1.0
       GEN 567,4,1,1.0
       GEN 571,4,1,1.0
       GEN 575,4,1,1.0
       GEN 579,4,1,1.0
       GEN 583,4,1,1.0
           587,1.0
C
C*** TEMP. FOR ET*********
C    LH2 BARREL
       GEN 601,16,1,-423.0
C
C   INTERTANK
       GEN 617,4,1,55.0
C
C  LOX BARREL
       GEN 621,4,1,-297.0
C
C   AFT OGIVE
       GEN 625,4,1,-297.0
C
C   FWD OGIVE
       GEN 629,4,1,-297.00
C    AFTDOME
       GEN 633,4,1,-423.00
C
C   NOSECAP
           637,80.0
C A/L OF SURFACE NODE
       GEN 651,16,1,1.0
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C*****************
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      GEN 730,33,1,0.
      GEN 765,33,1,0.
C****************
      GEN 801,37,1,0.              $ ET RAD
C*****************************
C  SOFI THERM COND Y-INTERCEPT
C *****************************
      GEN 901,32,1,0.00168         $ CPR488
      GEN 933,4,1,0.0021           $ NCFI 2265
          937,0.023                $ SLA-561
C*********************
C  SLOPE OF K CURVE
C*********************
      GEN 951,32,1,2.452E-05       $ CPR488
      GEN 983,4,1,3.164E-05        $ NCFI 2265
          987,5.833E-05            $ SLA-561
C*********************
      GEN 1001,125,1,0.0           $ LOCAL WIND (FT/S)
C*** ET NODES AREA********
C    LH2 BARREL
      GEN 1201,16,1,411.86
C
C   INTERTANK
      GEN 1217,4,1,538.13
C
C  LOX BARREL
      GEN 1221,4,1,142.165
C
C   AFT OGIVE
      GEN 1225,4,1,238.764
C
C   FWD OGIVE
      GEN 1229,4,1,155.326
C    AFTDOME
      GEN 1233,4,1,233.946
C
C   NOSECAP
          1237,23.292
C
C    RSRB NODES AREA
C
      GEN 1238,4,1,85.143
      GEN 1242,28,1,123.917
      GEN 1270,8,1,138.836
      GEN 1278,4,1,94.947
C
C    LSRB NODES AREA
C
      GEN 1282,4,1,85.143
      GEN 1286,28,1,123.917
      GEN 1314,8,1,138.836
      GEN 1322,4,1,94.947
C
C****************************
      GEN 1351,125,1,0.0            $ WIND FACTOR
C****************************
      GEN 2001,125,1,0.             $ ET & SRB TEMP.
      GEN 2151,24,1,27.60           $ ET TANK DIAMETER-FT
      GEN 2175,4,1,25.60
      GEN 2179,4,1,13.8
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        GEN 2183,4,1,27.60
            2187,4.20
        GEN 2188,4,1,6.66              $ RSRB TANK DIAMETER
        GEN 2192,36,1,12.16
        GEN 2228,4,1,14.0
        GEN 2232,4,1,6.66              $ LSRB TANK DIAMETER
        GEN 2236,36,1,12.16
        GEN 2272,4,1,14.0
        GEN 2301,125,1,0.              $ CONDENSATION RATE
        GEN 3001,37,1,0.
C*****************************
C           RADIATION CONDUCTOR
C*****************************
        GEN 5001,7,1,0.
        GEN 5011,5,1,0.
        GEN 5021,5,1,0.
        GEN 5031,5,1,0.
        GEN 5041,15,1,0.
        GEN 5061,16,1,0.
        GEN 5081,14,1,0.
        GEN 5101,15,1,0.
        GEN 5121,15,1,0.
        GEN 5141,13,1,0.
        GEN 5161,10,1,0.
        GEN 5181,7,1,0.
        GEN 5201,15,1,0.
        GEN 5221,16,1,0.
        GEN 5241,14,1,0.
        GEN 5261,15,1,0.
        GEN 5281,7,1,0.
        GEN 5301,15,1,0.
        GEN 5321,7,1,0.
        GEN 5331,13,1,0.
        GEN 5401,5,1,0.
        GEN 5411,13,1,0.
        GEN 5431,3,1,0.
        GEN 5441,7,1,0.
        GEN 5451,3,1,0.
        GEN 5461,14,1,0.
        GEN 5481,3,1,0.
        GEN 5491,6,1,0.
        GEN 5501,3,1,0.
        GEN 5511,10,1,0.
        GEN 5531,3,1,0.
        GEN 5541,3,1,0.
        GEN 5551,25,1,0.
        GEN 5601,21,1,0.
        GEN 5631,19,1,0.
        GEN 5651,21,1,0.
        GEN 5681,2,1,0.
C     CONVECTION COEFFICIENT
        GEN 6001,37,1,0.
C*********************************************************
        END
        BCD 3ARRAY DATA
C
                1$ TIME ARRAY
            0.000E+00, 0.100E+01, 0.200E+01, 0.300E+01, 0.400E+01, 0.500E+01$
            0.600E+01, 0.700E+01, 0.800E+01, 0.900E+01, 0.100E+02, 0.110E+02$
            0.120E+02, 0.130E+02, 0.140E+02, 0.150E+02, 0.160E+02, 0.170E+02$
            0.180E+02, 0.190E+02, 0.200E+02, 0.210E+02, 0.220E+02, 0.230E+02$
            0.240E+02
           END$
C
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 0.743E+04, 0.140E+05, 0.151E+05, 0.165E+04, 0.900E+03, 0.456E+04$
 0.363E+04, 0.311E-06, 0.398E-06, 0.177E-08, 0.121E-09, 0.327E-10$
 0.803E-11
END$
   18$  HEAT RATE ARRAY
 0.136E-10, 0.940E-11, 0.236E-10, 0.220E-08, 0.661E-08, 0.242E-08$
 0.167E+01, 0.298E+03, 0.131E+04, 0.226E+04, 0.243E+04, 0.215E+04$
 0.856E+04, 0.153E+05, 0.161E+05, 0.234E+04, 0.126E+04, 0.414E+04$
 0.363E+04, 0.308E-06, 0.395E-06, 0.269E-06, 0.132E-09, 0.474E-10$
 0.136E-10
END$
   19$  HEAT RATE ARRAY
 0.192E-10, 0.139E-10, 0.325E-10, 0.905E-08, 0.547E-08, 0.987E-09$
 0.137E+01, 0.268E+03, 0.124E+04, 0.215E+04, 0.234E+04, 0.210E+04$
 0.843E+04, 0.155E+05, 0.161E+05, 0.226E+04, 0.121E+04, 0.446E+04$
 0.354E+04, 0.307E-06, 0.394E-06, 0.357E-06, 0.225E-09, 0.617E-10$
 0.192E-10
END$
   20$  HEAT RATE ARRAY
 0.543E-10, 0.246E-10, 0.942E-10, 0.362E-09, 0.267E-07, 0.321E-07$
 0.231E+02, 0.278E+04, 0.925E+04, 0.137E+05, 0.842E+04, 0.247E+04$
 0.110E+04, 0.452E+04, 0.102E+05, 0.107E+05, 0.217E+03, 0.116E+04$
 0.118E+04, 0.321E-07, 0.267E-07, 0.110E-08, 0.831E-09, 0.227E-09$
 0.543E-10
END$
   21$  HEAT RATE ARRAY
 0.108E-09, 0.715E-10, 0.176E-09, 0.106E-08, 0.264E-07, 0.322E-07$
 0.233E+02, 0.276E+04, 0.920E+04, 0.136E+05, 0.106E+05, 0.321E+04$
 0.101E+04, 0.591E+04, 0.129E+05, 0.108E+05, 0.204E+03, 0.921E+03$
 0.932E+03, 0.305E-07, 0.264E-07, 0.158E-08, 0.983E-09, 0.353E-09$
 0.108E-09
END$
   22$  HEAT RATE ARRAY
 0.168E-09, 0.128E-09, 0.268E-09, 0.156E-08, 0.234E-07, 0.308E-07$
 0.234E+02, 0.279E+04, 0.947E+04, 0.141E+05, 0.127E+05, 0.547E+04$
 0.536E+04, 0.101E+05, 0.155E+05, 0.121E+05, 0.439E+03, 0.101E+04$
 0.936E+03, 0.283E-07, 0.234E-07, 0.186E-08, 0.109E-08, 0.526E-09$
 0.168E-09
END$
   23$  HEAT RATE ARRAY
 0.226E-09, 0.177E-09, 0.366E-09, 0.136E-08, 0.171E-07, 0.266E-07$
 0.226E+02, 0.275E+04, 0.955E+04, 0.143E+05, 0.138E+05, 0.842E+04$
 0.131E+05, 0.155E+05, 0.168E+05, 0.114E+05, 0.534E+03, 0.147E+04$
 0.902E+03, 0.251E-07, 0.171E-07, 0.150E-08, 0.109E-08, 0.701E-09$
 0.226E-09
END$
   24$  HEAT RATE ARRAY
 0.182E-10, 0.138E-10, 0.314E-10, 0.179E-09, 0.401E-06, 0.315E-06$
 0.729E+02, 0.693E+04, 0.176E+05, 0.211E+05, 0.134E+05, 0.855E+04$
 0.734E+04, 0.343E+04, 0.219E+04, 0.179E+04, 0.986E+03, 0.462E+03$
 0.121E+03, 0.990E-08, 0.956E-08, 0.171E-09, 0.967E-10, 0.444E-10$
 0.182E-10
END$
   25$  HEAT RATE ARRAY
 0.143E-10, 0.112E-10, 0.249E-10, 0.164E-08, 0.398E-06, 0.311E-06$
 0.720E+02, 0.682E+04, 0.172E+05, 0.204E+05, 0.127E+05, 0.797E+04$
 0.751E+04, 0.279E+04, 0.172E+04, 0.139E+04, 0.784E+03, 0.335E+03$
 0.815E+02, 0.464E-08, 0.870E-08, 0.218E-09, 0.732E-10, 0.350E-10$
 0.143E-10
END$
   26$  HEAT RATE ARRAY
 0.154E-10, 0.128E-10, 0.274E-10, 0.269E-06, 0.395E-06, 0.309E-06$
 0.720E+02, 0.689E+04, 0.176E+05, 0.211E+05, 0.135E+05, 0.858E+04$
 0.868E+04, 0.408E+04, 0.271E+04, 0.195E+04, 0.102E+04, 0.419E+03$
 0.829E+02, 0.223E-08, 0.654E-08, 0.220E-08, 0.660E-10, 0.349E-10$
 0.154E-10
END$
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   27$  HEAT RATE ARRAY
 0.132E-10, 0.112E-10, 0.120E-09, 0.357E-06, 0.394E-06, 0.307E-06$
 0.717E+02, 0.686E+04, 0.176E+05, 0.210E+05, 0.134E+05, 0.862E+04$
 0.853E+04, 0.399E+04, 0.270E+04, 0.190E+04, 0.959E+03, 0.390E+03$
 0.702E+02, 0.898E-09, 0.539E-08, 0.903E-08, 0.532E-10, 0.288E-10$
 0.132E-10
END$
   28$  HEAT RATE ARRAY
 0.397E-09, 0.294E-09, 0.110E-06, 0.673E-06, 0.587E-06, 0.498E-06$
 0.820E+02, 0.653E+04, 0.142E+05, 0.125E+05, 0.692E+04, 0.297E+04$
 0.576E+04, 0.513E+04, 0.667E+04, 0.311E+04, 0.174E+04, 0.974E+04$
 0.433E+04, 0.498E-06, 0.587E-06, 0.673E-06, 0.110E-06, 0.975E-09$
 0.397E-09
END$
   29$  HEAT RATE ARRAY
 0.197E-08, 0.143E-08, 0.313E-08, 0.153E-07, 0.747E-08, 0.109E-08$
 0.163E+01, 0.340E+03, 0.160E+04, 0.278E+04, 0.320E+04, 0.426E+04$
 0.134E+05, 0.310E+05, 0.330E+05, 0.299E+04, 0.160E+04, 0.491E+04$
 0.473E+04, 0.524E-06, 0.500E-06, 0.467E-06, 0.776E-07, 0.384E-08$
 0.197E-08
END$
   30$  HEAT RATE ARRAY
 0.410E-09, 0.304E-09, 0.664E-09, 0.118E-08, 0.444E-08, 0.812E-07$
 0.254E+02, 0.368E+04, 0.128E+05, 0.197E+05, 0.196E+05, 0.153E+05$
 0.303E+05, 0.282E+05, 0.238E+05, 0.160E+05, 0.137E+04, 0.197E+04$
 0.846E+03, 0.623E-07, 0.445E-08, 0.129E-08, 0.131E-08, 0.100E-08$
 0.410E-09
END$
   31$  HEAT RATE ARRAY
 0.152E-10, 0.130E-10, 0.731E-07, 0.463E-06, 0.497E-06, 0.523E-06$
 0.942E+02, 0.104E+05, 0.334E+05, 0.382E+05, 0.330E+05, 0.170E+05$
 0.135E+05, 0.800E+04, 0.378E+04, 0.244E+04, 0.122E+04, 0.492E+03$
 0.838E+02, 0.195E-09, 0.454E-08, 0.112E-07, 0.597E-10, 0.320E-10$
 0.152E-10
END$
   32$  HEAT RATE ARRAY
 0.153E-10, 0.111E-10, 0.252E-10, 0.977E-10, 0.522E-08, 0.185E-07$
 0.822E+01, 0.956E+03, 0.305E+04, 0.439E+04, 0.416E+04, 0.351E+04$
 0.693E+04, 0.601E+04, 0.429E+04, 0.332E+04, 0.154E+04, 0.869E+03$
 0.433E+03, 0.185E-07, 0.523E-08, 0.327E-09, 0.128E-09, 0.412E-10$
 0.153E-10
END$
   33$  HEAT RATE ARRAY
 0.972E-11, 0.741E-11, 0.181E-10, 0.125E-09, 0.232E-08, 0.354E-07$
 0.679E+01, 0.761E+03, 0.311E+04, 0.509E+04, 0.517E+04, 0.435E+04$
 0.932E+04, 0.737E+04, 0.622E+04, 0.426E+04, 0.243E+04, 0.118E+04$
 0.123E+04, 0.154E-06, 0.181E-06, 0.480E-09, 0.154E-09, 0.302E-10$
 0.972E-11
END$
   34$  HEAT RATE ARRAY
 0.313E-10, 0.242E-10, 0.563E-10, 0.298E-09, 0.211E-06, 0.184E-06$
 0.241E+02, 0.177E+04, 0.510E+04, 0.753E+04, 0.776E+04, 0.622E+04$
 0.121E+05, 0.929E+04, 0.680E+04, 0.576E+04, 0.326E+04, 0.264E+04$
 0.127E+04, 0.184E-06, 0.211E-06, 0.613E-09, 0.232E-09, 0.777E-10$
 0.313E-10
END$
   35$  HEAT RATE ARRAY
 0.313E-10, 0.242E-10, 0.524E-10, 0.205E-09, 0.181E-06, 0.154E-06$
 0.233E+02, 0.217E+04, 0.538E+04, 0.758E+04, 0.651E+04, 0.491E+04$
 0.933E+04, 0.758E+04, 0.508E+04, 0.395E+04, 0.202E+04, 0.111E+04$
 0.357E+03, 0.354E-07, 0.223E-08, 0.297E-09, 0.158E-09, 0.719E-10$
 0.313E-10
END$
   36$  HEAT RATE ARRAY
 0.602E-09, 0.526E-09, 0.901E-09, 0.965E-09, 0.697E-09, 0.396E-07$
 0.175E+02, 0.274E+04, 0.110E+05, 0.182E+05, 0.200E+05, 0.174E+05$
 0.340E+05, 0.321E+05, 0.244E+05, 0.123E+05, 0.591E+03, 0.945E+03$
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 0.755E+03, 0.396E-07, 0.703E-09, 0.999E-09, 0.105E-08, 0.878E-09$
 0.602E-09
ENDS$
   37$  HEAT RATE ARRAY
 0.346E-08, 0.292E-08, 0.522E-08, 0.651E-08, 0.426E-08, 0.125E-08$
 0.791E+00, 0.160E+03, 0.740E+03, 0.125E+04, 0.136E+04, 0.218E+04$
 0.177E+05, 0.355E+05, 0.457E+05, 0.137E+04, 0.790E+03, 0.852E+04$
 0.712E+04, 0.709E-06, 0.590E-06, 0.446E-06, 0.298E-06, 0.520E-08$
 0.346E-08
ENDS$
   38$  HEAT RATE ARRAY
 0.602E-09, 0.526E-09, 0.396E-06, 0.371E-06, 0.345E-06, 0.313E-06$
 0.559E+02, 0.482E+04, 0.116E+05, 0.117E+05, 0.728E+04, 0.304E+04$
 0.218E+04, 0.561E+04, 0.885E+04, 0.121E+04, 0.662E+03, 0.596E+04$
 0.295E+04, 0.313E-06, 0.345E-06, 0.371E-06, 0.396E-06, 0.878E-09$
 0.602E-09
ENDS$
   39$  HEAT RATE ARRAY
 0.490E-11, 0.432E-11, 0.292E-06, 0.440E-06, 0.586E-06, 0.708E-06$
 0.153E+03, 0.155E+05, 0.431E+05, 0.507E+05, 0.372E+05, 0.191E+05$
 0.176E+05, 0.387E+04, 0.135E+04, 0.860E+03, 0.425E+03, 0.170E+03$
 0.298E+02, 0.133E-10, 0.204E-09, 0.817E-09, 0.174E-10, 0.101E-10$
 0.490E-11
ENDS$
   40$  HEAT RATE ARRAY
 0.879E-10, 0.968E-10, 0.303E-08, 0.630E-08, 0.947E-08, 0.132E-07$
 0.332E+01, 0.398E+03, 0.133E+04, 0.196E+04, 0.204E+04, 0.167E+04$
 0.319E+04, 0.308E+04, 0.250E+04, 0.181E+04, 0.448E+01, 0.203E+01$
 0.160E+03, 0.132E-07, 0.947E-08, 0.630E-08, 0.303E-08, 0.110E-09$
 0.879E-10
ENDS$
   41$  HEAT RATE ARRAY
 0.712E-10, 0.583E-10, 0.111E-09, 0.153E-09, 0.113E-09, 0.539E-10$
 0.345E-01, 0.711E+01, 0.339E+02, 0.599E+02, 0.709E+03, 0.154E+04$
 0.299E+04, 0.285E+04, 0.218E+04, 0.565E+02, 0.288E+02, 0.159E+03$
 0.533E+02, 0.261E-08, 0.411E-09, 0.418E-09, 0.294E-09, 0.136E-09$
 0.712E-10
ENDS$
   42$  HEAT RATE ARRAY
 0.240E-09, 0.182E-09, 0.383E-09, 0.567E-09, 0.403E-09, 0.123E-09$
 0.446E-01, 0.882E+01, 0.398E+02, 0.687E+02, 0.733E+02, 0.383E+03$
 0.195E+04, 0.306E+04, 0.139E+04, 0.756E+02, 0.445E+02, 0.742E+03$
 0.461E+03, 0.441E-07, 0.356E-07, 0.248E-07, 0.137E-07, 0.517E-09$
 0.240E-09
ENDS$
   43$  HEAT RATE ARRAY
 0.712E-10, 0.583E-10, 0.115E-09, 0.191E-07, 0.443E-08, 0.366E-10$
 0.364E-01, 0.831E+01, 0.368E+02, 0.609E+02, 0.726E+02, 0.413E+03$
 0.912E+03, 0.933E+03, 0.100E+03, 0.587E+02, 0.324E+02, 0.227E+03$
 0.182E+03, 0.194E-07, 0.201E-07, 0.202E-07, 0.186E-07, 0.136E-09$
 0.712E-10
ENDS$
   44$  HEAT RATE ARRAY
 0.722E-11, 0.536E-11, 0.117E-10, 0.419E-10, 0.219E-10, 0.585E-11$
 0.155E-01, 0.379E+01, 0.175E+02, 0.297E+02, 0.710E+02, 0.105E+04$
 0.193E+04, 0.732E+03, 0.134E+03, 0.243E+02, 0.124E+02, 0.156E+02$
 0.173E+02, 0.177E-08, 0.158E-08, 0.145E-08, 0.555E-09, 0.133E-10$
 0.722E-11
ENDS$
   45$  HEAT RATE ARRAY
 0.644E-10, 0.456E-10, 0.109E-09, 0.258E-09, 0.321E-09, 0.372E-09$
 0.292E+00, 0.570E+02, 0.268E+03, 0.472E+03, 0.658E+03, 0.203E+04$
 0.404E+04, 0.377E+04, 0.320E+04, 0.448E+03, 0.228E+03, 0.969E+02$
 0.944E+02, 0.959E-08, 0.146E-08, 0.781E-09, 0.356E-09, 0.206E-09$
 0.644E-10
ENDS$
   46$  HEAT RATE ARRAY
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 0.459E-10, 0.318E-10, 0.747E-10, 0.243E-09, 0.500E-09, 0.614E-09$
 0.351E+00, 0.628E+02, 0.287E+03, 0.505E+03, 0.549E+03, 0.206E+04$
 0.410E+04, 0.383E+04, 0.324E+04, 0.483E+03, 0.247E+03, 0.311E+03$
 0.171E+03, 0.975E-08, 0.167E-08, 0.790E-09, 0.282E-09, 0.166E-09$
 0.459E-10
END$
   47$  HEAT RATE ARRAY
 0.290E-10, 0.161E-10, 0.488E-10, 0.228E-09, 0.702E-09, 0.796E-09$
 0.354E+00, 0.574E+02, 0.253E+03, 0.444E+03, 0.482E+03, 0.200E+04$
 0.400E+04, 0.373E+04, 0.316E+04, 0.428E+03, 0.222E+03, 0.303E+03$
 0.971E+02, 0.773E-08, 0.189E-08, 0.772E-09, 0.274E-09, 0.139E-09$
 0.290E-10
END$
   48$  HEAT RATE ARRAY
 0.195E-10, 0.914E-11, 0.338E-10, 0.182E-09, 0.105E-08, 0.123E-08$
 0.390E+00, 0.519E+02, 0.208E+03, 0.364E+03, 0.396E+03, 0.193E+04$
 0.387E+04, 0.360E+04, 0.306E+04, 0.356E+03, 0.185E+03, 0.113E+03$
 0.123E+03, 0.103E-07, 0.225E-08, 0.659E-09, 0.254E-09, 0.912E-10$
 0.195E-10
END$
   49$  HEAT RATE ARRAY
 0.124E-10, 0.397E-11, 0.225E-10, 0.142E-09, 0.152E-08, 0.175E-08$
 0.451E+00, 0.514E+02, 0.183E+03, 0.319E+03, 0.347E+03, 0.162E+04$
 0.379E+04, 0.353E+04, 0.300E+04, 0.316E+03, 0.166E+03, 0.314E+03$
 0.175E+03, 0.869E-08, 0.276E-08, 0.379E-09, 0.242E-09, 0.683E-10$
 0.124E-10
END$
   50$  HEAT RATE ARRAY
 0.264E-11, 0.987E-12, 0.693E-11, 0.841E-10, 0.240E-08, 0.262E-08$
 0.513E+00, 0.466E+02, 0.105E+03, 0.173E+03, 0.185E+03, 0.469E+03$
 0.352E+04, 0.327E+04, 0.279E+04, 0.162E+03, 0.841E+02, 0.228E+03$
 0.129E+03, 0.120E-07, 0.389E-08, 0.281E-09, 0.206E-09, 0.429E-10$
 0.264E-11
END$
   51$  HEAT RATE ARRAY
 0.205E-11, 0.655E-12, 0.553E-11, 0.627E-10, 0.248E-08, 0.282E-08$
 0.634E+00, 0.695E+02, 0.181E+03, 0.273E+03, 0.284E+03, 0.258E+03$
 0.375E+04, 0.346E+04, 0.292E+04, 0.252E+03, 0.142E+03, 0.189E+03$
 0.194E+03, 0.136E-07, 0.552E-08, 0.270E-09, 0.162E-09, 0.351E-10$
 0.205E-11
END$
   52$  HEAT RATE ARRAY
 0.344E-09, 0.227E-09, 0.587E-09, 0.138E-08, 0.102E-08, 0.315E-09$
 0.319E+00, 0.642E+02, 0.294E+03, 0.517E+03, 0.565E+03, 0.445E+03$
 0.146E+04, 0.449E+04, 0.349E+04, 0.573E+03, 0.321E+03, 0.134E+03$
 0.113E+04, 0.142E-06, 0.128E-06, 0.105E-06, 0.155E-08, 0.116E-08$
 0.344E-09
END$
   53$  HEAT RATE ARRAY
 0.237E-09, 0.147E-09, 0.393E-09, 0.126E-08, 0.973E-09, 0.302E-09$
 0.342E+00, 0.694E+02, 0.318E+03, 0.558E+03, 0.616E+03, 0.491E+03$
 0.156E+04, 0.458E+04, 0.303E+04, 0.622E+03, 0.345E+03, 0.170E+04$
 0.155E+04, 0.141E-06, 0.128E-06, 0.105E-06, 0.147E-08, 0.940E-09$
 0.237E-09
END$
   54$  HEAT RATE ARRAY
 0.164E-09, 0.873E-10, 0.278E-09, 0.111E-08, 0.999E-09, 0.312E-09$
 0.367E+00, 0.755E+02, 0.350E+03, 0.609E+03, 0.673E+03, 0.545E+03$
 0.168E+04, 0.468E+04, 0.301E+04, 0.676E+03, 0.370E+03, 0.181E+04$
 0.104E+04, 0.138E-06, 0.128E-06, 0.105E-06, 0.151E-08, 0.743E-09$
 0.164E-09
END$
   55$  HEAT RATE ARRAY
 0.795E-10, 0.191E-10, 0.148E-09, 0.836E-09, 0.978E-09, 0.309E-09$
 0.398E+00, 0.830E+02, 0.390E+03, 0.672E+03, 0.740E+03, 0.607E+03$
 0.181E+04, 0.479E+04, 0.391E+04, 0.739E+03, 0.401E+03, 0.163E+03$
 0.113E+04, 0.142E-06, 0.128E-06, 0.105E-06, 0.144E-08, 0.494E-09$
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 0.602E-09, 0.526E-09, 0.396E-06, 0.371E-06, 0.345E-06, 0.313E-06$
 0.559E+02, 0.482E+04, 0.116E+05, 0.117E+05, 0.728E+04, 0.304E+04$
 0.218E+04, 0.561E+04, 0.885E+04, 0.121E+04, 0.662E+03, 0.596E+04$
 0.295E+04, 0.313E-06, 0.345E-06, 0.371E-06, 0.396E-06, 0.878E-09$
 0.602E-09
END$
   39$  HEAT RATE ARRAY
 0.490E-11, 0.432E-11, 0.292E-06, 0.440E-06, 0.586E-06, 0.708E-06$
 0.153E+03, 0.155E+05, 0.431E+05, 0.507E+05, 0.372E+05, 0.191E+05$
 0.176E+05, 0.387E+04, 0.135E+04, 0.860E+03, 0.425E+03, 0.170E+03$
 0.298E+02, 0.133E-10, 0.204E-09, 0.817E-09, 0.174E-10, 0.101E-10$
 0.490E-11
END$
   40$  HEAT RATE ARRAY
 0.879E-10, 0.968E-10, 0.303E-08, 0.630E-08, 0.947E-08, 0.132E-07$
 0.332E+01, 0.398E+03, 0.133E+04, 0.196E+04, 0.204E+04, 0.167E+04$
 0.319E+04, 0.308E+04, 0.250E+04, 0.181E+04, 0.448E+01, 0.203E+01$
 0.160E+03, 0.132E-07, 0.947E-08, 0.630E-08, 0.303E-08, 0.110E-09$
 0.879E-10
END$
   41$  HEAT RATE ARRAY
 0.712E-10, 0.583E-10, 0.111E-09, 0.153E-09, 0.113E-09, 0.539E-10$
 0.345E-01, 0.711E+01, 0.339E+02, 0.599E+02, 0.709E+03, 0.154E+04$
 0.299E+04, 0.285E+04, 0.218E+04, 0.565E+02, 0.288E+02, 0.159E+03$
 0.533E+02, 0.261E-08, 0.411E-09, 0.418E-09, 0.294E-09, 0.136E-09$
 0.712E-10
END$
   42$  HEAT RATE ARRAY
 0.240E-09, 0.182E-09, 0.383E-09, 0.567E-09, 0.403E-09, 0.123E-09$
 0.446E-01, 0.882E+01, 0.398E+02, 0.687E+02, 0.733E+02, 0.383E+03$
 0.195E+04, 0.306E+04, 0.139E+04, 0.756E+02, 0.445E+02, 0.742E+03$
 0.461E+03, 0.441E-07, 0.356E-07, 0.248E-07, 0.137E-07, 0.517E-09$
 0.240E-09
END$
   43$  HEAT RATE ARRAY
 0.712E-10, 0.583E-10, 0.115E-09, 0.191E-07, 0.443E-08, 0.366E-10$
 0.364E-01, 0.831E+01, 0.368E+02, 0.609E+02, 0.726E+02, 0.413E+03$
 0.912E+03, 0.933E+03, 0.100E+03, 0.587E+02, 0.324E+02, 0.227E+03$
 0.182E+03, 0.194E-07, 0.201E-07, 0.202E-07, 0.186E-07, 0.136E-09$
 0.712E-10
END$
   44$  HEAT RATE ARRAY
 0.722E-11, 0.536E-11, 0.117E-10, 0.419E-10, 0.219E-10, 0.585E-11$
 0.155E-01, 0.379E+01, 0.175E+02, 0.297E+02, 0.710E+02, 0.105E+04$
 0.193E+04, 0.732E+03, 0.134E+03, 0.243E+02, 0.124E+02, 0.156E+02$
 0.173E+02, 0.177E-08, 0.158E-08, 0.145E-08, 0.555E-09, 0.133E-10$
 0.722E-11
END$
   45$  HEAT RATE ARRAY
 0.644E-10, 0.456E-10, 0.109E-09, 0.258E-09, 0.321E-09, 0.372E-09$
 0.292E+00, 0.570E+02, 0.268E+03, 0.472E+03, 0.658E+03, 0.203E+04$
 0.404E+04, 0.377E+04, 0.320E+04, 0.448E+03, 0.228E+03, 0.969E+02$
 0.944E+02, 0.959E-08, 0.146E-08, 0.781E-09, 0.356E-09, 0.206E-09$
 0.644E-10
END$
   46$  HEAT RATE ARRAY
 0.459E-10, 0.318E-10, 0.747E-10, 0.243E-09, 0.500E-09, 0.614E-09$
 0.351E+00, 0.628E+02, 0.287E+03, 0.505E+03, 0.549E+03, 0.206E+04$
 0.410E+04, 0.383E+04, 0.324E+04, 0.483E+03, 0.247E+03, 0.311E+03$
 0.171E+03, 0.975E-08, 0.167E-08, 0.790E-09, 0.282E-09, 0.166E-09$
 0.459E-10
END$
   47$  HEAT RATE ARRAY
 0.290E-10, 0.161E-10, 0.488E-10, 0.228E-09, 0.702E-09, 0.796E-09$
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 0.354E+00, 0.574E+02, 0.253E+03, 0.444E+03, 0.482E+03, 0.200E+04$
 0.400E+04, 0.373E+04, 0.316E+04, 0.428E+03, 0.222E+03, 0.303E+03$
 0.971E+02, 0.773E-08, 0.189E-08, 0.772E-09, 0.274E-09, 0.139E-09$
 0.290E-10
 END$
   48$  HEAT RATE ARRAY
 0.195E-10, 0.914E-11, 0.338E-10, 0.182E-09, 0.105E-08, 0.123E-08$
 0.390E+00, 0.519E+02, 0.208E+03, 0.364E+03, 0.396E+03, 0.193E+04$
 0.387E+04, 0.360E+04, 0.306E+04, 0.356E+03, 0.185E+03, 0.113E+03$
 0.123E+03, 0.103E-07, 0.225E-08, 0.659E-09, 0.254E-09, 0.912E-10$
 0.195E-10
 END$
   49$  HEAT RATE ARRAY
 0.124E-10, 0.397E-11, 0.225E-10, 0.142E-09, 0.152E-08, 0.175E-08$
 0.451E+00, 0.514E+02, 0.183E+03, 0.319E+03, 0.347E+03, 0.162E+04$
 0.379E+04, 0.353E+04, 0.300E+04, 0.316E+03, 0.166E+03, 0.314E+03$
 0.175E+03, 0.869E-08, 0.276E-08, 0.379E-09, 0.242E-09, 0.683E-10$
 0.124E-10
 END$
   50$  HEAT RATE ARRAY
 0.264E-11, 0.987E-12, 0.693E-11, 0.841E-10, 0.240E-08, 0.262E-08$
 0.513E+00, 0.466E+02, 0.105E+03, 0.173E+03, 0.185E+03, 0.469E+03$
 0.352E+04, 0.327E+04, 0.279E+04, 0.162E+03, 0.841E+02, 0.228E+03$
 0.129E+03, 0.120E-07, 0.389E-08, 0.281E-09, 0.206E-09, 0.429E-10$
 0.264E-11
 END$
   51$  HEAT RATE ARRAY
 0.205E-11, 0.655E-12, 0.553E-11, 0.627E-10, 0.248E-08, 0.282E-08$
 0.634E+00, 0.695E+02, 0.181E+03, 0.273E+03, 0.284E+03, 0.258E+03$
 0.375E+04, 0.346E+04, 0.292E+04, 0.252E+03, 0.142E+03, 0.189E+03$
 0.194E+03, 0.136E-07, 0.552E-08, 0.270E-09, 0.162E-09, 0.351E-10$
 0.205E-11
 END$
   52$  HEAT RATE ARRAY
 0.344E-09, 0.227E-09, 0.587E-09, 0.138E-08, 0.102E-08, 0.315E-09$
 0.319E+00, 0.642E+02, 0.294E+03, 0.517E+03, 0.565E+03, 0.445E+03$
 0.146E+04, 0.449E+04, 0.349E+04, 0.573E+03, 0.321E+03, 0.134E+03$
 0.113E+04, 0.142E-06, 0.128E-06, 0.105E-06, 0.155E-08, 0.116E-08$
 0.344E-09
 END$
   53$  HEAT RATE ARRAY
 0.237E-09, 0.147E-09, 0.393E-09, 0.126E-08, 0.973E-09, 0.302E-09$
 0.342E+00, 0.694E+02, 0.318E+03, 0.558E+03, 0.616E+03, 0.491E+03$
 0.156E+04, 0.458E+04, 0.303E+04, 0.622E+03, 0.345E+03, 0.170E+04$
 0.155E+04, 0.141E-06, 0.128E-06, 0.105E-06, 0.147E-08, 0.940E-09$
 0.237E-09
 END$
   54$  HEAT RATE ARRAY
 0.164E-09, 0.873E-10, 0.278E-09, 0.111E-08, 0.999E-09, 0.312E-09$
 0.367E+00, 0.755E+02, 0.350E+03, 0.609E+03, 0.673E+03, 0.545E+03$
 0.168E+04, 0.468E+04, 0.301E+04, 0.676E+03, 0.370E+03, 0.181E+04$
 0.104E+04, 0.138E-06, 0.128E-06, 0.105E-06, 0.151E-08, 0.743E-09$
 0.164E-09
 END$
   55$  HEAT RATE ARRAY
 0.795E-10, 0.191E-10, 0.148E-09, 0.836E-09, 0.978E-09, 0.309E-09$
 0.398E+00, 0.830E+02, 0.390E+03, 0.672E+03, 0.740E+03, 0.607E+03$
 0.181E+04, 0.479E+04, 0.391E+04, 0.739E+03, 0.401E+03, 0.163E+03$
 0.113E+04, 0.142E-06, 0.128E-06, 0.105E-06, 0.144E-08, 0.494E-09$
 0.795E-10
 END$
   56$  HEAT RATE ARRAY
 0.383E-10, 0.869E-11, 0.794E-10, 0.533E-09, 0.951E-09, 0.319E-09$
 0.352E+00, 0.755E+02, 0.356E+03, 0.609E+03, 0.661E+03, 0.547E+03$
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END$
   75$  HEAT RATE ARRAY
 0.146E-11, 0.120E-11, 0.275E-11, 0.179E-09, 0.896E-09, 0.396E-09$
 0.553E+00, 0.129E+03, 0.608E+03, 0.990E+03, 0.104E+04, 0.889E+03$
 0.252E+04, 0.566E+04, 0.355E+04, 0.974E+03, 0.553E+03, 0.405E+04$
 0.176E+04, 0.159E-06, 0.143E-06, 0.121E-08, 0.587E-09, 0.725E-10$
 0.146E-11
END$
   76$  HEAT RATE ARRAY
 0.425E-12, 0.342E-12, 0.103E-11, 0.103E-09, 0.689E-09, 0.292E-09$
 0.508E+00, 0.132E+03, 0.631E+03, 0.991E+03, 0.102E+04, 0.905E+03$
 0.259E+04, 0.569E+04, 0.372E+04, 0.933E+03, 0.560E+03, 0.491E+04$
 0.176E+04, 0.159E-06, 0.102E-08, 0.102E-08, 0.419E-09, 0.229E-10$
 0.425E-12
END$
   77$  HEAT RATE ARRAY
 0.326E-11, 0.253E-11, 0.658E-11, 0.831E-10, 0.177E-07, 0.542E-07$
 0.439E+01, 0.157E+03, 0.718E+03, 0.123E+04, 0.125E+04, 0.969E+03$
 0.198E+04, 0.134E+04, 0.116E+04, 0.102E+04, 0.586E+03, 0.116E+04$
 0.640E+03, 0.720E-07, 0.827E-07, 0.318E-09, 0.147E-09, 0.265E-10$
 0.326E-11
END$
   78$  HEAT RATE ARRAY
 0.239E-11, 0.184E-11, 0.511E-11, 0.614E-10, 0.359E-09, 0.690E-07$
 0.121E+02, 0.935E+03, 0.997E+03, 0.138E+04, 0.140E+04, 0.112E+04$
 0.231E+04, 0.161E+04, 0.137E+04, 0.116E+04, 0.671E+03, 0.156E+04$
 0.648E+03, 0.722E-07, 0.451E-09, 0.286E-09, 0.106E-09, 0.109E-10$
 0.239E-11
END$
   79$  HEAT RATE ARRAY
 0.501E-11, 0.380E-11, 0.852E-11, 0.363E-10, 0.285E-08, 0.689E-07$
 0.485E+01, 0.143E+03, 0.601E+03, 0.101E+04, 0.105E+04, 0.860E+03$
 0.230E+04, 0.136E+04, 0.946E+03, 0.727E+03, 0.384E+03, 0.213E+03$
 0.738E+02, 0.507E-08, 0.333E-08, 0.670E-10, 0.316E-10, 0.123E-10$
 0.501E-11
END$
   80$  HEAT RATE ARRAY
 0.532E-11, 0.405E-11, 0.896E-11, 0.382E-10, 0.818E-09, 0.160E-06$
 0.303E+02, 0.926E+03, 0.816E+03, 0.134E+04, 0.139E+04, 0.117E+04$
 0.293E+04, 0.190E+04, 0.132E+04, 0.999E+03, 0.533E+03, 0.301E+03$
 0.901E+02, 0.514E-08, 0.103E-08, 0.920E-10, 0.372E-10, 0.130E-10$
 0.532E-11
END$
   81$  HEAT RATE ARRAY
 0.276E-12, 0.242E-12, 0.132E-09, 0.266E-09, 0.306E-09, 0.258E-08$
 0.126E+01, 0.190E+03, 0.863E+03, 0.155E+04, 0.181E+04, 0.154E+04$
 0.299E+04, 0.284E+04, 0.862E+03, 0.516E+02, 0.248E+02, 0.958E+01$
 0.163E+01, 0.187E-10, 0.916E-11, 0.582E-11, 0.123E-11, 0.603E-12$
 0.276E-12
END$
   82$  HEAT RATE ARRAY
 0.114E-12, 0.955E-13, 0.539E-09, 0.143E-08, 0.157E-08, 0.177E-08$
 0.358E+00, 0.393E+02, 0.123E+03, 0.147E+03, 0.122E+03, 0.396E+03$
 0.192E+04, 0.193E+04, 0.854E+02, 0.267E+02, 0.139E+02, 0.554E+01$
 0.797E+00, 0.288E-11, 0.122E-10, 0.284E-10, 0.105E-11, 0.276E-12$
 0.114E-12
END$
   83$  HEAT RATE ARRAY
 0.249E-12, 0.207E-12, 0.184E-07, 0.200E-07, 0.199E-07, 0.194E-07$
 0.370E+01, 0.346E+03, 0.910E+03, 0.105E+04, 0.803E+03, 0.504E+03$
 0.911E+03, 0.762E+03, 0.837E+02, 0.516E+02, 0.280E+02, 0.115E+02$
 0.178E+01, 0.498E-11, 0.433E-08, 0.189E-07, 0.548E-11, 0.575E-12$
 0.249E-12
END$
   84$  HEAT RATE ARRAY
 0.231E-12, 0.206E-12, 0.131E-07, 0.242E-07, 0.352E-07, 0.440E-07$
 0.994E+01, 0.104E+04, 0.301E+04, 0.371E+04, 0.289E+04, 0.165E+04$
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 0.194E+04, 0.693E+03, 0.667E+02, 0.429E+02, 0.210E+02, 0.837E+01$
 0.149E+01, 0.348E-12, 0.775E-12, 0.942E-12, 0.782E-12, 0.468E-12$
 0.231E-12
END$
   85$  HEAT RATE ARRAY
 0.251E-11, 0.216E-11, 0.846E-10, 0.521E-09, 0.128E-08, 0.957E-08$
 0.320E+01, 0.484E+03, 0.172E+04, 0.265E+04, 0.263E+04, 0.204E+04$
 0.403E+04, 0.373E+04, 0.787E+03, 0.420E+03, 0.198E+03, 0.793E+02$
 0.142E+02, 0.282E-09, 0.146E-09, 0.285E-10, 0.100E-10, 0.552E-11$
 0.251E-11
END$
   86$  HEAT RATE ARRAY
 0.289E-11, 0.248E-11, 0.272E-10, 0.544E-09, 0.150E-08, 0.974E-08$
 0.326E+01, 0.491E+03, 0.174E+04, 0.269E+04, 0.266E+04, 0.207E+04$
 0.409E+04, 0.379E+04, 0.656E+03, 0.452E+03, 0.212E+03, 0.857E+02$
 0.169E+02, 0.518E-09, 0.335E-09, 0.367E-10, 0.118E-10, 0.648E-11$
 0.289E-11
END$
   87$  HEAT RATE ARRAY
 0.276E-11, 0.235E-11, 0.582E-11, 0.514E-09, 0.171E-08, 0.990E-08$
 0.327E+01, 0.487E+03, 0.171E+04, 0.263E+04, 0.260E+04, 0.202E+04$
 0.400E+04, 0.369E+04, 0.577E+03, 0.396E+03, 0.183E+03, 0.761E+02$
 0.167E+02, 0.686E-09, 0.528E-09, 0.403E-10, 0.116E-10, 0.629E-11$
 0.276E-11
END$
   88$  HEAT RATE ARRAY
 0.271E-11, 0.227E-11, 0.461E-11, 0.415E-09, 0.208E-08, 0.103E-07$
 0.331E+01, 0.483E+03, 0.167E+04, 0.256E+04, 0.251E+04, 0.195E+04$
 0.386E+04, 0.357E+04, 0.475E+03, 0.324E+03, 0.147E+03, 0.634E+02$
 0.178E+02, 0.109E-08, 0.887E-09, 0.445E-10, 0.119E-10, 0.639E-11$
 0.271E-11
END$
   89$  HEAT RATE ARRAY
 0.265E-11, 0.219E-11, 0.437E-11, 0.134E-09, 0.259E-08, 0.109E-07$
 0.337E+01, 0.484E+03, 0.165E+04, 0.251E+04, 0.247E+04, 0.191E+04$
 0.379E+04, 0.299E+04, 0.416E+03, 0.282E+03, 0.125E+03, 0.562E+02$
 0.203E+02, 0.160E-08, 0.135E-08, 0.443E-10, 0.129E-10, 0.651E-11$
 0.265E-11
END$
   90$  HEAT RATE ARRAY
 0.165E-11, 0.120E-11, 0.279E-11, 0.287E-10, 0.372E-08, 0.120E-07$
 0.345E+01, 0.475E+03, 0.155E+04, 0.235E+04, 0.229E+04, 0.177E+04$
 0.352E+04, 0.857E+03, 0.216E+03, 0.144E+03, 0.639E+02, 0.353E+02$
 0.225E+02, 0.253E-08, 0.223E-08, 0.293E-10, 0.129E-10, 0.496E-11$
 0.165E-11
END$
   91$  HEAT RATE ARRAY
 0.237E-11, 0.168E-11, 0.395E-11, 0.189E-10, 0.536E-08, 0.136E-07$
 0.375E+01, 0.505E+03, 0.165E+04, 0.250E+04, 0.245E+04, 0.189E+04$
 0.374E+04, 0.466E+03, 0.329E+03, 0.222E+03, 0.959E+02, 0.621E+02$
 0.291E+02, 0.276E-08, 0.232E-08, 0.254E-10, 0.169E-10, 0.665E-11$
 0.237E-11
END$
   92$  HEAT RATE ARRAY
 0.540E-12, 0.446E-12, 0.697E-09, 0.443E-08, 0.476E-08, 0.499E-08$
 0.949E+00, 0.110E+03, 0.367E+03, 0.448E+03, 0.404E+03, 0.235E+03$
 0.865E+03, 0.304E+03, 0.142E+03, 0.105E+03, 0.552E+02, 0.224E+02$
 0.328E+01, 0.108E-10, 0.526E-10, 0.112E-09, 0.294E-11, 0.127E-11$
 0.540E-12
END$
   93$  HEAT RATE ARRAY
 0.696E-12, 0.559E-12, 0.174E-09, 0.447E-08, 0.510E-08, 0.441E-08$
 0.983E+00, 0.101E+03, 0.285E+03, 0.356E+03, 0.276E+03, 0.179E+03$
 0.818E+03, 0.155E+03, 0.113E+03, 0.867E+02, 0.464E+02, 0.197E+02$
 0.468E+01, 0.264E-09, 0.270E-09, 0.124E-09, 0.390E-11, 0.176E-11$
 0.696E-12
END$
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 0.149E-11
END$
   75$  HEAT RATE ARRAY
 0.146E-11, 0.120E-11, 0.275E-11, 0.179E-09, 0.896E-09, 0.396E-09$
 0.553E+00, 0.129E+03, 0.608E+03, 0.990E+03, 0.104E+04, 0.889E+03$
 0.252E+04, 0.566E+04, 0.355E+04, 0.974E+03, 0.553E+03, 0.405E+04$
 0.176E+04, 0.159E-06, 0.143E-06, 0.121E-08, 0.587E-09, 0.725E-10$
 0.146E-11
END$
   76$  HEAT RATE ARRAY
 0.425E-12, 0.342E-12, 0.103E-11, 0.103E-09, 0.689E-09, 0.292E-09$
 0.508E+00, 0.132E+03, 0.631E+03, 0.991E+03, 0.102E+04, 0.905E+03$
 0.259E+04, 0.569E+04, 0.372E+04, 0.933E+03, 0.560E+03, 0.491E+04$
 0.176E+04, 0.159E-06, 0.102E-08, 0.102E-08, 0.419E-09, 0.229E-10$
 0.425E-12
END$
   77$  HEAT RATE ARRAY
 0.326E-11, 0.253E-11, 0.658E-11, 0.831E-10, 0.177E-07, 0.542E-07$
 0.439E+01, 0.157E+03, 0.718E+03, 0.123E+04, 0.125E+04, 0.969E+03$
 0.198E+04, 0.134E+04, 0.116E+04, 0.102E+04, 0.586E+03, 0.116E+04$
 0.640E+03, 0.720E-07, 0.827E-07, 0.318E-09, 0.147E-09, 0.265E-10$
 0.326E-11
END$
   78$  HEAT RATE ARRAY
 0.239E-11, 0.184E-11, 0.511E-11, 0.614E-10, 0.359E-09, 0.690E-07$
 0.121E+02, 0.935E+03, 0.997E+03, 0.138E+04, 0.140E+04, 0.112E+04$
 0.231E+04, 0.161E+04, 0.137E+04, 0.116E+04, 0.671E+03, 0.156E+04$
 0.648E+03, 0.722E-07, 0.451E-09, 0.286E-09, 0.106E-09, 0.109E-10$
 0.239E-11
END$
   79$  HEAT RATE ARRAY
 0.501E-11, 0.380E-11, 0.852E-11, 0.363E-10, 0.285E-08, 0.689E-07$
 0.485E+01, 0.143E+03, 0.601E+03, 0.101E+04, 0.105E+04, 0.860E+03$
 0.230E+04, 0.136E+04, 0.946E+03, 0.727E+03, 0.384E+03, 0.213E+03$
 0.738E+02, 0.507E-08, 0.333E-08, 0.670E-10, 0.316E-10, 0.123E-10$
 0.501E-11
END$
   80$  HEAT RATE ARRAY
 0.532E-11, 0.405E-11, 0.896E-11, 0.382E-10, 0.818E-09, 0.160E-06$
 0.303E+02, 0.926E+03, 0.816E+03, 0.134E+04, 0.139E+04, 0.117E+04$
 0.293E+04, 0.190E+04, 0.132E+04, 0.999E+03, 0.533E+03, 0.301E+03$
 0.901E+02, 0.514E-08, 0.103E-08, 0.920E-10, 0.372E-10, 0.130E-10$
 0.532E-11
END$
   81$  HEAT RATE ARRAY
 0.276E-12, 0.242E-12, 0.132E-09, 0.266E-09, 0.306E-09, 0.258E-08$
 0.126E+01, 0.190E+03, 0.863E+03, 0.155E+04, 0.181E+04, 0.154E+04$
 0.299E+04, 0.284E+04, 0.862E+03, 0.516E+02, 0.248E+02, 0.958E+01$
 0.163E+01, 0.187E-10, 0.916E-11, 0.582E-11, 0.123E-11, 0.603E-12$
 0.276E-12
END$
   82$  HEAT RATE ARRAY
 0.114E-12, 0.955E-13, 0.539E-09, 0.143E-08, 0.157E-08, 0.177E-08$
 0.358E+00, 0.393E+02, 0.123E+03, 0.147E+03, 0.122E+03, 0.396E+03$
 0.192E+04, 0.193E+04, 0.854E+02, 0.267E+02, 0.139E+02, 0.554E+01$
 0.797E+00, 0.288E-11, 0.122E-10, 0.284E-10, 0.105E-11, 0.276E-12$
 0.114E-12
END$
   83$  HEAT RATE ARRAY
 0.249E-12, 0.207E-12, 0.184E-07, 0.200E-07, 0.199E-07, 0.194E-07$
 0.370E+01, 0.346E+03, 0.910E+03, 0.105E+04, 0.803E+03, 0.504E+03$
 0.911E+03, 0.762E+03, 0.837E+02, 0.516E+02, 0.280E+02, 0.115E+02$
 0.178E+01, 0.498E-11, 0.433E-08, 0.189E-07, 0.548E-11, 0.575E-12$
 0.249E-12
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END$
   84$  HEAT RATE ARRAY
 0.231E-12, 0.206E-12, 0.131E-07, 0.242E-07, 0.352E-07, 0.440E-07$
 0.994E+01, 0.104E+04, 0.301E+04, 0.371E+04, 0.289E+04, 0.165E+04$
 0.194E+04, 0.693E+03, 0.667E+02, 0.429E+02, 0.210E+02, 0.837E+01$
 0.149E+01, 0.348E-12, 0.775E-12, 0.942E-12, 0.782E-12, 0.468E-12$
 0.231E-12
END$
   85$  HEAT RATE ARRAY
 0.251E-11, 0.216E-11, 0.846E-10, 0.521E-09, 0.128E-08, 0.957E-08$
 0.320E+01, 0.484E+03, 0.172E+04, 0.265E+04, 0.263E+04, 0.204E+04$
 0.403E+04, 0.373E+04, 0.787E+03, 0.420E+03, 0.198E+03, 0.793E+02$
 0.142E+02, 0.282E-09, 0.146E-09, 0.285E-10, 0.100E-10, 0.552E-11$
 0.251E-11
END$
   86$  HEAT RATE ARRAY
 0.289E-11, 0.248E-11, 0.272E-10, 0.544E-09, 0.150E-08, 0.974E-08$
 0.326E+01, 0.491E+03, 0.174E+04, 0.269E+04, 0.266E+04, 0.207E+04$
 0.409E+04, 0.379E+04, 0.656E+03, 0.452E+03, 0.212E+03, 0.857E+02$
 0.169E+02, 0.518E-09, 0.335E-09, 0.367E-10, 0.118E-10, 0.648E-11$
 0.289E-11
END$
   87$  HEAT RATE ARRAY
 0.276E-11, 0.235E-11, 0.582E-11, 0.514E-09, 0.171E-08, 0.990E-08$
 0.327E+01, 0.487E+03, 0.171E+04, 0.263E+04, 0.260E+04, 0.202E+04$
 0.400E+04, 0.369E+04, 0.577E+03, 0.396E+03, 0.183E+03, 0.761E+02$
 0.167E+02, 0.686E-09, 0.528E-09, 0.403E-10, 0.116E-10, 0.629E-11$
 0.276E-11
END$
   88$  HEAT RATE ARRAY
 0.271E-11, 0.227E-11, 0.461E-11, 0.415E-09, 0.208E-08, 0.103E-07$
 0.331E+01, 0.483E+03, 0.167E+04, 0.256E+04, 0.251E+04, 0.195E+04$
 0.386E+04, 0.357E+04, 0.475E+03, 0.324E+03, 0.147E+03, 0.634E+02$
 0.178E+02, 0.109E-08, 0.887E-09, 0.445E-10, 0.119E-10, 0.639E-11$
 0.271E-11
END$
   89$  HEAT RATE ARRAY
 0.265E-11, 0.219E-11, 0.437E-11, 0.134E-09, 0.259E-08, 0.109E-07$
 0.337E+01, 0.484E+03, 0.165E+04, 0.251E+04, 0.247E+04, 0.191E+04$
 0.379E+04, 0.299E+04, 0.416E+03, 0.282E+03, 0.125E+03, 0.562E+02$
 0.203E+02, 0.160E-08, 0.135E-08, 0.443E-10, 0.129E-10, 0.651E-11$
 0.265E-11
END$
   90$  HEAT RATE ARRAY
 0.165E-11, 0.120E-11, 0.279E-11, 0.287E-10, 0.372E-08, 0.120E-07$
 0.345E+01, 0.475E+03, 0.155E+04, 0.235E+04, 0.229E+04, 0.177E+04$
 0.352E+04, 0.857E+03, 0.216E+03, 0.144E+03, 0.639E+02, 0.353E+02$
 0.225E+02, 0.253E-08, 0.223E-08, 0.293E-10, 0.129E-10, 0.496E-11$
 0.165E-11
END$
   91$  HEAT RATE ARRAY
 0.237E-11, 0.168E-11, 0.395E-11, 0.189E-10, 0.536E-08, 0.136E-07$
 0.375E+01, 0.505E+03, 0.165E+04, 0.250E+04, 0.245E+04, 0.189E+04$
 0.374E+04, 0.466E+03, 0.329E+03, 0.222E+03, 0.959E+02, 0.621E+02$
 0.291E+02, 0.276E-08, 0.232E-08, 0.254E-10, 0.169E-10, 0.665E-11$
 0.237E-11
END$
   92$  HEAT RATE ARRAY
 0.540E-12, 0.446E-12, 0.697E-09, 0.443E-08, 0.476E-08, 0.499E-08$
 0.949E+00, 0.110E+03, 0.367E+03, 0.448E+03, 0.404E+03, 0.235E+03$
 0.865E+03, 0.304E+03, 0.142E+03, 0.105E+03, 0.552E+02, 0.224E+02$
 0.328E+01, 0.108E-10, 0.526E-10, 0.112E-09, 0.294E-11, 0.127E-11$
 0.540E-12
END$
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 0.517E-11, 0.398E-11, 0.834E-11, 0.296E-10, 0.597E-08, 0.155E-07$
 0.446E+01, 0.606E+03, 0.213E+04, 0.336E+04, 0.325E+04, 0.256E+04$
 0.499E+04, 0.121E+04, 0.863E+03, 0.592E+03, 0.255E+03, 0.149E+03$
 0.370E+02, 0.413E-08, 0.913E-09, 0.326E-10, 0.240E-10, 0.120E-10$
 0.517E-11
END$
  114$  HEAT RATE ARRAY
 0.654E-11, 0.504E-11, 0.104E-10, 0.342E-10, 0.148E-08, 0.122E-07$
 0.419E+01, 0.630E+03, 0.236E+04, 0.375E+04, 0.367E+04, 0.291E+04$
 0.545E+04, 0.180E+04, 0.126E+04, 0.868E+03, 0.383E+03, 0.217E+03$
 0.372E+02, 0.107E-07, 0.314E-09, 0.681E-10, 0.330E-10, 0.146E-10$
 0.654E-11
END$
  115$  HEAT RATE ARRAY
 0.276E-11, 0.207E-11, 0.493E-11, 0.279E-10, 0.333E-08, 0.507E-08$
 0.141E+01, 0.171E+03, 0.618E+03, 0.100E+04, 0.988E+03, 0.812E+03$
 0.230E+04, 0.131E+04, 0.986E+03, 0.756E+03, 0.423E+03, 0.202E+03$
 0.256E+03, 0.689E-07, 0.286E-08, 0.805E-10, 0.288E-10, 0.751E-11$
 0.276E-11
END$
  116$  HEAT RATE ARRAY
 0.446E-11, 0.339E-11, 0.758E-11, 0.356E-10, 0.103E-08, 0.514E-08$
 0.171E+01, 0.211E+03, 0.810E+03, 0.135E+04, 0.137E+04, 0.113E+04$
 0.293E+04, 0.188E+04, 0.137E+04, 0.101E+04, 0.536E+03, 0.131E+04$
 0.160E+04, 0.160E-06, 0.821E-09, 0.959E-10, 0.369E-10, 0.112E-10$
 0.446E-11
END$
  117$  HEAT RATE ARRAY
 0.808E-11, 0.625E-11, 0.143E-10, 0.674E-10, 0.825E-07, 0.720E-07$
 0.121E+02, 0.102E+04, 0.242E+04, 0.257E+04, 0.180E+04, 0.107E+04$
 0.198E+04, 0.155E+04, 0.100E+04, 0.941E+03, 0.553E+03, 0.232E+03$
 0.232E+03, 0.542E-07, 0.175E-07, 0.928E-10, 0.448E-10, 0.192E-10$
 0.808E-11
END$
  118$  HEAT RATE ARRAY
 0.993E-11, 0.766E-11, 0.172E-10, 0.743E-10, 0.346E-09, 0.721E-07$
 0.123E+02, 0.104E+04, 0.255E+04, 0.279E+04, 0.204E+04, 0.126E+04$
 0.231E+04, 0.187E+04, 0.117E+04, 0.106E+04, 0.594E+03, 0.139E+04$
 0.639E+03, 0.690E-07, 0.256E-09, 0.116E-09, 0.534E-10, 0.232E-10$
 0.993E-11
END$
  119$  HEAT RATE ARRAY
 0.704E-11, 0.562E-11, 0.117E-10, 0.398E-10, 0.142E-06, 0.159E-06$
 0.333E+02, 0.328E+04, 0.884E+04, 0.101E+05, 0.697E+04, 0.321E+04$
 0.251E+04, 0.163E+04, 0.112E+04, 0.814E+03, 0.391E+03, 0.185E+03$
 0.282E+02, 0.162E-09, 0.128E-09, 0.386E-10, 0.279E-10, 0.154E-10$
 0.704E-11
END$
  120$  HEAT RATE ARRAY
 0.764E-11, 0.594E-11, 0.125E-10, 0.423E-10, 0.377E-09, 0.159E-06$
 0.333E+02, 0.328E+04, 0.888E+04, 0.101E+05, 0.703E+04, 0.325E+04$
 0.256E+04, 0.164E+04, 0.109E+04, 0.803E+03, 0.368E+03, 0.192E+03$
 0.261E+02, 0.100E-09, 0.591E-10, 0.406E-10, 0.301E-10, 0.168E-10$
 0.764E-11
END$
  121$  HEAT RATE ARRAY
 0.386E-12, 0.275E-12, 0.663E-12, 0.362E-10, 0.351E-09, 0.551E-09$
 0.325E+00, 0.705E+02, 0.135E+04, 0.260E+04, 0.510E+03, 0.470E+03$
 0.182E+04, 0.590E+04, 0.548E+04, 0.448E+03, 0.145E+04, 0.788E+03$
 0.161E+03, 0.275E-08, 0.645E-09, 0.275E-09, 0.126E-09, 0.875E-11$
 0.386E-12
END$
  122$  HEAT RATE ARRAY
 0.854E-13, 0.632E-13, 0.226E-12, 0.600E-11, 0.493E-09, 0.196E-09$
 0.191E+00, 0.498E+02, 0.239E+03, 0.368E+03, 0.380E+03, 0.345E+03$
 0.473E+04, 0.741E+04, 0.364E+04, 0.346E+03, 0.554E+04, 0.354E+04$
 0.118E+04, 0.515E-07, 0.674E-09, 0.720E-09, 0.263E-09, 0.763E-12$
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 0.854E-13
END$
  123$  HEAT RATE ARRAY
 0.524E-12, 0.401E-12, 0.126E-11, 0.455E-10, 0.312E-09, 0.383E-09$
 0.843E+01, 0.829E+03, 0.207E+04, 0.571E+03, 0.583E+03, 0.494E+03$
 0.104E+04, 0.227E+04, 0.646E+03, 0.502E+03, 0.152E+04, 0.126E+04$
 0.452E+03, 0.170E-07, 0.394E-09, 0.283E-09, 0.128E-09, 0.916E-11$
 0.524E-12
END$
  124$  HEAT RATE ARRAY
 0.142E-11, 0.107E-11, 0.239E-11, 0.115E-10, 0.500E-09, 0.137E-08$
 0.167E+02, 0.949E+03, 0.469E+03, 0.278E+04, 0.619E+03, 0.546E+03$
 0.225E+04, 0.186E+04, 0.687E+03, 0.486E+03, 0.272E+03, 0.159E+03$
 0.527E+02, 0.302E-08, 0.507E-09, 0.510E-10, 0.160E-10, 0.380E-11$
 0.142E-11
END$
  125$  HEAT RATE ARRAY
 0.338E-11, 0.260E-11, 0.557E-11, 0.204E-10, 0.512E-09, 0.271E-08$
 0.306E+01, 0.531E+03, 0.225E+04, 0.401E+04, 0.463E+04, 0.325E+04$
 0.181E+04, 0.852E+03, 0.590E+03, 0.113E+04, 0.171E+03, 0.101E+03$
 0.169E+02, 0.510E-09, 0.220E-09, 0.670E-10, 0.362E-10, 0.752E-11$
 0.338E-11
END$
  126$  HEAT RATE ARRAY
 0.298E-11, 0.227E-11, 0.486E-11, 0.184E-10, 0.498E-09, 0.302E-08$
 0.100E+01, 0.111E+03, 0.403E+03, 0.694E+03, 0.713E+03, 0.107E+04$
 0.224E+04, 0.940E+03, 0.660E+03, 0.463E+03, 0.224E+03, 0.141E+04$
 0.879E+03, 0.137E-08, 0.493E-09, 0.347E-10, 0.173E-10, 0.698E-11$
 0.298E-11
END$
  127$  HEAT RATE ARRAY
 0.428E-11, 0.330E-11, 0.740E-11, 0.327E-10, 0.265E-09, 0.169E-07$
 0.855E+01, 0.842E+03, 0.236E+04, 0.293E+04, 0.240E+04, 0.136E+04$
 0.103E+04, 0.869E+03, 0.560E+03, 0.451E+03, 0.226E+03, 0.124E+04$
 0.445E+03, 0.345E-09, 0.185E-09, 0.797E-10, 0.411E-10, 0.968E-11$
 0.428E-11
END$
  128$  HEAT RATE ARRAY
 0.278E-11, 0.214E-11, 0.447E-11, 0.167E-10, 0.212E-09, 0.513E-07$
 0.223E+02, 0.237E+04, 0.694E+04, 0.869E+04, 0.691E+04, 0.406E+04$
 0.470E+04, 0.611E+03, 0.409E+03, 0.293E+03, 0.127E+03, 0.707E+02$
 0.953E+01, 0.566E-10, 0.358E-10, 0.137E-10, 0.108E-10, 0.607E-11$
 0.278E-11
END$
  129$  HEAT RATE ARRAY
 0.231E-10, 0.150E-10, 0.694E-09, 0.187E-07, 0.602E-07, 0.496E-07$
 0.235E+03, 0.613E+05, 0.281E+06, 0.492E+06, 0.484E+06, 0.346E+06$
 0.757E+06, 0.372E+06, 0.455E+06, 0.407E+06, 0.229E+06, 0.918E+05$
 0.128E+05, 0.915E-07, 0.909E-07, 0.502E-07, 0.146E-07, 0.106E-08$
 0.231E-10
END$
  130$  HEAT RATE ARRAY
 0.474E-08, 0.365E-08, 0.827E-08, 0.351E-07, 0.877E-07, 0.904E-07$
 0.244E+03, 0.620E+05, 0.283E+06, 0.494E+06, 0.531E+06, 0.433E+06$
 0.756E+06, 0.639E+06, 0.308E+06, 0.356E+06, 0.229E+06, 0.912E+05$
 0.124E+05, 0.490E-07, 0.574E-07, 0.384E-07, 0.217E-07, 0.111E-07$
 0.474E-08
END$
  131$  HEAT RATE ARRAY
 0.187E-10, 0.118E-10, 0.499E-10, 0.207E-08, 0.291E-07, 0.408E-07$
 0.168E+03, 0.454E+05, 0.222E+06, 0.334E+06, 0.346E+06, 0.326E+06$
 0.688E+06, 0.625E+06, 0.450E+06, 0.318E+06, 0.190E+06, 0.852E+05$
 0.125E+05, 0.114E-06, 0.666E-07, 0.370E-07, 0.822E-08, 0.422E-09$
 0.187E-10
END$
  132$  HEAT RATE ARRAY
 0.254E-08, 0.196E-08, 0.402E-08, 0.123E-07, 0.531E-07, 0.109E-06$
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 0.294E+02, 0.288E+04, 0.770E+04, 0.863E+04, 0.586E+04, 0.258E+04$
 0.174E+04, 0.104E+04, 0.753E+03, 0.528E+03, 0.265E+03, 0.112E+03$
 0.188E+02, 0.124E-09, 0.115E-09, 0.210E-10, 0.150E-10, 0.833E-11$
 0.386E-11
END$
  112$  HEAT RATE ARRAY
 0.486E-11, 0.395E-11, 0.819E-11, 0.277E-10, 0.127E-06, 0.142E-06$
 0.296E+02, 0.290E+04, 0.778E+04, 0.877E+04, 0.601E+04, 0.270E+04$
 0.195E+04, 0.122E+04, 0.856E+03, 0.611E+03, 0.303E+03, 0.135E+03$
 0.225E+02, 0.235E-09, 0.209E-09, 0.274E-10, 0.195E-10, 0.107E-10$
 0.486E-11
END$
  113$  HEAT RATE ARRAY
 0.517E-11, 0.398E-11, 0.834E-11, 0.296E-10, 0.597E-08, 0.155E-07$
 0.446E+01, 0.606E+03, 0.213E+04, 0.336E+04, 0.325E+04, 0.256E+04$
 0.499E+04, 0.121E+04, 0.863E+03, 0.592E+03, 0.255E+03, 0.149E+03$
 0.370E+02, 0.413E-08, 0.913E-09, 0.326E-10, 0.240E-10, 0.120E-10$
 0.517E-11
END$
  114$  HEAT RATE ARRAY
 0.654E-11, 0.504E-11, 0.104E-10, 0.342E-10, 0.148E-08, 0.122E-07$
 0.419E+01, 0.630E+03, 0.236E+04, 0.375E+04, 0.367E+04, 0.291E+04$
 0.545E+04, 0.180E+04, 0.126E+04, 0.868E+03, 0.383E+03, 0.217E+03$
 0.372E+02, 0.107E-07, 0.314E-09, 0.681E-10, 0.330E-10, 0.146E-10$
 0.654E-11
END$
  115$  HEAT RATE ARRAY
 0.276E-11, 0.207E-11, 0.493E-11, 0.279E-10, 0.333E-08, 0.507E-08$
 0.141E+01, 0.171E+03, 0.618E+03, 0.100E+04, 0.988E+03, 0.812E+03$
 0.230E+04, 0.131E+04, 0.986E+03, 0.756E+03, 0.423E+03, 0.202E+03$
 0.256E+03, 0.689E-07, 0.286E-08, 0.805E-10, 0.288E-10, 0.751E-11$
 0.276E-11
END$
  116$  HEAT RATE ARRAY
 0.446E-11, 0.339E-11, 0.758E-11, 0.356E-10, 0.103E-08, 0.514E-08$
 0.171E+01, 0.211E+03, 0.810E+03, 0.135E+04, 0.137E+04, 0.113E+04$
 0.293E+04, 0.188E+04, 0.137E+04, 0.101E+04, 0.536E+03, 0.131E+04$
 0.160E+04, 0.160E-06, 0.821E-09, 0.959E-10, 0.369E-10, 0.112E-10$
 0.446E-11
END$
  117$  HEAT RATE ARRAY
 0.808E-11, 0.625E-11, 0.143E-10, 0.674E-10, 0.825E-07, 0.720E-07$
 0.121E+02, 0.102E+04, 0.242E+04, 0.257E+04, 0.180E+04, 0.107E+04$
 0.198E+04, 0.155E+04, 0.100E+04, 0.941E+03, 0.553E+03, 0.232E+03$
 0.232E+03, 0.542E-07, 0.175E-07, 0.928E-10, 0.448E-10, 0.192E-10$
 0.808E-11
END$
  118$  HEAT RATE ARRAY
 0.993E-11, 0.766E-11, 0.172E-10, 0.743E-10, 0.346E-09, 0.721E-07$
 0.123E+02, 0.104E+04, 0.255E+04, 0.279E+04, 0.204E+04, 0.126E+04$
 0.231E+04, 0.187E+04, 0.117E+04, 0.106E+04, 0.594E+03, 0.139E+04$
 0.639E+03, 0.690E-07, 0.256E-09, 0.116E-09, 0.534E-10, 0.232E-10$
 0.993E-11
END$
  119$  HEAT RATE ARRAY
 0.704E-11, 0.562E-11, 0.117E-10, 0.398E-10, 0.142E-06, 0.159E-06$
 0.333E+02, 0.328E+04, 0.884E+04, 0.101E+05, 0.697E+04, 0.321E+04$
 0.251E+04, 0.163E+04, 0.112E+04, 0.814E+03, 0.391E+03, 0.185E+03$
 0.282E+02, 0.162E-09, 0.128E-09, 0.386E-10, 0.279E-10, 0.154E-10$
 0.704E-11
END$
  120$  HEAT RATE ARRAY
 0.764E-11, 0.594E-11, 0.125E-10, 0.423E-10, 0.377E-09, 0.159E-06$
 0.333E+02, 0.328E+04, 0.888E+04, 0.101E+05, 0.703E+04, 0.325E+04$
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 0.256E+04, 0.164E+04, 0.109E+04, 0.803E+03, 0.368E+03, 0.192E+03$
 0.261E+02, 0.100E-09, 0.591E-10, 0.406E-10, 0.301E-10, 0.168E-10$
 0.764E-11
END$
  121$  HEAT RATE ARRAY
 0.386E-12, 0.275E-12, 0.663E-12, 0.362E-10, 0.351E-09, 0.551E-09$
 0.325E+00, 0.705E+02, 0.135E+04, 0.260E+04, 0.510E+03, 0.470E+03$
 0.182E+04, 0.590E+04, 0.548E+04, 0.448E+03, 0.145E+04, 0.788E+03$
 0.161E+03, 0.275E-08, 0.645E-09, 0.275E-09, 0.126E-09, 0.875E-11$
 0.386E-12
END$
  122$  HEAT RATE ARRAY
 0.854E-13, 0.632E-13, 0.226E-12, 0.600E-11, 0.493E-09, 0.196E-09$
 0.191E+00, 0.498E+02, 0.239E+03, 0.368E+03, 0.380E+03, 0.345E+03$
 0.473E+04, 0.741E+04, 0.364E+04, 0.346E+03, 0.554E+04, 0.354E+04$
 0.118E+04, 0.515E-07, 0.674E-09, 0.720E-09, 0.263E-09, 0.763E-12$
 0.854E-13
END$
  123$  HEAT RATE ARRAY
 0.524E-12, 0.401E-12, 0.126E-11, 0.455E-10, 0.312E-09, 0.383E-09$
 0.843E+01, 0.829E+03, 0.207E+04, 0.571E+03, 0.583E+03, 0.494E+03$
 0.104E+04, 0.227E+04, 0.646E+03, 0.502E+03, 0.152E+04, 0.126E+04$
 0.452E+03, 0.170E-07, 0.394E-09, 0.283E-09, 0.128E-09, 0.916E-11$
 0.524E-12
END$
  124$  HEAT RATE ARRAY
 0.142E-11, 0.107E-11, 0.239E-11, 0.115E-10, 0.500E-09, 0.137E-08$
 0.167E+02, 0.949E+03, 0.469E+03, 0.278E+04, 0.619E+03, 0.546E+03$
 0.225E+04, 0.186E+04, 0.687E+03, 0.486E+03, 0.272E+03, 0.159E+03$
 0.527E+02, 0.302E-08, 0.507E-09, 0.510E-10, 0.160E-10, 0.380E-11$
 0.142E-11
END$
  125$  HEAT RATE ARRAY
 0.338E-11, 0.260E-11, 0.557E-11, 0.204E-10, 0.512E-09, 0.271E-08$
 0.306E+01, 0.531E+03, 0.225E+04, 0.401E+04, 0.463E+04, 0.325E+04$
 0.181E+04, 0.852E+03, 0.590E+03, 0.113E+04, 0.171E+03, 0.101E+03$
 0.169E+02, 0.510E-09, 0.220E-09, 0.670E-10, 0.362E-10, 0.752E-11$
 0.338E-11
END$
  126$  HEAT RATE ARRAY
 0.298E-11, 0.227E-11, 0.486E-11, 0.184E-10, 0.498E-09, 0.302E-08$
 0.100E+01, 0.111E+03, 0.403E+03, 0.694E+03, 0.713E+03, 0.107E+04$
 0.224E+04, 0.940E+03, 0.660E+03, 0.463E+03, 0.224E+03, 0.141E+04$
 0.879E+03, 0.137E-08, 0.493E-09, 0.347E-10, 0.173E-10, 0.698E-11$
 0.298E-11
END$
  127$  HEAT RATE ARRAY
 0.428E-11, 0.330E-11, 0.740E-11, 0.327E-10, 0.265E-09, 0.169E-07$
 0.855E+01, 0.842E+03, 0.236E+04, 0.293E+04, 0.240E+04, 0.136E+04$
 0.103E+04, 0.869E+03, 0.560E+03, 0.451E+03, 0.226E+03, 0.124E+04$
 0.445E+03, 0.345E-09, 0.185E-09, 0.797E-10, 0.411E-10, 0.968E-11$
 0.428E-11
END$
  128$  HEAT RATE ARRAY
 0.278E-11, 0.214E-11, 0.447E-11, 0.167E-10, 0.212E-09, 0.513E-07$
 0.223E+02, 0.237E+04, 0.694E+04, 0.869E+04, 0.691E+04, 0.406E+04$
 0.470E+04, 0.611E+03, 0.409E+03, 0.293E+03, 0.127E+03, 0.707E+02$
 0.953E+01, 0.566E-10, 0.358E-10, 0.137E-10, 0.108E-10, 0.607E-11$
 0.278E-11
END$
  129$  HEAT RATE ARRAY
 0.231E-10, 0.150E-10, 0.694E-09, 0.187E-07, 0.602E-07, 0.496E-07$
 0.235E+03, 0.613E+05, 0.281E+06, 0.492E+06, 0.484E+06, 0.346E+06$
 0.757E+06, 0.372E+06, 0.455E+06, 0.407E+06, 0.229E+06, 0.918E+05$
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 0.128E+05, 0.915E-07, 0.909E-07, 0.502E-07, 0.146E-07, 0.106E-08$
 0.231E-10
ENDS$
  130$  HEAT RATE ARRAY
 0.474E-08, 0.365E-08, 0.827E-08, 0.351E-07, 0.877E-07, 0.904E-07$
 0.244E+03, 0.620E+05, 0.283E+06, 0.494E+06, 0.531E+06, 0.433E+06$
 0.756E+06, 0.639E+06, 0.308E+06, 0.356E+06, 0.229E+06, 0.912E+05$
 0.124E+05, 0.490E-07, 0.574E-07, 0.384E-07, 0.217E-07, 0.111E-07$
 0.474E-08
ENDS$
  131$  HEAT RATE ARRAY
 0.187E-10, 0.118E-10, 0.499E-10, 0.207E-08, 0.291E-07, 0.408E-07$
 0.168E+03, 0.454E+05, 0.222E+06, 0.334E+06, 0.346E+06, 0.326E+06$
 0.688E+06, 0.625E+06, 0.450E+06, 0.318E+06, 0.190E+06, 0.852E+05$
 0.125E+05, 0.114E-06, 0.666E-07, 0.370E-07, 0.822E-08, 0.422E-09$
 0.187E-10
ENDS$
  132$  HEAT RATE ARRAY
 0.254E-08, 0.196E-08, 0.402E-08, 0.123E-07, 0.531E-07, 0.109E-06$
 0.236E+03, 0.575E+05, 0.264E+06, 0.455E+06, 0.482E+06, 0.381E+06$
 0.687E+06, 0.600E+06, 0.414E+06, 0.283E+06, 0.115E+06, 0.676E+05$
 0.886E+04, 0.368E-07, 0.158E-07, 0.109E-07, 0.942E-08, 0.546E-08$
 0.254E-08
ENDS$
  133$  HEAT RATE ARRAY
 0.405E-09, 0.421E-09, 0.585E-09, 0.557E-09, 0.388E-09, 0.113E-07$
 0.723E+01, 0.146E+04, 0.667E+04, 0.127E+05, 0.149E+05, 0.126E+05$
 0.245E+05, 0.233E+05, 0.182E+05, 0.613E+04, 0.504E+02, 0.899E+03$
 0.382E+03, 0.113E-07, 0.390E-09, 0.560E-09, 0.599E-09, 0.513E-09$
 0.405E-09
ENDS$
  134$  HEAT RATE ARRAY
 0.158E-08, 0.158E-08, 0.230E-08, 0.224E-08, 0.156E-08, 0.475E-09$
 0.114E+00, 0.249E+02, 0.112E+03, 0.169E+03, 0.176E+04, 0.575E+04$
 0.183E+05, 0.247E+05, 0.264E+05, 0.557E+04, 0.111E+03, 0.426E+04$
 0.325E+04, 0.258E-06, 0.191E-06, 0.118E-06, 0.571E-07, 0.205E-08$
 0.158E-08
ENDS$
  135$  HEAT RATE ARRAY
 0.405E-09, 0.421E-09, 0.806E-07, 0.912E-07, 0.103E-06, 0.112E-06$
 0.234E+02, 0.238E+04, 0.691E+04, 0.911E+04, 0.842E+04, 0.640E+04$
 0.120E+05, 0.118E+05, 0.103E+05, 0.385E+04, 0.487E+02, 0.208E+04$
 0.123E+04, 0.112E-06, 0.103E-06, 0.912E-07, 0.806E-07, 0.513E-09$
 0.405E-09
ENDS$
  136$  HEAT RATE ARRAY
 0.389E-12, 0.348E-12, 0.547E-07, 0.115E-06, 0.190E-06, 0.258E-06$
 0.615E+02, 0.675E+04, 0.203E+05, 0.262E+05, 0.216E+05, 0.133E+05$
 0.182E+05, 0.106E+05, 0.205E+04, 0.733E+02, 0.357E+02, 0.142E+02$
 0.254E+01, 0.500E-12, 0.122E-11, 0.155E-11, 0.130E-11, 0.784E-12$
 0.389E-12
ENDS$
  137$  HEAT RATE ARRAY
 0.167E-09, 0.139E-09, 0.284E-09, 0.947E-09, 0.102E-05, 0.312E-06$
 0.266E+02, 0.566E+04, 0.267E+05, 0.459E+05, 0.501E+05, 0.417E+05$
 0.844E+05, 0.807E+05, 0.668E+05, 0.491E+05, 0.264E+05, 0.109E+05$
 0.162E+04, 0.328E-06, 0.103E-05, 0.163E-05, 0.128E-08, 0.442E-09$
 0.167E-09
ENDS$
  138$  HEAT RATE ARRAY
 0.314E-10, 0.214E-10, 0.115E-09, 0.135E-08, 0.878E-07, 0.269E-07$
 0.689E+02, 0.115E+05, 0.297E+05, 0.569E+05, 0.874E+05, 0.374E+05$
 0.395E+05, 0.696E+05, 0.107E+06, 0.923E+05, 0.715E+05, 0.365E+05$
 0.497E+04, 0.418E-07, 0.101E-06, 0.135E-06, 0.930E-07, 0.103E-09$
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 0.314E-10
END$
  139$  HEAT RATE ARRAY
 0.736E-10, 0.598E-10, 0.131E-09, 0.564E-09, 0.103E-05, 0.313E-06$
 0.159E+02, 0.319E+04, 0.129E+05, 0.226E+05, 0.267E+05, 0.191E+05$
 0.353E+05, 0.362E+05, 0.337E+05, 0.258E+05, 0.157E+05, 0.715E+04$
 0.113E+04, 0.330E-06, 0.104E-05, 0.148E-05, 0.110E-05, 0.202E-09$
 0.736E-10
END$
  140$  HEAT RATE ARRAY
 0.387E-10, 0.283E-10, 0.169E-09, 0.294E-08, 0.874E-07, 0.267E-07$
 0.688E+02, 0.115E+05, 0.338E+05, 0.953E+05, 0.872E+05, 0.373E+05$
 0.392E+05, 0.693E+05, 0.107E+06, 0.922E+05, 0.714E+05, 0.364E+05$
 0.494E+04, 0.390E-07, 0.978E-07, 0.133E-06, 0.136E-06, 0.106E-09$
 0.387E-10
END$
  141$  HEAT RATE ARRAY
 0.783E-10, 0.625E-10, 0.143E-09, 0.211E-07, 0.103E-05, 0.313E-06$
 0.152E+02, 0.305E+04, 0.125E+05, 0.247E+05, 0.254E+05, 0.178E+05$
 0.324E+05, 0.334E+05, 0.315E+05, 0.240E+05, 0.146E+05, 0.669E+04$
 0.107E+04, 0.331E-06, 0.104E-05, 0.148E-05, 0.159E-05, 0.216E-09$
 0.783E-10
END$
  142$  HEAT RATE ARRAY
 0.320E-10, 0.246E-10, 0.182E-09, 0.117E-06, 0.871E-07, 0.266E-07$
 0.687E+02, 0.118E+05, 0.611E+05, 0.999E+05, 0.870E+05, 0.372E+05$
 0.389E+05, 0.689E+05, 0.107E+06, 0.920E+05, 0.713E+05, 0.363E+05$
 0.489E+04, 0.341E-07, 0.933E-07, 0.130E-06, 0.136E-06, 0.276E-07$
 0.320E-10
END$
  143$  HEAT RATE ARRAY
 0.786E-10, 0.613E-10, 0.151E-09, 0.138E-05, 0.103E-05, 0.313E-06$
 0.141E+02, 0.286E+04, 0.138E+05, 0.234E+05, 0.234E+05, 0.162E+05$
 0.290E+05, 0.301E+05, 0.286E+05, 0.219E+05, 0.134E+05, 0.621E+04$
 0.101E+04, 0.331E-06, 0.104E-05, 0.149E-05, 0.159E-05, 0.327E-06$
 0.786E-10
END$
  144$  HEAT RATE ARRAY
 0.173E-10, 0.140E-10, 0.118E-09, 0.125E-06, 0.868E-07, 0.264E-07$
 0.685E+02, 0.147E+05, 0.870E+05, 0.996E+05, 0.867E+05, 0.369E+05$
 0.383E+05, 0.683E+05, 0.106E+06, 0.916E+05, 0.711E+05, 0.362E+05$
 0.484E+04, 0.298E-07, 0.896E-07, 0.127E-06, 0.135E-06, 0.113E-06$
 0.173E-10
END$
  145$  HEAT RATE ARRAY
 0.864E-10, 0.670E-10, 0.187E-09, 0.148E-05, 0.103E-05, 0.313E-06$
 0.121E+02, 0.267E+04, 0.140E+05, 0.198E+05, 0.197E+05, 0.133E+05$
 0.230E+05, 0.253E+05, 0.243E+05, 0.184E+05, 0.115E+05, 0.542E+04$
 0.899E+03, 0.330E-06, 0.104E-05, 0.149E-05, 0.159E-05, 0.134E-05$
 0.864E-10
END$
  146$  HEAT RATE ARRAY
 0.105E-07, 0.805E-11, 0.396E-07, 0.125E-06, 0.867E-07, 0.264E-07$
 0.759E+02, 0.242E+05, 0.869E+05, 0.995E+05, 0.866E+05, 0.368E+05$
 0.380E+05, 0.680E+05, 0.106E+06, 0.915E+05, 0.711E+05, 0.362E+05$
 0.482E+04, 0.280E-07, 0.881E-07, 0.126E-06, 0.134E-06, 0.115E-06$
 0.105E-07
END$
  147$  HEAT RATE ARRAY
 0.124E-06, 0.709E-10, 0.469E-06, 0.148E-05, 0.103E-05, 0.312E-06$
 0.120E+02, 0.331E+04, 0.132E+05, 0.185E+05, 0.183E+05, 0.121E+05$
 0.207E+05, 0.230E+05, 0.225E+05, 0.171E+05, 0.108E+05, 0.513E+04$
 0.839E+03, 0.328E-06, 0.104E-05, 0.149E-05, 0.159E-05, 0.137E-05$
 0.124E-06
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END$
  148$  HEAT RATE ARRAY
 0.862E-07, 0.226E-07, 0.132E-06, 0.125E-06, 0.866E-07, 0.263E-07$
 0.909E+02, 0.242E+05, 0.868E+05, 0.993E+05, 0.864E+05, 0.366E+05$
 0.377E+05, 0.677E+05, 0.106E+06, 0.914E+05, 0.710E+05, 0.361E+05$
 0.481E+04, 0.272E-07, 0.874E-07, 0.125E-06, 0.134E-06, 0.115E-06$
 0.862E-07
END$
  149$  HEAT RATE ARRAY
 0.102E-05, 0.268E-06, 0.156E-05, 0.148E-05, 0.103E-05, 0.312E-06$
 0.124E+02, 0.312E+04, 0.123E+05, 0.170E+05, 0.165E+05, 0.107E+05$
 0.178E+05, 0.200E+05, 0.200E+05, 0.154E+05, 0.992E+04, 0.474E+04$
 0.749E+03, 0.323E-06, 0.104E-05, 0.149E-05, 0.159E-05, 0.137E-05$
 0.102E-05
END$
  150$  HEAT RATE ARRAY
 0.940E-07, 0.952E-07, 0.134E-06, 0.125E-06, 0.866E-07, 0.263E-07$
 0.909E+02, 0.242E+05, 0.868E+05, 0.993E+05, 0.864E+05, 0.366E+05$
 0.377E+05, 0.676E+05, 0.106E+06, 0.914E+05, 0.710E+05, 0.361E+05$
 0.480E+04, 0.269E-07, 0.871E-07, 0.125E-06, 0.134E-06, 0.115E-06$
 0.940E-07
END$
  151$  HEAT RATE ARRAY
 0.111E-05, 0.113E-05, 0.159E-05, 0.148E-05, 0.103E-05, 0.312E-06$
 0.122E+02, 0.307E+04, 0.121E+05, 0.166E+05, 0.162E+05, 0.104E+05$
 0.173E+05, 0.194E+05, 0.196E+05, 0.151E+05, 0.979E+04, 0.465E+04$
 0.706E+03, 0.319E-06, 0.103E-05, 0.148E-05, 0.159E-05, 0.137E-05$
 0.111E-05
END$
  152$  HEAT RATE ARRAY
 0.940E-07, 0.115E-06, 0.134E-06, 0.125E-06, 0.866E-07, 0.263E-07$
 0.908E+02, 0.242E+05, 0.867E+05, 0.992E+05, 0.863E+05, 0.365E+05$
 0.375E+05, 0.674E+05, 0.105E+06, 0.912E+05, 0.709E+05, 0.361E+05$
 0.480E+04, 0.266E-07, 0.869E-07, 0.125E-06, 0.134E-06, 0.115E-06$
 0.940E-07
END$
  153$  HEAT RATE ARRAY
 0.111E-05, 0.137E-05, 0.159E-05, 0.148E-05, 0.103E-05, 0.312E-06$
 0.113E+02, 0.288E+04, 0.112E+05, 0.151E+05, 0.145E+05, 0.899E+04$
 0.146E+05, 0.168E+05, 0.177E+05, 0.137E+05, 0.901E+04, 0.430E+04$
 0.636E+03, 0.316E-06, 0.103E-05, 0.148E-05, 0.159E-05, 0.137E-05$
 0.111E-05
END$
  154$  HEAT RATE ARRAY
 0.940E-07, 0.115E-06, 0.134E-06, 0.125E-06, 0.866E-07, 0.263E-07$
 0.908E+02, 0.242E+05, 0.867E+05, 0.990E+05, 0.861E+05, 0.364E+05$
 0.372E+05, 0.672E+05, 0.105E+06, 0.911E+05, 0.709E+05, 0.361E+05$
 0.479E+04, 0.265E-07, 0.867E-07, 0.125E-06, 0.134E-06, 0.115E-06$
 0.940E-07
END$
  155$  HEAT RATE ARRAY
 0.111E-05, 0.137E-05, 0.159E-05, 0.148E-05, 0.103E-05, 0.312E-06$
 0.104E+02, 0.268E+04, 0.103E+05, 0.135E+05, 0.127E+05, 0.753E+04$
 0.117E+05, 0.140E+05, 0.154E+05, 0.121E+05, 0.821E+04, 0.397E+04$
 0.570E+03, 0.314E-06, 0.103E-05, 0.148E-05, 0.159E-05, 0.137E-05$
 0.111E-05
END$
  156$  HEAT RATE ARRAY
 0.000E+00, 0.000E+00, 0.000E+00, 0.000E+00, 0.000E+00, 0.000E+00$
 0.899E+02, 0.239E+05, 0.110E+06, 0.193E+06, 0.209E+06, 0.170E+06$
 0.326E+06, 0.314E+06, 0.255E+06, 0.178E+06, 0.902E+05, 0.357E+05$
 0.474E+04, 0.000E+00, 0.000E+00, 0.000E+00, 0.000E+00, 0.000E+00$
 0.000E+00
END$
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 157$  HEAT RATE ARRAY
0.142E-07, 0.122E-07, 0.262E-07, 0.827E-07, 0.114E-06, 0.899E-07$
0.208E+04, 0.552E+06, 0.254E+07, 0.426E+07, 0.434E+07, 0.342E+07$
0.635E+07, 0.595E+07, 0.459E+07, 0.274E+07, 0.147E+07, 0.628E+06$
0.109E+06, 0.269E-07, 0.597E-07, 0.688E-07, 0.501E-07, 0.295E-07$
0.142E-07
END$
 158$  HEAT RATE ARRAY
0.141E-07, 0.117E-07, 0.247E-07, 0.696E-07, 0.126E-06, 0.469E-07$
0.207E+04, 0.421E+06, 0.180E+07, 0.290E+07, 0.331E+07, 0.278E+07$
0.572E+07, 0.617E+07, 0.522E+07, 0.392E+07, 0.208E+07, 0.824E+06$
0.110E+06, 0.111E-06, 0.181E-06, 0.196E-06, 0.878E-07, 0.362E-07$
0.141E-07
END$
 159$  HEAT RATE ARRAY
0.161E-07, 0.134E-07, 0.252E-07, 0.539E-07, 0.108E-06, 0.350E-07$
0.207E+04, 0.401E+06, 0.210E+07, 0.388E+07, 0.430E+07, 0.358E+07$
0.703E+07, 0.683E+07, 0.562E+07, 0.398E+07, 0.208E+07, 0.824E+06$
0.110E+06, 0.968E-07, 0.162E-06, 0.189E-06, 0.938E-07, 0.405E-07$
0.161E-07
END$
 160$  HEAT RATE ARRAY
0.193E-07, 0.178E-07, 0.311E-07, 0.732E-07, 0.975E-07, 0.765E-07$
0.208E+04, 0.552E+06, 0.254E+07, 0.433E+07, 0.460E+07, 0.370E+07$
0.703E+07, 0.661E+07, 0.525E+07, 0.357E+07, 0.161E+07, 0.598E+06$
0.109E+06, 0.161E-07, 0.453E-07, 0.643E-07, 0.622E-07, 0.380E-07$
0.193E-07
END$
 161$  HEAT RATE ARRAY
0.131E-10, 0.813E-11, 0.289E-10, 0.405E-09, 0.254E-08, 0.727E-08$
0.124E+02, 0.166E+04, 0.280E+04, 0.379E+04, 0.385E+04, 0.318E+04$
0.847E+04, 0.755E+04, 0.603E+04, 0.324E+04, 0.189E+04, 0.327E+04$
0.271E+04, 0.351E-06, 0.387E-06, 0.223E-08, 0.109E-08, 0.165E-09$
0.131E-10
END$
 162$  HEAT RATE ARRAY
0.385E-10, 0.302E-10, 0.657E-10, 0.399E-09, 0.385E-06, 0.350E-06$
0.514E+02, 0.333E+04, 0.482E+04, 0.660E+04, 0.629E+04, 0.473E+04$
0.849E+04, 0.538E+04, 0.372E+04, 0.293E+04, 0.154E+04, 0.135E+04$
0.650E+03, 0.693E-08, 0.144E-08, 0.371E-09, 0.228E-09, 0.940E-10$
0.385E-10
END$
 163$  DIFFUSE HEAT ARRAY
0.000E+00, 0.000E+00, 0.000E+00, 0.000E+00, 0.582E-10, 0.774E-08$
0.587E-07, 0.546E+02, 0.793E+02, 0.799E+02, 0.888E+02, 0.888E+02$
0.697E+02, 0.688E+02, 0.680E+02, 0.105E+03, 0.824E+02, 0.685E+02$
0.539E+02, 0.143E+02, 0.295E-09, 0.113E-09, 0.112E-10, 0.000E+00$
0.000E+00
END$
C
C
200 $   RHO*CP - ORBITER HEAT TILES
      -250.,0.63, -150.,0.945, 0.,1.35, 250,1.89
END
201 $   RHO*CP - ET SOFI (SLA-561) NOSECAP
      -400.,0.85, -200.,2.55, 0.,4.42, 100.,5.18, 200.,5.35
END
202  $  RHO*CP - ET SOFI (CPR488) IT,LO2 & LH2 BARRELS, LO2 OGIVE
      -400.,0.36, -200.,0.372, -100.,0.384, 0.,0.432
      100.,0.648, 200.,0.756
END
203  $  RHO*CP - ET SOFI (NFCI-22-65) LH2 AFT DOME
      -400.,0.42, -200.,0.434, -100.,0.448, 0.,0.504
      100.,0.756, 200.,0.882
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      END
      204  $  CP - ET SKIN -- AL 2219 & 2024 (LO2, LH2,IT,NC)
            -400.,.04, -300.,0.1, -200.,.15, -100.,.18
            0.,.199, 100.,.205
      END
C
C     THERMAL CONDUCTIVITY
C
      300   $  K - ORBITER HEAT TILES
              -250.,0.2796, -150.,0.30, 0.,0.33, 250.,0.4104
      END
      301   $  K - ET SOFI (SLA-561) NOSECAP
              -400.,0.015, -200.,0.032, 0.,0.05, 100.,0.055
              200.,0.06
      END
      302   $  K - ET SOFI (CPR488)
              -400.,0.0035, -200.,0.008, -100.,0.01, 0.,0.013
              100.,0.016
      END
      303   $  K - ET SOFI (NFCI-22-65)  AFT DOME
              -400.,0.004, -200.,0.01, -100.,0.013, 0.,0.016
              100.,0.02
      END
      304   $  K - ET SKIN --  AL 2219 (LO2,LH2)
              -400.,15., -300.,35., -200.,48., -100.,59.
              0.,65., 100.,72.
      END
      305   $  K - ET SKIN  --  AL 2024  (NC,IT)
             -400.,20., -300.,38., -200.,50., -100.,58.
             0.,65., 100.,72.
      END
C
C
C
C
      501, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.57,.57,.68,.92,.79,.16,.15,.16,.79,.92,.68,.57,.57,END$
C
      502, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.55,.55,.67,.92,.77,.23,.20,.23,.77,.92,.67,.55,.55,END$
C
      503, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.56,.56,.68,.93,.76,.27,.24,.27,.76,.93,.68,.56,.56,END$
C
      504, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.59,.59,.71,.94,.76,.30,.29,.30,.76,.94,.71,.59,.59,END$
C
      505, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.60,.59,.51,.43,.22,.54,.60,.66,.58,.36,.54,.61,.60,END$
C
      506, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.64,.61,.46,.32,.29,.56,.58,.60,.54,.43,.61,.67,.64,END$
C
      507, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.66,.63,.49,.36,.35,.50,.53,.56,.58,.51,.66,.69,.66,END$
C
      508, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.69,.67,.54,.40,.40,.52,.61,.70,.55,.56,.72,.72,.69,END$
C
      509, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.59,.59,.63,.56,.64,.66,.94,.66,.64,.56,.63,.59,.59,END$
C
      510, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.72,.72,.61,.57,.61,.73,.87,.73,.61,.57,.61,.72,.72,END$
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C
      511, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.68,.68,.52,.64,.68,.60,.56,.60,.68,.64,.52,.68,.68,END$
C
      512, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.62,.62,.44,.61,.66,.60,.52,.60,.66,.61,.44,.62,.62,END$
C
      513, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.60,.61,.54,.36,.58,.66,.60,.54,.22,.43,.51,.59,.60,END$
C
      514, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.64,.67,.61,.43,.54,.60,.58,.56,.29,.32,.46,.61,.64,END$
C
      515, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.66,.69,.66,.51,.58,.56,.53,.50,.35,.36,.49,.63,.66,END$
C
      516, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.69,.72,.72,.56,.55,.70,.61,.52,.40,.40,.54,.67,.69,END$
C
      517, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.72,.72,.80,.96,.83,.40,.39,.40,.83,.96,.80,.72,.72,END$
C
      518, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.74,.69,.57,.46,.45,.54,.70,.86,.58,.69,.85,.78,.74,END$
C
      519, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.47,.47,.35,.58,.65,.70,.71,.70,.65,.58,.35,.47,.47,END$
C
      520, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.74,.78,.85,.69,.58,.86,.70,.54,.45,.46,.57,.69,.73,END$
C
      521, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.81,.81,.87,.97,.90,.49,.45,.49,.90,.97,.87,.81,.81,END$
C
      522, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.73,.66,.56,.47,.45,.53,.71,.90,.65,.76,.91,.81,.73,END$
C
      523, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.37,.37,.35,.59,.67,.79,.80,.79,.67,.59,.35,.37,.37,END$
C
      524, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.73,.81,.91,.76,.65,.90,.71,.53,.45,.47,.56,.66,.73,END$
C
      525, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.51,.51,.58,.81,.91,.91,.89,.91,.91,.81,.58,.51,.51,END$
C
      526, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.90,.84,.76,.67,.59,.82,.95,1.1,.76,.88,1.0,.96,.90,END$
C
      527, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.86,.86,.93,1.0,1.1,.73,.70,.73,1.1,1.0,.93,.86,.86,END$
C
      528, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.90,.96,1.0,.88,.76,1.1,.95,.82,.59,.67,.76,.84,.90,END$
C
      529, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.78,.78,.89,1.1,1.2,1.1,1.1,1.1,1.2,1.1,.89,.78,.78,END$
C
      530, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,1.1,1.1,1.0,.97,.87,1.2,1.2,1.2,.95,1.1,1.2,1.2,1.1,END$
C
      531, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.96,.96,1.0,1.1,1.2,1.0,.96,1.0,1.2,1.1,1.0,.96,.96,END$
C
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      532, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,1.1,1.2,1.2,1.1,.95,1.2,1.2,1.2,.87,.97,1.0,1.0,1.1,END$
C
      533, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.52,.52,.61,.97,1.0,.48,.73,.48,1.0,.97,.61,.52,.52,END$
C
      534, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.86,.87,.83,.78,.46,.49,.48,.46,.92,.79,.78,.85,.86,END$
C
      535, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.78,.78,.89,1.1,1.0,.20,.17,.20,1.0,1.1,.89,.78,.78,END$
C
      536, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,.86,.85,.78,.79,.92,.46,.48,.49,.46,.78,.83,.87,.86,END$
C
      537, 13,0.,10.,25.,50.,100.,150.,180.,210.,260.,310.,335.,350.,360.$
          1.0,1.2,1.2,1.3,1.4,1.6,1.4,1.4,1.4,1.6,1.4,1.3,1.2,1.2,END$
C SRB'S WIND FACTOR
C
      601, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.56,.26,.76,.19,.46,1.1,1.1,1.1,.46,.19,.76,.26,.56,END$
C
      602, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.73,1.1,.68,.81,.49,1.2,.84,.50,.25,.62,.37,.43,.73,END$
C
      603, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.0,1.1,.79,.50,.60,.59,.81,.59,.60,.50,.79,1.1,1.0,END$
C
      604, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.1,.43,.37,.62,.25,.50,1.3,1.2,.49,.81,.68,1.1,1.1,END$
C
      605, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.31,.25,.62,.18,.34,.84,.76,.84,.34,.18,.62,.25,.31,END$
C
      606, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.31,.25,.62,.18,.34,.84,.76,.84,.34,.18,.62,.25,.31,END$
C
      607, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.30,.22,.45,.22,.23,.69,.62,.69,.23,.22,.45,.22,.30,END$
C
      608, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.30,.19,.29,.27,.14,.60,.49,.60,.14,.27,.29,.19,.30,END$
C
      609, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.34,.25,.12,.24,.19,.60,.64,.60,.19,.24,.12,.25,.34,END$
C
      610, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.33,.28,.19,.20,.13,.52,.67,.52,.13,.20,.19,.28,.33,END$
C
      611, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.23,.30,.58,.23,.21,.36,.42,.36,.21,.23,.58,.30,.23,END$
C
      612, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.97,.95,.56,.43,.31,1.0,1.1,.85,.23,.45,.43,.70,.97,END$
C
      613, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.97,.95,.56,.43,.31,1.0,1.1,.85,.23,.45,.43,.70,.97,END$
C
      614, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.93,.96,.51,.25,.24,.92,1.0,.75,.23,.32,.45,.65,.93,END$
C
      615, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.89,.96,.46,.08,.18,.82,.89,.73,.25,.22,.49,.61,.89,END$
C
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616, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.88,.97,.47,.12,.29,.49,.88,.69,.31,.23,.30,.62,.88,END$
C
617, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.87,.96,.57,.17,.34,.12,.78,.57,.31,.31,.50,.64,.87,END$
C
618, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.91,.96,.61,.25,.25,.19,.59,.46,.26,.45,.72,.83,.91,END$
C
619, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.98,1.1,.76,.30,.49,.28,.31,.28,.49,.30,.76,1.1,.98,END$
C
620, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.98,1.1,.76,.30,.49,.28,.31,.28,.49,.30,.76,1.1,.98,END$
C
621, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.96,1.0,.70,.20,.47,.29,.26,.29,.47,.20,.70,1.0,.96,END$
C
622, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.95,1.0,.64,.11,.44,.31,.22,.31,.44,.11,.64,1.0,.95,END$
C
623, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.93,1.0,.68,.12,.42,.30,.28,.30,.42,.12,.68,1.0,.93,END$
C
624, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.92,1.0,.75,.23,.36,.27,.28,.27,.36,.23,.75,1.0,.92,END$
C
625, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.88,1.0,1.0,.60,.20,.18,.26,.18,.20,.60,1.0,1.0,.88,END$
C
626, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.70,.43,.45,.23,.85,1.2,1.0,.31,.43,.56,.95,1.1,END$
C
627, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.70,.43,.45,.23,.85,1.2,1.0,.31,.43,.56,.95,1.1,END$
C
628, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.65,.45,.32,.23,.75,1.2,.92,.24,.25,.51,.96,1.1,END$
C
629, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.61,.49,.22,.25,.73,1.2,.82,.18,.10,.46,.96,1.1,END$
C
630, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.62,.30,.23,.31,.69,1.1,.49,.29,.12,.47,.97,1.1,END$
C
631, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.64,.50,.31,.31,.57,.49,.12,.34,.17,.57,.96,1.1,END$
C
632, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.83,.72,.45,.26,.46,.13,.19,.25,.25,.61,.96,1.1,END$
C
633, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.23,.47,.92,.90,.70,.23,.40,.23,.70,.90,.92,.47,.23,END$
C
634, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,.28,.50,.91,1.2,.76,.22,.44,.22,.76,1.2,.91,.50,.28,END$
C
635, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.1,.96,.53,.32,.19,.26,.29,.28,.49,.56,.67,.98,1.1,END$
C
636, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
    1.0,1.0,.93,.50,.38,.22,.28,.27,.21,.47,.52,.54,.92,1.0,END$
C
637, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
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C          1.0,.86,1.2,1.3,.82,.38,.16,.23,.16,.38,.82,1.3,1.2,.86,END$

      638, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.83,1.2,1.3,.80,.39,.20,.20,.20,.39,.80,1.3,1.2,.83,END$
C

      639, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,1.1,.98,.67,.56,.49,.28,.17,.26,.19,.32,.53,.96,1.1,END$
C

      640, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.99,.92,.54,.52,.47,.21,.31,.28,.22,.38,.50,.93,.99,END$
C

      641, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.37,.54,.83,1.1,.46,.55,.56,.55,.46,1.1,.83,.54,.37,END$
C

      642, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.85,.88,.55,.46,.33,.29,.76,.60,.41,.62,.66,.90,.85,END$
C

      643, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.80,1.1,1.2,.65,.20,.27,.33,.27,.20,.65,1.2,1.1,.80,END$
C

      644, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.82,.90,.66,.62,.41,.60,.59,.29,.33,.46,.55,.88,.82,END$
C

      645, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.82,.98,.88,.75,.44,.86,1.1,.86,.44,.75,.88,.98,.82,END$
C

      646, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,1.2,1.2,.77,.44,.69,1.2,1.3,1.1,.71,.73,.83,1.1,1.2,END$
C

      647, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.95,.86,.73,.82,.81,.96,.83,.96,.81,.82,.73,.86,.95,END$
C

      648, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,1.0,1.1,.83,.73,.71,1.1,.90,1.2,.69,.44,.77,1.2,1.0,END$
C

      649, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.37,.40,.64,.71,.31,.58,.69,.58,.31,.71,.64,.40,.37,END$
C

      650, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.37,.40,.64,.71,.31,.58,.69,.58,.31,.71,.64,.40,.37,END$
C

      651, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.34,.43,.62,.65,.34,.51,.55,.51,.34,.65,.62,.43,.34,END$
C

      652, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.31,.46,.61,.60,.38,.46,.44,.46,.38,.60,.61,.46,.31,END$
C

      653, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.46,.48,.51,.55,.53,.59,.63,.59,.53,.55,.51,.48,.46,END$
C

      654, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.48,.44,.52,.62,.57,.70,.67,.70,.57,.62,.52,.44,.48,END$
C

      655, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,.32,.36,.69,.89,.79,.45,.40,.45,.79,.89,.69,.36,.32,END$
C

      656, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,1.3,1.1,.65,.45,.62,1.3,1.3,1.3,.67,.50,.66,1.2,1.3,END$
C

      657, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,1.3,1.1,.65,.45,.62,1.3,1.3,1.3,.67,.50,.66,.23,1.3,END$
C

      658, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
           1.0,1.3,1.1,.57,.54,.68,1.2,1.3,1.3,.72,.51,.59,1.2,1.3,END$
```

```
C
      659, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.3,.99,.50,.63,.74,1.1,1.3,1.3,.76,.52,.52,1.2,1.3,END$
C
      660, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.3,.94,.37,.58,.78,1.0,1.2,1.2,.83,.52,.45,1.1,1.3,END$
C
      661, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.2,.88,.32,.58,.76,.99,.55,.87,.83,.52,.42,1.1,1.2,END$
C
      662, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.2,.84,.54,.73,.71,.79,.12,.34,.80,.54,.41,1.0,1.2,END$
C
      663, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.68,.59,.67,.77,.55,.32,.35,.32,.55,.77,.67,.59,.68,END$
C
      664, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.68,.59,.67,.77,.55,.32,.35,.32,.55,.77,.67,.59,.68,END$
C
      665, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.62,.49,.64,.78,.56,.32,.28,.32,.56,.78,.64,.49,.62,END$
C
      666, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.57,.41,.62,.79,.58,.32,.22,.32,.58,.79,.62,.41,.57,END$
C
      667, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.54,.36,.62,.80,.65,.27,.27,.27,.65,.80,.62,.36,.54,END$
C
      668, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.51,.34,.64,.82,.69,.30,.28,.30,.69,.82,.64,.34,.51,END$
C
      669, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.51,.46,.40,.93,.72,.27,.29,.27,.72,.93,.80,.46,.51,END$
C
      670, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.1,1.2,.66,.50,.67,1.3,1.1,1.3,.62,.45,.65,1.1,1.1,END$
C
      671, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.1,1.2,.66,.50,.67,1.3,1.1,1.3,.62,.45,.65,1.1,1.1,END$
C
      672, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.1,1.2,.59,.51,.72,1.3,1.0,1.2,.68,.54,.57,1.1,1.1,END$
C
      673, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.1,1.2,.52,.52,.76,1.3,.89,1.1,.74,.63,.50,.99,1.1,END$
C
      674, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.1,1.1,.45,.52,.83,1.2,.89,1.0,.78,.58,.37,.94,1.1,END$
C
      675, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,1.0,1.1,.42,.52,.83,.87,.81,.99,.76,.58,.32,.88,1.0,END$
C
      676, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.96,1.0,.41,.54,.80,.34,.62,.79,.71,.73,.54,.84,.96,END$
C
      677, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.20,.38,.95,1.3,1.0,.25,.36,.25,1.1,1.3,.95,.38,.20,END$
C
      678, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.21,.34,.88,1.2,.88,.20,.34,.20,.88,1.2,.88,.34,1.0,END$
C
      679, 13,0.,30.,60.,90.,120.,150.,180.,210.,240.,270.,300.,330.,360.$
          1.0,.51,.46,.40,.93,.72,.27,.29,.27,.72,.93,.80,.46,.51,END$
C
```

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DA11MC(2.40000000E 1,TIMEM,A1      ,A72     ,1.000E 0,Q12076 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A73     ,1.000E 0,Q12077 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A74     ,1.000E 0,Q12078 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A75     ,1.000E 0,Q12079 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A76     ,1.000E 0,Q12080 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A77     ,1.000E 0,Q12081 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A78     ,1.000E 0,Q12082 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A79     ,1.000E 0,Q12083 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A80     ,1.000E 0,Q12084 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A81     ,1.000E 0,Q12001 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A82     ,1.000E 0,Q12002 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A83     ,1.000E 0,Q12003 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A84     ,1.000E 0,Q12004 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A85     ,1.000E 0,Q12005 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A86     ,1.000E 0,Q12006 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A87     ,1.000E 0,Q12007 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A88     ,1.000E 0,Q12008 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A89     ,1.000E 0,Q12009 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A90     ,1.000E 0,Q12010 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A91     ,1.000E 0,Q12011 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A92     ,1.000E 0,Q12012 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A93     ,1.000E 0,Q12013 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A94     ,1.000E 0,Q12014 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A95     ,1.000E 0,Q12015 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A96     ,1.000E 0,Q12016 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A97     ,1.000E 0,Q12017 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A98     ,1.000E 0,Q12018 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A99     ,1.000E 0,Q12019 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A100    ,1.000E 0,Q12020 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A101    ,1.000E 0,Q12021 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A102    ,1.000E 0,Q12022 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A103    ,1.000E 0,Q12023 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A104    ,1.000E 0,Q12024 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A105    ,1.000E 0,Q12025 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A106    ,1.000E 0,Q12026 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A107    ,1.000E 0,Q12027 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A108    ,1.000E 0,Q12028 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A109    ,1.000E 0,Q12029 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A110    ,1.000E 0,Q12030 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A111    ,1.000E 0,Q12031 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A112    ,1.000E 0,Q12032 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A113    ,1.000E 0,Q12033 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A114    ,1.000E 0,Q12034 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A115    ,1.000E 0,Q12035 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A116    ,1.000E 0,Q12036 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A117    ,1.000E 0,Q12037 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A118    ,1.000E 0,Q12038 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A119    ,1.000E 0,Q12039 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A120    ,1.000E 0,Q12040 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A121    ,1.000E 0,Q12085 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A122    ,1.000E 0,Q12086 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A123    ,1.000E 0,Q12087 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A124    ,1.000E 0,Q12088 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A125    ,1.000E 0,Q12041 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A126    ,1.000E 0,Q12042 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A127    ,1.000E 0,Q12043 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A128    ,1.000E 0,Q12044 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A129    ,1.000E 0,Q500   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A130    ,1.000E 0,Q501   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A131    ,1.000E 0,Q502   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A132    ,1.000E 0,Q503   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A133    ,1.000E 0,Q1029  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A134    ,1.000E 0,Q1030  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A135    ,1.000E 0,Q1031  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A136    ,1.000E 0,Q1032  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A137    ,1.000E 0,Q6000  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A138    ,1.000E 0,Q6001  )$
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            DA11MC(2.40000000E 1,TIMEM,A1      ,A139    ,1.000E 0,Q6010   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A140    ,1.000E 0,Q6011   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A141    ,1.000E 0,Q6020   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A142    ,1.000E 0,Q6021   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A143    ,1.000E 0,Q6030   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A144    ,1.000E 0,Q6031   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A145    ,1.000E 0,Q6040   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A146    ,1.000E 0,Q6041   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A147    ,1.000E 0,Q6050   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A148    ,1.000E 0,Q6051   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A149    ,1.000E 0,Q6060   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A150    ,1.000E 0,Q6061   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A151    ,1.000E 0,Q6070   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A152    ,1.000E 0,Q6071   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A153    ,1.000E 0,Q6080   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A154    ,1.000E 0,Q6081   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A155    ,1.000E 0,Q6090   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A156    ,1.000E 0,Q6091   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A157    ,1.000E 0,Q9000   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A158    ,1.000E 0,Q9001   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A159    ,1.000E 0,Q9002   )$
            DA11MC(2.40000000E 1,TIMEM,A1      ,A160    ,1.000E 0,Q9003   )$
C
F           ENDIF
C=========================
C        SOLAR HEAT OF ET
M           XK3001=Q1001
M           XK3002=Q1002
M           XK3003=Q1003
M           XK3004=Q1004
M           XK3005=Q1005
M           XK3006=Q1006
M           XK3007=Q1007
M           XK3008=Q1008
M           XK3009=Q1009
M           XK3010=Q1010
M           XK3011=Q1011
M           XK3012=Q1012
M           XK3013=Q1013
M           XK3014=Q1014
M           XK3015=Q1015
M           XK3016=Q1016
M           XK3017=Q1017
M           XK3018=Q1018
M           XK3019=Q1019
M           XK3020=Q1020
M           XK3021=Q1021
M           XK3022=Q1022
M           XK3023=Q1023
M           XK3024=Q1024
M           XK3025=Q1025
M           XK3026=Q1026
M           XK3027=Q1027
M           XK3028=Q1028
M           XK3029=Q1029
M           XK3030=Q1030
M           XK3031=Q1031
M           XK3032=Q1032
M           XK3033=Q1033
M           XK3034=Q1034
M           XK3035=Q1035
M           XK3036=Q1036
M           XK3037=Q1037
F14         CONTINUE
C
M           T8888=XK47
M           T8889=XK3
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DA11MC(2.40000000E 1,TIMEM,A1      ,A17     ,1.000E 0,Q1006  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A18     ,1.000E 0,Q1007  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A19     ,1.000E 0,Q1008  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A20     ,1.000E 0,Q1009  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A21     ,1.000E 0,Q1010  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A22     ,1.000E 0,Q1011  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A23     ,1.000E 0,Q1012  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A24     ,1.000E 0,Q1013  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A25     ,1.000E 0,Q1014  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A26     ,1.000E 0,Q1015  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A27     ,1.000E 0,Q1016  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A28     ,1.000E 0,Q1017  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A29     ,1.000E 0,Q1018  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A30     ,1.000E 0,Q1019  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A31     ,1.000E 0,Q1020  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A32     ,1.000E 0,Q1033  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A33     ,1.000E 0,Q1034  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A34     ,1.000E 0,Q1035  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A35     ,1.000E 0,Q1036  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A36     ,1.000E 0,Q1025  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A37     ,1.000E 0,Q1026  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A38     ,1.000E 0,Q1027  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A39     ,1.000E 0,Q1028  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A40     ,1.000E 0,Q1037  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A41     ,1.000E 0,Q12045 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A42     ,1.000E 0,Q12046 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A43     ,1.000E 0,Q12047 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A44     ,1.000E 0,Q12048 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A45     ,1.000E 0,Q12049 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A46     ,1.000E 0,Q12050 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A47     ,1.000E 0,Q12051 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A48     ,1.000E 0,Q12052 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A49     ,1.000E 0,Q12053 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A50     ,1.000E 0,Q12054 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A51     ,1.000E 0,Q12055 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A52     ,1.000E 0,Q12056 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A53     ,1.000E 0,Q12057 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A54     ,1.000E 0,Q12058 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A55     ,1.000E 0,Q12059 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A56     ,1.000E 0,Q12060 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A57     ,1.000E 0,Q12061 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A58     ,1.000E 0,Q12062 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A59     ,1.000E 0,Q12063 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A60     ,1.000E 0,Q12064 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A61     ,1.000E 0,Q12065 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A62     ,1.000E 0,Q12066 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A63     ,1.000E 0,Q12067 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A64     ,1.000E 0,Q12068 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A65     ,1.000E 0,Q12069 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A66     ,1.000E 0,Q12070 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A67     ,1.000E 0,Q12071 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A68     ,1.000E 0,Q12072 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A69     ,1.000E 0,Q12073 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A70     ,1.000E 0,Q12074 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A71     ,1.000E 0,Q12075 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A72     ,1.000E 0,Q12076 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A73     ,1.000E 0,Q12077 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A74     ,1.000E 0,Q12078 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A75     ,1.000E 0,Q12079 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A76     ,1.000E 0,Q12080 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A77     ,1.000E 0,Q12081 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A78     ,1.000E 0,Q12082 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A79     ,1.000E 0,Q12083 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A80     ,1.000E 0,Q12084 )$
```

```
DA11MC(2.40000000E 1,TIMEM,A1      ,A81     ,1.000E 0,Q12001 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A82     ,1.000E 0,Q12002 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A83     ,1.000E 0,Q12003 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A84     ,1.000E 0,Q12004 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A85     ,1.000E 0,Q12005 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A86     ,1.000E 0,Q12006 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A87     ,1.000E 0,Q12007 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A88     ,1.000E 0,Q12008 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A89     ,1.000E 0,Q12009 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A90     ,1.000E 0,Q12010 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A91     ,1.000E 0,Q12011 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A92     ,1.000E 0,Q12012 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A93     ,1.000E 0,Q12013 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A94     ,1.000E 0,Q12014 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A95     ,1.000E 0,Q12015 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A96     ,1.000E 0,Q12016 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A97     ,1.000E 0,Q12017 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A98     ,1.000E 0,Q12018 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A99     ,1.000E 0,Q12019 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A100    ,1.000E 0,Q12020 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A101    ,1.000E 0,Q12021 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A102    ,1.000E 0,Q12022 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A103    ,1.000E 0,Q12023 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A104    ,1.000E 0,Q12024 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A105    ,1.000E 0,Q12025 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A106    ,1.000E 0,Q12026 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A107    ,1.000E 0,Q12027 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A108    ,1.000E 0,Q12028 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A109    ,1.000E 0,Q12029 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A110    ,1.000E 0,Q12030 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A111    ,1.000E 0,Q12031 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A112    ,1.000E 0,Q12032 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A113    ,1.000E 0,Q12033 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A114    ,1.000E 0,Q12034 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A115    ,1.000E 0,Q12035 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A116    ,1.000E 0,Q12036 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A117    ,1.000E 0,Q12037 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A118    ,1.000E 0,Q12038 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A119    ,1.000E 0,Q12039 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A120    ,1.000E 0,Q12040 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A121    ,1.000E 0,Q12085 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A122    ,1.000E 0,Q12086 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A123    ,1.000E 0,Q12087 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A124    ,1.000E 0,Q12088 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A125    ,1.000E 0,Q12041 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A126    ,1.000E 0,Q12042 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A127    ,1.000E 0,Q12043 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A128    ,1.000E 0,Q12044 )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A129    ,1.000E 0,Q500   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A130    ,1.000E 0,Q501   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A131    ,1.000E 0,Q502   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A132    ,1.000E 0,Q503   )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A133    ,1.000E 0,Q1029  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A134    ,1.000E 0,Q1030  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A135    ,1.000E 0,Q1031  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A136    ,1.000E 0,Q1032  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A137    ,1.000E 0,Q6000  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A138    ,1.000E 0,Q6001  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A139    ,1.000E 0,Q6010  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A140    ,1.000E 0,Q6011  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A141    ,1.000E 0,Q6020  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A142    ,1.000E 0,Q6021  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A143    ,1.000E 0,Q6030  )$
DA11MC(2.40000000E 1,TIMEM,A1      ,A144    ,1.000E 0,Q6031  )$
```

```
M          XK2083=T12046
M          XK2084=T12047
M          XK2085=T12048
M          XK2086=T12049
M          XK2087=T12050
M          XK2088=T12051
M          XK2089=T12052
M          XK2090=T12053
M          XK2091=T12054
M          XK2092=T12055
M          XK2093=T12056
M          XK2094=T12057
M          XK2095=T12058
M          XK2096=T12059
M          XK2097=T12060
M          XK2098=T12061
M          XK2099=T12062
M          XK2100=T12063
M          XK2101=T12064
M          XK2102=T12065
M          XK2103=T12066
M          XK2104=T12067
M          XK2105=T12068
M          XK2106=T12069
M          XK2107=T12070
M          XK2108=T12071
M          XK2109=T12072
M          XK2110=T12073
M          XK2111=T12074
M          XK2112=T12075
M          XK2113=T12076
M          XK2114=T12077
M          XK2115=T12078
M          XK2116=T12079
M          XK2117=T12080
M          XK2118=T12081
M          XK2119=T12082
M          XK2120=T12083
M          XK2121=T12084
M          XK2122=T12085
M          XK2123=T12086
M          XK2124=T12087
M          XK2125=T12088
C==============================
C      XK101,XK137=LOCAL WIND
C==============================
M          XK262=1.0
           D2DEG1(XK260,XK262,A501,XK1351)
           D2DEG1(XK260,XK262,A502,XK1352)
           D2DEG1(XK260,XK262,A503,XK1353)
           D2DEG1(XK260,XK262,A504,XK1354)
           D2DEG1(XK260,XK262,A505,XK1355)
           D2DEG1(XK260,XK262,A506,XK1356)
           D2DEG1(XK260,XK262,A507,XK1357)
           D2DEG1(XK260,XK262,A508,XK1358)
           D2DEG1(XK260,XK262,A509,XK1359)
           D2DEG1(XK260,XK262,A510,XK1360)
           D2DEG1(XK260,XK262,A511,XK1361)
           D2DEG1(XK260,XK262,A512,XK1362)
           D2DEG1(XK260,XK262,A513,XK1363)
           D2DEG1(XK260,XK262,A514,XK1364)
           D2DEG1(XK260,XK262,A515,XK1365)
           D2DEG1(XK260,XK262,A516,XK1366)
           D2DEG1(XK260,XK262,A517,XK1367)
           D2DEG1(XK260,XK262,A518,XK1368)
           D2DEG1(XK260,XK262,A519,XK1369)
           D2DEG1(XK260,XK262,A520,XK1370)
```

```
      D2DEG1(XK260,XK262,A521,XK1371)
      D2DEG1(XK260,XK262,A522,XK1372)
      D2DEG1(XK260,XK262,A523,XK1373)
      D2DEG1(XK260,XK262,A524,XK1374)
      D2DEG1(XK260,XK262,A525,XK1375)
      D2DEG1(XK260,XK262,A526,XK1376)
      D2DEG1(XK260,XK262,A527,XK1377)
      D2DEG1(XK260,XK262,A528,XK1378)
      D2DEG1(XK260,XK262,A529,XK1379)
      D2DEG1(XK260,XK262,A530,XK1380)
      D2DEG1(XK260,XK262,A531,XK1381)
      D2DEG1(XK260,XK262,A532,XK1382)
      D2DEG1(XK260,XK262,A533,XK1383)
      D2DEG1(XK260,XK262,A534,XK1384)
      D2DEG1(XK260,XK262,A535,XK1385)
      D2DEG1(XK260,XK262,A536,XK1386)
      D2DEG1(XK260,XK262,A537,XK1387)
C  SRB'S WIND FACTOR
C RIGHT SRB
      D2DEG1(XK260,XK262,A601,XK1388)
      D2DEG1(XK260,XK262,A602,XK1389)
      D2DEG1(XK260,XK262,A603,XK1390)
      D2DEG1(XK260,XK262,A604,XK1391)
      D2DEG1(XK260,XK262,A605,XK1392)
      D2DEG1(XK260,XK262,A606,XK1393)
      D2DEG1(XK260,XK262,A607,XK1394)
      D2DEG1(XK260,XK262,A608,XK1395)
      D2DEG1(XK260,XK262,A609,XK1396)
      D2DEG1(XK260,XK262,A610,XK1397)
      D2DEG1(XK260,XK262,A611,XK1398)
      D2DEG1(XK260,XK262,A612,XK1399)
      D2DEG1(XK260,XK262,A613,XK1400)
      D2DEG1(XK260,XK262,A614,XK1401)
      D2DEG1(XK260,XK262,A615,XK1402)
      D2DEG1(XK260,XK262,A616,XK1403)
      D2DEG1(XK260,XK262,A617,XK1404)
      D2DEG1(XK260,XK262,A618,XK1405)
      D2DEG1(XK260,XK262,A619,XK1406)
      D2DEG1(XK260,XK262,A620,XK1407)
      D2DEG1(XK260,XK262,A621,XK1408)
      D2DEG1(XK260,XK262,A622,XK1409)
      D2DEG1(XK260,XK262,A623,XK1410)
      D2DEG1(XK260,XK262,A624,XK1411)
      D2DEG1(XK260,XK262,A625,XK1412)
      D2DEG1(XK260,XK262,A626,XK1413)
      D2DEG1(XK260,XK262,A627,XK1414)
      D2DEG1(XK260,XK262,A628,XK1415)
      D2DEG1(XK260,XK262,A629,XK1416)
      D2DEG1(XK260,XK262,A630,XK1417)
      D2DEG1(XK260,XK262,A631,XK1418)
      D2DEG1(XK260,XK262,A632,XK1419)
      D2DEG1(XK260,XK262,A633,XK1420)
      D2DEG1(XK260,XK262,A634,XK1421)
      D2DEG1(XK260,XK262,A635,XK1422)
      D2DEG1(XK260,XK262,A636,XK1423)
      D2DEG1(XK260,XK262,A637,XK1424)
      D2DEG1(XK260,XK262,A638,XK1425)
      D2DEG1(XK260,XK262,A639,XK1426)
      D2DEG1(XK260,XK262,A640,XK1427)
      D2DEG1(XK260,XK262,A641,XK1428)
      D2DEG1(XK260,XK262,A642,XK1429)
      D2DEG1(XK260,XK262,A643,XK1430)
      D2DEG1(XK260,XK262,A644,XK1431)
C LEFT SRB
      D2DEG1(XK260,XK262,A645,XK1432)
      D2DEG1(XK260,XK262,A646,XK1433)
      D2DEG1(XK260,XK262,A647,XK1434)
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M          XK2018=T1018
M          XK2019=T1019
M          XK2020=T1020
M          XK2021=T1021
M          XK2022=T1022
M          XK2023=T1023
M          XK2024=T1024
M          XK2025=T1025
M          XK2026=T1026
M          XK2027=T1027
M          XK2028=T1028
M          XK2029=T1029
M          XK2030=T1030
M          XK2031=T1031
M          XK2032=T1032
M          XK2033=T1033
M          XK2034=T1034
M          XK2035=T1035
M          XK2036=T1036
M          XK2037=T1037
C
M          XK2038=T12001
M          XK2039=T12002
M          XK2040=T12003
M          XK2041=T12004
M          XK2042=T12005
M          XK2043=T12006
M          XK2044=T12007
M          XK2045=T12008
M          XK2046=T12009
M          XK2047=T12010
M          XK2048=T12011
M          XK2049=T12012
M          XK2050=T12013
M          XK2051=T12014
M          XK2052=T12015
M          XK2053=T12016
M          XK2054=T12017
M          XK2055=T12018
M          XK2056=T12019
M          XK2057=T12020
M          XK2058=T12021
M          XK2059=T12022
M          XK2060=T12023
M          XK2061=T12024
M          XK2062=T12025
M          XK2063=T12026
M          XK2064=T12027
M          XK2065=T12028
M          XK2066=T12029
M          XK2067=T12030
M          XK2068=T12031
M          XK2069=T12032
M          XK2070=T12033
M          XK2071=T12034
M          XK2072=T12035
M          XK2073=T12036
M          XK2074=T12037
M          XK2075=T12038
M          XK2076=T12039
M          XK2077=T12040
M          XK2078=T12041
M          XK2079=T12042
M          XK2080=T12043
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M          XK2081=T12044
C
M          XK2082=T12045
M          XK2083=T12046
M          XK2084=T12047
M          XK2085=T12048
M          XK2086=T12049
M          XK2087=T12050
M          XK2088=T12051
M          XK2089=T12052
M          XK2090=T12053
M          XK2091=T12054
M          XK2092=T12055
M          XK2093=T12056
M          XK2094=T12057
M          XK2095=T12058
M          XK2096=T12059
M          XK2097=T12060
M          XK2098=T12061
M          XK2099=T12062
M          XK2100=T12063
M          XK2101=T12064
M          XK2102=T12065
M          XK2103=T12066
M          XK2104=T12067
M          XK2105=T12068
M          XK2106=T12069
M          XK2107=T12070
M          XK2108=T12071
M          XK2109=T12072
M          XK2110=T12073
M          XK2111=T12074
M          XK2112=T12075
M          XK2113=T12076
M          XK2114=T12077
M          XK2115=T12078
M          XK2116=T12079
M          XK2117=T12080
M          XK2118=T12081
M          XK2119=T12082
M          XK2120=T12083
M          XK2121=T12084
M          XK2122=T12085
M          XK2123=T12086
M          XK2124=T12087
M          XK2125=T12088
C==============================
C      XK101,XK137=LOCAL WIND
C==============================
M          XK262=1.0
           D2DEG1(XK260,XK262,A501,XK1351)
           D2DEG1(XK260,XK262,A502,XK1352)
           D2DEG1(XK260,XK262,A503,XK1353)
           D2DEG1(XK260,XK262,A504,XK1354)
           D2DEG1(XK260,XK262,A505,XK1355)
           D2DEG1(XK260,XK262,A506,XK1356)
           D2DEG1(XK260,XK262,A507,XK1357)
           D2DEG1(XK260,XK262,A508,XK1358)
           D2DEG1(XK260,XK262,A509,XK1359)
           D2DEG1(XK260,XK262,A510,XK1360)
           D2DEG1(XK260,XK262,A511,XK1361)
           D2DEG1(XK260,XK262,A512,XK1362)
           D2DEG1(XK260,XK262,A513,XK1363)
           D2DEG1(XK260,XK262,A514,XK1364)
```

```
            D2DEG1(XK260,XK262,A515,XK1365)
            D2DEG1(XK260,XK262,A516,XK1366)
            D2DEG1(XK260,XK262,A517,XK1367)
            D2DEG1(XK260,XK262,A518,XK1368)
            D2DEG1(XK260,XK262,A519,XK1369)
            D2DEG1(XK260,XK262,A520,XK1370)
            D2DEG1(XK260,XK262,A521,XK1371)
            D2DEG1(XK260,XK262,A522,XK1372)
            D2DEG1(XK260,XK262,A523,XK1373)
            D2DEG1(XK260,XK262,A524,XK1374)
            D2DEG1(XK260,XK262,A525,XK1375)
            D2DEG1(XK260,XK262,A526,XK1376)
            D2DEG1(XK260,XK262,A527,XK1377)
            D2DEG1(XK260,XK262,A528,XK1378)
            D2DEG1(XK260,XK262,A529,XK1379)
            D2DEG1(XK260,XK262,A530,XK1380)
            D2DEG1(XK260,XK262,A531,XK1381)
            D2DEG1(XK260,XK262,A532,XK1382)
            D2DEG1(XK260,XK262,A533,XK1383)
            D2DEG1(XK260,XK262,A534,XK1384)
            D2DEG1(XK260,XK262,A535,XK1385)
            D2DEG1(XK260,XK262,A536,XK1386)
            D2DEG1(XK260,XK262,A537,XK1387)
C  SRB'S WIND FACTOR
C RIGHT SRB
            D2DEG1(XK260,XK262,A601,XK1388)
            D2DEG1(XK260,XK262,A602,XK1389)
            D2DEG1(XK260,XK262,A603,XK1390)
            D2DEG1(XK260,XK262,A604,XK1391)
            D2DEG1(XK260,XK262,A605,XK1392)
            D2DEG1(XK260,XK262,A606,XK1393)
            D2DEG1(XK260,XK262,A607,XK1394)
            D2DEG1(XK260,XK262,A608,XK1395)
            D2DEG1(XK260,XK262,A609,XK1396)
            D2DEG1(XK260,XK262,A610,XK1397)
            D2DEG1(XK260,XK262,A611,XK1398)
            D2DEG1(XK260,XK262,A612,XK1399)
            D2DEG1(XK260,XK262,A613,XK1400)
            D2DEG1(XK260,XK262,A614,XK1401)
            D2DEG1(XK260,XK262,A615,XK1402)
            D2DEG1(XK260,XK262,A616,XK1403)
            D2DEG1(XK260,XK262,A617,XK1404)
            D2DEG1(XK260,XK262,A618,XK1405)
            D2DEG1(XK260,XK262,A619,XK1406)
            D2DEG1(XK260,XK262,A620,XK1407)
            D2DEG1(XK260,XK262,A621,XK1408)
            D2DEG1(XK260,XK262,A622,XK1409)
            D2DEG1(XK260,XK262,A623,XK1410)
            D2DEG1(XK260,XK262,A624,XK1411)
            D2DEG1(XK260,XK262,A625,XK1412)
            D2DEG1(XK260,XK262,A626,XK1413)
            D2DEG1(XK260,XK262,A627,XK1414)
            D2DEG1(XK260,XK262,A628,XK1415)
            D2DEG1(XK260,XK262,A629,XK1416)
            D2DEG1(XK260,XK262,A630,XK1417)
            D2DEG1(XK260,XK262,A631,XK1418)
            D2DEG1(XK260,XK262,A632,XK1419)
            D2DEG1(XK260,XK262,A633,XK1420)
            D2DEG1(XK260,XK262,A634,XK1421)
            D2DEG1(XK260,XK262,A635,XK1422)
            D2DEG1(XK260,XK262,A636,XK1423)
            D2DEG1(XK260,XK262,A637,XK1424)
            D2DEG1(XK260,XK262,A638,XK1425)
            D2DEG1(XK260,XK262,A639,XK1426)
```

```
            D2DEG1(XK260,XK262,A640,XK1427)
            D2DEG1(XK260,XK262,A641,XK1428)
            D2DEG1(XK260,XK262,A642,XK1429)
            D2DEG1(XK260,XK262,A643,XK1430)
            D2DEG1(XK260,XK262,A644,XK1431)
C LEFT SRB
            D2DEG1(XK260,XK262,A645,XK1432)
            D2DEG1(XK260,XK262,A646,XK1433)
            D2DEG1(XK260,XK262,A647,XK1434)
            D2DEG1(XK260,XK262,A648,XK1435)
            D2DEG1(XK260,XK262,A649,XK1436)
            D2DEG1(XK260,XK262,A650,XK1437)
            D2DEG1(XK260,XK262,A651,XK1438)
            D2DEG1(XK260,XK262,A652,XK1439)
            D2DEG1(XK260,XK262,A653,XK1440)
            D2DEG1(XK260,XK262,A654,XK1441)
            D2DEG1(XK260,XK262,A655,XK1442)
            D2DEG1(XK260,XK262,A656,XK1443)
            D2DEG1(XK260,XK262,A657,XK1444)
            D2DEG1(XK260,XK262,A658,XK1445)
            D2DEG1(XK260,XK262,A659,XK1446)
            D2DEG1(XK260,XK262,A660,XK1447)
            D2DEG1(XK260,XK262,A661,XK1448)
            D2DEG1(XK260,XK262,A662,XK1449)
            D2DEG1(XK260,XK262,A663,XK1450)
            D2DEG1(XK260,XK262,A664,XK1451)
            D2DEG1(XK260,XK262,A665,XK1452)
            D2DEG1(XK260,XK262,A666,XK1453)
            D2DEG1(XK260,XK262,A667,XK1454)
            D2DEG1(XK260,XK262,A668,XK1455)
            D2DEG1(XK260,XK262,A669,XK1456)
            D2DEG1(XK260,XK262,A670,XK1457)
            D2DEG1(XK260,XK262,A671,XK1458)
            D2DEG1(XK260,XK262,A672,XK1459)
            D2DEG1(XK260,XK262,A673,XK1460)
            D2DEG1(XK260,XK262,A674,XK1461)
            D2DEG1(XK260,XK262,A675,XK1462)
            D2DEG1(XK260,XK262,A676,XK1463)
            D2DEG1(XK260,XK262,A677,XK1464)
            D2DEG1(XK260,XK262,A678,XK1465)
            D2DEG1(XK260,XK262,A679,XK1466)
            D2DEG1(XK260,XK262,A680,XK1467)
            D2DEG1(XK260,XK262,A681,XK1468)
            D2DEG1(XK260,XK262,A682,XK1469)
            D2DEG1(XK260,XK262,A683,XK1470)
            D2DEG1(XK260,XK262,A684,XK1471)
            D2DEG1(XK260,XK262,A685,XK1472)
            D2DEG1(XK260,XK262,A686,XK1473)
            D2DEG1(XK260,XK262,A687,XK1474)
            D2DEG1(XK260,XK262,A688,XK1475)
C
M           IF(KTEST.EQ.1)THEN
M            XK1379=.74
M            XK1380=.85
M            XK1381=.90
M            XK1382=.90
M            XK1387=1.2
F           ENDIF
C
M            T151 =XK1351
M            T152 =XK1352
M            T153 =XK1353
M            T154 =XK1354
M            T155 =XK1355
```

```
M          T156 =XK1356
M          T157 =XK1357
M          T158 =XK1358
M          T159 =XK1359
M          T160=XK1360
M          T161=XK1361
M          T162=XK1362
M          T163=XK1363
M          T164=XK1364
M          T165=XK1365
M          T166=XK1366
M          T167=XK1367
M          T168=XK1368
M          T169=XK1369
M          T170=XK1370
M          T171=XK1371
M          T172=XK1372
M          T173=XK1373
M          T174=XK1374
M          T175=XK1375
M          T176=XK1376
M          T177=XK1377
M          T178=XK1378
M          T179=XK1379
M          T180=XK1380
M          T181=XK1381
M          T182=XK1382
M          T183=XK1383
M          T184=XK1384
M          T185=XK1385
M          T186=XK1386
M          T187=XK1387
C
M         XK1001=XK261*XK1351*1.688
M         XK1002=XK261*XK1352*1.688
M         XK1003=XK261*XK1353*1.688
M         XK1004=XK261*XK1354*1.688
M         XK1005=XK261*XK1355*1.688
M         XK1006=XK261*XK1356*1.688
M         XK1007=XK261*XK1357*1.688
M         XK1008=XK261*XK1358*1.688
M         XK1009=XK261*XK1359*1.688
M         XK1010=XK261*XK1360*1.688
M         XK1011=XK261*XK1361*1.688
M         XK1012=XK261*XK1362*1.688
M         XK1013=XK261*XK1363*1.688
M         XK1014=XK261*XK1364*1.688
M         XK1015=XK261*XK1365*1.688
M         XK1016=XK261*XK1366*1.688
M         XK1017=XK261*XK1367*1.688
M         XK1018=XK261*XK1368*1.688
M         XK1019=XK261*XK1369*1.688
M         XK1020=XK261*XK1370*1.688
M         XK1021=XK261*XK1371*1.688
M         XK1022=XK261*XK1372*1.688
M         XK1023=XK261*XK1373*1.688
M         XK1024=XK261*XK1374*1.688
M         XK1025=XK261*XK1375*1.688
M         XK1026=XK261*XK1376*1.688
M         XK1027=XK261*XK1377*1.688
M         XK1028=XK261*XK1378*1.688
M         XK1029=XK261*XK1379*1.688
M         XK1030=XK261*XK1380*1.688
M         XK1031=XK261*XK1381*1.688
```

```
M          XK1032=XK261*XK1382*1.688
M          XK1033=XK261*XK1383*1.688
M          XK1034=XK261*XK1384*1.688
M          XK1035=XK261*XK1385*1.688
M          XK1036=XK261*XK1386*1.688
M          XK1037=XK261*XK1387*1.688
C
M          XK1038=XK261*XK1388*1.688
M          XK1039=XK261*XK1389*1.688
M          XK1040=XK261*XK1390*1.688
M          XK1041=XK261*XK1391*1.688
M          XK1042=XK261*XK1392*1.688
M          XK1043=XK261*XK1393*1.688
M          XK1044=XK261*XK1394*1.688
M          XK1045=XK261*XK1395*1.688
M          XK1046=XK261*XK1396*1.688
M          XK1047=XK261*XK1397*1.688
M          XK1048=XK261*XK1398*1.688
M          XK1049=XK261*XK1399*1.688
M          XK1050=XK261*XK1400*1.688
M          XK1051=XK261*XK1401*1.688
M          XK1052=XK261*XK1402*1.688
M          XK1053=XK261*XK1403*1.688
M          XK1054=XK261*XK1404*1.688
M          XK1055=XK261*XK1405*1.688
M          XK1056=XK261*XK1406*1.688
M          XK1057=XK261*XK1407*1.688
M          XK1058=XK261*XK1408*1.688
M          XK1059=XK261*XK1409*1.688
M          XK1060=XK261*XK1410*1.688
M          XK1061=XK261*XK1411*1.688
M          XK1062=XK261*XK1412*1.688
M          XK1063=XK261*XK1413*1.688
M          XK1064=XK261*XK1414*1.688
M          XK1065=XK261*XK1415*1.688
M          XK1066=XK261*XK1416*1.688
M          XK1067=XK261*XK1417*1.688
M          XK1068=XK261*XK1418*1.688
M          XK1069=XK261*XK1419*1.688
M          XK1070=XK261*XK1420*1.688
M          XK1071=XK261*XK1421*1.688
M          XK1072=XK261*XK1422*1.688
M          XK1073=XK261*XK1423*1.688
M          XK1074=XK261*XK1424*1.688
M          XK1075=XK261*XK1425*1.688
M          XK1076=XK261*XK1426*1.688
M          XK1077=XK261*XK1427*1.688
M          XK1078=XK261*XK1428*1.688
M          XK1079=XK261*XK1429*1.688
M          XK1080=XK261*XK1430*1.688
M          XK1081=XK261*XK1431*1.688
C
M          XK1082=XK261*XK1432*1.688
M          XK1083=XK261*XK1433*1.688
M          XK1084=XK261*XK1434*1.688
M          XK1085=XK261*XK1435*1.688
M          XK1086=XK261*XK1436*1.688
M          XK1087=XK261*XK1437*1.688
M          XK1088=XK261*XK1438*1.688
M          XK1089=XK261*XK1439*1.688
M          XK1090=XK261*XK1440*1.688
M          XK1091=XK261*XK1441*1.688
M          XK1092=XK261*XK1442*1.688
M          XK1093=XK261*XK1443*1.688
```

```
C=========================================
M           TW=XK(2001+M-1)
M           XK34=(-0.56529*TW)+1093.2494
M           SY=XK10-TW
C
F           DM=DMAX1(0.D0,SY)
C
M           XK35=XK34+143.3/.25*(DMIN1(0.25D0,DM))
C
C=====  LATENT HEAT ========================
M           XK(2301+M-1)=XK42*XK35
M           T(16001+M-1)=XK(2301+M-1)
C=========================================
F125         CONTINUE
C
M           IF(KTEST.EQ.1)THEN
M           Q1001=0.
M           Q1002=0.
M           Q1003=0.
M           Q1004=0.
M           Q1005=0.
M           Q1006=0.
M           Q1007=0.
M           Q1008=0.
M           Q1009=0.
M           Q1010=0.
M           Q1011=0.
M           Q1012=0.
M           Q1013=0.
M           Q1014=0.
M           Q1015=0.
M           Q1016=0.
M           Q1017=0.
M           Q1018=0.
M           Q1019=0.
M           Q1020=0.
M           Q1021=0.
M           Q1022=0.
M           Q1023=0.
M           Q1024=0.
M           Q1025=0.
M           Q1026=0.
M           Q1027=0.
M           Q1028=0.
M           Q1029=0.
M           Q1030=0.
M           Q1031=0.
M           Q1032=0.
M           Q1033=0.
M           Q1034=0.
M           Q1035=0.
M           Q1036=0.
M           Q1037=0.
C
M           Q12001=0.
M           Q12002=0.
M           Q12003=0.
M           Q12004=0.
M           Q12005=0.
M           Q12006=0.
M           Q12007=0.
M           Q12008=0.
M           Q12009=0.
M           Q12010=0.
M           Q12011=0.
M           Q12012=0.
M           Q12013=0.
```

```
M           Q12014=0.
M           Q12015=0.
M           Q12016=0.
M           Q12017=0.
M           Q12018=0.
M           Q12019=0.
M           Q12020=0.
M           Q12021=0.
M           Q12022=0.
M           Q12023=0.
M           Q12024=0.
M           Q12025=0.
M           Q12026=0.
M           Q12027=0.
M           Q12028=0.
M           Q12029=0.
M           Q12030=0.
M           Q12031=0.
M           Q12032=0.
M           Q12033=0.
M           Q12034=0.
M           Q12035=0.
M           Q12036=0.
M           Q12037=0.
M           Q12038=0.
M           Q12039=0.
M           Q12040=0.
M           Q12041=0.
M           Q12042=0.
M           Q12043=0.
M           Q12044=0.
C
M           Q12045=0.
M           Q12046=0.
M           Q12047=0.
M           Q12048=0.
M           Q12049=0.
M           Q12050=0.
M           Q12051=0.
M           Q12052=0.
M           Q12053=0.
M           Q12054=0.
M           Q12055=0.
M           Q12056=0.
M           Q12057=0.
M           Q12058=0.
M           Q12059=0.
M           Q12060=0.
M           Q12061=0.
M           Q12062=0.
M           Q12063=0.
M           Q12064=0.
M           Q12065=0.
M           Q12066=0.
M           Q12067=0.
M           Q12068=0.
M           Q12069=0.
M           Q12070=0.
M           Q12071=0.
M           Q12072=0.
M           Q12073=0.
M           Q12074=0.
M           Q12075=0.
M           Q12076=0.
M           Q12077=0.
M           Q12078=0.
M           Q12079=0.
```

```
C***********  NATURAL OR FORCED CONVECTION *********************
C==============================================================
C
F            IF(CONNAT.GT.CONFOR) CONV=CONNAT
M31          G(8038+M-1)=CONV*XK(1238+M-1)
F25         CONTINUE
C
F            DO 125 M=1,37
C
M            T40=XK47
C
M            TFILM=(XK(2001+M-1)+T40)/2.0
C
F           AIRCON=2.1E-5*TFILM+.0133
F           COND=AIRCON
C
C==============================================================
C****** DECIDE FOR NATURAL OR FORCED CONVECTION COEFICIENT*****          ENT
C==============================================================
C
F            IF(ITEST.EQ.3)GO TO 602
F            IF(ITEST.EQ.2)GO TO 20
F            IF(ITEST.EQ.1)GO TO 602
C
C==============================================================
C******************  NATURAL CONVECTION ************************
C==============================================================
C
F602       IF(TFILM.LE.32.)GRF=-(32500.*TFILM-4.2E6)
F          IF(TFILM.GT.32.)GRF=-20588.*TFILM+3818824.
C
C
M            RA=GRF*ABS(XK(2001+M-1)-T40)*.72
F            CONNAT=.1*COND*RA**(1./3.)
M            XK28=CONNAT
F            CONV=CONNAT
F            IF(ITEST.EQ.1)GO TO 30
C
C==============================================================
C****************  FORCED CONVECTION **************************
C==============================================================
C
F20        IF(TFILM.LE.32.)VIS=5.E-7*TFILM+1.3E-4
F           IF(TFILM.GT.32.)VIS=5.15E-7*TFILM+1.2853E-4
C
C
M            RE=XK(2151+M-1)*XK(1001+M-1)/VIS
M            CONFOR=(.46*RE**.5+.00128*RE)*COND/XK(2151+M-1)
C
C        CHURCHILL & BERNSTEIN FORCED CONVECTION
C
F            AB=(0.62*SQRT(RE)*.8964)/1.1378
F            BC=(1+(RE/2.82E+5)**.625)**.8
CM            CONFOR=(0.3+AB*BC)*COND/XK(2151+M-1)
C
C         AHM
C
CM            CONFOR=(0.0675*RE**.73333)*COND/XK(2151+M-1)
C
M            XK29=CONFOR
F            CONV=CONFOR
F            IF(ITEST.EQ.2)GO TO 30
C
C==============================================================
```

```
C***********  NATURAL OR FORCED CONVECTION *********************
C==============================================================
C
F           IF(CONNAT.GT.CONFOR) CONV=CONNAT
M30         G(8001+M-1)=CONV*XK(1201+M-1)
C
C
M           TF=XK(2001+M-1)
M           XK66=100.0
M           RH=XK66
M           TR=TF+460.0
F           C1=2.631760E-19
F           E1=23.35631703
F           C2=4.0942242E-16
F           E2=18.75385414
F           IF(TF.LE.33.7708962)W=C1*(TR/100.)**E1
F           IF(TF.GT.33.7708962)W=C2*(TR/100.)**E2
F           W=W*RH/100.
F           SW=W
C
F           SS=STEST-SW
M           XK32=1.1*CONV*(DMAX1(0.D0,SS))/.24
M           XK42=XK32*XK(1201+M-1)
M           XK33=XK32*12./62.4
C
C===== CONDENSATION RATE ====================
M           T(201+M-1)=XK33
C===========================================
M           TW=XK(2001+M-1)
M           XK34=(-0.56529*TW)+1093.2494
M           SY=XK10-TW
C
F           DM=DMAX1(0.D0,SY)
C
M           XK35=XK34+143.3/.25*(DMIN1(0.25D0,DM))
C
C=====  LATENT HEAT ========================
M           XK(2301+M-1)=XK42*XK35
M           T(16001+M-1)=XK(2301+M-1)
C===========================================
F125         CONTINUE
C
M           IF(KTEST.EQ.1)THEN
M           Q1001=0.
M           Q1002=0.
M           Q1003=0.
M           Q1004=0.
M           Q1005=0.
M           Q1006=0.
M           Q1007=0.
M           Q1008=0.
M           Q1009=0.
M           Q1010=0.
M           Q1011=0.
M           Q1012=0.
M           Q1013=0.
M           Q1014=0.
M           Q1015=0.
M           Q1016=0.
M           Q1017=0.
M           Q1018=0.
M           Q1019=0.
M           Q1020=0.
M           Q1021=0.
```

```
M          Q1022=0.
M          Q1023=0.
M          Q1024=0.
M          Q1025=0.
M          Q1026=0.
M          Q1027=0.
M          Q1028=0.
M          Q1029=0.
M          Q1030=0.
M          Q1031=0.
M          Q1032=0.
M          Q1033=0.
M          Q1034=0.
M          Q1035=0.
M          Q1036=0.
M          Q1037=0.
C
M          Q12001=0.
M          Q12002=0.
M          Q12003=0.
M          Q12004=0.
M          Q12005=0.
M          Q12006=0.
M          Q12007=0.
M          Q12008=0.
M          Q12009=0.
M          Q12010=0.
M          Q12011=0.
M          Q12012=0.
M          Q12013=0.
M          Q12014=0.
M          Q12015=0.
M          Q12016=0.
M          Q12017=0.
M          Q12018=0.
M          Q12019=0.
M          Q12020=0.
M          Q12021=0.
M          Q12022=0.
M          Q12023=0.
M          Q12024=0.
M          Q12025=0.
M          Q12026=0.
M          Q12027=0.
M          Q12028=0.
M          Q12029=0.
M          Q12030=0.
M          Q12031=0.
M          Q12032=0.
M          Q12033=0.
M          Q12034=0.
M          Q12035=0.
M          Q12036=0.
M          Q12037=0.
M          Q12038=0.
M          Q12039=0.
M          Q12040=0.
M          Q12041=0.
M          Q12042=0.
M          Q12043=0.
M          Q12044=0.
C
M          Q12045=0.
M          Q12046=0.
```

```
M           Q12047=0.
M           Q12048=0.
M           Q12049=0.
M           Q12050=0.
M           Q12051=0.
M           Q12052=0.
M           Q12053=0.
M           Q12054=0.
M           Q12055=0.
M           Q12056=0.
M           Q12057=0.
M           Q12058=0.
M           Q12059=0.
M           Q12060=0.
M           Q12061=0.
M           Q12062=0.
M           Q12063=0.
M           Q12064=0.
M           Q12065=0.
M           Q12066=0.
M           Q12067=0.
M           Q12068=0.
M           Q12069=0.
M           Q12070=0.
M           Q12071=0.
M           Q12072=0.
M           Q12073=0.
M           Q12074=0.
M           Q12075=0.
M           Q12076=0.
M           Q12077=0.
M           Q12078=0.
M           Q12079=0.
M           Q12080=0.
M           Q12081=0.
M           Q12082=0.
M           Q12083=0.
M           Q12084=0.
M           Q12085=0.
M           Q12086=0.
M           Q12087=0.
M           Q12088=0.
F           ENDIF
C*******************************
M           T13001=Q1001
M           T13002=Q1002
M           T13003=Q1003
M           T13004=Q1004
M           T13005=Q1005
M           T13006=Q1006
M           T13007=Q1007
M           T13008=Q1008
M           T13009=Q1009
M           T13010=Q1010
M           T13011=Q1011
M           T13012=Q1012
M           T13013=Q1013
M           T13014=Q1014
M           T13015=Q1015
M           T13016=Q1016
M           T13017=Q1017
M           T13018=Q1018
M           T13019=Q1019
M           T13020=Q1020
```

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M           T13021=Q1021
M           T13022=Q1022
M           T13023=Q1023
M           T13024=Q1024
M           T13025=Q1025
M           T13026=Q1026
M           T13027=Q1027
M           T13028=Q1028
M           T13029=Q1029
M           T13030=Q1030
M           T13031=Q1031
M           T13032=Q1032
M           T13033=Q1033
M           T13034=Q1034
M           T13035=Q1035
M           T13036=Q1036
M           T13037=Q1037
C=====================================
C    ET SOLAR HEAT + ET LATENT HEAT
C=====================================
M           Q1001=Q1001+T16001
M           Q1002=Q1002+T16002
M           Q1003=Q1003+T16003
M           Q1004=Q1004+T16004
M           Q1005=Q1005+T16005
M           Q1006=Q1006+T16006
M           Q1007=Q1007+T16007
M           Q1008=Q1008+T16008
M           Q1009=Q1009+T16009
M           Q1010=Q1010+T16010
M           Q1011=Q1011+T16011
M           Q1012=Q1012+T16012
M           Q1013=Q1013+T16013
M           Q1014=Q1014+T16014
M           Q1015=Q1015+T16015
M           Q1016=Q1016+T16016
M           Q1017=Q1017+T16017
M           Q1018=Q1018+T16018
M           Q1019=Q1019+T16019
M           Q1020=Q1020+T16020
M           Q1021=Q1021+T16021
M           Q1022=Q1022+T16022
M           Q1023=Q1023+T16023
M           Q1024=Q1024+T16024
M           Q1025=Q1025+T16025
M           Q1026=Q1026+T16026
M           Q1027=Q1027+T16027
M           Q1028=Q1028+T16028
M           Q1029=Q1029+T16029
M           Q1030=Q1030+T16030
M           Q1031=Q1031+T16031
M           Q1032=Q1032+T16032
M           Q1033=Q1033+T16033
M           Q1034=Q1034+T16034
M           Q1035=Q1035+T16035
M           Q1036=Q1036+T16036
M           Q1037=Q1037+T16037
C
C==========================================
C
C            ICE RATE CALCULATION
C
C==========================================
C
```

```
C     TEMPERATURE  OF ORBITER
C     -----------------------
M           XK700=T8000
M           XK701=T8005
M           XK702=T8010
M           XK703=T8011
M           XK704=T8015
M           XK705=T8016
M           XK706=T8020
M           XK707=T8025
M           XK708=T8030
M           XK709=T8035
C
C     TEMPERATURE OF MLP
C     ------------------
M           XK710=T500
M           XK711=T501
M           XK712=T502
M           XK713=T503
C     TEMPERATURE OF GROUND
C     ---------------------
M           XK714=T9000
M           XK715=T9001
M           XK716=T9002
M           XK717=T9003
C     TEMPERATURE OF FSS
C     ------------------
M           XK718=T6011
M           XK719=T6021
M           XK720=T6031
M           XK721=T6041
M           XK722=T6050
M           XK723=T6060
M           XK724=T6070
M           XK725=T6080
M           XK726=T6090
C     TEMPERATURE OF SRB
C     ------------------
M           XK730=T12001
M           XK731=T12002
M           XK732=T12003
M           XK733=T12005
M           XK734=T12006
M           XK735=T12007
M           XK736=T12008
M           XK737=T12009
M           XK738=T12010
M           XK739=T12011
M           XK740=T12012
M           XK741=T12013
M           XK742=T12014
M           XK743=T12015
M           XK744=T12016
M           XK745=T12017
M           XK746=T12018
M           XK747=T12019
M           XK748=T12020
M           XK749=T12021
M           XK750=T12022
M           XK751=T12023
M           XK752=T12024
M           XK753=T12025
M           XK754=T12033
M           XK755=T12034
```

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M            XK756=T12035
M            XK757=T12036
M            XK758=T12037
M            XK759=T12038
M            XK760=T12041
M            XK761=T12042
M            XK762=T12043
C
M            XK765=T12045
M            XK766=T12047
M            XK767=T12048
M            XK768=T12049
M            XK769=T12050
M            XK770=T12051
M            XK771=T12052
M            XK772=T12053
M            XK773=T12054
M            XK774=T12055
M            XK775=T12063
M            XK776=T12064
M            XK777=T12065
M            XK778=T12066
M            XK779=T12067
M            XK780=T12068
M            XK781=T12069
M            XK782=T12070
M            XK783=T12071
M            XK784=T12072
M            XK785=T12073
M            XK786=T12074
M            XK787=T12075
M            XK788=T12076
M            XK789=T12077
M            XK790=T12078
M            XK791=T12081
M            XK792=T12082
M            XK793=T12083
M            XK794=T12084
M            XK795=T12085
M            XK796=T12087
M            XK797=T12088
C
C==========================================
C            RADIATION CONDUCTOR
C==========================================
C#1
M            XK5001= 0.49948E-07
M            XK5002= 0.49919E-07
M            XK5003= 0.39188E-08
M            XK5004= 0.38654E-08
M            XK5005= 0.19134E-07
M            XK5006= 0.19369E-07
M            XK5007= 0.47836E-06
C#2
M            XK5011= 0.34200E-07
M            XK5012= 0.34190E-07
M            XK5013= 0.24268E-07
M            XK5014= 0.24402E-07
M            XK5015= 0.50599E-06
C#3
M            XK5021= 0.23431E-07
M            XK5022= 0.23431E-07
M            XK5023= 0.32610E-07
M            XK5024= 0.32692E-07
```

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M          XK5025= 0.51294E-06
C#4
M          XK5031= 0.16302E-07
M          XK5032= 0.16311E-07
M          XK5033= 0.30132E-07
M          XK5034= 0.30192E-07
M          XK5035= 0.53264E-06
C#5
M          XK5041= 0.67515E-07
M          XK5042= 0.28694E-07
M          XK5043= 0.66278E-08
M          XK5044= 0.13960E-07
M          XK5045= 0.62238E-08
M          XK5046= 0.13255E-07
M          XK5047= 0.50286E-07
M          XK5048= 0.12348E-06
M          XK5049= 0.33598E-08
M          XK5050= 0.26639E-08
M          XK5051= 0.11149E-07
M          XK5052= 0.22857E-07
M          XK5053= 0.15493E-07
M          XK5054= 0.12559E-07
M          XK5055= 0.22329E-06
C#6
M          XK5061= 0.22509E-07
M          XK5062= 0.33473E-07
M          XK5063= 0.37149E-08
M          XK5064= 0.13310E-08
M          XK5065= 0.11812E-07
M          XK5066= 0.92062E-08
M          XK5067= 0.12671E-08
M          XK5068= 0.11704E-07
M          XK5069= 0.90002E-08
M          XK5070= 0.19889E-08
M          XK5071= 0.10559E-06
M          XK5072= 0.76722E-07
M          XK5073= 0.18103E-07
M          XK5074= 0.14230E-07
M          XK5075= 0.79301E-08
M          XK5076= 0.28062E-06
C#7
M          XK5081= 0.20604E-07
M          XK5082= 0.53864E-08
M          XK5083= 0.13506E-07
M          XK5084= 0.34653E-08
M          XK5085= 0.53562E-08
M          XK5086= 0.13453E-07
M          XK5087= 0.34064E-08
M          XK5088= 0.39728E-07
M          XK5089= 0.12430E-06
M          XK5090= 0.21226E-07
M          XK5091= 0.12313E-07
M          XK5092= 0.22692E-07
M          XK5093= 0.24334E-07
M          XK5094= 0.29888E-06
C#8
M          XK5101= 0.60039E-08
M          XK5102= 0.99623E-09
M          XK5103= 0.10999E-07
M          XK5104= 0.98405E-08
M          XK5105= 0.99467E-09
M          XK5106= 0.10993E-07
M          XK5107= 0.98318E-08
M          XK5108= 0.13201E-08
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M          XK5109= 0.97222E-07
M          XK5110= 0.87119E-07
M          XK5111= 0.85008E-08
M          XK5112= 0.32280E-08
M          XK5113= 0.20573E-07
M          XK5114= 0.27579E-07
M          XK5115= 0.31905E-06
C#9
M          XK5121= 0.67797E-08
M          XK5122= 0.61526E-08
M          XK5123= 0.37943E-06
M          XK5124= 0.16370E-07
M          XK5125= 0.16367E-07
M          XK5126= 0.62799E-07
M          XK5127= 0.21291E-08
M          XK5128= 0.26963E-08
M          XK5129= 0.13197E-08
M          XK5130= 0.21284E-08
M          XK5131= 0.26956E-08
M          XK5132= 0.13190E-08
M          XK5133= 0.33936E-08
M          XK5134= 0.33431E-08
M          XK5135= 0.78796E-07
C#10
M          XK5141= 0.11946E-07
M          XK5142= 0.66691E-08
M          XK5143= 0.27355E-06
M          XK5144= 0.18009E-06
M          XK5145= 0.10547E-08
M          XK5146= 0.13263E-08
M          XK5147= 0.12350E-08
M          XK5148= 0.10541E-08
M          XK5149= 0.13257E-08
M          XK5150= 0.12345E-08
M          XK5151= 0.35844E-08
M          XK5152= 0.34648E-08
M          XK5153= 0.10003E-06
C#11
M          XK5161= 0.99544E-08
M          XK5162= 0.40683E-06
M          XK5163= 0.40962E-08
M          XK5164= 0.11005E-08
M          XK5165= 0.11737E-08
M          XK5166= 0.10998E-08
M          XK5167= 0.11731E-08
M          XK5168= 0.11579E-07
M          XK5169= 0.11510E-07
M          XK5170= 0.13198E-06
C#12
M          XK5181= 0.45615E-08
M          XK5182= 0.22784E-06
M          XK5183= 0.98285E-07
M          XK5184= 0.32778E-08
M          XK5185= 0.13665E-07
M          XK5186= 0.13616E-07
M          XK5187= 0.21965E-06
C#13
M          XK5201= 0.67514E-07
M          XK5202= 0.28693E-07
M          XK5203= 0.66278E-08
M          XK5204= 0.13960E-07
M          XK5205= 0.50286E-07
M          XK5206= 0.12348E-06
M          XK5207= 0.62238E-08
```

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M          XK5208= 0.13255E-07
M          XK5209= 0.33597E-08
M          XK5210= 0.11149E-07
M          XK5211= 0.26638E-08
M          XK5212= 0.22850E-07
M          XK5213= 0.15483E-07
M          XK5214= 0.12523E-07
M          XK5215= 0.22356E-06
C#14
M          XK5221= 0.22509E-07
M          XK5222= 0.33472E-07
M          XK5223= 0.37148E-08
M          XK5224= 0.13310E-08
M          XK5225= 0.11812E-07
M          XK5226= 0.92061E-08
M          XK5227= 0.19889E-08
M          XK5228= 0.10559E-06
M          XK5229= 0.76722E-07
M          XK5230= 0.12670E-08
M          XK5231= 0.11704E-07
M          XK5232= 0.90001E-08
M          XK5233= 0.18100E-07
M          XK5234= 0.14213E-07
M          XK5235= 0.79123E-08
M          XK5236= 0.28076E-06
C#15
M          XK5241= 0.20604E-07
M          XK5242= 0.53864E-08
M          XK5243= 0.13506E-07
M          XK5244= 0.34653E-08
M          XK5245= 0.39728E-07
M          XK5246= 0.12430E-06
M          XK5247= 0.21226E-07
M          XK5248= 0.53562E-08
M          XK5249= 0.13453E-07
M          XK5250= 0.34064E-08
M          XK5251= 0.12310E-07
M          XK5252= 0.22676E-07
M          XK5253= 0.24318E-07
M          XK5254= 0.29905E-06
C#16
M          XK5261= 0.60039E-08
M          XK5262= 0.99621E-09
M          XK5263= 0.10998E-07
M          XK5264= 0.98405E-08
M          XK5265= 0.13201E-08
M          XK5266= 0.97222E-07
M          XK5267= 0.87119E-07
M          XK5268= 0.99466E-09
M          XK5269= 0.10993E-07
M          XK5270= 0.98318E-08
M          XK5271= 0.84983E-08
M          XK5272= 0.32246E-08
M          XK5273= 0.20559E-07
M          XK5274= 0.27565E-07
M          XK5275= 0.31924E-06
C#17
M          XK5281= 0.13619E-08
M          XK5282= 0.13606E-08
M          XK5283= 0.14459E-07
M          XK5284= 0.14478E-07
M          XK5285= 0.34525E-07
M          XK5286= 0.34581E-07
M          XK5287= 0.71535E-06
```

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C#18
M           XK5301= 0.70640E-08
M           XK5302= 0.70640E-08
M           XK5303= 0.54795E-07
M           XK5304= 0.13541E-07
M           XK5305= 0.39896E-08
M           XK5306= 0.13541E-07
M           XK5307= 0.39894E-08
M           XK5308= 0.12711E-06
M           XK5309= 0.31670E-07
M           XK5310= 0.74287E-08
M           XK5311= 0.51773E-08
M           XK5312= 0.52021E-08
M           XK5313= 0.31012E-07
M           XK5314= 0.37945E-07
M           XK5315= 0.44551E-06
C#19
M           XK5321= 0.52560E-07
M           XK5322= 0.77272E-07
M           XK5323= 0.16729E-08
M           XK5324= 0.16715E-08
M           XK5325= 0.38280E-07
M           XK5326= 0.38238E-07
M           XK5327= 0.58055E-06
C#20
M           XK5331= 0.70606E-08
M           XK5332= 0.54795E-07
M           XK5333= 0.70606E-08
M           XK5334= 0.13538E-07
M           XK5335= 0.39879E-08
M           XK5336= 0.12711E-06
M           XK5337= 0.31670E-07
M           XK5338= 0.13538E-07
M           XK5339= 0.39877E-08
M           XK5340= 0.74257E-08
M           XK5341= 0.30681E-07
M           XK5342= 0.37577E-07
M           XK5343= 0.46915E-06
C#21
M           XK5401= 0.29111E-08
M           XK5402= 0.29163E-08
M           XK5403= 0.84627E-08
M           XK5404= 0.84730E-08
M           XK5405= 0.19278E-06
C#22
M           XK5411= 0.41484E-08
M           XK5412= 0.41484E-08
M           XK5413= 0.16241E-07
M           XK5414= 0.13379E-08
M           XK5415= 0.16788E-08
M           XK5416= 0.15171E-08
M           XK5417= 0.20218E-08
M           XK5418= 0.27296E-08
M           XK5419= 0.14443E-08
M           XK5420= 0.11027E-08
M           XK5421= 0.62964E-08
M           XK5422= 0.79239E-08
M           XK5423= 0.15988E-06
C#23
M           XK5431= 0.12310E-07
M           XK5432= 0.12303E-07
M           XK5433= 0.18912E-06
C#24
M           XK5441= 0.41465E-08
```

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M          XK5442= 0.16241E-07
M          XK5443= 0.41465E-08
M          XK5444= 0.13304E-08
M          XK5445= 0.61246E-08
M          XK5446= 0.77324E-08
M          XK5447= 0.17598E-06
C#25
M          XK5451= 0.17104E-07
M          XK5452= 0.17101E-07
M          XK5453= 0.50960E-06
C#26
M          XK5461= 0.18251E-08
M          XK5462= 0.18251E-08
M          XK5463= 0.40592E-08
M          XK5464= 0.43111E-08
M          XK5465= 0.57232E-08
M          XK5466= 0.46122E-08
M          XK5467= 0.39720E-08
M          XK5468= 0.67407E-08
M          XK5469= 0.73349E-08
M          XK5470= 0.39263E-08
M          XK5471= 0.31076E-08
M          XK5472= 0.14982E-07
M          XK5473= 0.15042E-07
M          XK5474= 0.46055E-06
C#27
M          XK5481= 0.17083E-07
M          XK5482= 0.17096E-07
M          XK5483= 0.50535E-06
C#28
M          XK5491= 0.18197E-08
M          XK5492= 0.40586E-08
M          XK5493= 0.18197E-08
M          XK5494= 0.14499E-07
M          XK5495= 0.14500E-07
M          XK5496= 0.51343E-06
C#29
M          XK5501= 0.13557E-08
M          XK5502= 0.13636E-08
M          XK5503= 0.23324E-06
C#30
M          XK5511= 0.12406E-08
M          XK5512= 0.15299E-08
M          XK5513= 0.12162E-08
M          XK5514= 0.17768E-08
M          XK5515= 0.28993E-08
M          XK5516= 0.32397E-08
M          XK5517= 0.18224E-08
M          XK5518= 0.14667E-08
M          XK5519= 0.14877E-08
M          XK5520= 0.21898E-06
C#31
M          XK5531= 0.13508E-08
M          XK5532= 0.13509E-08
M          XK5533= 0.23324E-06
C#32
M          XK5541= 0.13186E-08
M          XK5542= 0.13186E-08
M          XK5543= 0.23683E-06
C#33
M          XK5551= 0.29290E-08
M          XK5552= 0.47229E-08
M          XK5553= 0.15810E-07
M          XK5554= 0.15809E-07
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M            XK5555= 0.11091E-06
M            XK5556= 0.28791E-07
M            XK5557= 0.21199E-08
M            XK5558= 0.21666E-08
M            XK5559= 0.17195E-08
M            XK5560= 0.45276E-08
M            XK5561= 0.21197E-08
M            XK5562= 0.21665E-08
M            XK5563= 0.17195E-08
M            XK5564= 0.45276E-08
M            XK5565= 0.15657E-08
M            XK5566= 0.28930E-08
M            XK5567= 0.15656E-08
M            XK5568= 0.28930E-08
M            XK5569= 0.30415E-08
M            XK5570= 0.30313E-08
M            XK5571= 0.46829E-07
M            XK5572= 0.46810E-07
M            XK5573= 0.20264E-08
M            XK5574= 0.19562E-08
M            XK5575= 0.36398E-07
C#34
M            XK5601= 0.33658E-08
M            XK5602= 0.21193E-07
M            XK5603= 0.56760E-08
M            XK5604= 0.75184E-08
M            XK5605= 0.56823E-08
M            XK5606= 0.15812E-08
M            XK5607= 0.51951E-08
M            XK5608= 0.13999E-08
M            XK5609= 0.66748E-07
M            XK5610= 0.13615E-07
M            XK5611= 0.13671E-08
M            XK5612= 0.13171E-08
M            XK5613= 0.46283E-08
M            XK5614= 0.13411E-08
M            XK5615= 0.29254E-07
M            XK5616= 0.67429E-08
M            XK5617= 0.69828E-07
M            XK5618= 0.16472E-07
M            XK5619= 0.34336E-08
M            XK5620= 0.37487E-08
M            XK5621= 0.78809E-07
C#35
M            XK5631= 0.13301E-08
M            XK5632= 0.17346E-08
M            XK5633= 0.10935E-08
M            XK5634= 0.40305E-08
M            XK5635= 0.10935E-08
M            XK5636= 0.40305E-08
M            XK5637= 0.13299E-08
M            XK5638= 0.17344E-08
M            XK5639= 0.14129E-08
M            XK5640= 0.26682E-08
M            XK5641= 0.26682E-08
M            XK5642= 0.14128E-08
M            XK5643= 0.49391E-07
M            XK5644= 0.49379E-07
M            XK5645= 0.38463E-07
M            XK5646= 0.38442E-07
M            XK5647= 0.35962E-08
M            XK5648= 0.36787E-08
M            XK5649= 0.14727E-06
C#36
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M           XK5651= 0.33655E-08
M           XK5652= 0.21192E-07
M           XK5653= 0.56759E-08
M           XK5654= 0.75183E-08
M           XK5655= 0.56821E-08
M           XK5656= 0.15810E-08
M           XK5657= 0.66748E-07
M           XK5658= 0.13615E-07
M           XK5659= 0.51949E-08
M           XK5660= 0.13997E-08
M           XK5661= 0.13411E-08
M           XK5662= 0.13670E-08
M           XK5663= 0.46283E-08
M           XK5664= 0.13169E-08
M           XK5665= 0.67436E-08
M           XK5666= 0.29241E-07
M           XK5667= 0.16477E-07
M           XK5668= 0.69808E-07
M           XK5669= 0.33612E-08
M           XK5670= 0.36743E-08
M           XK5671= 0.79220E-07
C#37
M           XK5681= 0.19488E-09
M           XK5682= 0.34926E-07
C97         CONTINUE
C
      END
C*******************************
      BCD 3VARIABLES 2
C
F         DOUBLE PRECISION SM
C
C             ICE RATE CALCULATION
C             --------------------
C=========================================================
C
C     Q RAD OF ET
C -----------
C NODE#1
M          XK801=(XK5001*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5002*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5003*((XK712+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5004*((XK713+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5005*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5006*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5007*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#2
M          XK802=(XK5011*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5012*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5013*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5014*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5015*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#3
M          XK803=(XK5021*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5022*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5023*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5024*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5025*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#4
M          XK804=(XK5031*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M    +          +(XK5032*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
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M     +          +(XK5033*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5034*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5035*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#5
M          XK805=(XK5041*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5042*((XK702+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5043*((XK773+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5044*((XK774+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5045*((XK780+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5046*((XK781+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5047*((XK787+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5048*((XK788+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5049*((XK789+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5050*((XK791+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5051*((XK793+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5052*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5053*((XK712+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5054*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5055*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#6
M          XK806=(XK5061*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5062*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5063*((XK702+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5064*((XK771+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5065*((XK772+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5066*((XK773+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5067*((XK778+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5068*((XK779+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5069*((XK780+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5070*((XK785+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5071*((XK786+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5072*((XK787+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5073*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5074*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5075*((XK716+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5076*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#7
M          XK807=(XK5081*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5082*((XK770+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5083*((XK771+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5084*((XK772+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5085*((XK777+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5086*((XK778+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5087*((XK779+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5088*((XK784+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5089*((XK785+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5090*((XK786+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5091*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5092*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5093*((XK716+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5094*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#8
M          XK808=(XK5101*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5102*((XK768+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5103*((XK769+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5104*((XK770+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5105*((XK775+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5106*((XK776+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5107*((XK777+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5108*((XK782+460.)**4-(XK10+460.)**4)/XK1201)
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M     +          +(XK5109*((XK783-460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5110*((XK784-460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5111*((XK710+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5112*((XK712+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5113*((XK715+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5114*((XK716+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5115*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#9
M          XK809=(XK5121*((XK2010+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5122*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5123*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5124*((XK702+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5125*((XK704+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5126*((XK706+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5127*((XK773+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5128*((XK774+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5129*((XK789+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5130*((XK738+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5131*((XK739+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5132*((XK754+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5133*((XK712+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5134*((XK713+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5135*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#10
M          XK810=(XK5141*((XK2011+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5142*((XK2012+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5143*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5144*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5145*((XK772+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5146*((XK773+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5147*((XK774+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5148*((XK737+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5149*((XK738+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5150*((XK739+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5151*((XK716+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5152*((XK717+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5153*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#11
M          XK811=(XK5161*((XK2012+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5162*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5163*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5164*((XK771+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5165*((XK772+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5166*((XK736+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5167*((XK737+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5168*((XK716+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5169*((XK717+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5170*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#12
M          XK812=(XK5181*((XK2019+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5182*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5183*((XK708+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5184*((XK709+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5185*((XK716+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5186*((XK717+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5187*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#13
M          XK813=(XK5201*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5202*((XK704+460.)**4-(XK10+460.)**4)/XK1201)
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M     +          +(XK5203*((XK738+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5204*((XK739+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5205*((XK745+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5206*((XK746+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5207*((XK752+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5208*((XK753+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5209*((XK754+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5210*((XK756+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5211*((XK758+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5212*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5213*((XK713+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5214*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5215*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#14
M          XK814=(XK5221*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5222*((XK701+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5223*((XK704+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5224*((XK736+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5225*((XK737+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5226*((XK738+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5227*((XK743+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5228*((XK744+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5229*((XK745+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5230*((XK750+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5231*((XK751+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5232*((XK752+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5233*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5234*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5235*((XK717+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5236*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#15
M          XK815=(XK5241*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5242*((XK735+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5243*((XK736+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5244*((XK737+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5245*((XK742+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5246*((XK743+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5247*((XK744+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5248*((XK749+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5249*((XK750+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5250*((XK751+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5251*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5252*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5253*((XK717+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5254*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
C
C NODE#16
M          XK816=(XK5261*((XK700+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5262*((XK733+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5263*((XK734+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5264*((XK735+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5265*((XK740+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5266*((XK741+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5267*((XK742+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5268*((XK747+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5269*((XK748+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5270*((XK749+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5271*((XK711+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5272*((XK713+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5273*((XK714+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5274*((XK717+460.)**4-(XK10+460.)**4)/XK1201)
M     +          +(XK5275*((XK23+460.)**4-(XK10+460.)**4)/XK1201)
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C NODE#17
M          XK817=(XK5281*((XK775+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5282*((XK747+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5283*((XK710+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5284*((XK711+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5285*((XK714+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5286*((XK715+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5287*((XK23+460.)**4-(XK10+460.)**4)/XK1217)
C
C NODE#18
M          XK818=(XK5301*((XK765+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5302*((XK766+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5303*((XK767+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5304*((XK768+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5305*((XK769+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5306*((XK775+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5307*((XK776+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5308*((XK782+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5309*((XK783+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5310*((XK710+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5311*((XK722+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5312*((XK723+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5313*((XK715+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5314*((XK716+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5315*((XK23+460.)**4-(XK10+460.)**4)/XK1217)
C
C NODE#19
M          XK819=(XK5321*((XK708+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5322*((XK709+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5323*((XK768+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5324*((XK733+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5325*((XK716+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5326*((XK717+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5327*((XK23+460.)**4-(XK10+460.)**4)/XK1217)
C
C NODE#20
M          XK820=(XK5331*((XK730+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5332*((XK731+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5333*((XK732+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5334*((XK733+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5335*((XK734+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5336*((XK740+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5337*((XK741+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5338*((XK747+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5339*((XK748+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5340*((XK711+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5341*((XK714+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5342*((XK717+460.)**4-(XK10+460.)**4)/XK1217)
M     +          +(XK5343*((XK23+460.)**4-(XK10+460.)**4)/XK1217)
C
C NODE#21
M          XK821=(XK5401*((XK710+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5402*((XK711+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5403*((XK714+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5404*((XK715+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5405*((XK23+460.)**4-(XK10+460.)**4)/XK1221)
C
C NODE#22
M          XK822=(XK5411*((XK765+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5412*((XK766+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5413*((XK767+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5414*((XK710+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5415*((XK718+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5416*((XK719+460.)**4-(XK10+460.)**4)/XK1221)
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M     +          +(XK5417*((XK722+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5418*((XK723+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5419*((XK724+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5420*((XK725+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5421*((XK715+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5422*((XK716+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5423*((XK23+460.)**4-(XK10+460.)**4)/XK1221)
C
C NODE#23
M          XK823=(XK5431*((XK716+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5432*((XK717+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5433*((XK23+460.)**4-(XK10+460.)**4)/XK1221)
C
C NODE#24
M          XK824=(XK5441*((XK730+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5442*((XK731+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5443*((XK732+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5444*((XK711+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5445*((XK714+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5446*((XK717+460.)**4-(XK10+460.)**4)/XK1221)
M     +          +(XK5447*((XK23+460.)**4-(XK10+460.)**4)/XK1221)
C
C NODE#25
M          XK825=(XK5451*((XK716+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5452*((XK717+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5453*((XK23+460.)**4-(XK10+460.)**4)/XK1225)
C
C NODE#26
M          XK826=(XK5461*((XK765+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5462*((XK766+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5463*((XK767+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5464*((XK718+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5465*((XK719+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5466*((XK720+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5467*((XK722+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5468*((XK723+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5469*((XK724+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5470*((XK725+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5471*((XK726+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5472*((XK715+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5473*((XK716+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5474*((XK23+460.)**4-(XK10+460.)**4)/XK1225)
C
C NODE#27
M          XK827=(XK5481*((XK714+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5482*((XK715+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5483*((XK23+460.)**4-(XK10+460.)**4)/XK1225)
C
C NODE#28
M          XK828=(XK5491*((XK730+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5492*((XK731+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5493*((XK732+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5494*((XK714+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5495*((XK717+460.)**4-(XK10+460.)**4)/XK1225)
M     +          +(XK5496*((XK23+460.)**4-(XK10+460.)**4)/XK1225)
C
C NODE#29
M          XK829=(XK5501*((XK716+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5502*((XK717+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5503*((XK23+460.)**4-(XK10+460.)**4)/XK1229)
C
C NODE#30
M          XK830=(XK5511*((XK719+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5512*((XK720+460.)**4-(XK10+460.)**4)/XK1229)
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M     +          +(XK5513*((XK721+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5514*((XK723+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5515*((XK724+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5516*((XK725+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5517*((XK726+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5518*((XK715+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5519*((XK716+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5520*((XK23+460.)**4-(XK10+460.)**4)/XK1229)
C
C NODE#31
M          XK831=(XK5531*((XK714+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5532*((XK715+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5533*((XK23+460.)**4-(XK10+460.)**4)/XK1229)
C
C NODE#32
M          XK832=(XK5541*((XK714+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5542*((XK717+460.)**4-(XK10+460.)**4)/XK1229)
M     +          +(XK5543*((XK23+460.)**4-(XK10+460.)**4)/XK1229)
C
C NODE#33
M          XK171=(XK5551*((XK2009+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5552*((XK701+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5553*((XK702+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5554*((XK704+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5555*((XK706+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5556*((XK707+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5557*((XK789+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5558*((XK790+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5559*((XK793+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5560*((XK794+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5561*((XK754+460.)**4-(XK10+460.)**4)/XK1233)
M          XK172=(XK5562*((XK755+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5563*((XK756+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5564*((XK757+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5565*((XK795+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5566*((XK797+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5567*((XK760+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5568*((XK761+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5569*((XK710+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5570*((XK711+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5571*((XK712+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5572*((XK713+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5573*((XK716+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5574*((XK717+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5575*((XK23+460.)**4-(XK10+460.)**4)/XK1233)
M          XK833=XK171+XK172
C
C NODE#34
M          XK173=(XK5601*((XK701+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5602*((XK702+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5603*((XK706+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5604*((XK707+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5605*((XK789+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5606*((XK790+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5607*((XK791+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5608*((XK792+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5609*((XK793+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5610*((XK794+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5611*((XK795+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5612*((XK796+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5613*((XK797+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5614*((XK761+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5615*((XK710+460.)**4-(XK10+460.)**4)/XK1233)
M     +          +(XK5616*((XK711+460.)**4-(XK10+460.)**4)/XK1233)
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```
M           XK174=(XK5617*((XK712+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5618*((XK713+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5619*((XK715+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5620*((XK716+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5621*((XK23+460.)**4-(XK10+460.)**4)/XK1233)
M           XK834=XK173+XK174
C
C NODE#35
M           XK835=(XK5631*((XK791+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5632*((XK792+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5633*((XK793+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5634*((XK794+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5635*((XK756+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5636*((XK757+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5637*((XK758+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5638*((XK759+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5639*((XK796+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5640*((XK797+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5641*((XK761+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5642*((XK762+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5643*((XK710+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5644*((XK711+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5645*((XK712+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5646*((XK713+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5647*((XK714+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5648*((XK715+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5649*((XK23+460.)**4-(XK10+460.)**4)/XK1233)
C
C NODE#36
M           XK174=(XK5651*((XK701+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5652*((XK704+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5653*((XK706+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5654*((XK707+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5655*((XK754+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5656*((XK755+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5657*((XK756+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5658*((XK757+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5659*((XK758+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5660*((XK759+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5661*((XK797+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5662*((XK760+460.)**4-(XK10+460.)**4)/XK1233)
M           XK175=(XK5663*((XK761+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5664*((XK762+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5665*((XK710+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5666*((XK711+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5667*((XK712+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5668*((XK713+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5669*((XK714+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5670*((XK717+460.)**4-(XK10+460.)**4)/XK1233)
M     +           +(XK5671*((XK23+460.)**4-(XK10+460.)**4)/XK1233)
M           XK836=XK174+XK175
C
C NODE#37
M           XK837=(XK5681*((XK726+460.)**4-(XK10+460.)**4)/XK1237)
M     +           +(XK5682*((XK23+460.)**4-(XK10+460.)**4)/XK1237)
C
C
F           DO 35 N=1,37
M           XK11=0.
M           XK12=0.
M           XK13=0.
M           XK28=0.
M           XK29=0.
M           XK66=0.
```

```
M          XK171=0.
M          XK172=0.
M          XK173=0.
M          XK174=0.
M          XK175=0.
M          XK176=0.
M          TK177=0.
C
M          XK11=(((XK(901+N-1))+(XK(951+N-1))*((XK(601+N-1)+XK10)
M     +    /2.0+460.))/XK(401+N-1))*(XK10-XK(601+N-1))
C
M           T40=XK47
C
M           TFILM=(XK10+T40)/2.0
C
F          AIRCON=2.1E-5*TFILM+.0133
F          COND=AIRCON
C
C=====================================================
C DECIDE FOR NATURAL OR FORCED CONVECTION  COEFFICIENT                    ENT
C=====================================================
C
F           IF(ITEST.EQ.3)GO TO 300
F           IF(ITEST.EQ.2)GO TO 21
F           IF(ITEST.EQ.1)GO TO 300
C
C=====================================================
C***************** NATURAL CONVECTION ***************
C=====================================================
C
F300       IF(TFILM.LE.32.)GRF=-(32500.*TFILM-4.2E6)
F          IF(TFILM.GT.32.)GRF=-20588.*TFILM+3818824.
C
C
M           RA=GRF*ABS(XK10-T40)*.72
F           CONNAT=.1*COND*RA**(1./3.)
M           XK28=CONNAT
F           CONV=CONNAT
F           IF(ITEST.EQ.1)GO TO 31
C
C=========================================================
C******************** FORCED CONVECTION *****************
C=========================================================
C
F21        IF(TFILM.LE.32.)VIS=5.E-7*TFILM+1.3E-4
F           IF(TFILM.GT.32.)VIS=5.15E-7*TFILM+1.2853E-4
C
M           RE=XK(2151+N-1)*XK(1001+N-1)/VIS
M           CONFOR=(.46*RE**.5+.00128*RE)*COND/XK(2151+N-1)
M           XK29=CONFOR
F           CONV=CONFOR
F           IF(ITEST.EQ.2)GO TO 31
C
C=========================================================
C************** NATURAL OR FORCED CONVECTION ************
C=========================================================
C
F           IF(CONNAT.GT.CONFOR) CONV=CONNAT
M          XK(6001+N-1)=CONV*(T40-XK10)
C
C=========================================================
C
M          XK66=100.
M          TF=XK10
```

```
M          RH=XK66
F31        TR=TF+460.0
F          C1=2.6317601E-19
F          E1=23.35631703
F          C2=4.0942242E-16
F          E2=18.75385414
F          IF(TF.LE.33.7708962)W=C1*(TR/100.)**E1
F          IF(TF.GT.33.7708962)W=C2*(TR/100.)**E2
F          W=W*RH/100.
F          WHTY=W
C
C
F           SM=STEST-WHTY
M           XK14=(1.1*CONV*(DMAX1(0.D0,SM))/.24)*1075.16                    $  LAT
C
C
M          XK40=XK(3001+N-1)/XK(1201+N-1)
C
C=========================================================
C                  HEAT BALANCE
C=========================================================
C
M          XK12=XK11-(XK(801+N-1)+XK(6001+N-1)+XK14+XK40)
C
C/////////////////////////////////////////////////////////
C///////////////  ICE RATE  ////////////////////////////
C/////////////////////////////////////////////////////
C
C
C          ZTOT=XK12/143.3
C          XK13=ZTOT*12./57.
C
C     ICE RATE ( LB H2O/FT2/HR )
M          XK16=XK12/143.3
C     ICE RATE (IN/HR)
M          XK13=XK16*12./57.
M          T(701+N-1)=XK13
C=========================================
C     ICE ACCUMMULATION
C=========================================
C
C     ICE FORMATION
C
M         IF(XK13 .GE. 0.0 )THEN
M          T(801+N-1)=T(801+N-1)+XK13*DTIMEI
M          T(901+N-1)=T(901+N-1)+XK16*DTIMEI*XK(1201+N-1)
F         ENDIF
M          XK15=0.
M          XK17=0.
C
C     ICE MELTING
C
M         IF(XK13 .LT. 0.0 )THEN
M          XK15=-XK13*DTIMEI
M          XK17=-XK16*DTIMEI*XK(1201+N-1)
M          T(801+N-1)=T(801+N-1)-XK15
M          T(901+N-1)=T(901+N-1)-XK17
F         ENDIF
C
M          XK18=T(801+N-1)
M          XK19=T(901+N-1)
C
M         IF(XK18 .LT. 0.0 )THEN
M          T(801+N-1)=0.0
```

```
M          T(901+N-1)=0.0
F         ENDIF
C
M          XK36=T(201+N-1)
M         IF(KTEST .EQ. 2)THEN
M          T(401+N-1)=XK36*DTIMEI
F         ENDIF
C
C
F35        CONTINUE
C=====================================================
       END
C*********************************
       BCD 3OUTPUT CALLS
C
F       DIMENSION TAMB(0:23),RELHUM(0:23),CLOUD(0:23)
F       DIMENSION WS(0:23),WD(0:23)
F          INTEGER HR
F          COMMON/ICE/TAMB,RELHUM,CLOUD,WD,WS
C
C
M          IF(KTEST .EQ. 2)THEN
M          RTEST=RTEST+1
M          HR=RTEST
F          ENDIF
C
C
           TPRINT
M          IF(KTEST.EQ.2)THEN
C
M          XK47=TAMB(HR)
M          XK3=RELHUM(HR)
M          XK9=CLOUD(HR)
M          XK260=WD(HR)
M          XK261=WS(HR)
F          ENDIF
C
M       DIF=TIMEND-TIMEN
M      IF(DIF .LT. .01 .AND. KTEST .EQ. 2)THEN
F      STOP
F      ENDIF
       END
       BCD 3END OF DATA
```

SINDA OUTPUT LISTING (STEADY-STATE & TRANSIENT)

```
STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

*** NOTE *** STDSTL REQUIRES    1544 DYNAMIC STORAGE LOCATIONS OUT OF    18964 AVAILABLE ***

****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
    LOOPCT=      0
                    , SENGIN= 1.03689E+08, ENGBAL=-3.32370E+10                          , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

 T   1001 =   36.0000 T   1002 =   36.0000 T   1003 =   36.0000 T   1004 =   36.0000 T   1005 =   36.0000 T   1006 =   36.0000
 T   1007 =   36.0000 T   1008 =   36.0000 T   1009 =   36.0000 T   1010 =   36.0000 T   1011 =   36.0000 T   1012 =   36.0000
 T   1013 =   36.0000 T   1014 =   36.0000 T   1015 =   36.0000 T   1016 =   36.0000 T   1017 =   36.0000 T   1018 =   36.0000
 T   1019 =   36.0000 T   1020 =   36.0000 T   1021 =   36.0000 T   1022 =   36.0000 T   1023 =   36.0000 T   1024 =   36.0000
 T   1025 =   36.0000 T   1026 =   36.0000 T   1027 =   36.0000 T   1028 =   36.0000 T   1029 =   36.0000 T   1030 =   36.0000
 T   1031 =   36.0000 T   1032 =   36.0000 T   1033 =   36.0000 T   1034 =   36.0000 T   1035 =   36.0000 T   1036 =   36.0000
 T   1037 =   36.0000 T   2001 =   36.0000 T   3001 =   36.0000 T   4001 =   36.0000 T   5001 =   36.0000 T   2002 =   36.0000
 T   3002 =   36.0000 T   4002 =   36.0000 T   5002 =   36.0000 T   2003 =   36.0000 T   3003 =   36.0000 T   4003 =   36.0000
 T   5003 =   36.0000 T   2004 =   36.0000 T   3004 =   36.0000 T   4004 =   36.0000 T   5004 =   36.0000 T   2005 =   36.0000
 T   3005 =   36.0000 T   4005 =   36.0000 T   5005 =   36.0000 T   2006 =   36.0000 T   3006 =   36.0000 T   4006 =   36.0000
 T   5006 =   36.0000 T   2007 =   36.0000 T   3007 =   36.0000 T   4007 =   36.0000 T   5007 =   36.0000 T   2008 =   36.0000
 T   3008 =   36.0000 T   4008 =   36.0000 T   5008 =   36.0000 T   2009 =   36.0000 T   3009 =   36.0000 T   4009 =   36.0000
 T   5009 =   36.0000 T   2010 =   36.0000 T   3010 =   36.0000 T   4010 =   36.0000 T   5010 =   36.0000 T   2011 =   36.0000
 T   3011 =   36.0000 T   4011 =   36.0000 T   5011 =   36.0000 T   2012 =   36.0000 T   3012 =   36.0000 T   4012 =   36.0000
 T   5012 =   36.0000 T   2013 =   36.0000 T   3013 =   36.0000 T   4013 =   36.0000 T   5013 =   36.0000 T   2014 =   36.0000
 T   3014 =   36.0000 T   4014 =   36.0000 T   5014 =   36.0000 T   2015 =   36.0000 T   3015 =   36.0000 T   4015 =   36.0000
 T   5015 =   36.0000 T   2016 =   36.0000 T   3016 =   36.0000 T   4016 =   36.0000 T   5016 =   36.0000 T   2017 =   50.0000
 T   3017 =   50.0000 T   4017 =   50.0000 T   5017 =   50.0000 T   2018 =   50.0000 T   3018 =   50.0000 T   4018 =   50.0000
 T   5018 =   50.0000 T   2019 =   50.0000 T   3019 =   50.0000 T   4019 =   50.0000 T   5019 =   50.0000 T   2020 =   50.0000
 T   3020 =   50.0000 T   4020 =   50.0000 T   5020 =   50.0000 T   2021 =   36.0000 T   3021 =   36.0000 T   4021 =   36.0000
 T   5021 =   36.0000 T   2022 =   36.0000 T   3022 =   36.0000 T   4022 =   36.0000 T   5022 =   36.0000 T   2023 =   36.0000
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 T  21010 =   50.0000 T  21011 =   50.0000 T  21013 =   50.0000 T  21014 =   50.0000 T  21015 =   50.0000 T  21004 =   50.0000
 T  21008 =   50.0000 T  21012 =   50.0000 T  21016 =   50.0000 T  21017 =   50.0000 T  21018 =   50.0000 T  21019 =   50.0000
 T  21020 =   50.0000 T  21021 =   50.0000 T  21022 =   50.0000 T  21023 =   50.0000 T  21024 =   50.0000 T  21025 =   50.0000
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 T  21032 =   50.0000 T  21033 =   50.0000 T  21034 =   50.0000 T  21035 =   50.0000 T  21036 =   50.0000 T  21037 =   50.0000
 T  12001 =   50.0000 T  12002 =   50.0000 T  12003 =   50.0000 T  12004 =   50.0000 T  12041 =   50.0000 T  12042 =   50.0000
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 T  12085 =   50.0000 T  12086 =   50.0000 T  12087 =   50.0000 T  12088 =   50.0000 T  12005 =   70.0000 T  12012 =   70.0000
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 T  12007 =   70.0000 T  12014 =   70.0000 T  12021 =   70.0000 T  12028 =   70.0000 T  12008 =   70.0000 T  12015 =   70.0000
 T  12022 =   70.0000 T  12029 =   70.0000 T  12009 =   70.0000 T  12016 =   70.0000 T  12023 =   70.0000 T  12030 =   70.0000
 T  12010 =   70.0000 T  12017 =   70.0000 T  12024 =   70.0000 T  12031 =   70.0000 T  12011 =   70.0000 T  12018 =   70.0000
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 T  12049 =   70.0000 T  12056 =   70.0000 T  12063 =   70.0000 T  12070 =   70.0000 T  12050 =   70.0000 T  12057 =   70.0000
 T  12064 =   70.0000 T  12071 =   70.0000 T  12051 =   70.0000 T  12058 =   70.0000 T  12065 =   70.0000 T  12072 =   70.0000
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
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 T  32071 =   82.0000 T  32072 =   82.0000 T  32073 =   82.0000 T  32074 =   82.0000 T  32075 =  -82.0000 T  32076 =   82.0000
```

```
T  32077 -   82.0000 T  32078 -   82.0000 T  32079 -   82.0000 T  32080 -   82.0000 T  32081 -   82.0000 T  32082 -   82.0000
T  32083 -   82.0000 T  32084 -   82.0000 T  33005 -   82.0000 T  33006 -   82.0000 T  33007 -   82.0000 T  33008 -   82.0000
T  33009 -   82.0000 T  33010 -   82.0000 T  33011 -   82.0000 T  33012 -   82.0000 T  33013 -   82.0000 T  33014 -   82.0000
T  33015 -   82.0000 T  33016 -   82.0000 T  33017 -   82.0000 T  33018 -   82.0000 T  33019 -   82.0000 T  33020 -   82.0000
T  33021 -   82.0000 T  33022 -   82.0000 T  33023 -   82.0000 T  33024 -   82.0000 T  33025 -   82.0000 T  33026 -   82.0000
T  33027 -   82.0000 T  33028 -   82.0000 T  33029 -   82.0000 T  33030 -   82.0000 T  33031 -   82.0000 T  33032 -   82.0000
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T  33059 -   82.0000 T  33060 -   82.0000 T  33061 -   82.0000 T  33062 -   82.0000 T  33063 -   82.0000 T  33064 -   82.0000
T  33065 -   82.0000 T  33066 -   82.0000 T  33067 -   82.0000 T  33068 -   82.0000 T  33069 -   82.0000 T  33070 -   82.0000
T  33071 -   82.0000 T  33072 -   82.0000 T  33073 -   82.0000 T  33074 -   82.0000 T  33075 -   82.0000 T  33076 -   82.0000
T  33077 -   82.0000 T  33078 -   82.0000 T  33079 -   82.0000 T  33080 -   82.0000 T  33081 -   82.0000 T  33082 -   82.0000
T  33083 -   82.0000 T  33084 -   82.0000 T  34005 -   82.0000 T  34006 -   82.0000 T  34007 -   82.0000 T  34008 -   82.0000
T  34009 -   82.0000 T  34010 -   82.0000 T  34011 -   82.0000 T  34012 -   82.0000 T  34013 -   82.0000 T  34014 -   82.0000
T  34015 -   82.0000 T  34016 -   82.0000 T  34017 -   82.0000 T  34018 -   82.0000 T  34019 -   82.0000 T  34020 -   82.0000
T  34021 -   82.0000 T  34022 -   82.0000 T  34023 -   82.0000 T  34024 -   82.0000 T  34025 -   82.0000 T  34026 -   82.0000
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
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T  34059 -   82.0000 T  34060 -   82.0000 T  34061 -   82.0000 T  34062 -   82.0000 T  34063 -   82.0000 T  34064 -   82.0000
T  34065 -   82.0000 T  34066 -   82.0000 T  34067 -   82.0000 T  34068 -   82.0000 T  34069 -   82.0000 T  34070 -   82.0000
T  34071 -   82.0000 T  34072 -   82.0000 T  34073 -   82.0000 T  34074 -   82.0000 T  34075 -   82.0000 T  34076 -   82.0000
T  34077 -   82.0000 T  34078 -   82.0000 T  34079 -   82.0000 T  34080 -   82.0000 T  34081 -   82.0000 T  34082 -   82.0000
T  34083 -   82.0000 T  34084 -   82.0000 T  42006 -   70.0000 T  42013 -   70.0000 T  42020 -   70.0000 T  42027 -   70.0000
T  42008 -   70.0000 T  42015 -   70.0000 T  42022 -   70.0000 T  42029 -   70.0000 T  42010 -   70.0000 T  42017 -   70.0000
T  42024 -   70.0000 T  42031 -   70.0000 T  42050 -   70.0000 T  42057 -   70.0000 T  42064 -   70.0000 T  42071 -   70.0000
T  42052 -   70.0000 T  42059 -   70.0000 T  42066 -   70.0000 T  42073 -   70.0000 T  42054 -   70.0000 T  42061 -   70.0000
T  42068 -   70.0000 T  42075 -   70.0000 T  43006 -   70.0000 T  43013 -   70.0000 T  43020 -   70.0000 T  43027 -   70.0000
T  43008 -   70.0000 T  43015 -   70.0000 T  43022 -   70.0000 T  43029 -   70.0000 T  43010 -   70.0000 T  43017 -   70.0000
T  43024 -   70.0000 T  43031 -   70.0000 T  43050 -   70.0000 T  43057 -   70.0000 T  43064 -   70.0000 T  43071 -   70.0000
T  43052 -   70.0000 T  43059 -   70.0000 T  43066 -   70.0000 T  43073 -   70.0000 T  43054 -   70.0000 T  43061 -   70.0000
T  43068 -   70.0000 T  43075 -   70.0000 T   8000 -   50.0000 T   8005 -   50.0000 T   8010 -   50.0000 T   8011 -   50.0000
T   8015 -   50.0000 T   8016 -   50.0000 T   8020 -   50.0000 T   8025 -   50.0000 T   8030 -   50.0000 T   8035 -   50.0000
T   6000 -   50.0000 T   6010 -   50.0000 T   6020 -   50.0000 T   6030 -   50.0000 T   6040 -   50.0000 T   6050 -   50.0000
T   6060 -   50.0000 T   6070 -   50.0000 T   6080 -   50.0000 T   6090 -   50.0000 T   6001 -   50.0000 T   6011 -   50.0000
T   6021 -   50.0000 T   6031 -   50.0000 T   6041 -   50.0000 T   6051 -   50.0000 T   6061 -   50.0000 T   6071 -   50.0000
T   6081 -   50.0000 T   6091 -   50.0000 T    500 -   50.0000 T    501 -   50.0000 T    502 -   50.0000 T    503 -   50.0000
T   9000 -   50.0000 T   9001 -   50.0000 T   9002 -   50.0000 T   9003 -   50.0000 T     40 -   63.2000 T   9999 -   34.7631
T   7000 - -423.0000 T   7001 - -297.0000 T   7002 -   55.0000 T   7003 -   80.0000 T   8888 -   63.2000 T   8889 -   28.4000
T   8890 -    0.0000 T   8891 -  240.0000 T   8892 -   12.0000 T  13001 -    0.0000 T  13002 -    0.0000 T  13003 -    0.0000
T  13004 -    0.0000 T  13005 -    0.0000 T  13006 -    0.0000 T  13007 -    0.0000 T  13008 -    0.0000 T  13009 -    0.0000
T  13010 -    0.0000 T  13011 -    0.0000 T  13012 -    0.0000 T  13013 -    0.0000 T  13014 -    0.0000 T  13015 -    0.0000
T  13016 -    0.0000 T  13017 -    0.0000 T  13018 -    0.0000 T  13019 -    0.0000 T  13020 -    0.0000 T  13021 -    0.0000
T  13022 -    0.0000 T  13023 -    0.0000 T  13024 -    0.0000 T  13025 -    0.0000 T  13026 -    0.0000 T  13027 -    0.0000
T  13028 -    0.0000 T  13029 -    0.0000 T  13030 -    0.0000 T  13031 -    0.0000 T  13032 -    0.0000 T  13033 -    0.0000
T  13034 -    0.0000 T  13035 -    0.0000 T  13036 -    0.0000 T  13037 -    0.0000 T  16001 -    0.0000 T  16002 -    0.0000
T  16003 -    0.0000 T  16004 -    0.0000 T  16005 -    0.0000 T  16006 -    0.0000 T  16007 -    0.0000 T  16008 -    0.0000
T  16009 -    0.0000 T  16010 -    0.0000 T  16011 -    0.0000 T  16012 -    0.0000 T  16013 -    0.0000 T  16014 -    0.0000
T  16015 -    0.0000 T  16016 -    0.0000 T  16017 -    0.0000 T  16018 -    0.0000 T  16019 -    0.0000 T  16020 -    0.0000
T  16021 -    0.0000 T  16022 -    0.0000 T  16023 -    0.0000 T  16024 -    0.0000 T  16025 -    0.0000 T  16026 -    0.0000
T  16027 -    0.0000 T  16028 -    0.0000 T  16029 -    0.0000 T  16030 -    0.0000 T  16031 -    0.0000 T  16032 -    0.0000
T  16033 -    0.0000 T  16034 -    0.0000 T  16035 -    0.0000 T  16036 -    0.0000 T  16037 -    0.0000 T    101 -   10.8977
T    102 -   11.2218 T    103 -   11.4244 T    104 -   11.6675 T    105 -   12.3967 T    106 -   11.4244 T    107 -   11.5864
T    108 -   12.3562 T    109 -   13.1259 T    110 -   13.3284 T    111 -   13.1259 T    112 -   12.8828 T    113 -    7.0491
T    114 -    8.0619 T    115 -    8.3050 T    116 -    9.0747 T    117 -   13.3284 T    118 -   14.0172 T    119 -   13.5715
T    120 -    9.8444 T    121 -   14.9084 T    122 -   15.1920 T    123 -   14.5438 T    124 -    9.7634 T    125 -   18.4330
T    126 -   18.1494 T    127 -   19.2837 T    128 -   13.8146 T    129 -   14.9894 T    130 -   17.2176 T    131 -   18.2304
T    132 -   18.2304 T    133 -   16.0428 T    134 -   14.9084 T    135 -   13.7741 T    136 -    9.5608 T    137 -   24.3072
T    151 -    0.5380 T    152 -    0.5540 T    153 -    0.5640 T    154 -    0.5760 T    155 -    0.6120 T    156 -    0.5640
T    157 -    0.5720 T    158 -    0.6100 T    159 -    0.6480 T    160 -    0.6580 T    161 -    0.6480 T    162 -    0.6360
T    163 -    0.3480 T    164 -    0.3980 T    165 -    0.4100 T    166 -    0.4480 T    167 -    0.6580 T    168 -    0.6920
T    169 -    0.6700 T    170 -    0.4860 T    171 -    0.7360 T    172 -    0.7500 T    173 -    0.7180 T    174 -    0.4820
T    175 -    0.9100 T    176 -    0.8960 T    177 -    0.9520 T    178 -    0.6820 T    179 -    0.7400 T    180 -    0.8500
T    181 -    0.9000 T    182 -    0.9000 T    183 -    0.7920 T    184 -    0.7360 T    185 -    0.6800 T    186 -    0.4720
T    187 -    1.2000 T    201 -    0.0000 T    202 -    0.0000 T    203 -    0.0000 T    204 -    0.0000 T    205 -    0.0000
T    206 -    0.0000 T    207 -    0.0000 T    208 -    0.0000 T    209 -    0.0000 T    210 -    0.0000 T    211 -    0.0000
T    212 -    0.0000 T    213 -    0.0000 T    214 -    0.0000 T    215 -    0.0000 T    216 -    0.0000 T    217 -    0.0000
T    218 -    0.0000 T    219 -    0.0000 T    220 -    0.0000 T    221 -    0.0000 T    222 -    0.0000 T    223 -    0.0000
T    224 -    0.0000 T    225 -    0.0000 T    226 -    0.0000 T    227 -    0.0000 T    228 -    0.0000 T    229 -    0.0000
T    230 -    0.0000 T    231 -    0.0000 T    232 -    0.0000 T    233 -    0.0000 T    234 -    0.0000 T    235 -    0.0000
T    236 -    0.0000 T    237 -    0.0000 T    401 -    0.0000 T    402 -    0.0000 T    403 -    0.0000 T    404 -    0.0000
T    405 -    0.0000 T    406 -    0.0000 T    407 -    0.0000 T    408 -    0.0000 T    409 -    0.0000 T    410 -    0.0000
T    411 -    0.0000 T    412 -    0.0000 T    413 -    0.0000 T    414 -    0.0000 T    415 -    0.0000 T    416 -    0.0000
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T    417 -    0.0000 T    418 -    0.0000 T    419 -    0.0000 T    420 -    0.0000 T    421 -    0.0000 T    422 -    0.0000
T    423 -    0.0000 T    424 -    0.0000 T    425 -    0.0000 T    426 -    0.0000 T    427 -    0.0000 T    428 -    0.0000
T    429 -    0.0000 T    430 -    0.0000 T    431 -    0.0000 T    432 -    0.0000 T    433 -    0.0000 T    434 -    0.0000
T    435 -    0.0000 T    436 -    0.0000 T    437 -    0.0000 T    701 -    1.0000 T    702 -    1.0000 T    703 -    1.0000
T    704 -    1.0000 T    705 -    1.0000 T    706 -    1.0000 T    707 -    1.0000 T    708 -    1.0000 T    709 -    1.0000
T    710 -    1.0000 T    711 -    1.0000 T    712 -    1.0000 T    713 -    1.0000 T    714 -    1.0000 T    715 -    1.0000
T    716 -    1.0000 T    717 -    1.0000 T    718 -    1.0000 T    719 -    1.0000 T    720 -    1.0000 T    721 -    1.0000
T    722 -    1.0000 T    723 -    1.0000 T    724 -    1.0000 T    725 -    1.0000 T    726 -    1.0000 T    727 -    1.0000
T    728 -    1.0000 T    729 -    1.0000 T    730 -    1.0000 T    731 -    1.0000 T    732 -    1.0000 T    733 -    1.0000
T    734 -    1.0000 T    735 -    1.0000 T    736 -    1.0000 T    737 -    1.0000 T    801 -    0.0000 T    802 -    0.0000
T    803 -    0.0000 T    804 -    0.0000 T    805 -    0.0000 T    806 -    0.0000 T    807 -    0.0000 T    808 -    0.0000
T    809 -    0.0000 T    810 -    0.0000 T    811 -    0.0000 T    812 -    0.0000 T    813 -    0.0000 T    814 -    0.0000
T    815 -    0.0000 T    816 -    0.0000 T    817 -    0.0000 T    818 -    0.0000 T    819 -    0.0000 T    820 -    0.0000
T    821 -    0.0000 T    822 -    0.0000 T    823 -    0.0000 T    824 -    0.0000 T    825 -    0.0000 T    826 -    0.0000
T    827 -    0.0000 T    828 -    0.0000 T    829 -    0.0000 T    830 -    0.0000 T    831 -    0.0000 T    832 -    0.0000
T    833 -    0.0000 T    834 -    0.0000 T    835 -    0.0000 T    836 -    0.0000 T    837 -    0.0000 T    901 -    0.0000
T    902 -    0.0000 T    903 -    0.0000 T    904 -    0.0000 T    905 -    0.0000 T    906 -    0.0000 T    907 -    0.0000
T    908 -    0.0000 T    909 -    0.0000 T    910 -    0.0000 T    911 -    0.0000 T    912 -    0.0000 T    913 -    0.0000
T    914 -    0.0000 T    915 -    0.0000 T    916 -    0.0000 T    917 -    0.0000 T    918 -    0.0000 T    919 -    0.0000
T    920 -    0.0000 T    921 -    0.0000 T    922 -    0.0000 T    923 -    0.0000 T    924 -    0.0000 T    925 -    0.0000
T    926 -    0.0000 T    927 -    0.0000 T    928 -    0.0000 T    929 -    0.0000 T    930 -    0.0000 T    931 -    0.0000
T    932 -    0.0000 T    933 -    0.0000 T    934 -    0.0000 T    935 -    0.0000 T    936 -    0.0000 T    937 -    0.0000

STDSTL RUN, ARLXCA=0.50000E-01, DRLXCA=0.50000E-01, BALENG=0.10000E+31, BENODE=0.50000E+30, NLOOP=   1600

*** NOTE *** RELAXATION CRITERIA HAS BEEN MET WITH LOOPCT =    588
```

```
    ENGBAL = -370.971      AT LOOPCT =     588

*** NOTE *** SYSTEM ENERGY BALANCE CRITERIA HAS BEEN MET, ENGBAL = -370.971     , LOOPCT =     588

    EBNODE(  12007)= -313.113      AT LOOPCT=     588

*** NOTE *** NODAL ENERGY BALANCE CRITERIA HAS BEEN MET, EBNODE(  12007)= -313.113     , LOOPCT =     588

****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(       0)= 0.00000E+00, ATMPCC(       0)= 0.00000E+00, DTMPCC(       0)= 0.00000E+00
    LOOPCT=   588                                                      , ARLXCC(       0)= 0.00000E+00, DRLXCC(  33028)= 2.24799E-02
                  , SENGIN= 5.74391E+05, ENGBAL=-3.70958E+02

 T   1001 =   39.9108 T   1002 =   35.9095 T   1003 =   37.1033 T   1004 =   40.3810 T   1005 =   43.9132 T   1006 =   38.3889
 T   1007 =   40.1427 T   1008 =   42.8596 T   1009 =   44.4107 T   1010 =   40.5095 T   1011 =   40.4694 T   1012 =   42.3742
 T   1013 =   36.2534 T   1014 =   33.2981 T   1015 =   34.5560 T   1016 =   38.1149 T   1017 =   54.8118 T   1018 =   57.2593
 T   1019 =   55.6909 T   1020 =   55.4715 T   1021 =   41.6694 T   1022 =   42.6810 T   1023 =   41.4785 T   1024 =   36.7089
 T   1025 =   45.2448 T   1026 =   45.4224 T   1027 =   46.3580 T   1028 =   41.8105 T   1029 =   50.4351 T   1030 =   50.7885
 T   1031 =   51.4452 T   1032 =   51.2953 T   1033 =   46.3063 T   1034 =   46.4927 T   1035 =   43.8276 T   1036 =   41.8282
 T   1037 =   59.6327 T   2001 =    4.0594 T   3001 =  -78.3443 T   4001 = -182.6490 T   5001 = -327.5227 T   2002 =    0.2865
 T   3002 =  -81.6223 T   4002 = -184.9975 T   5002 = -328.5182 T   2003 =    1.4121 T   3003 =  -80.6443 T   4003 = -184.2966
 T   5003 = -328.2208 T   2004 =    4.5030 T   3004 =  -77.9583 T   4004 = -182.3717 T   5004 = -327.4036 T   2005 =    7.8340
 T   3005 =  -75.0635 T   4005 = -180.2961 T   5005 = -326.5187 T   2006 =    2.6246 T   3006 =  -79.5901 T   4006 = -183.5402
 T   5006 = -327.8966 T   2007 =    4.2790 T   3007 =  -78.1521 T   4007 = -182.5097 T   5007 = -327.4595 T   2008 =    6.8405
 T   3008 =  -75.9266 T   4008 = -180.9145 T   5008 = -326.7814 T   2009 =    8.3031 T   3009 =  -74.6559 T   4009 = -180.0041
 T   5009 = -326.3950 T   2010 =    4.6243 T   3010 =  -77.8524 T   4010 = -182.2946 T   5010 = -327.3666 T   2011 =    4.5862
 T   3011 =  -77.8859 T   4011 = -182.3189 T   5011 = -327.3776 T   2012 =    6.3827 T   3012 =  -76.3244 T   4012 = -181.1998
 T   5012 = -326.9031 T   2013 =    0.6104 T   3013 =  -81.3418 T   4013 = -184.7979 T   5013 = -328.4379 T   2014 =   -2.1761
 T   3014 =  -83.7625 T   4014 = -186.5318 T   5014 = -329.1720 T   2015 =   -0.9901 T   3015 =  -82.7321 T   4015 = -185.7935
 T   5015 = -328.8587 T   2016 =    2.3666 T   3016 =  -79.8144 T   4016 = -183.7020 T   5016 = -327.9695 T   2017 =   54.8350
 T   3017 =   54.8816 T   4017 =   54.9285 T   5017 =   54.9758 T   2018 =   56.9771 T   3018 =   56.4124 T   4018 =   55.8473
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
 T   5018 =   55.2822 T   2019 =   55.6042 T   3019 =   55.4311 T   4019 =   55.2582 T   5019 =   55.0858 T   2020 =   55.4124
 T   3020 =   55.2941 T   4020 =   55.1760 T   5020 =   55.0583 T   2021 =   11.5892 T   3021 =  -55.6923 T   4021 = -137.9198
 T   5021 = -238.7494 T   2022 =   12.5296 T   3022 =  -54.9131 T   4022 = -137.3440 T   5022 = -238.5286 T   2023 =   11.4117
 T   3023 =  -55.8393 T   4023 = -138.0284 T   5023 = -238.7911 T   2024 =    6.9771 T   3024 =  -59.5148 T   4024 = -140.7352
 T   5024 = -239.8287 T   2025 =   14.9130 T   3025 =  -52.9384 T   4025 = -135.8845 T   5025 = -237.9690 T   2026 =   15.0781
 T   3026 =  -52.8016 T   4026 = -135.7834 T   5026 = -237.9305 T   2027 =   15.9481 T   3027 =  -52.0805 T   4027 = -135.2500
 T   5027 = -237.7260 T   2028 =   11.7201 T   3028 =  -55.5846 T   4028 = -137.8409 T   5028 = -238.7197 T   2029 =   19.7387
 T   3029 =  -48.9389 T   4029 = -132.9270 T   5029 = -236.8408 T   2030 =   20.0674 T   3030 =  -48.6661 T   4030 = -132.7246
 T   5030 = -236.7625 T   2031 =   20.6782 T   3031 =  -48.1593 T   4031 = -132.3490 T   5031 = -236.6183 T   2032 =   20.5389
 T   3032 =  -48.2749 T   4032 = -132.4347 T   5032 = -236.6511 T   2033 =    9.6823 T   3033 =  -73.6959 T   4033 = -176.0278
 T   5033 = -323.4097 T   2034 =    9.8589 T   3034 =  -73.5499 T   4034 = -175.9206 T   5034 = -323.3646 T   2035 =    7.3318
 T   3035 =  -75.6412 T   4035 = -177.4606 T   5035 = -324.0280 T   2036 =    5.4358 T   3036 =  -77.2104 T   4036 = -178.6164
 T   5036 = -324.5270 T   2037 =   62.1994 T   3037 =   67.3144 T   4037 =   72.4050 T   5037 =   77.4716 T  21001 = -422.9849
 T  21002 = -422.9801 T  21003 = -422.9811 T  21005 = -422.9840 T  21006 = -422.9793 T  21007 = -422.9812 T  21009 = -422.9848
 T  21010 = -422.9801 T  21011 = -422.9807 T  21013 = -422.9845 T  21014 = -422.9804 T  21015 = -422.9814 T  21004 = -422.9841
 T  21008 = -422.9831 T  21012 = -422.9832 T  21016 = -422.9832 T  21017 =   54.9998 T  21018 =   54.9999 T  21019 =   54.9999
 T  21020 =   54.9999 T  21021 = -296.9904 T  21022 = -296.9904 T  21023 = -296.9905 T  21024 = -296.9908 T  21025 = -296.9906
 T  21026 = -296.9909 T  21027 = -296.9911 T  21028 = -296.9908 T  21029 = -296.9969 T  21030 = -296.9965 T  21031 = -296.9966
 T  21032 = -296.9965 T  21033 = -422.9845 T  21034 = -422.9855 T  21035 = -422.9852 T  21036 = -422.9861 T  21037 =   79.9992
 T  12001 =   54.7129 T  12002 =   55.1561 T  12003 =   55.8753 T  12004 =   54.5742 T  12041 =   54.1626 T  12042 =   54.1492
 T  12043 =   49.5001 T  12044 =   51.8081 T  12045 =   54.8783 T  12046 =   56.3569 T  12047 =   57.3650 T  12048 =   58.8487
 T  12085 =   54.9650 T  12086 =   55.8601 T  12087 =   53.1583 T  12088 =   54.3406 T  12005 =   52.8848 T  12012 =   56.6518
 T  12019 =   54.5445 T  12026 =   51.5627 T  12006 =   52.5360 T  12013 =   52.6721 T  12020 =   54.2154 T  12027 =   51.5375
 T  12007 =   51.8192 T  12014 =   50.6635 T  12021 =   53.8146 T  12028 =   50.2529 T  12008 =   48.0501 T  12015 =   50.7495
 T  12022 =   53.4054 T  12029 =   48.5874 T  12009 =   49.7864 T  12016 =   51.7248 T  12023 =   53.1672 T  12030 =   51.2201
 T  12010 =   48.9525 T  12017 =   51.9831 T  12024 =   52.3800 T  12031 =   52.1047 T  12011 =   51.8961 T  12018 =   51.5650
 T  12025 =   49.3681 T  12032 =   50.6024 T  12033 =   56.9654 T  12034 =   56.7082 T  12035 =   55.5150 T  12036 =   55.1230
 T  12037 =   52.8826 T  12038 =   53.0418 T  12039 =   49.2449 T  12040 =   49.9359 T  22001 =   54.6981 T  22002 =   55.1903
 T  22003 =   55.7477 T  22004 =   54.5874 T  22041 =   54.2495 T  22042 =   54.0358 T  22043 =   49.8584 T  22044 =   51.6699
 T  12049 =   52.6852 T  12056 =   55.6345 T  12063 =   55.3077 T  12070 =   59.6257 T  12050 =   52.4257 T  12057 =   55.6611
 T  12064 =   55.0353 T  12071 =   57.6129 T  12051 =   52.8632 T  12058 =   55.9500 T  12065 =   54.9891 T  12072 =   57.1268
 T  12052 =   53.4816 T  12059 =   56.1960 T  12066 =   55.1242 T  12073 =   57.3322 T  12053 =   55.2681 T  12060 =   56.6482
 T  12067 =   55.6124 T  12074 =   57.2308 T  12054 =   56.1611 T  12061 =   56.6636 T  12068 =   55.9350 T  12075 =   57.4604
 T  12055 =   57.8996 T  12062 =   56.6183 T  12069 =   56.2279 T  12076 =   57.7577 T  12077 =   58.8160 T  12078 =   57.3822
 T  12079 =   56.2104 T  12080 =   56.4576 T  12081 =   55.9024 T  12082 =   54.3307 T  12083 =   55.2607 T  12084 =   53.7846
 T  22045 =   55.1087 T  22046 =   56.3297 T  22047 =   57.3374 T  22048 =   58.5877 T  22085 =   54.9941 T  22086 =   55.7352
 T  22087 =   53.2936 T  22088 =   54.3011 T  22005 =   52.8848 T  22006 =   52.5360 T  22007 =   51.8192 T  22008 =   48.0501
 T  22009 =   49.7864 T  22010 =   48.9525 T  22011 =   51.8961 T  22012 =   56.6518 T  22013 =   52.6721 T  22014 =   50.6635
 T  22015 =   50.7495 T  22016 =   51.7248 T  22017 =   51.9831 T  22018 =   51.5650 T  22019 =   54.5445 T  22020 =   54.2154
 T  22021 =   53.8146 T  22022 =   53.4054 T  22023 =   53.1672 T  22024 =   52.3800 T  22025 =   49.3681 T  22026 =   51.5627
 T  22027 =   51.5375 T  22028 =   50.2529 T  22029 =   48.5874 T  22030 =   51.2201 T  22031 =   52.1047 T  22032 =   50.6024
 T  22049 =   52.6852 T  22050 =   52.4257 T  22051 =   52.8632 T  22052 =   53.4816 T  22053 =   55.2681 T  22054 =   56.1611
 T  22055 =   57.8996 T  22056 =   55.6345 T  22057 =   55.6611 T  22058 =   55.9500 T  22059 =   56.1960 T  22060 =   56.6482
 T  22061 =   56.6636 T  22062 =   56.6183 T  22063 =   55.3077 T  22064 =   55.0353 T  22065 =   54.9891 T  22066 =   55.1242
 T  22067 =   55.6124 T  22068 =   55.9350 T  22069 =   56.2279 T  22070 =   59.6257 T  22071 =   57.6129 T  22072 =   57.1268
 T  22073 =   57.3322 T  22074 =   57.2308 T  22075 =   57.4604 T  22076 =   57.7577 T  22033 =   56.9654 T  22034 =   56.7082
 T  22035 =   55.5150 T  22036 =   55.1230 T  22037 =   52.8826 T  22038 =   53.0418 T  22039 =   49.2449 T  22040 =   49.9359
 T  22077 =   58.8160 T  22078 =   57.3822 T  22079 =   56.2104 T  22080 =   56.4576 T  22081 =   55.9024 T  22082 =   54.3307
 T  22083 =   55.2607 T  22084 =   53.7846 T  31005 =   52.8848 T  31006 =   52.5366 T  31007 =   51.8167 T  31008 =   48.0468
 T  31009 =   49.7865 T  31010 =   48.9526 T  31011 =   51.8961 T  31012 =   56.6555 T  31013 =   52.7000 T  31014 =   50.6644
 T  31015 =   50.7496 T  31016 =   51.7247 T  31017 =   51.9831 T  31018 =   51.5650 T  31019 =   54.5446 T  31020 =   54.2157
 T  31021 =   53.8146 T  31022 =   53.4133 T  31023 =   53.1671 T  31024 =   52.3800 T  31025 =   49.3681 T  31026 =   51.5628
 T  31027 =   51.5375 T  31028 =   50.2148 T  31029 =   48.5884 T  31030 =   51.2201 T  31031 =   52.1047 T  31032 =   50.6024
 T  31033 =   56.9654 T  31034 =   56.7082 T  31035 =   55.5150 T  31036 =   55.1230 T  31037 =   52.8826 T  31038 =   53.0418
 T  31039 =   49.2449 T  31040 =   49.9356 T  31049 =   52.6852 T  31050 =   52.4257 T  31051 =   52.8482 T  31052 =   53.4833
 T  31053 =   55.2682 T  31054 =   56.1611 T  31055 =   57.8996 T  31056 =   55.6345 T  31057 =   55.6611 T  31058 =   55.9500
 T  31059 =   56.1960 T  31060 =   56.6482 T  31061 =   56.6637 T  31062 =   56.6183 T  31063 =   55.3077 T  31064 =   55.0353
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
 T  31065 =   54.9891 T  31066 =   55.1242 T  31067 =   55.6124 T  31068 =   55.9350 T  31069 =   56.2279 T  31070 =   59.6257
 T  31071 =   57.6128 T  31072 =   57.1269 T  31073 =   57.3451 T  31074 =   57.2318 T  31075 =   57.4605 T  31076 =   57.7577
 T  31077 =   58.8160 T  31078 =   57.3822 T  31079 =   56.2104 T  31080 =   56.4576 T  31081 =   55.9024 T  31082 =   54.3307
 T  31083 =   55.2607 T  31084 =   53.7846 T  32005 =   52.8848 T  32006 =   52.5372 T  32007 =   51.8138 T  32008 =   48.0421
 T  32009 =   49.7866 T  32010 =   48.9526 T  32011 =   51.8961 T  32012 =   56.6589 T  32013 =   52.7252 T  32014 =   50.6655
 T  32015 =   50.7498 T  32016 =   51.7247 T  32017 =   51.9831 T  32018 =   51.5650 T  32019 =   54.5446 T  32020 =   54.2160
 T  32021 =   53.8147 T  32022 =   53.4204 T  32023 =   53.1671 T  32024 =   52.3800 T  32025 =   49.3681 T  32026 =   51.5628
 T  32027 =   51.5375 T  32028 =   50.1801 T  32029 =   48.5892 T  32030 =   51.2201 T  32031 =   52.1047 T  32032 =   50.6024
 T  32033 =   56.9655 T  32034 =   56.7082 T  32035 =   55.5150 T  32036 =   55.1230 T  32037 =   52.8826 T  32038 =   53.0418
 T  32039 =   49.2449 T  32040 =   49.9354 T  32049 =   52.6852 T  32050 =   52.4257 T  32051 =   52.8346 T  32052 =   53.4849
 T  32053 =   55.2684 T  32054 =   56.1611 T  32055 =   57.8996 T  32056 =   55.6345 T  32057 =   55.6611 T  32058 =   55.9500
 T  32059 =   56.1960 T  32060 =   56.6482 T  32061 =   56.6637 T  32062 =   56.6183 T  32063 =   55.3077 T  32064 =   55.0353
 T  32065 =   54.9891 T  32066 =   55.1242 T  32067 =   55.6124 T  32068 =   55.9350 T  32069 =   56.2279 T  32070 =   59.6257
 T  32071 =   57.6128 T  32072 =   57.1271 T  32073 =   57.3570 T  32074 =   57.2326 T  32075 =   57.4605 T  32076 =   57.7577
```

32077 =	58.8160 T	32078 =	57.3822 T	32079 =	[illegible] T	32080 =	56.4576 T	32081 =	55.9024 T	32082 =	54.3307
32083 =	55.2607 T	32084 =	53.7846 T	33005 =	[illegible] T	33006 =	52.5375 T	33007 =	51.8122 T	33008 =	48.0395
33009 =	49.7866 T	33010 =	48.9526 T	33011 =	[illegible] T	33012 =	56.6607 T	33013 =	52.7387 T	33014 =	50.6661
33015 =	50.7498 T	33016 =	51.7246 T	33017 =	[illegible] T	33018 =	51.5650 T	33019 =	54.5446 T	33020 =	54.2162
33021 =	53.8147 T	33022 =	53.4243 T	33023 =	[illegible] T	33024 =	52.3800 T	33025 =	49.3681 T	33026 =	51.5628
33027 =	51.5375 T	33028 =	50.1616 T	33029 =	[illegible] T	33030 =	51.2201 T	33031 =	52.1047 T	33032 =	50.6024
33033 =	56.9655 T	33034 =	56.7082 T	33035 =	[illegible] T	33036 =	55.1230 T	33037 =	52.8826 T	33038 =	53.0418
33039 =	49.2449 T	33040 =	49.9352 T	33049 =	[illegible] T	33050 =	52.4257 T	33051 =	52.8273 T	33052 =	53.4858
33053 =	55.2685 T	33054 =	56.1611 T	33055 =	[illegible] T	33056 =	55.6345 T	33057 =	55.6611 T	33058 =	55.9500
33059 =	56.1960 T	33060 =	56.6482 T	33061 =	[illegible] T	33062 =	56.6183 T	33063 =	55.3077 T	33064 =	55.0353
33065 =	54.9891 T	33066 =	55.1242 T	33067 =	[illegible] T	33068 =	55.9350 T	33069 =	56.2279 T	33070 =	59.6257
33071 =	57.6128 T	33072 =	57.1271 T	33073 =	[illegible] T	33074 =	57.2331 T	33075 =	57.4605 T	33076 =	57.7577
33077 =	58.8160 T	33078 =	57.3822 T	33079 =	56.2104 T	33080 =	56.4576 T	33081 =	55.9024 T	33082 =	54.3307
33083 =	55.2607 T	33084 =	53.7846 T	34005 =	52.8847 T	34006 =	52.5375 T	34007 =	51.8122 T	34008 =	48.0395
34009 =	49.7866 T	34010 =	48.9526 T	34011 =	51.8961 T	34012 =	56.6607 T	34013 =	52.7387 T	34014 =	50.6661
34015 =	50.7498 T	34016 =	51.7246 T	34017 =	51.9831 T	34018 =	51.5650 T	34019 =	54.5446 T	34020 =	54.2162
34021 =	53.8147 T	34022 =	53.4243 T	34023 =	53.1671 T	34024 =	52.3800 T	34025 =	49.3681 T	34026 =	51.5628
34027 =	51.5375 T	34028 =	50.1616 T	34029 =	48.5896 T	34030 =	51.2201 T	34031 =	52.1047 T	34032 =	50.6024
34033 =	56.9655 T	34034 =	56.7082 T	34035 =	55.5150 T	34036 =	55.1230 T	34037 =	52.8826 T	34038 =	53.0418
34039 =	49.2449 T	34040 =	49.9352 T	34049 =	52.6852 T	34050 =	52.4257 T	34051 =	52.8273 T	34052 =	53.4858
34053 =	55.2685 T	34054 =	56.1611 T	34055 =	57.8996 T	34056 =	55.6345 T	34057 =	55.6611 T	34058 =	55.9500
34059 =	56.1960 T	34060 =	56.6482 T	34061 =	56.6637 T	34062 =	56.6183 T	34063 =	55.3077 T	34064 =	55.0353
34065 =	54.9891 T	34066 =	55.1242 T	34067 =	55.6124 T	34068 =	55.9350 T	34069 =	56.2279 T	34070 =	59.6257
34071 =	57.6128 T	34072 =	57.1271 T	34073 =	57.3634 T	34074 =	57.2331 T	34075 =	57.4605 T	34076 =	57.7577
34077 =	58.8160 T	34078 =	57.3822 T	34079 =	56.2104 T	34080 =	56.4576 T	34081 =	55.9024 T	34082 =	54.3307
34083 =	55.2607 T	34084 =	53.7846 T	42006 =	52.1778 T	42013 =	51.6678 T	42020 =	54.0150 T	42027 =	50.8952
42008 =	48.9183 T	42015 =	51.2371 T	42022 =	53.2863 T	42029 =	49.9038 T	42010 =	50.4243 T	42017 =	51.7741
42024 =	50.8740 T	42031 =	51.3535 T	42050 =	52.6444 T	42057 =	55.8055 T	42064 =	55.0122 T	42071 =	57.3698
42052 =	54.3748 T	42059 =	56.4221 T	42066 =	55.3683 T	42073 =	57.2816 T	42054 =	57.0303 T	42061 =	56.6410
42068 =	56.0815 T	42075 =	57.6091 T	43006 =	52.1778 T	43013 =	51.6678 T	43020 =	54.0150 T	43027 =	50.8952
43008 =	48.9183 T	43015 =	51.2371 T	43022 =	53.2863 T	43029 =	49.9038 T	43010 =	50.4243 T	43017 =	51.7741
43024 =	50.8740 T	43031 =	51.3535 T	43050 =	52.6444 T	43057 =	55.8055 T	43064 =	55.0122 T	43071 =	57.3698
43052 =	54.3748 T	43059 =	56.4221 T	43066 =	55.3683 T	43073 =	57.2816 T	43054 =	57.0303 T	43061 =	56.6410
43068 =	56.0815 T	43075 =	57.6091 T	8000 =	42.2006 T	8005 =	43.2398 T	8010 =	43.5973 T	8011 =	43.4797
8015 =	41.8289 T	8016 =	42.2933 T	8020 =	43.9289 T	8025 =	42.1796 T	8030 =	45.1768 T	8035 =	52.0474
6000 =	35.2032 T	6010 =	35.1665 T	6020 =	35.1318 T	6030 =	35.0990 T	6040 =	35.0321 T	6050 =	35.0814
6060 =	35.0537 T	6070 =	34.9155 T	6080 =	34.8596 T	6090 =	34.8239 T	6001 =	35.0457 T	6011 =	35.0383
6021 =	34.9733 T	6031 =	34.8963 T	6041 =	34.8647 T	6051 =	34.8433 T	6061 =	34.8054 T	6071 =	34.7900
6081 =	34.7802 T	6091 =	34.7631 T	500 =	35.9990 T	501 =	35.8321 T	502 =	36.4643 T	503 =	36.2271
9000 =	34.7690 T	9001 =	34.7698 T	9002 =	34.7684 T	9003 =	34.7677 T	40 =	63.2000 T	9999 =	34.7631
7000 =	-423.0000 T	7001 =	-297.0000 T	7002 =	55.0000 T	7003 =	80.0000 T	8888 =	63.2000 T	8889 =	28.4000
8890 =	0.0000 T	8891 =	240.0000 T	8892 =	12.0000 T	13001 =	0.0000 T	13002 =	0.0000 T	13003 =	0.0000
13004 =	0.0000 T	13005 =	0.0000 T	13006 =	0.0000 T	13007 =	0.0000 T	13008 =	0.0000 T	13009 =	0.0000

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STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

13010 =	0.0000 T	13011 =	0.0000 T	13012 =	0.0000 T	13013 =	0.0000 T	13014 =	0.0000 T	13015 =	0.0000
13016 =	0.0000 T	13017 =	0.0000 T	13018 =	0.0000 T	13019 =	0.0000 T	13020 =	0.0000 T	13021 =	0.0000
13022 =	0.0000 T	13023 =	0.0000 T	13024 =	0.0000 T	13025 =	0.0000 T	13026 =	0.0000 T	13027 =	0.0000
13028 =	0.0000 T	13029 =	0.0000 T	13030 =	0.0000 T	13031 =	0.0000 T	13032 =	0.0000 T	13033 =	0.0000
13034 =	0.0000 T	13035 =	0.0000 T	13036 =	0.0000 T	13037 =	0.0000 T	16001 =	0.0000 T	16002 =	0.0000
16003 =	0.0000 T	16004 =	0.0000 T	16005 =	0.0000 T	16006 =	0.0000 T	16007 =	0.0000 T	16008 =	0.0000
16009 =	0.0000 T	16010 =	0.0000 T	16011 =	0.0000 T	16012 =	0.0000 T	16013 =	0.0000 T	16014 =	0.0000
16015 =	0.0000 T	16016 =	0.0000 T	16017 =	0.0000 T	16018 =	0.0000 T	16019 =	0.0000 T	16020 =	0.0000
16021 =	0.0000 T	16022 =	0.0000 T	16023 =	0.0000 T	16024 =	0.0000 T	16025 =	0.0000 T	16026 =	0.0000
16027 =	0.0000 T	16028 =	0.0000 T	16029 =	0.0000 T	16030 =	0.0000 T	16031 =	0.0000 T	16032 =	0.0000
16033 =	0.0000 T	16034 =	0.0000 T	16035 =	0.0000 T	16036 =	0.0000 T	16037 =	0.0000 T	101 =	10.8977
102 =	11.2218 T	103 =	11.4244 T	104 =	11.6675 T	105 =	12.3967 T	106 =	11.4244 T	107 =	11.5864
108 =	12.3562 T	109 =	13.1259 T	110 =	13.3284 T	111 =	13.1259 T	112 =	12.8828 T	113 =	7.0491
114 =	8.0619 T	115 =	8.3050 T	116 =	9.0747 T	117 =	13.3284 T	118 =	14.0172 T	119 =	13.5715
120 =	9.8444 T	121 =	14.9084 T	122 =	15.1920 T	123 =	14.5438 T	124 =	9.7634 T	125 =	18.4330
126 =	18.1494 T	127 =	19.2837 T	128 =	13.8146 T	129 =	14.9894 T	130 =	17.2176 T	131 =	18.2304
132 =	18.2304 T	133 =	16.0428 T	134 =	14.9084 T	135 =	13.7741 T	136 =	9.5608 T	137 =	24.3072
151 =	0.5380 T	152 =	0.5540 T	153 =	0.5640 T	154 =	0.5760 T	155 =	0.6120 T	156 =	0.5640
157 =	0.5720 T	158 =	0.6100 T	159 =	0.6480 T	160 =	0.6580 T	161 =	0.6480 T	162 =	0.6360
163 =	0.3480 T	164 =	0.3980 T	165 =	0.4100 T	166 =	0.4480 T	167 =	0.6580 T	168 =	0.6920
169 =	0.6700 T	170 =	0.4860 T	171 =	0.7360 T	172 =	0.7500 T	173 =	0.7180 T	174 =	0.4820
175 =	0.9100 T	176 =	0.8960 T	177 =	0.9520 T	178 =	0.6820 T	179 =	0.7400 T	180 =	0.8500
181 =	0.9000 T	182 =	0.9000 T	183 =	0.7920 T	184 =	0.7360 T	185 =	0.6800 T	186 =	0.4720
187 =	1.2000 T	201 =	0.0000 T	202 =	0.0000 T	203 =	0.0000 T	204 =	0.0000 T	205 =	0.0000
206 =	0.0000 T	207 =	0.0000 T	208 =	0.0000 T	209 =	0.0000 T	210 =	0.0000 T	211 =	0.0000
212 =	0.0000 T	213 =	0.0000 T	214 =	0.0000 T	215 =	0.0000 T	216 =	0.0000 T	217 =	0.0000
218 =	0.0000 T	219 =	0.0000 T	220 =	0.0000 T	221 =	0.0000 T	222 =	0.0000 T	223 =	0.0000
224 =	0.0000 T	225 =	0.0000 T	226 =	0.0000 T	227 =	0.0000 T	228 =	0.0000 T	229 =	0.0000
230 =	0.0000 T	231 =	0.0000 T	232 =	0.0000 T	233 =	0.0000 T	234 =	0.0000 T	235 =	0.0000
236 =	0.0000 T	237 =	0.0000 T	401 =	0.0000 T	402 =	0.0000 T	403 =	0.0000 T	404 =	0.0000
405 =	0.0000 T	406 =	0.0000 T	407 =	0.0000 T	408 =	0.0000 T	409 =	0.0000 T	410 =	0.0000
411 =	0.0000 T	412 =	0.0000 T	413 =	0.0000 T	414 =	0.0000 T	415 =	0.0000 T	416 =	0.0000
417 =	0.0000 T	418 =	0.0000 T	419 =	0.0000 T	420 =	0.0000 T	421 =	0.0000 T	422 =	0.0000
423 =	0.0000 T	424 =	0.0000 T	425 =	0.0000 T	426 =	0.0000 T	427 =	0.0000 T	428 =	0.0000
429 =	0.0000 T	430 =	0.0000 T	431 =	0.0000 T	432 =	0.0000 T	433 =	0.0000 T	434 =	0.0000
435 =	0.0000 T	436 =	0.0000 T	437 =	0.0000 T	701 =	1.0000 T	702 =	1.0000 T	703 =	1.0000
704 =	1.0000 T	705 =	1.0000 T	706 =	1.0000 T	707 =	1.0000 T	708 =	1.0000 T	709 =	1.0000
710 =	1.0000 T	711 =	1.0000 T	712 =	1.0000 T	713 =	1.0000 T	714 =	1.0000 T	715 =	1.0000
716 =	1.0000 T	717 =	1.0000 T	718 =	1.0000 T	719 =	1.0000 T	720 =	1.0000 T	721 =	1.0000
722 =	1.0000 T	723 =	1.0000 T	724 =	1.0000 T	725 =	1.0000 T	726 =	1.0000 T	727 =	1.0000
728 =	1.0000 T	729 =	1.0000 T	730 =	1.0000 T	731 =	1.0000 T	732 =	1.0000 T	733 =	1.0000
734 =	1.0000 T	735 =	1.0000 T	736 =	1.0000 T	737 =	1.0000 T	801 =	0.0000 T	802 =	0.0000
803 =	0.0000 T	804 =	0.0000 T	805 =	0.0000 T	806 =	0.0000 T	807 =	0.0000 T	808 =	0.0000
809 =	0.0000 T	810 =	0.0000 T	811 =	0.0000 T	812 =	0.0000 T	813 =	0.0000 T	814 =	0.0000
815 =	0.0000 T	816 =	0.0000 T	817 =	0.0000 T	818 =	0.0000 T	819 =	0.0000 T	820 =	0.0000
821 =	0.0000 T	822 =	0.0000 T	823 =	0.0000 T	824 =	0.0000 T	825 =	0.0000 T	826 =	0.0000
827 =	0.0000 T	828 =	0.0000 T	829 =	0.0000 T	830 =	0.0000 T	831 =	0.0000 T	832 =	0.0000
833 =	0.0000 T	834 =	0.0000 T	835 =	0.0000 T	836 =	0.0000 T	837 =	0.0000 T	901 =	0.0000
902 =	0.0000 T	903 =	0.0000 T	904 =	0.0000 T	905 =	0.0000 T	906 =	0.0000 T	907 =	0.0000
908 =	0.0000 T	909 =	0.0000 T	910 =	0.0000 T	911 =	0.0000 T	912 =	0.0000 T	913 =	0.0000
914 =	0.0000 T	915 =	0.0000 T	916 =	0.0000 T	917 =	0.0000 T	918 =	0.0000 T	919 =	0.0000
920 =	0.0000 T	921 =	0.0000 T	922 =	0.0000 T	923 =	0.0000 T	924 =	0.0000 T	925 =	0.0000
926 =	0.0000 T	927 =	0.0000 T	928 =	0.0000 T	929 =	0.0000 T	930 =	0.0000 T	931 =	0.0000
932 =	0.0000 T	933 =	0.0000 T	934 =	0.0000 T	935 =	0.0000 T	936 =	0.0000 T	937 =	0.0000

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STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

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*** NOTE *** FWDBKL REQUIRES   5748 DYNAMIC STORAGE LOCATIONS OUT OF  18964 AVAILABLE ***
             TIMEND=  24.500    , CSGFAC=  1.0000    , DTIMEI= 0.50000E-02, NLOOP =          1600
             TIMEO =  16.500    , OUTPUT=  1.0000    , DTIMEH= 0.10000E+09, DTIMEL= 0.00000E+00
             ARLXCA= 0.50000E-01, ATMPCA= 0.00000E+00, DRLXCA= 0.50000E-01, DTMPCA= 0.10000E+09
```

```
EXTLIM= 50.000

*****************
TIME= 1.65000E+01, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
    LOOPCT=     0                                                      , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T  1001 =   39.9108 T  1002 =   35.9095 T  1003 =   37.1033 T  1004 =   40.3810 T  1005 =   43.9132 T  1006 =   38.3889
T  1007 =   40.1427 T  1008 =   42.8596 T  1009 =   44.4107 T  1010 =   40.5095 T  1011 =   40.4694 T  1012 =   42.3742
T  1013 =   36.2534 T  1014 =   33.2981 T  1015 =   34.5560 T  1016 =   38.1149 T  1017 =   54.8118 T  1018 =   57.2593
T  1019 =   55.6909 T  1020 =   55.4715 T  1021 =   41.6694 T  1022 =   42.6810 T  1023 =   41.4785 T  1024 =   36.7089
T  1025 =   45.2448 T  1026 =   45.4224 T  1027 =   46.3580 T  1028 =   41.8105 T  1029 =   50.4351 T  1030 =   50.7885
T  1031 =   51.4452 T  1032 =   51.2953 T  1033 =   46.3063 T  1034 =   46.4927 T  1035 =   43.8276 T  1036 =   41.8282
T  1037 =   59.6327 T  2001 =    4.0594 T  3001 =  -78.3443 T  4001 = -182.6490 T  5001 = -327.5227 T  2002 =    0.2865
T  3002 =  -81.6223 T  4002 = -184.9975 T  5002 = -328.5182 T  2003 =    1.4121 T  3003 =  -80.6443 T  4003 = -184.2966
T  5003 = -328.2208 T  2004 =    4.5030 T  3004 =  -77.9583 T  4004 = -182.3717 T  5004 = -327.4036 T  2005 =    7.8340
T  3005 =  -75.0635 T  4005 = -180.2961 T  5005 = -326.5187 T  2006 =    2.6246 T  3006 =  -79.5901 T  4006 = -183.5402
T  5006 = -327.8966 T  2007 =    4.2790 T  3007 =  -78.1521 T  4007 = -182.5097 T  5007 = -327.4595 T  2008 =    6.8405
T  3008 =  -75.9266 T  4008 = -180.9145 T  5008 = -326.7814 T  2009 =    8.3031 T  3009 =  -74.6559 T  4009 = -180.0041
T  5009 = -326.3950 T  2010 =    4.6243 T  3010 =  -77.8524 T  4010 = -182.2946 T  5010 = -327.3666 T  2011 =    4.5862
T  3011 =  -77.8859 T  4011 = -182.3189 T  5011 = -327.3776 T  2012 =    6.3827 T  3012 =  -76.3244 T  4012 = -181.1998
T  5012 = -326.9031 T  2013 =    0.6104 T  3013 =  -81.3418 T  4013 = -184.7979 T  5013 = -328.4379 T  2014 =   -2.1761
T  3014 =  -83.7625 T  4014 = -186.5318 T  5014 = -329.1720 T  2015 =   -0.9901 T  3015 =  -82.7321 T  4015 = -185.7935
T  5015 = -328.8587 T  2016 =    2.3666 T  3016 =  -79.8144 T  4016 = -183.7020 T  5016 = -327.9695 T  2017 =   54.8350
T  3017 =   54.8816 T  4017 =   54.9285 T  5017 =   54.9758 T  2018 =   56.9771 T  3018 =   56.4124 T  4018 =   55.8473
T  5018 =   55.2822 T  2019 =   55.6042 T  3019 =   55.4311 T  4019 =   55.2582 T  5019 =   55.0858 T  2020 =   55.4124
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
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T	206 -	0.0000	T	207 -	0.0000	T	208 -	0.0000	T	209 -	0.0000	T	210 -	0.0000	T	211 -	0.0000
T	212 -	0.0000	T	213 -	0.0000	T	214 -	0.0000	T	215 -	0.0000	T	216 -	0.0000	T	217 -	0.0000
T	218 -	0.0000	T	219 -	0.0000	T	220 -	0.0000	T	221 -	0.0000	T	222 -	0.0000	T	223 -	0.0000
T	224 -	0.0000	T	225 -	0.0000	T	226 -	0.0000	T	227 -	0.0000	T	228 -	0.0000	T	229 -	0.0000

T	230 -	0.0000	T	231 -	0.0000	T	232 -	0.0000	T	233 -	0.0000	T	234 -	0.0000	T	235 -	0.0000
T	236 -	0.0000	T	237 -	0.0000	T	401 -	0.0000	T	402 -	0.0000	T	403 -	0.0000	T	404 -	0.0000
T	405 -	0.0000	T	406 -	0.0000	T	407 -	0.0000	T	408 -	0.0000	T	409 -	0.0000	T	410 -	0.0000
T	411 -	0.0000	T	412 -	0.0000	T	413 -	0.0000	T	414 -	0.0000	T	415 -	0.0000	T	416 -	0.0000
T	417 -	0.0000	T	418 -	0.0000	T	419 -	0.0000	T	420 -	0.0000	T	421 -	0.0000	T	422 -	0.0000
T	423 -	0.0000	T	424 -	0.0000	T	425 -	0.0000	T	426 -	0.0000	T	427 -	0.0000	T	428 -	0.0000
T	429 -	0.0000	T	430 -	0.0000	T	431 -	0.0000	T	432 -	0.0000	T	433 -	0.0000	T	434 -	0.0000
T	435 -	0.0000	T	436 -	0.0000	T	437 -	0.0000	T	701 -	-0.0218	T	702 -	-0.0070	T	703 -	-0.0114
T	704 -	-0.0236	T	705 -	-0.0371	T	706 -	-0.0161	T	707 -	-0.0226	T	708 -	-0.0332	T	709 -	-0.0392
T	710 -	-0.0238	T	711 -	-0.0235	T	712 -	-0.0310	T	713 -	-0.0102	T	714 -	-0.0008	T	715 -	-0.0045
T	716 -	-0.0156	T	717 -	-0.0831	T	718 -	-0.0942	T	719 -	-0.0865	T	720 -	-0.0749	T	721 -	-0.0275
T	722 -	-0.0316	T	723 -	-0.0265	T	724 -	-0.0086	T	725 -	-0.0482	T	726 -	-0.0490	T	727 -	-0.0545
T	728 -	-0.0302	T	729 -	-0.0803	T	730 -	-0.0875	T	731 -	-0.0933	T	732 -	-0.0929	T	733 -	-0.0492
T	734 -	-0.0488	T	735 -	-0.0368	T	736 -	-0.0267	T	737 -	-0.2195	T	801 -	0.0000	T	802 -	0.0000
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T	815 -	0.0000	T	816 -	0.0000	T	817 -	0.0000	T	818 -	0.0000	T	819 -	0.0000	T	820 -	0.0000
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T	908 -	0.0000	T	909 -	0.0000	T	910 -	0.0000	T	911 -	0.0000	T	912 -	0.0000	T	913 -	0.0000
T	914 -	0.0000	T	915 -	0.0000	T	916 -	0.0000	T	917 -	0.0000	T	918 -	0.0000	T	919 -	0.0000
T	920 -	0.0000	T	921 -	0.0000	T	922 -	0.0000	T	923 -	0.0000	T	924 -	0.0000	T	925 -	0.0000
T	926 -	0.0000	T	927 -	0.0000	T	928 -	0.0000	T	929 -	0.0000	T	930 -	0.0000	T	931 -	0.0000
T	932 -	0.0000	T	933 -	0.0000	T	934 -	0.0000	T	935 -	0.0000	T	936 -	0.0000	T	937 -	0.0000

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    LOOPCT=     1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC( 43061)= 1.84921E-02
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T	1007 -	38.2621	T	1008 -	41.3856	T	1009 -	42.2126	T	1010 -	38.2280	T	1011 -	38.1784	T	1012 -	40.5113
T	1013 -	34.3770	T	1014 -	30.9753	T	1015 -	32.1212	T	1016 -	35.8811	T	1017 -	53.9233	T	1018 -	57.4549
T	1019 -	55.6674	T	1020 -	54.8826	T	1021 -	38.9209	T	1022 -	41.7834	T	1023 -	39.6789	T	1024 -	34.1095
T	1025 -	43.4530	T	1026 -	44.7071	T	1027 -	43.9898	T	1028 -	39.4453	T	1029 -	52.7941	T	1030 -	52.2390
T	1031 -	51.6423	T	1032 -	50.6557	T	1033 -	43.8960	T	1034 -	44.5963	T	1035 -	41.0497	T	1036 -	39.8239
T	1037 -	60.1124	T	2001 -	1.1964	T	3001 -	-80.8157	T	4001 -	-184.4119	T	5001 -	-328.2715	T	2002 -	-3.0352
T	3002 -	-84.4996	T	4002 -	-187.0551	T	5002 -	-329.3934	T	2003 -	-1.6946	T	3003 -	-83.3332	T	4003 -	-186.2186
T	5003 -	-329.0380	T	2004 -	1.8437	T	3004 -	-80.2526	T	4004 -	-184.0076	T	5004 -	-328.0984	T	2005 -	6.4567
T	3005 -	-76.2261	T	4005 -	-181.1114	T	5005 -	-326.8613	T	2006 -	0.7320	T	3006 -	-81.2135	T	4006 -	-184.6929

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T   3008 =  -77.0769 T   4008 = -181.7215 T   5008 = -327.1206 T   2009 =    6.2391 T   3009 =  -76.4390 T   4009 = -181.2771
T   5009 = -326.9363 T   2010 =    2.4868 T   3010 =  -79.6933 T   4010 = -183.6057 T   5010 = -327.9232 T   2011 =    2.4448
T   3011 =  -79.7240 T   4011 = -183.6249 T   5011 = -327.9311 T   2012 =    4.6559 T   3012 =  -77.7892 T   4012 = -182.2309
T   5012 = -327.3374 T   2013 =   -1.1578 T   3013 =  -82.8771 T   4013 = -185.8980 T   5013 = -328.9064 T   2014 =   -4.3656
T   3014 =  -85.6642 T   4014 = -187.8944 T   5014 = -329.7521 T   2015 =   -3.2839 T   3015 =  -84.7229 T   4015 = -187.2193
T   5015 = -329.4656 T   2016 =    0.2626 T   3016 =  -81.6399 T   4016 = -185.0091 T   5016 = -328.5260 T   2017 =   54.0760
T   3017 =   54.3572 T   4017 =   54.6210 T   5017 =   54.8745 T   2018 =   57.2148 T   3018 =   56.6468 T   4018 =   56.0145
T   5018 =   55.3424 T   2019 =   55.6405 T   3019 =   55.5113 T   4019 =   55.3282 T   5019 =   55.1127 T   2020 =   54.9068
T   3020 =   54.9424 T   4020 =   54.9688 T   5020 =   54.9899 T   2021 =    9.0418 T   3021 =  -57.7939 T   4021 = -139.4673
T   5021 = -239.3417 T   2022 =   11.7300 T   3022 =  -55.5368 T   4022 = -137.7839 T   5022 = -238.6931 T   2023 =    9.7581
T   3023 =  -57.1877 T   4023 = -139.0127 T   5023 = -239.1662 T   2024 =    4.5529 T   3024 =  -61.5526 T   4024 = -142.1429
T   5024 = -240.3672 T   2025 =   13.2649 T   3025 =  -54.2845 T   4025 = -136.8692 T   5025 = -238.3447 T   2026 =   14.4528
T   3026 =  -53.2756 T   4026 = -136.1100 T   5026 = -238.0509 T   2027 =   13.7529 T   3027 =  -53.8927 T   4027 = -136.5865
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T   3029 =  -46.9426 T   4029 = -131.3821 T   5029 = -236.2319 T   2030 =   21.5506 T   3030 =  -47.2779 T   4030 = -131.6040
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
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T   5036 = -325.0118 T   2037 =   62.7446 T   3037 =   67.8255 T   4037 =   72.7595 T   5037 =   77.5974 T   21001 = -422.9851
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T  21010 = -422.9803 T  21011 = -422.9808 T  21013 = -422.9846 T  21014 = -422.9806 T  21015 = -422.9816 T  21004 = -422.9843
T  21008 = -422.9832 T  21012 = -422.9833 T  21016 = -422.9833 T  21017 =   54.9998 T  21018 =   54.9999 T  21019 =   54.9999
T  21020 =   54.9998 T  21021 = -296.9905 T  21022 = -296.9905 T  21023 = -296.9906 T  21024 = -296.9909 T  21025 = -296.9907
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T  12001 =   54.3837 T  12002 =   54.6619 T  12003 =   55.1995 T  12004 =   54.2821 T  12041 =   54.0893 T  12042 =   55.0138
T  12043 =   48.9992 T  12044 =   51.0498 T  12045 =   54.7620 T  12046 =   56.3159 T  12047 =   56.8415 T  12048 =   58.5285
T  12085 =   54.8226 T  12086 =   56.4560 T  12087 =   52.6291 T  12088 =   53.7435 T  12005 =   54.5732 T  12012 =   57.9225
T  12019 =   55.5138 T  12026 =   53.4011 T  12006 =   54.2209 T  12013 =   54.1847 T  12020 =   55.2692 T  12027 =   53.4586
T  12007 =   53.0510 T  12014 =   52.3674 T  12021 =   54.9171 T  12028 =   52.3937 T  12008 =   50.4745 T  12015 =   52.2041
T  12022 =   54.5930 T  12029 =   51.0652 T  12009 =   51.8598 T  12016 =   52.9434 T  12023 =   54.3569 T  12030 =   52.9411
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T  12025 =   51.2613 T  12032 =   52.2879 T  12033 =   57.5209 T  12034 =   57.5032 T  12035 =   56.3320 T  12036 =   57.0687
T  12037 =   54.0103 T  12038 =   54.1149 T  12039 =   51.1386 T  12040 =   51.6638 T  22001 =   54.6528 T  22002 =   55.0880
T  22003 =   55.5872 T  22004 =   54.5452 T  22041 =   54.4147 T  22042 =   54.7949 T  22043 =   49.8125 T  22044 =   51.5211
T  12049 =   55.1624 T  12056 =   58.0364 T  12063 =   56.3036 T  12070 =   60.7064 T  12050 =   54.9626 T  12057 =   58.3576
T  12064 =   56.1516 T  12071 =   58.6280 T  12051 =   55.1970 T  12058 =   58.3718 T  12065 =   56.0652 T  12072 =   57.9688
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T  22067 =   56.5364 T  22068 =   56.7754 T  22069 =   57.0631 T  22070 =   60.7131 T  22071 =   58.6359 T  22072 =   57.9771
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
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T  34065 =   71.0000 T  34066 =   71.0000 T  34067 =   71.0000 T  34068 =   71.0000 T  34069 =   71.0000 T  34070 =   71.0000
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T  34077 -    71.0000 T  34078 -    71.0000 T  34079 -    71.0000 T  34080 -    71.0000 T  34081 -    71.0000 T  34082 -    71.0000
T  34083 -    71.0000 T  34084 -    71.0000 T  42006 -    98.2013 T  42013 -    97.6931 T  42020 -    99.7679 T  42027 -    96.6812
T  42008 -    95.7396 T  42015 -    98.0262 T  42022 -    99.8162 T  42029 -    96.4642 T  42010 -    99.0416 T  42017 -   100.1088
T  42024 -    99.2253 T  42031 -    99.7011 T  42050 -    95.3992 T  42057 -    98.6095 T  42064 -    97.6861 T  42071 -    99.7830
T  42052 -    97.1137 T  42059 -    99.2163 T  42066 -    98.0377 T  42073 -    99.6826 T  42054 -    99.4942 T  42061 -    99.1749
T  42068 -    98.4898 T  42075 -    99.7549 T  43006 -    55.6062 T  43013 -    54.6606 T  43020 -    57.4211 T  43027 -    54.3667
T  43008 -    52.1304 T  43015 -    54.1820 T  43022 -    56.7072 T  43029 -    53.3057 T  43010 -    53.4554 T  43017 -    54.7107
T  43024 -    54.3358 T  43031 -    54.7136 T  43050 -    62.1245 T  43057 -    72.3982 T  43064 -    59.2855 T  43071 -    61.0935
T  43052 -    63.7362 T  43059 -    72.8035 T  43066 -    59.6004 T  43073 -    60.9220 T  43054 -    66.2151 T  43061 -    73.2823
T  43068 -    60.3510 T  43075 -    61.1958 T   8000 -    42.5366 T   8005 -    43.5200 T   8010 -    45.3112 T   8011 -    43.4799
T   8015 -    42.5263 T   8016 -    42.2933 T   8020 -    44.1571 T   8025 -    42.8291 T   8030 -    45.9517 T   8035 -    53.3319
T   6000 -    36.8317 T   6010 -    36.4631 T   6020 -    36.4455 T   6030 -    36.4357 T   6040 -    36.3523 T   6050 -    36.4092
T   6060 -    36.3789 T   6070 -    36.2298 T   6080 -    36.1706 T   6090 -    36.1365 T   6001 -    37.5867 T   6011 -    37.5728
T   6021 -    37.5021 T   6031 -    37.4050 T   6041 -    37.3649 T   6051 -    37.3422 T   6061 -    37.2982 T   6071 -    37.2826
T   6081 -    37.2735 T   6091 -    37.0441 T    500 -    36.6145 T    501 -    36.3149 T    502 -    37.0643 T    503 -    36.6912
T   9000 -    37.0682 T   9001 -    37.0973 T   9002 -    37.0986 T   9003 -    37.0945 T     40 -    63.0000 T   9999 -    34.8694
T   7000 -  -423.0000 T   7001 -  -297.0000 T   7002 -    55.0000 T   7003 -    80.0000 T   8888 -    63.0000 T   8889 -    30.0000
T   8890 -     0.0000 T   8891 -   238.0000 T   8892 -     9.8000 T  13001 -   201.5651 T  13002 -   193.5451 T  13003 -   195.5501
T  13004 -   194.7481 T  13005 -   724.0681 T  13006 -   720.0581 T  13007 -   728.0781 T  13008 -   728.0781 T  13009 -   193.5451
T  13010 -   543.6181 T  13011 -   675.9481 T  13012 -   776.1981 T  13013 -    44.5335 T  13014 -    42.7691 T  13015 -    48.4633
T  13016 -    50.6688 T  13017 -   216.8031 T  13018 -  1076.9481 T  13019 -  1040.8581 T  13020 -    61.2151 T  13021 -   115.7511
T  13022 -   760.1581 T  13023 -   362.7671 T  13024 -    36.9145 T  13025 -   659.9081 T  13026 -  1522.0581 T  13027 -   164.2721
T  13028 -    50.1876 T  13029 -   311.4391 T  13030 -   720.0581 T  13031 -    97.7061 T  13032 -    27.2103 T  13033 -    95.3001
T  13034 -   287.3791 T  13035 -   113.3451 T  13036 -    94.0971 T  13037 -    57.2853 T  16001 -     0.0000 T  16002 -     0.0000
T  16003 -     0.0000 T  16004 -     0.0000 T  16005 -     0.0000 T  16006 -     0.0000 T  16007 -     0.0000 T  16008 -     0.0000
T  16009 -     0.0000 T  16010 -     0.0000 T  16011 -     0.0000 T  16012 -     0.0000 T  16013 -     0.0000 T  16014 -    64.5623
T  16015 -     0.0000 T  16016 -     0.0000 T  16017 -     0.0000 T  16018 -     0.0000 T  16019 -     0.0000 T  16020 -     0.0000
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T  16021 -     0.0000 T  16022 -     0.0000 T  16023 -     0.0000 T  16024 -     0.0000 T  16025 -     0.0000 T  16026 -     0.0000
T  16027 -     0.0000 T  16028 -     0.0000 T  16029 -     0.0000 T  16030 -     0.0000 T  16031 -     0.0000 T  16032 -     0.0000
T  16033 -     0.0000 T  16034 -     0.0000 T  16035 -     0.0000 T  16036 -     0.0000 T  16037 -     0.0000 T    101 -     8.4829
T    102 -     8.8072 T    103 -     9.0057 T    104 -     9.2240 T    105 -    10.1769 T    106 -     9.3696 T    107 -     9.4490
T    108 -    10.1901 T    109 -    10.7327 T    110 -    10.9643 T    111 -    10.6665 T    112 -    10.4813 T    113 -     5.9685
T    114 -     6.4625 T    115 -     6.8816 T    116 -     7.4904 T    117 -    10.6004 T    118 -    11.6326 T    119 -    11.1165
T    120 -     8.3992 T    121 -    11.9039 T    122 -    12.5722 T    123 -    11.9568 T    124 -     8.0264 T    125 -    15.0536
T    126 -    15.0470 T    127 -    15.5035 T    128 -    11.4341 T    129 -    19.1230 T    130 -    17.5349 T    131 -    18.3951
T    132 -    16.7938 T    133 -    12.7575 T    134 -    11.8708 T    135 -    10.7195 T    136 -     7.8279 T    137 -    25.0121
T    151 -     0.5128 T    152 -     0.5324 T    153 -     0.5444 T    154 -     0.5576 T    155 -     0.6152 T    156 -     0.5664
T    157 -     0.5712 T    158 -     0.6160 T    159 -     0.6488 T    160 -     0.6628 T    161 -     0.6448 T    162 -     0.6336
T    163 -     0.3608 T    164 -     0.4088 T    165 -     0.4160 T    166 -     0.4528 T    167 -     0.6408 T    168 -     0.7032
T    169 -     0.6720 T    170 -     0.4896 T    171 -     0.7196 T    172 -     0.7600 T    173 -     0.7228 T    174 -     0.4852
T    175 -     0.9100 T    176 -     0.9096 T    177 -     0.9372 T    178 -     0.6912 T    179 -     1.1560 T    180 -     1.0600
T    181 -     1.1120 T    182 -     1.0152 T    183 -     0.7712 T    184 -     0.7176 T    185 -     0.6480 T    186 -     0.4732
T    187 -     1.5120 T    201 -     0.0000 T    202 -     0.0000 T    203 -     0.0000 T    204 -     0.0000 T    205 -     0.0000
T    206 -     0.0000 T    207 -     0.0000 T    208 -     0.0000 T    209 -     0.0000 T    210 -     0.0000 T    211 -     0.0000
T    212 -     0.0000 T    213 -     0.0000 T    214 -     0.0000 T    215 -     0.0000 T    216 -     0.0000 T    217 -     0.0000
T    218 -     0.0000 T    219 -     0.0000 T    220 -     0.0000 T    221 -     0.0000 T    222 -     0.0000 T    223 -     0.0000
T    224 -     0.0000 T    225 -     0.0000 T    226 -     0.0000 T    227 -     0.0000 T    228 -     0.0000 T    229 -     0.0000
T    230 -     0.0000 T    231 -     0.0000 T    232 -     0.0000 T    233 -     0.0000 T    234 -     0.0000 T    235 -     0.0000
T    236 -     0.0000 T    237 -     0.0000 T    401 -     0.0000 T    402 -     0.0000 T    403 -     0.0000 T    404 -     0.0000
T    405 -     0.0000 T    406 -     0.0000 T    407 -     0.0000 T    408 -     0.0000 T    409 -     0.0000 T    410 -     0.0000
T    411 -     0.0000 T    412 -     0.0000 T    413 -     0.0000 T    414 -     0.0000 T    415 -     0.0000 T    416 -     0.0000
T    417 -     0.0000 T    418 -     0.0000 T    419 -     0.0000 T    420 -     0.0000 T    421 -     0.0000 T    422 -     0.0000
T    423 -     0.0000 T    424 -     0.0000 T    425 -     0.0000 T    426 -     0.0000 T    427 -     0.0000 T    428 -     0.0000
T    429 -     0.0000 T    430 -     0.0000 T    431 -     0.0000 T    432 -     0.0000 T    433 -     0.0000 T    434 -     0.0000
T    435 -     0.0000 T    436 -     0.0000 T    437 -     0.0000 T    701 -    -0.0114 T    702 -     0.0033 T    703 -    -0.0012
T    704 -    -0.0133 T    705 -    -0.0301 T    706 -    -0.0096 T    707 -    -0.0159 T    708 -    -0.0266 T    709 -    -0.0294
T    710 -    -0.0153 T    711 -    -0.0152 T    712 -    -0.0233 T    713 -    -0.0054 T    714 -     0.0050 T    715 -     0.0016
T    716 -    -0.0088 T    717 -    -0.0718 T    718 -    -0.0871 T    719 -    -0.0789 T    720 -    -0.0672 T    721 -    -0.0156
T    722 -    -0.0267 T    723 -    -0.0185 T    724 -    -0.0005 T    725 -    -0.0373 T    726 -    -0.0431 T    727 -    -0.0398
T    728 -    -0.0199 T    729 -    -0.1023 T    730 -    -0.0953 T    731 -    -0.0944 T    732 -    -0.0858 T    733 -    -0.0363
T    734 -    -0.0381 T    735 -    -0.0243 T    736 -    -0.0195 T    737 -    -0.2262 T    801 -     0.0000 T    802 -     0.0021
T    803 -     0.0000 T    804 -     0.0000 T    805 -     0.0000 T    806 -     0.0000 T    807 -     0.0000 T    808 -     0.0000
T    809 -     0.0000 T    810 -     0.0000 T    811 -     0.0000 T    812 -     0.0000 T    813 -     0.0000 T    814 -     0.0048
T    815 -     0.0013 T    816 -     0.0000 T    817 -     0.0000 T    818 -     0.0000 T    819 -     0.0000 T    820 -     0.0000
T    821 -     0.0000 T    822 -     0.0000 T    823 -     0.0000 T    824 -     0.0000 T    825 -     0.0000 T    826 -     0.0000
T    827 -     0.0000 T    828 -     0.0000 T    829 -     0.0000 T    830 -     0.0000 T    831 -     0.0000 T    832 -     0.0000
T    833 -     0.0000 T    834 -     0.0000 T    835 -     0.0000 T    836 -     0.0000 T    837 -     0.0000 T    901 -     0.0000
T    902 -     4.0953 T    903 -     0.0000 T    904 -     0.0000 T    905 -     0.0000 T    906 -     0.0000 T    907 -     0.0000
T    908 -     0.0000 T    909 -     0.0000 T    910 -     0.0000 T    911 -     0.0000 T    912 -     0.0000 T    913 -     0.0000
T    914 -     9.3974 T    915 -     2.5784 T    916 -     0.0000 T    917 -     0.0000 T    918 -     0.0000 T    919 -     0.0000
T    920 -     0.0000 T    921 -     0.0000 T    922 -     0.0000 T    923 -     0.0000 T    924 -     0.0000 T    925 -     0.0000
T    926 -     0.0000 T    927 -     0.0000 T    928 -     0.0000 T    929 -     0.0000 T    930 -     0.0000 T    931 -     0.0000
T    932 -     0.0000 T    933 -     0.0000 T    934 -     0.0000 T    935 -     0.0000 T    936 -     0.0000 T    937 -     0.0000

****************
      GEN 425,3,1,12054,7,12061,7,1.65              $ SRM
      GEN 429,3,1,12055,7,12062,7,1.65              $ SRM
C
          433,12049,12070,1.65                                                    3 -    24.7795 T   1004 -    28.6851 T   1005 -
38.6698 T   1006 -    32.3812
 T   1007 -    33.4296 T   1008 -    38.0612 T   1009 -    38.7669 T   1010 -    35.0836 T   1011 -    33.0047 T   1012 -    35.4327
 T   1013 -    35.0322 T   1014 -    31.2500 T   1015 -    30.9986 T   1016 -    33.6782 T   1017 -    48.5774 T   1018 -    53.9552
 T   1019 -    51.6451 T   1020 -    52.0465 T   1021 -    31.0151 T   1022 -    37.9605 T   1023 -    35.7139 T   1024 -    31.2152
 T   1025 -    38.7598 T   1026 -    41.0177 T   1027 -    37.5274 T   1028 -    37.0525 T   1029 -    48.2542 T   1030 -    47.9311
 T   1031 -    47.1037 T   1032 -    47.8578 T   1033 -    36.3931 T   1034 -    37.1473 T   1035 -    29.0475 T   1036 -    36.5801
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
 T   1037 -    56.2830 T   2001 -    -9.9035 T   3001 -   -90.4731 T   4001 - -191.3402 T   5001 - -331.2228 T   2002 -   -12.4339
 T   3002 -   -92.6732 T   4002 - -192.9163 T   5002 - -331.8883 T   2003 -  -10.2064 T   3003 -   -90.7377 T   4003 - -191.5297
 T   5003 - -331.2997 T   2004 -    -6.5227 T   3004 -   -87.5356 T   4004 - -189.2350 T   5004 - -330.3263 T   2005 -     2.8946
 T   3005 -   -79.3498 T   4005 - -183.3661 T   5005 - -327.8266 T   2006 -   -3.0376 T   3006 -   -84.5071 T   4006 - -187.0632
 T   5006 - -329.3970 T   2007 -    -2.0484 T   3007 -   -83.6470 T   4007 - -186.4469 T   5007 - -329.1365 T   2008 -     2.3194
 T   3008 -   -79.8510 T   4008 - -183.7258 T   5008 - -327.9792 T   2009 -    2.9868 T   3009 -   -79.2691 T   4009 - -183.3082
 T   5009 - -327.8027 T   2010 -    -0.4887 T   3010 -   -82.2915 T   4010 - -185.4749 T   5010 - -328.7214 T   2011 -    -2.4482
 T   3011 -   -83.9934 T   4011 - -186.6946 T   5011 - -329.2413 T   2012 -   -0.1573 T   3012 -   -82.0011 T   4012 - -185.2660
 T   5012 - -328.6351 T   2013 -    -0.5386 T   3013 -   -82.3371 T   4013 - -185.5098 T   5013 - -328.7407 T   2014 -    -4.1066
 T   3014 -   -85.4391 T   4014 - -187.7330 T   5014 - -329.6834 T   2015 -   -4.3438 T   3015 -   -85.6454 T   4015 - -187.8813
 T   5015 - -329.7476 T   2016 -    -1.8159 T   3016 -   -83.4473 T   4016 - -186.3054 T   5016 - -329.0783 T   2017 -    49.3917
 T   3017 -    51.0072 T   4017 -    52.6105 T   5017 -    54.2044 T   2018 -   54.0936 T   3018 -    54.3604 T   4018 -    54.6193
 T   5018 -    54.8734 T   2019 -    52.0734 T   3019 -    52.9186 T   4019 -   53.7549 T   5019 -    54.5854 T   2020 -    52.4232
 T   3020 -    53.1671 T   4020 -    53.9034 T   5020 -    54.6347 T   2021 -    1.6571 T   3021 -   -63.9972 T   4021 - -143.8362
 T   5021 - -241.0155 T   2022 -     8.1431 T   3022 -   -58.5449 T   4022 - -140.0252 T   5022 - -239.5564 T   2023 -     6.0493
 T   3023 -   -60.2945 T   4023 - -141.2737 T   5023 - -240.0346 T   2024 -    1.8441 T   3024 -   -63.8396 T   4024 - -143.7273
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T	5024 =	-240.9740 T	2025 =	8.8858 T	3025 =	-57.9304 T	4025 =	-139.5723 T	5025 =	-239.3832 T	2026 =	10.9847
T	3026 =	-56.1920 T	4026 =	-138.2887 T	5026 =	-238.8915 T	2027 =	7.7404 T	3027 =	-58.8787 T	4027 =	-140.2722
T	5027 =	-239.6520 T	2028 =	7.2989 T	3028 =	-59.2443 T	4028 =	-140.5419 T	5028 =	-239.7548 T	2029 =	17.7221
T	3029 =	-50.5925 T	4029 =	-134.1383 T	5029 =	-237.3027 T	2030 =	17.4169 T	3030 =	-50.8544 T	4030 =	-134.3388
T	5030 =	-237.3809 T	2031 =	16.6468 T	3031 =	-51.4943 T	4031 =	-134.8137 T	5031 =	-237.5638 T	2032 =	17.3466
T	3032 =	-50.9165 T	4032 =	-134.3876 T	5032 =	-237.4006 T	2033 =	0.2922 T	3033 =	-81.4543 T	4033 =	-181.7336
T	5033 =	-325.8665 T	2034 =	1.0080 T	3034 =	-80.8611 T	4034 =	-181.2965 T	5034 =	-325.6790 T	2035 =	-6.6773
T	3035 =	-87.2244 T	4035 =	-185.9827 T	5035 =	-327.6967 T	2036 =	0.4688 T	3036 =	-81.3089 T	4036 =	-181.6274
T	5036 =	-325.8222 T	2037 =	59.3801 T	3037 =	65.4636 T	4037 =	71.3799 T	5037 =	77.1465 T	21001 =	-422.9857
T	21002 =	-422.9811 T	21003 =	-422.9819 T	21005 =	-422.9843 T	21006 =	-422.9797 T	21007 =	-422.9817 T	21009 =	-422.9851
T	21010 =	-422.9805 T	21011 =	-422.9812 T	21013 =	-422.9846 T	21014 =	-422.9806 T	21015 =	-422.9817 T	21004 =	-422.9848
T	21008 =	-422.9834 T	21012 =	-422.9836 T	21016 =	-422.9834 T	21017 =	54.9998 T	21018 =	54.9998 T	21019 =	54.9998
T	21020 =	54.9998 T	21021 =	-296.9908 T	21022 =	-296.9906 T	21023 =	-296.9907 T	21024 =	-296.9910 T	21025 =	-296.9909
T	21026 =	-296.9910 T	21027 =	-296.9914 T	21028 =	-296.9910 T	21029 =	-296.9970 T	21030 =	-296.9965 T	21031 =	-296.9966
T	21032 =	-296.9966 T	21033 =	-422.9850 T	21034 =	-422.9860 T	21035 =	-422.9860 T	21036 =	-422.9864 T	21037 =	79.9992
T	12001 =	53.5786 T	12002 =	53.2390 T	12003 =	52.1702 T	12004 =	53.5828 T	12041 =	51.3559 T	12042 =	52.0395
T	12043 =	47.3200 T	12044 =	48.1493 T	12045 =	53.1997 T	12046 =	53.9466 T	12047 =	54.0855 T	12048 =	56.2664
T	12085 =	50.8910 T	12086 =	53.6129 T	12087 =	49.8479 T	12088 =	51.2177 T	12005 =	54.4136 T	12012 =	57.5679
T	12019 =	53.8267 T	12026 =	53.9003 T	12006 =	54.2776 T	12013 =	54.7397 T	12020 =	53.6609 T	12027 =	54.0281
T	12007 =	53.3683 T	12014 =	53.2138 T	12021 =	53.3953 T	12028 =	53.4203 T	12008 =	51.9515 T	12015 =	52.9553
T	12022 =	53.2467 T	12029 =	52.6128 T	12009 =	52.7710 T	12016 =	53.3079 T	12023 =	53.0779 T	12030 =	52.7332
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T	12049 =	54.3790 T	12056 =	56.1869 T	12063 =	54.4819 T	12070 =	58.9745 T	12050 =	54.3016 T	12057 =	56.4151
T	12064 =	54.3807 T	12071 =	57.3298 T	12051 =	54.2518 T	12058 =	56.3901 T	12065 =	54.2530 T	12072 =	56.5648
T	12052 =	54.4640 T	12059 =	56.4101 T	12066 =	54.2723 T	12073 =	56.2350 T	12053 =	55.4768 T	12060 =	56.5739
T	12067 =	54.3985 T	12074 =	56.1028 T	12054 =	56.3087 T	12061 =	56.2856 T	12068 =	54.6296 T	12075 =	56.4088
T	12055 =	57.1700 T	12062 =	55.9980 T	12069 =	54.8450 T	12076 =	56.7508 T	12077 =	57.1536 T	12078 =	55.8126
T	12079 =	55.6600 T	12080 =	56.0781 T	12081 =	54.4520 T	12082 =	53.6421 T	12083 =	54.8658 T	12084 =	53.8842
T	22045 =	54.7734 T	22046 =	55.8236 T	22047 =	56.3240 T	22048 =	57.8466 T	22085 =	54.2153 T	22086 =	55.6370
T	22087 =	52.4456 T	22088 =	53.4436 T	22005 =	54.4242 T	22006 =	54.2882 T	22007 =	53.3795 T	22008 =	51.9634
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T	22027 =	54.0389 T	22028 =	53.4314 T	22029 =	52.6243 T	22030 =	52.7449 T	22031 =	52.0668 T	22032 =	51.6098
T	22049 =	54.3898 T	22050 =	54.3123 T	22051 =	54.2627 T	22052 =	54.4748 T	22053 =	55.4870 T	22054 =	56.3183
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T	42008 =	92.8660 T	42015 =	95.0743 T	42022 =	96.8080 T	42029 =	93.5813 T	42010 =	96.0152 T	42017 =	97.0360
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T    821 =     0.0093 T    822 =     0.0000 T    823 =     0.0000 T    824 =     0.0080 T    825 =     0.0000 T    826 =     0.0000
T    827 =     0.0000 T    828 =     0.0000 T    829 =     0.0000 T    830 =     0.0000 T    831 =     0.0000 T    832 =     0.0000
T    833 =     0.0000 T    834 =     0.0000 T    835 =     0.0107 T    836 =     0.0000 T    837 =     0.0000 T    901 =    38.0159
T    902 =    65.5645 T    903 =    49.9203 T    904 =    24.4308 T    905 =     0.0000 T    906 =     3.8988 T    907 =     0.0000
T    908 =     0.0000 T    909 =     0.0000 T    910 =     0.0000 T    911 =     1.0790 T    912 =     0.0000 T    913 =     0.0000
T    914 =    21.4911 T    915 =    15.1112 T    916 =     0.0000 T    917 =     0.0000 T    918 =     0.0000 T    919 =     0.0000
T    920 =     0.0000 T    921 =     7.8630 T    922 =     0.0000 T    923 =     0.0000 T    924 =     6.8112 T    925 =     0.0000
T    926 =     0.0000 T    927 =     0.0000 T    928 =     0.0000 T    929 =     0.0000 T    930 =     0.0000 T    931 =     0.0000
T    932 =     0.0000 T    933 =     0.0000 T    934 =     0.0000 T    935 =    11.8382 T    936 =     0.0000 T    937 =     0.0000

****************
TIME= 1.95000E+01, DTIMEU= 2.50000E-03, CSGMIN( 21037)= 1.11551E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(  1027)= 6.88541E-02
    LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC( 12079)=-1.41173E-03

T    1001 =    23.6295 T   1002 =    18.3788 T   1003 =    19.4274 T   1004 =    22.9533 T   1005 =    33.4163 T   1006 =    28.6548
T    1007 =    29.3265 T   1008 =    32.9941 T   1009 =    33.5357 T   1010 =    30.9788 T   1011 =    28.8968 T   1012 =    30.9403
T    1013 =    31.7733 T   1014 =    28.3277 T   1015 =    27.7238 T   1016 =    30.1422 T   1017 =    42.8848 T   1018 =    49.1870
T    1019 =    46.5800 T   1020 =    47.3931 T   1021 =    25.8000 T   1022 =    32.9313 T   1023 =    31.4161 T   1024 =    27.6712
T    1025 =    33.2016 T   1026 =    35.3473 T   1027 =    31.8704 T   1028 =    32.3377 T   1029 =    41.3446 T   1030 =    41.2335
T    1031 =    39.8722 T   1032 =    41.2460 T   1033 =    30.7848 T   1034 =    31.5648 T   1035 =    25.3680 T   1036 =    32.0951
T    1037 =    51.7927 T   2001 =   -11.2913 T   3001 =   -91.6814 T   4001 =  -192.2074 T   5001 =  -331.5919 T   2002 =   -16.2428
T    3002 =   -95.9838 T   4002 =  -195.2888 T   5002 =  -332.8969 T   2003 =   -15.2540 T   3003 =   -95.1247 T   4003 =  -194.6736
T    5003 =  -332.6366 T   2004 =   -11.9289 T   3004 =   -92.2350 T   4004 =  -192.6036 T   5004 =  -331.7596 T   2005 =    -2.0588
T    3005 =   -83.6535 T   4005 =  -186.4508 T   5005 =  -329.1406 T   2006 =    -6.5511 T   3006 =   -87.5598 T   4006 =  -189.2509
T    5006 =  -330.3282 T   2007 =    -5.9173 T   3007 =   -87.0086 T   4007 =  -188.8561 T   5007 =  -330.1621 T   2008 =    -2.4586
T    3008 =   -84.0029 T   4008 =  -186.7020 T   5008 =  -329.2470 T   2009 =    -1.9455 T   3009 =   -83.5543 T   4009 =  -186.3794
T    5009 =  -329.1109 T   2010 =    -4.3595 T   3010 =   -85.6553 T   4010 =  -187.8860 T   5010 =  -329.7482 T   2011 =    -6.3220
T    3011 =   -87.3597 T   4011 =  -189.1073 T   5011 =  -330.2684 T   2012 =    -4.3943 T   3012 =   -85.6837 T   4012 =  -187.9061
T    5012 =  -329.7595 T   2013 =    -3.6121 T   3013 =   -85.0084 T   4013 =  -187.4249 T   5013 =  -329.5563 T   2014 =    -6.8602
T    3014 =   -87.8293 T   4014 =  -189.4447 T   5014 =  -330.4116 T   2015 =    -7.4294 T   3015 =   -88.3237 T   4015 =  -189.7992
T    5015 =  -330.5635 T   2016 =    -5.1482 T   3016 =   -86.3406 T   4016 =  -188.3778 T   5016 =  -329.9603 T   2017 =    44.4198
T    3017 =    47.4696 T   4017 =    50.4961 T   5017 =    53.5016 T   2018 =    49.9273 T   3018 =    51.3915 T   4018 =    52.8416
T    5018 =    54.2815 T   2019 =    47.6474 T   3019 =    49.7659 T   4019 =    51.8682 T   5019 =    53.9576 T   2020 =    48.3613
T    3020 =    50.2777 T   4020 =    52.1758 T   5020 =    54.0602 T   2021 =    -3.2162 T   3021 =   -68.1014 T   4021 =  -146.6735
T    5021 =  -242.1003 T   2022 =     3.4470 T   3022 =   -62.4900 T   4022 =  -142.7941 T   5022 =  -240.6169 T   2023 =     2.0310
T    3023 =   -63.6831 T   4023 =  -143.6194 T   5023 =  -240.9327 T   2024 =    -1.4680 T   3024 =   -66.6298 T   4024 =  -145.6567
T    5024 =  -241.7119 T   2025 =     3.6991 T   3025 =   -62.2783 T   4025 =  -142.6483 T   5025 =  -240.5615 T   2026 =     5.7047
T    3026 =   -60.5877 T   4026 =  -141.4783 T   5026 =  -240.1139 T   2027 =     2.4315 T   3027 =   -63.3521 T   4027 =  -143.3929
T    5027 =  -240.8472 T   2028 =     2.8918 T   3028 =   -62.9586 T   4028 =  -143.1190 T   5028 =  -240.7418 T   2029 =    11.2947
T    3029 =   -55.9237 T   4029 =  -138.0836 T   5029 =  -238.8172 T   2030 =    11.1865 T   3030 =   -56.0233 T   4030 =  -138.1649
T    5030 =  -238.8500 T   2031 =     9.9216 T   3031 =   -57.0696 T   4031 =  -138.9365 T   5031 =  -239.1456 T   2032 =    11.1978
T    3032 =   -56.0141 T   4032 =  -138.1581 T   5032 =  -238.8475 T   2033 =    -5.0252 T   3033 =   -85.8523 T   4033 =  -184.9698
T    5033 =  -327.2595 T   2034 =    -4.2849 T   3034 =   -85.2390 T   4034 =  -184.5182 T   5034 =  -327.0659 T   2035 =   -10.1671
T    3035 =   -90.1118 T   4035 =  -188.1076 T   5035 =  -328.6109 T   2036 =    -3.7836 T   3036 =   -84.8263 T   4036 =  -184.2157
T    5036 =  -326.9364 T   2037 =    55.4681 T   3037 =    62.6959 T   4037 =    69.7347 T   5037 =    76.6015 T  21001 =  -422.9858
T   21002 =  -422.9814 T  21003 =  -422.9823 T  21005 =  -422.9846 T  21006 =  -422.9800 T  21007 =  -422.9820 T  21009 =  -422.9854
T   21010 =  -422.9808 T  21011 =  -422.9815 T  21013 =  -422.9848 T  21014 =  -422.9808 T  21015 =  -422.9819 T  21004 =  -422.9851
T   21008 =  -422.9837 T  21012 =  -422.9839 T  21016 =  -422.9836 T  21017 =    54.9997 T  21018 =    54.9998 T  21019 =    54.9997
T   21020 =    54.9998 T  21021 =  -296.9910 T  21022 =  -296.9908 T  21023 =  -296.9909 T  21024 =  -296.9911 T  21025 =  -296.9911
T   21026 =  -296.9913 T  21027 =  -296.9916 T  21028 =  -296.9912 T  21029 =  -296.9970 T  21030 =  -296.9966 T  21031 =  -296.9968
T   21032 =  -296.9967 T  21033 =  -422.9854 T  21034 =  -422.9863 T  21035 =  -422.9862 T  21036 =  -422.9866 T  21037 =    79.9991
T   12001 =    49.5566 T  12002 =    49.4257 T  12003 =    47.8807 T  12004 =    49.5491 T  12041 =    47.5278 T  12042 =    48.2855
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T	12043	=	44.1125	T	12044	=	44.4706	T	12045	=	49.1913	T	12046	=	49.7499	T	12047	=
T	12085	=	46.9197	T	12086	=	49.4999	T	12087	=	46.1179	T	12088	=	47.5016	T	12005	=
T	12019	=	50.9127	T	12026	=	51.4782	T	12006	=	51.8483	T	12013	=	52.4755	T	12020	=
T	12007	=	51.2999	T	12014	=	51.1960	T	12021	=	50.5891	T	12028	=	51.3627	T	12008	=
T	12022	=	50.5536	T	12029	=	50.9698	T	12009	=	51.1948	T	12016	=	51.1516	T	12023	=

T	12047	=	49.7495	T	12048	=	52.0625											
T	12005	=	51.8660	T	12012	=	54.9352											
T	12020	=	50.8047	T	12027	=	51.6508											
T	12008	=	50.6762	T	12015	=	50.9269											
T	12023	=	50.4582	T	12030	=	50.5897											

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	12010	=	51.4496	T	12017	=	51.1969	T	12024	=	50.2361	T	12031	=	49.5841	T	12011	=
T	12025	=	49.2543	T	12032	=	49.6357	T	12033	=	52.8354	T	12034	=	52.0395	T	12035	=
T	12037	=	49.9360	T	12038	=	50.1939	T	12039	=	49.4181	T	12040	=	49.6193	T	22001	=
T	22003	=	52.5607	T	22004	=	52.8468	T	22041	=	52.1106	T	22042	=	52.5675	T	22043	=
T	12049	=	51.7447	T	12056	=	52.5629	T	12063	=	51.4375	T	12070	=	55.4955	T	12050	=
T	12064	=	51.3563	T	12071	=	53.8091	T	12051	=	51.6013	T	12058	=	52.7244	T	12065	=
T	12052	=	51.7262	T	12059	=	52.7214	T	12066	=	51.1865	T	12073	=	52.6235	T	12053	=
T	12067	=	51.1748	T	12074	=	52.5379	T	12054	=	53.2981	T	12061	=	52.5627	T	12068	=
T	12055	=	54.1248	T	12062	=	52.2913	T	12069	=	51.5905	T	12076	=	53.2667	T	12077	=
T	12079	=	51.9959	T	12080	=	52.3947	T	12081	=	51.2214	T	12082	=	50.8502	T	12083	=
T	22045	=	53.1593	T	22046	=	53.9749	T	22047	=	54.3446	T	22048	=	56.0113	T	22085	=
T	22087	=	50.8593	T	22088	=	51.9096	T	22005	=	51.8784	T	22006	=	51.8608	T	22007	=
T	22009	=	51.2075	T	22010	=	51.4620	T	22011	=	52.2879	T	22012	=	54.9458	T	22013	=
T	22015	=	50.9398	T	22016	=	51.1644	T	22017	=	51.2097	T	22018	=	51.2556	T	22019	=
T	22021	=	50.6025	T	22022	=	50.5670	T	22023	=	50.4716	T	22024	=	50.2496	T	22025	=
T	22027	=	51.6633	T	22028	=	51.3754	T	22029	=	50.9826	T	22030	=	50.6029	T	22031	=
T	22049	=	51.7573	T	22050	=	51.7537	T	22051	=	51.6140	T	22052	=	51.7388	T	22053	=
T	22055	=	54.1361	T	22056	=	52.5750	T	22057	=	52.7712	T	22058	=	52.7365	T	22059	=
T	22061	=	52.5750	T	22062	=	52.3038	T	22063	=	51.4504	T	22064	=	51.3693	T	22065	=
T	22067	=	51.1879	T	22068	=	51.4016	T	22069	=	51.6034	T	22070	=	55.5058	T	22071	=
T	22073	=	52.6357	T	22074	=	52.5501	T	22075	=	52.8699	T	22076	=	53.2785	T	22033	=
T	22035	=	52.0032	T	22036	=	52.2508	T	22037	=	49.9498	T	22038	=	50.2075	T	22039	=
T	22077	=	53.8392	T	22078	=	52.3936	T	22079	=	52.0086	T	22080	=	52.4071	T	22081	=
T	22083	=	52.0867	T	22084	=	51.5922	T	31005	=	70.3074	T	31006	=	70.2977	T	31007	=
T	31009	=	70.2254	T	31010	=	70.2109	T	31011	=	70.2810	T	31012	=	70.4382	T	31013	=
T	31015	=	70.2354	T	31016	=	70.2571	T	31017	=	70.2615	T	31018	=	70.2536	T	31019	=
T	31021	=	70.2926	T	31022	=	70.2837	T	31023	=	70.2761	T	31024	=	70.2556	T	31025	=
T	31027	=	70.2771	T	31028	=	70.2455	T	31029	=	70.2046	T	31030	=	70.2426	T	31031	=
T	31033	=	70.3898	T	31034	=	70.3765	T	31035	=	70.3477	T	31036	=	70.3644	T	31037	=
T	31039	=	70.1713	T	31040	=	70.1885	T	31049	=	70.3160	T	31050	=	70.3105	T	31051	=
T	31053	=	70.3752	T	31054	=	70.4082	T	31055	=	70.4548	T	31056	=	70.4031	T	31057	=
T	31059	=	70.4156	T	31060	=	70.4280	T	31061	=	70.4208	T	31062	=	70.4174	T	31063	=
T	31065	=	70.3314	T	31066	=	70.3333	T	31067	=	70.3429	T	31068	=	70.3525	T	31069	=
T	31071	=	70.4405	T	31072	=	70.4122	T	31073	=	70.4056	T	31074	=	70.4017	T	31075	=
T	31077	=	70.4629	T	31078	=	70.4085	T	31079	=	70.4009	T	31080	=	70.4119	T	31081	=
T	31083	=	70.3476	T	31084	=	70.3046	T	32005	=	70.9880	T	32006	=	70.9878	T	32007	=
T	32009	=	70.9862	T	32010	=	70.9858	T	32011	=	70.9873	T	32012	=	70.9904	T	32013	=
T	32015	=	70.9865	T	32016	=	70.9870	T	32017	=	70.9871	T	32018	=	70.9869	T	32019	=
T	32021	=	70.9880	T	32022	=	70.9878	T	32023	=	70.9877	T	32024	=	70.9872	T	32025	=
T	32027	=	70.9873	T	32028	=	70.9866	T	32029	=	70.9857	T	32030	=	70.9868	T	32031	=
T	32033	=	70.9899	T	32034	=	70.9897	T	32035	=	70.9890	T	32036	=	70.9893	T	32037	=
T	32039	=	70.9855	T	32040	=	70.9858	T	32049	=	70.9882	T	32050	=	70.9881	T	32051	=
T	32053	=	70.9895	T	32054	=	70.9901	T	32055	=	70.9910	T	32056	=	70.9901	T	32057	=
T	32059	=	70.9904	T	32060	=	70.9907	T	32061	=	70.9906	T	32062	=	70.9906	T	32063	=
T	32065	=	70.9888	T	32066	=	70.9889	T	32067	=	70.9891	T	32068	=	70.9893	T	32069	=
T	32071	=	70.9907	T	32072	=	70.9903	T	32073	=	70.9902	T	32074	=	70.9901	T	32075	=
T	32077	=	70.9913	T	32078	=	70.9904	T	32079	=	70.9903	T	32080	=	70.9904	T	32081	=
T	32083	=	70.9890	T	32084	=	70.9881	T	33005	=	70.9999	T	33006	=	70.9999	T	33007	=
T	33009	=	70.9998	T	33010	=	70.9998	T	33011	=	70.9998	T	33012	=	70.9999	T	33013	=
T	33015	=	70.9998	T	33016	=	70.9998	T	33017	=	70.9998	T	33018	=	70.9998	T	33019	=
T	33021	=	70.9999	T	33022	=	70.9999	T	33023	=	70.9999	T	33024	=	70.9998	T	33025	=
T	33027	=	70.9998	T	33028	=	70.9998	T	33029	=	70.9998	T	33030	=	70.9998	T	33031	=
T	33033	=	70.9999	T	33034	=	70.9999	T	33035	=	70.9999	T	33036	=	70.9999	T	33037	=
T	33039	=	70.9998	T	33040	=	70.9998	T	33049	=	70.9999	T	33050	=	70.9999	T	33051	=
T	33053	=	70.9999	T	33054	=	70.9999	T	33055	=	70.9999	T	33056	=	70.9999	T	33057	=
T	33059	=	70.9999	T	33060	=	70.9999	T	33061	=	70.9999	T	33062	=	70.9999	T	33063	=
T	33065	=	70.9999	T	33066	=	70.9999	T	33067	=	70.9999	T	33068	=	70.9999	T	33069	=

T	12048	=	52.0625															
T	12012	=	54.9352															
T	12027	=	51.6508															
T	12015	=	50.9269															
T	12030	=	50.5897															

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	33071	=	70.9999	T	33072	=	70.9999	T	33073	=	70.9999	T	33074	=	70.9999	T	33075	=
T	33077	=	70.9999	T	33078	=	70.9999	T	33079	=	70.9999	T	33080	=	70.9999	T	33081	=
T	33083	=	70.9999	T	33084	=	70.9999	T	34005	=	71.0000	T	34006	=	71.0000	T	34007	=
T	34009	=	71.0000	T	34010	=	71.0000	T	34011	=	71.0000	T	34012	=	71.0000	T	34013	=
T	34015	=	71.0000	T	34016	=	71.0000	T	34017	=	71.0000	T	34018	=	71.0000	T	34019	=
T	34021	=	71.0000	T	34022	=	71.0000	T	34023	=	71.0000	T	34024	=	71.0000	T	34025	=
T	34027	=	71.0000	T	34028	=	71.0000	T	34029	=	71.0000	T	34030	=	71.0000	T	34031	=
T	34033	=	71.0000	T	34034	=	71.0000	T	34035	=	71.0000	T	34036	=	71.0000	T	34037	=
T	34039	=	71.0000	T	34040	=	71.0000	T	34049	=	71.0000	T	34050	=	71.0000	T	34051	=
T	34053	=	71.0000	T	34054	=	71.0000	T	34055	=	71.0000	T	34056	=	71.0000	T	34057	=
T	34059	=	71.0000	T	34060	=	71.0000	T	34061	=	71.0000	T	34062	=	71.0000	T	34063	=
T	34065	=	71.0000	T	34066	=	71.0000	T	34067	=	71.0000	T	34068	=	71.0000	T	34069	=
T	34071	=	71.0000	T	34072	=	71.0000	T	34073	=	71.0000	T	34074	=	71.0000	T	34075	=
T	34077	=	71.0000	T	34078	=	71.0000	T	34079	=	71.0000	T	34080	=	71.0000	T	34081	=
T	34083	=	71.0000	T	34084	=	71.0000	T	42006	=	92.5267	T	42013	=	92.0835	T	42020	=
T	42008	=	90.1797	T	42015	=	92.2759	T	42022	=	93.8933	T	42029	=	90.8558	T	42010	=
T	42024	=	93.2013	T	42031	=	93.6283	T	42050	=	90.2095	T	42057	=	93.3436	T	42064	=
T	42052	=	91.8067	T	42059	=	93.8903	T	42066	=	92.5041	T	42073	=	94.1360	T	42054	=
T	42068	=	92.9537	T	42075	=	94.2539	T	43006	=	62.7940	T	43013	=	61.9183	T	43020	=
T	43008	=	59.5022	T	43015	=	61.5696	T	43022	=	63.9702	T	43029	=	60.6012	T	43010	=
T	43024	=	61.9065	T	43031	=	62.2933	T	43050	=	68.0862	T	43057	=	77.6329	T	43064	=
T	43052	=	69.7028	T	43059	=	78.0436	T	43066	=	66.1453	T	43073	=	67.4802	T	43054	=
T	43068	=	66.8449	T	43075	=	67.7212	T	8000	=	39.2420	T	8005	=	41.0862	T	8010	=
T	8015	=	39.3051	T	8016	=	42.2931	T	8020	=	40.9403	T	8025	=	40.5849	T	8030	=
T	6000	=	35.0733	T	6010	=	35.2428	T	6020	=	35.1984	T	6030	=	35.1887	T	6040	=
T	6060	=	35.0524	T	6070	=	34.9082	T	6080	=	34.8390	T	6090	=	34.8081	T	6001	=
T	6021	=	35.2886	T	6031	=	35.1834	T	6041	=	35.1503	T	6051	=	35.1255	T	6061	=
T	6081	=	35.0494	T	6091	=	34.1592	T	500	=	35.5947	T	501	=	35.3357	T	502	=
T	9000	=	30.3165	T	9001	=	30.3202	T	9002	=	30.3201	T	9003	=	30.3171	T	40	=
T	7000	=	-423.0000	T	7001	=	-297.0000	T	7002	=	55.0000	T	7003	=	80.0000	T	8888	=
T	8890	=	0.0000	T	8891	=	210.0000	T	8892	=	6.0000	T	13001	=	0.0000	T	13002	=
T	13004	=	0.0000	T	13005	=	0.0000	T	13006	=	0.0000	T	13007	=	0.0000	T	13008	=
T	13010	=	0.0000	T	13011	=	0.0000	T	13012	=	0.0000	T	13013	=	0.0000	T	13014	=
T	13016	=	0.0000	T	13017	=	0.0000	T	13018	=	0.0000	T	13019	=	0.0000	T	13020	=
T	13022	=	0.0000	T	13023	=	0.0000	T	13024	=	0.0000	T	13025	=	0.0000	T	13026	=
T	13028	=	0.0000	T	13029	=	0.0000	T	13030	=	0.0000	T	13031	=	0.0000	T	13032	=
T	13034	=	0.0000	T	13035	=	0.0000	T	13036	=	0.0000	T	13037	=	0.0000	T	16001	=
T	16003	=	4289.0796	T	16004	=	3607.4140	T	16005	=	2325.1479	T	16006	=	4316.1128	T	16007	=
T	16009	=	2274.7323	T	16010	=	4086.8299	T	16011	=	4228.9308	T	16012	=	3455.9369	T	16013	=
T	16015	=	3963.0392	T	16016	=	3325.3108	T	16017	=	0.0000	T	16018	=	0.0000	T	16019	=

T	33076	=	70.9999															
T	33082	=	70.9999															
T	34008	=	71.0000															
T	34014	=	71.0000															
T	34020	=	71.0000															
T	34026	=	71.0000															
T	34032	=	71.0000															
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T	34052	=	71.0000															
T	34058	=	71.0000															
T	34064	=	71.0000															
T	34070	=	71.0000															
T	34076	=	71.0000															
T	34082	=	71.0000															
T	42027	=	91.1629															
T	42017	=	94.1215															
T	42071	=	94.3077															
T	42061	=	93.8389															
T	43027	=	61.5235															
T	43017	=	62.3531															
T	43071	=	67.6483															
T	43061	=	78.4668															
T	8011	=	43.4797															
T	8035	=	49.5380															
T	6050	=	35.0943															
T	6011	=	35.3660															
T	6071	=	35.0593															
T	503	=	35.7349															
T	9999	=	29.9084															
T	8889	=	56.0000															
T	13003	=	0.0000															
T	13009	=	0.0000															
T	13015	=	0.0000															
T	13021	=	0.0000															
T	13027	=	0.0000															
T	13033	=	0.0000															
T	16002	=	4481.0972															
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T  16021 - 1916.8241 T  16022 - 1439.4180 T  16023 - 1800.8848 T  16024 - 1811.4239 T  16025 - 2564.6433 T  16026 - 2035.2583
T  16027 - 2882.3635 T  16028 - 2681.3478 T  16029 -    0.0000 T  16030 -    0.0000 T  16031 -    0.0000 T  16032 -    0.0000
T  16033 - 1646.1547 T  16034 - 1446.5387 T  16035 - 1765.3478 T  16036 - 1256.3582 T  16037 -    0.0000 T    101 -    1.6205
T    102 -    2.3294 T    103 -    2.7346 T    104 -    3.0384 T    105 -    6.6845 T    106 -    6.0768 T    107 -    5.6717
T    108 -    7.0896 T    109 -    6.6845 T    110 -    7.3934 T    111 -    6.0768 T    112 -    6.0768 T    113 -    5.4691
T    114 -    5.6717 T    115 -    5.0640 T    116 -    5.2666 T    117 -    4.0512 T    118 -    8.7101 T    119 -    7.0896
T    120 -    5.4691 T    121 -    4.9627 T    122 -    9.1152 T    123 -    8.0011 T    124 -    5.3678 T    125 -    9.2165
T    126 -   11.1408 T    127 -    7.3934 T    128 -    8.3050 T    129 -   11.1408 T    130 -   12.1536 T    131 -   10.1280
T    132 -   12.1536 T    133 -    4.8614 T    134 -    4.6589 T    135 -    2.0256 T    136 -    4.9627 T    137 -   14.1792
T    151 -    0.1600 T    152 -    0.2300 T    153 -    0.2700 T    154 -    0.3000 T    155 -    0.6600 T    156 -    0.6000
T    157 -    0.5600 T    158 -    0.7000 T    159 -    0.6600 T    160 -    0.7300 T    161 -    0.6000 T    162 -    0.6000
T    163 -    0.5400 T    164 -    0.5600 T    165 -    0.5000 T    166 -    0.5200 T    167 -    0.4000 T    168 -    0.8600
T    169 -    0.7000 T    170 -    0.5400 T    171 -    0.4900 T    172 -    0.9000 T    173 -    0.7900 T    174 -    0.5300
T    175 -    0.9100 T    176 -    1.1000 T    177 -    0.7300 T    178 -    0.8200 T    179 -    1.1000 T    180 -    1.2000
T    181 -    1.0000 T    182 -    1.2000 T    183 -    0.4800 T    184 -    0.4600 T    185 -    0.2000 T    186 -    0.4900
T    187 -    1.4000 T    201 -    0.0013 T    202 -    0.0017 T    203 -    0.0016 T    204 -    0.0014 T    205 -    0.0010
T    206 -    0.0017 T    207 -    0.0015 T    208 -    0.0011 T    209 -    0.0010 T    210 -    0.0016 T    211 -    0.0016
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T    212 -    0.0013 T    213 -    0.0011 T    214 -    0.0016 T    215 -    0.0015 T    216 -    0.0013 T    217 -    0.0000
T    218 -    0.0000 T    219 -    0.0000 T    220 -    0.0000 T    221 -    0.0017 T    222 -    0.0014 T    223 -    0.0016
T    224 -    0.0016 T    225 -    0.0014 T    226 -    0.0011 T    227 -    0.0014 T    228 -    0.0015 T    229 -    0.0000
T    230 -    0.0000 T    231 -    0.0000 T    232 -    0.0000 T    233 -    0.0011 T    234 -    0.0010 T    235 -    0.0012
T    236 -    0.0010 T    237 -    0.0000 T    401 -    0.0000 T    402 -    0.0000 T    403 -    0.0000 T    404 -    0.0000
T    405 -    0.0000 T    406 -    0.0000 T    407 -    0.0000 T    408 -    0.0000 T    409 -    0.0000 T    410 -    0.0000
T    411 -    0.0000 T    412 -    0.0000 T    413 -    0.0000 T    414 -    0.0000 T    415 -    0.0000 T    416 -    0.0000
T    417 -    0.0000 T    418 -    0.0000 T    419 -    0.0000 T    420 -    0.0000 T    421 -    0.0000 T    422 -    0.0000
T    423 -    0.0000 T    424 -    0.0000 T    425 -    0.0000 T    426 -    0.0000 T    427 -    0.0000 T    428 -    0.0000
T    429 -    0.0000 T    430 -    0.0000 T    431 -    0.0000 T    432 -    0.0000 T    433 -    0.0000 T    434 -    0.0000
T    435 -    0.0000 T    436 -    0.0000 T    437 -    0.0000 T    701 -    0.0259 T    702 -    0.0424 T    703 -    0.0388
T    704 -    0.0259 T    705 -   -0.0044 T    706 -    0.0158 T    707 -    0.0121 T    708 -   -0.0023 T    709 -   -0.0049
T    710 -    0.0086 T    711 -    0.0145 T    712 -    0.0063 T    713 -    0.0022 T    714 -    0.0159 T    715 -    0.0164
T    716 -    0.0082 T    717 -   -0.0322 T    718 -   -0.0635 T    719 -   -0.0505 T    720 -   -0.0474 T    721 -    0.0241
T    722 -    0.0012 T    723 -    0.0086 T    724 -    0.0189 T    725 -   -0.0006 T    726 -   -0.0115 T    727 -    0.0049
T    728 -    0.0027 T    729 -   -0.0522 T    730 -   -0.0540 T    731 -   -0.0445 T    732 -   -0.0543 T    733 -    0.0063
T    734 -    0.0033 T    735 -    0.0218 T    736 -    0.0007 T    737 -   -0.1448 T    801 -    0.0453 T    802 -    0.0760
T    803 -    0.0644 T    804 -    0.0384 T    805 -    0.0000 T    806 -    0.0171 T    807 -    0.0114 T    808 -    0.0000
T    809 -    0.0000 T    810 -    0.0079 T    811 -    0.0144 T    812 -    0.0057 T    813 -    0.0016 T    814 -    0.0265
T    815 -    0.0237 T    816 -    0.0077 T    817 -    0.0000 T    818 -    0.0000 T    819 -    0.0000 T    820 -    0.0000
T    821 -    0.0334 T    822 -    0.0011 T    823 -    0.0086 T    824 -    0.0270 T    825 -    0.0000 T    826 -    0.0000
T    827 -    0.0049 T    828 -    0.0027 T    829 -    0.0000 T    830 -    0.0000 T    831 -    0.0000 T    832 -    0.0000
T    833 -    0.0056 T    834 -    0.0026 T    835 -    0.0323 T    836 -    0.0002 T    837 -    0.0000 T    901 -   88.6573
T    902 -  148.6483 T    903 -  125.9996 T    904 -   75.1397 T    905 -    0.0000 T    906 -   33.3691 T    907 -   22.2949
T    908 -    0.0000 T    909 -    0.0000 T    910 -   15.3700 T    911 -   28.2198 T    912 -   11.1485 T    913 -    3.1851
T    914 -   51.7780 T    915 -   46.4255 T    916 -   15.0356 T    917 -    0.0000 T    918 -    0.0000 T    919 -    0.0000
T    920 -    0.0000 T    921 -   28.2877 T    922 -    0.8925 T    923 -    7.2814 T    924 -   22.8591 T    925 -    0.0000
T    926 -    0.0000 T    927 -    7.5652 T    928 -    4.1850 T    929 -    0.0000 T    930 -    0.0000 T    931 -    0.0000
T    932 -    0.0000 T    933 -    6.2271 T    934 -    2.9359 T    935 -   35.8620 T    936 -    0.2192 T    937 -    0.0000

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TIME= 2.05000E+01, DTIMEU= 2.50000E-03, CSGMIN(  21037)= 1.11551E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(   2010)=-1.652333
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T    1001 -   22.3408 T    1002 -   17.8290 T    1003 -   20.7261 T    1004 -   25.3861 T    1005 -   34.1673 T    1006 -   30.[illegible]
T    1007 -   30.6699 T    1008 -   33.7058 T    1009 -   34.4546 T    1010 -   31.9444 T    1011 -   30.5776 T    1012 -   31.954[illegible]
T    1013 -   31.9867 T    1014 -   29.2946 T    1015 -   28.8795 T    1016 -   31.0868 T    1017 -   42.6651 T    1018 -   47.954
T    1019 -   45.6907 T
          -  10262,   1005,  12077, 0.35059E-08$
          -  10263,   1005,  12081, 0.27800E-08$
          -  10264,   1005,  12083, 0.11635E-07$
          -  10265,   1005,     50
T    3002 -  -96.4341 T    4002 - -195.6114 T    5002 - -333.0340 T    2003 -  -14.0297 T    3003 -  -94.0612 T    4003 - -193.9[illegible]
T    5003 - -332.3128 T    2004 -   -9.6353 T    3004 -  -90.2427 T    4004 - -191.1763 T    5004 - -331.1526 T    2005 -   -1.353
T    3005 -  -83.0433 T    4005 - -186.0151 T    5005 - -328.9555 T    2006 -   -5.2750 T    3006 -  -86.4530 T    4006 - -188.458[illegible]
T    5006 - -329.9914 T    2007 -   -4.6525 T    3007 -  -85.9121 T    4007 - -188.0716 T    5007 - -329.8286 T    2008 -   -1.789[illegible]
T    3008 -  -83.4240 T    4008 - -186.2884 T    5008 - -329.0712 T    2009 -   -1.0810 T    3009 -  -82.8054 T    4009 - -185.844
T    5009 - -328.8832 T    2010 -   -3.4245 T    3010 -  -84.8449 T    4010 - -187.3088 T    5010 - -329.5032 T    2011 -   -4.[illegible]
T    3011 -  -85.9868 T    4011 - -188.1246 T    5011 - -329.8505 T    2012 -   -3.4389 T    3012 -  -84.8573 T    4012 - -187.3[illegible]
T    5012 - -329.5092 T    2013 -   -3.4115 T    3013 -  -84.8348 T    4013 - -187.3007 T    5013 - -329.5035 T    2014 -   -5.949[illegible]
T    3014 -  -87.0392 T    4014 - -188.8792 T    5014 - -330.1711 T    2015 -   -6.3409 T    3015 -  -87.3794 T    4015 - -189.[illegible]
T    5015 - -330.2760 T    2016 -   -4.2589 T    3016 -  -85.5696 T    4016 - -187.8262 T    5016 - -329.7257 T    2017 -   44.22[illegible]
T    3017 -   47.3313 T    4017 -   50.4131 T    5017 -   53.4739 T    2018 -   48.8465 T    3018 -   50.6182 T    4018 -   52.3[illegible]
T    5018 -   54.1269 T    2019 -   46.8688 T    3019 -   49.2100 T    4019 -   51.5352 T    5019 -   53.8468 T    2020 -   47.42[illegible]
T    3020 -   49.6089 T    4020 -   51.7747 T    5020 -   53.9265 T    2021 -   -0.7661 T    3021 -  -66.0391 T    4021 - -145.244[illegible]
T    5021 - -241.5557 T    2022 -    4.2151 T    3022 -  -61.8429 T    4022 - -142.3464 T    5022 - -240.4455 T    2023 -    2.[illegible]
T    3023 -  -63.0886 T    4023 - -143.2083 T    5023 - -240.7754 T    2024 -   -0.2329 T    3024 -  -65.5901 T    4024 - -144.[illegible]
T    5024 - -241.4372 T    2025 -    4.6830 T    3025 -  -61.4492 T    4025 - -142.0747 T    5025 - -240.3420 T    2026 -    6.2[illegible]
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T    3026 -  -60.0993 T    4026 - -141.1403 T    5026 - -239.9844 T    2027 -    3.7238 T    3027 -  -62.2578 T    4027 - -142.6[illegible]
T    5027 - -240.5568 T    2028 -    3.6692 T    3028 -  -62.3037 T    4028 - -142.6660 T    5028 - -240.5684 T    2029 -   11.[illegible]
T    3029 -  -55.9679 T    4029 - -138.1260 T    5029 - -238.8360 T    2030 -   10.9980 T    3030 -  -56.1819 T    4030 - -138.[illegible]
T    5030 - -238.8961 T    2031 -   10.1030 T    3031 -  -56.9239 T    4031 - -138.8323 T    5031 - -239.1066 T    2032 -   10.[illegible]
T    3032 -  -56.2267 T    4032 - -138.3174 T    5032 - -238.9091 T    2033 -   -3.4294 T    3033 -  -84.5363 T    4033 - -184.[illegible]
T    5033 - -326.8444 T    2034 -   -2.9196 T    3034 -  -84.1144 T    4034 - -183.6933 T    5034 - -326.7117 T    2035 -   -9.[illegible]
T    3035 -  -89.9434 T    4035 - -187.9834 T    5035 - -328.5574 T    2036 -   -2.9832 T    3036 -  -84.1680 T    4036 - -183.[illegible]
T    5036 - -326.7295 T    2037 -   54.1973 T    3037 -   61.6887 T    4037 -   69.0784 T    5037 -   76.3728 T   21001 - -422.[illegible]
T   21002 - -422.9814 T   21003 - -422.9822 T   21005 - -422.9845 T   21006 - -422.9799 T   21007 - -422.9819 T   21009 - -422.[illegible]
T   21010 - -422.9807 T   21011 - -422.9814 T   21013 - -422.9848 T   21014 - -422.9807 T   21015 - -422.9818 T   21004 - -422.[illegible]
T   21008 - -422.9837 T   21012 - -422.9838 T   21016 - -422.9836 T   21017 -   54.9997 T   21018 -   54.9998 T   21019 -   54.[illegible]
T   21020 -   54.9997 T   21021 - -296.9909 T   21022 - -296.9908 T   21023 - -296.9908 T   21024 - -296.9911 T   21025 - -296.[illegible]
T   21026 - -296.9912 T   21027 - -296.9916 T   21028 - -296.9912 T   21029 - -296.9970 T   21030 - -296.9966 T   21031 - -296.[illegible]
T   21032 - -296.9967 T   21033 - -422.9853 T   21034 - -422.9862 T   21035 - -422.9862 T   21036 - -422.9866 T   21037 -   79.[illegible]
T    12001 -   48.1024 T    12002 -   48.1363 T    12003 -   46.6516 T    12004 -   48.0586 T    12041 -   46.3118 T    12042 -   47.[illegible]
T    12043 -   42.9814 T    12044 -   43.3646 T    12045 -   47.7557 T    12046 -   48.3007 T    12047 -   48.3683 T    12048 -   50.[illegible]
T    12085 -   45.7924 T    12086 -   48.1045 T    12087 -   44.9751 T    12088 -   46.3514 T    12005 -   50.0663 T    12012 -   53.[illegible]
T    12019 -   48.9920 T    12026 -   49.7231 T    12006 -   50.1070 T    12013 -   50.9769 T    12020 -   48.9351 T    12027 -   49.[illegible]
T    12007 -   49.7000 T    12014 -   49.8924 T    12021 -   48.7614 T    12028 -   49.7169 T    12008 -   49.3934 T    12015 -   49.[illegible]
T    12022 -   48.7761 T    12029 -   49.4734 T    12009 -   49.8013 T    12016 -   49.8246 T    12023 -   48.7168 T    12030 -   48.[illegible]
T    12010 -   50.2578 T    12017 -   49.8706 T    12024 -   48.5803 T    12031 -   47.8651 T    12011 -   50.9689 T    12018 -   49.[illegible]
T    12025 -   47.9371 T    12032 -   48.1438 T    12033 -   50.9567 T    12034 -   50.0475 T    12035 -   50.2860 T    12036 -   50.[illegible]
T    12037 -   48.2383 T    12038 -   48.5283 T    12039 -   48.[illegible]789 T    12040 -   48.2279 T    22001 -   51.4355 T    22002 -   51.[illegible]
T    22003 -   50.7825 T    22004 -   51.3693 T    22041 -   50.[illegible]232 T    22042 -   50.9742 T    22043 -   46.7584 T    22044 -   47.[illegible]
T    12049 -   49.8876 T    12056 -   50.5054 T    12063 -   49.4453 T    12070 -   53.3547 T    12050 -   49.9315 T    12057 -   50.[illegible]
T    12064 -   49.3957 T    12071 -   51.8998 T    12051 -   49.[illegible]763 T    12058 -   50.6525 T    12065 -   49.2417 T    12072 -   51.[illegible]
T    12052 -   49.8735 T    12059 -   50.6494 T    12066 -   49.[illegible]339 T    12073 -   50.8485 T    12053 -   50.4851 T    12060 -   51.[illegible]
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ORIGINAL PAGE IS
OF POOR QUALITY

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T	12055 -	52.0732	T	12062 -	50.0180	T	12069 -	49.5727	T	12076 -	51.3844	T	12077 -	51.6279	T	12078 -	50.2434
T	12079 -	49.7312	T	12080 -	50.2585	T	12081 -	49.2368	T	12082 -	49.0410	T	12083 -	50.3842	T	12084 -	49.9866
T	22045 -	51.5727	T	22046 -	52.2291	T	22047 -	52.5292	T	22048 -	54.2465	T	22085 -	50.5412	T	22086 -	52.2608
T	22087 -	49.2752	T	22088 -	50.3635	T	22005 -	50.0795	T	22006 -	50.1202	T	22007 -	49.7135	T	22008 -	49.4070
T	22009 -	49.8147	T	22010 -	50.2709	T	22011 -	50.9815	T	22012 -	53.0782	T	22013 -	50.9895	T	22014 -	49.9057
T	22015 -	49.6632	T	22016 -	49.8379	T	22017 -	49.8839	T	22018 -	49.9699	T	22019 -	49.0060	T	22020 -	48.9492
T	22021 -	48.7755	T	22022 -	48.7902	T	22023 -	48.7310	T	22024 -	48.5945	T	22025 -	47.9516	T	22026 -	49.7366
T	22027 -	49.9164	T	22028 -	49.7304	T	22029 -	49.4869	T	22030 -	48.9792	T	22031 -	47.8798	T	22032 -	48.1583
T	22049 -	49.9010	T	22050 -	49.9448	T	22051 -	49.7887	T	22052 -	49.8869	T	22053 -	50.4982	T	22054 -	51.3522
T	22055 -	52.0853	T	22056 -	50.5184	T	22057 -	50.6935	T	22058 -	50.6654	T	22059 -	50.6623	T	22060 -	50.6656
T	22061 -	50.4263	T	22062 -	50.0315	T	22063 -	49.4591	T	22064 -	49.4095	T	22065 -	49.2555	T	22066 -	49.2497
T	22067 -	49.1931	T	22068 -	49.4054	T	22069 -	49.5864	T	22070 -	53.3660	T	22071 -	51.9119	T	22072 -	51.1855
T	22073 -	50.8613	T	22074 -	50.7909	T	22075 -	51.0706	T	22076 -	51.3969	T	22033 -	50.9695	T	22034 -	50.0610
T	22035 -	50.2992	T	22036 -	50.3557	T	22037 -	48.2527	T	22038 -	48.5426	T	22039 -	48.0934	T	22040 -	48.2423
T	22077 -	51.6404	T	22078 -	50.2567	T	22079 -	49.7449	T	22080 -	50.2718	T	22081 -	49.2507	T	22082 -	49.0550
T	22083 -	50.3974	T	22084 -	50.0000	T	31005 -	70.0470	T	31006 -	70.0377	T	31007 -	69.9960	T	31008 -	69.9126
T	31009 -	69.9610	T	31010 -	69.9519	T	31011 -	70.0311	T	31012 -	70.2163	T	31013 -	70.0589	T	31014 -	69.9785
T	31015 -	69.9678	T	31016 -	69.9917	T	31017 -	69.9967	T	31018 -	69.9900	T	31019 -	70.0393	T	31020 -	70.0299
T	31021 -	70.0153	T	31022 -	70.0065	T	31023 -	69.9980	T	31024 -	69.9757	T	31025 -	69.8860	T	31026 -	70.0089
T	31027 -	70.0146	T	31028 -	69.9807	T	31029 -	69.9366	T	31030 -	69.9678	T	31031 -	69.9492	T	31032 -	69.9219
T	31033 -	70.1395	T	31034 -	70.1145	T	31035 -	70.0879	T	31036 -	70.1063	T	31037 -	69.9687	T	31038 -	69.9788
T	31039 -	69.8828	T	31040 -	69.9020	T	31049 -	70.0536	T	31050 -	70.0485	T	31051 -	70.0502	T	31052 -	70.0651
T	31053 -	70.1201	T	31054 -	70.1640	T	31055 -	70.2205	T	31056 -	70.1474	T	31057 -	70.1587	T	31058 -	70.1592
T	31059 -	70.1617	T	31060 -	70.1741	T	31061 -	70.1644	T	31062 -	70.1572	T	31063 -	70.0735	T	31064 -	70.0670
T	31065 -	70.0605	T	31066 -	70.0623	T	31067 -	70.0712	T	31068 -	70.0835	T	31069 -	70.0960	T	31070 -	70.2966
T	31071 -	70.2022	T	31072 -	70.1642	T	31073 -	70.1530	T	31074 -	70.1483	T	31075 -	70.1634	T	31076 -	70.1829
T	31077 -	70.2221	T	31078 -	70.1494	T	31079 -	70.1357	T	31080 -	70.1523	T	31081 -	70.0715	T	31082 -	70.0282
T	31083 -	70.0890	T	31084 -	70.0410	T	32005 -	70.9787	T	32006 -	70.9783	T	32007 -	70.9772	T	32008 -	70.9745
T	32009 -	70.9759	T	32010 -	70.9754	T	32011 -	70.9777	T	32012 -	70.9827	T	32013 -	70.9786	T	32014 -	70.9765

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	32015 -	70.9763	T	32016 -	70.9771	T	32017 -	70.9772	T	32018 -	70.9769	T	32019 -	70.9791	T	32020 -	70.9788
T	32021 -	70.9784	T	32022 -	70.9781	T	32023 -	70.9779	T	32024 -	70.9772	T	32025 -	70.9746	T	32026 -	70.9775
T	32027 -	70.9776	T	32028 -	70.9765	T	32029 -	70.9752	T	32030 -	70.9766	T	32031 -	70.9767	T	32032 -	70.9756
T	32033 -	70.9815	T	32034 -	70.9811	T	32035 -	70.9801	T	32036 -	70.9806	T	32037 -	70.9772	T	32038 -	70.9774
T	32039 -	70.9744	T	32040 -	70.9750	T	32049 -	70.9790	T	32050 -	70.9788	T	32051 -	70.9789	T	32052 -	70.9794
T	32053 -	70.9810	T	32054 -	70.9820	T	32055 -	70.9835	T	32056 -	70.9819	T	32057 -	70.9822	T	32058 -	70.9822
T	32059 -	70.9823	T	32060 -	70.9827	T	32061 -	70.9825	T	32062 -	70.9824	T	32063 -	70.9800	T	32064 -	70.9798
T	32065 -	70.9796	T	32066 -	70.9797	T	32067 -	70.9801	T	32068 -	70.9804	T	32069 -	70.9807	T	32070 -	70.9853
T	32071 -	70.9830	T	32072 -	70.9821	T	32073 -	70.9820	T	32074 -	70.9819	T	32075 -	70.9822	T	32076 -	70.9827
T	32077 -	70.9838	T	32078 -	70.9822	T	32079 -	70.9819	T	32080 -	70.9823	T	32081 -	70.9801	T	32082 -	70.9788
T	32083 -	70.9801	T	32084 -	70.9787	T	33005 -	70.9997	T	33006 -	70.9997	T	33007 -	70.9996	T	33008 -	70.9996
T	33009 -	70.9996	T	33010 -	70.9996	T	33011 -	70.9996	T	33012 -	70.9997	T	33013 -	70.9997	T	33014 -	70.9996
T	33015 -	70.9996	T	33016 -	70.9996	T	33017 -	70.9996	T	33018 -	70.9996	T	33019 -	70.9997	T	33020 -	70.9997
T	33021 -	70.9997	T	33022 -	70.9997	T	33023 -	70.9997	T	33024 -	70.9996	T	33025 -	70.9996	T	33026 -	70.9996
T	33027 -	70.9996	T	33028 -	70.9996	T	33029 -	70.9996	T	33030 -	70.9996	T	33031 -	70.9996	T	33032 -	70.9996
T	33033 -	70.9997	T	33034 -	70.9997	T	33035 -	70.9997	T	33036 -	70.9997	T	33037 -	70.9996	T	33038 -	70.9996
T	33039 -	70.9996	T	33040 -	70.9996	T	33049 -	70.9997	T	33050 -	70.9997	T	33051 -	70.9997	T	33052 -	70.9997
T	33053 -	70.9997	T	33054 -	70.9997	T	33055 -	70.9997	T	33056 -	70.9997	T	33057 -	70.9997	T	33058 -	70.9997
T	33059 -	70.9997	T	33060 -	70.9997	T	33061 -	70.9997	T	33062 -	70.9997	T	33063 -	70.9997	T	33064 -	70.9997
T	33065 -	70.9997	T	33066 -	70.9997	T	33067 -	70.9997	T	33068 -	70.9997	T	33069 -	70.9997	T	33070 -	70.9998
T	33071 -	70.9997	T	33072 -	70.9997	T	33073 -	70.9997	T	33074 -	70.9997	T	33075 -	70.9997	T	33076 -	70.9997
T	33077 -	70.9998	T	33078 -	70.9997	T	33079 -	70.9997	T	33080 -	70.9997	T	33081 -	70.9997	T	33082 -	70.9997
T	33083 -	70.9997	T	33084 -	70.9997	T	34005 -	71.0000	T	34006 -	71.0000	T	34007 -	71.0000	T	34008 -	71.0000
T	34009 -	71.0000	T	34010 -	71.0000	T	34011 -	71.0000	T	34012 -	71.0000	T	34013 -	71.0000	T	34014 -	71.0000
T	34015 -	71.0000	T	34016 -	71.0000	T	34017 -	71.0000	T	34018 -	71.0000	T	34019 -	71.0000	T	34020 -	71.0000
T	34021 -	71.0000	T	34022 -	71.0000	T	34023 -	71.0000	T	34024 -	71.0000	T	34025 -	71.0000	T	34026 -	71.0000
T	34027 -	71.0000	T	34028 -	71.0000	T	34029 -	71.0000	T	34030 -	71.0000	T	34031 -	71.0000	T	34032 -	71.0000
T	34033 -	71.0000	T	34034 -	71.0000	T	34035 -	71.0000	T	34036 -	71.0000	T	34037 -	71.0000	T	34038 -	71.0000
T	34039 -	71.0000	T	34040 -	71.0000	T	34049 -	71.0000	T	34050 -	71.0000	T	34051 -	71.0000	T	34052 -	71.0000
T	34053 -	71.0000	T	34054 -	71.0000	T	34055 -	71.0000	T	34056 -	71.0000	T	34057 -	71.0000	T	34058 -	71.0000
T	34059 -	71.0000	T	34060 -	71.0000	T	34061 -	71.0000	T	34062 -	71.0000	T	34063 -	71.0000	T	34064 -	71.0000
T	34065 -	71.0000	T	34066 -	71.0000	T	34067 -	71.0000	T	34068 -	71.0000	T	34069 -	71.0000	T	34070 -	71.0000
T	34071 -	71.0000	T	34072 -	71.0000	T	34073 -	71.0000	T	34074 -	71.0000	T	34075 -	71.0000	T	34076 -	71.0000
T	34077 -	71.0000	T	34078 -	71.0000	T	34079 -	71.0000	T	34080 -	71.0000	T	34081 -	71.0000	T	34082 -	71.0000
T	34083 -	71.0000	T	34084 -	71.0000	T	42006 -	89.8406	T	42013 -	89.4467	T	42020 -	91.0764	T	42027 -	88.5541
T	42008 -	87.6044	T	42015 -	89.5801	T	42022 -	91.0576	T	42029 -	88.2244	T	42010 -	90.4791	T	42017 -	91.3201
T	42024 -	90.3640	T	42031 -	90.7533	T	42050 -	87.7039	T	42057 -	90.7322	T	42064 -	89.5163	T	42071 -	91.6303
T	42052 -	89.2265	T	42059 -	91.2447	T	42066 -	89.8043	T	42073 -	91.4235	T	42054 -	91.4952	T	42061 -	91.1791
T	42068 -	90.2454	T	42075 -	91.5623	T	43006 -	65.4492	T	43013 -	64.6163	T	43020 -	67.1660	T	43027 -	64.1737
T	43008 -	62.2511	T	43015 -	64.3153	T	43022 -	66.6361	T	43029 -	63.3079	T	43010 -	64.0154	T	43017 -	65.1932
T	43024 -	64.7007	T	43031 -	65.0895	T	43050 -	70.0378	T	43057 -	78.9792	T	43064 -	68.1747	T	43071 -	70.0163
T	43052 -	71.6490	T	43059 -	79.4010	T	43066 -	68.4842	T	43073 -	69.8462	T	43054 -	74.0843	T	43061 -	79.7791
T	43068 -	69.1600	T	43075 -	70.0767	T	8000 -	37.9056	T	8005 -	39.7953	T	8010 -	38.6375	T	8011 -	43.4790
T	8015 -	37.7795	T	8016 -	42.2925	T	8020 -	39.4355	T	8025 -	39.2675	T	8030 -	40.2628	T	8035 -	47.5271
T	6000 -	33.7373	T	6010 -	34.1737	T	6020 -	34.1060	T	6030 -	34.0943	T	6040 -	33.9432	T	6050 -	33.9658
T	6060 -	33.9201	T	6070 -	33.7781	T	6080 -	33.6996	T	6090 -	33.6678	T	6001 -	34.0894	T	6011 -	34.0406
T	6021 -	33.9616	T	6031 -	33.8505	T	6041 -	33.8181	T	6051 -	33.7918	T	6061 -	33.7462	T	6071 -	33.7221
T	6081 -	33.7116	T	6091 -	32.5406	T	500 -	34.8511	T	501 -	34.6127	T	502 -	35.3562	T	503 -	35.0198
T	9000 -	28.4385	T	9001 -	28.4419	T	9002 -	28.4416	T	9003 -	28.4385	T	40 -	53.2000	T	9999 -	28.1022
T	7000 -	-423.0000	T	7001 -	-297.0000	T	7002 -	55.0000	T	7003 -	80.0000	T	8888 -	53.2000	T	8889 -	61.0000
T	8890 -	0.0000	T	8891 -	215.0000	T	8892 -	7.5000	T	13001 -	0.0000	T	13002 -	0.0000	T	13003 -	0.0000
T	13004 -	0.0000	T	13005 -	0.0000	T	13006 -	0.0000	T	13007 -	0.0000	T	13008 -	0.0000	T	13009 -	0.0000
T	13010 -	0.0000	T	13011 -	0.0000	T	13012 -	0.0000	T	13013 -	0.0000	T	13014 -	0.0000	T	13015 -	0.0000
T	13016 -	0.0000	T	13017 -	0.0000	T	13018 -	0.0000	T	13019 -	0.0000	T	13020 -	0.0000	T	13021 -	0.0000
T	13022 -	0.0000	T	13023 -	0.0000	T	13024 -	0.0000	T	13025 -	0.0000	T	13026 -	0.0000	T	13027 -	0.0000
T	13028 -	0.0000	T	13029 -	0.0000	T	13030 -	0.0000	T	13031 -	0.0000	T	13032 -	0.0000	T	13033 -	0.0000
T	13034 -	0.0000	T	13035 -	0.0000	T	13036 -	0.0000	T	13037 -	0.0000	T	16001 -	3742.0573	T	16002 -	4827.3427

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	16003 -	4838.9260	T	16004 -	4193.2942	T	16005 -	2628.3897	T	16006 -	4787.2915	T	16007 -	4266.7372	T	16008 -	2954.3161
T	16009 -	2527.3945	T	16010 -	4192.5663	T	16011 -	4617.6840	T	16012 -	3511.9690	T	16013 -	2974.7019	T	16014 -	4645.4367
T	16015 -	4430.1014	T	16016 -	3731.5959	T	16017 -	0.0000	T	16018 -	0.0000	T	16019 -	0.0000	T	16020 -	0.0000
T	16021 -	2153.7212	T	16022 -	1578.0634	T	16023 -	1819.9575	T	16024 -	2025.9713	T	16025 -	2788.5227	T	16026 -	2293.4761
T	16027 -	2835.7245	T	16028 -	2962.5100	T	16029 -	0.0000	T	16030 -	0.0000	T	16031 -	0.0000	T	16032 -	0.0000
T	16033 -	1635.9333	T	16034 -	1445.0622	T	16035 -	1966.9247	T	16036 -	1412.0166	T	16037 -	0.0000	T	101 -	2.8232
T	102 -	3.5954	T	103 -	4.0385	T	104 -	4.3804	T	105 -	8.2543	T	106 -	7.5200	T	107 -	7.1149
T	108 -	8.6721	T	109 -	8.3303	T	110 -	9.0899	T	111 -	7.6973	T	112 -	7.6720	T	113 -	6.4313
T	114 -	6.7478	T	115 -	6.1401	T	116 -	6.4313	T	117 -	5.6084	T	118 -	10.5331	T	119 -	8.7987
T	120 -	6.7225	T	121 -	6.7225	T	122 -	11.0775	T	123 -	9.8495	T	124 -	6.6085	T	125 -	11.5206
T	126 -	13.4956	T	127 -	9.7102	T	128 -	10.0900	T	129 -	14.0526	T	130 -	14.8755	T	131 -	12.9132
T	132 -	14.7742	T	133 -	6.7351	T	134 -	6.4060	T	135 -	3.5448	T	136 -	6.1654	T	137 -	17.9772
T	151 -	0.2230	T	152 -	0.2840	T	153 -	0.3190	T	154 -	0.3460	T	155 -	0.6520	T	156 -	0.5940
T	157 -	0.5620	T	158 -	0.6850	T	159 -	0.6580	T	160 -	0.7180	T	161 -	0.6080	T	162 -	0.6060
T	163 -	0.5080	T	164 -	0.5330	T	165 -	0.4850	T	166 -	0.5080	T	167 -	0.4430	T	168 -	0.8320

```
T   169 =    0.6950 T   170 =    0.5310 T   171 =    0.5310 T   172 =    0.8750 T   173 =    0.7780 T   174 =    0.5220
T   175 =    0.9100 T   176 =    1.0660 T   177 =    0.7670 T   178 =    0.7970 T   179 =    1.1100 T   180 =    1.1750
T   181 =    1.0200 T   182 =    1.1670 T   183 =    0.5320 T   184 =    0.5060 T   185 =    0.2800 T   186 =    0.4870
T   187 =    1.4200 T   201 =    0.0014 T   202 =    0.0018 T   203 =    0.0018 T   204 =    0.0016 T   205 =    0.0011
T   206 =    0.0018 T   207 =    0.0016 T   208 =    0.0013 T   209 =    0.0011 T   210 =    0.0018 T   211 =    0.0018
T   212 =    0.0015 T   213 =    0.0013 T   214 =    0.0018 T   215 =    0.0017 T   216 =    0.0014 T   217 =    0.0000
T   218 =    0.0000 T   219 =    0.0000 T   220 =    0.0000 T   221 =    0.0019 T   222 =    0.0016 T   223 =    0.0018
T   224 =    0.0018 T   225 =    0.0015 T   226 =    0.0013 T   227 =    0.0016 T   228 =    0.0016 T   229 =    0.0000
T   230 =    0.0000 T   231 =    0.0000 T   232 =    0.0000 T   233 =    0.0013 T   234 =    0.0011 T   235 =    0.0013
T   236 =    0.0011 T   237 =    0.0000 T   401 =    0.0000 T   402 =    0.0000 T   403 =    0.0000 T   404 =    0.0000
T   405 =    0.0000 T   406 =    0.0000 T   407 =    0.0000 T   408 =    0.0000 T   409 =    0.0000 T   410 =    0.0000
T   411 =    0.0000 T   412 =    0.0000 T   413 =    0.0000 T   414 =    0.0000 T   415 =    0.0000 T   416 =    0.0000
T   417 =    0.0000 T   418 =    0.0000 T   419 =    0.0000 T   420 =    0.0000 T   421 =    0.0000 T   422 =    0.0000
T   423 =    0.0000 T   424 =    0.0000 T   425 =    0.0000 T   426 =    0.0000 T   427 =    0.0000 T   428 =    0.0000
T   429 =    0.0000 T   430 =    0.0000 T   431 =    0.0000 T   432 =    0.0000 T   433 =    0.0000 T   434 =    0.0000
T   435 =    0.0000 T   436 =    0.0000 T   437 =    0.0000 T   701 =    0.0281 T   702 =    0.0403 T   703 =    0.0347
T   704 =    0.0219 T   705 =   -0.0071 T   706 =    0.0133 T   707 =    0.0095 T   708 =   -0.0047 T   709 =   -0.0084
T   710 =    0.0052 T   711 =    0.0109 T   712 =    0.0029 T   713 =    0.0013 T   714 =    0.0147 T   715 =    0.0149
T   716 =    0.0065 T   717 =   -0.0365 T   718 =   -0.0661 T   719 =   -0.0535 T   720 =   -0.0493 T   721 =    0.0191
T   722 =   -0.0024 T   723 =    0.0051 T   724 =    0.0166 T   725 =   -0.0050 T   726 =   -0.0153 T   727 =   -0.0005
T   728 =    0.0001 T   729 =   -0.0596 T   730 =   -0.0601 T   731 =   -0.0519 T   732 =   -0.0598 T   733 =    0.0007
T   734 =   -0.0017 T   735 =    0.0196 T   736 =   -0.0017 T   737 =   -0.1587 T   801 =    0.0734 T   802 =    0.1164
T   803 =    0.0992 T   804 =    0.0603 T   805 =    0.0000 T   806 =    0.0300 T   807 =    0.0205 T   808 =    0.0000
T   809 =    0.0000 T   810 =    0.0125 T   811 =    0.0249 T   812 =    0.0082 T   813 =    0.0025 T   814 =    0.0409
T   815 =    0.0384 T   816 =    0.0138 T   817 =    0.0000 T   818 =    0.0000 T   819 =    0.0000 T   820 =    0.0000
T   821 =    0.0526 T   822 =    0.0000 T   823 =    0.0136 T   824 =    0.0436 T   825 =    0.0000 T   826 =    0.0000
T   827 =    0.0043 T   828 =    0.0027 T   829 =    0.0000 T   830 =    0.0000 T   831 =    0.0000 T   832 =    0.0000
T   833 =    0.0057 T   834 =    0.0004 T   835 =    0.0517 T   836 =    0.0000 T   837 =    0.0000 T   901 =  143.6430
T   902 =  227.7358 T   903 =  194.0340 T   904 =  117.9960 T   905 =    0.0000 T   906 =   58.6874 T   907 =   40.0510
T   908 =    0.0000 T   909 =    0.0000 T   910 =   24.5507 T   911 =   48.6475 T   912 =   16.0589 T   913 =    4.9499
T   914 =   80.0229 T   915 =   75.1216 T   916 =   27.0251 T   917 =    0.0000 T   918 =    0.0000 T   919 =    0.0000
T   920 =    0.0000 T   921 =   44.5276 T   922 =    0.0000 T   923 =   11.5440 T   924 =   36.9591 T   925 =    0.0000
T   926 =    0.0000 T   927 =    6.7052 T   928 =    4.2497 T   929 =    0.0000 T   930 =    0.0000 T   931 =    0.0000
T   932 =    0.0000 T   933 =    6.3855 T   934 =    0.4163 T   935 =   57.4482 T   936 =    0.0000 T   937 =    0.0000

****************
TIME= 2.15000E+01, DTIMEU= 2.50000E-03, CSGMIN(  21037)= 1.11551E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(   2024)=-2.20211E-02
    LOOPCT=     1                                                     , ARLXCC(      0)= 0.00000E+00, DRLXCC(   2024)=-2.20211E-02

T   1001 =   37.5323 T   1002 =   34.6743 T   1003 =   35.1505 T   1004 =   37.0300 T   1005 =   37.0930 T   1006 =   33.0689
T   1007 =   34.8071 T   1008 =   35.9938 T   1009 =   37.7633 T   1010 =   34.4069 T   1011 =   35.3253 T   1012 =   36.5726
T   1013 =   29.3149 T   1014 =   27.6307 T   1015 =   30.1110 T   1016 =   32.7581 T   1017 =   48.6369 T   1018 =   49.7959
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T   1019 =   48.5605 T   1020 =   48.6608 T   1021 =   37.3247 T   1022 =   35.5361 T   1023 =   35.2218 T   1024 =   31.9320
T   1025 =   38.2917 T   1026 =   37.4343 T   1027 =   39.8174 T   1028 =   34.9538 T   1029 =   45.9766 T   1030 =   43.8450
T   1031 =   45.4653 T   1032 =   43.2791 T   1033 =   40.3542 T   1034 =   40.4856 T   1035 =   39.8935 T   1036 =   36.1530
T   1037 =   53.2187 T   2001 =    1.8160 T   3001 =  -80.2945 T   4001 = -184.0476 T   5001 = -328.1189 T   2002 =   -0.8787
T   3002 =  -82.6353 T   4002 = -185.7238 T   5002 = -328.8277 T   2003 =   -0.4298 T   3003 =  -82.2455 T   4003 = -185.4449
T   5003 = -328.7101 T   2004 =    1.3423 T   3004 =  -80.7062 T   4004 = -184.3424 T   5004 = -328.2437 T   2005 =    1.4015
T   3005 =  -80.6551 T   4005 = -184.3061 T   5005 = -328.2284 T   2006 =   -2.3926 T   3006 =  -83.9511 T   4006 = -186.6669
T   5006 = -329.2289 T   2007 =   -0.7540 T   3007 =  -82.5278 T   4007 = -185.6476 T   5007 = -328.7968 T   2008 =    0.3650
T   3008 =  -81.5555 T   4008 = -184.9511 T   5008 = -328.5022 T   2009 =    2.0351 T   3009 =  -80.1026 T   4009 = -183.9092
T   5009 = -328.0597 T   2010 =   -1.1303 T   3010 =  -82.8533 T   4010 = -185.8798 T   5010 = -328.8945 T   2011 =   -0.2645
T   3011 =  -82.1013 T   4011 = -185.3411 T   5011 = -328.6656 T   2012 =    0.9116 T   3012 =  -81.0795 T   4012 = -184.6093
T   5012 = -328.3564 T   2013 =   -5.9322 T   3013 =  -87.0270 T   4013 = -188.8730 T   5013 = -330.1732 T   2014 =   -7.5199
T   3014 =  -88.4056 T   4014 = -189.8594 T   5014 = -330.5886 T   2015 =   -5.1815 T   3015 =  -86.3742 T   4015 = -188.4041
T   5015 = -329.9703 T   2016 =   -2.6858 T   3016 =  -84.2061 T   4016 = -186.8509 T   5016 = -329.3110 T   2017 =   49.4347
T   3017 =   51.0288 T   4017 =   52.6196 T   5017 =   54.2068 T   2018 =   50.4466 T   3018 =   51.7486 T   4018 =   53.0499
T   5018 =   54.3499 T   2019 =   49.3685 T   3019 =   50.9820 T   4019 =   52.5918 T   5019 =   54.1976 T   2020 =   49.4551
T   3020 =   51.0427 T   4020 =   52.6276 T   5020 =   54.2094 T   2021 =    7.5502 T   3021 =  -59.0380 T   4021 = -140.3903
T   5021 = -239.6964 T   2022 =    5.8806 T   3022 =  -60.4398 T   4022 = -141.3757 T   5022 = -240.0740 T   2023 =    5.5866
T   3023 =  -60.6878 T   4023 = -141.5476 T   5023 = -240.1398 T   2024 =    2.5444 T   3024 =  -63.2479 T   4024 = -143.3205
T   5024 = -240.8187 T   2025 =    8.4487 T   3025 =  -58.2947 T   4025 = -139.8425 T   5025 = -239.4871 T   2026 =    7.6518
T   3026 =  -58.9546 T   4026 = -140.3296 T   5026 = -239.6740 T   2027 =    9.8668 T   3027 =  -57.1203 T   4027 = -138.9758
T   5027 = -239.1554 T   2028 =    5.3358 T   3028 =  -60.9000 T   4028 = -141.6951 T   5028 = -240.1968 T   2029 =   15.5876
T   3029 =  -52.3901 T   4029 = -135.4892 T   5029 = -237.8266 T   2030 =   13.6093 T   3030 =  -54.0229 T   4030 = -136.6913
T   5030 = -238.2860 T   2031 =   15.1150 T   3031 =  -52.7766 T   4031 = -135.7709 T   5031 = -237.9333 T   2032 =   13.0829
T   3032 =  -54.4597 T   4032 = -137.0146 T   5032 = -238.4102 T   2033 =    4.0384 T   3033 =  -78.3661 T   4033 = -179.4667
T   5033 = -324.8919 T   2034 =    4.1620 T   3034 =  -78.2652 T   4034 = -179.3934 T   5034 = -324.8616 T   2035 =    3.6012
T   3035 =  -78.7284 T   4035 = -179.7339 T   5035 = -325.0077 T   2036 =    0.0535 T   3036 =  -81.6649 T   4036 = -181.8964
T   5036 = -325.9401 T   2037 =   56.5499 T   3037 =   63.2195 T   4037 =   69.9168 T   5037 =   76.6365 T   21001 = -422.9850
T  21002 = -422.9802 T   21003 = -422.9812 T   21005 = -422.9844 T   21006 = -422.9797 T   21007 = -422.9816 T   21009 = -422.9851
T  21010 = -422.9806 T   21011 = -422.9810 T   21013 = -422.9849 T   21014 = -422.9809 T   21015 = -422.9817 T   21004 = -422.9843
T  21008 = -422.9835 T   21012 = -422.9835 T   21016 = -422.9835 T   21017 =   54.9998 T   21018 =   54.9998 T   21019 =   54.9998
T  21020 =   54.9998 T   21021 = -296.9906 T   21022 = -296.9907 T   21023 = -296.9907 T   21024 = -296.9909 T   21025 = -296.9909
T  21026 = -296.9912 T   21027 = -296.9913 T   21028 = -296.9911 T   21029 = -296.9970 T   21030 = -296.9966 T   21031 = -296.9967
T  21032 = -296.9966 T   21033 = -422.9848 T   21034 = -422.9858 T   21035 = -422.9854 T   21036 = -422.9864 T   21037 =   79.9991
T  12001 =   47.1804 T   12002 =   50.1376 T   12003 =   48.6936 T   12004 =   49.0852 T   12041 =   49.6459 T   12042 =   48.8410
T  12043 =   46.6887 T   12044 =   46.2871 T   12045 =   49.3384 T   12046 =   49.6251 T   12047 =   50.3426 T   12048 =   51.3851
T  12085 =   49.4945 T   12086 =   49.0250 T   12087 =   48.1904 T   12088 =   47.7612 T   12005 =   49.4323 T   12012 =   53.2570
T  12019 =   49.4344 T   12026 =   49.3540 T   12006 =   49.4787 T   12013 =   50.9332 T   12020 =   49.3840 T   12027 =   49.5707
T  12007 =   49.1082 T   12014 =   49.5735 T   12021 =   48.9637 T   12028 =   48.9732 T   12008 =   48.9470 T   12015 =   49.0841
T  12022 =   48.6873 T   12029 =   48.3632 T   12009 =   49.3082 T   12016 =   49.1039 T   12023 =   48.6196 T   12030 =   48.4539
T  12010 =   49.7149 T   12017 =   49.3564 T   12024 =   48.7192 T   12031 =   48.2108 T   12011 =   50.6450 T   12018 =   49.7367
T  12025 =   49.0792 T   12032 =   48.4536 T   12033 =   51.9472 T   12034 =   51.7559 T   12035 =   51.0059 T   12036 =   50.9590
T  12037 =   49.9120 T   12038 =   50.0503 T   12039 =   48.3796 T   12040 =   48.6622 T   22001 =   50.1443 T   22002 =   51.1011
T  22003 =   50.1457 T   22004 =   50.6331 T   22041 =   50.1720 T   22042 =   50.2516 T   22043 =   46.6789 T   22044 =   47.0443
T  12049 =   50.4077 T   12056 =   50.4619 T   12063 =   50.6327 T   12070 =   53.7971 T   12050 =   50.4545 T   12057 =   50.6705
T  12064 =   50.5963 T   12071 =   52.1252 T   12051 =   50.3146 T   12058 =   50.7079 T   12065 =   50.5108 T   12072 =   51.5673
T  12052 =   50.4029 T   12059 =   50.7721 T   12066 =   50.5534 T   12073 =   51.5791 T   12053 =   50.8731 T   12060 =   50.8981
T  12067 =   50.6280 T   12074 =   51.4252 T   12054 =   51.6765 T   12061 =   50.8431 T   12068 =   50.8098 T   12075 =   51.6674
T  12055 =   52.6842 T   12062 =   50.8062 T   12069 =   51.1246 T   12076 =   52.1640 T   12077 =   52.8837 T   12078 =   51.9425
T  12079 =   51.0884 T   12080 =   50.7884 T   12081 =   51.1073 T   12082 =   50.7241 T   12083 =   51.4026 T   12084 =   50.4402
T  22045 =   50.9237 T   22046 =   51.4067 T   22047 =   51.8525 T   22048 =   53.2878 T   22085 =   50.1433 T   22086 =   51.2531
T  22087 =   48.8927 T   22088 =   49.5504 T   22005 =   49.4456 T   22006 =   49.4920 T   22007 =   49.1217 T   22008 =   48.9606
T  22009 =   49.3215 T   22010 =   49.7280 T   22011 =   50.6576 T   22012 =   53.2679 T   22013 =   50.9455 T   22014 =   49.5867
T  22015 =   49.0976 T   22016 =   49.1174 T   22017 =   49.3698 T   22018 =   49.7497 T   22019 =   49.4476 T   22020 =   49.3972
T  22021 =   48.9772 T   22022 =   48.7010 T   22023 =   48.6334 T   22024 =   48.7329 T   22025 =   49.0924 T   22026 =   49.3674
T  22027 =   49.5839 T   22028 =   48.9868 T   22029 =   48.3773 T   22030 =   48.4678 T   22031 =   48.2247 T   22032 =   48.4674
T  22049 =   50.4203 T   22050 =   50.4671 T   22051 =   50.3273 T   22052 =   50.4155 T   22053 =   50.8854 T   22054 =   51.6883
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T  22055 =   52.6954 T   22056 =   50.4746 T   22057 =   50.6831 T   22058 =   50.7204 T   22059 =   50.7846 T   22060 =   50.9105
T  22061 =   50.8555 T   22062 =   50.8186 T   22063 =   50.6452 T   22064 =   50.6087 T   22065 =   50.5233 T   22066 =   50.5658
T  22067 =   50.6404 T   22068 =   50.8221 T   22069 =   51.1367 T   22070 =   53.8077 T   22071 =   52.1368 T   22072 =   51.5793
```

T	22073 -	51.5910	T	22074 -	51.4372	T	22075 -	51.6793	T	22076 -	52.1756	T	22033 -	51.9589	T	22034 -	51.7676
T	22035 -	51.0181	T	22036 -	50.9713	T	22037 -	49.9248	T	22038 -	50.0630	T	22039 -	48.3935	T	22040 -	48.6759
T	22077 -	52.8948	T	22078 -	51.9542	T	22079 -	51.1006	T	22080 -	50.8008	T	22081 -	51.1194	T	22082 -	50.7365
T	22083 -	51.4145	T	22084 -	50.4528	T	31005 -	69.7764	T	31006 -	69.7680	T	31007 -	69.7220	T	31008 -	69.6374
T	31009 -	69.6900	T	31010 -	69.6871	T	31011 -	69.7760	T	31012 -	69.9895	T	31013 -	69.8053	T	31014 -	69.7097
T	31015 -	69.6940	T	31016 -	69.7186	T	31017 -	69.7257	T	31018 -	69.7227	T	31019 -	69.7626	T	31020 -	69.7527
T	31021 -	69.7341	T	31022 -	69.7234	T	31023 -	69.7143	T	31024 -	69.6924	T	31025 -	69.6041	T	31026 -	69.7364
T	31027 -	69.7449	T	31028 -	69.7060	T	31029 -	69.6569	T	31030 -	69.6849	T	31031 -	69.6583	T	31032 -	69.6353
T	31033 -	69.8909	T	31034 -	69.8603	T	31035 -	69.8288	T	31036 -	69.8468	T	31037 -	69.6919	T	31038 -	69.7047
T	31039 -	69.5945	T	31040 -	69.6164	T	31049 -	69.7895	T	31050 -	69.7852	T	31051 -	69.7849	T	31052 -	69.8007
T	31053 -	69.8617	T	31054 -	69.9160	T	31055 -	69.9837	T	31056 -	69.8851	T	31057 -	69.8989	T	31058 -	69.8995
T	31059 -	69.9024	T	31060 -	69.9156	T	31061 -	69.9044	T	31062 -	69.8949	T	31063 -	69.8084	T	31064 -	69.8015
T	31065 -	69.7937	T	31066 -	69.7958	T	31067 -	69.8048	T	31068 -	69.8195	T	31069 -	69.8355	T	31070 -	70.0739
T	31071 -	69.9600	T	31072 -	69.9143	T	31073 -	69.9018	T	31074 -	69.8955	T	31075 -	69.9138	T	31076 -	69.9388
T	31077 -	69.9835	T	31078 -	69.8971	T	31079 -	69.8734	T	31080 -	69.8898	T	31081 -	69.8083	T	31082 -	69.7615
T	31083 -	69.8336	T	31084 -	69.7766	T	32005 -	70.9664	T	32006 -	70.9659	T	32007 -	70.9643	T	32008 -	70.9607
T	32009 -	70.9627	T	32010 -	70.9621	T	32011 -	70.9654	T	32012 -	70.9726	T	32013 -	70.9665	T	32014 -	70.9635
T	32015 -	70.9631	T	32016 -	70.9641	T	32017 -	70.9644	T	32018 -	70.9640	T	32019 -	70.9666	T	32020 -	70.9663
T	32021 -	70.9657	T	32022 -	70.9653	T	32023 -	70.9649	T	32024 -	70.9640	T	32025 -	70.9604	T	32026 -	70.9648
T	32027 -	70.9650	T	32028 -	70.9635	T	32029 -	70.9616	T	32030 -	70.9634	T	32031 -	70.9632	T	32032 -	70.9618
T	32033 -	70.9703	T	32034 -	70.9696	T	32035 -	70.9684	T	32036 -	70.9690	T	32037 -	70.9640	T	32038 -	70.9643
T	32039 -	70.9602	T	32040 -	70.9610	T	32049 -	70.9668	T	32050 -	70.9665	T	32051 -	70.9667	T	32052 -	70.9673
T	32053 -	70.9695	T	32054 -	70.9711	T	32055 -	70.9733	T	32056 -	70.9708	T	32057 -	70.9712	T	32058 -	70.9712
T	32059 -	70.9713	T	32060 -	70.9719	T	32061 -	70.9716	T	32062 -	70.9714	T	32063 -	70.9680	T	32064 -	70.9677
T	32065 -	70.9675	T	32066 -	70.9676	T	32067 -	70.9680	T	32068 -	70.9685	T	32069 -	70.9690	T	32070 -	70.9761
T	32071 -	70.9726	T	32072 -	70.9713	T	32073 -	70.9710	T	32074 -	70.9708	T	32075 -	70.9713	T	32076 -	70.9720
T	32077 -	70.9737	T	32078 -	70.9711	T	32079 -	70.9706	T	32080 -	70.9712	T	32081 -	70.9681	T	32082 -	70.9663
T	32083 -	70.9684	T	32084 -	70.9664	T	33005 -	70.9993	T	33006 -	70.9993	T	33007 -	70.9993	T	33008 -	70.9992
T	33009 -	70.9993	T	33010 -	70.9992	T	33011 -	70.9993	T	33012 -	70.9995	T	33013 -	70.9993	T	33014 -	70.9993
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T	33065 -	70.9994	T	33066 -	70.9994	T	33067 -	70.9994	T	33068 -	70.9994	T	33069 -	70.9994	T	33070 -	70.9996
T	33071 -	70.9995	T	33072 -	70.9995	T	33073 -	70.9995	T	33074 -	70.9994	T	33075 -	70.9995	T	33076 -	70.9995
T	33077 -	70.9995	T	33078 -	70.9995	T	33079 -	70.9995	T	33080 -	70.9995	T	33081 -	70.9994	T	33082 -	70.9994
T	33083 -	70.9994	T	33084 -	70.9993	T	34005 -	71.0000	T	34006 -	71.0000	T	34007 -	71.0000	T	34008 -	71.0000
T	34009 -	71.0000	T	34010 -	71.0000	T	34011 -	71.0000	T	34012 -	71.0000	T	34013 -	71.0000	T	34014 -	71.0000
T	34015 -	71.0000	T	34016 -	71.0000	T	34017 -	71.0000	T	34018 -	71.0000	T	34019 -	71.0000	T	34020 -	71.0000
T	34021 -	71.0000	T	34022 -	71.0000	T	34023 -	71.0000	T	34024 -	71.0000	T	34025 -	71.0000	T	34026 -	71.0000
T	34027 -	71.0000	T	34028 -	71.0000	T	34029 -	71.0000	T	34030 -	71.0000	T	34031 -	71.0000	T	34032 -	71.0000
T	34033 -	71.0000	T	34034 -	71.0000	T	34035 -	71.0000	T	34036 -	71.0000	T	34037 -	71.0000	T	34038 -	71.0000
T	34039 -	71.0000	T	34040 -	71.0000	T	34049 -	71.0000	T	34050 -	71.0000	T	34051 -	71.0000	T	34052 -	71.0000
T	34053 -	71.0000	T	34054 -	71.0000	T	34055 -	71.0000	T	34056 -	71.0000	T	34057 -	71.0000	T	34058 -	71.0000
T	34059 -	71.0000	T	34060 -	71.0000	T	34061 -	71.0000	T	34062 -	71.0000	T	34063 -	71.0000	T	34064 -	71.0000
T	34065 -	71.0000	T	34066 -	71.0000	T	34067 -	71.0000	T	34068 -	71.0000	T	34069 -	71.0000	T	34070 -	71.0000
T	34071 -	71.0000	T	34072 -	71.0000	T	34073 -	71.0000	T	34074 -	71.0000	T	34075 -	71.0000	T	34076 -	71.0000
T	34077 -	71.0000	T	34078 -	71.0000	T	34079 -	71.0000	T	34080 -	71.0000	T	34081 -	71.0000	T	34082 -	71.0000
T	34083 -	71.0000	T	34084 -	71.0000	T	42006 -	87.2771	T	42013 -	86.9521	T	42020 -	88.4089	T	42027 -	86.0651
T	42008 -	85.1582	T	42015 -	87.0174	T	42022 -	88.3681	T	42029 -	85.7081	T	42010 -	87.9165	T	42017 -	88.6679
T	42024 -	87.7066	T	42031 -	88.0456	T	42050 -	85.3406	T	42057 -	88.2460	T	42064 -	87.0183	T	42071 -	89.1036

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	42052 -	86.7887	T	42059 -	88.7320	T	42066 -	87.2879	T	42073 -	88.8798	T	42054 -	89.0147	T	42061 -	88.6618
T	42068 -	87.7244	T	42075 -	89.0357	T	43006 -	67.6098	T	43013 -	66.8210	T	43020 -	69.2761	T	43027 -	66.3368
T	43008 -	64.5073	T	43015 -	66.5577	T	43022 -	68.7931	T	43029 -	65.5200	T	43010 -	66.3699	T	43017 -	67.5119
T	43024 -	66.9752	T	43031 -	67.3618	T	43050 -	71.5778	T	43057 -	79.9599	T	43064 -	70.0520	T	43071 -	71.9182
T	43052 -	73.1771	T	43059 -	80.3889	T	43066 -	70.3585	T	43073 -	71.7436	T	43054 -	75.5948	T	43061 -	80.7250
T	43068 -	71.0121	T	43075 -	71.9664	T	8000 -	37.7424	T	8005 -	39.3291	T	8010 -	38.7738	T	8011 -	43.4782
T	8015 -	37.7681	T	8016 -	42.2918	T	8020 -	39.3056	T	8025 -	38.9011	T	8030 -	40.0140	T	8035 -	46.9027
T	6000 -	32.9481	T	6010 -	33.5078	T	6020 -	33.4263	T	6030 -	33.4062	T	6040 -	33.2539	T	6050 -	33.2731
T	6060 -	33.2272	T	6070 -	33.0887	T	6080 -	33.0090	T	6090 -	32.9753	T	6001 -	33.4648	T	6011 -	33.4135
T	6021 -	33.3366	T	6031 -	33.2266	T	6041 -	33.1955	T	6051 -	33.1688	T	6061 -	33.1240	T	6071 -	33.0986
T	6081 -	33.0877	T	6091 -	32.0382	T	500 -	34.5054	T	501 -	34.2814	T	502 -	34.9950	T	503 -	34.6769
T	9000 -	30.3466	T	9001 -	30.3484	T	9002 -	30.3472	T	9003 -	30.3455	T	40 -	55.6000	T	9999 -	30.6677
T	7000 -	-423.0000	T	7001 -	-297.0000	T	7002 -	55.0000	T	7003 -	80.0000	T	8888 -	55.6000	T	8889 -	58.0000
T	8890 -	0.0000	T	8891 -	256.0000	T	8892 -	9.8000	T	13001 -	0.0000	T	13002 -	0.0000	T	13003 -	0.0000
T	13004 -	0.0000	T	13005 -	0.0000	T	13006 -	0.0000	T	13007 -	0.0000	T	13008 -	0.0000	T	13009 -	0.0000
T	13010 -	0.0000	T	13011 -	0.0000	T	13012 -	0.0000	T	13013 -	0.0000	T	13014 -	0.0000	T	13015 -	0.0000
T	13016 -	0.0000	T	13017 -	0.0000	T	13018 -	0.0000	T	13019 -	0.0000	T	13020 -	0.0000	T	13021 -	0.0000
T	13022 -	0.0000	T	13023 -	0.0000	T	13024 -	0.0000	T	13025 -	0.0000	T	13026 -	0.0000	T	13027 -	0.0000
T	13028 -	0.0000	T	13029 -	0.0000	T	13030 -	0.0000	T	13031 -	0.0000	T	13032 -	0.0000	T	13033 -	0.0000
T	13034 -	0.0000	T	13035 -	0.0000	T	13036 -	0.0000	T	13037 -	0.0000	T	16001 -	2333.6368	T	16002 -	4090.8281
T	16003 -	3775.2131	T	16004 -	2612.9868	T	16005 -	2131.0383	T	16006 -	3956.4485	T	16007 -	3267.7026	T	16008 -	2607.2752
T	16009 -	1917.0406	T	16010 -	3682.0783	T	16011 -	3452.2995	T	16012 -	2658.2604	T	16013 -	3299.2570	T	16014 -	4567.7411
T	16015 -	4315.8113	T	16016 -	3204.2794	T	16017 -	0.0000	T	16018 -	0.0000	T	16019 -	0.0000	T	16020 -	0.0000
T	16021 -	1235.9516	T	16022 -	1435.2512	T	16023 -	1532.1887	T	16024 -	1767.9347	T	16025 -	1752.7489	T	16026 -	2026.3174
T	16027 -	835.5143	T	16028 -	2671.3237	T	16029 -	0.0000	T	16030 -	0.0000	T	16031 -	0.0000	T	16032 -	0.0000
T	16033 -	257.4736	T	16034 -	174.6521	T	16035 -	487.6749	T	16036 -	1207.7188	T	16037 -	0.0000	T	101 -	12.2348
T	102 -	12.0230	T	103 -	11.9238	T	104 -	11.9635	T	105 -	9.7005	T	106 -	9.0123	T	107 -	9.5681
T	108 -	9.2968	T	109 -	10.6136	T	110 -	10.2497	T	111 -	11.1430	T	112 -	10.8386	T	113 -	4.0628
T	114 -	5.1546	T	115 -	5.9883	T	116 -	6.7758	T	117 -	13.1611	T	118 -	9.9651	T	119 -	10.8187
T	120 -	7.5632	T	121 -	14.3456	T	122 -	11.0834	T	123 -	11.2422	T	124 -	7.5500	T	125 -	15.0536
T	126 -	13.0222	T	127 -	17.7070	T	128 -	10.0644	T	129 -	19.7185	T	130 -	16.0461	T	131 -	19.5862
T	132 -	14.8286	T	133 -	15.8542	T	134 -	14.6102	T	135 -	15.4837	T	136 -	7.6492	T	137 -	26.2032
T	151 -	0.7396	T	152 -	0.7268	T	153 -	0.7208	T	154 -	0.7232	T	155 -	0.5864	T	156 -	0.5448
T	157 -	0.5784	T	158 -	0.5620	T	159 -	0.6416	T	160 -	0.6196	T	161 -	0.6736	T	162 -	0.6552
T	163 -	0.2456	T	164 -	0.3116	T	165 -	0.3620	T	166 -	0.4096	T	167 -	0.7956	T	168 -	0.6024
T	169 -	0.6540	T	170 -	0.4572	T	171 -	0.8672	T	172 -	0.6700	T	173 -	0.6796	T	174 -	0.4564
T	175 -	0.9100	T	176 -	0.7872	T	177 -	1.0704	T	178 -	0.6084	T	179 -	1.1920	T	180 -	0.9700
T	181 -	1.1840	T	182 -	0.8964	T	183 -	0.9584	T	184 -	0.8832	T	185 -	0.9360	T	186 -	0.4624
T	187 -	1.5840	T	201 -	0.0010	T	202 -	0.0018	T	203 -	0.0016	T	204 -	0.0011	T	205 -	0.0009
T	206 -	0.0017	T	207 -	0.0014	T	208 -	0.0011	T	209 -	0.0008	T	210 -	0.0016	T	211 -	0.0015
T	212 -	0.0012	T	213 -	0.0013	T	214 -	0.0017	T	215 -	0.0017	T	216 -	0.0014	T	217 -	0.0000
T	218 -	0.0000	T	219 -	0.0000	T	220 -	0.0000	T	221 -	0.0012	T	222 -	0.0014	T	223 -	0.0015
T	224 -	0.0017	T	225 -	0.0010	T	226 -	0.0011	T	227 -	0.0005	T	228 -	0.0015	T	229 -	0.0000
T	230 -	0.0000	T	231 -	0.0000	T	232 -	0.0000	T	233 -	0.0002	T	234 -	0.0001	T	235 -	0.0004
T	236 -	0.0009	T	237 -	0.0000	T	401 -	0.0000	T	402 -	0.0000	T	403 -	0.0000	T	404 -	0.0000
T	405 -	0.0000	T	406 -	0.0000	T	407 -	0.0000	T	408 -	0.0000	T	409 -	0.0000	T	410 -	0.0000
T	411 -	0.0000	T	412 -	0.0000	T	413 -	0.0000	T	414 -	0.0000	T	415 -	0.0000	T	416 -	0.0000
T	417 -	0.0000	T	418 -	0.0000	T	419 -	0.0000	T	420 -	0.0000	T	421 -	0.0000	T	422 -	0.0000
T	423 -	0.0000	T	424 -	0.0000	T	425 -	0.0000	T	426 -	0.0000	T	427 -	0.0000	T	428 -	0.0000
T	429 -	0.0000	T	430 -	0.0000	T	431 -	0.0000	T	432 -	0.0000	T	433 -	0.0000	T	434 -	0.0000
T	435 -	0.0000	T	436 -	0.0000	T	437 -	0.0000	T	701 -	-0.0247	T	702 -	-0.0074	T	703 -	-0.0103

```
T    704 -    -0.0216 T    705 -    -0.0210 T    706 -    -0.0008 T    707 -    -0.0093 T    708 -    -0.0154 T    709 -    -0.0249
T    710 -    -0.0068 T    711 -    -0.0114 T    712 -    -0.0184 T    713 -     0.0086 T    714 -     0.0172 T    715 -     0.0099
T    716 -    -0.0016 T    717 -    -0.0791 T    718 -    -0.0723 T    719 -    -0.0710 T    720 -    -0.0604 T    721 -    -0.0228
T    722 -    -0.0114 T    723 -    -0.0099 T    724 -     0.0049 T    725 -    -0.0309 T    726 -    -0.0242 T    727 -    -0.0448
T    728 -    -0.0096 T    729 -    -0.1000 T    730 -    -0.0791 T    731 -    -0.0968 T    732 -    -0.0735 T    733 -    -0.0456
T    734 -    -0.0451 T    735 -    -0.0419 T    736 -    -0.0147 T    737 -    -0.2291 T    801 -     0.0486 T    802 -     0.1090
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T    803 -     0.0889 T    804 -     0.0387 T    805 -     0.0000 T    806 -     0.0293 T    807 -     0.0113 T    808 -     0.0000
T    809 -     0.0000 T    810 -     0.0056 T    811 -     0.0134 T    812 -     0.0000 T    813 -     0.0112 T    814 -     0.0581
T    815 -     0.0483 T    816 -     0.0122 T    817 -     0.0000 T    818 -     0.0000 T    819 -     0.0000 T    820 -     0.0000
T    821 -     0.0297 T    822 -     0.0000 T    823 -     0.0037 T    824 -     0.0486 T    825 -     0.0000 T    826 -     0.0000
T    827 -     0.0000 T    828 -     0.0000 T    829 -     0.0000 T    830 -     0.0000 T    831 -     0.0000 T    832 -     0.0000
T    833 -     0.0000 T    834 -     0.0000 T    835 -     0.0096 T    836 -     0.0000 T    837 -     0.0000 T    901 -    95.0927
T    902 -   213.2700 T    903 -   173.8879 T    904 -    75.6362 T    905 -     0.0000 T    906 -    57.2741 T    907 -    22.0232
T    908 -     0.0000 T    909 -     0.0000 T    910 -    11.0312 T    911 -    26.2108 T    912 -     0.0000 T    913 -    21.8546
T    914 -   113.6494 T    915 -    94.4482 T    916 -    23.9576 T    917 -     0.0000 T    918 -     0.0000 T    919 -     0.0000
T    920 -     0.0000 T    921 -    25.1449 T    922 -     0.0000 T    923 -     3.1654 T    924 -    41.1953 T    925 -     0.0000
T    926 -     0.0000 T    927 -     0.0000 T    928 -     0.0000 T    929 -     0.0000 T    930 -     0.0000 T    931 -     0.0000
T    932 -     0.0000 T    933 -     0.0000 T    934 -     0.0000 T    935 -    10.6392 T    936 -     0.0000 T    937 -     0.0000

****************
TIME= 2.25000E+01, DTIMEU= 2.50000E-03, CSGMIN(  21037)= 1.11551E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(   1024)=-1.64339E-01
     LOOPCT=      2                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(   1024)= 8.41179E-04

T    1001 -    38.5288 T    1002 -    35.8821 T    1003 -    36.3708 T    1004 -    38.1242 T    1005 -    35.7406 T    1006 -    32.0399
T    1007 -    34.3241 T    1008 -    35.8285 T    1009 -    37.3847 T    1010 -    33.9134 T    1011 -    35.1666 T    1012 -    36.3829
T    1013 -    31.1172 T    1014 -    26.9763 T    1015 -    29.7236 T    1016 -    32.4209 T    1017 -    48.2826 T    1018 -    49.1845
T    1019 -    47.6439 T    1020 -    47.9831 T    1021 -    37.8911 T    1022 -    35.7626 T    1023 -    34.6029 T    1024 -    31.8124
T    1025 -    38.0222 T    1026 -    37.6197 T    1027 -    39.8766 T    1028 -    35.0675 T    1029 -    44.8955 T    1030 -    43.1587
T    1031 -    44.4112 T    1032 -    42.4653 T    1033 -    40.6623 T    1034 -    40.5378 T    1035 -    40.6337 T    1036 -    37.8723
T    1037 -    52.4590 T    2001 -     2.7562 T    3001 -   -79.4767 T    4001 - -183.4609 T    5001 - -327.8687 T    2002 -     0.2606
T    3002 -   -81.6447 T    4002 - -185.0135 T    5002 - -328.5250 T    2003 -     0.7214 T    3003 -   -81.2446 T    4003 - -184.7270
T    5003 - -328.4041 T    2004 -     2.3748 T    3004 -   -79.8080 T    4004 - -183.6979 T    5004 - -327.9689 T    2005 -     0.1275
T    3005 -   -81.7605 T    4005 - -185.0976 T    5005 - -328.5653 T    2006 -    -3.3621 T    3006 -   -84.7925 T    4006 - -187.2695
T    5006 - -329.4853 T    2007 -    -1.2084 T    3007 -   -82.9214 T    4007 - -185.9291 T    5007 - -328.9166 T    2008 -     0.2102
T    3008 -   -81.6887 T    4008 - -185.0458 T    5008 - -328.5423 T    2009 -     1.6781 T    3009 -   -80.4127 T    4009 - -184.1315
T    5009 - -328.1545 T    2010 -    -1.5955 T    3010 -   -83.2574 T    4010 - -186.1695 T    5010 - -329.0178 T    2011 -    -0.4140
T    3011 -   -82.2309 T    4011 - -185.4339 T    5011 - -328.7051 T    2012 -     0.7331 T    3012 -   -81.2342 T    4012 - -184.7200
T    5012 - -328.4035 T    2013 -    -4.2328 T    3013 -   -85.5505 T    4013 - -187.8149 T    5013 - -329.7228 T    2014 -    -8.1367
T    3014 -   -88.9412 T    4014 - -190.2431 T    5014 - -330.7518 T    2015 -    -5.5464 T    3015 -   -86.6910 T    4015 - -188.6310
T    5015 - -330.0668 T    2016 -    -3.0032 T    3016 -   -84.4812 T    4016 - -187.0476 T    5016 - -329.3947 T    2017 -    49.1270
T    3017 -    50.8115 T    4017 -    52.4904 T    5017 -    54.1640 T    2018 -    49.9155 T    3018 -    51.3735 T    4018 -    52.8268
T    5018 -    54.2759 T    2019 -    48.5698 T    3019 -    50.4154 T    4019 -    52.2538 T    5019 -    54.0853 T    2020 -    48.8659
T    3020 -    50.6261 T    4020 -    52.3797 T    5020 -    54.1272 T    2021 -     8.0769 T    3021 -   -58.6015 T    4021 - -140.0680
T    5021 - -239.5729 T    2022 -     6.0926 T    3022 -   -60.2606 T    4022 - -141.2515 T    5022 - -240.0264 T    2023 -     5.0086
T    3023 -   -61.1746 T    4023 - -141.8842 T    5023 - -240.2687 T    2024 -     2.4713 T    3024 -   -63.3015 T    4024 - -143.3529
T    5024 - -240.8307 T    2025 -     8.1984 T    3025 -   -58.5016 T    4025 - -139.9949 T    5025 - -239.5454 T    2026 -     7.8243
T    3026 -   -58.8113 T    4026 - -140.2236 T    5026 - -239.6333 T    2027 -     9.9221 T    3027 -   -57.0742 T    4027 - -138.9415
T    5027 - -239.1423 T    2028 -     5.4425 T    3028 -   -60.8095 T    4028 - -141.6322 T    5028 - -240.1727 T    2029 -    14.5882
T    3029 -   -53.2082 T    4029 - -136.0865 T    5029 - -238.0538 T    2030 -    12.9730 T    3030 -   -54.5477 T    4030 - -137.0776
T    5030 - -238.4338 T    2031 -    14.1375 T    3031 -   -53.5827 T    4031 - -136.3642 T    5031 - -238.1602 T    2032 -    12.3282
T    3032 -   -55.0823 T    4032 - -137.4728 T    5032 - -238.5855 T    2033 -     4.3309 T    3033 -   -78.1238 T    4033 - -179.2881
T    5033 - -324.8149 T    2034 -     4.2127 T    3034 -   -78.2218 T    4034 - -179.3607 T    5034 - -324.8472 T    2035 -     4.3037
T    3035 -   -78.1463 T    4035 - -179.3048 T    5035 - -324.8227 T    2036 -     1.6850 T    3036 -   -80.3135 T    4036 - -180.9007
T    5036 - -325.5110 T    2037 -    55.9512 T    3037 -    62.8933 T    4037 -    69.7755 T    5037 -    76.6001 T   21001 - -422.9850
T   21002 - -422.9801 T   21003 - -422.9811 T   21005 - -422.9845 T   21006 - -422.9798 T   21007 - -422.9816 T   21009 - -422.9851
T   21010 - -422.9806 T   21011 - -422.9810 T   21013 - -422.9848 T   21014 - -422.9809 T   21015 - -422.9818 T   21004 - -422.9843
T   21008 - -422.9836 T   21012 - -422.9835 T   21016 - -422.9835 T   21017 -    54.9998 T   21018 -    54.9998 T   21019 -    54.9998
T   21020 -    54.9998 T   21021 - -296.9905 T   21022 - -296.9907 T   21023 - -296.9908 T   21024 - -296.9909 T   21025 - -296.9909
T   21026 - -296.9912 T   21027 - -296.9913 T   21028 - -296.9911 T   21029 - -296.9970 T   21030 - -296.9966 T   21031 - -296.9967
T   21032 - -296.9967 T   21033 - -422.9848 T   21034 - -422.9858 T   21035 - -422.9854 T   21036 - -422.9863 T   21037 -    79.9991
T   12001 -    46.5794 T   12002 -    49.8979 T   12003 -    48.1295 T   12004 -    48.8126 T   12041 -    49.7023 T   12042 -    48.6910
T   12043 -    48.1854 T   12044 -    46.3125 T   12045 -    49.3406 T   12046 -    48.9883 T   12047 -    49.5210 T   12048 -    50.5181
T   12085 -    49.2551 T   12086 -    47.9046 T   12087 -    48.4567 T   12088 -    46.8136 T   12005 -    49.0446 T   12012 -    53.1022
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T   12019 -    49.4050 T   12026 -    49.2023 T   12006 -    49.0853 T   12013 -    50.8142 T   12020 -    49.3523 T   12027 -    49.4141
T   12007 -    48.8017 T   12014 -    49.3841 T   12021 -    48.7795 T   12028 -    48.6704 T   12008 -    48.7538 T   12015 -    48.7466
T   12022 -    48.3215 T   12029 -    47.8832 T   12009 -    48.7762 T   12016 -    48.3481 T   12023 -    48.3345 T   12030 -    48.0359
T   12010 -    49.3260 T   12017 -    49.0552 T   12024 -    48.7978 T   12031 -    48.2255 T   12011 -    50.5465 T   12018 -    50.0235
T   12025 -    50.0684 T   12032 -    48.7201 T   12033 -    51.9325 T   12034 -    51.8314 T   12035 -    51.1548 T   12036 -    50.9116
T   12037 -    50.8069 T   12038 -    50.8479 T   12039 -    48.7248 T   12040 -    48.9544 T   22001 -    49.0991 T   22002 -    50.7060
T   22003 -    49.5568 T   22004 -    50.0455 T   22041 -    50.0540 T   22042 -    49.7865 T   22043 -    47.1454 T   22044 -    46.8551
T   12049 -    50.6213 T   12056 -    49.9714 T   12063 -    50.7515 T   12070 -    53.5564 T   12050 -    50.6606 T   12057 -    50.1896
T   12064 -    50.7173 T   12071 -    51.7947 T   12051 -    50.4781 T   12058 -    50.1476 T   12065 -    50.6259 T   12072 -    51.1898
T   12052 -    50.4861 T   12059 -    50.1427 T   12066 -    50.6413 T   12073 -    51.1981 T   12053 -    50.6133 T   12060 -    50.1871
T   12067 -    50.6539 T   12074 -    50.8279 T   12054 -    51.3596 T   12061 -    50.1651 T   12068 -    50.7824 T   12075 -    51.0443
T   12055 -    52.3591 T   12062 -    50.2836 T   12069 -    51.1749 T   12076 -    51.7791 T   12077 -    52.6079 T   12078 -    51.8942
T   12079 -    51.1067 T   12080 -    50.2396 T   12081 -    51.4148 T   12082 -    51.2305 T   12083 -    51.6227 T   12084 -    50.4070
T   22045 -    50.4812 T   22046 -    50.6649 T   22047 -    51.1497 T   22048 -    52.3881 T   22085 -    49.9038 T   22086 -    50.3001
T   22087 -    48.7853 T   22088 -    48.8044 T   22005 -    49.0581 T   22006 -    49.0987 T   22007 -    48.8153 T   22008 -    48.7673
T   22009 -    48.7898 T   22010 -    49.3392 T   22011 -    50.5590 T   22012 -    53.1131 T   22013 -    50.8264 T   22014 -    49.3973
T   22015 -    48.7602 T   22016 -    48.3620 T   22017 -    49.0686 T   22018 -    50.0362 T   22019 -    49.4181 T   22020 -    49.3654
T   22021 -    48.7930 T   22022 -    48.3353 T   22023 -    48.3483 T   22024 -    48.8113 T   22025 -    50.0808 T   22026 -    49.2156
T   22027 -    49.4272 T   22028 -    48.6840 T   22029 -    47.8974 T   22030 -    48.0499 T   22031 -    48.2393 T   22032 -    48.7335
T   22049 -    50.6336 T   22050 -    50.6729 T   22051 -    50.4906 T   22052 -    50.4986 T   22053 -    50.6258 T   22054 -    51.3717
T   22055 -    52.3705 T   22056 -    49.9843 T   22057 -    50.2024 T   22058 -    50.1604 T   22059 -    50.1555 T   22060 -    50.1999
T   22061 -    50.1780 T   22062 -    50.2964 T   22063 -    50.7638 T   22064 -    50.7296 T   22065 -    50.6382 T   22066 -    50.6537
T   22067 -    50.6663 T   22068 -    50.7947 T   22069 -    51.1870 T   22070 -    53.5671 T   22071 -    51.8064 T   22072 -    51.2020
T   22073 -    51.2103 T   22074 -    50.8403 T   22075 -    51.0566 T   22076 -    51.7909 T   22033 -    51.9441 T   22034 -    51.8430
T   22035 -    51.1668 T   22036 -    50.9238 T   22037 -    50.8190 T   22038 -    50.8600 T   22039 -    48.7382 T   22040 -    48.9677
T   22077 -    52.6192 T   22078 -    51.9059 T   22079 -    51.1188 T   22080 -    50.2524 T   22081 -    51.4267 T   22082 -    51.2424
T   22083 -    51.6344 T   22084 -    50.4195 T   31005 -    69.5055 T   31006 -    69.4978 T   31007 -    69.4485 T   31008 -    69.3646
T   31009 -    69.4183 T   31010 -    69.4222 T   31011 -    69.5240 T   31012 -    69.7680 T   31013 -    69.5564 T   31014 -    69.4438
T   31015 -    69.4206 T   31016 -    69.4417 T   31017 -    69.4556 T   31018 -    69.4625 T   31019 -    69.4948 T   31020 -    69.4845
T   31021 -    69.4593 T   31022 -    69.4437 T   31023 -    69.4345 T   31024 -    69.4173 T   31025 -    69.3434 T   31026 -    69.4672
T   31027 -    69.4783 T   31028 -    69.4311 T   31029 -    69.3733 T   31030 -    69.4025 T   31031 -    69.3765 T   31032 -    69.3593
T   31033 -    69.6535 T   31034 -    69.6217 T   31035 -    69.5811 T   31036 -    69.5964 T   31037 -    69.4387 T   31038 -    69.4522
T   31039 -    69.3175 T   31040 -    69.3424 T   31049 -    69.5364 T   31050 -    69.5328 T   31051 -    69.5302 T   31052 -    69.5463
T   31053 -    69.6096 T   31054 -    69.6732 T   31055 -    69.7530 T   31056 -    69.6249 T   31057 -    69.6413 T   31058 -    69.6418
T   31059 -    69.6450 T   31060 -    69.6590 T   31061 -    69.6475 T   31062 -    69.6389 T   31063 -    69.5572 T   31064 -    69.5501
T   31065 -    69.5411 T   31066 -    69.5436 T   31067 -    69.5529 T   31068 -    69.5693 T   31069 -    69.5899 T   31070 -    69.8572
T   31071 -    69.7222 T   31072 -    69.6695 T   31073 -    69.6574 T   31074 -    69.6475 T   31075 -    69.6685 T   31076 -    69.7016
T   31077 -    69.7546 T   31078 -    69.6592 T   31079 -    69.6248 T   31080 -    69.6321 T   31081 -    69.5639 T   31082 -    69.5146
T   31083 -    69.5919 T   31084 -    69.5209 T   32005 -    70.9512 T   32006 -    70.9507 T   32007 -    70.9485 T   32008 -    70.9440
```

```
T 32009 - 70.9466 T 32010 - 70.9460 T 32011 - 70.9503 T 32012 - 70.9600 T 32013 - 70.9518 T 32014 - 70.9476
T 32015 - 70.9470 T 32016 - 70.9483 T 32017 - 70.9486 T 32018 - 70.9483 T 32019 - 70.9513 T 32020 - 70.9508
T 32021 - 70.9500 T 32022 - 70.9494 T 32023 - 70.9490 T 32024 - 70.9479 T 32025 - 70.9433 T 32026 - 70.9492
T 32027 - 70.9494 T 32028 - 70.9475 T 32029 - 70.9451 T 32030 - 70.9471 T 32031 - 70.9466 T 32032 - 70.9450
T 32033 - 70.9566 T 32034 - 70.9556 T 32035 - 70.9539 T 32036 - 70.9547 T 32037 - 70.9480 T 32038 - 70.9484
T 32039 - 70.9430 T 32040 - 70.9440 T 32049 - 70.9518 T 32050 - 70.9515 T 32051 - 70.9517 T 32052 - 70.9525
T 32053 - 70.9554 T 32054 - 70.9576 T 32055 - 70.9606 T 32056 - 70.9568 T 32057 - 70.9574 T 32058 - 70.9574
T 32059 - 70.9576 T 32060 - 70.9583 T 32061 - 70.9579 T 32062 - 70.9576 T 32063 - 70.9532 T 32064 - 70.9529
T 32065 - 70.9526 T 32066 - 70.9527 T 32067 - 70.9532 T 32068 - 70.9539 T 32069 - 70.9545 T 32070 - 70.9645
T 32071 - 70.9596 T 32072 - 70.9577 T 32073 - 70.9573 T 32074 - 70.9570 T 32075 - 70.9578 T 32076 - 70.9588
T 32077 - 70.9610 T 32078 - 70.9574 T 32079 - 70.9566 T 32080 - 70.9573 T 32081 - 70.9534 T 32082 - 70.9510
T 32083 - 70.9540 T 32084 - 70.9513 T 33005 - 70.9989 T 33006 - 70.9989 T 33007 - 70.9988 T 33008 - 70.9987
T 33009 - 70.9987 T 33010 - 70.9987 T 33011 - 70.9988 T 33012 - 70.9991 T 33013 - 70.9989 T 33014 - 70.9988
T 33015 - 70.9988 T 33016 - 70.9988 T 33017 - 70.9988 T 33018 - 70.9988 T 33019 - 70.9989 T 33020 - 70.9989
T 33021 - 70.9989 T 33022 - 70.9988 T 33023 - 70.9988 T 33024 - 70.9988 T 33025 - 70.9987 T 33026 - 70.9988
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T 33039 - 70.9987 T 33040 - 70.9987 T 33049 - 70.9989 T 33050 - 70.9989 T 33051 - 70.9989 T 33052 - 70.9989
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STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T 33053 - 70.9990 T 33054 - 70.9990 T 33055 - 70.9991 T 33056 - 70.9990 T 33057 - 70.9990 T 33058 - 70.9990
T 33059 - 70.9991 T 33060 - 70.9991 T 33061 - 70.9991 T 33062 - 70.9991 T 33063 - 70.9989 T 33064 - 70.9989
T 33065 - 70.9989 T 33066 - 70.9989 T 33067 - 70.9989 T 33068 - 70.9990 T 33069 - 70.9990 T 33070 - 70.9992
T 33071 - 70.9991 T 33072 - 70.9990 T 33073 - 70.9990 T 33074 - 70.9990 T 33075 - 70.9990 T 33076 - 70.9991
T 33077 - 70.9991 T 33078 - 70.9990 T 33079 - 70.9990 T 33080 - 70.9990 T 33081 - 70.9989 T 33082 - 70.9989
T 33083 - 70.9989 T 33084 - 70.9989 T 34005 - 71.0000 T 34006 - 71.0000 T 34007 - 71.0000 T 34008 - 71.0000
T 34009 - 71.0000 T 34010 - 71.0000 T 34011 - 71.0000 T 34012 - 71.0000 T 34013 - 71.0000 T 34014 - 71.0000
T 34015 - 71.0000 T 34016 - 71.0000 T 34017 - 71.0000 T 34018 - 71.0000 T 34019 - 71.0000 T 34020 - 71.0000
T 34021 - 71.0000 T 34022 - 71.0000 T 34023 - 71.0000 T 34024 - 71.0000 T 34025 - 71.0000 T 34026 - 71.0000
T 34027 - 71.0000 T 34028 - 71.0000 T 34029 - 71.0000 T 34030 - 71.0000 T 34031 - 71.0000 T 34032 - 71.0000
T 34033 - 71.0000 T 34034 - 71.0000 T 34035 - 71.0000 T 34036 - 71.0000 T 34037 - 71.0000 T 34038 - 71.0000
T 34039 - 71.0000 T 34040 - 71.0000 T 34049 - 71.0000 T 34050 - 71.0000 T 34051 - 71.0000 T 34052 - 71.0000
T 34053 - 71.0000 T 34054 - 71.0000 T 34055 - 71.0000 T 34056 - 71.0000 T 34057 - 71.0000 T 34058 - 71.0000
T 34059 - 71.0000 T 34060 - 71.0000 T 34061 - 71.0000 T 34062 - 71.0000 T 34063 - 71.0000 T 34064 - 71.0000
T 34065 - 71.0000 T 34066 - 71.0000 T 34067 - 71.0000 T 34068 - 71.0000 T 34069 - 71.0000 T 34070 - 71.0000
T 34071 - 71.0000 T 34072 - 71.0000 T 34073 - 71.0000 T 34074 - 71.0000 T 34075 - 71.0000 T 34076 - 71.0000
T 34077 - 71.0000 T 34078 - 71.0000 T 34079 - 71.0000 T 34080 - 71.0000 T 34081 - 71.0000 T 34082 - 71.0000
T 34083 - 71.0000 T 34084 - 71.0000 T 42006 - 84.8653 T 42013 - 84.6225 T 42020 - 85.9323 T 42027 - 83.7291
T 42008 - 82.8595 T 42015 - 84.5986 T 42022 - 85.8527 T 42029 - 83.3319 T 42010 - 85.5141 T 42017 - 86.1915
T 42024 - 85.2709 T 42031 - 85.5408 T 42050 - 83.1605 T 42057 - 85.9106 T 42064 - 84.7284 T 42071 - 86.7477
T 42052 - 84.5272 T 42059 - 86.3705 T 42066 - 84.9819 T 42073 - 86.5121 T 42054 - 86.7044 T 42061 - 86.3084
T 42068 - 85.4142 T 42075 - 86.6833 T 43006 - 69.3352 T 43013 - 68.5938 T 43020 - 70.9482 T 43027 - 68.0716
T 43008 - 66.3302 T 43015 - 68.3571 T 43022 - 70.5049 T 43029 - 67.2959 T 43010 - 68.2717 T 43017 - 69.3734
T 43024 - 68.7987 T 43031 - 69.1777 T 43050 - 72.7613 T 43057 - 80.6236 T 43064 - 71.5302 T 43071 - 73.4140
T 43052 - 74.3427 T 43059 - 81.0567 T 43066 - 71.8325 T 43073 - 73.2342 T 43054 - 76.7402 T 43061 - 81.3551
T 43068 - 72.4656 T 43075 - 73.4515 T 8000 - 37.5637 T 8005 - 38.9490 T 8010 - 38.7737 T 8011 - 43.4773
T 8015 - 37.8499 T 8016 - 42.2910 T 8020 - 39.2341 T 8025 - 38.6595 T 8030 - 39.7464 T 8035 - 46.2795
T 6000 - 32.4735 T 6010 - 33.0258 T 6020 - 32.9387 T 6030 - 32.9163 T 6040 - 32.7652 T 6050 - 32.7834
T 6060 - 32.7384 T 6070 - 32.6034 T 6080 - 32.5245 T 6090 - 32.4912 T 6001 - 32.9279 T 6011 - 32.8759
T 6021 - 32.8011 T 6031 - 32.6923 T 6041 - 32.6619 T 6051 - 32.6353 T 6061 - 32.5915 T 6071 - 32.5656
T 6081 - 32.5547 T 6091 - 31.5961 T 500 - 34.1755 T 501 - 33.9664 T 502 - 34.6495 T 503 - 34.3520
T 9000 - 30.3867 T 9001 - 30.3883 T 9002 - 30.3867 T 9003 - 30.3853 T 40 - 54.8000 T 9999 - 30.3870
T 7000 - -423.0000 T 7001 - -297.0000 T 7002 - 55.0000 T 7003 - 80.0000 T 8888 - 54.8000 T 8889 - 63.6000
T 8890 - 0.0000 T 8891 - 278.0000 T 8892 - 9.4000 T 13001 - 0.0000 T 13002 - 0.0000 T 13003 - 0.0000
T 13004 - 0.0000 T 13005 - 0.0000 T 13006 - 0.0000 T 13007 - 0.0000 T 13008 - 0.0000 T 13009 - 0.0000
T 13010 - 0.0000 T 13011 - 0.0000 T 13012 - 0.0000 T 13013 - 0.0000 T 13014 - 0.0000 T 13015 - 0.0000
T 13016 - 0.0000 T 13017 - 0.0000 T 13018 - 0.0000 T 13019 - 0.0000 T 13020 - 0.0000 T 13021 - 0.0000
T 13022 - 0.0000 T 13023 - 0.0000 T 13024 - 0.0000 T 13025 - 0.0000 T 13026 - 0.0000 T 13027 - 0.0000
T 13028 - 0.0000 T 13029 - 0.0000 T 13030 - 0.0000 T 13031 - 0.0000 T 13032 - 0.0000 T 13033 - 0.0000
T 13034 - 0.0000 T 13035 - 0.0000 T 13036 - 0.0000 T 13037 - 0.0000 T 16001 - 3184.0215 T 16002 - 5003.8128
T 16003 - 4657.3564 T 16004 - 3438.3733 T 16005 - 3264.6074 T 16006 - 4915.0370 T 16007 - 4226.0901 T 16008 - 3526.8622
T 16009 - 3031.0304 T 16010 - 4697.0394 T 16011 - 4521.2247 T 16012 - 3724.6899 T 16013 - 3818.5302 T 16014 - 5107.2223
T 16015 - 4963.0386 T 16016 - 3889.3719 T 16017 - 0.0000 T 16018 - 0.0000 T 16019 - 0.0000 T 16020 - 0.0000
T 16021 - 1733.0069 T 16022 - 1874.3400
        - 10812,  12036,  12042, 0.78395E-09$
        - 10813,  12036,    500, 0.82092E-08$
        - 10814,  12036,    501, 0.43805E-08$
        - 10815,  12036,    502, 0.23740E-07$
10.5612 T  112 - 10.1867 T  113 - 4.6903  8.7841 T  109 - 9.6980 T  110 - 9.4505 T  111 -
T 114 - 4.7729 T  115 - 5.6106 T  116 - 6.3469 T  117 - 13.9124 T  118 - 9.8313 T  119 - 9.9138
T 120 - 7.1974 T  121 - 14.6803 T  122 - 10.9420 T  123 - 10.1740 T  124 - 7.2545 T  125 - 13.8679
T 126 - 12.7445 T  127 - 16.8827 T  128 - 9.8186 T  129 - 18.4694 T  130 - 15.9307 T  131 - 18.4694
T 132 - 14.3757 T  133 - 15.6958 T  134 - 13.8552 T  135 - 16.4384 T  136 - 9.1268 T  137 - 24.2451
T 151 - 0.8368 T  152 - 0.8240 T  153 - 0.8212 T  154 - 0.8248 T  155 - 0.5008 T  156 - 0.5004
T 157 - 0.5548 T  158 - 0.5536 T  159 - 0.6112 T  160 - 0.5956 T  161 - 0.6656 T  162 - 0.6420
T 163 - 0.2956 T  164 - 0.3008 T  165 - 0.3536 T  166 - 0.4000 T  167 - 0.8768 T  168 - 0.6196
T 169 - 0.6248 T  170 - 0.4536 T  171 - 0.9252 T  172 - 0.6896 T  173 - 0.6412 T  174 - 0.4572
T 175 - 0.8740 T  176 - 0.8032 T  177 - 1.0640 T  178 - 0.6188 T  179 - 1.1640 T  180 - 1.0040
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STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T 181 - 1.1640 T  182 - 0.9060 T  183 - 0.9892 T  184 - 0.8732 T  185 - 1.0360 T  186 - 0.5752
T 187 - 1.5280 T  201 - 0.0014 T  202 - 0.0022 T  203 - 0.0020 T  204 - 0.0015 T  205 - 0.0014
T 206 - 0.0021 T  207 - 0.0018 T  208 - 0.0015 T  209 - 0.0013 T  210 - 0.0020 T  211 - 0.0020
T 212 - 0.0016 T  213 - 0.0015 T  214 - 0.0020 T  215 - 0.0019 T  216 - 0.0017 T  217 - 0.0000
T 218 - 0.0000 T  219 - 0.0000 T  220 - 0.0000 T  221 - 0.0017 T  222 - 0.0019 T  223 - 0.0020
T 224 - 0.0020 T  225 - 0.0016 T  226 - 0.0016 T  227 - 0.0012 T  228 - 0.0019 T  229 - 0.0000
T 230 - 0.0000 T  231 - 0.0000 T  232 - 0.0000 T  233 - 0.0008 T  234 - 0.0007 T  235 - 0.0008
T 236 - 0.0011 T  237 - 0.0000 T  401 - 0.0000 T  402 - 0.0000 T  403 - 0.0000 T  404 - 0.0000
T 405 - 0.0000 T  406 - 0.0000 T  407 - 0.0000 T  408 - 0.0000 T  409 - 0.0000 T  410 - 0.0000
T 411 - 0.0000 T  412 - 0.0000 T  413 - 0.0000 T  414 - 0.0000 T  415 - 0.0000 T  416 - 0.0000
T 417 - 0.0000 T  418 - 0.0000 T  419 - 0.0000 T  420 - 0.0000 T  421 - 0.0000 T  422 - 0.0000
T 423 - 0.0000 T  424 - 0.0000 T  425 - 0.0000 T  426 - 0.0000 T  427 - 0.0000 T  428 - 0.0000
T 429 - 0.0000 T  430 - 0.0000 T  431 - 0.0000 T  432 - 0.0000 T  433 - 0.0000 T  434 - 0.0000
T 435 - 0.0000 T  436 - 0.0000 T  437 - 0.0000 T  701 - -0.0313 T  702 - -0.0140 T  703 - -0.0172
T 704 - -0.0285 T  705 - -0.0139 T  706 - 0.0031 T  707 - -0.0072 T  708 - -0.0144 T  709 - -0.0223
T 710 - -0.0046 T  711 - -0.0105 T  712 - -0.0171 T  713 - 0.0040 T  714 - 0.0186 T  715 - 0.0109
T 716 - -0.0005 T  717 - -0.0844 T  718 - -0.0733 T  719 - -0.0684 T  720 - -0.0599 T  721 - -0.0265
T 722 - -0.0125 T  723 - -0.0068 T  724 - 0.0051 T  725 - -0.0280 T  726 - -0.0250 T  727 - -0.0440
T 728 - -0.0100 T  729 - -0.0974 T  730 - -0.0814 T  731 - -0.0949 T  732 - -0.0739 T  733 - -0.0474
T 734 - -0.0442 T  735 - -0.0482 T  736 - -0.0235 T  737 - -0.2232 T  801 - 0.0172 T  802 - 0.0949
T 803 - 0.0716 T  804 - 0.0100 T  805 - 0.0000 T  806 - 0.0323 T  807 - 0.0040 T  808 - 0.0000
T 809 - 0.0000 T  810 - 0.0009 T  811 - 0.0027 T  812 - 0.0000 T  813 - 0.0152 T  814 - 0.0767
T 815 - 0.0592 T  816 - 0.0117 T  817 - 0.0000 T  818 - 0.0000 T  819 - 0.0000 T  820 - 0.0000
T 821 - 0.0030 T  822 - 0.0000 T  823 - 0.0000 T  824 - 0.0538 T  825 - 0.0000 T  826 - 0.0000
T 827 - 0.0000 T  828 - 0.0000 T  829 - 0.0000 T  830 - 0.0000 T  831 - 0.0000 T  832 - 0.0000
T 833 - 0.0000 T  834 - 0.0000 T  835 - 0.0000 T  836 - 0.0000 T  837 - 0.0000 T  901 - 33.5555
```

```
T    902 =  185.7147 T    903 =  140.1255 T    904 =   19.5201 T    905 =    0.0000 T    906 =   63.1710 T    907 =    7.7894
T    908 =    0.0000 T    909 =    0.0000 T    910 =    1.7058 T    911 =    5.3585 T    912 =    0.0000 T    913 =   29.8063
T    914 =  150.0127 T    915 =  115.8207 T    916 =   22.9022 T    917 =    0.0000 T    918 =    0.0000 T    919 =    0.0000
T    920 =    0.0000 T    921 =    2.5751 T    922 =    0.0000 T    923 =    0.0000 T    924 =   45.5707 T    925 =    0.0000
T    926 =    0.0000 T    927 =    0.0000 T    928 =    0.0000 T    929 =    0.0000 T    930 =    0.0000 T    931 =    0.0000
T    932 =    0.0000 T    933 =    0.0000 T    934 =    0.0000 T    935 =    0.0000 T    936 =    0.0000 T    937 =    0.0000

****************
TIME= 2.35000E+01, DTIMEU= 2.50000E-03, CSGMIN(  21037)= 1.11551E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(   1014)= 4.36114E-02
                                                                      , ARLXCC(      0)= 0.00000E+00, DRLXCC(   1014)= 4.36114E-02
    LOOPCT=     1

T   1001 =   37.3100 T   1002 =   34.5690 T   1003 =   35.2605 T   1004 =   37.3249 T   1005 =   38.9406 T   1006 =   35.2218
T   1007 =   36.5350 T   1008 =   38.1731 T   1009 =   39.4705 T   1010 =   36.8317 T   1011 =   37.0194 T   1012 =   38.1749
T   1013 =   33.3021 T   1014 =   31.8159 T   1015 =   32.5625 T   1016 =   35.1426 T   1017 =   46.6970 T   1018 =   48.6273
T   1019 =   47.2589 T   1020 =   47.4532 T   1021 =   38.0477 T   1022 =   38.0441 T   1023 =   37.4157 T   1024 =   33.9673
T   1025 =   39.9190 T   1026 =   39.8258 T   1027 =   40.7927 T   1028 =   37.5012 T   1029 =   44.7733 T   1030 =   44.0066
T   1031 =   44.4480 T   1032 =   43.8127 T   1033 =   41.0236 T   1034 =   41.1458 T   1035 =   39.8980 T   1036 =   37.8641
T   1037 =   51.3159 T   2001 =    1.6071 T   3001 =  -80.4751 T   4001 = -184.1765 T   5001 = -328.1736 T   2002 =   -0.9775
T   3002 =  -82.7206 T   4002 = -185.7846 T   5002 = -328.8535 T   2003 =   -0.3255 T   3003 =  -82.1541 T   4003 = -185.3789
T   5003 = -328.6819 T   2004 =    1.6213 T   3004 =  -80.4624 T   4004 = -184.1669 T   5004 = -328.1687 T   2005 =    3.1450
T   3005 =  -79.1383 T   4005 = -183.2177 T   5005 = -327.7643 T   2006 =   -0.3619 T   3006 =  -82.1855 T   4006 = -185.4009
T   5006 = -328.6894 T   2007 =    0.8765 T   3007 =  -81.1095 T   4007 = -184.6301 T   5007 = -328.3631 T   2008 =    2.4214
T   3008 =  -79.7667 T   4008 = -183.6677 T   5008 = -327.9551 T   2009 =    3.6444 T   3009 =  -78.7048 T   4009 = -182.9074
T   5009 = -327.6329 T   2010 =    1.1559 T   3010 =  -80.8670 T   4010 = -184.4562 T   5010 = -328.2880 T   2011 =    1.3328
T   3011 =  -80.7135 T   4011 = -184.3464 T   5011 = -328.2418 T   2012 =    2.4225 T   3012 =  -79.7666 T   4012 = -183.6681
T   5012 = -327.9554 T   2013 =   -2.1716 T   3013 =  -83.7580 T   4013 = -186.5293 T   5013 = -329.1752 T   2014 =   -3.6599
T   3014 =  -85.0608 T   4014 = -187.4610 T   5014 = -329.5676 T   2015 =   -2.8696 T   3015 =  -84.3649 T   4015 = -186.9637
T   5015 = -329.3570 T   2016 =   -0.4362 T   3016 =  -82.2498 T   4016 = -185.4477 T   5016 = -328.7132 T   2017 =   47.7430
T   3017 =   49.8274 T   4017 =   51.9023 T   5017 =   53.9685 T   2018 =   49.4301 T   3018 =   51.0293 T   4018 =   52.6214
T   5018 =   54.2077 T   2019 =   48.2339 T   3019 =   50.1769 T   4019 =   52.1114 T   5019 =   54.0380 T   2020 =   48.4050
T   3020 =   50.3000 T   4020 =   52.1855 T   5020 =   54.0628 T   2021 =    8.2225 T   3021 =  -58.4808 T   4021 = -139.9788
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T   5021 = -239.5387 T   2022 =    8.2192 T   3022 =  -58.4835 T   4022 = -139.9808 T   5022 = -239.5396 T   2023 =    7.6351
T   3023 =  -58.9672 T   4023 = -140.3377 T   5023 = -239.6763 T   2024 =    4.4147 T   3024 =  -61.6749 T   4024 = -142.2304
T   5024 = -240.4013 T   2025 =    9.9617 T   3025 =  -57.0410 T   4025 = -138.9167 T   5025 = -239.1321 T   2026 =    9.8752
T   3026 =  -57.1128 T   4026 = -138.9698 T   5026 = -239.1528 T   2027 =   10.7739 T   3027 =  -56.3684 T   4027 = -138.4202
T   5027 = -238.9424 T   2028 =    7.7143 T   3028 =  -58.9023 T   4028 = -140.2906 T   5028 = -239.6588 T   2029 =   14.4742
T   3029 =  -53.3036 T   4029 = -136.1579 T   5029 = -238.0814 T   2030 =   13.7614 T   3030 =  -53.8945 T   4030 = -136.5948
T   5030 = -238.2486 T   2031 =   14.1717 T   3031 =  -53.5545 T   4031 = -136.3434 T   5031 = -238.1522 T   2032 =   13.5809
T   3032 =  -54.0444 T   4032 = -136.7059 T   5032 = -238.2913 T   2033 =    4.6737 T   3033 =  -77.8397 T   4033 = -179.0787
T   5033 = -324.7246 T   2034 =    4.7903 T   3034 =  -77.7426 T   4034 = -179.0071 T   5034 = -324.6946 T   2035 =    3.6066
T   3035 =  -78.7224 T   4035 = -179.7285 T   5035 = -325.0051 T   2036 =    1.6787 T   3036 =  -80.3170 T   4036 = -180.9023
T   5036 = -325.5114 T   2037 =   54.9660 T   3037 =   62.2121 T   4037 =   69.3791 T   5037 =   76.4704 T  21001 = -422.9850
T  21002 = -422.9802 T  21003 = -422.9812 T  21005 = -422.9843 T  21006 = -422.9795 T  21007 = -422.9815 T  21009 = -422.9850
T  21010 = -422.9804 T  21011 = -422.9809 T  21013 = -422.9847 T  21014 = -422.9806 T  21015 = -422.9816 T  21004 = -422.9843
T  21008 = -422.9834 T  21012 = -422.9834 T  21016 = -422.9833 T  21017 =   54.9997 T  21018 =   54.9998 T  21019 =   54.9998
T  21020 =   54.9998 T  21021 = -296.9905 T  21022 = -296.9906 T  21023 = -296.9906 T  21024 = -296.9909 T  21025 = -296.9908
T  21026 = -296.9911 T  21027 = -296.9913 T  21028 = -296.9910 T  21029 = -296.9970 T  21030 = -296.9966 T  21031 = -296.9967
T  21032 = -296.9966 T  21033 = -422.9848 T  21034 = -422.9858 T  21035 = -422.9854 T  21036 = -422.9863 T  21037 =   79.9991
T  12001 =   46.4854 T  12002 =   48.0508 T  12003 =   47.4777 T  12004 =   46.9593 T  12041 =   47.2298 T  12042 =   47.0717
T  12043 =   44.2247 T  12044 =   44.7541 T  12045 =   47.2932 T  12046 =   48.0144 T  12047 =   48.7414 T  12048 =   50.0527
T  12085 =   47.4769 T  12086 =   47.6482 T  12087 =   46.1985 T  12088 =   46.7191 T  12005 =   48.5570 T  12012 =   52.3822
T  12019 =   49.0530 T  12026 =   48.2713 T  12006 =   48.6248 T  12013 =   50.2363 T  12020 =   49.0302 T  12027 =   48.4853
T  12007 =   48.1585 T  12014 =   49.0011 T  12021 =   48.6627 T  12028 =   47.8637 T  12008 =   47.9238 T  12015 =   48.5258
T  12022 =   48.3625 T  12029 =   47.1974 T  12009 =   48.2398 T  12016 =   48.5000 T  12023 =   48.3081 T  12030 =   47.7194
T  12010 =   48.7041 T  12017 =   48.9231 T  12024 =   48.4023 T  12031 =   48.0188 T  12011 =   49.9176 T  12018 =   49.4130
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T  22003 =   48.9488 T  22004 =   49.0841 T  22041 =   49.3389 T  22042 =   49.0562 T  22043 =   46.5448 T  22044 =   46.3397
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T  12064 =   49.8672 T  12071 =   51.4613 T  12051 =   49.4723 T  12058 =   49.7406 T  12065 =   49.8030 T  12072 =   50.9788
T  12052 =   49.6182 T  12059 =   49.8037 T  12066 =   49.8394 T  12073 =   50.9711 T  12053 =   50.0346 T  12060 =   49.9608
T  12067 =   49.9382 T  12074 =   50.8341 T  12054 =   50.7140 T  12061 =   49.9721 T  12068 =   50.0761 T  12075 =   51.0252
T  12055 =   51.5766 T  12062 =   50.0586 T  12069 =   50.3224 T  12076 =   51.4514 T  12077 =   51.6591 T  12078 =   50.8952
T  12079 =   50.2100 T  12080 =   49.9293 T  12081 =   50.2635 T  12082 =   49.9331 T  12083 =   50.8960 T  12084 =   49.8626
T  22045 =   49.5579 T  22046 =   49.8592 T  22047 =   50.4223 T  22048 =   51.6230 T  22085 =   49.2686 T  22086 =   49.5257
T  22087 =   48.1436 T  22088 =   48.2128 T  22005 =   48.5706 T  22006 =   48.6383 T  22007 =   48.1723 T  22008 =   47.9377
T  22009 =   48.2536 T  22010 =   48.7175 T  22011 =   49.9304 T  22012 =   52.3935 T  22013 =   50.2488 T  22014 =   49.0143
T  22015 =   48.5393 T  22016 =   48.5134 T  22017 =   48.9363 T  22018 =   49.4260 T  22019 =   49.0662 T  22020 =   49.0435
T  22021 =   48.6761 T  22022 =   48.3761 T  22023 =   48.3218 T  22024 =   48.4159 T  22025 =   48.7868 T  22026 =   48.2851
T  22027 =   48.4990 T  22028 =   47.8777 T  22029 =   47.2118 T  22030 =   47.7335 T  22031 =   48.0326 T  22032 =   48.1197
T  22049 =   49.4615 T  22050 =   49.5327 T  22051 =   49.4853 T  22052 =   49.6312 T  22053 =   50.0473 T  22054 =   50.7263
T  22055 =   51.5884 T  22056 =   49.5142 T  22057 =   49.7058 T  22058 =   49.7535 T  22059 =   49.8166 T  22060 =   49.9735
T  22061 =   49.9848 T  22062 =   50.0712 T  22063 =   49.8899 T  22064 =   49.8800 T  22065 =   49.8158 T  22066 =   49.8522
T  22067 =   49.9509 T  22068 =   50.0887 T  22069 =   50.3349 T  22070 =   52.8311 T  22071 =   51.4731 T  22072 =   50.9909
T  22073 =   50.9832 T  22074 =   50.8462 T  22075 =   51.0372 T  22076 =   51.4632 T  22033 =   51.0661 T  22034 =   50.7527
T  22035 =   50.5791 T  22036 =   50.3019 T  22037 =   49.4925 T  22038 =   49.5515 T  22039 =   47.8945 T  22040 =   48.1074
T  22077 =   51.6709 T  22078 =   50.9074 T  22079 =   50.2226 T  22080 =   49.9421 T  22081 =   50.2761 T  22082 =   49.9459
T  22083 =   50.9082 T  22084 =   49.8754 T  31005 =   69.2347 T  31006 =   69.2280 T  31007 =   69.1745 T  31008 =   69.0905
T  31009 =   69.1455 T  31010 =   69.1563 T  31011 =   69.2724 T  31012 =   69.5451 T  31013 =   69.3080 T  31014 =   69.1799
T  31015 =   69.1498 T  31016 =   69.1678 T  31017 =   69.1889 T  31018 =   69.2052 T  31019 =   69.2303 T  31020 =   69.2197
T  31021 =   69.1889 T  31022 =   69.1686 T  31023 =   69.1592 T  31024 =   69.1459 T  31025 =   69.0842 T  31026 =   69.1959
T  31027 =   69.2098 T  31028 =   69.1544 T  31029 =   69.0882 T  31030 =   69.1216 T  31031 =   69.0997 T  31032 =   69.0865
T  31033 =   69.4141 T  31034 =   69.3798 T  31035 =   69.3353 T  31036 =   69.3466 T  31037 =   69.1854 T  31038 =   69.1993
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T  31053 =   69.3571 T  31054 =   69.4289 T  31055 =   69.5193 T  31056 =   69.3641 T  31057 =   69.3829 T  31058 =   69.3835
T  31059 =   69.3871 T  31060 =   69.4023 T  31061 =   69.3911 T  31062 =   69.3841 T  31063 =   69.3054 T  31064 =   69.2981
T  31065 =   69.2884 T  31066 =   69.2911 T  31067 =   69.3011 T  31068 =   69.3189 T  31069 =   69.3432 T  31070 =   69.6381
T  31071 =   69.4853 T  31072 =   69.4265 T  31073 =   69.4146 T  31074 =   69.4017 T  31075 =   69.4250 T  31076 =   69.4649
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)
T  31077 =   69.5213 T  31078 =   69.4180 T  31079 =   69.3745 T  31080 =   69.3746 T  31081 =   69.3172 T  31082 =   69.2655
T  31083 =   69.3512 T  31084 =   69.2666 T  32005 =   70.9331 T  32006 =   70.9325 T  32007 =   70.9298 T  32008 =   70.9244
T  32009 =   70.9276 T  32010 =   70.9271 T  32011 =   70.9326 T  32012 =   70.9452 T  32013 =   70.9345 T  32014 =   70.9290
T  32015 =   70.9281 T  32016 =   70.9295 T  32017 =   70.9301 T  32018 =   70.9299 T  32019 =   70.9332 T  32020 =   70.9326
T  32021 =   70.9314 T  32022 =   70.9307 T  32023 =   70.9301 T  32024 =   70.9289 T  32025 =   70.9237 T  32026 =   70.9307
T  32027 =   70.9311 T  32028 =   70.9287 T  32029 =   70.9255 T  32030 =   70.9279 T  32031 =   70.9271 T  32032 =   70.9254
T  32033 =   70.9404 T  32034 =   70.9390 T  32035 =   70.9368 T  32036 =   70.9378 T  32037 =   70.9293 T  32038 =   70.9300
T  32039 =   70.9229 T  32040 =   70.9242 T  32049 =   70.9342 T  32050 =   70.9339 T  32051 =   70.9340 T  32052 =   70.9350
T  32053 =   70.9386 T  32054 =   70.9416 T  32055 =   70.9455 T  32056 =   70.9401 T  32057 =   70.9409 T  32058 =   70.9409
T  32059 =   70.9411 T  32060 =   70.9420 T  32061 =   70.9414 T  32062 =   70.9411 T  32063 =   70.9359 T  32064 =   70.9355
T  32065 =   70.9350 T  32066 =   70.9352 T  32067 =   70.9358 T  32068 =   70.9366 T  32069 =   70.9376 T  32070 =   70.9506
T  32071 =   70.9441 T  32072 =   70.9416 T  32073 =   70.9411 T  32074 =   70.9407 T  32075 =   70.9417 T  32076 =   70.9431
T  32077 =   70.9459 T  32078 =   70.9412 T  32079 =   70.9400 T  32080 =   70.9407 T  32081 =   70.9362 T  32082 =   70.9333
T  32083 =   70.9371 T  32084 =   70.9335 T  33005 =   70.9982 T  33006 =   70.9982 T  33007 =   70.9981 T  33008 =   70.9979
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T  33009 =    70.9980 T  33010 =    70.9980 T  33011 =    70.9982 T  33012 =    70.9985 T  33013 =    70.9982 T  33014 =    70.9981
T  33015 =    70.9980 T  33016 =    70.9981 T  33017 =    70.9981 T  33018 =    70.9981 T  33019 =    70.9982 T  33020 =    70.9982
T  33021 =    70.9982 T  33022 =    70.9981 T  33023 =    70.9981 T  33024 =    70.9981 T  33025 =    70.9979 T  33026 =    70.9981
T  33027 =    70.9981 T  33028 =    70.9981 T  33029 =    70.9980 T  33030 =    70.9980 T  33031 =    70.9980 T  33032 =    70.9980
T  33033 =    70.9984 T  33034 =    70.9984 T  33035 =    70.9983 T  33036 =    70.9984 T  33037 =    70.9981 T  33038 =    70.9981
T  33039 =    70.9979 T  33040 =    70.9979 T  33049 =    70.9982 T  33050 =    70.9982 T  33051 =    70.9982 T  33052 =    70.9983
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T  33059 =    70.9985 T  33060 =    70.9985 T  33061 =    70.9985 T  33062 =    70.9985 T  33063 =    70.9983 T  33064 =    70.9983
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T  33071 =    70.9985 T  33072 =    70.9985 T  33073 =    70.9985 T  33074 =    70.9984 T  33075 =    70.9985 T  33076 =    70.9985
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T  34015 =    71.0000 T  34016 =    71.0000 T  34017 =    71.0000 T  34018 =    71.0000 T  34019 =    71.0000 T  34020 =    71.0000
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T  34059 =    71.0000 T  34060 =    71.0000 T  34061 =    71.0000 T  34062 =    71.0000 T  34063 =    71.0000 T  34064 =    71.0000
T  34065 =    71.0000 T  34066 =    71.0000 T  34067 =    71.0000 T  34068 =    71.0000 T  34069 =    71.0000 T  34070 =    71.0000
T  34071 =    71.0000 T  34072 =    71.0000 T  34073 =    71.0000 T  34074 =    71.0000 T  34075 =    71.0000 T  34076 =    71.0000
T  34077 =    71.0000 T  34078 =    71.0000 T  34079 =    71.0000 T  34080 =    71.0000 T  34081 =    71.0000 T  34082 =    71.0000
T  34083 =    71.0000 T  34084 =    71.0000 T  42006 =    82.5923 T  42013 =    82.4340 T  42020 =    83.6161 T  42027 =    81.5193
T  42008 =    80.6879 T  42015 =    82.3318 T  42022 =    83.5029 T  42029 =    81.0916 T  42010 =    83.2509 T  42017 =    83.8738
T  42024 =    82.9881 T  42031 =    83.1991 T  42050 =    81.0963 T  42057 =    83.7025 T  42064 =    82.5689 T  42071 =    84.5351
T  42052 =    82.3921 T  42059 =    84.1402 T  42066 =    82.8084 T  42073 =    84.2907 T  42054 =    84.5172 T  42061 =    84.0900
T  42068 =    83.2346 T  42075 =    84.4737 T  43006 =    70.6801 T  43013 =    69.9894 T  43020 =    72.2398 T  43027 =    69.4316
T  43008 =    67.7736 T  43015 =    69.7686 T  43022 =    71.8288 T  43029 =    68.6897 T  43010 =    69.7774 T  43017 =    70.8366
T  43024 =    70.2314 T  43031 =    70.5972 T  43050 =    73.6361 T  43057 =    81.0125 T  43064 =    72.6624 T  43071 =    74.5560
T  43052 =    75.1939 T  43059 =    81.4470 T  43066 =    72.9594 T  43073 =    74.3705 T  43054 =    77.5682 T  43061 =    81.7122
T  43068 =    73.5734 T  43075 =    74.5841 T   8000 =    37.8360 T   8005 =    38.9365 T   8010 =    38.6344 T   8011 =    43.4765
T   8015 =    37.7146 T   8016 =    42.2903 T   8020 =    39.1954 T   8025 =    38.3480 T   8030 =    39.7382 T   8035 =    45.7376
T   6000 =    31.9978 T   6010 =    32.5283 T   6020 =    32.4366 T   6030 =    32.4140 T   6040 =    32.2614 T   6050 =    32.2821
T   6060 =    32.2399 T   6070 =    32.1072 T   6080 =    32.0266 T   6090 =    31.9923 T   6001 =    32.3537 T   6011 =    32.3036
T   6021 =    32.2310 T   6031 =    32.1213 T   6041 =    32.0891 T   6051 =    32.0622 T   6061 =    32.0195 T   6071 =    31.9932
T   6081 =    31.9823 T   6091 =    31.0556 T    500 =    33.7972 T    501 =    33.6010 T    502 =    34.2580 T    503 =    33.9759
T   9000 =    29.6968 T   9001 =    29.6984 T   9002 =    29.6969 T   9003 =    29.6953 T     40 =    53.2000 T   9999 =    29.5706
T   7000 =  -423.0000 T   7001 =  -297.0000 T   7002 =    55.0000 T   7003 =    80.0000 T   8888 =    53.2000 T   8889 =    74.0000
T   8890 =     0.0000 T   8891 =   244.0000 T   8892 =    11.0000 T  13001 =     0.0000 T  13002 =     0.0000 T  13003 =     0.0000
T  13004 =     0.0000 T  13005 =     0.0000 T  13006 =     0.0000 T  13007 =     0.0000 T  13008 =     0.0000 T  13009 =     0.0000
T  13010 =     0.0000 T  13011 =     0.0000 T  13012 =     0.0000 T  13013 =     0.0000 T  13014 =     0.0000 T  13015 =     0.0000
T  13016 =     0.0000 T  13017 =     0.0000 T  13018 =     0.0000 T  13019 =     0.0000 T  13020 =     0.0000 T  13021 =     0.0000
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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A-.8)
T  13022 =     0.0000 T  13023 =     0.0000 T  13024 =     0.0000 T  13025 =     0.0000 T  13026 =     0.0000 T  13027 =     0.0000
T  13028 =     0.0000 T  13029 =     0.0000 T  13030 =     0.0000 T  13031 =     0.0000 T  13032 =     0.0000 T  13033 =     0.0000
T  13034 =     0.0000 T  13035 =     0.0000 T  13036 =     0.0000 T  13037 =     0.0000 T  16001 =  5299.9299 T  16002 =  6976.0763
T  16003 =  6644.0936 T  16004 =  5487.7750 T  16005 =  4400.7962 T  16006 =  6228.0444 T  16007 =  5631.8111 T  16008 =  4841.0475
T  16009 =  4296.3994 T  16010 =  6097.0245 T  16011 =  6024.6683 T  16012 =  5150.7632 T  16013 =  4477.1818 T  16014 =  6480.8107
T  16015 =  5722.3581 T  16016 =  5047.7750 T  16017 =     0.0000 T  16018 =     0.0000 T  16019 =     0.0000 T  16020 =     0.0000
T  16021 =  2672.8313 T  16022 =  2551.2535 T  16023 =  2679.7079 T  16024 =  2581.1767 T  16025 =  4329.7090 T  16026 =  4220.2167
T  16027 =  3899.7319 T  16028 =  4613.0481 T  16029 =   146.4908 T  16030 =   521.4650 T  16031 =   325.1029 T  16032 =   589.5079
T  16033 =  2269.5095 T  16034 =  2057.6616 T  16035 =  2575.6481 T  16036 =  2304.0829 T  16037 =     0.0000 T    101 =    10.9254
T    102 =    11.0888 T    103 =    11.2002 T    104 =    11.3785 T    105 =    11.2448 T    106 =    10.3832 T    107 =    10.6506
T    108 =    11.1037 T    109 =    12.0024 T    110 =    12.0395 T    111 =    12.1509 T    112 =    11.8984 T    113 =     5.9863
T    114 =     6.9890 T    115 =     7.3901 T    116 =     8.1402 T    117 =    12.8565 T    118 =    12.4331 T    119 =    12.3663
T    120 =     8.8904 T    121 =    14.2751 T    122 =    13.5546 T    123 =    13.1536 T    124 =     8.8309 T    125 =    16.8969
T    126 =    16.1319 T    127 =    18.2263 T    128 =    12.3217 T    129 =    21.6874 T    130 =    19.1250 T    131 =    21.0932
T    132 =    18.1149 T    133 =    15.4783 T    134 =    14.3493 T    135 =    13.8146 T    136 =     8.7195 T    137 =    28.5204
T    151 =     0.5884 T    152 =     0.5972 T    153 =     0.6032 T    154 =     0.6128 T    155 =     0.6056 T    156 =     0.5592
T    157 =     0.5736 T    158 =     0.5980 T    159 =     0.6464 T    160 =     0.6484 T    161 =     0.6544 T    162 =     0.6408
T    163 =     0.3224 T    164 =     0.3764 T    165 =     0.3980 T    166 =     0.4384 T    167 =     0.6924 T    168 =     0.6696
T    169 =     0.6660 T    170 =     0.4788 T    171 =     0.7688 T    172 =     0.7300 T    173 =     0.7084 T    174 =     0.4756
T    175 =     0.9100 T    176 =     0.8688 T    177 =     0.9816 T    178 =     0.6636 T    179 =     1.1680 T    180 =     1.0300
T    181 =     1.1360 T    182 =     0.9756 T    183 =     0.8336 T    184 =     0.7728 T    185 =     0.7440 T    186 =     0.4696
T    187 =     1.5360 T    201 =     0.0023 T    202 =     0.0030 T    203 =     0.0029 T    204 =     0.0024 T    205 =     0.0019
T    206 =     0.0027 T    207 =     0.0025 T    208 =     0.0021 T    209 =     0.0019 T    210 =     0.0027 T    211 =     0.0026
T    212 =     0.0022 T    213 =     0.0019 T    214 =     0.0025 T    215 =     0.0025 T    216 =     0.0022 T    217 =     0.0000
T    218 =     0.0000 T    219 =     0.0000 T    220 =     0.0000 T    221 =     0.0027 T    222 =     0.0026 T    223 =     0.0027
T    224 =     0.0026 T    225 =     0.0024 T    226 =     0.0023 T    227 =     0.0021 T    228 =     0.0025 T    229 =     0.0002
T    230 =     0.0006 T    231 =     0.0004 T    232 =     0.0007 T    233 =     0.0017 T    234 =     0.0016 T    235 =     0.0020
T    236 =     0.0018 T    237 =     0.0000 T    401 =     0.0000 T    402 =     0.0000 T    403 =     0.0000 T    404 =     0.0000
T    405 =     0.0000 T    406 =     0.0000 T    407 =     0.0000 T    408 =     0.0000 T    409 =     0.0000 T    410 =     0.0000
T    411 =     0.0000 T    412 =     0.0000 T    413 =     0.0000 T    414 =     0.0000 T    415 =     0.0000 T    416 =     0.0000
T    417 =     0.0000 T    418 =     0.0000 T    419 =     0.0000 T    420 =     0.0000 T    421 =     0.0000 T    422 =     0.0000
T    423 =     0.0000 T    424 =     0.0000 T    425 =     0.0000 T    426 =     0.0000 T    427 =     0.0000 T    428 =     0.0000
T    429 =     0.0000 T    430 =     0.0000 T    431 =     0.0000 T    432 =     0.0000 T    433 =     0.0000 T    434 =     0.0000
T    435 =     0.0000 T    436 =     0.0000 T    437 =     0.0000 T    701 =    -0.0224 T    702 =    -0.0068 T    703 =    -0.0107
T    704 =    -0.0227 T    705 =    -0.0319 T    706 =    -0.0108 T    707 =    -0.0179 T    708 =    -0.0274 T    709 =    -0.0356
T    710 =    -0.0195 T    711 =    -0.0206 T    712 =    -0.0276 T    713 =    -0.0043 T    714 =     0.0050 T    715 =     0.0001
T    716 =    -0.0112 T    717 =    -0.0819 T    718 =    -0.0873 T    719 =    -0.0818 T    720 =    -0.0697 T    721 =    -0.0272
T    722 =    -0.0266 T    723 =    -0.0227 T    724 =    -0.0042 T    725 =    -0.0438 T    726 =    -0.0425 T    727 =    -0.0525
T    728 =    -0.0237 T    729 =    -0.1170 T    730 =    -0.1009 T    731 =    -0.1116 T    732 =    -0.0963 T    733 =    -0.0495
T    734 =    -0.0488 T    735 =    -0.0394 T    736 =    -0.0230 T    737 =    -0.2568 T    801 =     0.0000 T    802 =     0.0880
T    803 =     0.0608 T    804 =     0.0000 T    805 =     0.0000 T    806 =     0.0214 T    807 =     0.0000 T    808 =     0.0000
T    809 =     0.0000 T    810 =     0.0000 T    811 =     0.0000 T    812 =     0.0000 T    813 =     0.0108 T    814 =     0.0817
T    815 =     0.0592 T    816 =     0.0004 T    817 =     0.0000 T    818 =     0.0000 T    819 =     0.0000 T    820 =     0.0000
T    821 =     0.0000 T    822 =     0.0000 T    823 =     0.0000 T    824 =     0.0495 T    825 =     0.0000 T    826 =     0.0000
T    827 =     0.0000 T    828 =     0.0000 T    829 =     0.0000 T    830 =     0.0000 T    831 =     0.0000 T    832 =     0.0000
T    833 =     0.0000 T    834 =     0.0000 T    835 =     0.0000 T    836 =     0.0000 T    837 =     0.0000 T    901 =     0.0000
T    902 =   172.2170 T    903 =   119.0028 T    904 =     0.0000 T    905 =     0.0000 T    906 =    41.9060 T    907 =     0.0000
T    908 =     0.0000 T    909 =     0.0000 T    910 =     0.0000 T    911 =     0.0000 T    912 =     0.0000 T    913 =    21.1175
T    914 =   159.8850 T    915 =   115.8697 T    916 =     0.7391 T    917 =     0.0000 T    918 =     0.0000 T    919 =     0.0000
T    920 =     0.0000 T    921 =     0.0000 T    922 =     0.0000 T    923 =     0.0000 T    924 =    41.9309 T    925 =     0.0000
T    926 =     0.0000 T    927 =     0.0000 T    928 =     0.0000 T    929 =     0.0000 T    930 =     0.0000 T    931 =     0.0000
T    932 =     0.0000 T    933 =     0.0000 T    934 =     0.0000 T    935 =     0.0000 T    936 =     0.0000 T    937 =     0.0000

****************
TIME= 2.45000E+01, DTIMEU= 2.50000E-03, CSGMIN(  21037)= 1.11551E-05, ATMPCC(      0)= 0.00000E+00, DTMPCC(   1013)= 3.02831E-02
    LOOPCT=      1                                                   , ARLXCC(      0)= 0.00000E+00, DRLXCC(   1013)= 3.02831E-02

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     STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A-.8)
T   1001 =    39.2159 T   1002 =    36.6123 T   1003 =    37.0719 T   1004 =    38.8156 T   1005 =    39.0276 T   1006 =    35.2987
T   1007 =    36.8963 T   1008 =    38.0394 T   1009 =    39.7436 T   1010 =    36.8312 T   1011 =    37.6008 T   1012 =    38.6685
```

T	1013 =	31.8095	T	1014 =	30.4650	T	1015 =	31.9868	T	1016 =	34.8605	T	1017 =	46.8426	T	1018 =	48.0484	
T	1019 =	46.8999	T	1020 =	47.0322	T	1021 =	39.2069	T	1022 =	37.7398	T	1023 =	37.4243	T	1024 =	33.8981	
T	1025 =	40.2452	T	1026 =	39.5403	T	1027 =	41.5850	T	1028 =	37.1777	T	1029 =	45.1496	T	1030 =	44.1303	
T	1031 =	44.8898	T	1032 =	43.8471	T	1033 =	42.0388	T	1034 =	42.0952	T	1035 =	41.4834	T	1036 =	38.0170	
T	1037 =	51.0061	T	2001 =	3.4043	T	3001 =	-78.9134	T	4001 =	-183.0569	T	5001 =	-327.6965	T	2002 =	0.9493	
T	3002 =	-81.0462	T	4002 =	-184.5843	T	5002 =	-328.3422	T	2003 =	1.3825	T	3003 =	-80.6699	T	4003 =	-184.3149	
T	5003 =	-328.2285	T	2004 =	3.0269	T	3004 =	-79.2411	T	4004 =	-183.2914	T	5004 =	-327.7957	T	2005 =	3.2270	
T	3005 =	-79.0672	T	4005 =	-183.1668	T	5005 =	-327.7426	T	2006 =	-0.2893	T	3006 =	-82.1224	T	4006 =	-185.3556	
T	5006 =	-328.6701	T	2007 =	1.2171	T	3007 =	-80.8136	T	4007 =	-184.4180	T	5007 =	-328.2728	T	2008 =	2.2951	
T	3008 =	-79.8766	T	4008 =	-183.7466	T	5008 =	-327.9887	T	2009 =	3.9019	T	3009 =	-78.4809	T	4009 =	-182.7469	
T	5009 =	-327.5645	T	2010 =	1.1554	T	3010 =	-80.8674	T	4010 =	-184.4564	T	5010 =	-328.2881	T	2011 =	1.8811	
T	3011 =	-80.2370	T	4011 =	-184.0047	T	5011 =	-328.0962	T	2012 =	2.8879	T	3012 =	-79.3621	T	4012 =	-183.3781	
T	5012 =	-327.8318	T	2013 =	-3.5923	T	3013 =	-84.9968	T	4013 =	-187.4184	T	5013 =	-329.5540	T	2014 =	-4.8473	
T	3014 =	-86.0833	T	4014 =	-188.1951	T	5014 =	-329.8802	T	2015 =	-3.4002	T	3015 =	-84.8245	T	4015 =	-187.2931	
T	5015 =	-329.4973	T	2016 =	-0.7025	T	3016 =	-82.4816	T	4016 =	-185.6141	T	5016 =	-328.7841	T	2017 =	47.8697	
T	3017 =	49.9169	T	4017 =	51.9557	T	5017 =	53.9862	T	2018 =	48.9236	T	3018 =	50.6679	T	4018 =	52.4050	
T	5018 =	54.1356	T	2019 =	47.9200	T	3019 =	49.9530	T	4019 =	51.9773	T	5019 =	53.9934	T	2020 =	48.0364	
T	3020 =	50.0367	T	4020 =	52.0277	T	5020 =	54.0102	T	2021 =	9.3001	T	3021 =	-57.5885	T	4021 =	-139.3203	
T	5021 =	-239.2863	T	2022 =	7.9364	T	3022 =	-58.7178	T	4022 =	-140.1538	T	5022 =	-239.6059	T	2023 =	7.6430	
T	3023 =	-58.9608	T	4023 =	-140.3331	T	5023 =	-239.6746	T	2024 =	4.3499	T	3024 =	-61.7297	T	4024 =	-142.2684	
T	5024 =	-240.4158	T	2025 =	10.2649	T	3025 =	-56.7901	T	4025 =	-138.7314	T	5025 =	-239.0611	T	2026 =	9.6096	
T	3026 =	-57.3328	T	4026 =	-139.1323	T	5026 =	-239.2151	T	2027 =	11.5104	T	3027 =	-55.7584	T	4027 =	-137.9696	
T	5027 =	-238.7696	T	2028 =	7.4136	T	3028 =	-59.1514	T	4028 =	-140.4745	T	5028 =	-239.7292	T	2029 =	14.8236	
T	3029 =	-53.0150	T	4029 =	-135.9451	T	5029 =	-237.9999	T	2030 =	13.8762	T	3030 =	-53.7995	T	4030 =	-136.5246	
T	5030 =	-238.2216	T	2031 =	14.5822	T	3031 =	-53.2145	T	4031 =	-136.0922	T	5031 =	-238.0559	T	2032 =	13.6128	
T	3032 =	-54.0178	T	4032 =	-136.6861	T	5032 =	-238.2837	T	2033 =	5.6361	T	3033 =	-77.0437	T	4033 =	-178.4928	
T	5033 =	-324.4722	T	2034 =	5.6898	T	3034 =	-76.9990	T	4034 =	-178.4600	T	5034 =	-324.4590	T	2035 =	5.1096	
T	3035 =	-77.4793	T	4035 =	-178.8136	T	5035 =	-324.6110	T	2036 =	1.8231	T	3036 =	-80.1982	T	4036 =	-180.8152	
T	5036 =	-325.4740	T	2037 =	54.6805	T	3037 =	61.9857	T	4037 =	69.2312	T	5037 =	76.4188	T	21001 =	-422.9849	
T	21002 =	-422.9800	T	21003 =	-422.9811	T	21005 =	-422.9843	T	21006 =	-422.9795	T	21007 =	-422.9814	T	21009 =	-422.9850	
T	21010 =	-422.9804	T	21011 =	-422.9809	T	21013 =	-422.9848	T	21014 =	-422.9807	T	21015 =	-422.9816	T	21004 =	-422.9842	
T	21008 =	-422.9834	T	21012 =	-422.9834	T	21016 =	-422.9834	T	21017 =	54.9997	T	21018 =	54.9998	T	21019 =	54.9997	
T	21020 =	54.9998	T	21021 =	-296.9905	T	21022 =	-296.9906	T	21023 =	-296.9906	T	21024 =	-296.9909	T	21025 =	-296.9908	
T	21026 =	-296.9911	T	21027 =	-296.9913	T	21028 =	-296.9910	T	21029 =	-296.9970	T	21030 =	-296.9966	T	21031 =	-296.9967	
T	21032 =	-296.9966	T	21033 =	-422.9847	T	21034 =	-422.9857	T	21035 =	-422.9854	T	21036 =	-422.9863	T	21037 =	79.9991	
T	12001 =	45.4211	T	12002 =	48.2519	T	12003 =	46.9452	T	12004 =	47.0624	T	12041 =	47.7408	T	12042 =	47.0624	
T	12043 =	45.1818	T	12044 =	44.7707	T	12045 =	47.3763	T	12046 =	47.6331	T	12047 =	48.3552	T	12048 =	49.3874	
T	12085 =	47.6526	T	12086 =	47.0950	T	12087 =	46.4723	T	12088 =	46.1596	T	12005 =	47.9985	T	12012 =	51.9011	
T	12019 =	48.5503	T	12026 =	47.8388	T	12006 =	48.0811	T	12013 =	49.9418	T	12020 =	48.5415	T	12027 =	48.0441	
T	12007 =	47.6902	T	12014 =	48.7333	T	12021 =	48.1536	T	12028 =	47.3435	T	12008 =	47.5484	T	12015 =	48.1837	
T	12022 =	47.8238	T	12029 =	46.5786	T	12009 =	47.8961	T	12016 =	48.1962	T	12023 =	47.7653	T	12030 =	47.1834	
T	12010 =	48.3294	T	12017 =	48.5469	T	12024 =	47.8969	T	12031 =	47.5510	T	12011 =	49.4713	T	12018 =	48.9705	
T	12025 =	48.4112	T	12032 =	47.6624	T	12033 =	50.6433	T	12034 =	50.3875	T	12035 =	50.1955	T	12036 =	49.8998	
T	12037 =	49.1193	T	12038 =	49.1623	T	12039 =	47.4983	T	12040 =	47.7340	T	22001 =	47.5124	T	22002 =	49.3500	
T	22003 =	48.3581	T	22004 =	48.4422	T	22041 =	48.8772	T	22042 =	48.4769	T	22043 =	46.1768	T	22044 =	45.9122	
T	12049 =	49.1051	T	12056 =	49.0068	T	12063 =	49.5097	T	12070 =	52.3037	T	12050 =	49.1866	T	12057 =	49.1939	
T	12064 =	49.5075	T	12071 =	51.0716	T	12051 =	49.1377	T	12058 =	49.2471	T	12065 =	49.4592	T	12072 =	50.6566	
T	12052 =	49.2730	T	12059 =	49.3168	T	12066 =	49.4989	T	12073 =	50.6914	T	12053 =	49.6565	T	12060 =	49.4734	
T	12067 =	49.5855	T	12074 =	50.5552	T	12054 =	50.3256	T	12061 =	49.4953	T	12068 =	49.7113	T	12075 =	50.7479	
T	12055 =	51.1615	T	12062 =	49.6055	T	12069 =	49.9505	T	12076 =	51.1576	T	12077 =	51.2496	T	12078 =	50.5212	
T	12079 =	49.8292	T	12080 =	49.4717	T	12081 =	49.9221	T	12082 =	49.6062	T	12083 =	50.6207	T	12084 =	49.5078	
T	22045 =	48.9319	T	22046 =	49.1820	T	22047 =	49.7950	T	22048 =	50.8916	T	22085 =	48.8010	T	22086 =	48.8277	
T	22087 =	47.6700	T	22088 =	47.6475	T	22005 =	48.0122	T	22006 =	48.0948	T	22007 =	47.7041	T	22008 =	47.5623	
T	22009 =	47.9098	T	22010 =	48.3429	T	22011 =	49.4842	T	22012 =	51.9126	T	22013 =	49.9543	T	22014 =	48.7465	
T	22015 =	48.1973	T	22016 =	48.2098	T	22017 =	48.5602	T	22018 =	48.9836	T	22019 =	48.5717	T	22020 =	48.5549	

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	22021 =	48.1672	T	22022 =	47.8376	T	22023 =	47.7792	T	22024 =	47.9106	T	22025 =	48.4245	T	22026 =	47.8526	
T	22027 =	48.0578	T	22028 =	47.3576	T	22029 =	46.5932	T	22030 =	47.1976	T	22031 =	47.5649	T	22032 =	47.6763	
T	22049 =	49.1182	T	22050 =	49.1996	T	22051 =	49.1507	T	22052 =	49.2860	T	22053 =	49.6693	T	22054 =	50.3379	
T	22055 =	51.1734	T	22056 =	49.0200	T	22057 =	49.2070	T	22058 =	49.2601	T	22059 =	49.3298	T	22060 =	49.4863	
T	22061 =	49.5081	T	22062 =	49.6183	T	22063 =	49.5225	T	22064 =	49.5203	T	22065 =	49.4721	T	22066 =	49.5117	
T	22067 =	49.5982	T	22068 =	49.7240	T	22069 =	49.9630	T	22070 =	52.3149	T	22071 =	51.0835	T	22072 =	50.6688	
T	22073 =	50.7035	T	22074 =	50.5673	T	22075 =	50.7600	T	22076 =	51.1694	T	22033 =	50.6555	T	22034 =	50.3998	
T	22035 =	50.2079	T	22036 =	49.9125	T	22037 =	49.1324	T	22038 =	49.1753	T	22039 =	47.5123	T	22040 =	47.7478	
T	22077 =	51.2615	T	22078 =	50.5335	T	22079 =	49.8419	T	22080 =	49.4846	T	22081 =	49.9346	T	22082 =	49.6189	
T	22083 =	50.6328	T	22084 =	49.5206	T	31005 =	68.9629	T	31006 =	68.9574	T	31007 =	68.8993	T	31008 =	68.8147	
T	31009 =	68.8731	T	31010 =	68.8897	T	31011 =	69.0193	T	31012 =	69.3192	T	31013 =	69.0596	T	31014 =	68.9177	
T	31015 =	68.8812	T	31016 =	68.8987	T	31017 =	68.9245	T	31018 =	68.9466	T	31019 =	68.9658	T	31020 =	68.9552	
T	31021 =	68.9199	T	31022 =	68.8957	T	31023 =	68.8858	T	31024 =	68.8744	T	31025 =	68.8203	T	31026 =	68.9220	
T	31027 =	68.9384	T	31028 =	68.8752	T	31029 =	68.8007	T	31030 =	68.8411	T	31031 =	68.8243	T	31032 =	68.8128	
T	31033 =	69.1720	T	31034 =	69.1346	T	31035 =	69.0887	T	31036 =	69.0958	T	31037 =	68.9274	T	31038 =	68.9416	
T	31039 =	68.7656	T	31040 =	68.7953	T	31049 =	69.0221	T	31050 =	69.0205	T	31051 =	69.0159	T	31052 =	69.0343	
T	31053 =	69.1040	T	31054 =	69.1834	T	31055 =	69.2833	T	31056 =	69.1026	T	31057 =	69.1235	T	31058 =	69.1248	
T	31059 =	69.1292	T	31060 =	69.1462	T	31061 =	69.1355	T	31062 =	69.1301	T	31063 =	69.0514	T	31064 =	69.0442	
T	31065 =	69.0340	T	31066 =	69.0372	T	31067 =	69.0481	T	31068 =	69.0674	T	31069 =	69.0943	T	31070 =	69.4157	
T	31071 =	69.2488	T	31072 =	69.1852	T	31073 =	69.1738	T	31074 =	69.1594	T	31075 =	69.1848	T	31076 =	69.2294	
T	31077 =	69.2849	T	31078 =	69.1738	T	31079 =	69.1219	T	31080 =	69.1176	T	31081 =	69.0670	T	31082 =	69.0121	
T	31083 =	69.1096	T	31084 =	69.0121	T	32005 =	70.9123	T	32006 =	70.9117	T	32007 =	70.9084	T	32008 =	70.9021	
T	32009 =	70.9058	T	32010 =	70.9055	T	32011 =	70.9124	T	32012 =	70.9280	T	32013 =	70.9146	T	32014 =	70.9076	
T	32015 =	70.9064	T	32016 =	70.9080	T	32017 =	70.9088	T	32018 =	70.9089	T	32019 =	70.9123	T	32020 =	70.9116	
T	32021 =	70.9101	T	32022 =	70.9091	T	32023 =	70.9085	T	32024 =	70.9071	T	32025 =	70.9013	T	32026 =	70.9095	
T	32027 =	70.9101	T	32028 =	70.9069	T	32029 =	70.9031	T	32030 =	70.9058	T	32031 =	70.9048	T	32032 =	70.9030	
T	32033 =	70.9217	T	32034 =	70.9199	T	32035 =	70.9172	T	32036 =	70.9183	T	32037 =	70.9081	T	32038 =	70.9089	
T	32039 =	70.9000	T	32040 =	70.9016	T	32049 =	70.9140	T	32050 =	70.9137	T	32051 =	70.9137	T	32052 =	70.9149	
T	32053 =	70.9192	T	32054 =	70.9230	T	32055 =	70.9280	T	32056 =	70.9207	T	32057 =	70.9217	T	32058 =	70.9218	
T	32059 =	70.9220	T	32060 =	70.9230	T	32061 =	70.9223	T	32062 =	70.9219	T	32063 =	70.9159	T	32064 =	70.9154	
T	32065 =	70.9149	T	32066 =	70.9151	T	32067 =	70.9158	T	32068 =	70.9168	T	32069 =	70.9180	T	32070 =	70.9344	
T	32071 =	70.9262	T	32072 =	70.9231	T	32073 =	70.9224	T	32074 =	70.9218	T	32075 =	70.9231	T	32076 =	70.9250	
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T	32083 =	70.9177	T	32084 =	70.9132	T	33005 =	70.9973	T	33006 =	70.9973	T	33007 =	70.9972	T	33008 =	70.9969	
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T	33065 =	70.9974	T	33066 =	70.9974	T	33067 =	70.9975	T	33068 =	70.9975	T	33069 =	70.9975	T	33070 =	70.9981	
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T	34015 =	70.9999	T	34016 =	70.9999	T	34017 =	70.9999	T	34018 =	70.9999	T	34019 =	70.9999	T	34020 =	70.9999	
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STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

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T	42008 -	78.6355	T	42015 -	80.2089	T	42022 -	81.2951	T	42029 -	78.9722	T	42010 -	81.1132	T	42017 -	81.6916
T	42024 -	80.8250	T	42031 -	80.9915	T	42050 -	79.1326	T	42057 -	81.6121	T	42064 -	80.5233	T	42071 -	82.4539
T	42052 -	80.3701	T	42059 -	82.0335	T	42066 -	80.7520	T	42073 -	82.2080	T	42054 -	82.4458	T	42061 -	81.9967
T	42068 -	81.1712	T	42075 -	82.4001	T	43006 -	71.6922	T	43013 -	71.0555	T	43020 -	73.2001	T	43027 -	70.4626
T	43008 -	68.8841	T	43015 -	70.8428	T	43022 -	72.8158	T	43029 -	69.7491	T	43010 -	70.9362	T	43017 -	71.9524
T	43024 -	71.3219	T	43031 -	71.6710	T	43050 -	74.2403	T	43057 -	81.1640	T	43064 -	73.4916	T	43071 -	75.3903
T	43052 -	75.7707	T	43059 -	81.5980	T	43066 -	73.7827	T	43073 -	75.1992	T	43054 -	78.1193	T	43061 -	81.8344
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T	8015 -	37.4774	T	8016 -	42.2895	T	8020 -	39.2083	T	8025 -	38.0955	T	8030 -	39.7567	T	8035 -	45.2626
T	6000 -	31.5640	T	6010 -	32.0698	T	6020 -	31.9746	T	6030 -	31.9512	T	6040 -	31.7987	T	6050 -	31.8209
T	6060 -	31.7810	T	6070 -	31.6507	T	6080 -	31.5693	T	6090 -	31.5341	T	6001 -	31.8687	T	6011 -	31.8203
T	6021 -	31.7498	T	6031 -	31.6402	T	6041 -	31.6069	T	6051 -	31.5802	T	6061 -	31.5384	T	6071 -	31.5119
T	6081 -	31.5009	T	6091 -	30.6352	T	500 -	33.4561	T	501 -	33.2699	T	502 -	33.9016	T	503 -	33.6330
T	9000 -	29.5163	T	9001 -	29.5178	T	9002 -	29.5161	T	9003 -	29.5147	T	40 -	52.8000	T	9999 -	29.4780
T	7000 -	-423.0000	T	7001 -	-297.0000	T	7002 -	55.0000	T	7003 -	80.0000	T	8888 -	52.8000	T	8889 -	78.0000
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T	13004 -	0.0000	T	13005 -	0.0000	T	13006 -	0.0000	T	13007 -	0.0000	T	13008 -	0.0000	T	13009 -	0.0000
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T	13016 -	0.0000	T	13017 -	0.0000	T	13018 -	0.0000	T	13019 -	0.0000	T	13020 -	0.0000	T	13021 -	0.0000
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T	16003 -	7338.0028	T	16004 -	6103.7436	T	16005 -	5060.7074	T	16006 -	6838.9469	T	16007 -	6264.4228	T	16008 -	5497.1094
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T	16015 -	6114.0968	T	16016 -	5520.8657	T	16017 -	0.0000	T	16018 -	0.0000	T	16019 -	0.0000	T	16020 -	0.0000
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T	16027 -	4537.5311	T	16028 -	5172.6717	T	16029 -	543.6231	T	16030 -	959.3134	T	16031 -	691.0498	T	16032 -	1025.5157
T	16033 -	2623.0881	T	16034 -	2404.1495	T	16035 -	2862.7963	T	16036 -	2611.0410	T	16037 -	0.0000	T	101 -	13.2650
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T	126 -	14.8693	T	127 -	19.6004	T	128 -	11.4676	T	129 -	22.0588	T	130 -	18.1966	T	131 -	21.8360
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T	710 -	-0.0193	T	711 -	-0.0241	T	712 -	-0.0305	T	713 -	0.0019	T	714 -	0.0097	T	715 -	0.0021
T	716 -	-0.0100	T	717 -	-0.0911	T	718 -	-0.0839	T	719 -	-0.0827	T	720 -	-0.0692	T	721 -	-0.0362

STS 36 PRE-LAUNCH SURFACE ENVIRONMENT MODEL (A=.8)

T	722 -	-0.0242	T	723 -	-0.0225	T	724 -	-0.0041	T	725 -	-0.0461	T	726 -	-0.0389	T	727 -	-0.0609
T	728 -	-0.0214	T	729 -	-0.1222	T	730 -	-0.0992	T	731 -	-0.1185	T	732 -	-0.0928	T	733 -	-0.0601
T	734 -	-0.0584	T	735 -	-0.0546	T	736 -	-0.0236	T	737 -	-0.2672	T	801 -	0.0000	T	802 -	0.0698
T	803 -	0.0396	T	804 -	0.0000	T	805 -	0.0000	T	806 -	0.0101	T	807 -	0.0000	T	808 -	0.0000
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T	815 -	0.0612	T	816 -	0.0000	T	817 -	0.0000	T	818 -	0.0000	T	819 -	0.0000	T	820 -	0.0000
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T	827 -	0.0000	T	828 -	0.0000	T	829 -	0.0000	T	830 -	0.0000	T	831 -	0.0000	T	832 -	0.0000
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T	914 -	178.7651	T	915 -	119.7997	T	916 -	0.0000	T	917 -	0.0000	T	918 -	0.0000	T	919 -	0.0000
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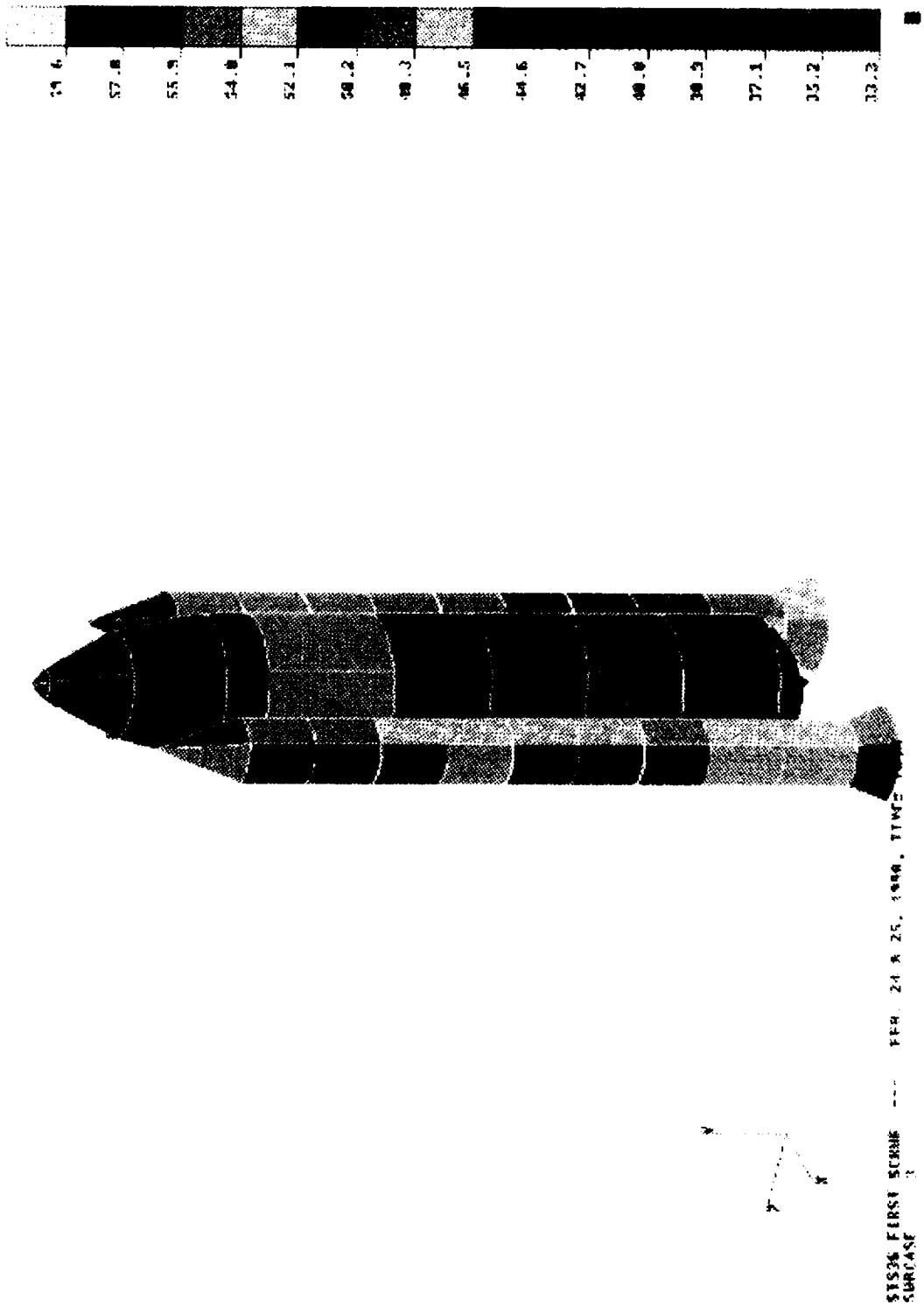

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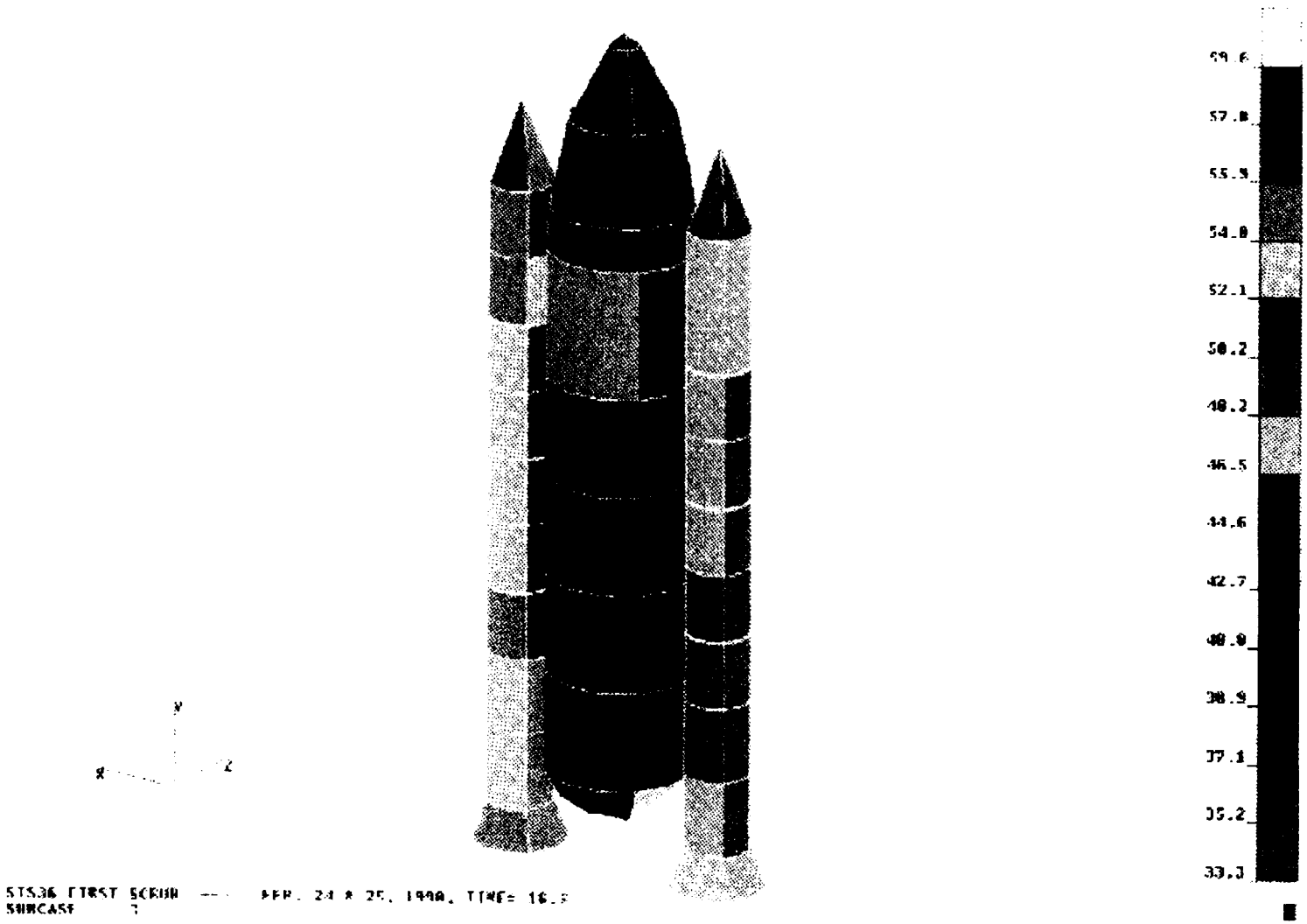

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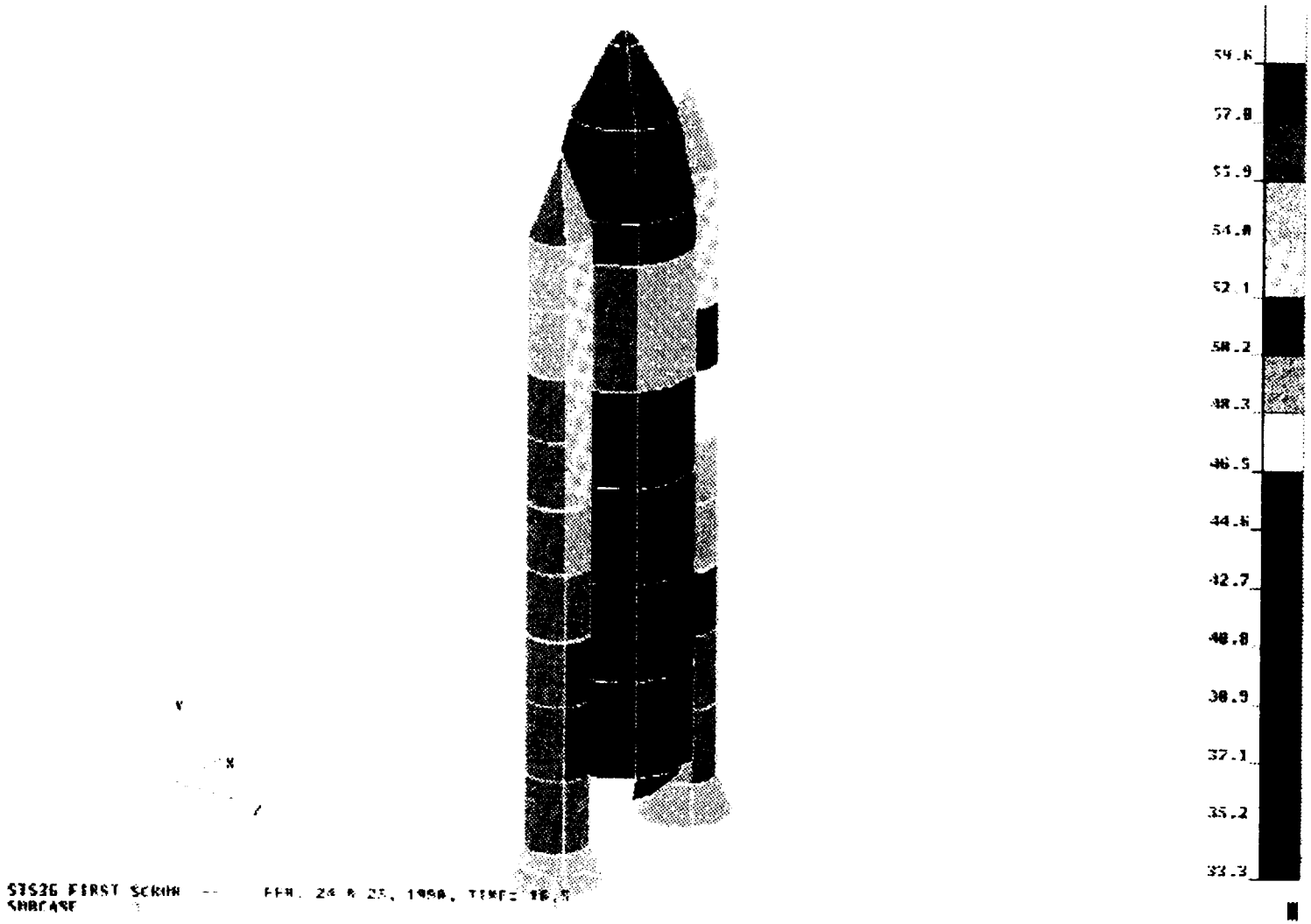

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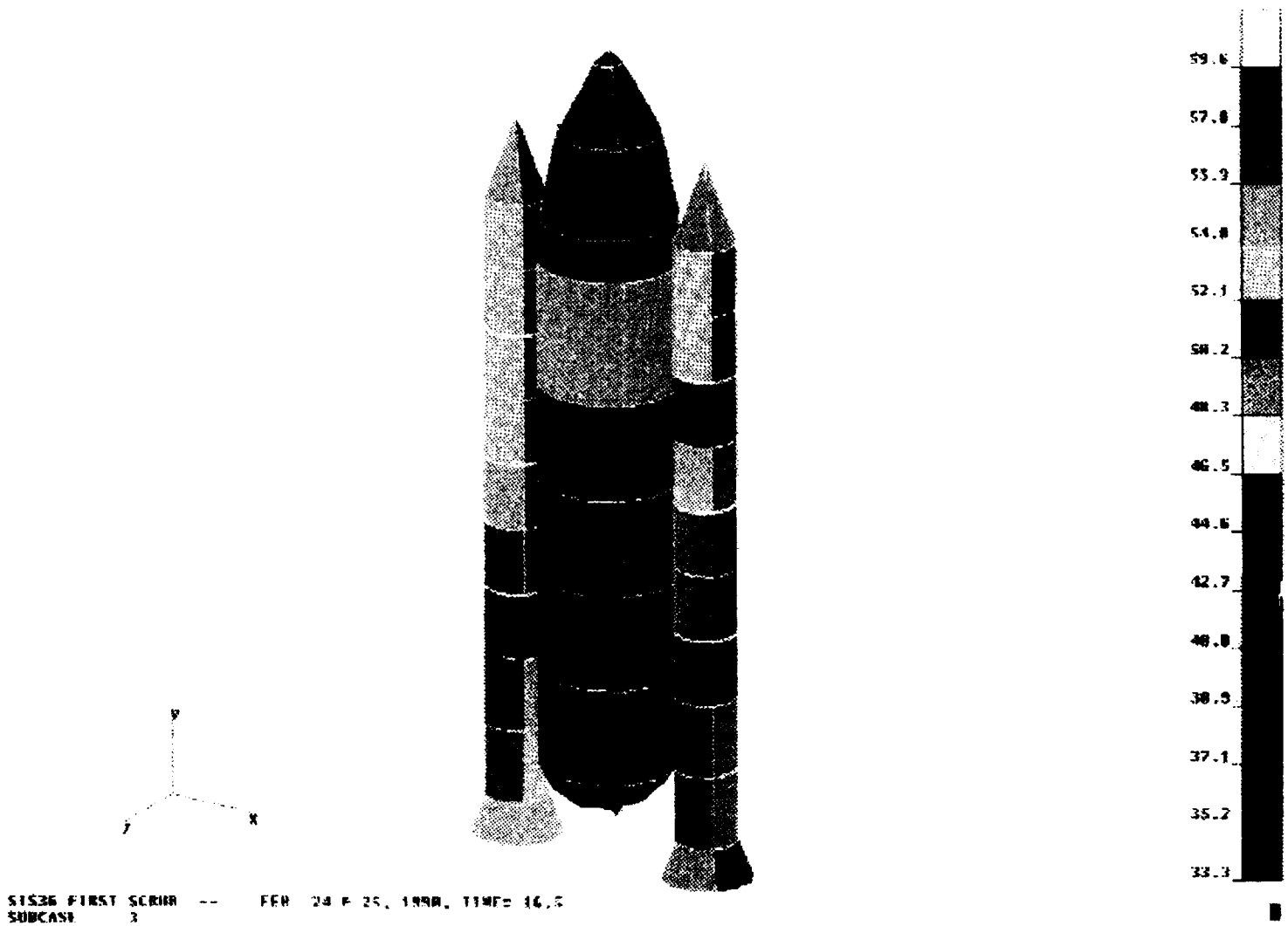

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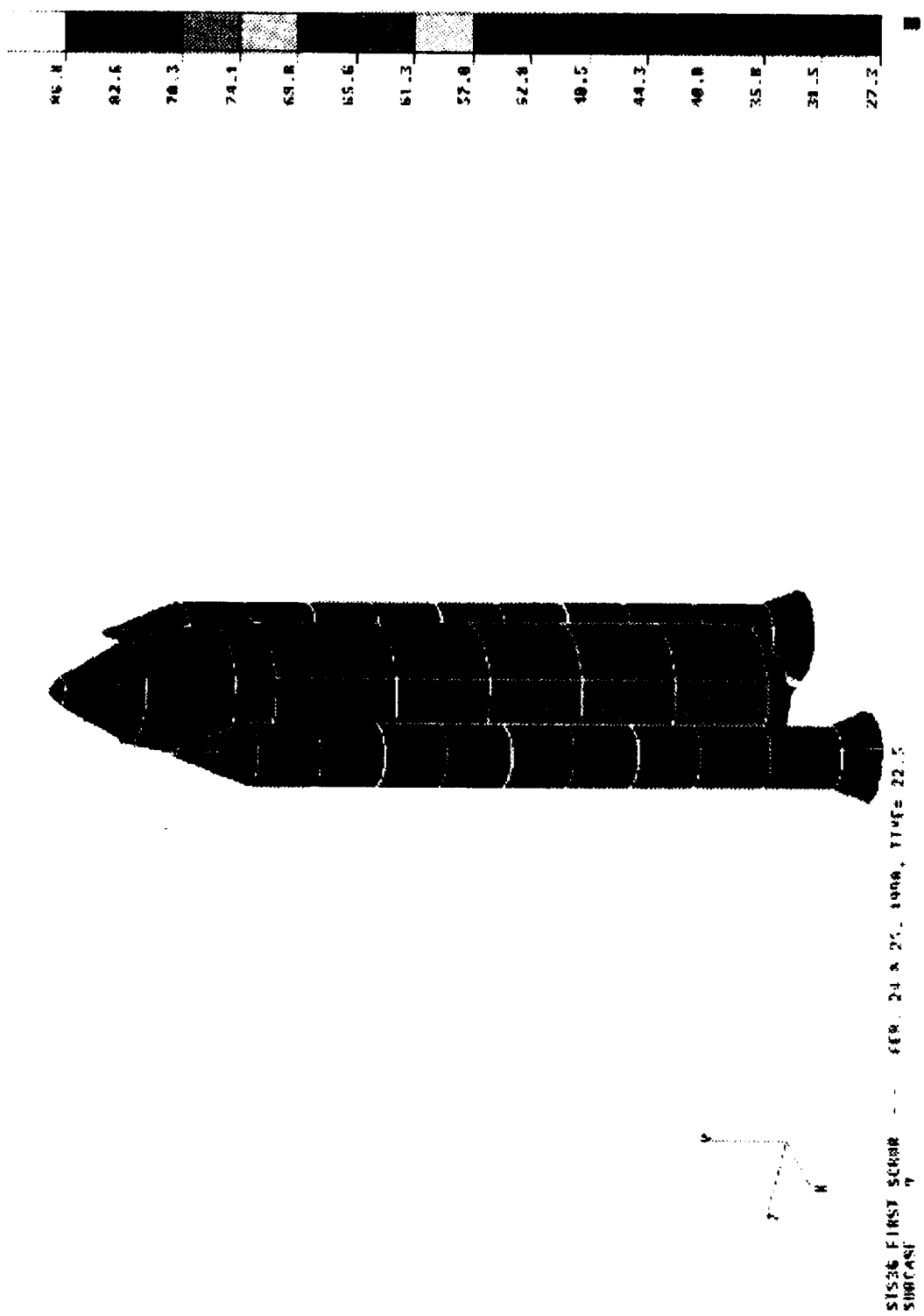

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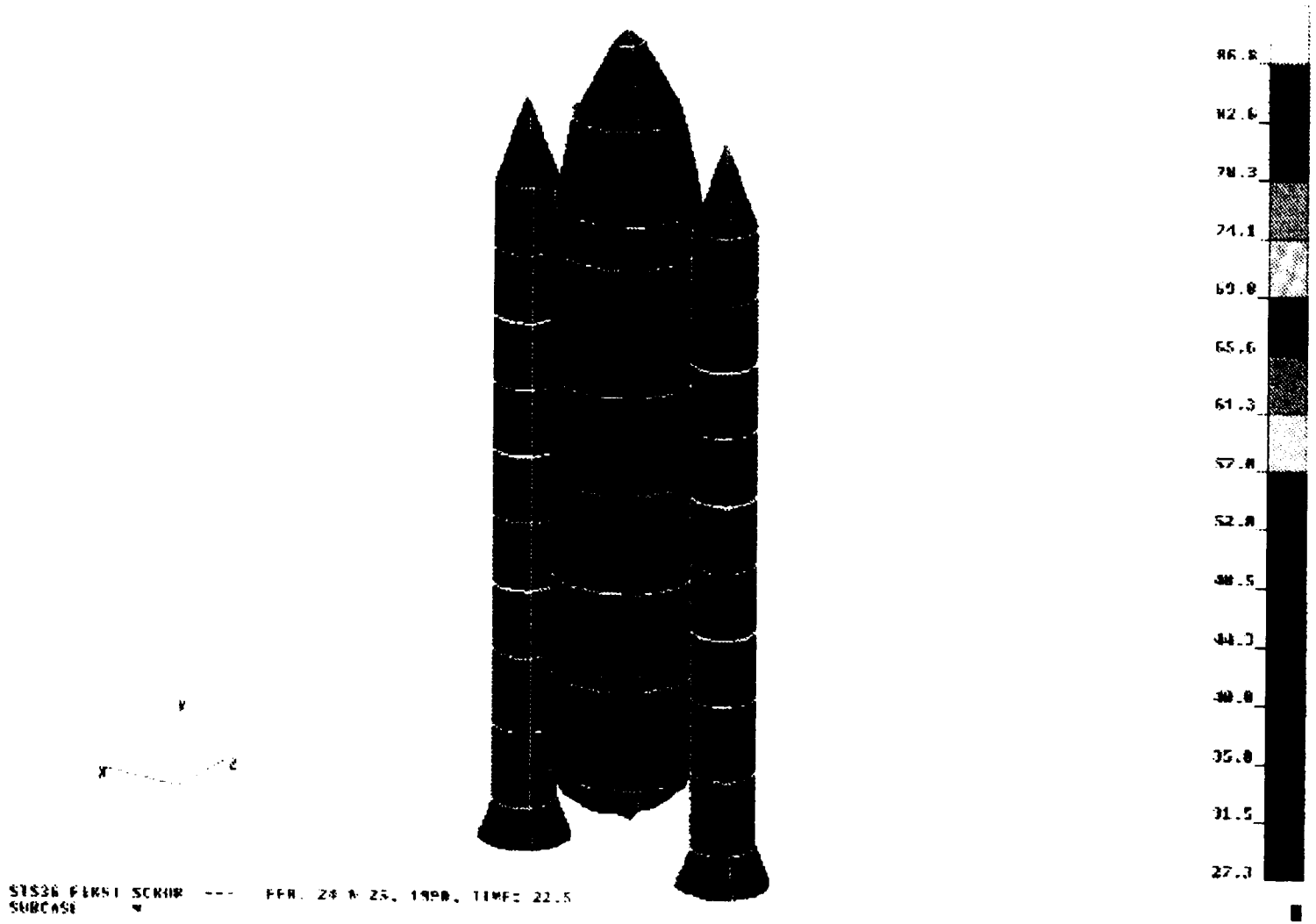

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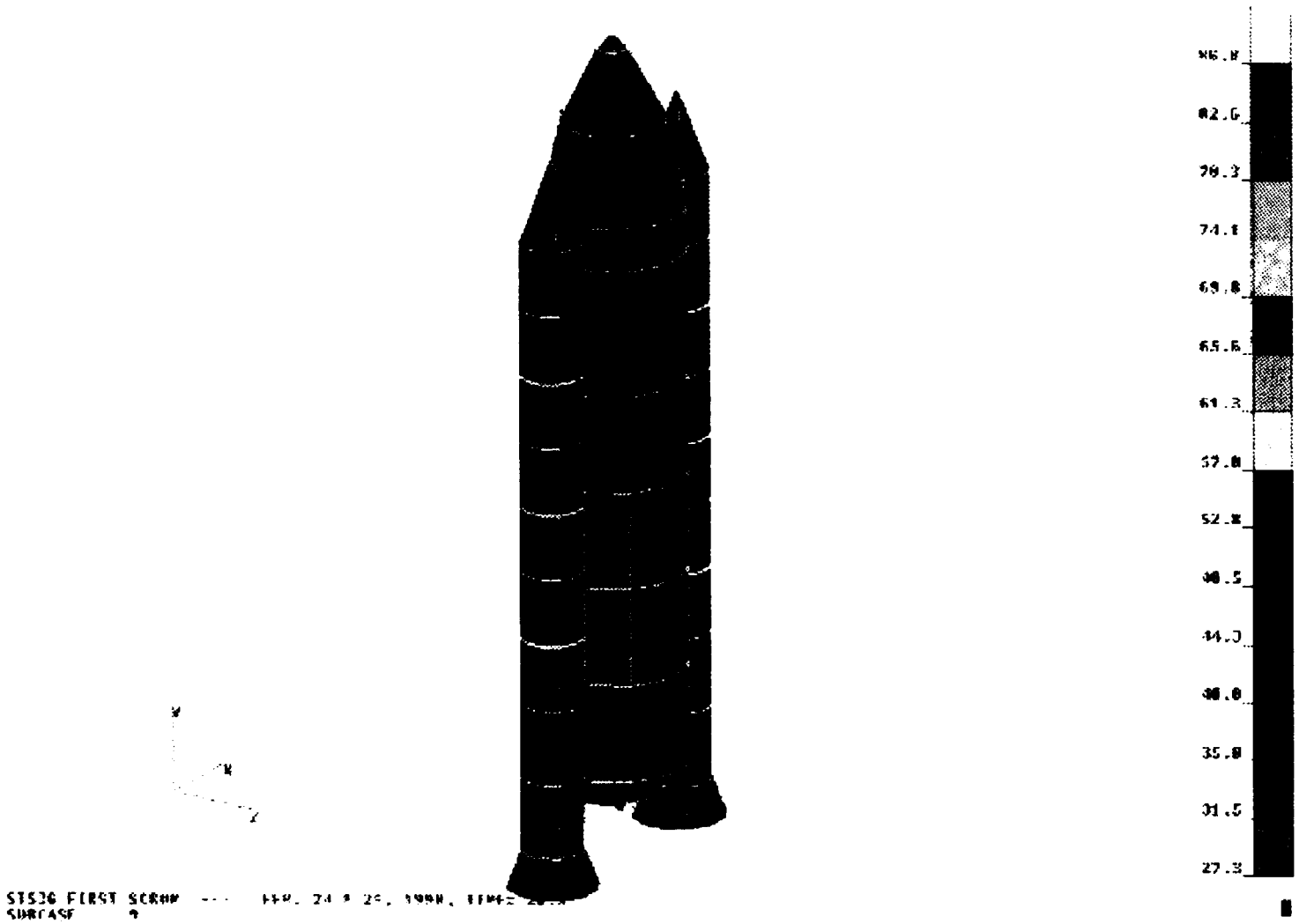

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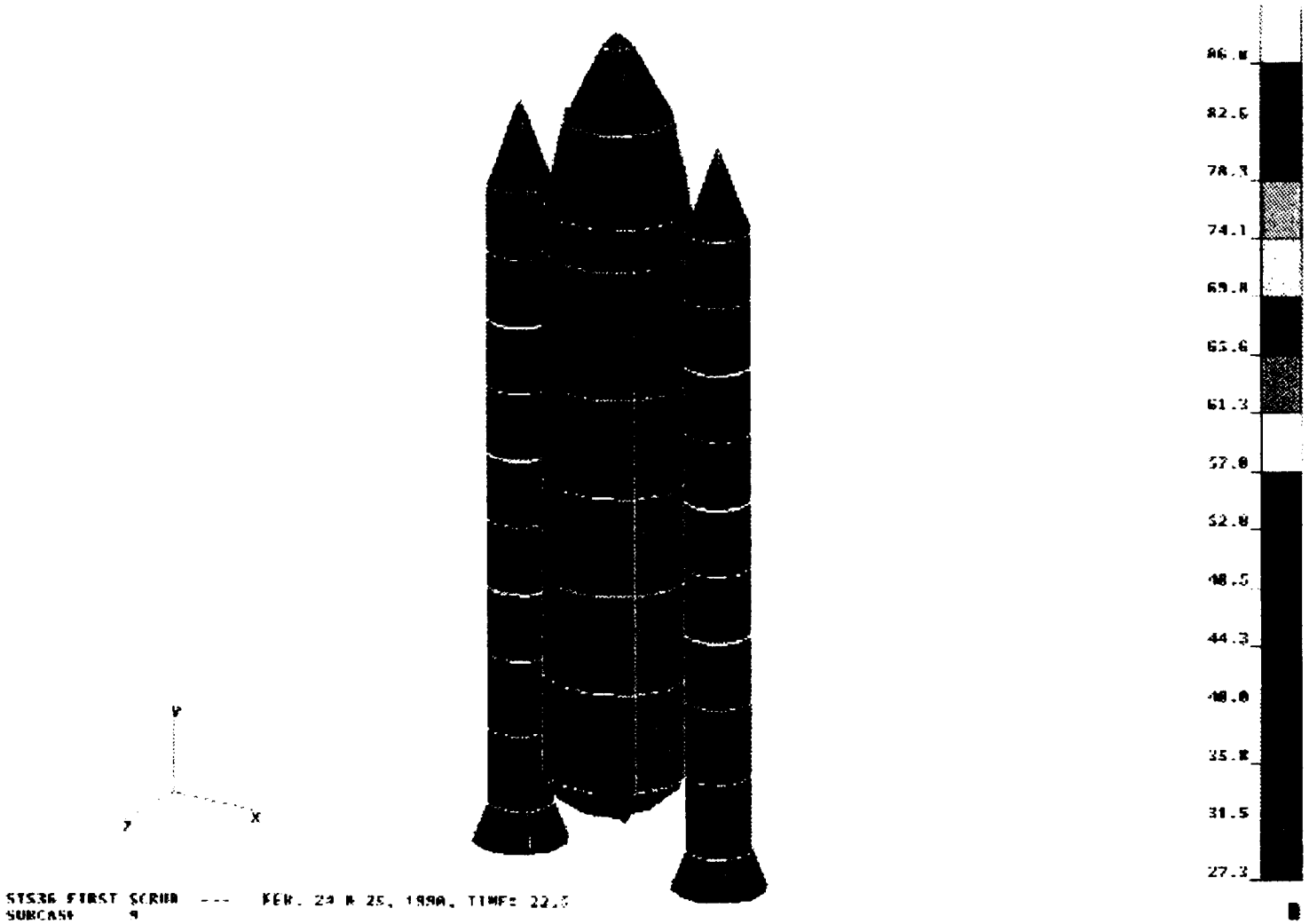

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Introduction to Chapter 4

Spacecraft Thermal Design Analysis

Thermal design of spacecraft and payloads represents a significant analytical challenge. Techniques for thermal design usually include a combination of techniques utilizing active and passive systems. Understanding of the orbital radiation environment is also required. In this chapter specialized analytical techniques are presented for spacecraft design problems which are encountered with significant frequency. Section one is an example illustrating sizing of a component heater for a typical application. Section two is a particularly innovative approach toward analytical determination of multilayer insulation (MLI) performance. Prediction of MLI properties is a task which occurs frequently for thermal vacuum testing related to correlation of analytical models. Finally, Section three illustrates utilization of TRASYS to predict orbital environments for simple geometries. The effects of orbital altitude and spacecraft orientation are presented. The results presented in this section can be used to estimate orbital heat fluxes for simple geometries. This can be used for rough order of magnitude hand calculations.

CHAPTER 4: SPACECRAFT THERMAL DESIGN ANALYSIS

SECTION 1: Resistive Heaters

ANALYSIS CODE: SINDA (Gaski Version)

I. Preface to the Problem

This chapter presents analytical methods applied to active thermal control systems (TCS). Most thermal designs use passive control (insulation blankets, optical properties, etc.) to the maximum extent possible due to restrictions on the available electrical power for active systems. However, in cases where strict thermal control is necessary, most designs require some amount of active control. It is usually the goal of the designer to control some portion of the hardware within a very restrictive temperature range. In many cases these designs are cold biased and retrofitted with resistive heaters. It is the purpose of this section to present methods used with the SINDA code to design such systems.

II. Identification of the Problem

This example was taken from the design of an active thermal control system for the Hubble Space Telescope Maintenance Mission. Orbital replacement units (ORU's); which included batteries, rate gyros, computers, etc.; were covered with multilayer insulation (MLI) and mounted on a shelf in the shuttle cargo bay. Ideally, ORUs should be maintained at approximately the same initial temperature at which they were maintained prior to launch. This was necessary due to the nature of the heat losses during the changeout timeline when the units were uninsulated and unheated. In addition, the active control system had to be located on the shelf to avoid an electrical disconnect by the astronaut during changeout.

III. Formulation of the Problem

The thermal model for this example is shown in Figure-1. It includes an ORU, the equipment shelf, and a support strut. The following information is known for the cold case design conditions:

(a) Effective sink temperature for radiation (orbital average)
(b) Boundary temperature at the strut for conduction (orbital average)
(c) Effective emissivity of the MLI is .02
(d) Contact conductance between the ORU and shelf is 100 btu/hr*ft^2*^{o}F
(e) Assume for this example that the heater is located as shown in Fig.-1a

With this information the goal of this analysis is to determine the heater size required to maintain the ORU above 60 ^{o}F.

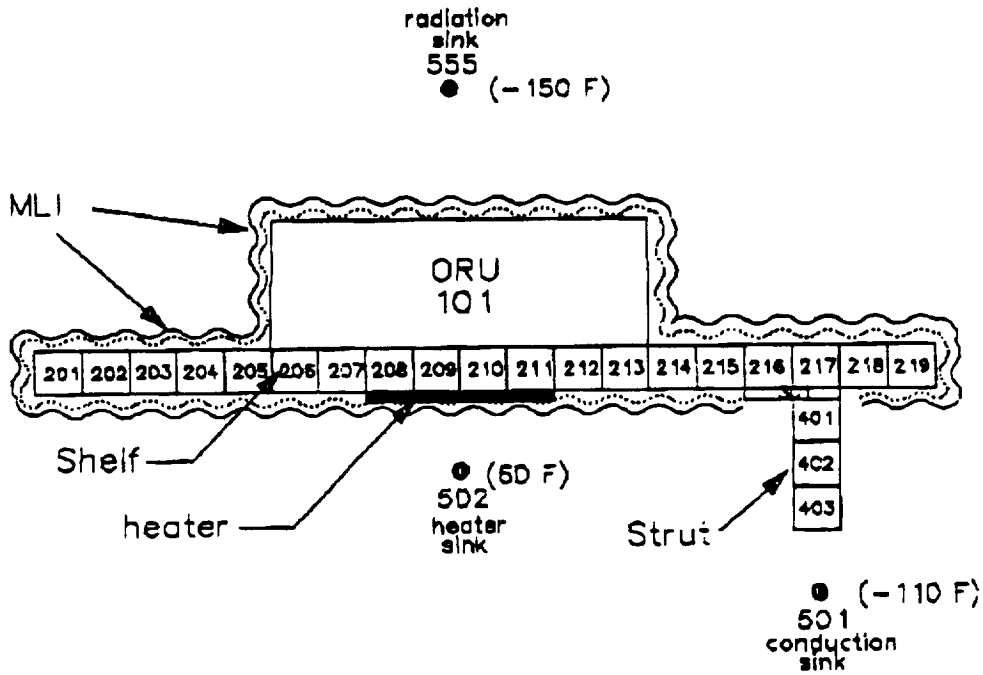


FIGURE-1a

IV. Analysis

A. Key Method

The key steps to calculate the required heater size are listed below.

(1) Connect all nodes located at the heater to a single boundary node. See Figure-1b.
(2) Set each conductor to a large value relative to other conductors at that node--the actual value is irrelevant.
(3) Set the boundary node to a temperature slightly above the desired temperature. In this case, something just above 60 °F.
(4) Run a steady state analysis for the cold case design conditions.
(5) If the hardware is at the desired temperature, calculate the heat flow from the heater nodes to the boundary node.

By connecting the heater nodes (208, 209, 210, & 211) to a boundary node (502) with a relatively high conductor, the nodes may be driven to the boundary

node temperature. If this results in an acceptable ORU temperature, then the minimum heater power is the heat loss from the boundary node to the heater nodes.

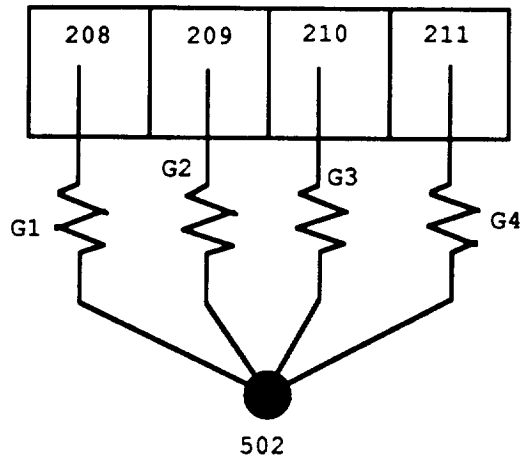


FIGURE-1b

$$q_1 = G_1*(T_{208} - T_{502}) \qquad q_2 = G_2*(T_{209} - T_{502})$$

$$q_3 = G_3*(T_{210} - T_{502}) \qquad q_4 = G_4*(T_{211} - T_{502})$$

$$q_T = q_1 + q_2 + q_3 + q_4$$

B. Thermal Model

A listing of the SINDA input deck is given on the following pages. Step No. 5 of the list is coded in the OUTPUT block before the data is written to the output file. Additional boundary nodes (900, 908-911) were defined for the sole purpose of storing heat rates once they are calculated. The heat rates will then be included in the output file.

An additional feature of the coding is located in the EXECUTION block. After the solution routine is completed, the program checks the ORU temperature to assure it is above 60 ^{o}F. If the temperature is below 60 ^{o}F, the solution routine is repeated with a higher boundary temperature at the heater nodes.

SINDA INPUT LISTING

```
      BCD 3THERMAL LPCS
      BCD 9ORU HEATER DESIGN, example for workbook, rev 2-25-91
C
C     FILE: c:\gaski\models\oru.sin
```

```
C
C       This model is an example case of the methods used to determine heater
C       sizes for active thermal control systems.
C
        END
        BCD 3NODE DATA
C
            101, 70., 5.8            $ ORU
        GEN 201, 19, 1, 70., 0.183   $ SHELF
            301, 70., 0.124          $ STRUT FITTING
            401, 70., 0.528          $ STRUT
            402, 70., 0.528          $ STRUT
            403, 70., 0.528          $ STRUT
C
        GEN 600, 20, 1, 70., -1.     $ MLI OUTER SURFACE
C
            -501,-110., 0.          $ STRUT BOUNDARY
            -502,  61., 0.          $ HEATER ZONE BOUNDARY
            -555,-150., 0.          $ MLI BOUNDARY
C
            -900, 0., 0.       $ Total heater power, watts
            -908, 0., 0.       $ Heater power to N208
            -909, 0., 0.       $
            -910, 0., 0.       $
            -911, 0., 0.       $
C
        END
        BCD 3CONDUCTOR DATA
C
        GEN 1001, 8, 1, 206, 1, 101, 0, 10.42   $ ORU-SHELF
        GEN 2001,18, 1, 201, 1, 202, 1,  7.07   $ SHELF-SHELF
            3001, 216, 301, 1.71                $ SHELF-STRUT
            3002, 217, 301, 1.71                $ SHELF-STRUT
            4001, 301, 401, .036                $ STRUT-STRUT
            4002, 401, 402, .073                $ STRUT-STRUT
            4003, 402, 403, .036                $ STRUT-STRUT
            5001, 403, 501, .023                $ STRUT-BOUNDARY
C
        GEN 5501, 4,1, 208,1,  502,0, 70.  $ SHELF-BOUNDARY
C
C RADIATION
C
            -1501, 101, 600, 1.8557E-10              $ ORU-MLI
C
            -2501, 201, 601, 1.42668E-11             $ SHELF-MLI
        GEN -2502, 4, 1, 202, 1, 602, 1, 9.5113E-12 $ SHELF-MLI
        GEN -2506, 8, 1, 206, 1, 606, 1, 4.7556E-12 $ SHELF-MLI
        GEN -2514, 5, 1, 214, 1, 614, 1, 9.5113E-12 $ SHELF-MLI
            -2519, 219, 619, 1.42668E-11             $ SHELF-MLI
C
            -6000, 600, 555, 8.165E-09               $ EXTERIOR MLI-BOUNDARY
        GEN -6001, 5, 1, 601, 1, 555, 0, 4.1850E-11 $ MLI-BOUNDARY
        GEN -6006, 8, 1, 606, 1, 555, 0, 8.3699E-11 $ MLI-BOUNDARY
        GEN -6014, 5, 1, 614, 1, 555, 0, 4.1850E-11 $ MLI-BOUNDARY
C
        END
        BCD 3CONSTANTS DATA
            NDIM, 1000
C
C
        END
```

```
      BCD 3ARRAY DATA
C
C
      END
      BCD 3EXECUTION
C
M     TIMEO = 1.
M     DTIMEL= 0.1
M     DTIMEH= 0.1
C
M     NLOOP = 1000
M     DRLXCA= 0.1
M     ARLXCA= 0.1
M     BALENG= 0.3
C
C  If the ORU temp. is less than 60 F increase the boundary and
C  repeat the solution routine.
C
F  10  CONTINUE
M            TIMEO= TIMEO + 1.
F         CALL STDSTL
M            T502= T502+.5
M     IF(T101.LE.60.) GO TO 10
C
      END
      BCD 3VARIABLES 1
      END
      BCD 3VARIABLES 2
C
C
      END
      BCD 3OUTPUT CALLS
C
C  Calculate the heat loss from each heater node.
C
M     T908= G5501*(T502 - T208)
M     T909= G5502*(T502 - T209)
M     T910= G5503*(T502 - T210)
M     T911= G5504*(T502 - T211)
M     T900= T908 + T909 + T910 + T911
M     T900= T900/3.4121                ! Convert to watts
C
M     CALL TPRINT
C
      END
      BCD 3END OF DATA
```

IV. Results

Final results of the SINDA steady-state solution routine are given on the following page. The required heater size is given as 5.8 watts (T900). This value is calculated by adding the energy transfer across the four conductors between the heater nodes (T208, T209, T210, & T211) and the boundary node (T502). This value is then coverted from Btu/hr to watts. It represents the steady-state energy load required to maintain the ORU at 60 ^{o}F. In other words, a heater operating at a 5.8 watt power level would have a duty cycle of 100%.

Once the minimum heater size calculation is completed, additional trade studies may be required to determine the optimum heater size, heater location, and thermostat setpoints. It is not the purpose of this section to address all of these options. However, this case was analyzed further to present additional size considerations. A rule-of-thumb often applied to resistive heaters with thermostatic control, is to size the heater 1.5 times larger than the design cold case at minimum voltage. For this case, that would be 1.5 x 5.8 = 8.7 watts. Unnecessary cost might be involved with requesting a 8.7 watt heater. Assuming the vendor has a 10 watt heater readily available, a transient analysis was completed using a 10 watt heater with thermostat setpoints at 61 to 63 ^{o}F.

Figure-2 presents the temperature of the ORU and the temperature of node no. 208. Node 208 is the assumed location of a single thermostat controlling the 10 watt heater. Figure-2 shows that the ORU remained above 60 ^{o}F as desired. The figure also shows a heater duty cycle of about 58%. Such duty cycle calculations are often required to assess life expectancy of the active control system components. For additional design considerations the reader is referred to Volume 3 of this workbook series.

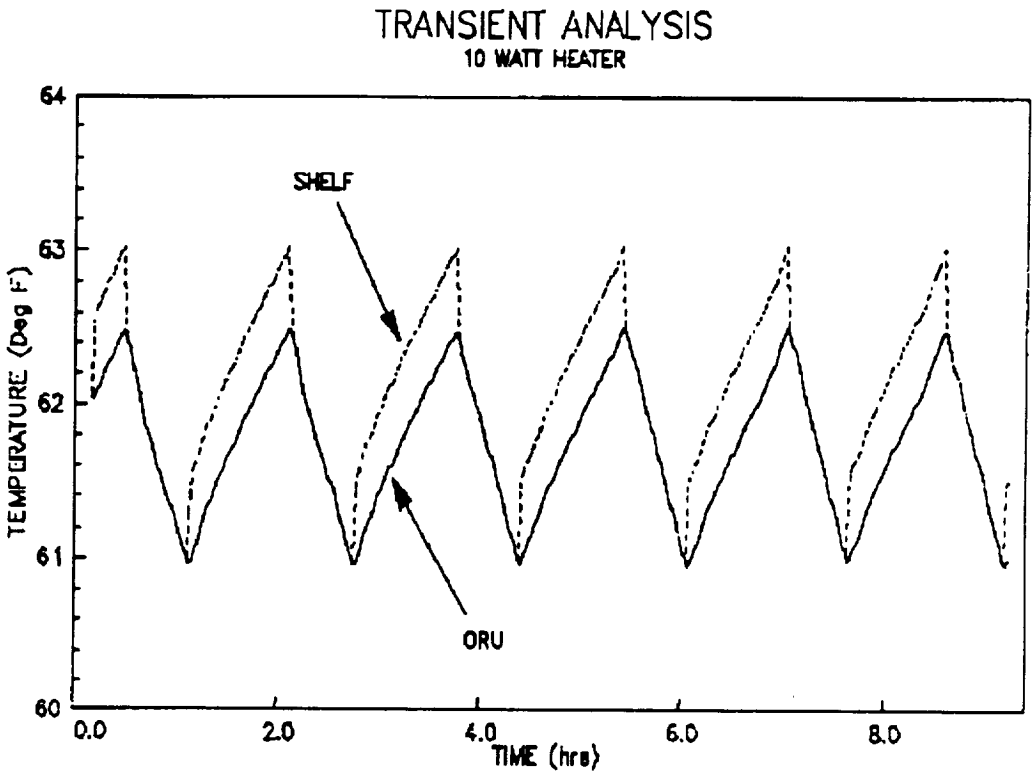

TRANSIENT ANALYSIS
10 WATT HEATER
SHELF
ORU
TEMPERATURE (Deg F)
64
63
62
61
60
0.0
2.0
4.0
6.0
8.0
TIME (hrs)

Figure 2

STEADY-STATE ANALYSIS

T	101 =	60.0837	T	201 =	58.8105	T	202 =	58.9033	T	203 =	59.0620	T	204 =	59.2856	T	205 =	59.5775
T	206 =	59.9387	T	207 =	60.1267	T	208 =	60.4187	T	209 =	60.4406	T	210 =	60.4405	T	211 =	60.4177
T	212 =	60.1116	T	213 =	59.8839	T	214 =	59.3860	T	215 =	58.9415	T	216 =	58.5631	T	217 =	58.3710
T	218 =	58.3154	T	219 =	58.3154	T	301 =	58.0316	T	401 =	16.6483	T	402 =	-3.7705	T	403 =	-45.1821
T	600 =	-138.7101	T	601 =	-61.1518	T	602 =	-79.5464	T	603 =	-79.4719	T	604 =	-79.3668	T	605 =	-79.2295
T	606 =	-124.5133	T	607 =	-124.4757	T	608 =	-124.4171	T	609 =	-124.4128	T	610 =	-124.4128	T	611 =	-124.4174
T	612 =	-124.4787	T	613 =	-124.5243	T	614 =	-79.3195	T	615 =	-79.5285	T	616 =	-79.7062	T	617 =	-79.7964
T	618 =	-79.8225	T	619 =	58.3154	T	501 =	-110.0000	T	502 =	60.5000	T	555 =	-150.0000	T	900 =	5.7975
T	908 =	5.6909	T	909 =	4.1614	T	910 =	4.1656	T	911 =	5.7635	T					

CHAPTER 4: SPACECRAFT THERMAL DESIGN ANALYSIS

SECTION 2: Thermal Math Model Manipulation

ANALYSIS CODE: SINDA (Gaski Version)

I. Preface

Typically, thermal models are constructed using various assumptions. Hopefully these assumptions lead to conservative analyses that envelope actual responses. They do not, however, necessarily lend themselves to the precise thermal predictions characteristic of correlated thermal models. Correlating a thermal model to agree with test results can be an arduous task. Considerable time and effort are often expended in performing repetitive analyses in an effort to alter the model until its results match that of the test. The fact that ideal steady state is seldom attained during testing mandates model comparisons be made using transient analyses, another demand for more time.

Multilayer insulation (MLI) is a classic example where its performance is modeled using assumed values. The purpose of this section is to demonstrate a technique in which the analyst can make use of SINDA's "BACKUP" control constant and iteratively change the assumed values until the model's results agree with those from testing.

II. Identification of the Problem

MLI is a common item on countless spacecraft. Despite its frequent use, its actual performance, as quantified here by its effective emittance, e*, is sensitive to numerous factors and difficult to quantify. Penetrations, folds, blanket size, etc. can all lead to less than ideal blanket performance. These factors combined with MLI seldom reaching its theoretical performance, even in the simplest geometries, makes blanket modeling on complex structures a matter of best guess. Further, since a blanket's peak performance is not reached until it has had sufficient time to vent, modeling the transient response in a testing environment becomes even more difficult. Given sufficient environmental test data, the question then becomes how do you accurately assess the actual blanket performance?

III. Formulation of the Problem

The example presented is a trivial one, but is a representative case where test results do not agree with the analytical predictions of the model in its present form. The model consists of a flat plate, 1 ft^2 in radiating area, covered in MLI, with a resistive heater to maintain the plate's temperature. The environment is provided by a thermal vacuum chamber with a liquid nitrogen (LN2) shroud. A schematic is shown in figure 1. The goal of this analysis is for the model to adjust its network during the analysis until its predictions correlate well with the test results.

IV. Analysis

A. Key Method

The key steps in applying this technique to either a trivial or a complex model, are listed below:

(1) First select the network parameters which are in question and are good candidates to manipulate. (Ideally, this process was completed prior to the test plan developement and there are sufficient test measurements available to adequately perform this task.)

(2) Next, an algorithm to modify the selected parameters is developed. This algorithm will be some mathematical function of what the model predicted, what the test results were, and the present value of one or more network parameters including the one in question. Recognize that in complex models there may be significant parameter interrelationships, e.g. one parameter may influence several temperatures. The algorithm used in this model is one which has worked well for MLI predictions, different type paramenters such as linear conductors will require their own special treatment. Whatever the algorithm, sufficient damping should be included to prevent over exaggerated changes to the network and the situation where SINDA's solution oscillates about the test data but never comes within the accuracy criteria. To avoid this predicament it's a good idea to add some logic to check for the number of times the solution has been consecutively scrubbed. If this does occur, the easiest way to escape this is to "punt", set the model's temperature to the test data and hope for better luck in the next iterative solution.

B. Thermal Model

A partial listing of the SINDA input model is given on the following pages. Numerous comments have been added and should be perused to better understand the added logic. It is important to remember here how SINDA calls the VARIABLES1 and VARIABLES2 subroutines. In general, VARIABLES1 is called each iteration until all of SINDA's accuracy parameters are met or NLOOP is exceeded. After a solution is found, VARIABLES2 is called. It is in VARIABLES2 where the user should make the test data comparisons and include the logic for setting the BACKUP constant. When the BACKUP constant is set, the last solution is scrubbed, (the initial conditions/previous solution are still available) the program goes back and the iterative solution starts again. In this example, when BACKUP is set, the effective emmitance of an MLI blanket is modified, and likewise the results from the next solution using the newly defined network.

SINDA INPUT DECK

```
    BCD 3THERMAL LPCS
    BCD 9SAMPLE TO DETERMINE e* FROM TEST DATA
    END
    BCD 3NODE DATA
C
      1,70.,.0023            $ 1 ft**2 Al plate
      2,70.,-1.0             $ Outside MLI surface
      -55555, -300., 1.      $ Shroud node, LN2
      -10,0.0,1.0            $ Storage for e*
C  ***********************************************************************
C FOR MORE COMPLEX MODELS YOU'LL PROBABLY NEED AT LEAST ONE BOUNDARY
C NODE FOR EACH TEST MEASUREMENT FOR TWO REASONS. FIRST,
C YOU CAN USE THESE TO SET THE MODEL TO THE INITIAL CONDITIONS (SEE
C THE EXECUTION BLOCK) AND SECOND THEY CAN BE USED TO INSERT THE TEST
C DATA INTO THE OUTPUT OR PLOT FILES.
C  ***********************************************************************
      -20,0.0,1.0            $ Boundary for Test Data
C                      $ Corresponding to Node 1
    END
    BCD 3CONDUCTOR DATA
C
C RADK'S
      -1,1,2,1.714E-9*.02       $Initial guess of .02
      -2,2,55555,1.714E-9*.88   $MLI Surface to Shroud
C
C  ***********************************************************************
C AS MENTIONED ABOVE, TO INITIALIZE THE MODEL, COUPLE THE MODEL'S
C CORRESPONDING NODES TO THE APPROPRIATE BOUNDARY NODES WITH THE TEST
C DATA. NOTE: THIS CAN BE DONE WITH A SINGLE CONDUCTOR WITH AS MANY
C NODE PAIRS AS YOU DESIRE. (THIS MAKES UNCOUPLING A LOT EASIER DOWN
C IN THE EXECUTION BLOCK)
C  ***********************************************************************
      3,1,20,10.0            $Test Data Coupling for Initializing

    END
    BCD 3CONSTANTS DATA
      NDIM=1000
      DTIMEI= 0.025
      TIMEO = 0.0
      OUTPUT= 0.025
      TIMEND= 0.0
C
      NLOOP = 2000
      DRLXCA= 0.005
      ARLXCA= 0.005
      RTEST= 0.0   $ Flag used in VARIABLES2 and SINROUTINE
      ITEST= 0     $ Flag used in VARIABLES2
C
C
    END
    BCD 3ARRAY DATA
      100$ TEST TEMPERATURE DATA FOR MEASUREMENT #1
          0.000E+00,0.700E+02,0.500E-01,0.284E+02,0.100E+00,-.153E+01
          0.150E+00,-.150E+02,0.200E+00,-.209E+02,0.250E+00,-.227E+02
      (Remainder of Array Data Removed for Brevity)
      END$
    END
    BCD 3EXECUTION
C
C
C  ***********************************************************************
```

```
C ORDINARILY WHEN WORKING WITH REAL TEST DATA FOR MORE COMPLEX MODELS
C YOU SHOULD FIRST ATTEMPT TO INTIALIZE THE MODEL TO THE INITIAL
C CONDITIONS OF THE TEST ARTICLE. THIS CAN BE ACCOMPLISHED IN A
C NUMBER OF WAYS BUT ONE RELATIVELY EASY WAY IS BY PLACING EACH
C TEST MEASUREMENT INTO A BOUNDARY NODE LOCATION WHICH IS COUPLED TO
C THE CORRESPONDING MODEL NODE WITH AN ARBITRARY LARGE CONDUCTOR. A
C STEADY STATE SOLUTION IS THEN PERFORMED TO INITIALIZE THE MODEL AS
C BEST AS POSSIBLE TO THE CONDITIONS AT THE START OF THE TEST. THEN
C AFTER THE MODEL IS INITIALIZED SET THE ARBITRARY CONDUCTOR TO ZERO
C TO UNCOUPLE THE MODEL FROM THE TEST DATA. YOU MAY WANT TO USE A
C VARIABLE HERE AS FLAG TO CHECK IN VARIABLES2 SO THAT YOU DON'T
C ATTEMPT ANY NETWORK MANIPULATION AFTER THE STEADY STATE SOLUTION.
C  ******************************************************************
C
M    CALL D1DEG1(TIMEO,A100,T20)$ FOR MEAS # 1
F    CALL SNDSNR
F    TIMEND=10.0
C ZERO OUT THE CONDUCTOR TO THE TEST DATA
M    G(3)=0.0
C CLEAR THE FLAG FOR VARIABLES2 CHECKS
F    ITEST=1
C
F    CALL FWDBKL
C
     END
     BCD 3VARIABLES 1
M    Q1=1.35
     END
     BCD 3VARIABLES 2
C    ***************************************************************
C  CHECK IF THIS VARIABLES2 CALL IS FOR THE INITIAL STEADY STATE
C  SOLUTION SO NO NETWORK ADJUSTING WILL BE DONE FOR THE INITIAL
C  CONDITIONS.
C    ***************************************************************
F    IF(ITEST.EQ.0) GOTO 100
C
C  READ THE TEST DATA
       D1DEG1(TIMEN,A100,T20)$ FOR MEAS # 1
C  AT THIS POINT, IF YOUR TEST DATA HAS NOT HAD MUCH REDUCTION
C  YOU MAY WANT TO DO SOME VALIDITY CHECKS TO DETECT BAD
C  MEASUREMENTS, ZERO COUNT READINGS ETC.
C
C  CALL THE SINROUTINE WITH THE ADJUSTMENT ALGORITHM
C  THE .25 IS AN ACCURACY PARAMETER, HOW WELL YOU WANT
C  TO MATCH THE TEST DATA. YOU COULD OF COURSE USE A USER
C  SPECIFIED CONSTANT BUT SOME CASES DICTATE THAT DIFFERENT
C  ACCURACY CRITERIA BE USED FOR DIFFERENT PARAMETERS
C
M    CALL GADJ(T1,T20,G1,.25)
C
C  SAVE THE NEW e*, FOR FUTURE REFERENCE
M      T10=G1/1.714E-9
C
F 100  CONTINUE
C  ******************************************************************
C  CHECK AND SEE IF THE RTEST VARIABLE WAS EVER TRIPPED.
C  IN A SIMPLE MODEL LIKE THIS YOU CAN CAN SET THE BACKUP
C  CONSTANT IN THE SINROUTINE BUT IF YOU ADJUSTING SEVERAL
C  PARAMETERS IT'S BETTER THIS WAY. THIS WAY IS MORE AMENABLE
C  TO KEEPING TRACK OF HOW MANY TIMES THE SOLUTION GOT SCRUBBED
C  RATHER THAN HOW MANY PARAMETERS DICTATED THAT THE SOLUTION
C  BE SCRUBBED.
C  ******************************************************************
F    IF(RTEST.EQ.1.0) THEN
```

```
F       BACKUP=1.0
F     ENDIF
F     RTEST=0.0
    END
    BCD 3OUTPUT CALLS
C
M     CALL D1DEG1(TIMEN,A100,T20)$ FOR MEAS # 1
F     CALL TPRINT
F     CALL TDUMP
C
C  PRINT SOME HEADINGS
F     IF(ITEST.EQ.1) THEN
F       WRITE(6,50)
F 50      FORMAT(60('='),/,5X,'TIMEN',9X,'PREDICT',9X,'TEST',12X,
F     *   'e*',/,60('='))
F       NLINE=NLINE+2
F     ENDIF
    END
    BCD 3SINROUTINE GADJ(TMOD,TESTT,COND,ACCPAR)
C   CALCULATE DIFFERENCE BETWEEN TEST AND PREDICTS
F   DELTA=TMOD-TESTT
C   BACKOUT THE PRESENT e* IN THE CONDUCTOR
F     ESTAR= COND/1.714E-9
C
F     IF(ABS(DELTA).GT.ACCPAR) THEN
C       WRITE TO THE OUT FILE A FEW VARIABLES SO YOU
C       CAN KEEP TRACK OF WHAT'S HAPPENING, THIS IS VERY
C       ESSENTIAL FOR THE FIRST TIME YOU ATTEMPT THIS!
F         WRITE(6,*) TIMEN,TMOD,TESTT,ESTAR
F         NLINE=NLINE+1
C       CALCULATE A NEW e*
F         ESTAR=ESTAR*(1.+(SIGN(0.05,DELTA)))**(ABS(DELTA)*.5)
C       REDEFINE THE CONDUCTOR
F         COND=ESTAR*1.714E-9
C SET THE FLAG THAT IS USED TO SET THE BACKUP CONSTANT UP IN VARIABLES2
F         RTEST=1.0
F     ENDIF
    END
    BCD 3END OF DATA
```

IV. Results

The results are given on the following page. Figure 2A is a portion taken from the output file with the added "writes" from the algorithm showing how the results for a particular e* compared with the results from test. Note that the e* for a given TIMEN was either the initial guess or the one calculated from the data listed in the previous write. If there are problems in matching the data, this information in the out file can be used to verify that the algorithm is functioning correctly. An indication of a bad algorithm is that execution never stops; BACKUP is continually set and TIMEND is never reached.

Figure 2B is a plot of what the model determined to be the e* during the test. These results are somewhat typical of blanket responses during the initial transient when outgassing degrades performance with the final performance even better than initially assumed.

SINDA OUTPUT
Figure 2A

```
*****************
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(     0)= 0.00000E+00, ATMPCC(     0)= 0.00000E+00,
DTMPCC(     0)= 0.00000E+00
  LOOPCT=   0                                  , ARLXCC(     0)= 0.00000E+00, DRLXCC(     0)= 0.00000E+00

T    1 =  69.8730 T    2 = -238.8354 T  55555 = -300.0000 T    10 =   0.0000 T    20 =  70.0000 T
```

TIMEN	PREDICT	TEST	e*
2.5000000E-02	57.37366	49.20000	2.0000000E-02
2.5000000E-02	52.09204	49.20000	2.4413325E-02
2.5000000E-02	50.01437	49.20000	2.6197935E-02

```
*****************
TIME= 2.50000E-02, DTIMEU= 2.50000E-02, CSGMIN(     1)= 2.02800E-01, ATMPCC(     2)= 5.09358E+00,
DTMPCC(     1)=-2.04646E+01
  LOOPCT=   3                                  , ARLXCC(     2)= 6.10352E-05, DRLXCC(     1)= 1.83105E-04

T    1 =  49.4084 T    2 = -233.7419 T  55555 = -300.0000 T    10 =   0.0267 T    20 =  49.2000 T
```

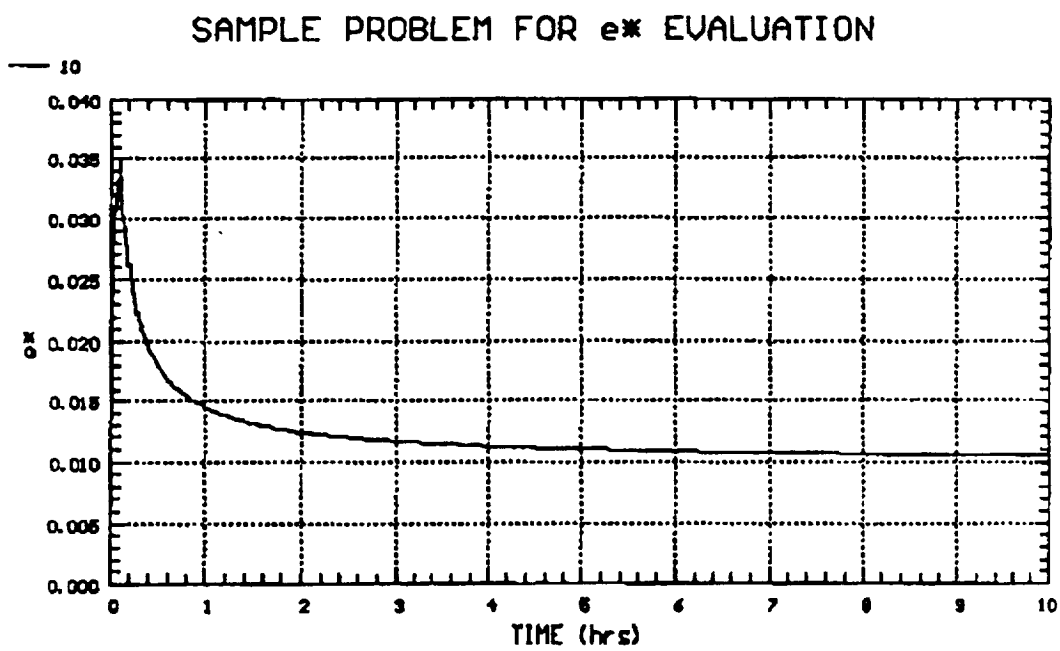


FIGURE 2B. Blanket Effective Emittance (e*)
as Determined by the Model

CHAPTER 4: SPACECRAFT THERMAL DESIGN ANALYSIS

SECTION 3: Simplified Spacecraft in Various Earth Orbits.

ANALYSIS CODE: TRASYS

I. Preface

The radiation incident on an orbiting spacecraft is an important design consideration and an important part of the thermal analysis performed on the spacecraft. This section is designed to accomplish two goals: First, to give the designer and analyst a reference of approximate values for incident radiation encountered from all sides of the spacecraft in various orbits. Second, to give examples of TRASYS input code used to define those orbits. Graphs of the results are presented to aid in visualizing the relationship between orbit parameters and incident radiation. Explanations of the input code are also given to aid the beginning TRASYS user in putting together the code necessary to define an orbit.

II. Statement of the Problem

Incident radiation is to be determined for all surfaces of a spacecraft in various orbits. The final data should provide approximate values applicable to a majority of useful Earth orbits. These orbits will include altitudes from 150 nautical miles to geosychronous orbit (approx. 23,000 nmi). They will also include the full range of orbital inclinations, for both Sun (inertial) and Earth oriented spacecraft.

III. Formulation of the Problem

A. The Spacecraft

In order for the data to be most applicable to a wide variety of spacecraft, a simple six-sided cube was chosen to model a spacecraft. The dimensions of the cube are 1ftx1ftx1ft, and surface properties of α=1 (absorptivity) and ε=1 (emissivity), to allow simple conversion of the results to any spacecraft. The labeling of the sides and their orientations are shown in Figure 1.

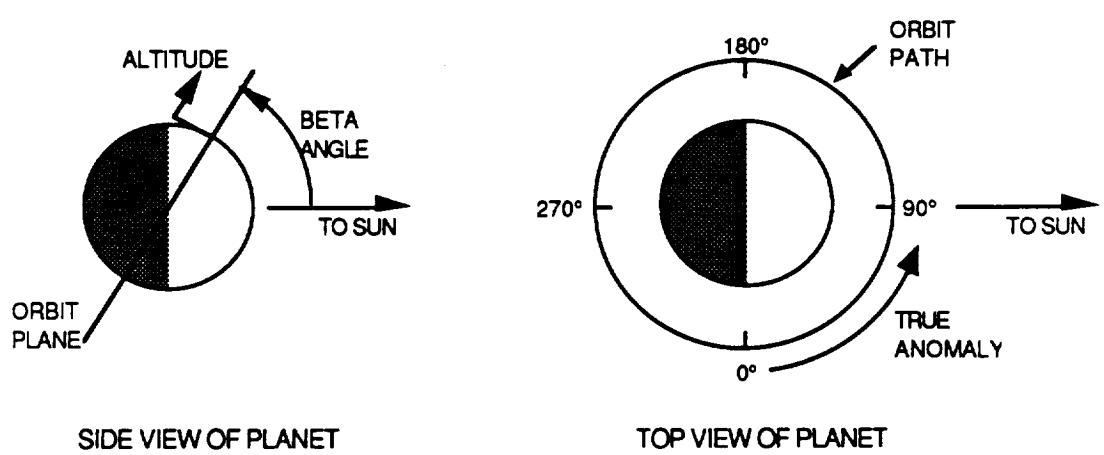


FIGURE 1: Orientation of Spacecraft

B. Definition of Orbit Parameters

All orbits will be circular, Earth orbits with a longitude of ascending node at -90° (The orbit crosses the equator at the Earth's day/night terminator). Calculations will be done at 12 equally spaced points around the orbit. TRASYS also does calculations at the planet's shadow entry and exit points. These points are defined by True Anomaly. True Anomaly is the angular position of the spacecraft in the orbit path. The parameters to be varied are the Beta (orbital inclination) value, the altitude, and the orientation of the spacecraft. Figures 1 and 2 illustrate these parameters.

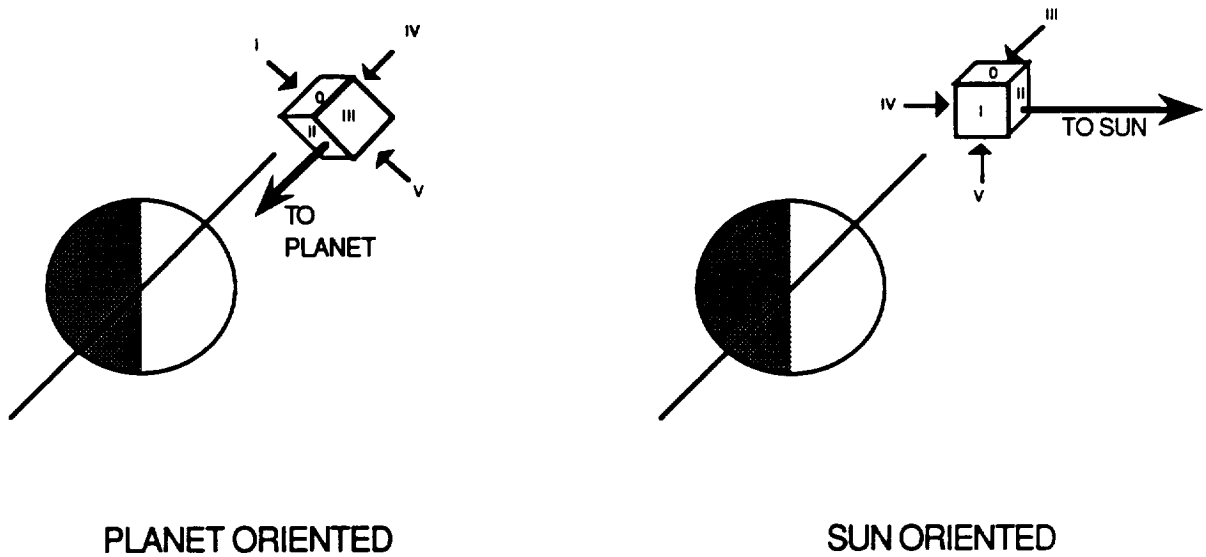


FIGURE 2: Orbit Parameters

By varying these parameters, data applicable to most orbits and orientations can be obtained. Notably absent from the orbits used are the elliptical orbits and spinning spacecraft. Though TRASYS can handle both of these variations, they will not be included here. Most spacecraft analyzed here at MSFC use circular orbits, elliptical orbits are usually encountered only briefly before or during deployment. Data for spinning spacecraft can be approximated by averaging data for the sides of the cube that would be affected by the spin. The orbits used are based on a baseline orbit of 200nmi, Beta=0°, and a Sun orientation. Table 1 details the orbits used to obtain the data.

ORBIT	BETA ANGLE (degrees)	ALTITUDE (nautical miles)	ORIENTATION
CASE I	0	150	SUN
CASE II	0	200	SUN
CASE III	0	300	SUN
CASE IV	0	400	SUN
CASE V	0	600	SUN
CASE VI	0	800	SUN
CASE VII	0	5000	SUN
CASE VIII	0	10000	SUN
CASE IX	0	17000	SUN
CASE X	0	23000	SUN
CASE XI	15	200	SUN
CASE XII	30	200	SUN
CASE XIII	45	200	SUN
CASE XIV	60	200	SUN
CASE XV	75	200	SUN
CASE XVI	90	200	SUN
CASE XVII	0	200	EARTH
CASE XVIII	30	200	EARTH
CASE XIX	60	200	EARTH

TABLE 1: Definition of Orbits

IV. Analysis

TRASYS requires an input file, a modified FORTRAN code that contains information about the model, its motions and surroundings, the results, and how the results should be calculated. This input file is divided into blocks, each with a different purpose. Each block begins with a 'HEADER' line. Figure 3 is the complete input file for the baseline orbit.

```
HEADER  OPTIONS DATA
TITLE SPACECRAFT THERMAL RADIATION MODEL
      MODEL =SCRAFT
      BCDOU - TXXXX
      RSO - TXXXX
      USER1 - TXXXX
      INFO - NO
HEADER SURFACE DATA
C     CUBE IN SPACE
S     SURFN=500
      ACTIVE=OUT
      PROP=1.,1.
      TYPE=BOX6
      P1=1.,1.,1.
      TZ=-.5
      TY=-.5
      TX=-.5
      NNX=1
      NNY=1
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

FIGURE 3: TRASYS Input File

Explanations of the input file will be limited to the Operations Data block. The information contained in the Operations Data block often seems redundant, but TRASYS usually requires all of it. When building the Operations Data block it is important to use the TRASYS manual to check each line for prerequisites. Use of one subroutine often requires that other subroutines also be included. The Operations Data block presented here has all of the lines needed to define most orbits, including elliptical orbits and orbits around various planets. Spinning spacecraft are possible with the use of one or two more lines (subroutines Spin and Spinav).

A. BUILD SCRAFT

Tells TRASYS to build the model or a part of the model. Each model and submodel is labeled and this command allows individual pieces of the model to be tested and analyzed separately. Note that the third line of figure 3 gives the model its name, SCRAFT.

B. FFDATA, GBDATA, RKDATA

These subroutines define information required to compute form factors (FF), graybody factors (GB), and radiation conductors (RADK's or RK). The actual calculation is done by the statements FFCAL, GBCAL, and RKCAL. These factors are either used in the calculation of incident

radiation, or the subroutine contains information needed in later calculations. Form factors are required for any model where there is radiation exchange between nodes on the model. The GB factors and the RADK's are calculated for input into SINDA. The RADK's are not required to calculate incident fluxes, but are included in this example because they are important SINDA input.

C. ORBIT1, ORIENT

ORBIT1 is used to define the orbit. It includes information about the orbit as defined in the celestial coordinate system, the location of the spacecraft in that orbit, and the location of the Sun and one star. It also defines the planet being orbited, which defines the planet radius, albedo, distance from the Sun, etc.. ORBIT2 is similar to ORBIT1 but uses Sun-referenced parameters in the orbit coordinate system, and may be substituted for ORBIT1. ORIENT is used to define the orientation of the spacecraft. Options are planet, Sun, or star oriented. Other values define which side of the spacecraft is 'facing' the direction of orientation.

D. DIDT1

DIDT1 contains values defining the accuracy desired in the incident flux calculations. Calculations of shadowing, i.e. what surfaces shade each other, and by how much, is the most time-consuming part of TRASYS. To verify that a model is working properly, or for models in which no shading will occur, it is better to bypass the shading calculations. The NOSH flag controls this. Note that the NOSH flag appears in the FFDATA statement also. DIDT2 or DIDT2S may be substituted if only one position in orbit is to be considered, they define everything in the ORBIT and ORIENT subroutines except the planet name and the direction the spacecraft 'faces'.

E. ORBGEN

ORBGEN allows the calculations of incident radiation to be done not only at the position specified in the ORBIT subroutine, but at as many places around that same orbit as are needed. It contains information on the type of orbit (redundant), at what points of the orbit to do calculations, the types of information to be calculated, and plot/no plot flags.

Much of the information in these lines is repeated. Some of the later lines override the previous information, some don't. The safest rule is to make sure that the information matches in both places, until you are familiar enough to recognize what can be passed as 'dummy' arguments, in which case you will have passed the scope of this example. The Operations Data block from each orbit has been included at the end of the example.

V. Presentation and Discussion of Results

The TRASYS output text file is long and mostly redundant. The incident radiation results are presented in three forms: For each step in the orbit Solar, Albedo (reflected Solar) and Planetary (infrared) direct incident fluxes are listed for each side of the cube. These values are summed and presented as totals for each step in seven arrays at the end of the output, one for each side and one containing

corresponding time values. An average heating rate for each side averaged over the entire orbit is also presented at the end of the file.

A. Comparison of the Six Sides

Figures 4a and 4b illustrate the variation in total incident flux on each side as the spacecraft moves around the baseline orbit. Note the abrupt drop in flux on side II as the spacecraft enters the planet's shadow, and the lack of this drop in the other sides.

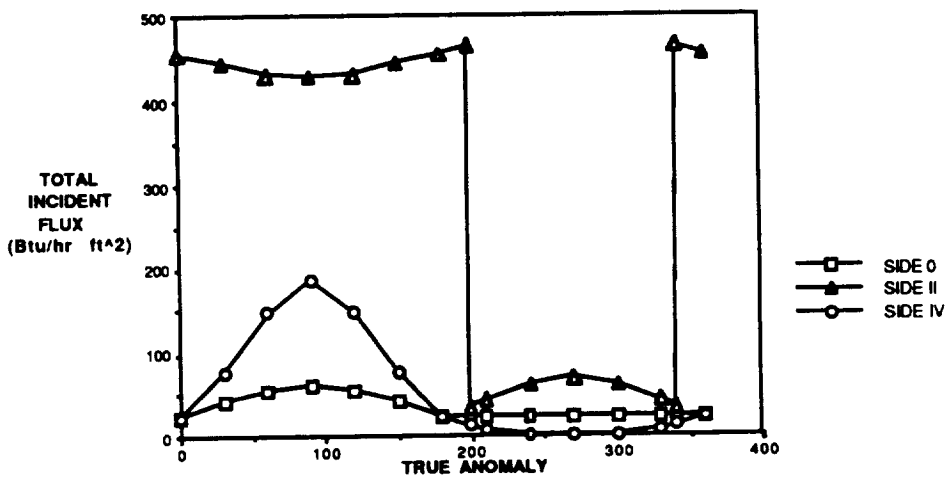


FIGURE 4a: Total incident flux for each side.
Alt=200nmi, Beta=0°
Sun oriented

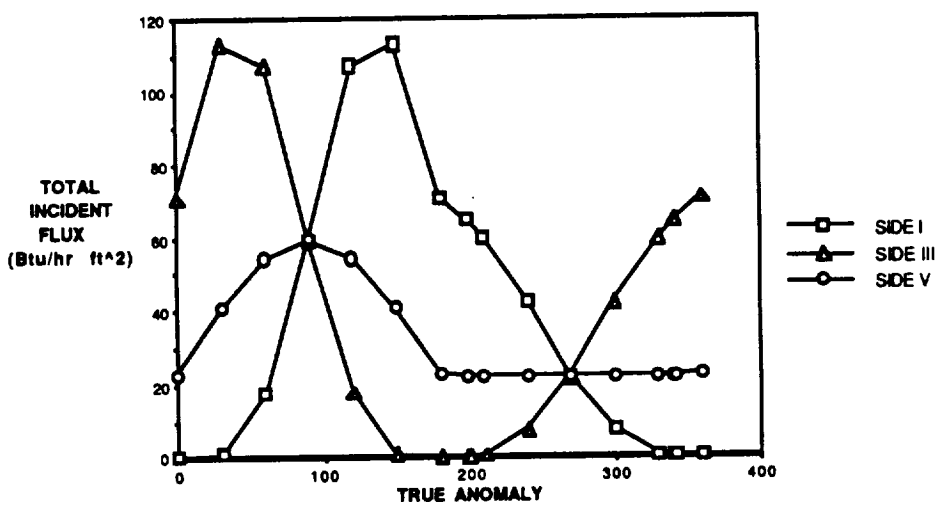


FIGURE 4b: Total incident flux for each side.
Alt=200nmi, Beta=0°
Sun oriented

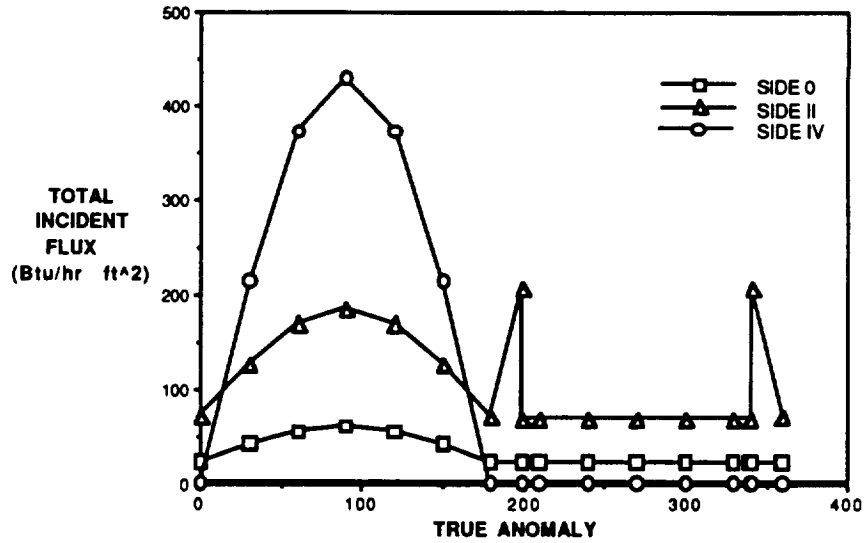


FIGURE 5a: Total incident flux for each side.
Alt=200nmi, Beta=0°
Earth oriented

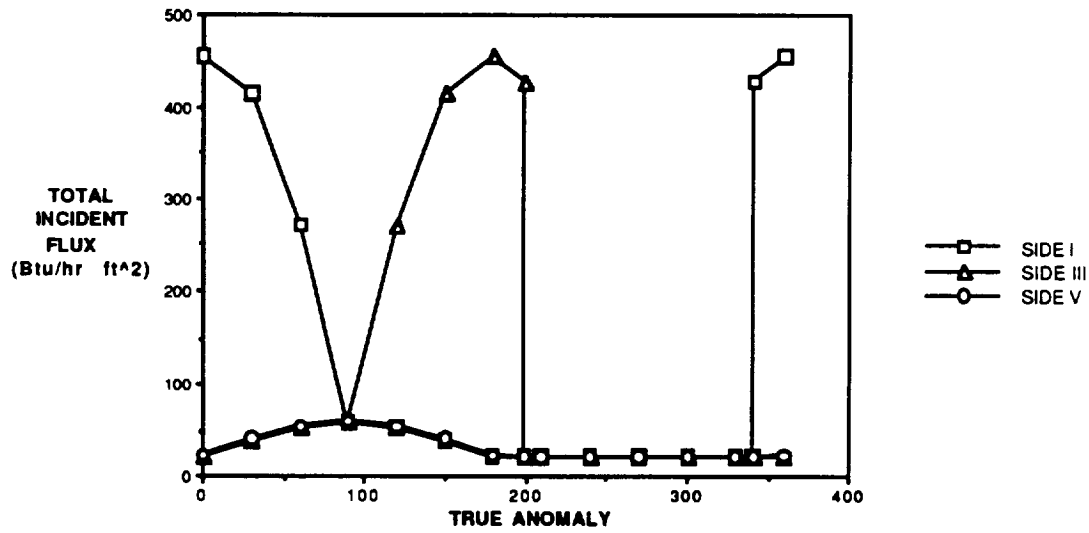


FIGURE 5b: Total incident flux for each side.
Alt=200nmi, Beta=0°
Earth oriented

Figures 5a and 5b illustrate the variation in total incident flux on each side as the spacecraft moves around the same orbit as in Figures 4a and 4b, but oriented to the Earth. Note the peaks on the three sides that see direct sunlight. Also note the drop in two of the sides due to the planet's shadow.

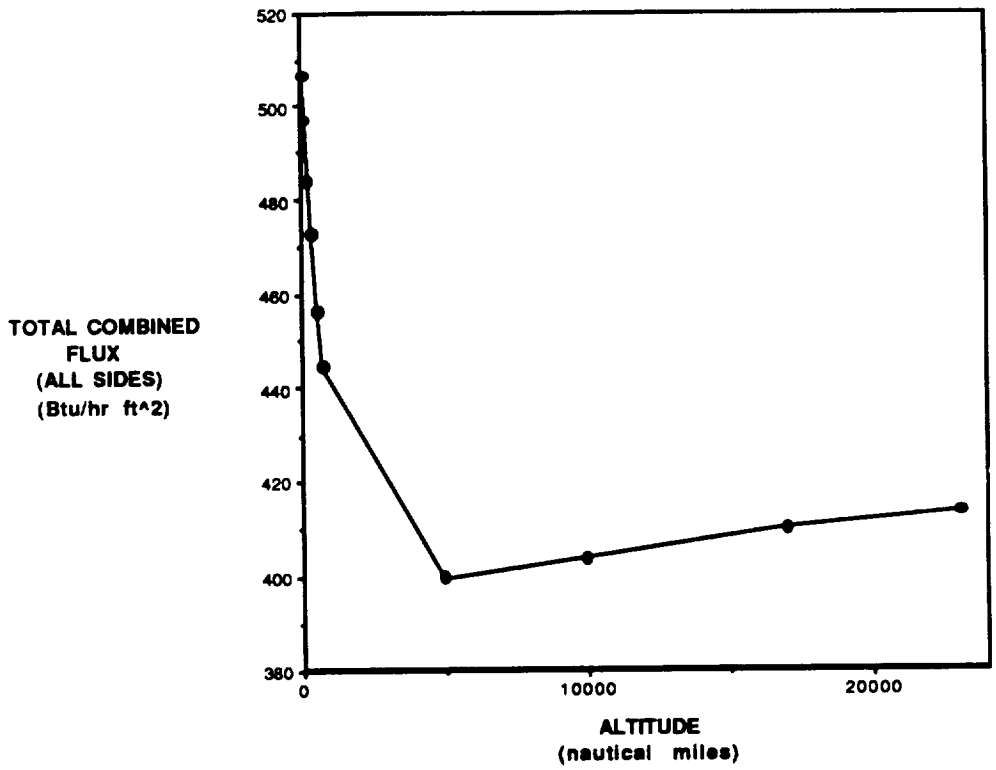


FIGURE 6: Total Average Flux vs. Altitude

B. Average Flux

The average flux encountered by the entire spacecraft during one orbit as it varies with altitude is shown in Figure 6. From low Earth orbits to approximately 500 nautical miles the curve drops due to the weaker effects of the planetary and albedo fluxes as the orbit becomes more distant. As the flux from these two becomes less significant, another influence can be seen. The increasingly larger orbit path makes the time spent in the planet's shadow less significant and the average starts to increase.

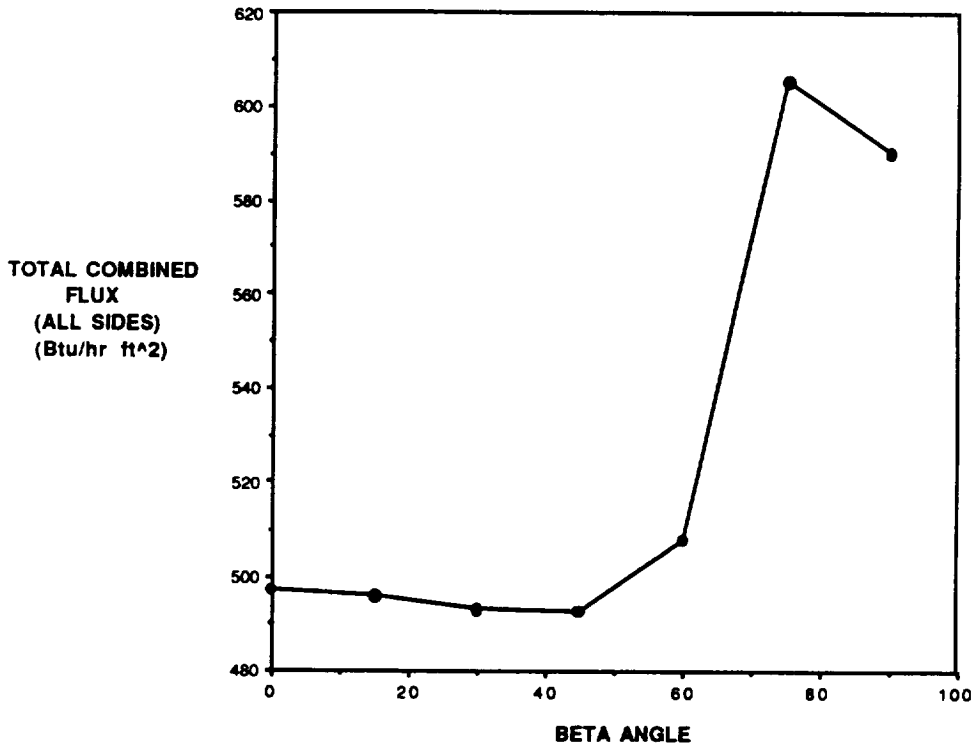


FIGURE 7: Total Average Flux vs. Beta Angle

Variations in the average flux with Beta angle also come from two sources. Figure 7 shows the decrease in flux at low Betas, which is due to the orbit's path moving away from the center of the sunlit side, reducing the flux due to albedo. From 45° to 75° the flux increases dramatically as the orbit path moves out of the planet's shadow. The first trend, due to lower effects of albedo continues after 75°.

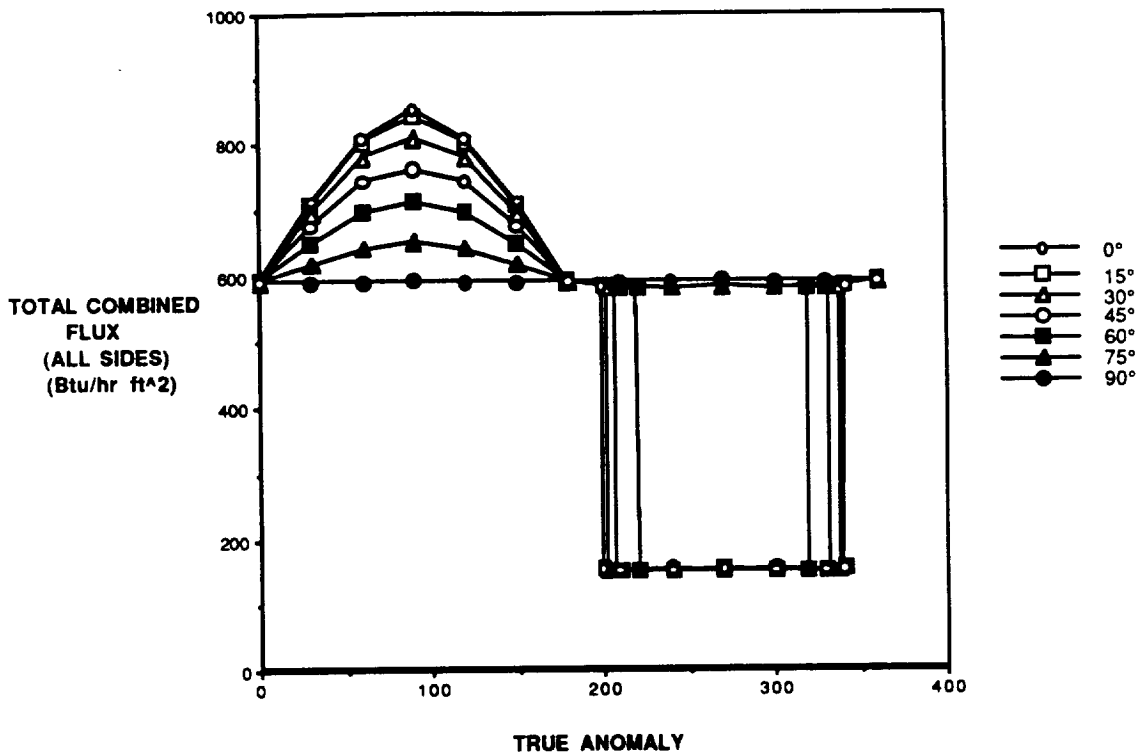


FIGURE 8: Variation of flux with Beta angle.

C. Total Incident Flux

Figure 8 illustrates the variation in total flux, from all six sides, with Beta angle at each point around the orbit. The 'dome' on the left of the graph decreases with Beta due to the decreased effect of albedo as in Figure 7. The angular portion of the orbit in the planet's shadow can also be seen decreasing to nothing with the Beta angle.

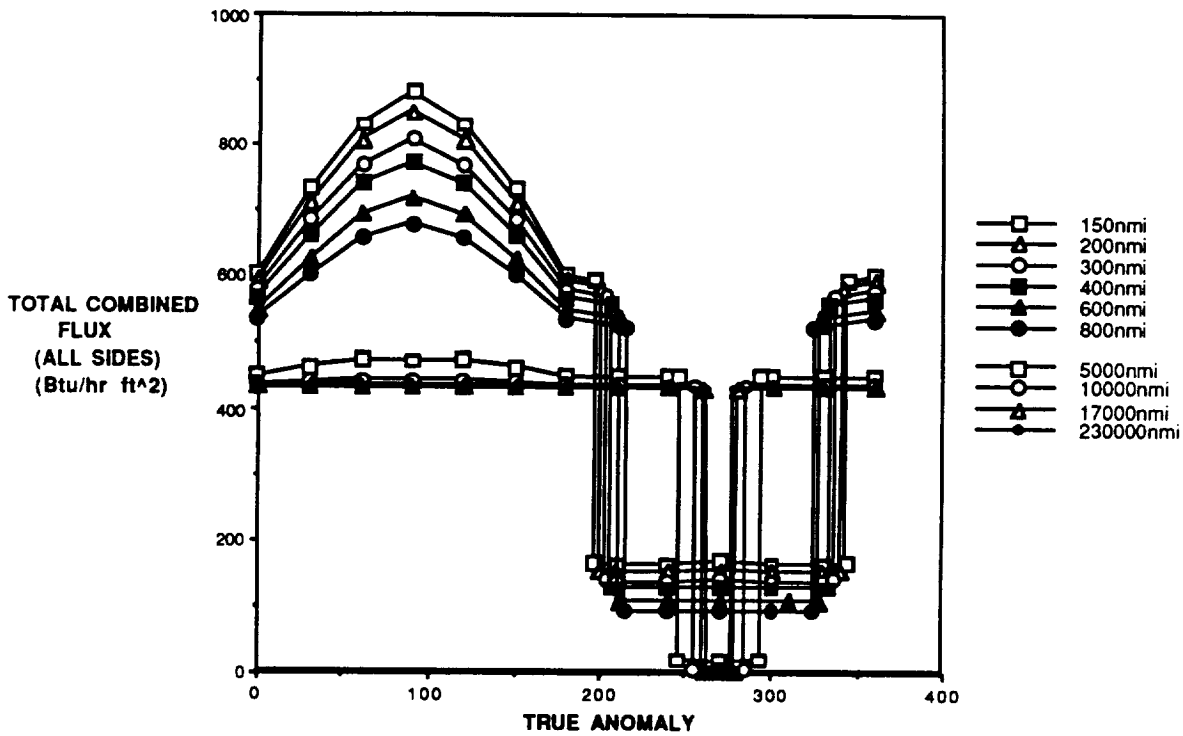


FIGURE 9: Total flux (all sides)

The variation in total flux on all six sides due to changing altitude is shown in Figure 9. The 'dome on the left represents the effects of albedo and planetary fluxes, and decreases with increasing distance from the planet. This effect can also be seen in the bottom of the 'well' on the right. The 'well' is caused by the planet's shadow and narrows as the orbit becomes larger and the shadow covers a smaller angular portion of the orbit.

TRASYS INPUT: OPERATIONS DATA BLOCKS

CASE I

ORBIT DATA:
BETA=0°
ALT=150nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*150.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE II

ORBIT DATA:
BETA=0°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*200.,0.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE III

ORBIT DATA:
BETA=0°
ALT=300nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*300.,0.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE IV

ORBIT DATA:
BETA=0°
ALT=400nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*400.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE V

ORBIT DATA:
BETA=0°
ALT=600nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*600.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE VI

ORBIT DATA:
BETA=0°
ALT=800nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*800.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE VII

ORBIT DATA:
BETA=0°
ALT=5000nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*5000.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE VIII

ORBIT DATA:
BETA=0°
ALT=10000nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*10000.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE IX

ORBIT DATA:
BETA=0°
ALT=17000nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*17000.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE X

ORBIT DATA:
BETA=0°
ALT=23000nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*23000.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XI

ORBIT DATA:
BETA15°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,15.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XII

ORBIT DATA:
BETA=30°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,30.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XIII

ORBIT DATA:
BETA=45°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,45.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XIV

ORBIT DATA:
BETA=60°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,60.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XV

ORBIT DATA:
BETA=75°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,75.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XVI

ORBIT DATA:
BETA=90°
ALT=200nmi
ORIENTATION: SUN

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.005,.1,4HSHAD,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0.0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,90.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(3HSUN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN INER,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XVII

ORBIT DATA:
BETA=0°
ALT=200nmi
ORIENTATION: EARTH

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,0.,0.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(4HPLAN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN CIRP,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XVIII

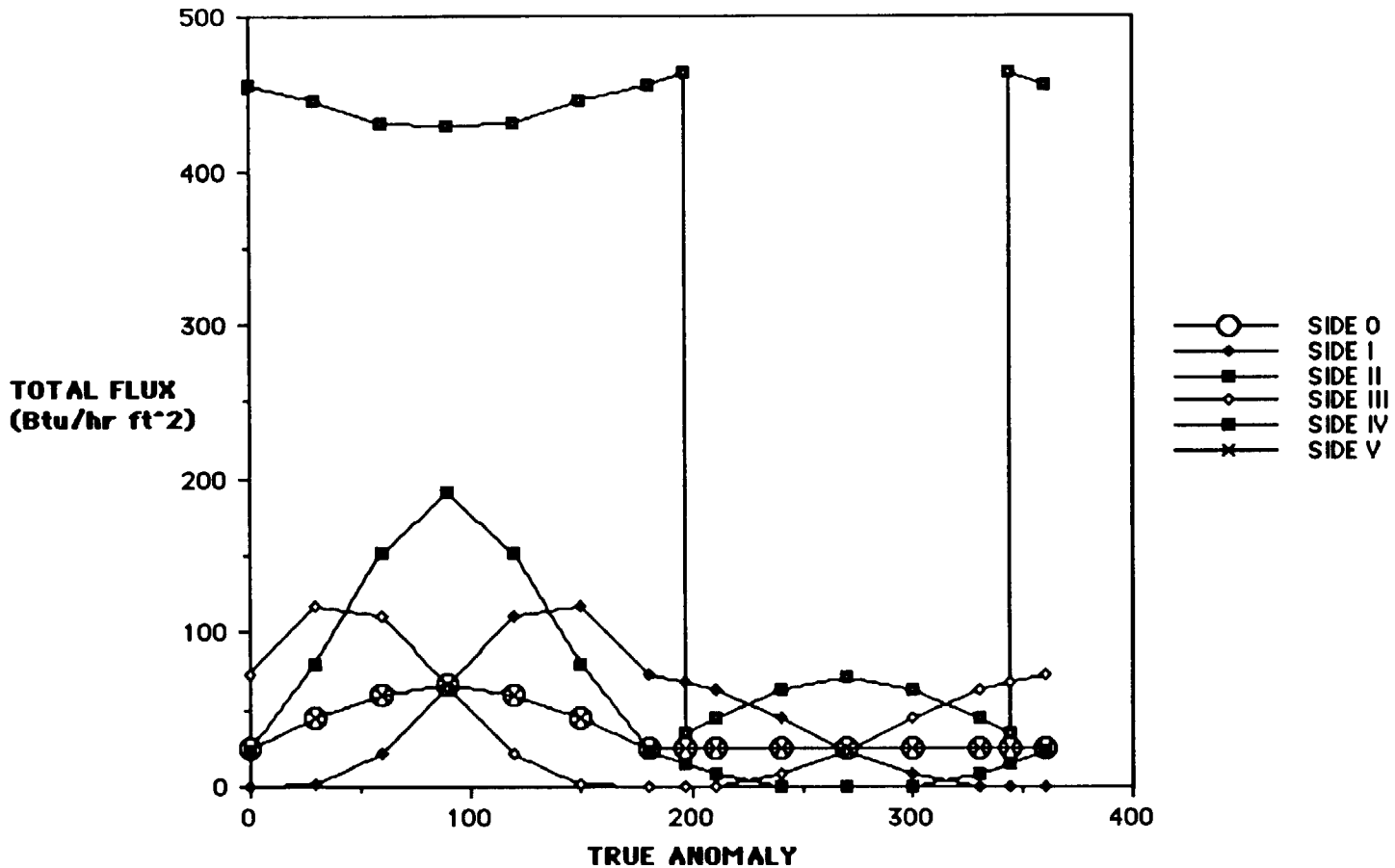
ORBIT DATA:
BETA=30°
ALT=200nmi
ORIENTATION: EARTH

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,30.,0.,0.,6080.*200.,0.,0.,0.,0.,0.)
      CALL ORIENT(4HPLAN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0,0,0.,0,0.,3HYES,0)
ORBGEN CIRP,0.,360.,12,AQ,NO,0.,1
END OF DATA
```

CASE XIX

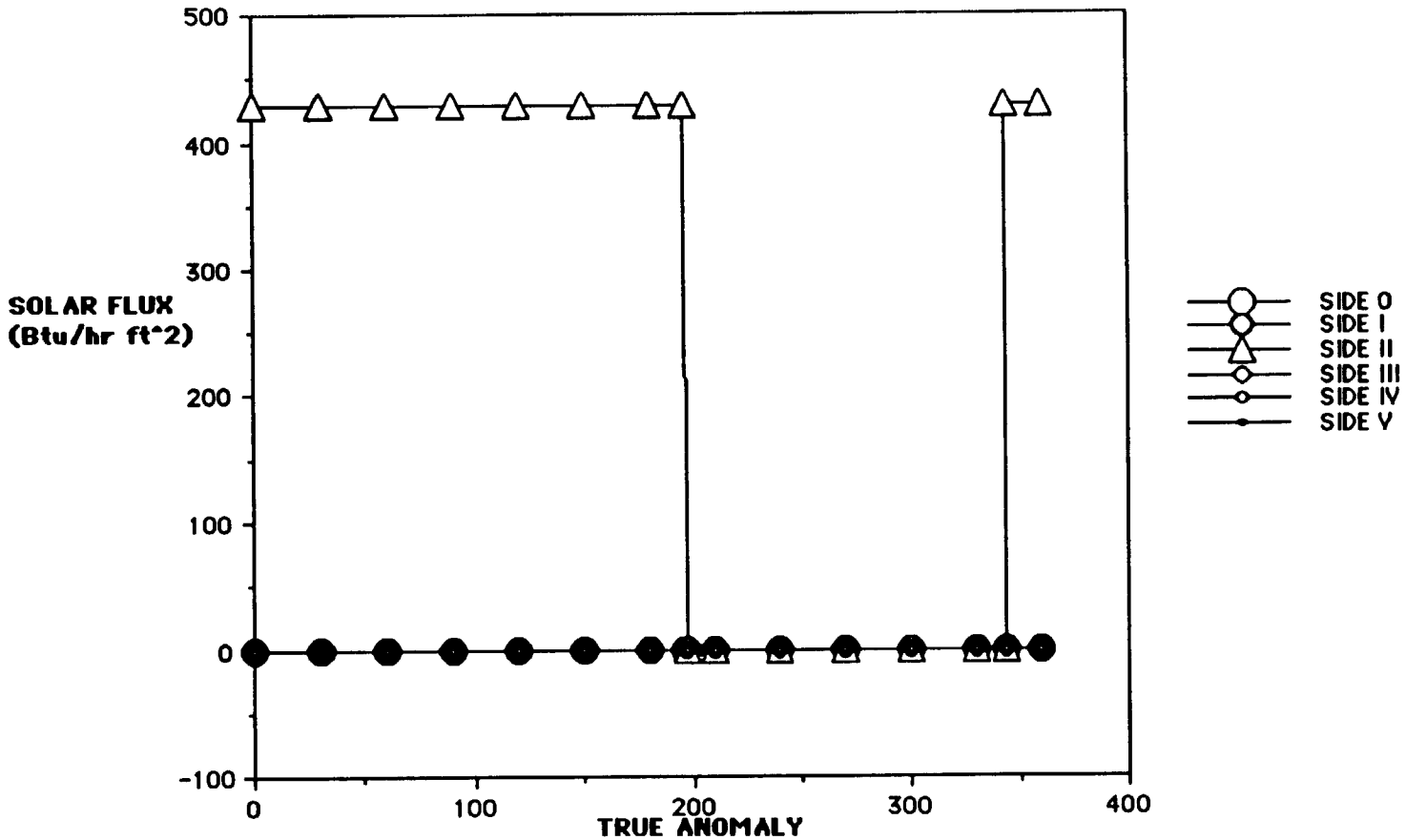
ORBIT DATA:
BETA=60°
ALT=200nmi
ORIENTATION: EARTH

```
HEADER OPERATIONS DATA
BUILD SCRAFT
      CALL FFDATA(.05,.1,4HNOSH,15.,1.E-6,3HYES,3HYES,2HNO,0,0)
L     FFCAL
      CALL GBDATA(4HBOTH,0,0)
L     GBCAL
      CALL RKDATA(0,3HYES,0.0002,1,5HSPACE,9999,0,1.0,2HNO,0)
L     RKCAL
      CALL ORBIT1(3HEAR,-90.,60.,0.,0.,6080.*200.,0.,0.,0.,0.,0.1
      CALL ORIENT(4HPLAN,1,2,3,0.,0.,0.)
      CALL DIDT1(4HNOSH,0.0,0.,0.,0.,3HYES,0)
ORBGEN CIRP,0.,360.,12,AQ,NO,0.,1
END OF DATA
```



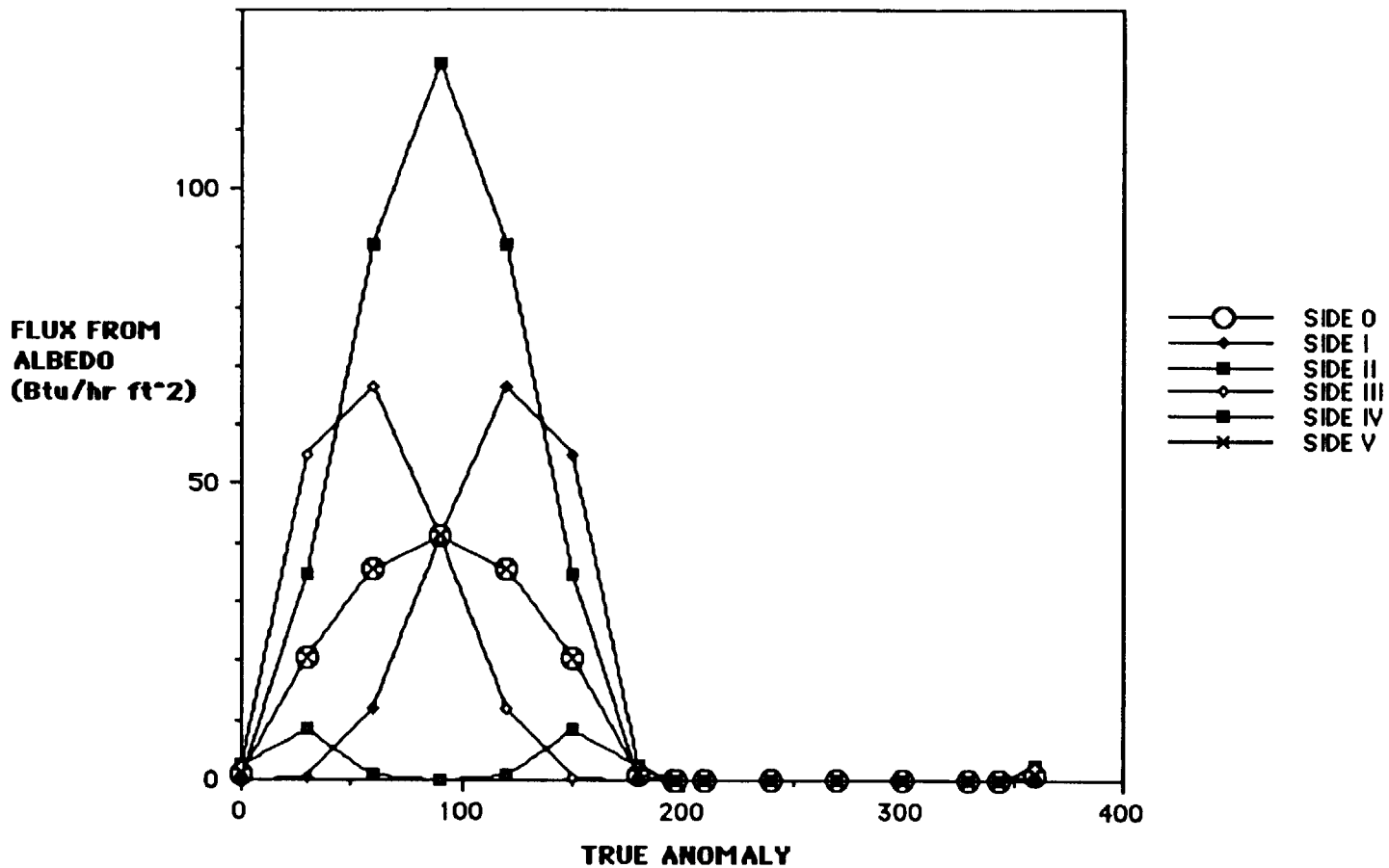
CASE I: TOTAL FLUX

ALTITUDE=150nmi
BETA=0°
SUN ORIENTED



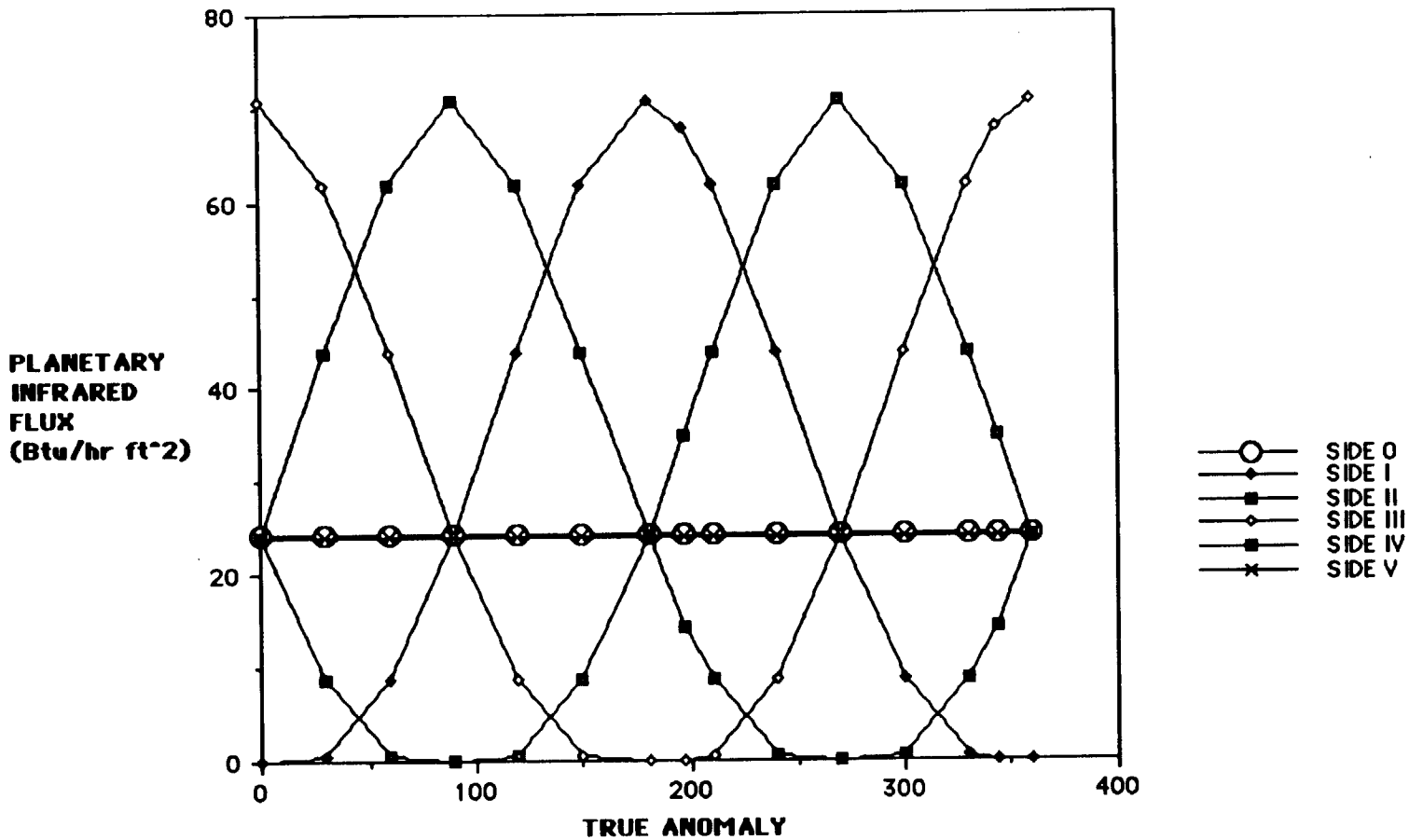
CASE I: SOLAR FLUX

ALTITUDE=150nmi
BETA=0°
SUN ORIENTED



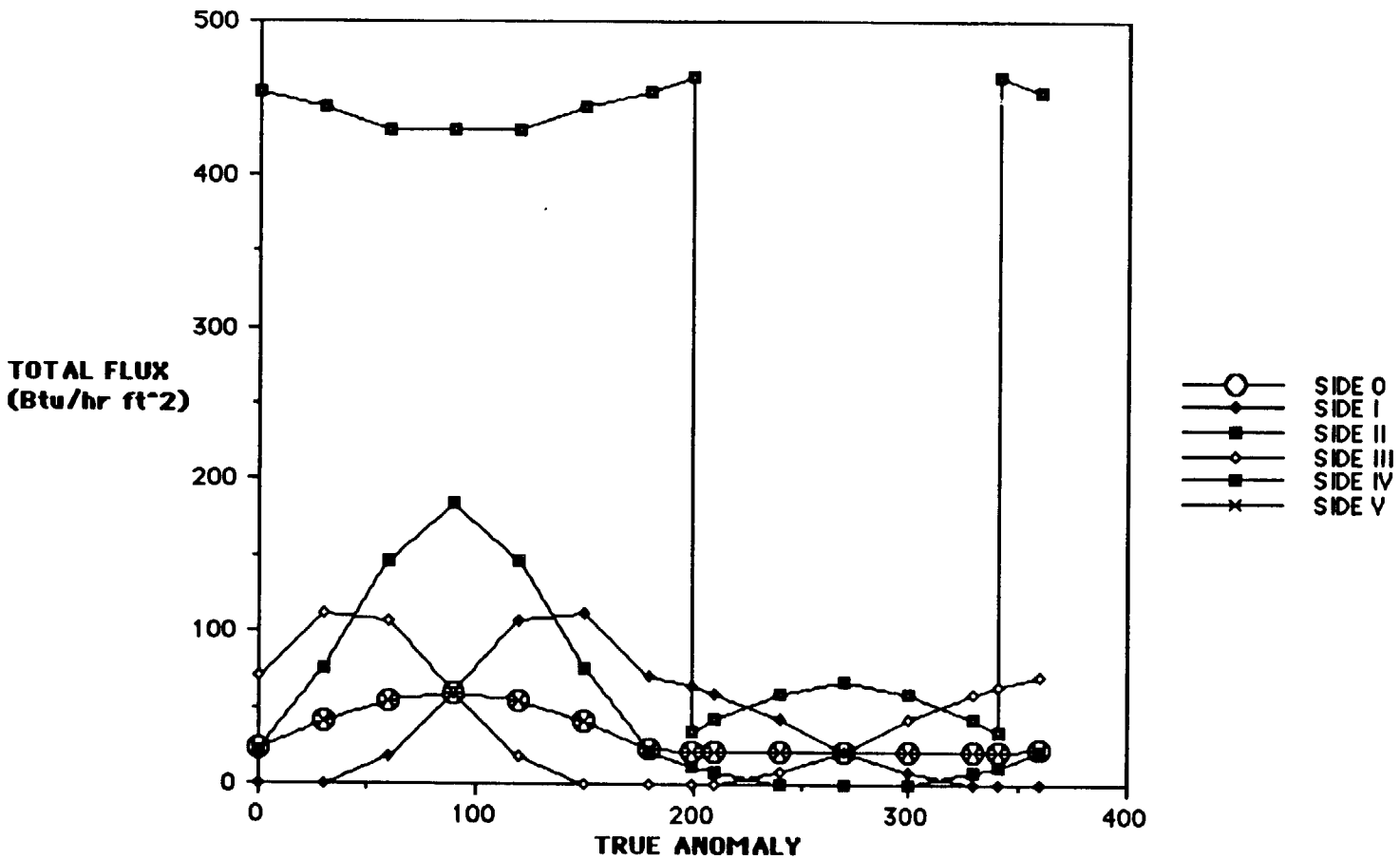
CASE I: ALBEDO FLUX

ALTITUDE=150nmi
BETA=0°
SUN ORIENTED



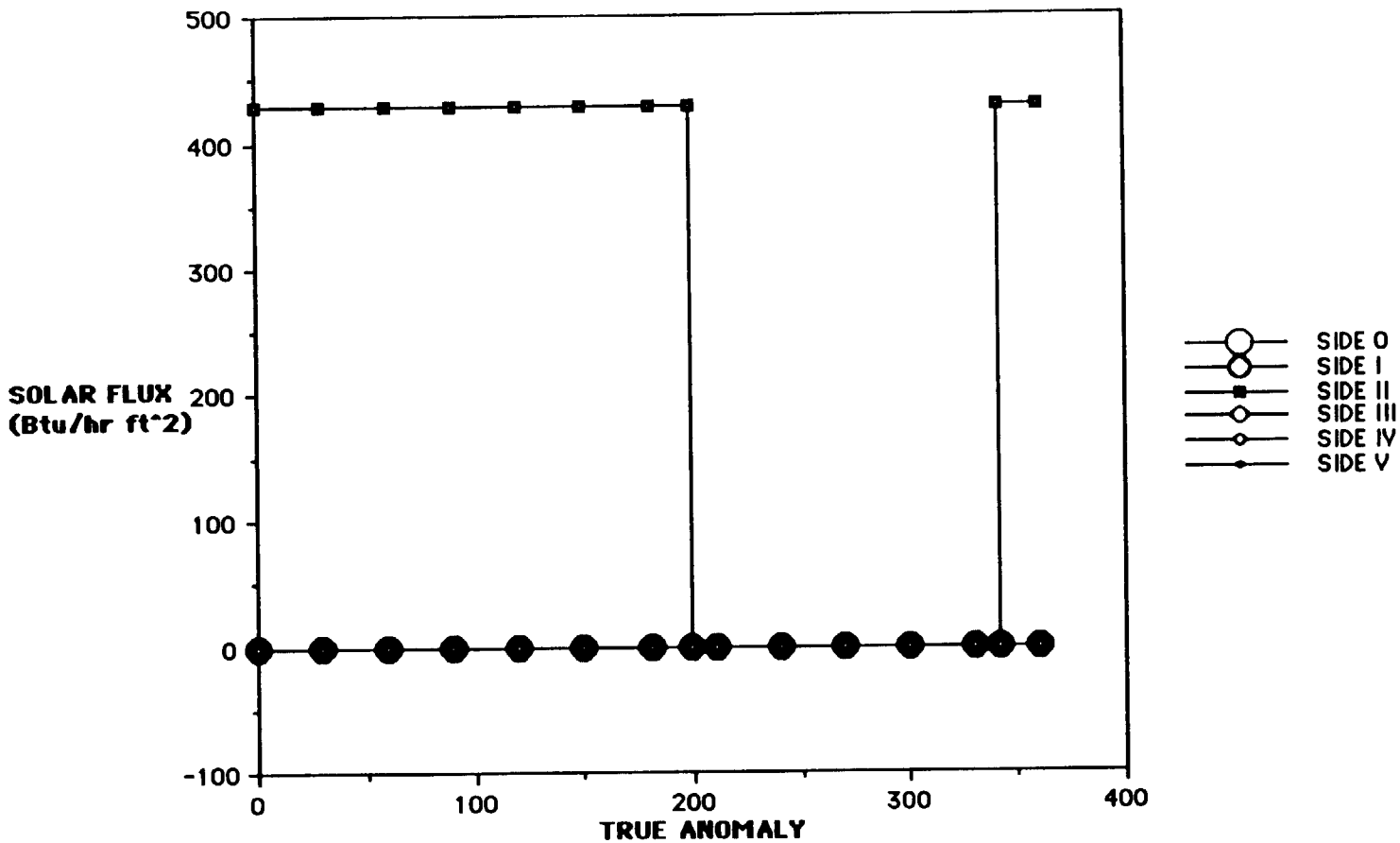
CASE I: PLANETARY FLUX

ALTITUDE =150nmi
BETA=0°
SUN ORIENTED



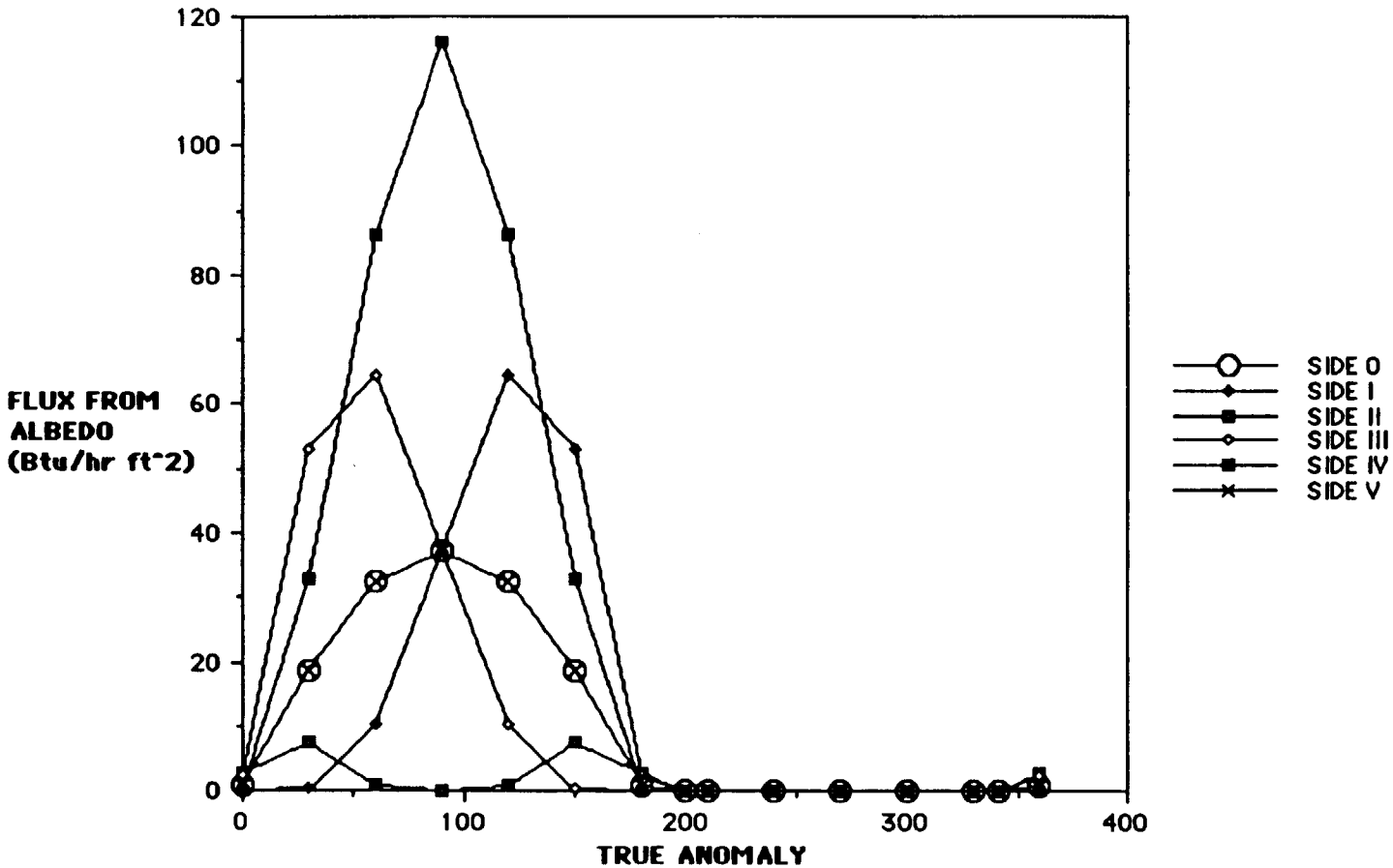
CASE II: TOTAL FLUX

ALTITUDE=200nmi
BETA=0°
SUN ORIENTED



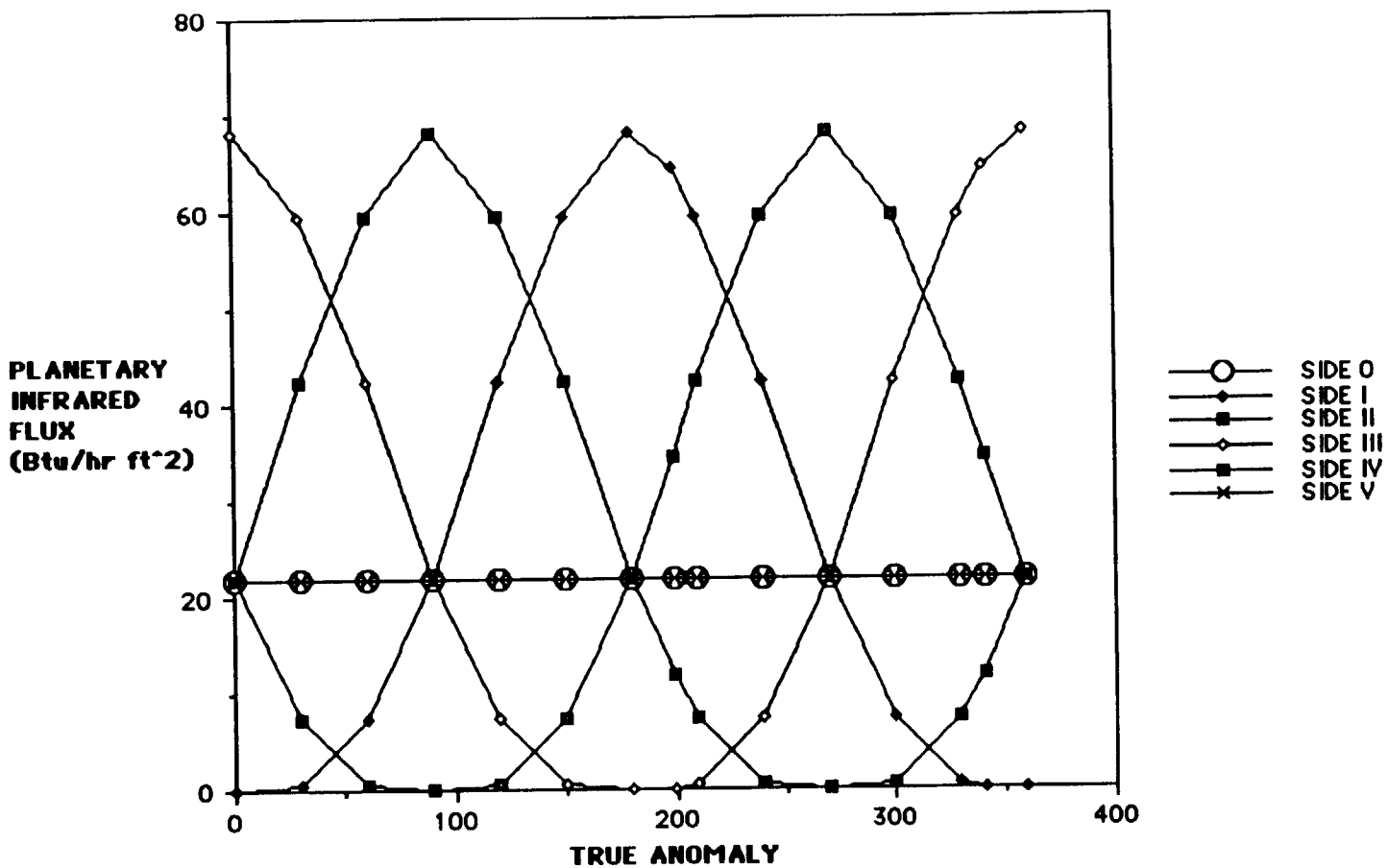
CASE II: SOLAR FLUX

ALTITUDE =200nmi
BETA=0°
SUN ORIENTED



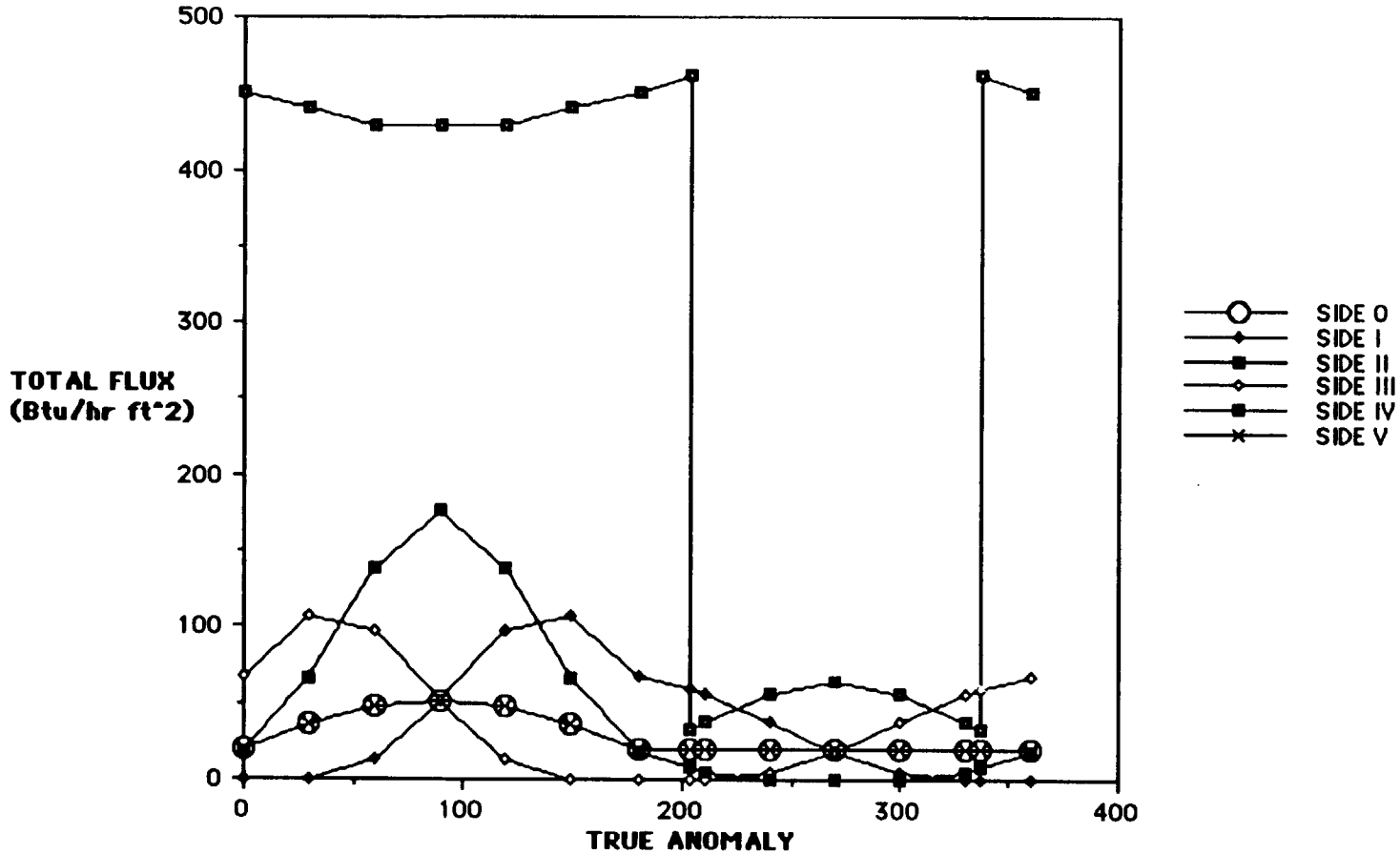
CASE II: ALBEDO FLUX

ALTITUDE=200nmi
BETA=0°
SUN ORIENTED



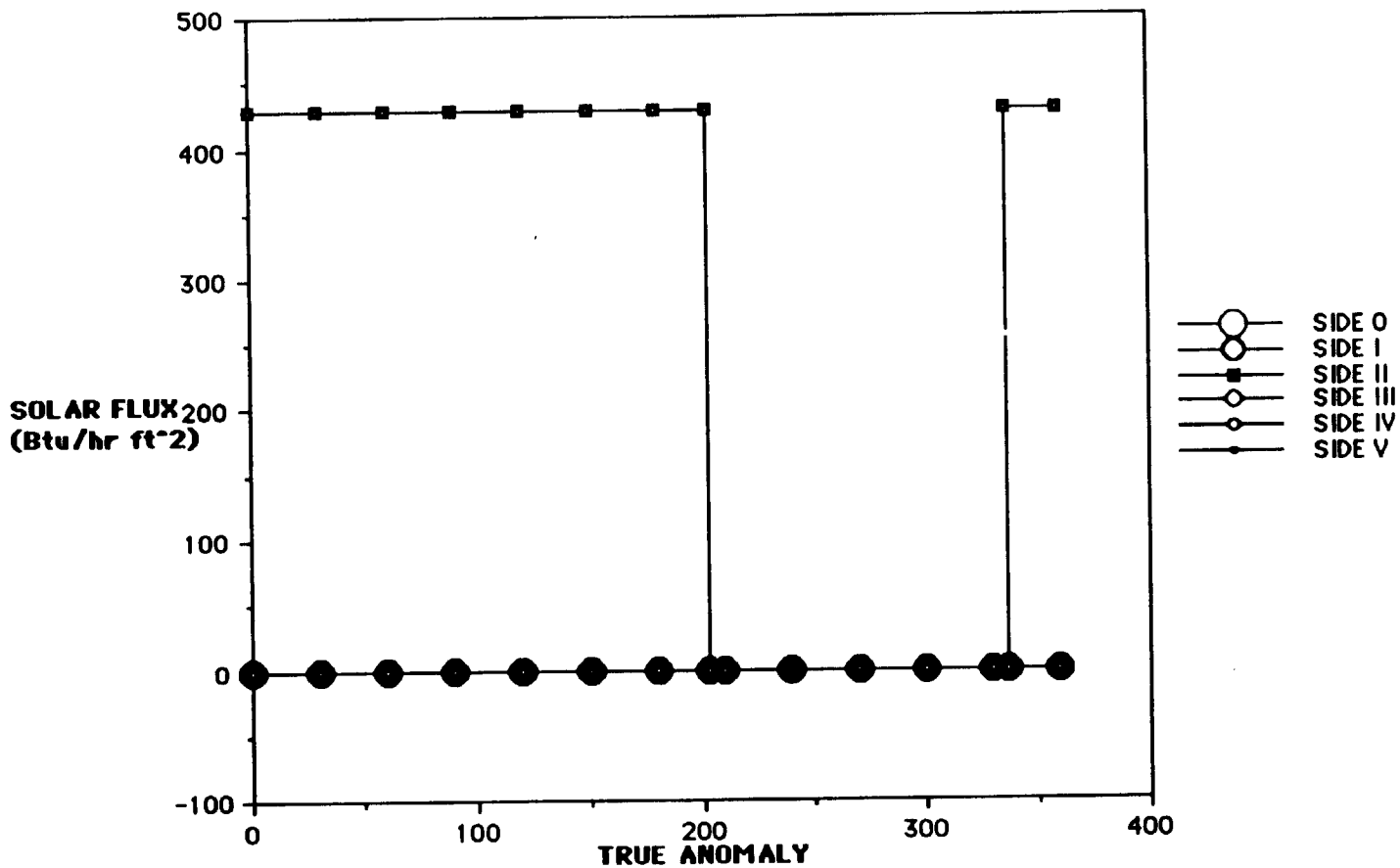
CASE II: PLANETARY FLUX

ALTITUDE=200nmi
BETA=0°
SUN ORIENTED



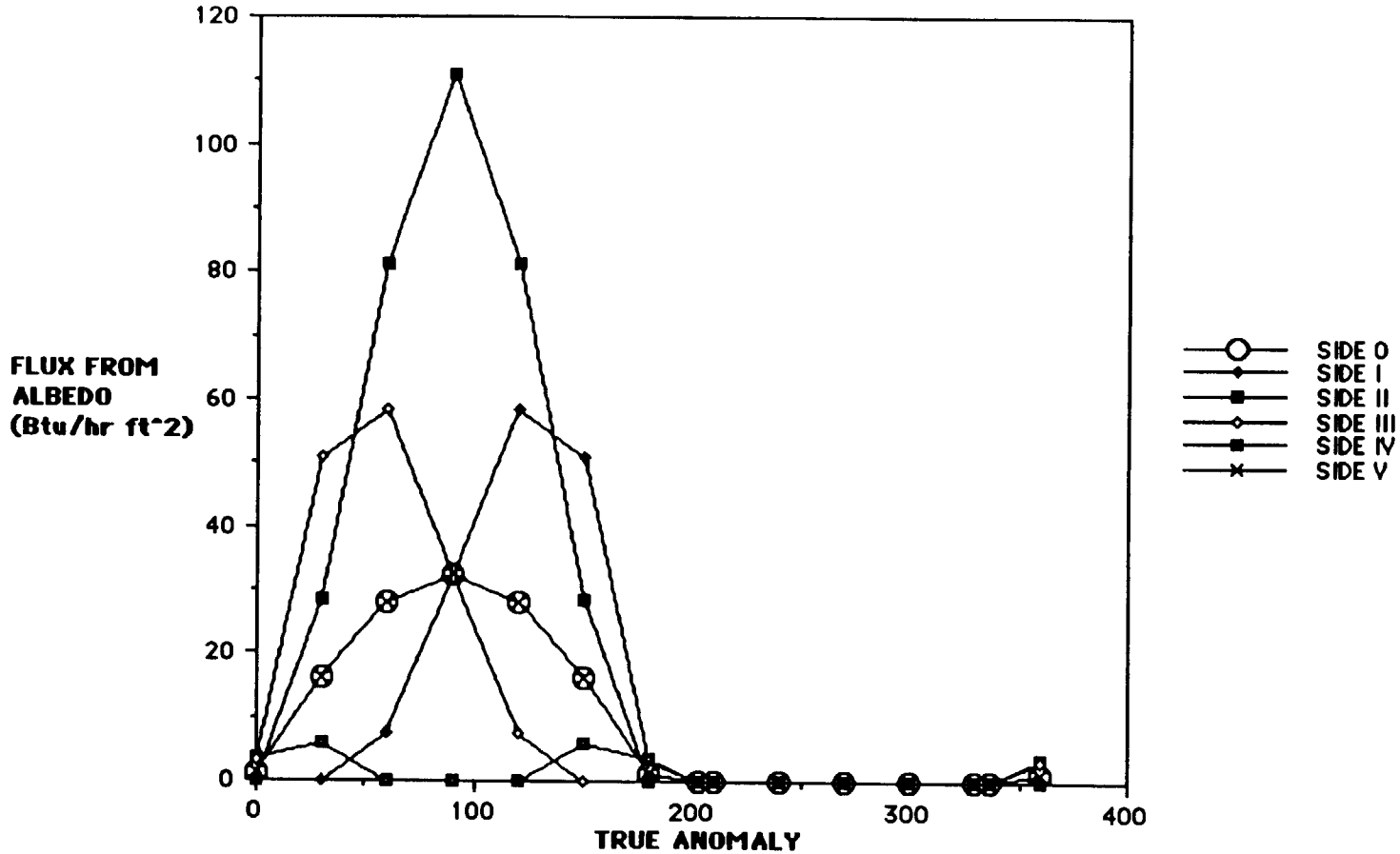
CASE III: TOTAL FLUX

ALTITUDE=300nmi
BETA=0°
SUN ORIENTED



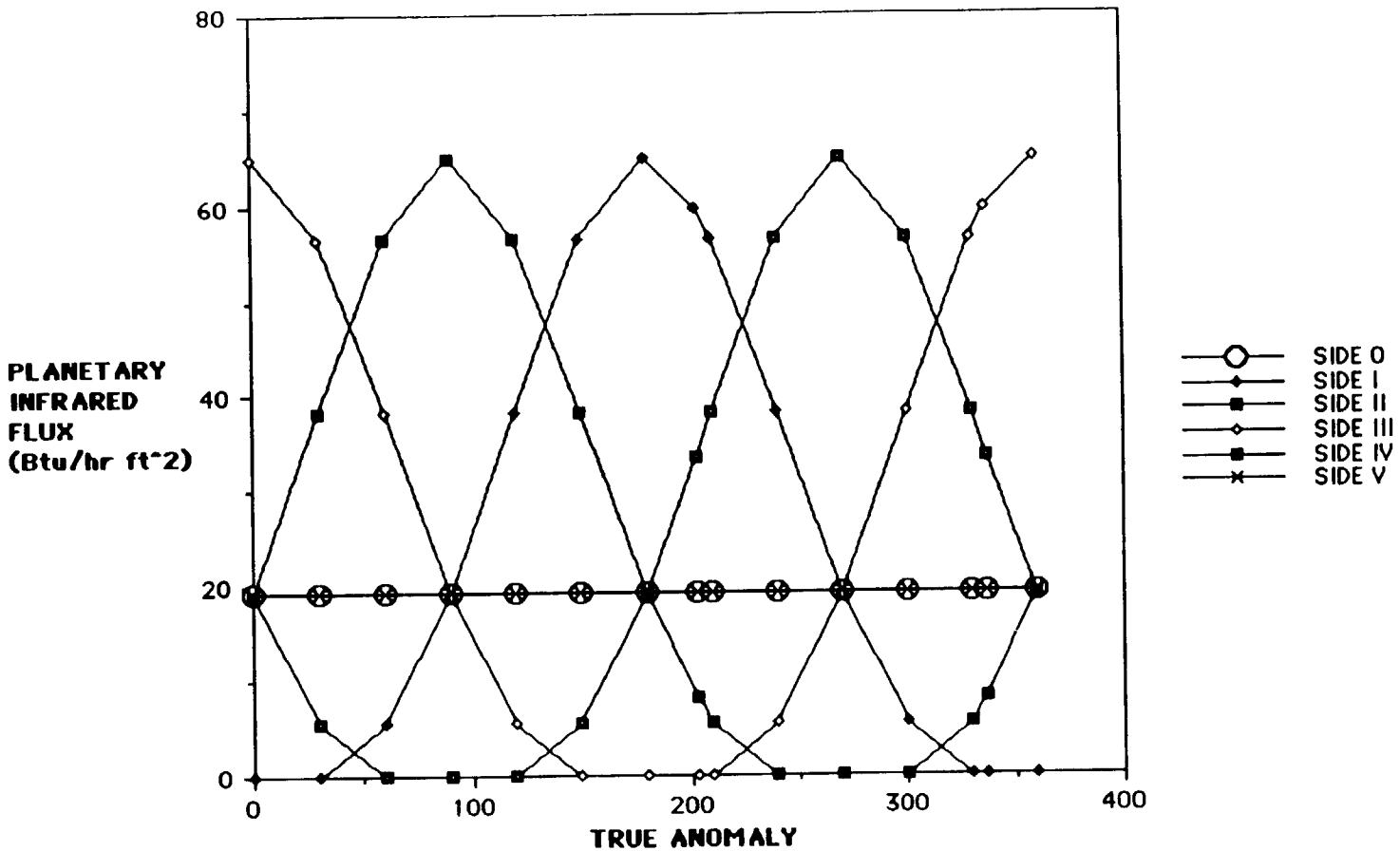
CASE III: SOLAR FLUX

ALTITUDE=300nmi
BETA=0°
SUN ORIENTED



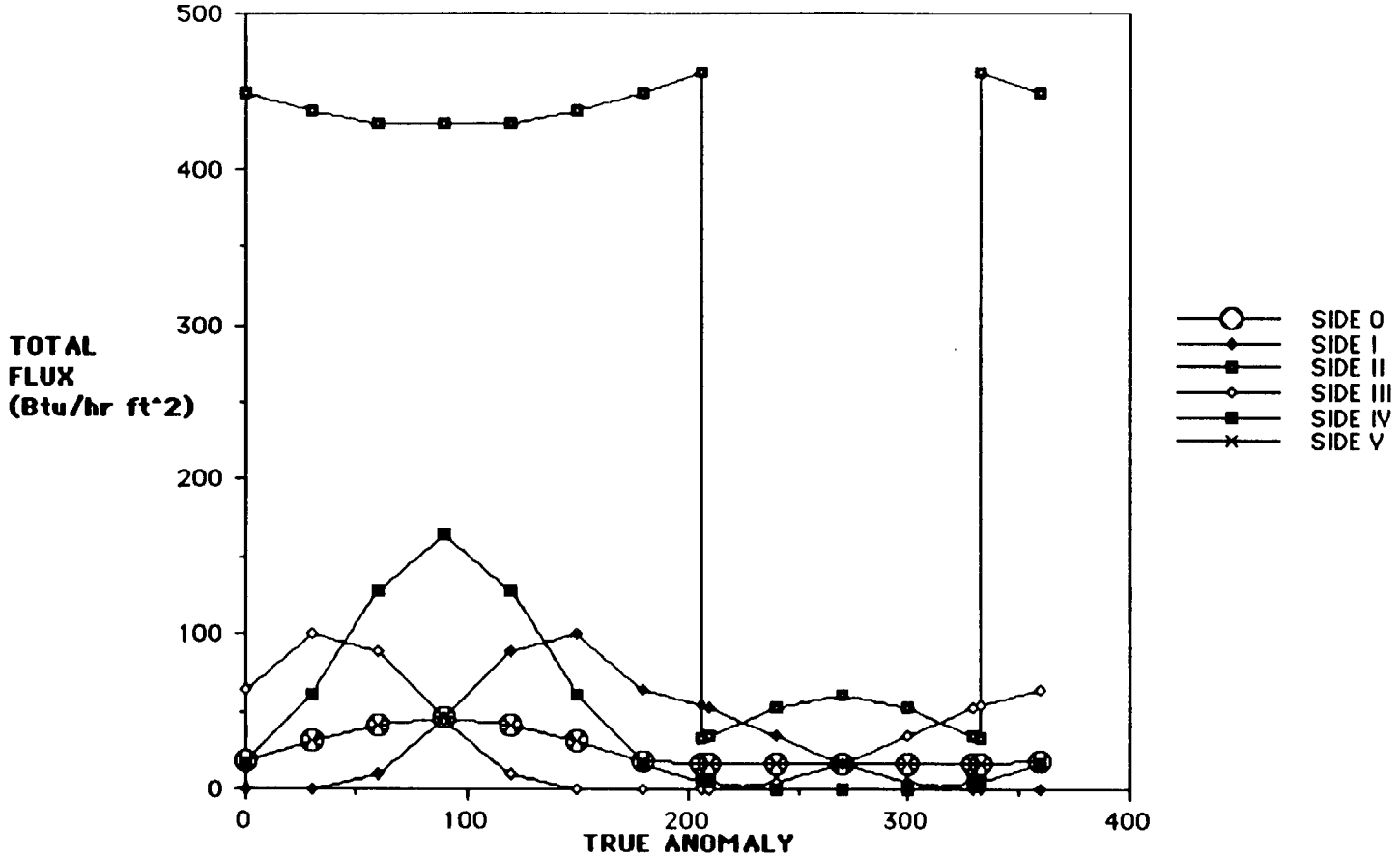
CASE III: ALBEDO FLUX

ALTITUDE=300nmi
BETA=0°
SUN ORIENTED



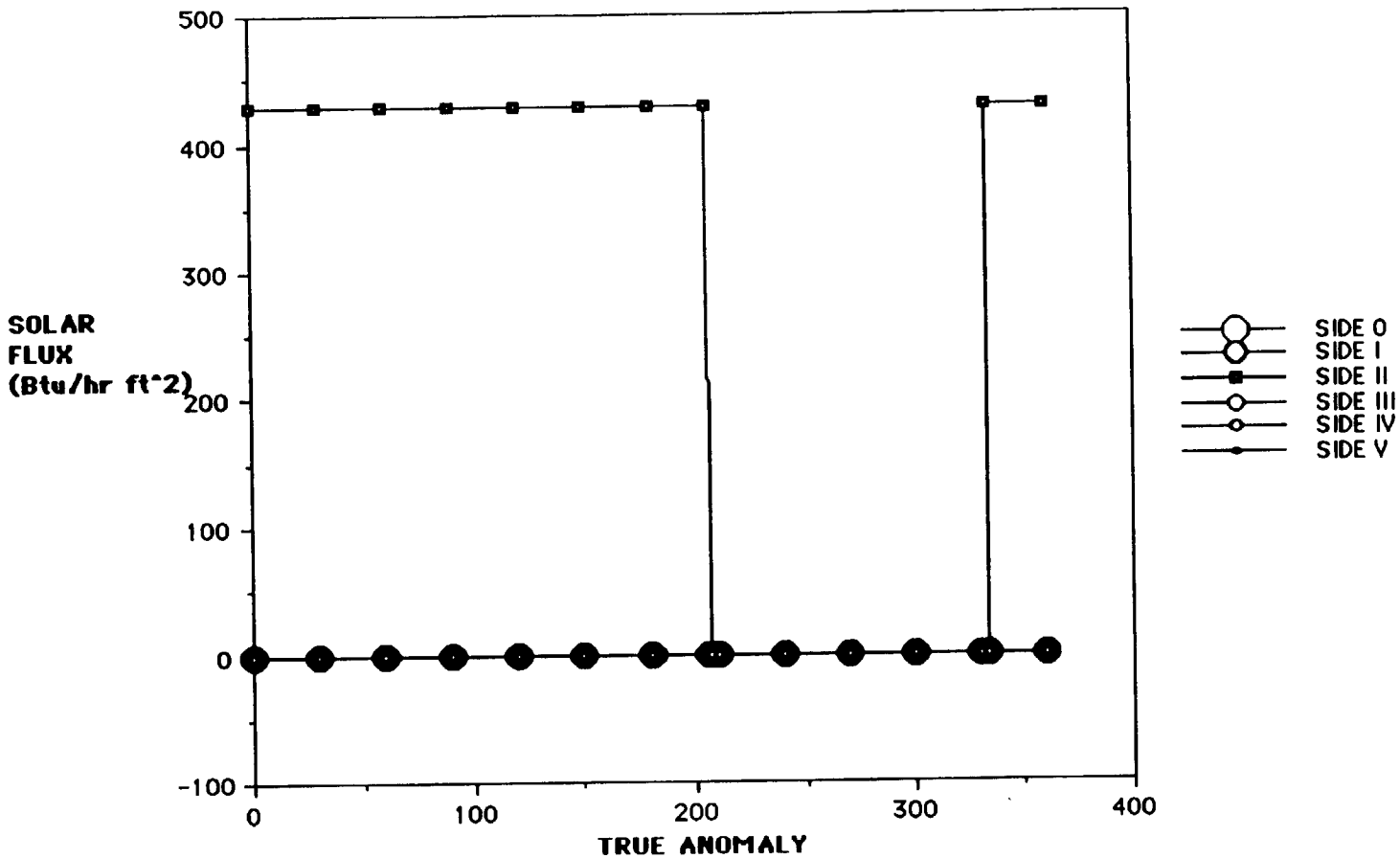
CASE III: PLANETARY FLUX

ALTITUDE=300nmi
BETA=0°
SUN ORIENTED



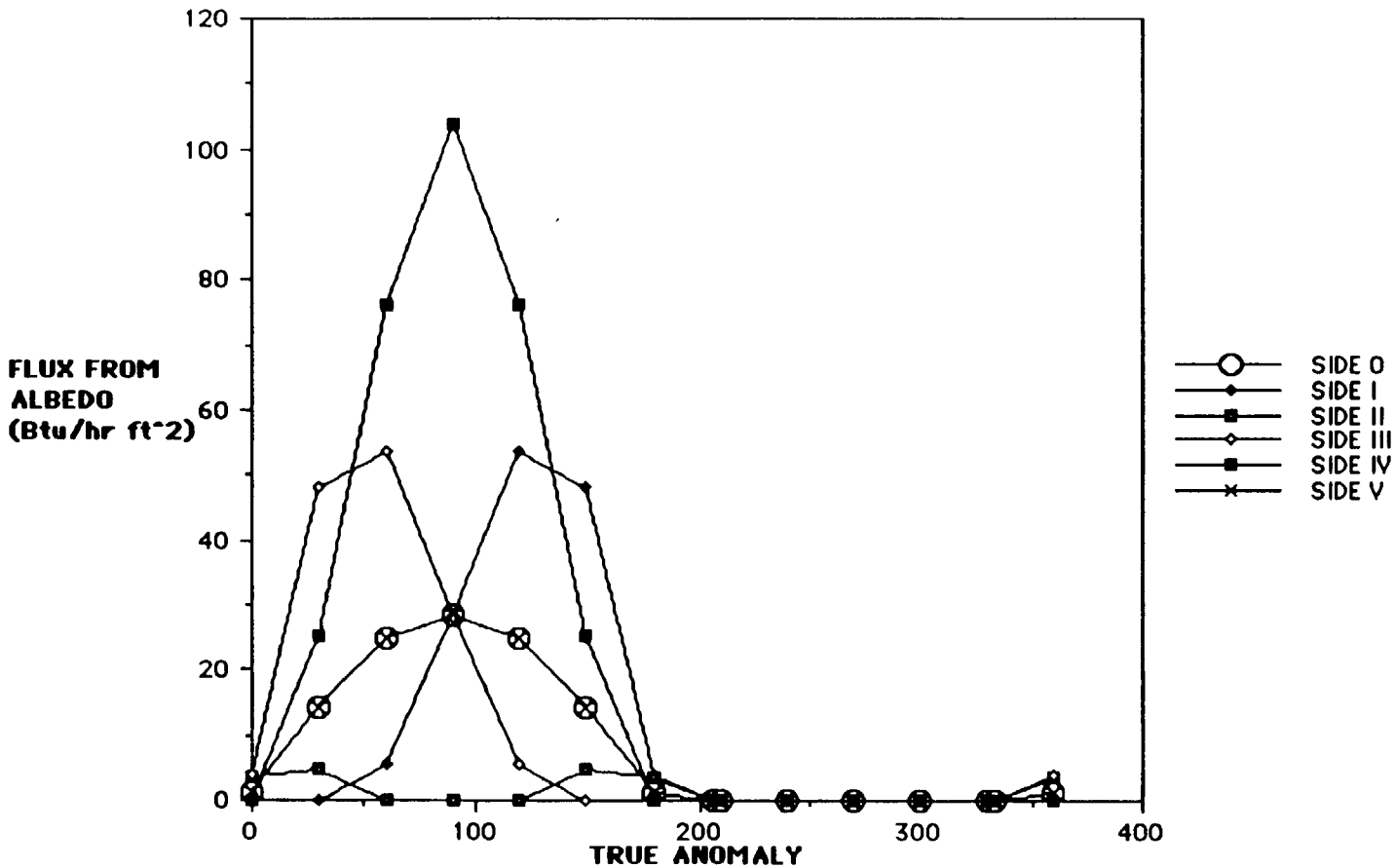
CASE IV: TOTAL FLUX

ALTITUDE=400nmi
BETA=0°
SUN ORIENTED



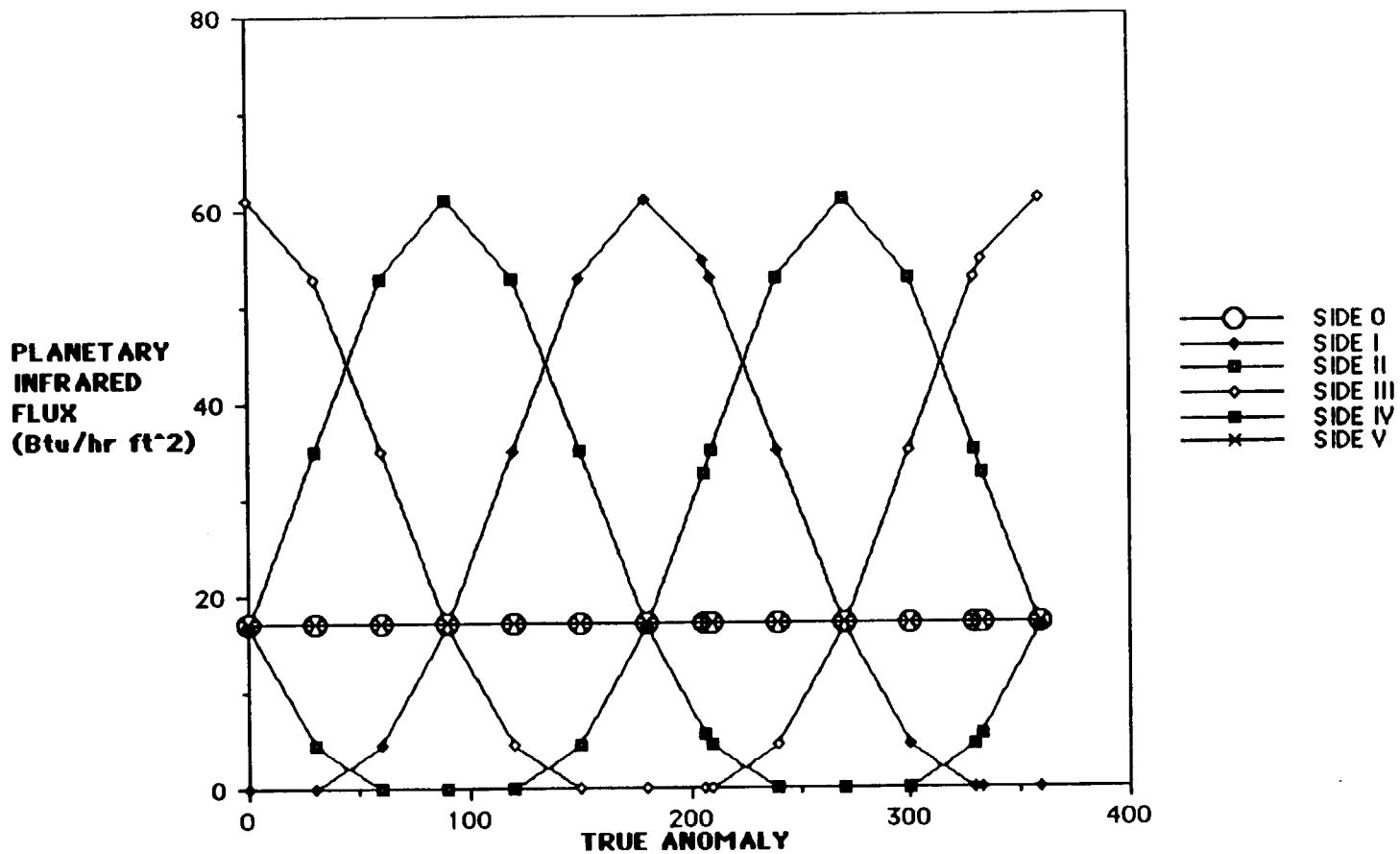
CASE IV: SOLAR FLUX

ALTITUDE=400nmi
BETA=0°
SUN ORIENTED



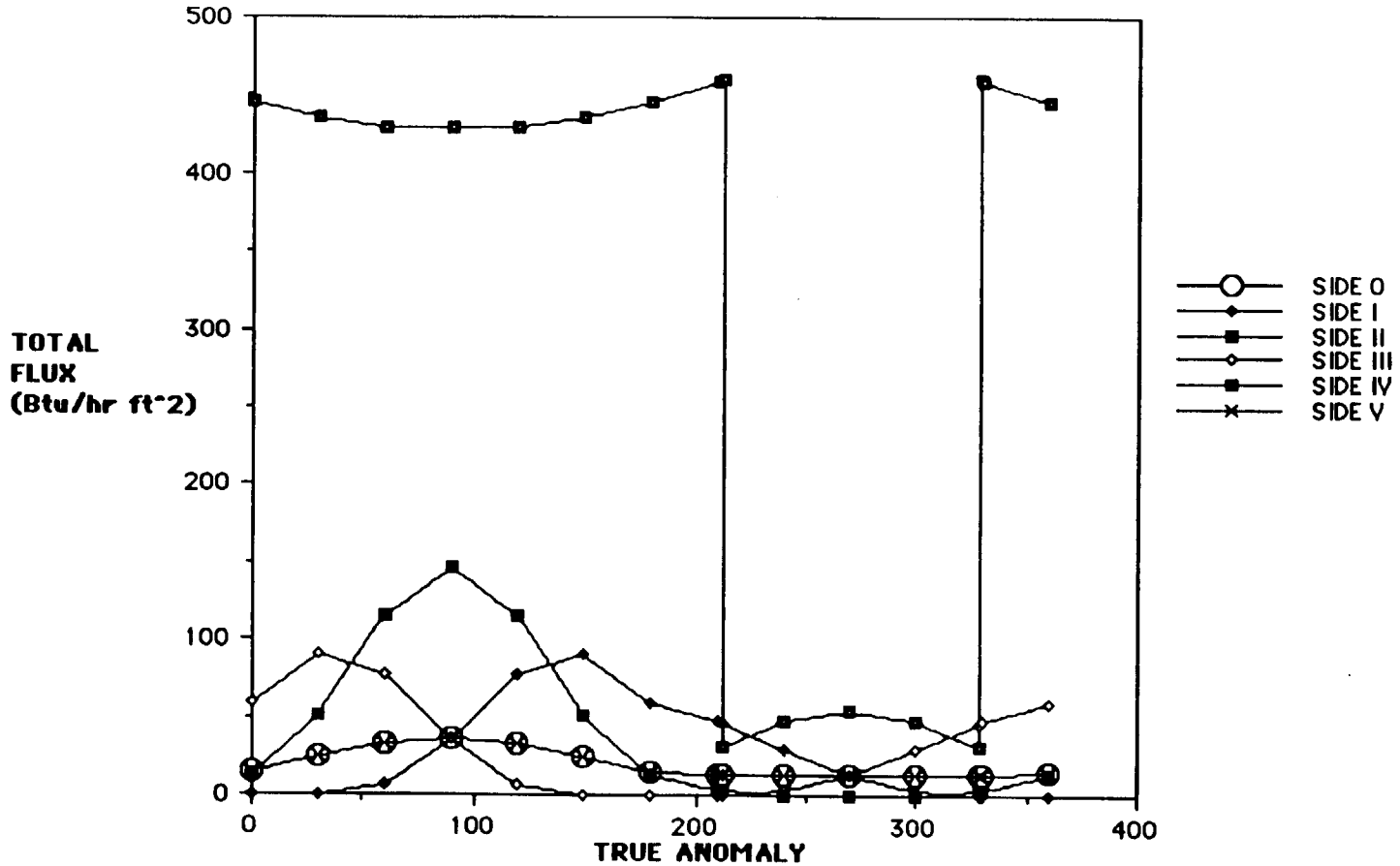
CASE IV: ALBEDO FLUX

ALTITUDE=400nmi
BETA=0°
SUN ORIENTED



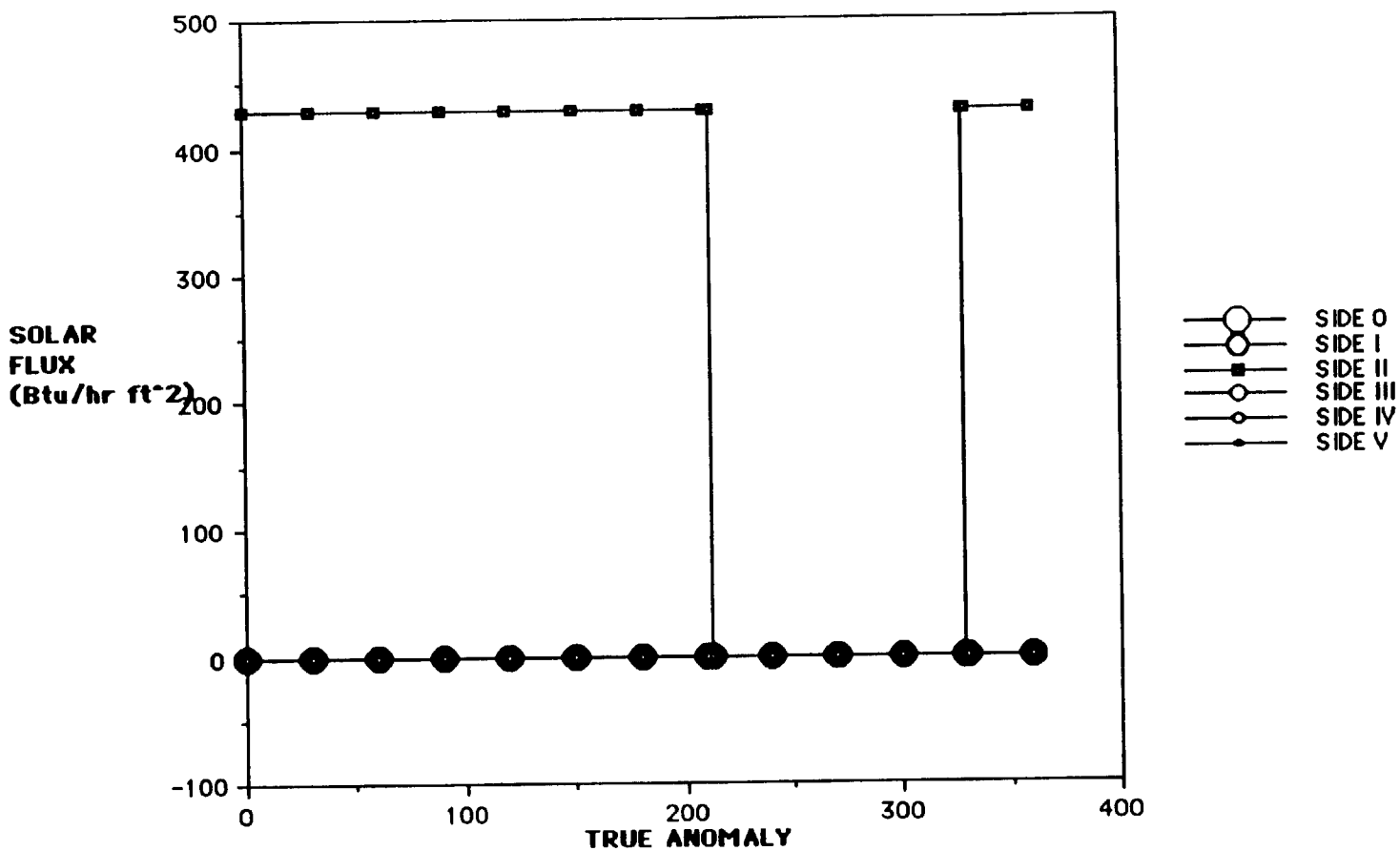
CASE IV: PLANETARY FLUX

ALTITUDE=400nmi
BETA=0°
SUN ORIENTED



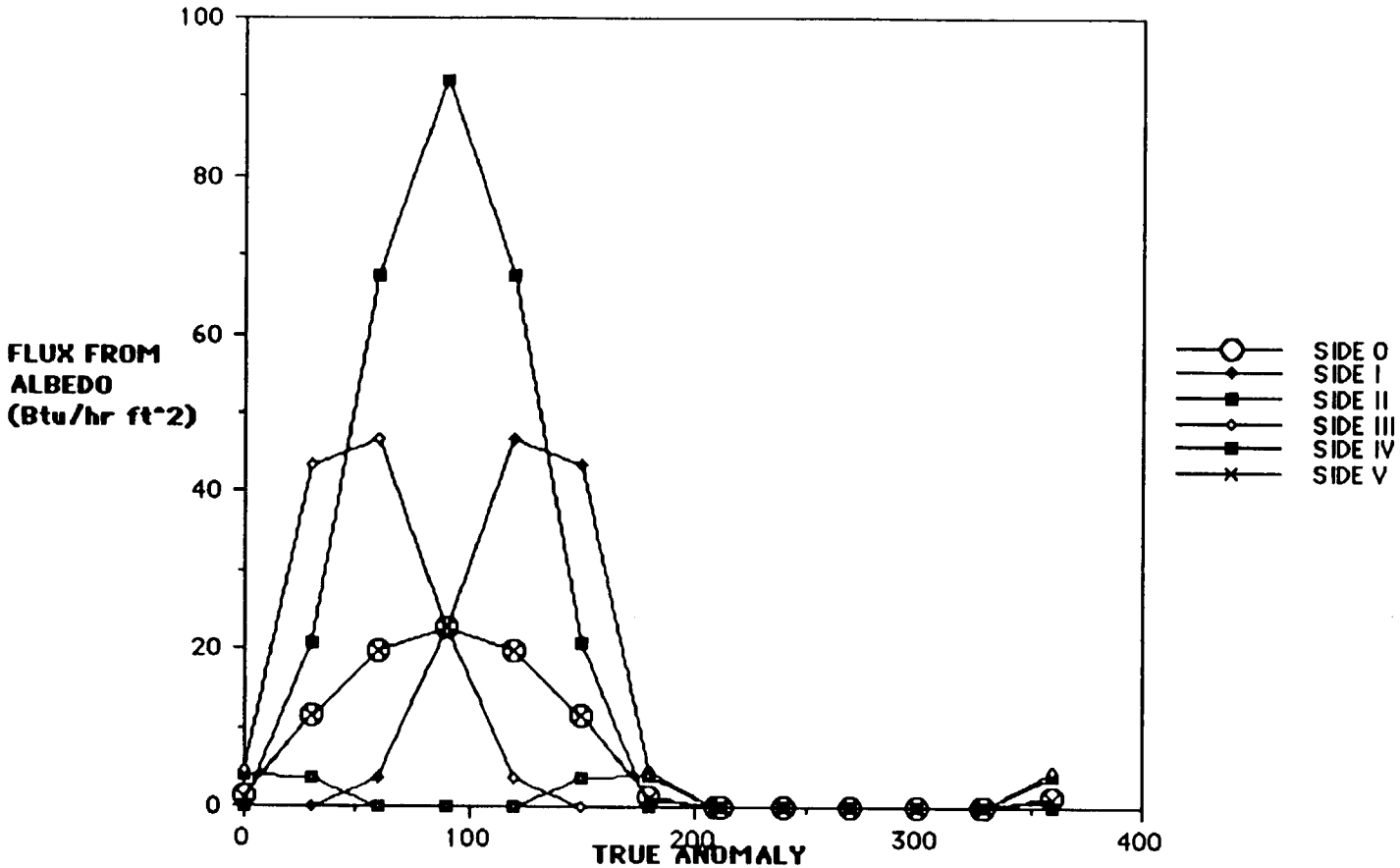
CASE V: TOTAL FLUX

ALTITUDE=600nmi
BETA=0°
SUN ORIENTED



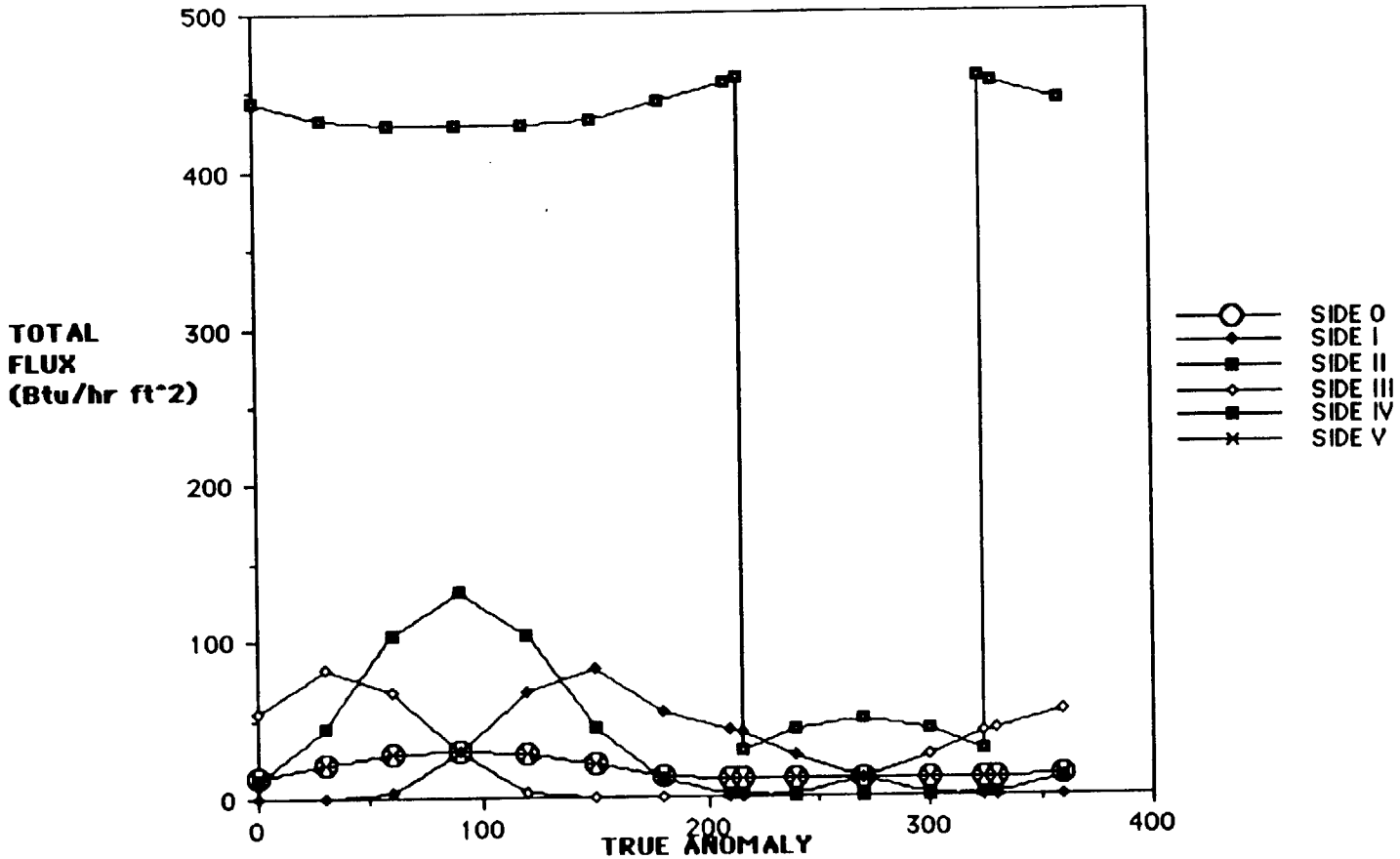
CASE V: SOLAR FLUX

ALTITUDE=600nmi
BETA=0°
SUN ORIENTED



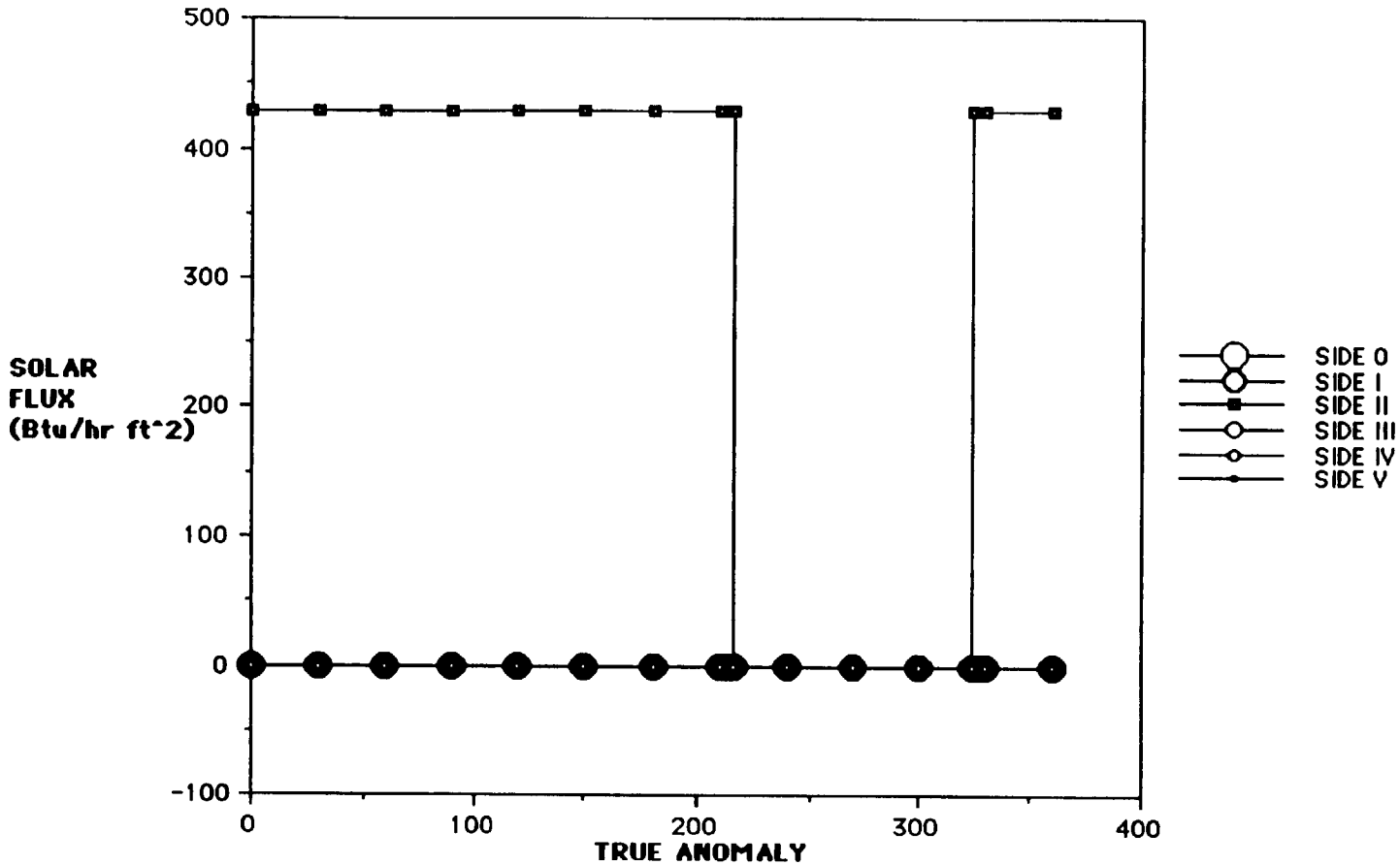
CASE V: ALBEDO FLUX

ALTITUDE=600nmi
BETA=0°
SUN ORIENTED



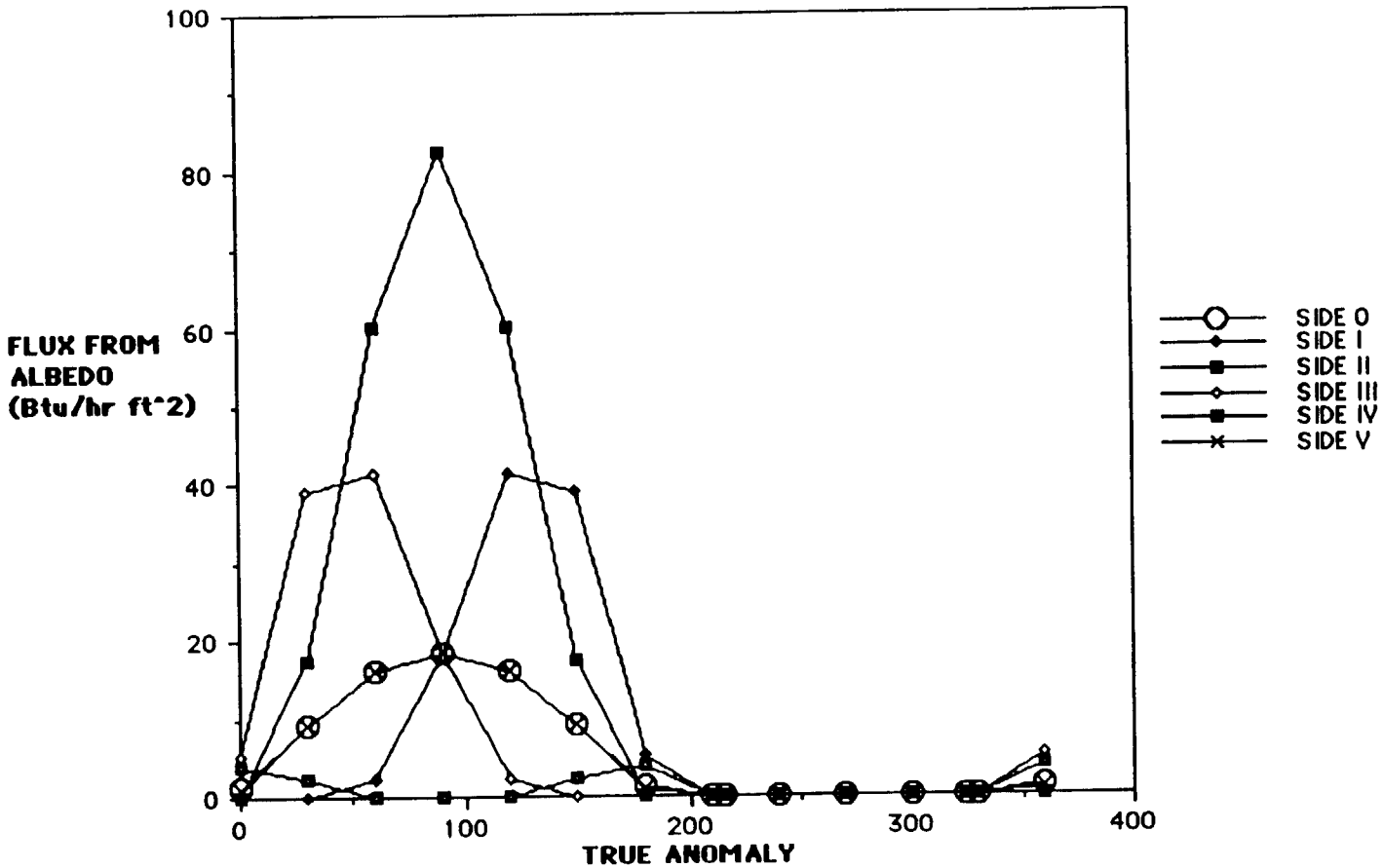
CASE VI: TOTAL FLUX

ALTITUDE=800nmi
BETA=0°
SUN ORIENTED



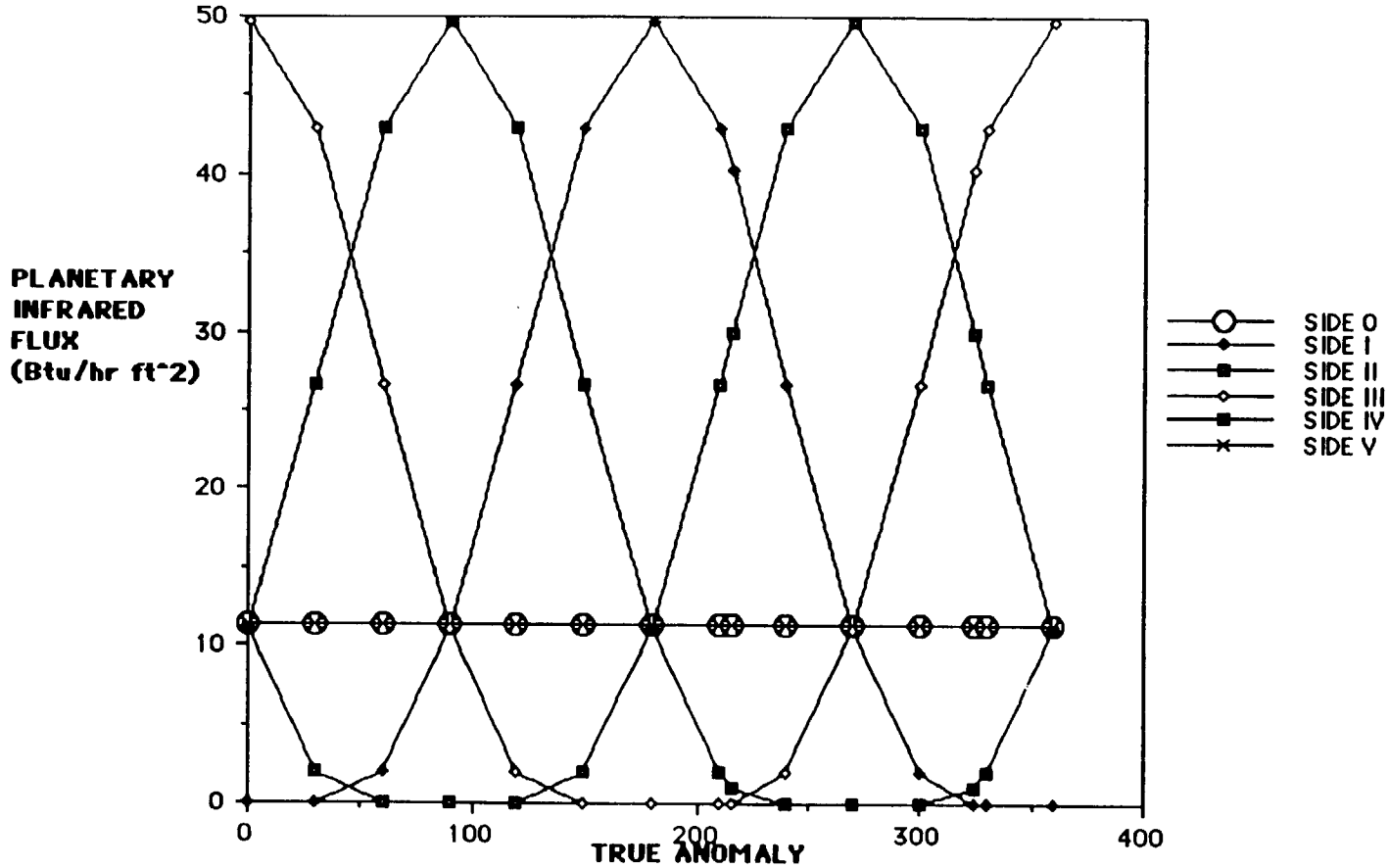
CASE VI: SOLAR FLUX

ALTITUDE=800nmi
BETA=0°
SUN ORIENTED



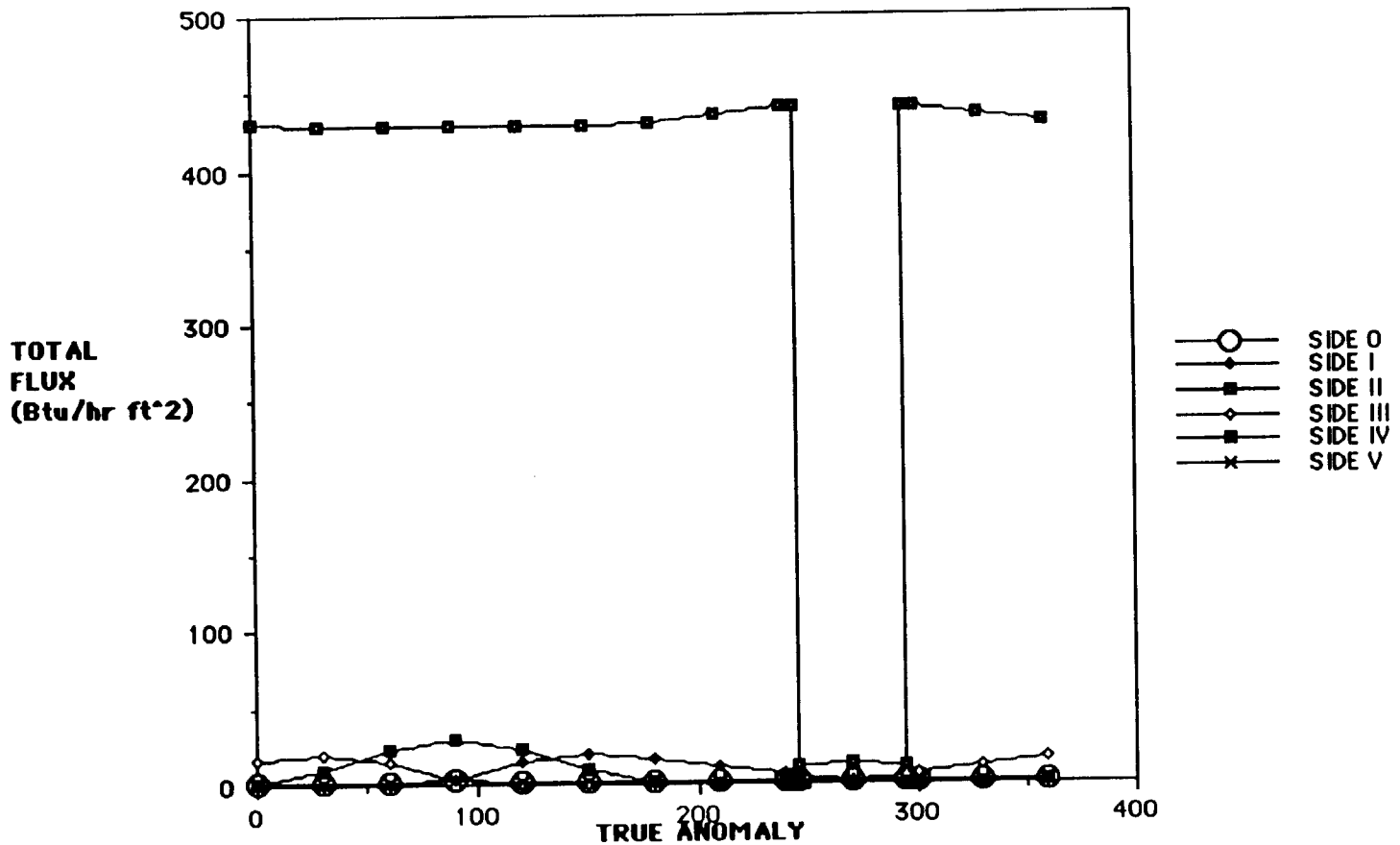
CASE VI: ALBEDO FLUX

ALTITUDE=800nmi
BETA=0°
SUN ORIENTED



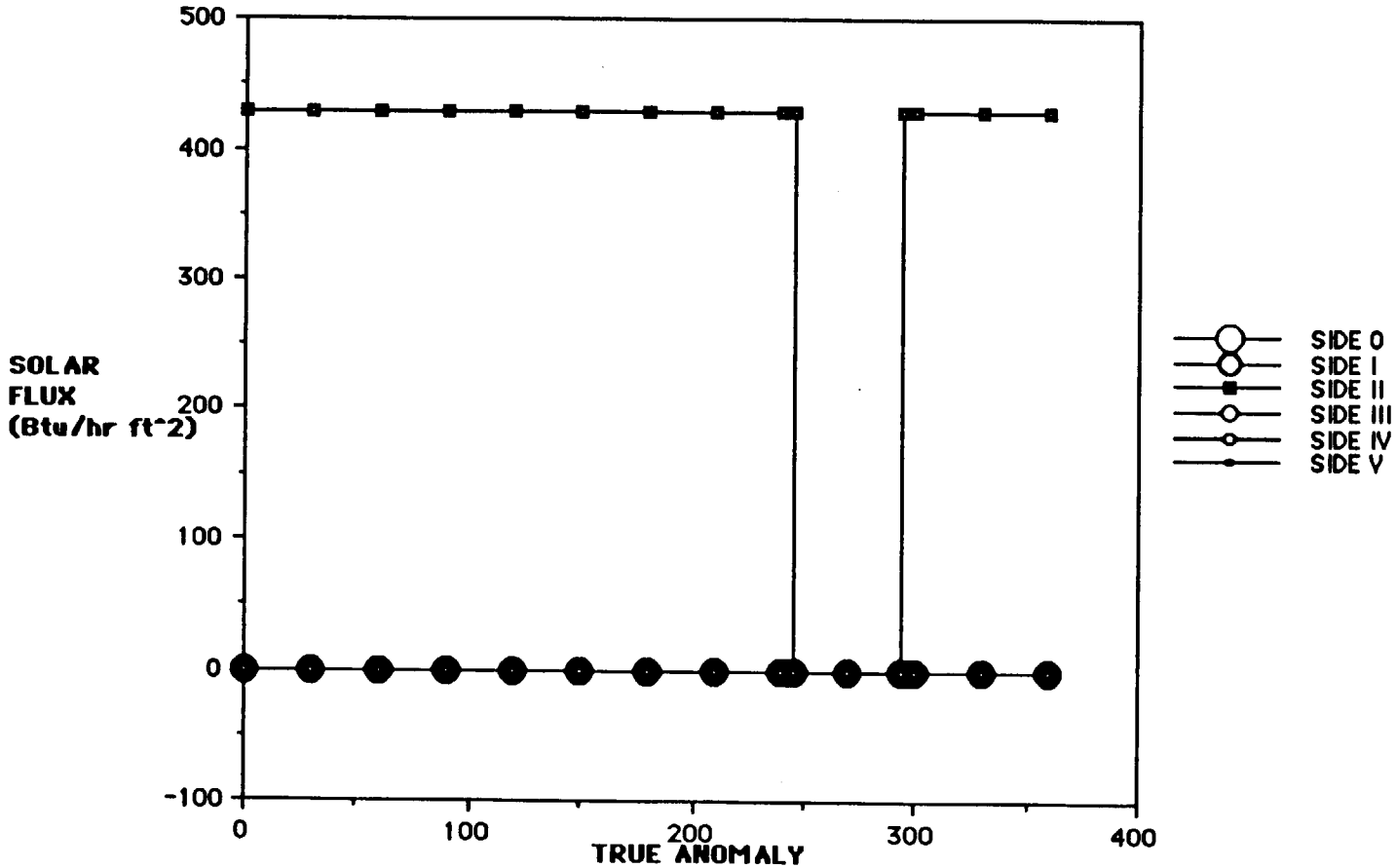
CASE VI: PLANETARY FLUX

ALTITUDE=800nmi
BETA=0°
SUN ORIENTED



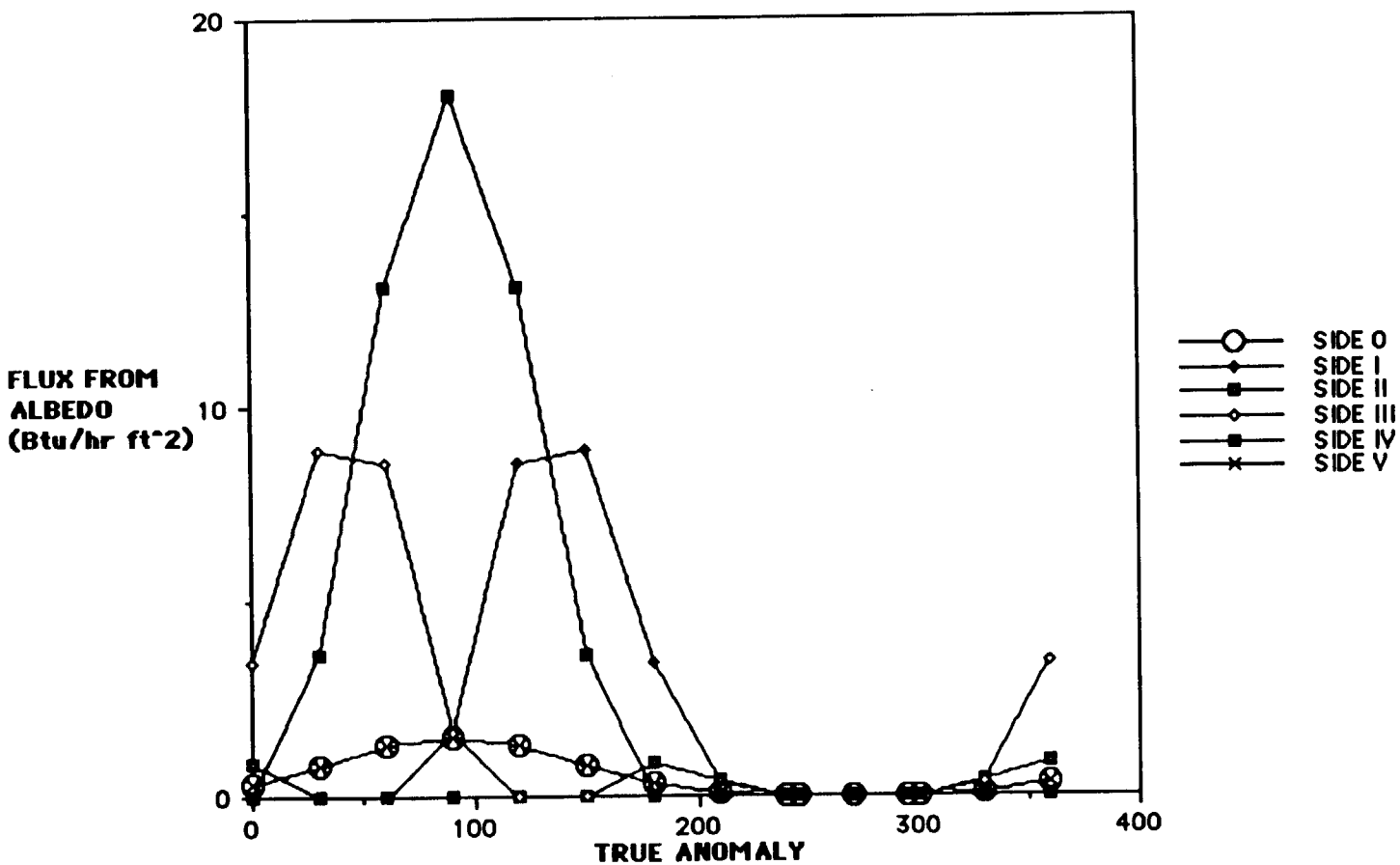
CASE VII: TOTAL FLUX

ALTITUDE=5000nmi
BETA=0°
SUN ORIENTED



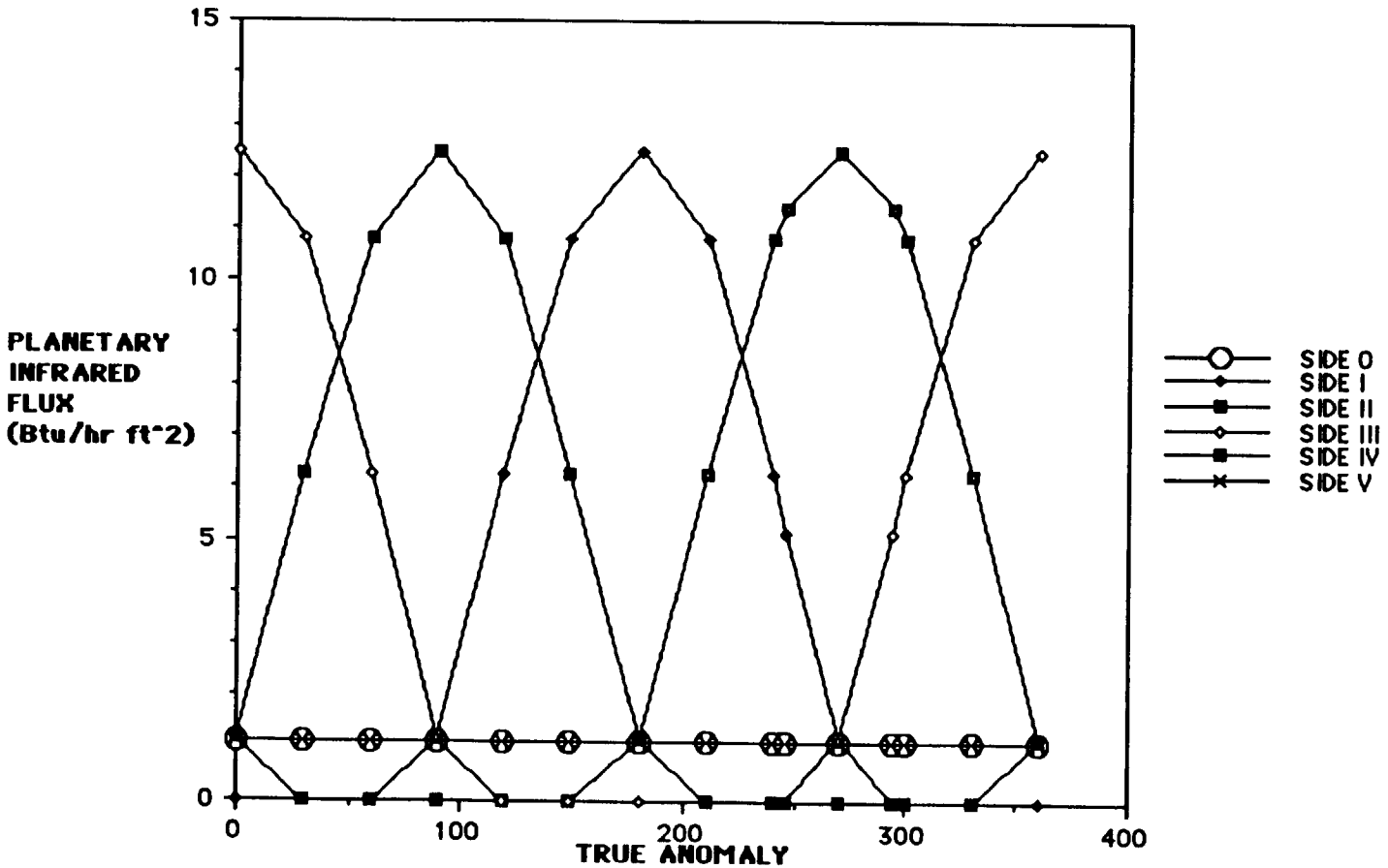
CASE VII: SOLAR FLUX

ALTITUDE=5000nmi
BETA=0°
SUN ORIENTED



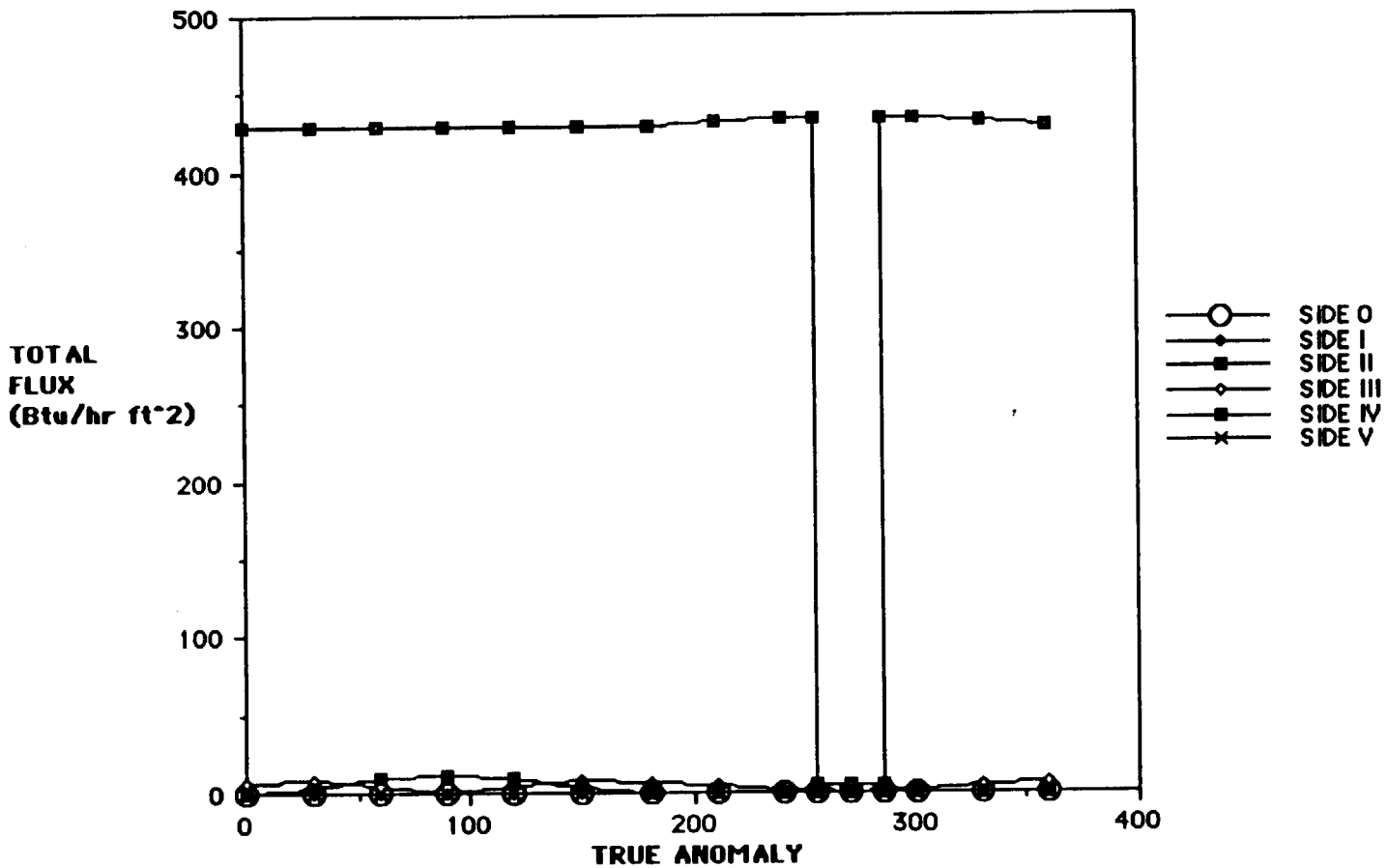
CASE VII: ALBEDO FLUX

ALTITUDE=5000nmi
BETA=0°
SUN ORIENTED



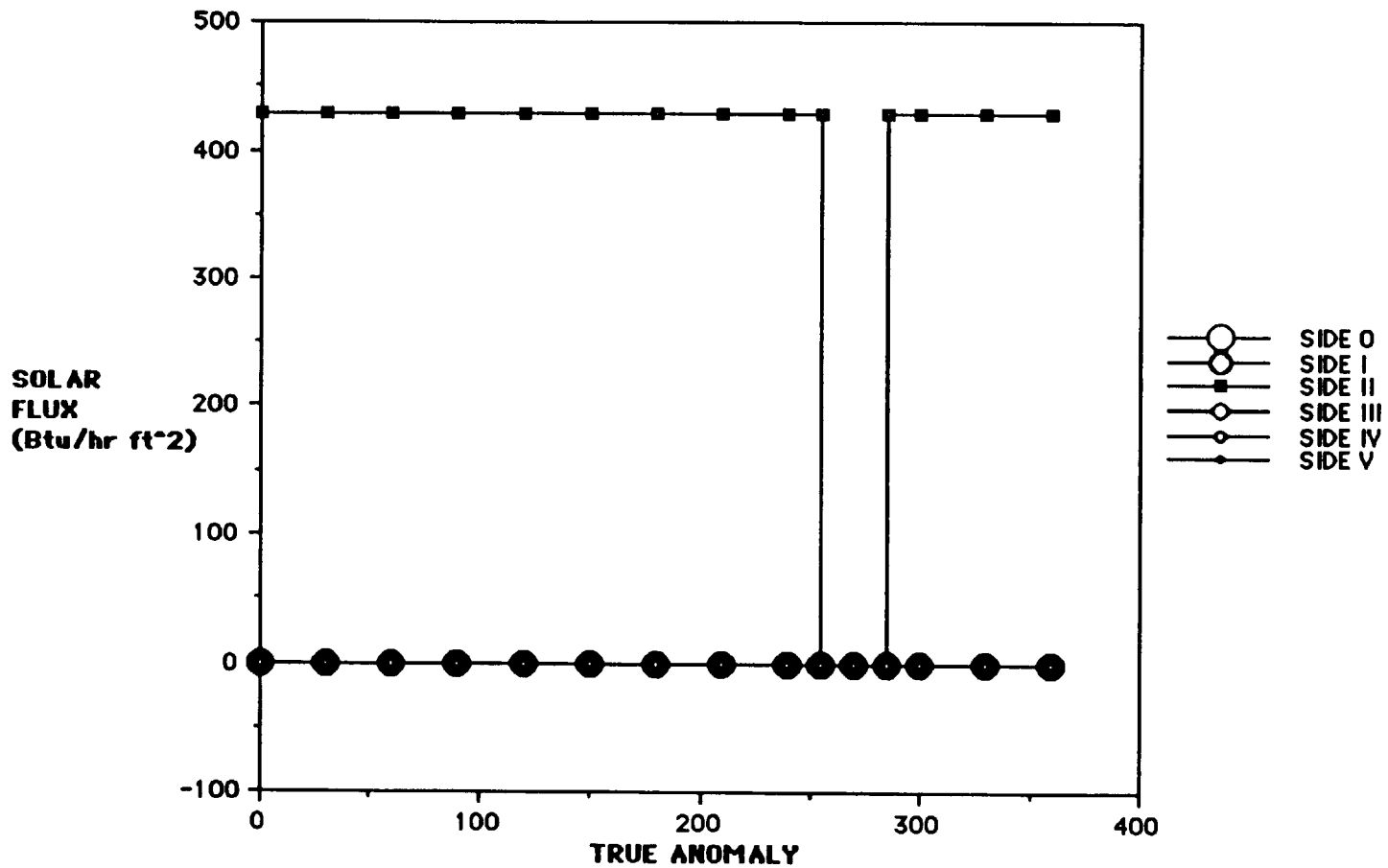
CASE VII: PLANETARY FLUX

ALTITUDE=5000nmi
BETA=0°
SUN ORIENTED



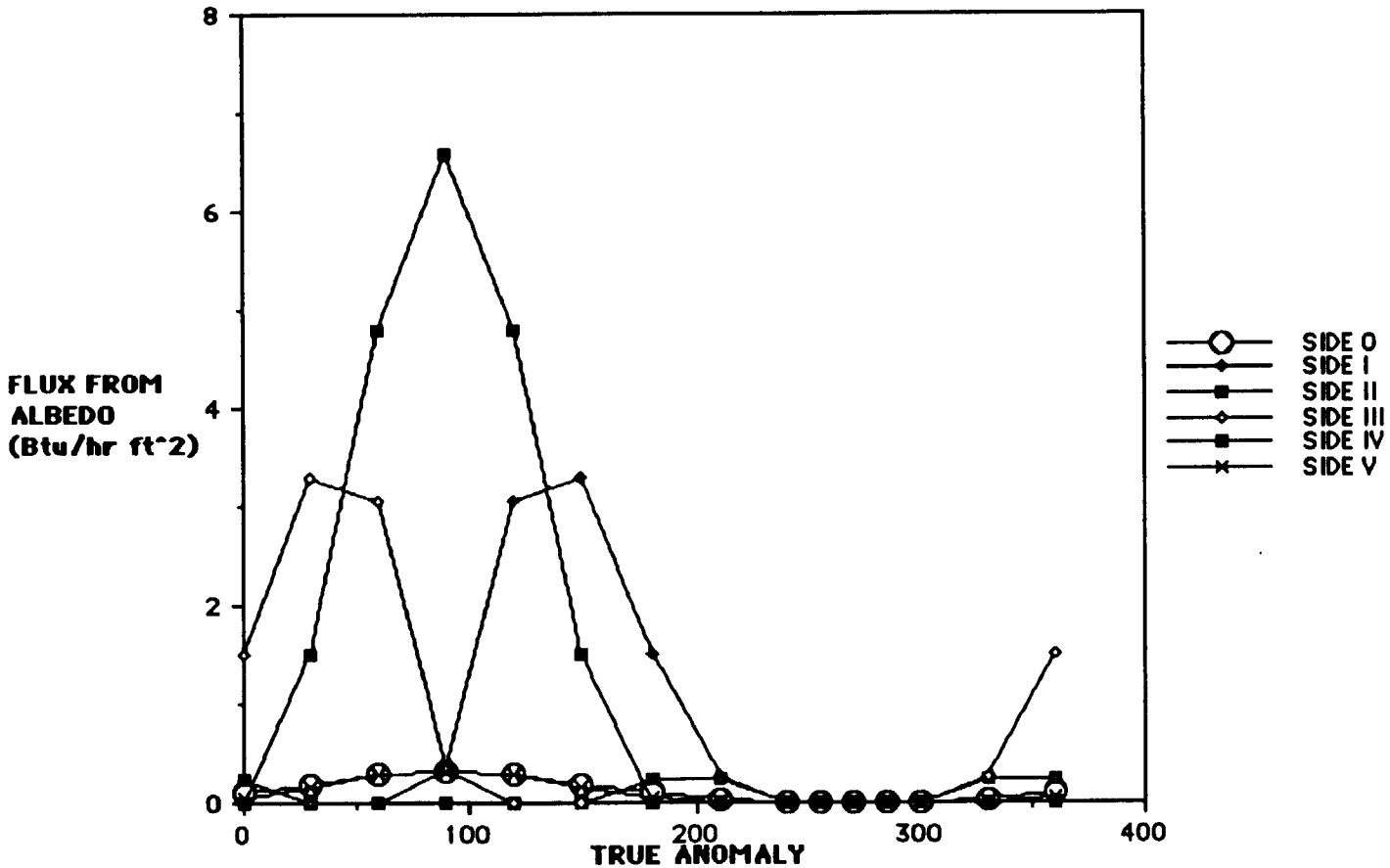
CASE VIII: TOTAL FLUX

ALTITUDE=10000nmi
BETA=0°
SUN ORIENTED



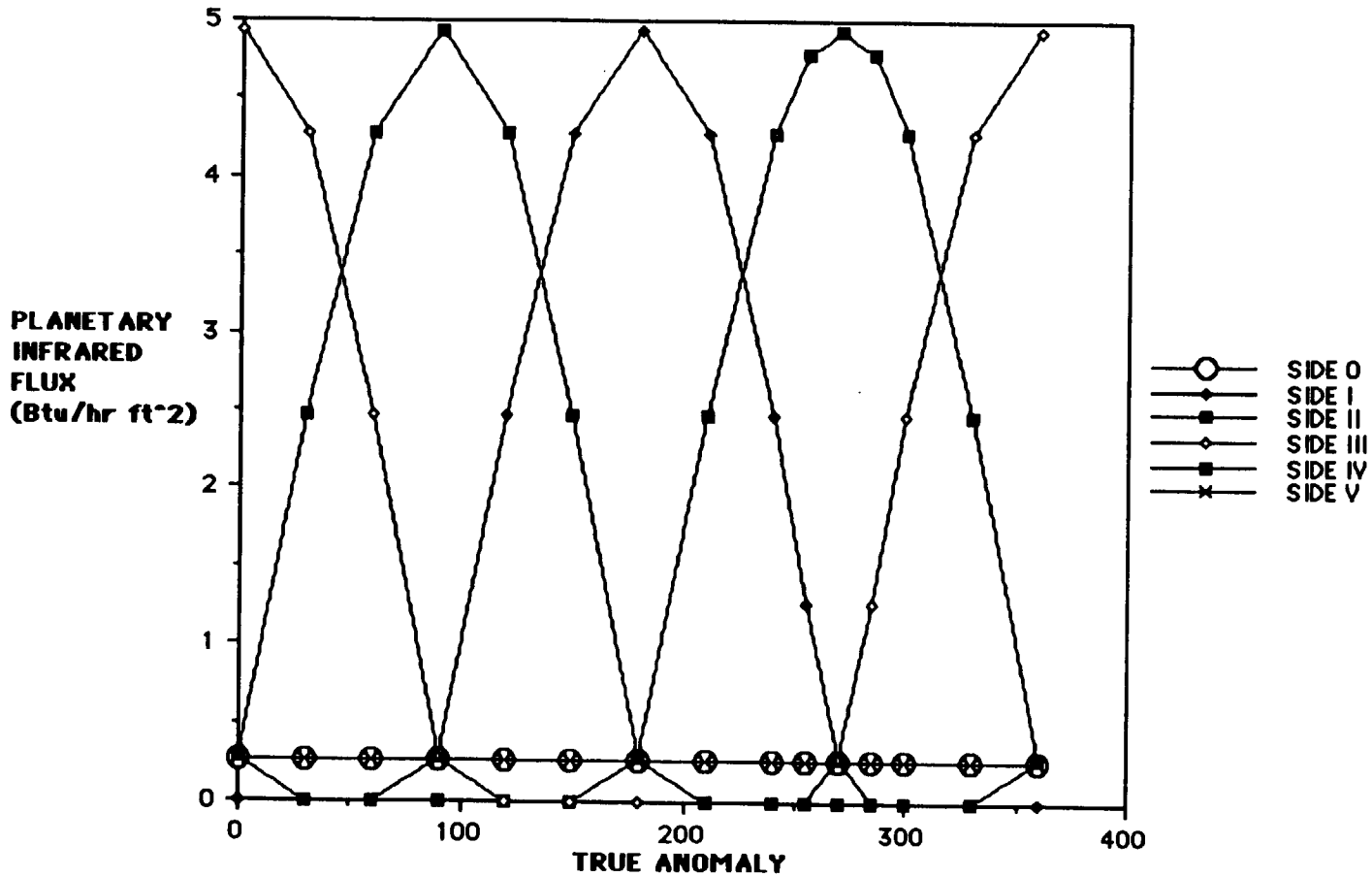
CASE VIII: SOLAR FLUX

ALTITUDE=10000nmi
BETA=0°
SUN ORIENTED



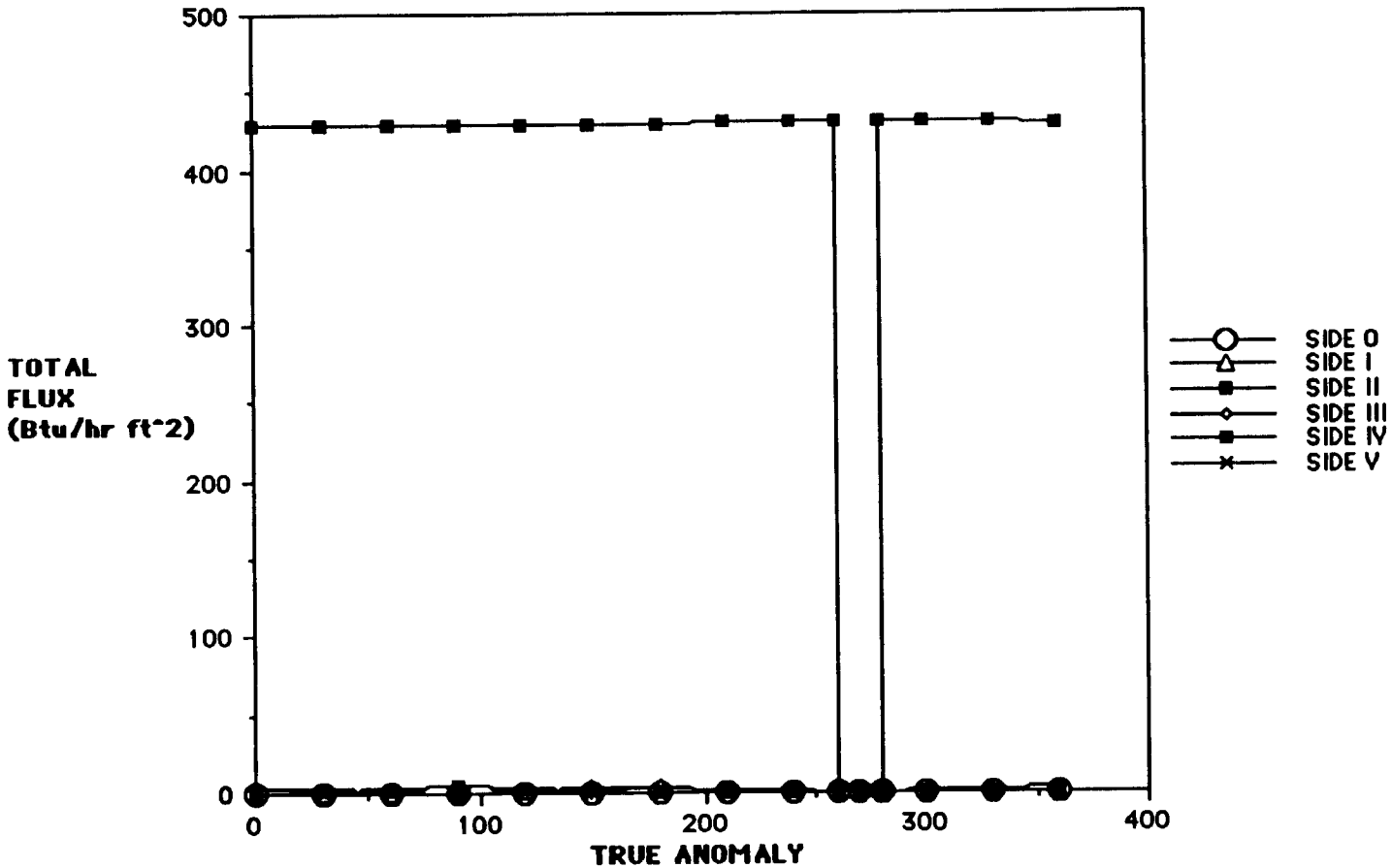
CASE VIII: ALBEDO FLUX

ALTITUDE=10000nmi
BETA=0°
SUN ORIENTED



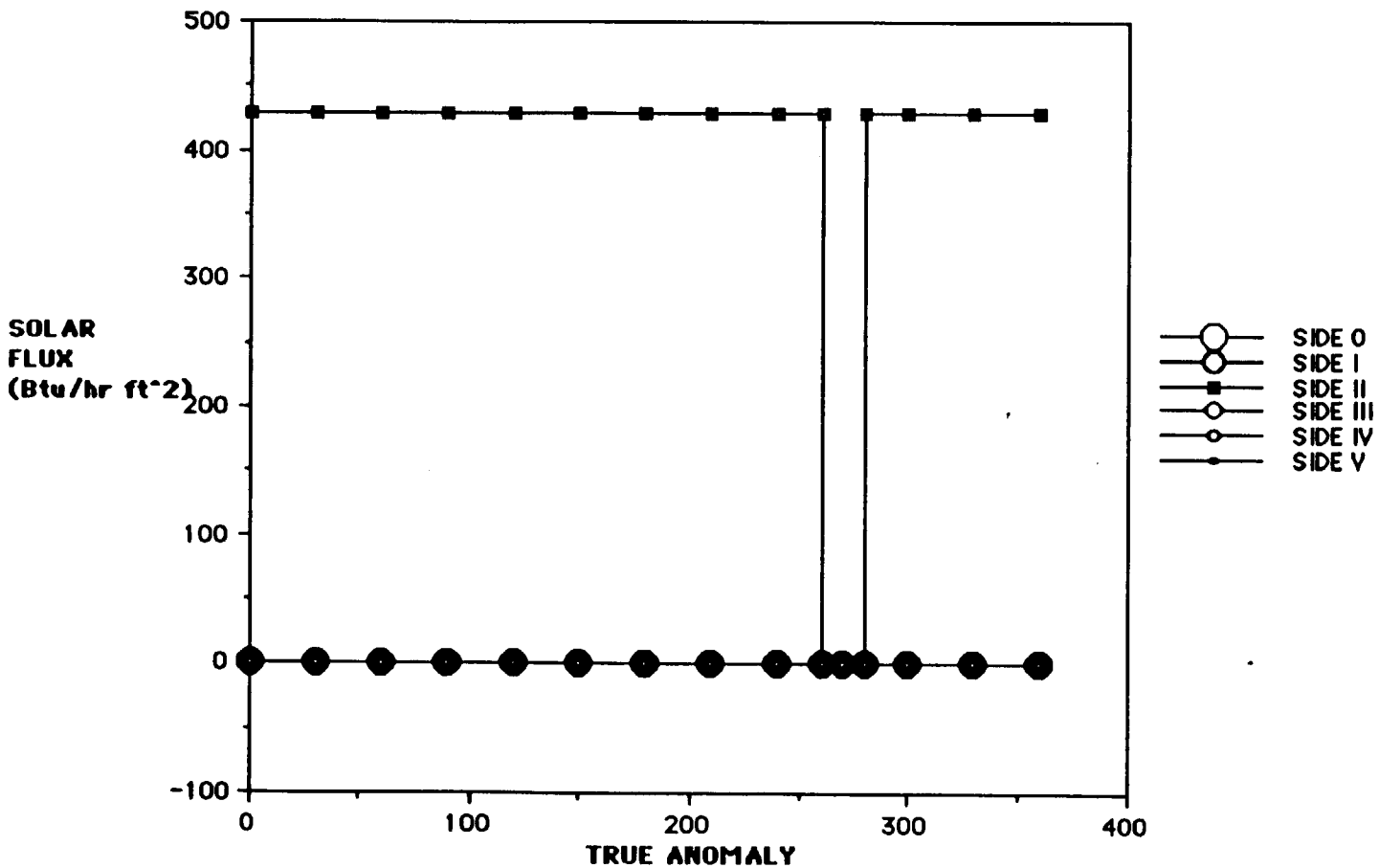
CASE VIII: PLANETARY FLUX

ALTITUDE=10000nmi
BETA=0°
SUN ORIENTED



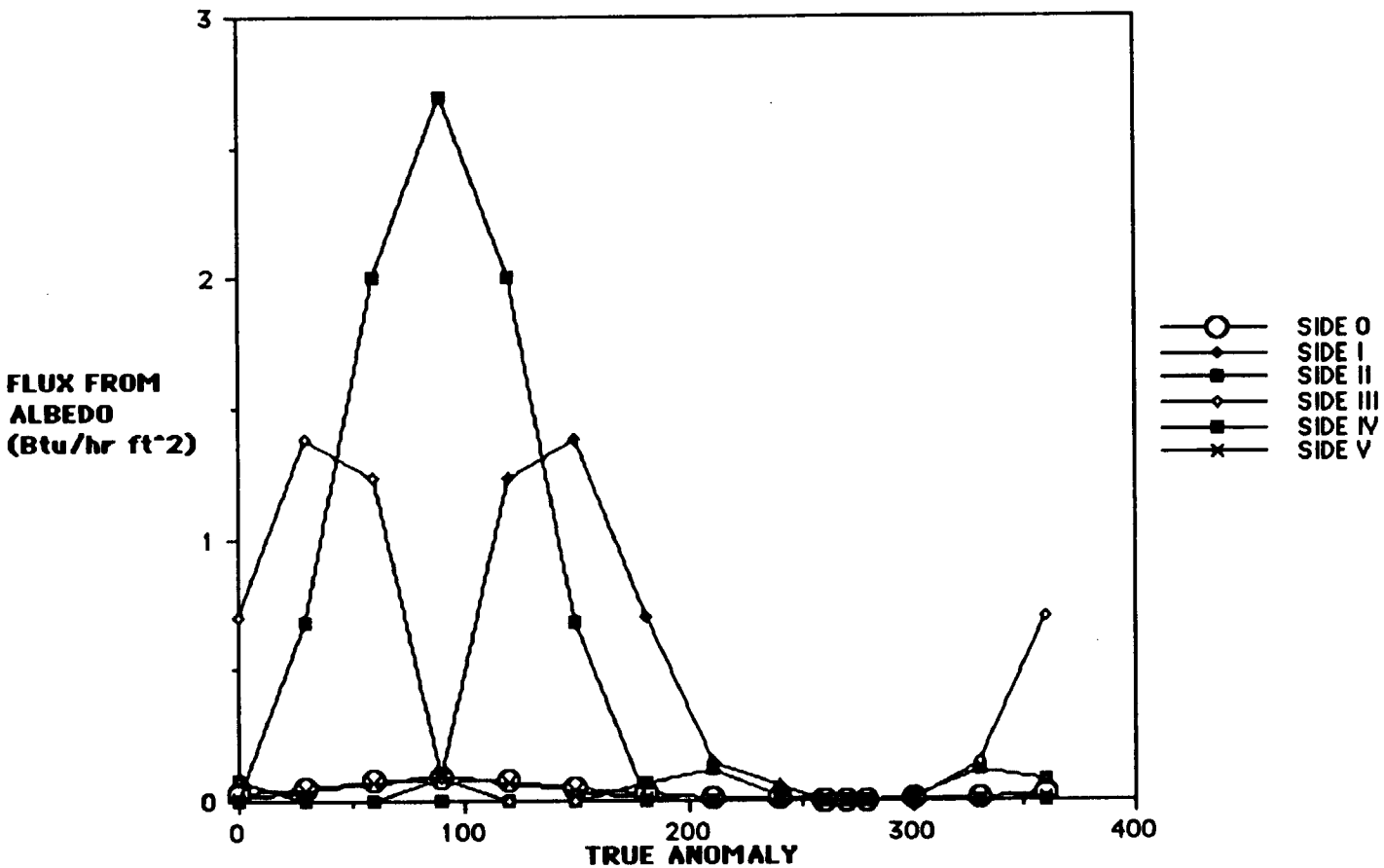
CASE IX: TOTAL FLUX

ALTITUDE=17000nmi
BETA=0°
SUN ORIENTED



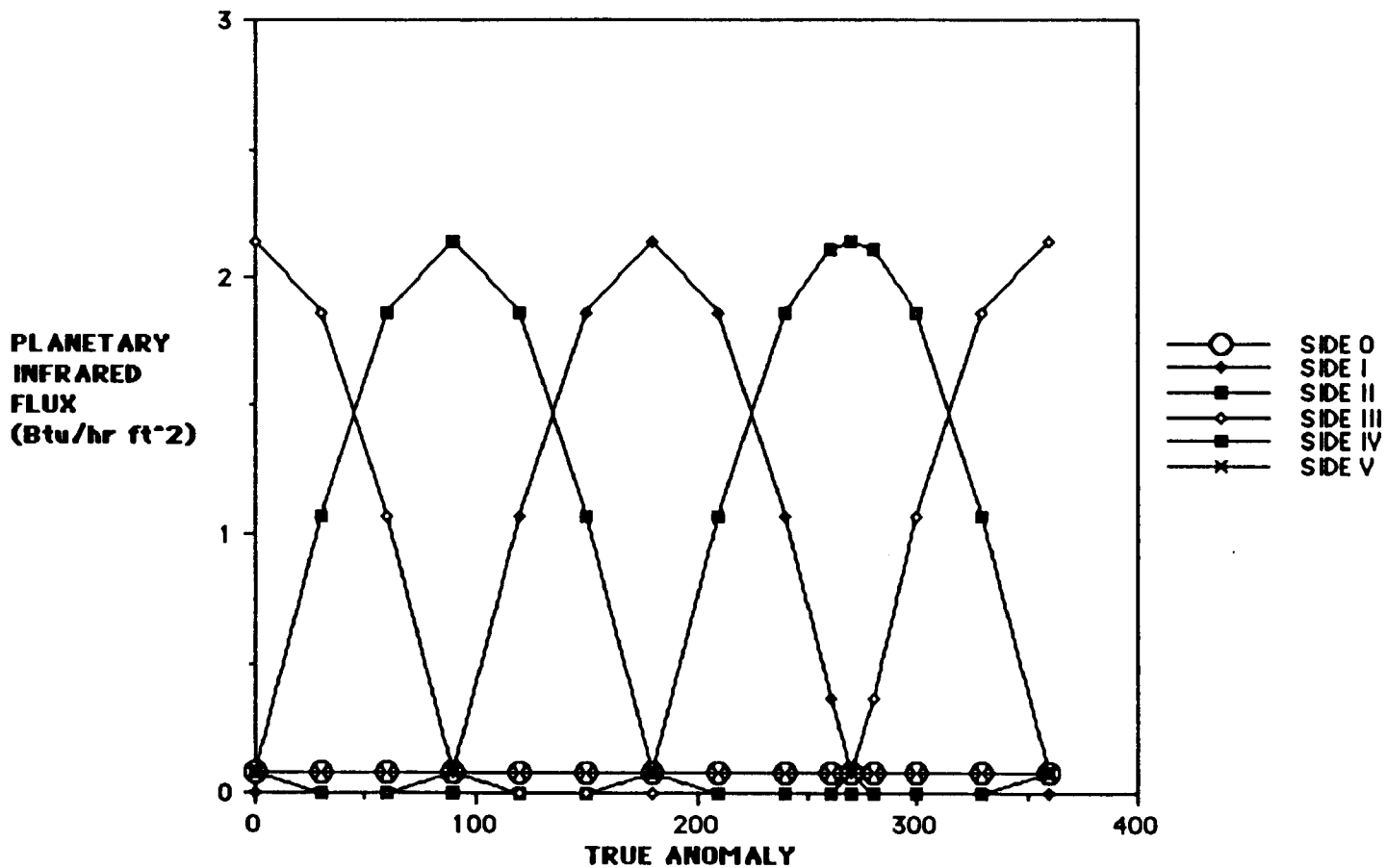
CASE IX: SOLAR FLUX

ALTITUDE=17000nmi
BETA=0°
SUN ORIENTED



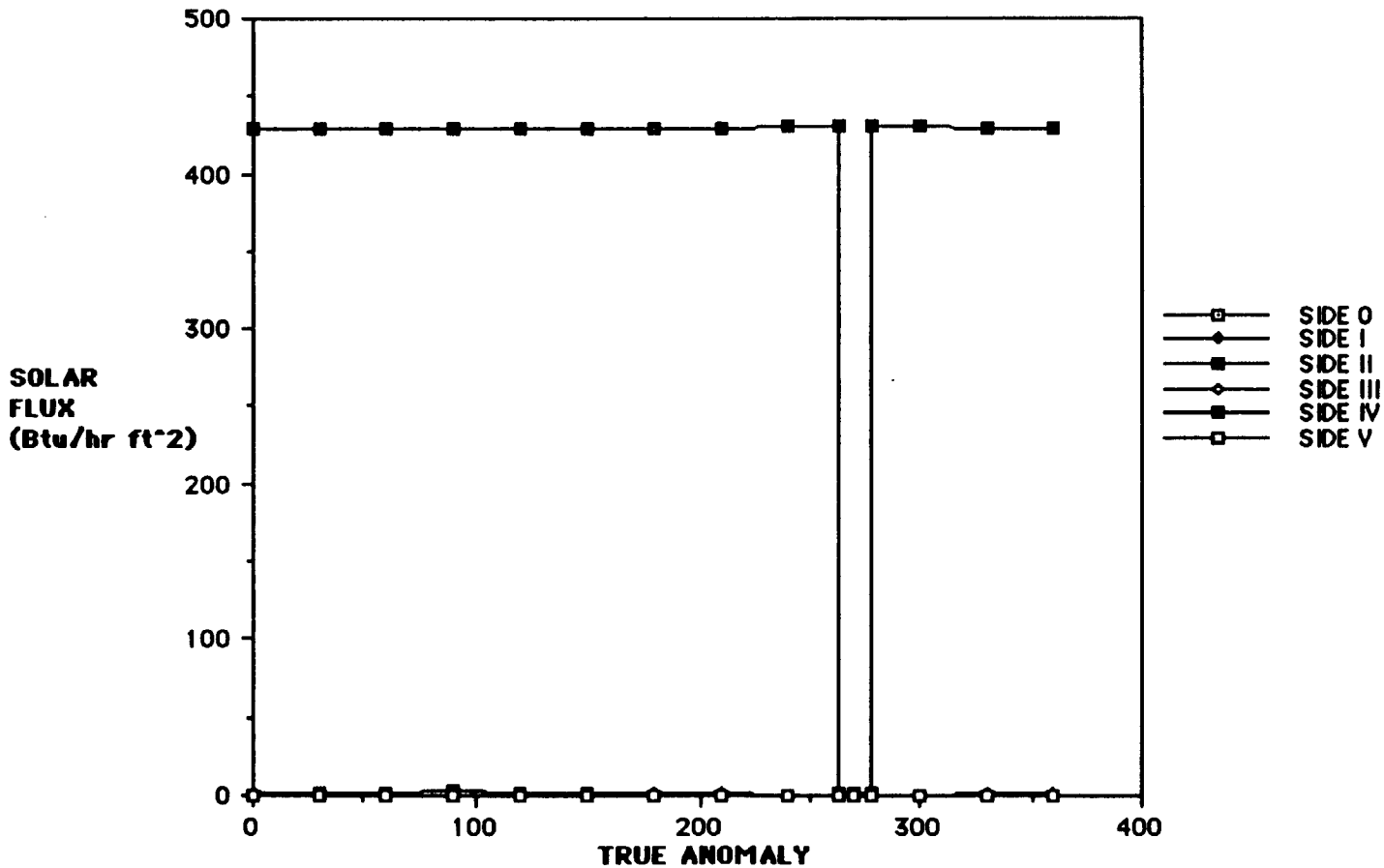
CASE IX: ALBEDO FLUX

ALTITUDE=17000nmi
BETA=0°
SUN ORIENTED



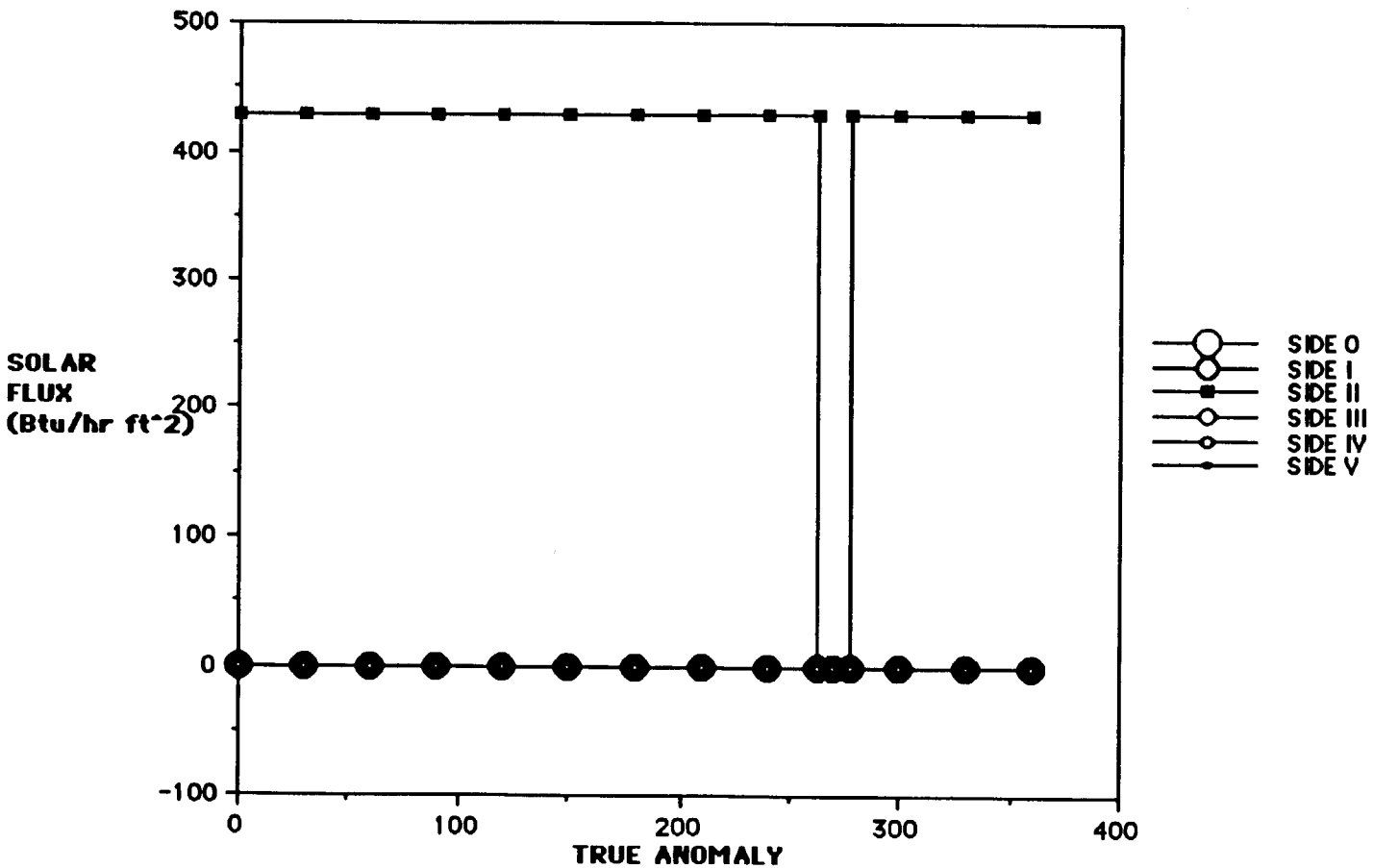
CASE IX: PLANETARY FLUX

ALTITUDE=17000nmi
BETA=0°
SUN ORIENTED



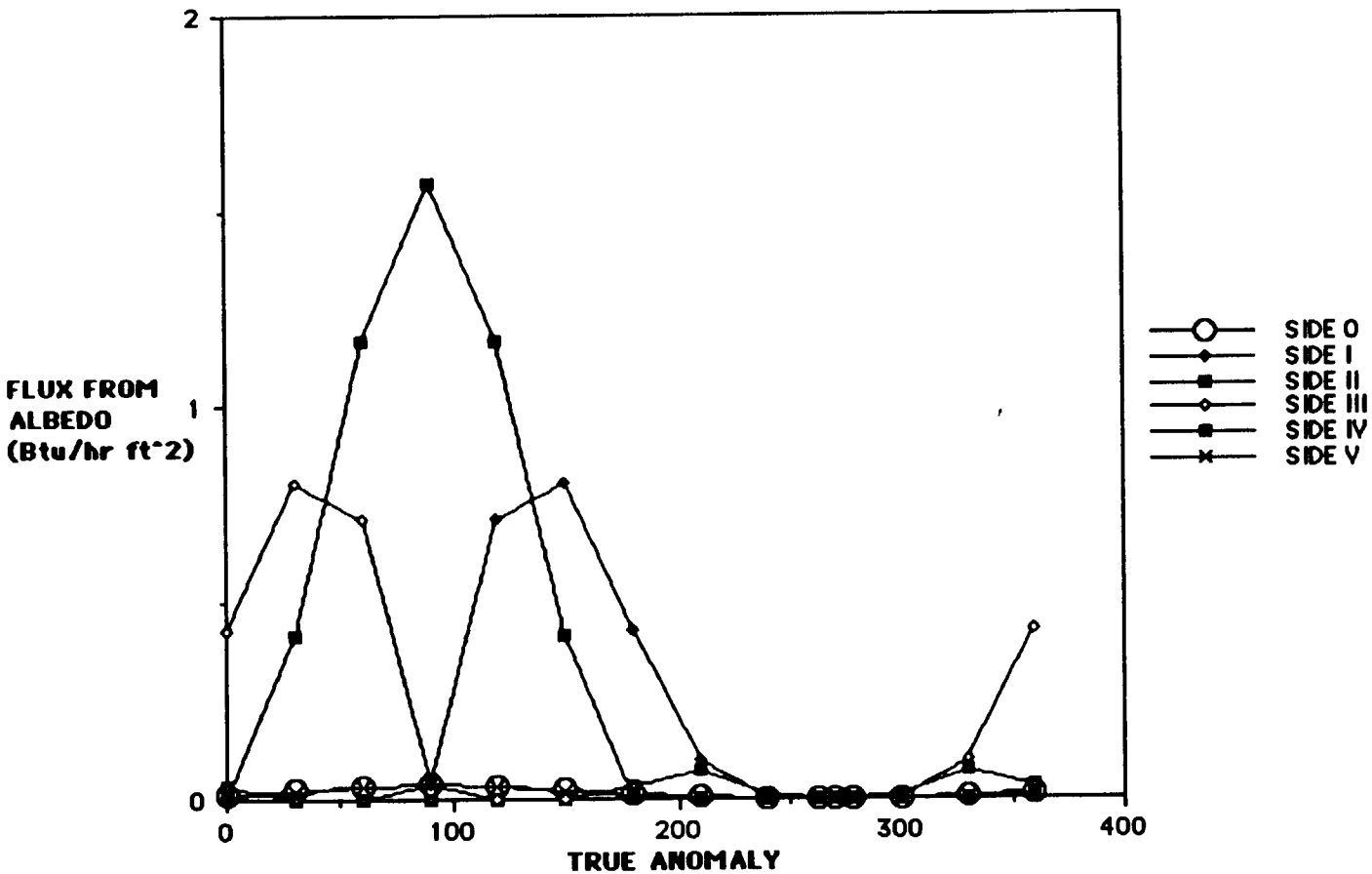
CASE X: TOTAL FLUX

ALTITUDE=23000nmi
BETA=0°
SUN ORIENTED



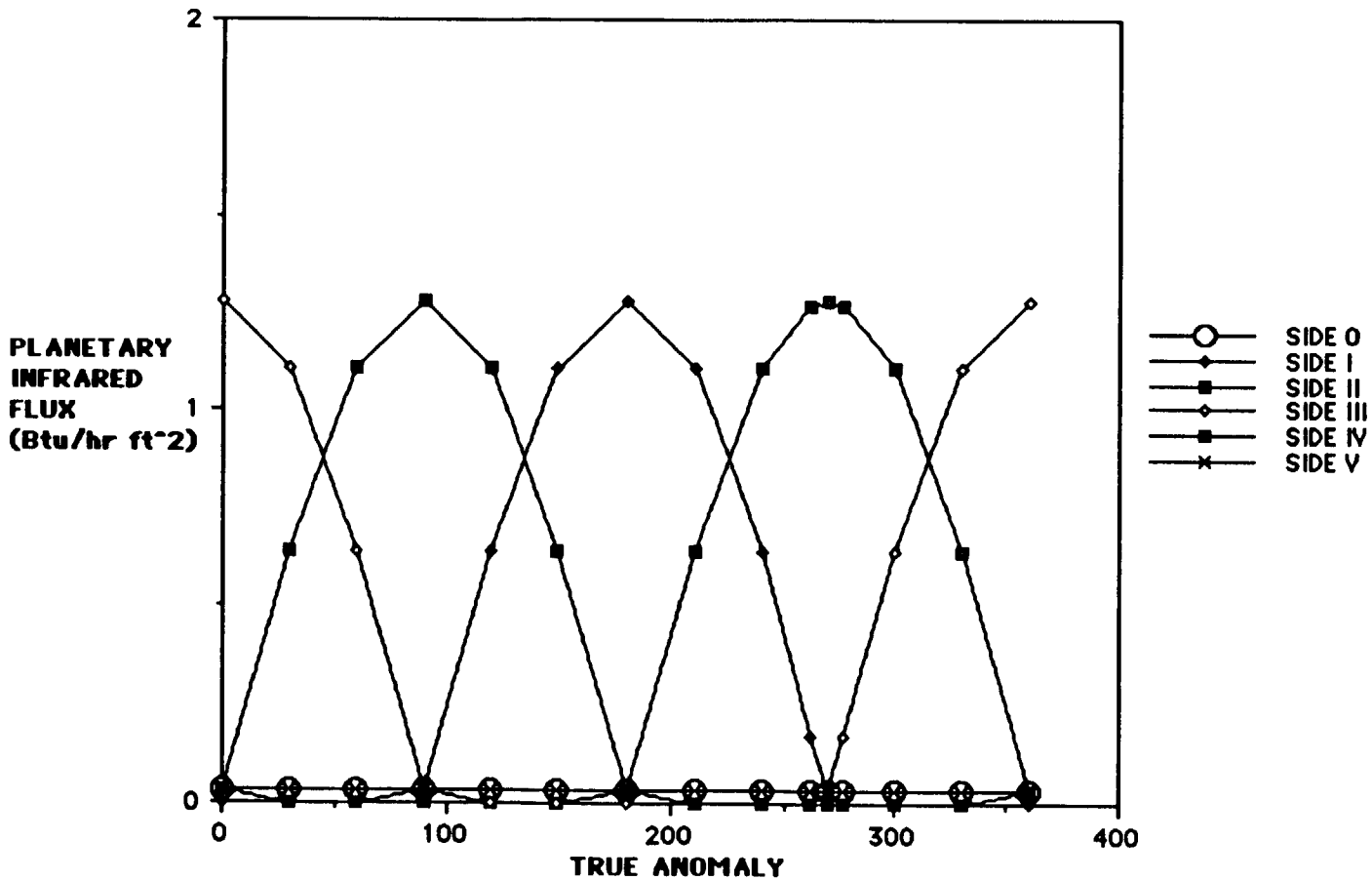
CASE X: SOLAR FLUX

ALTITUDE=23000nmi
BETA=0°
SUN ORIENTED



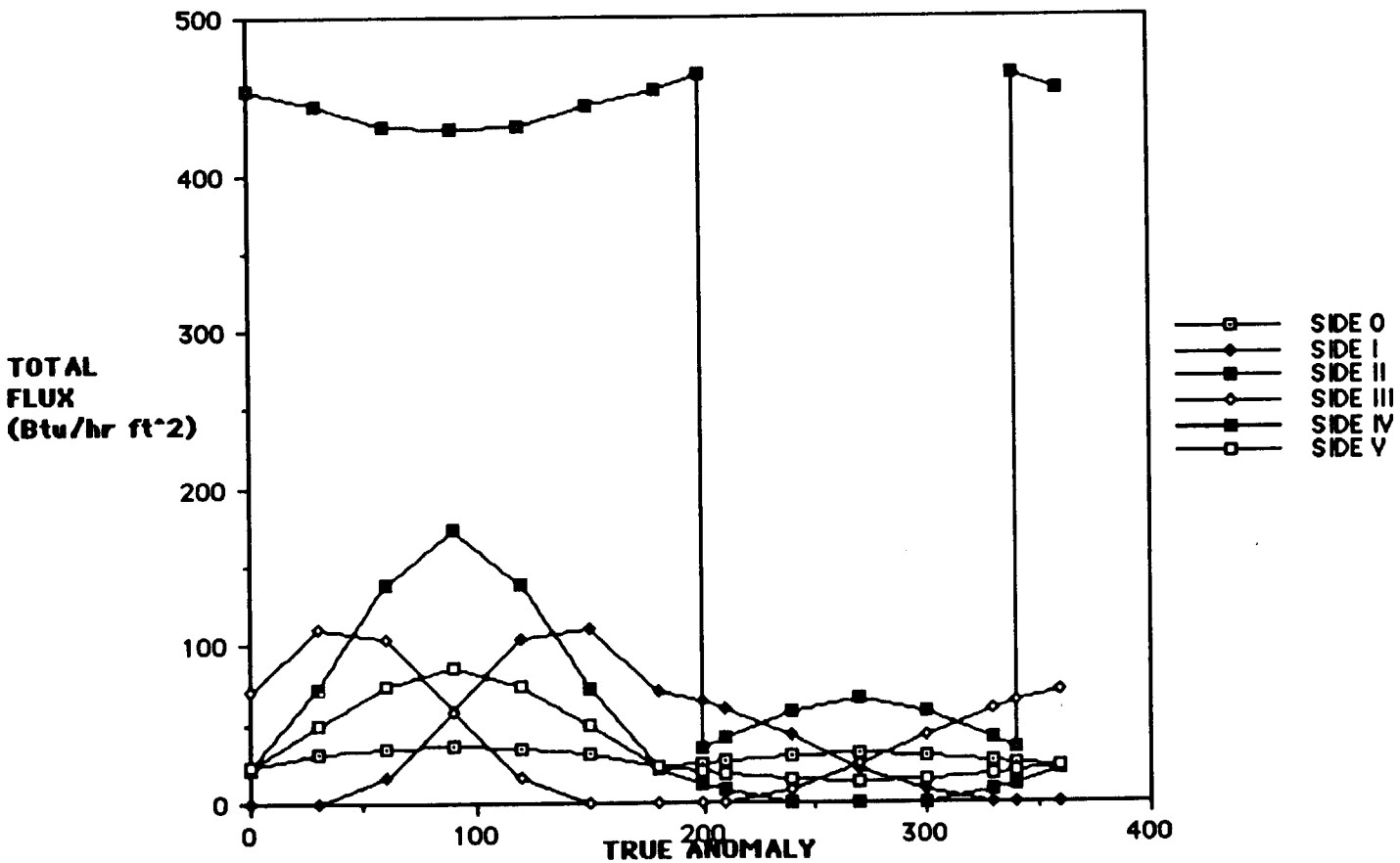
CASE X: ALBEDO FLUX

ALTITUDE=23000nmi
BETA=0°
SUN ORIENTED



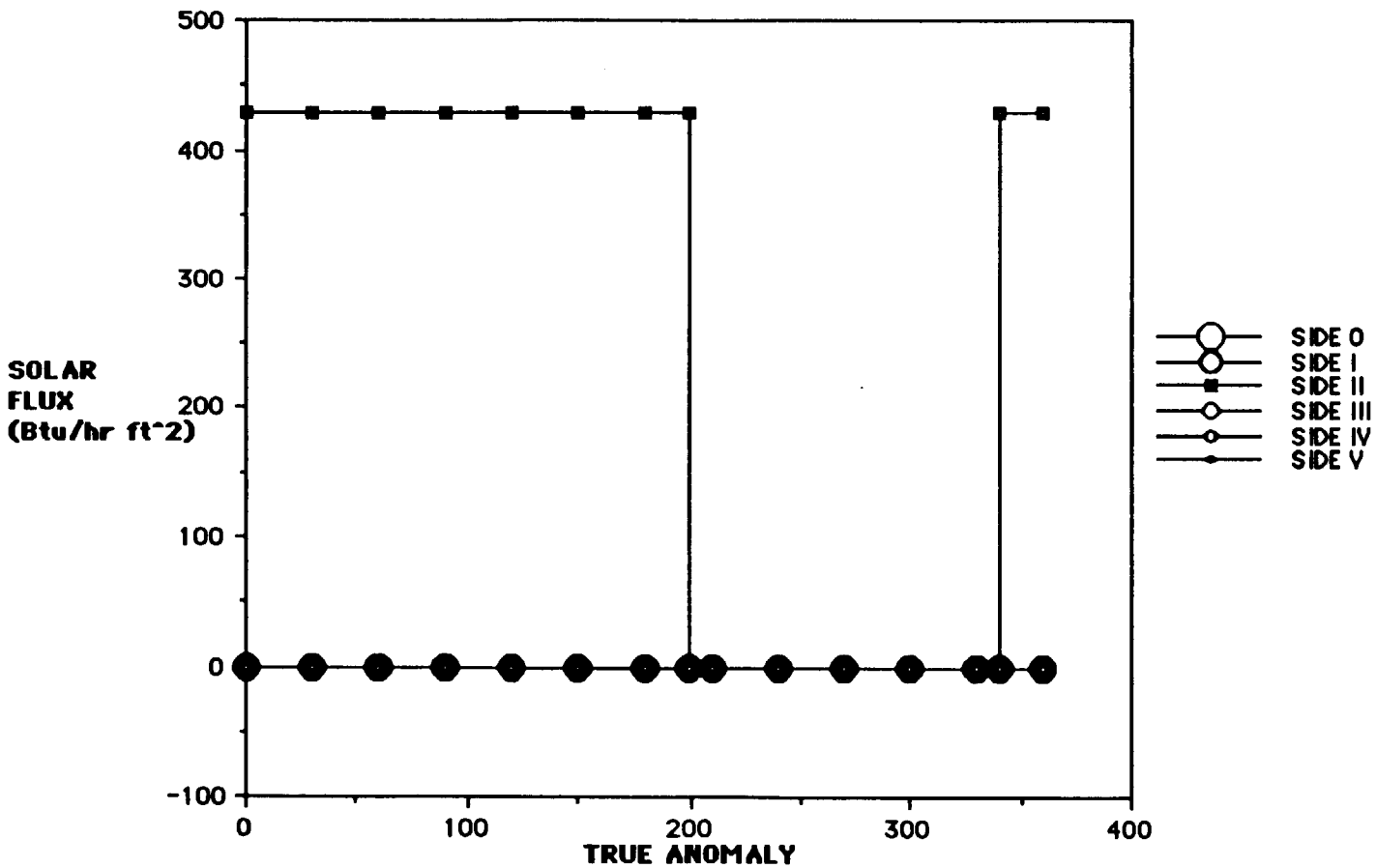
CASE X: PLANETARY FLUX

ALTITUDE=23000nmi
BETA=0°
SUN ORIENTED



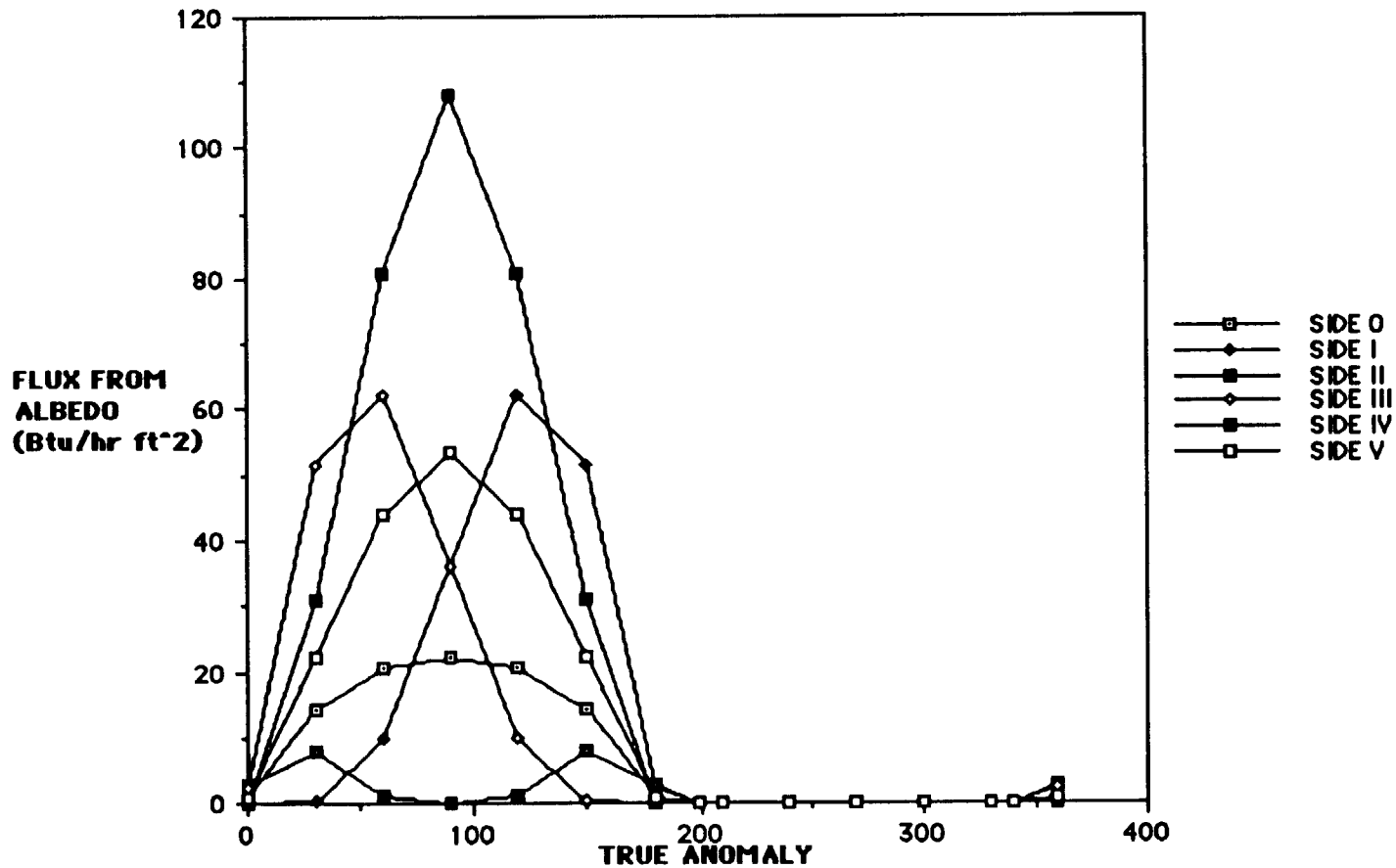
CASE XI: TOTAL FLUX

ALTITUDE=200nmi
BETA=15°
SUN ORIENTED



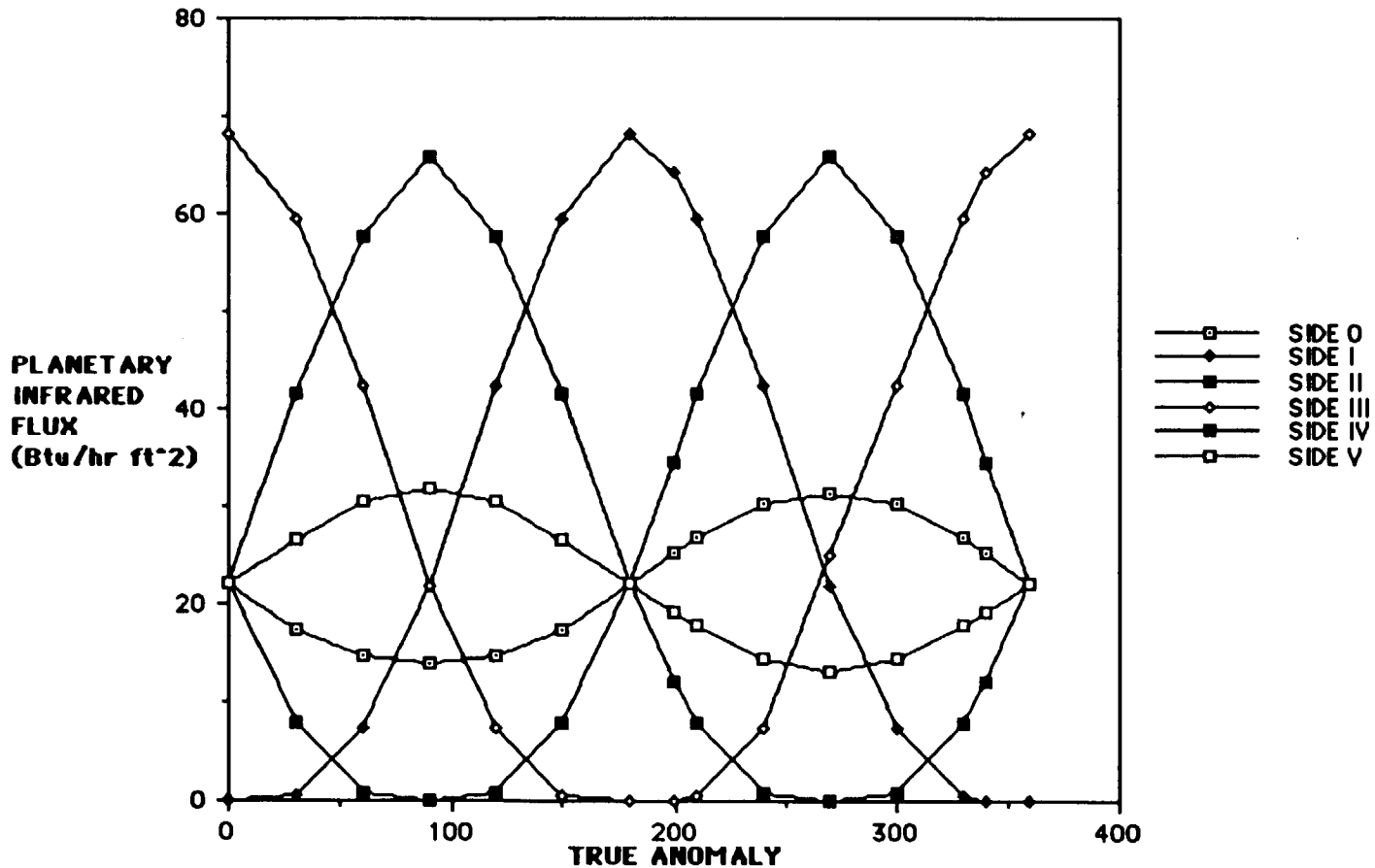
CASE XI: SOLAR FLUX

ALTITUDE=200nmi
BETA=15°
SUN ORIENTED



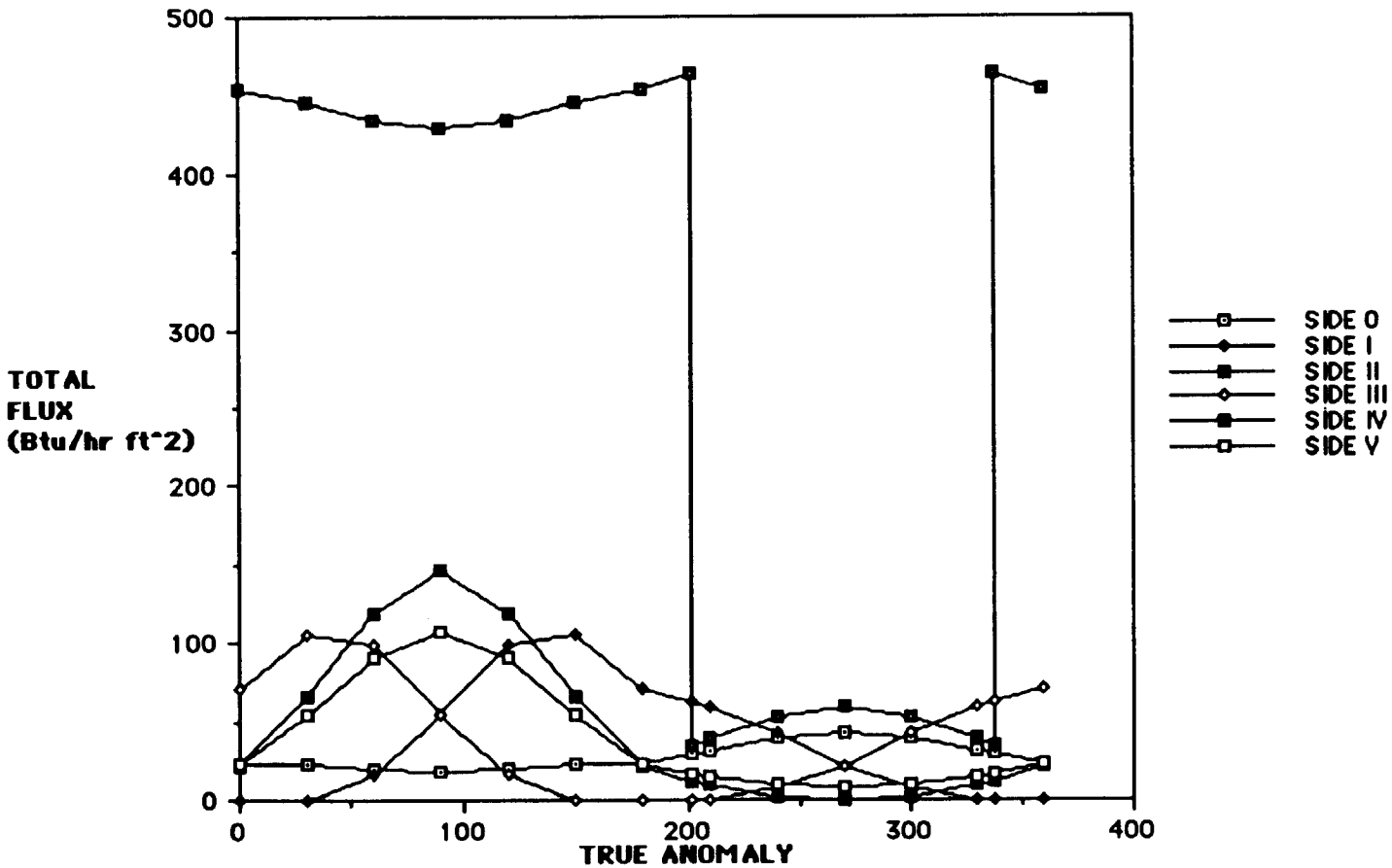
CASE XI: ALBEDO FLUX

ALTITUDE=200nmi
BETA=15°
SUN ORIENTED



CASE XI: PLANETARY FLUX

ALTITUDE=200nmi
BETA=15°
SUN ORIENTED



CASE XII: TOTAL FLUX

ALTITUDE=200nmi
BETA=30°
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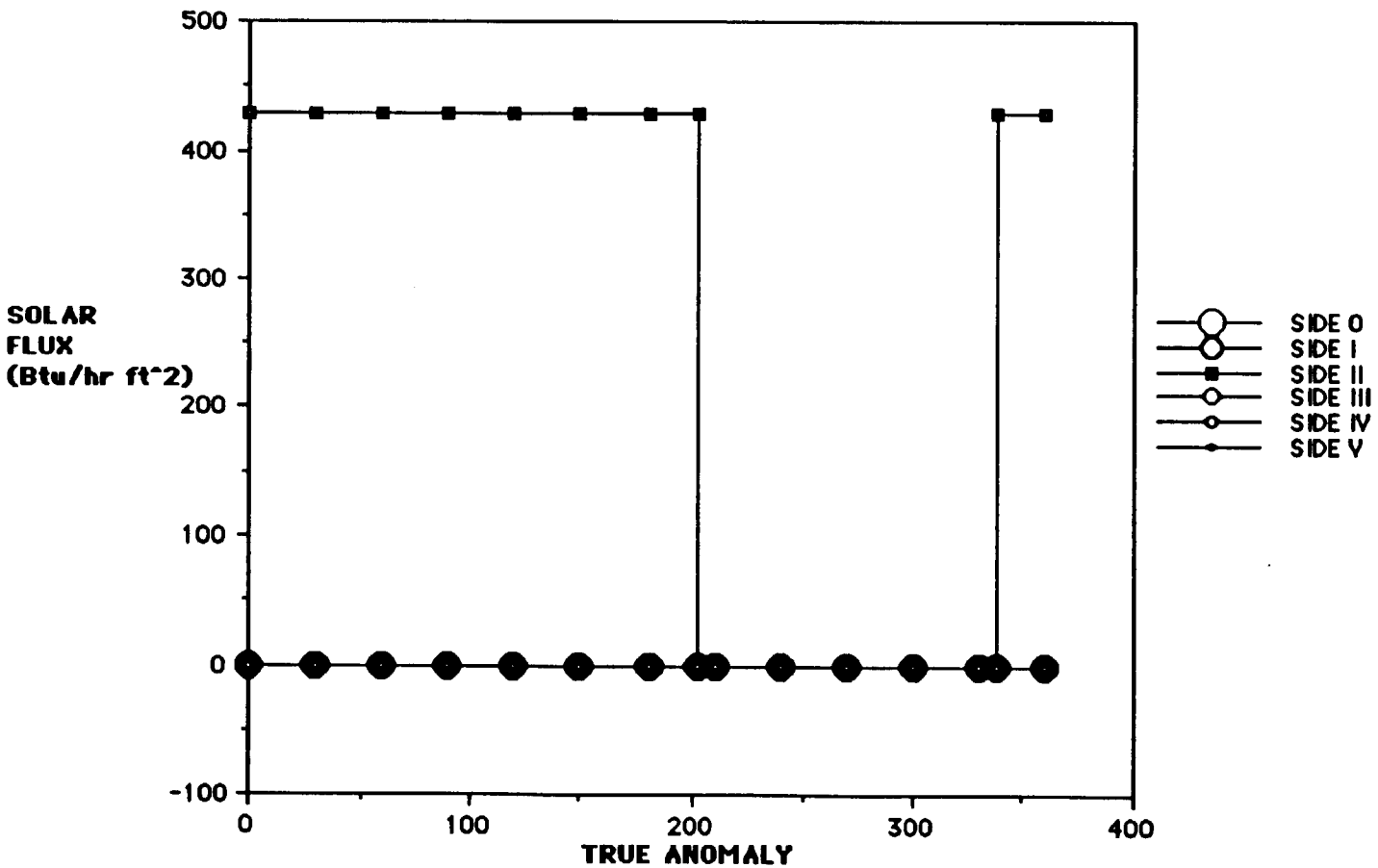

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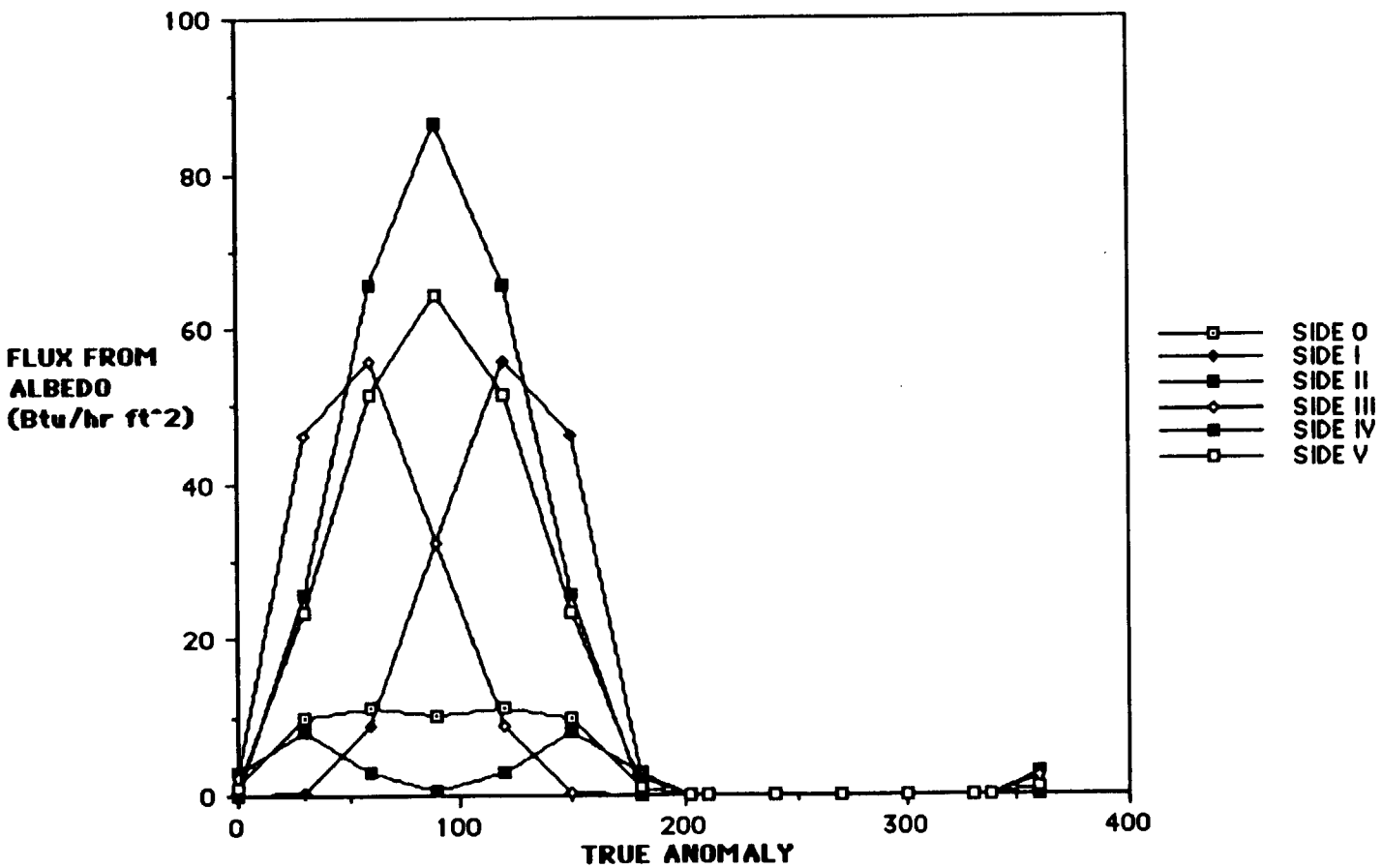

CASE XII: ALBEDO FLUX

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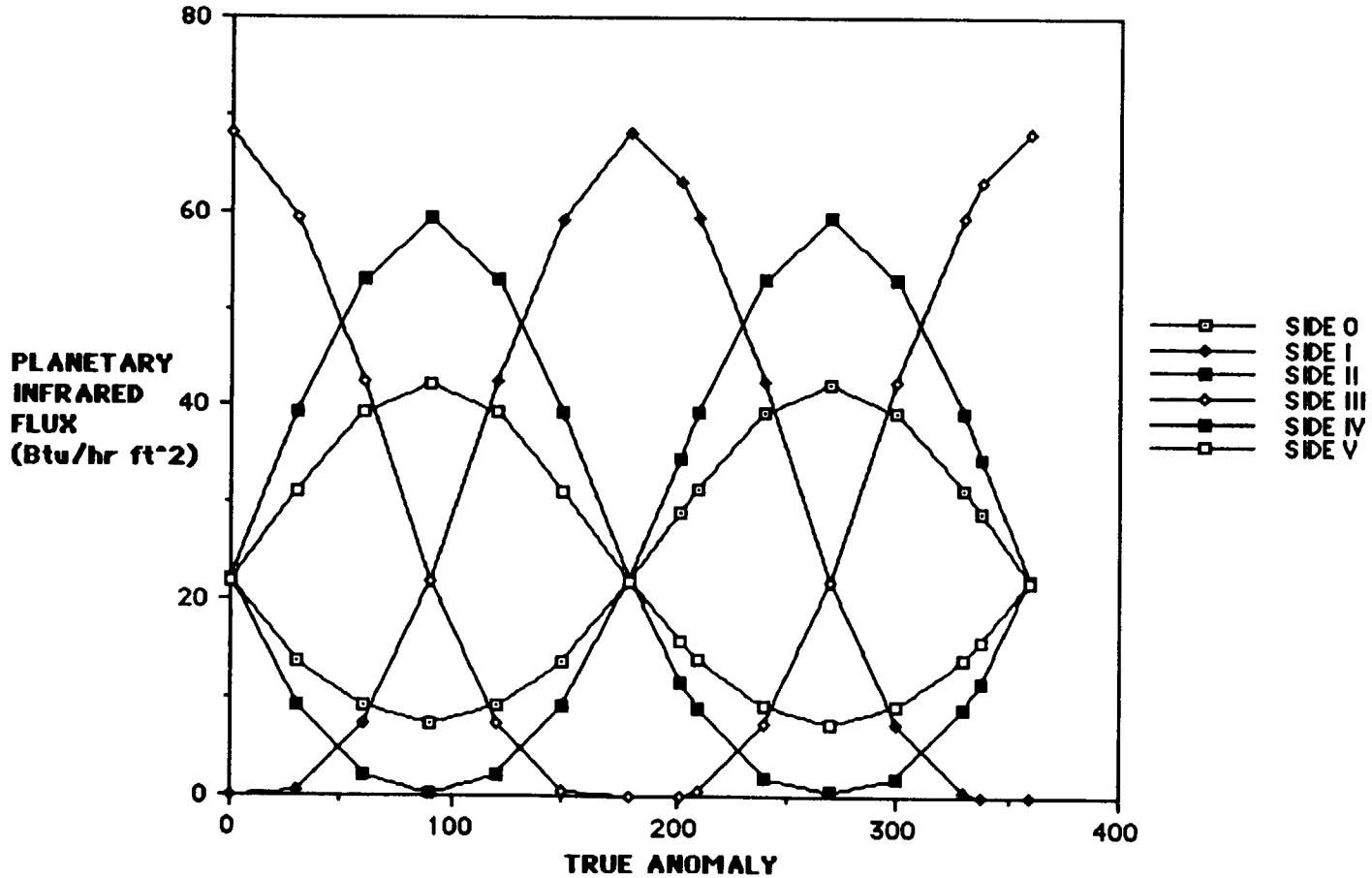

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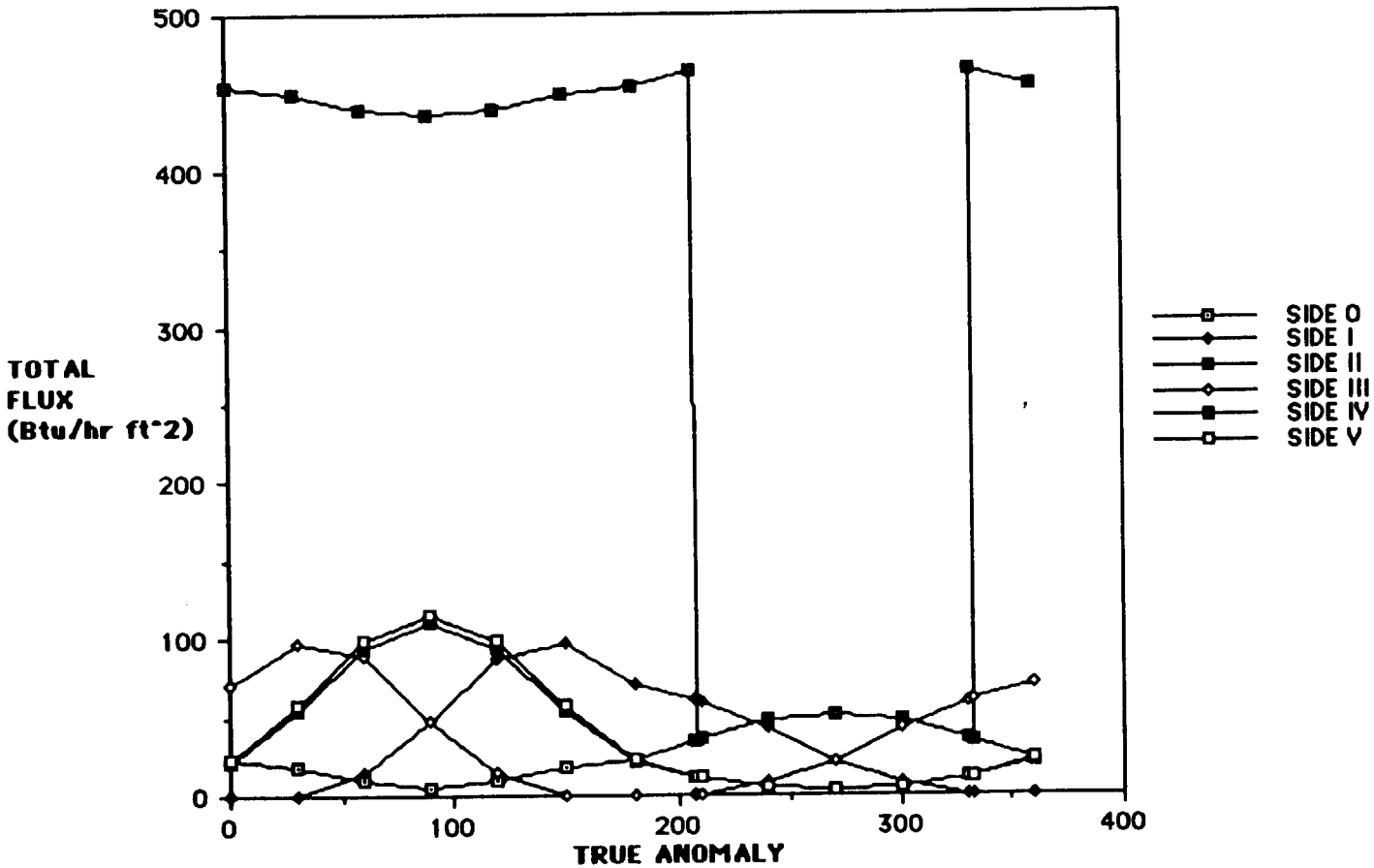

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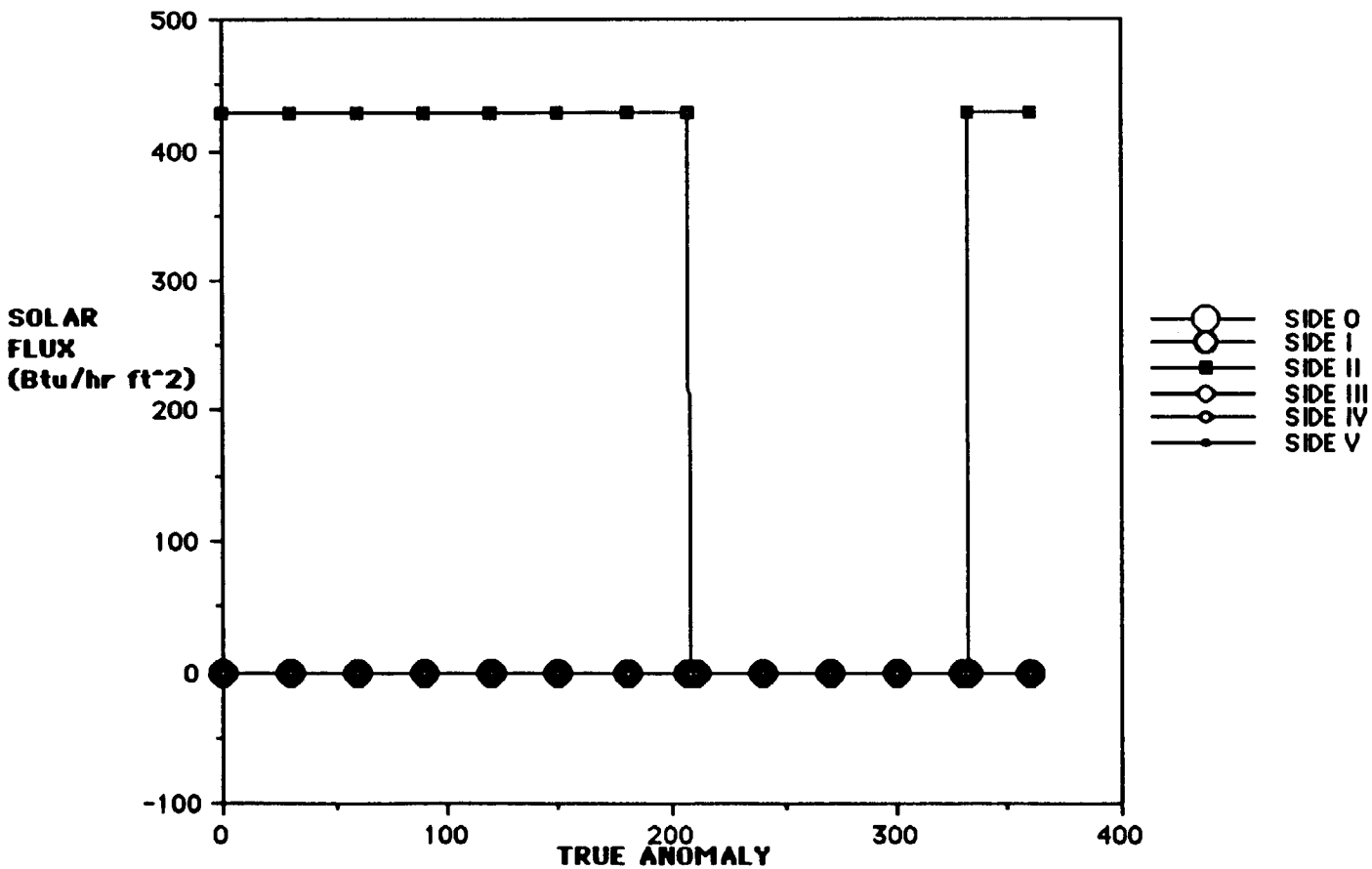

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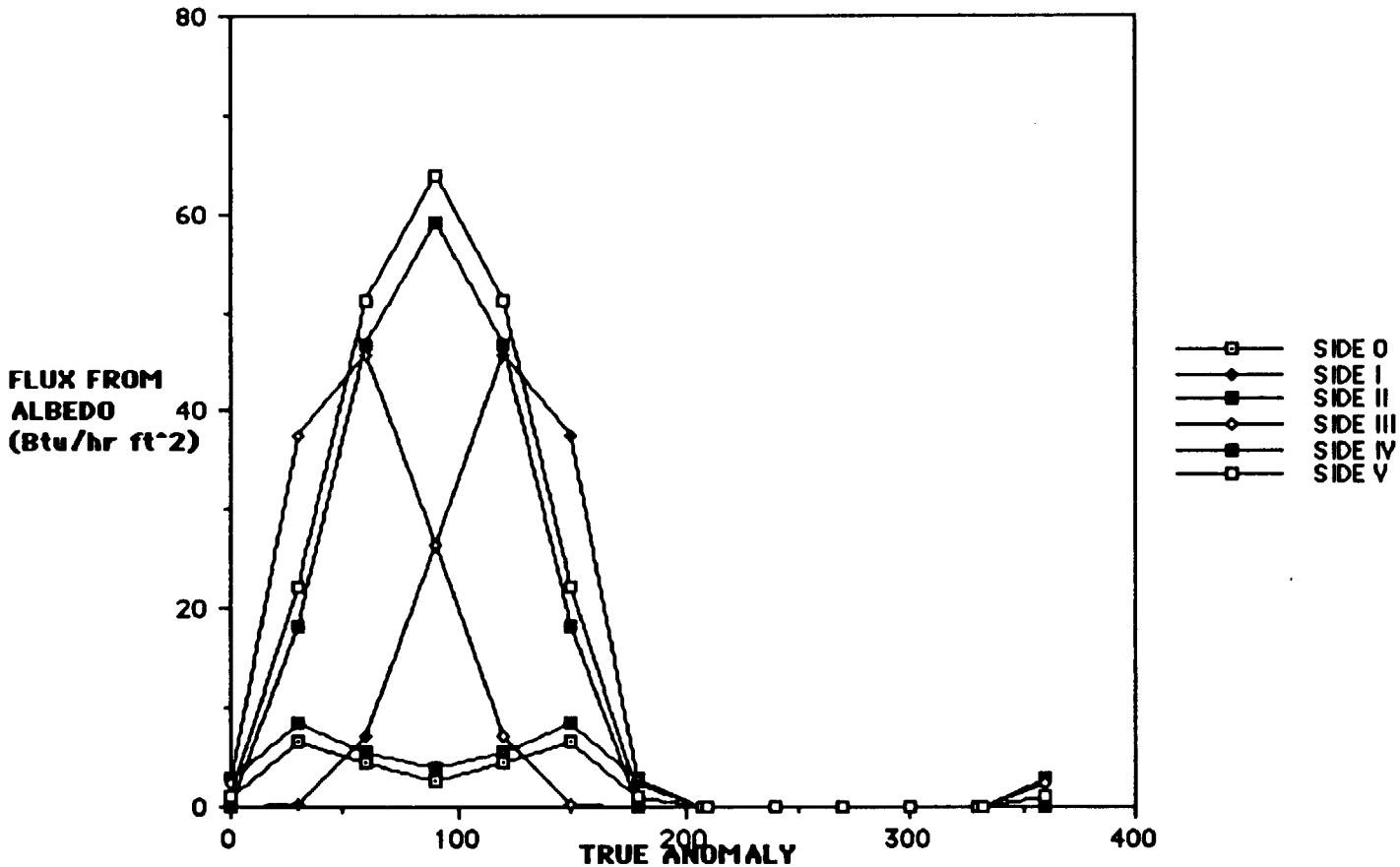

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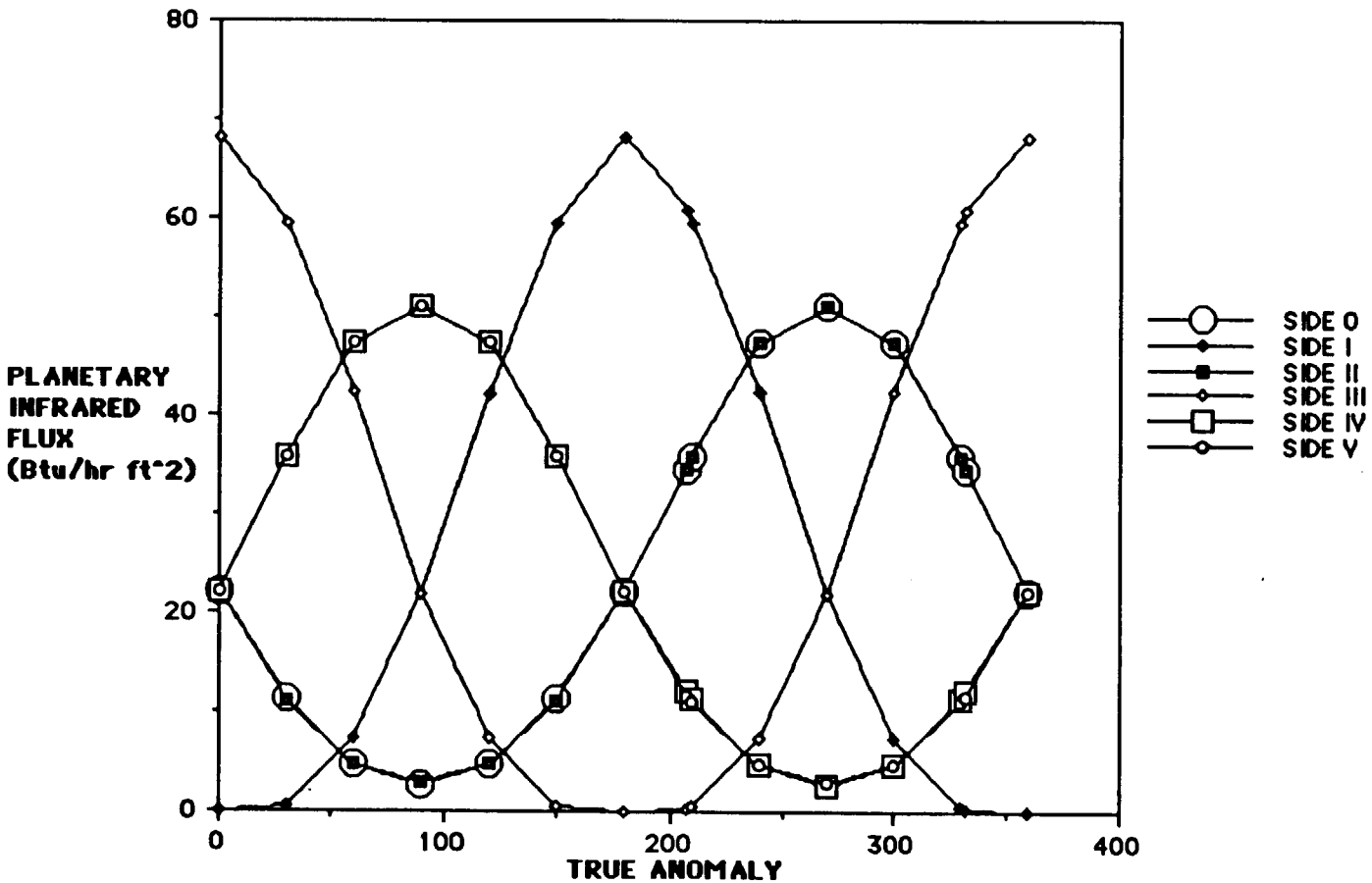

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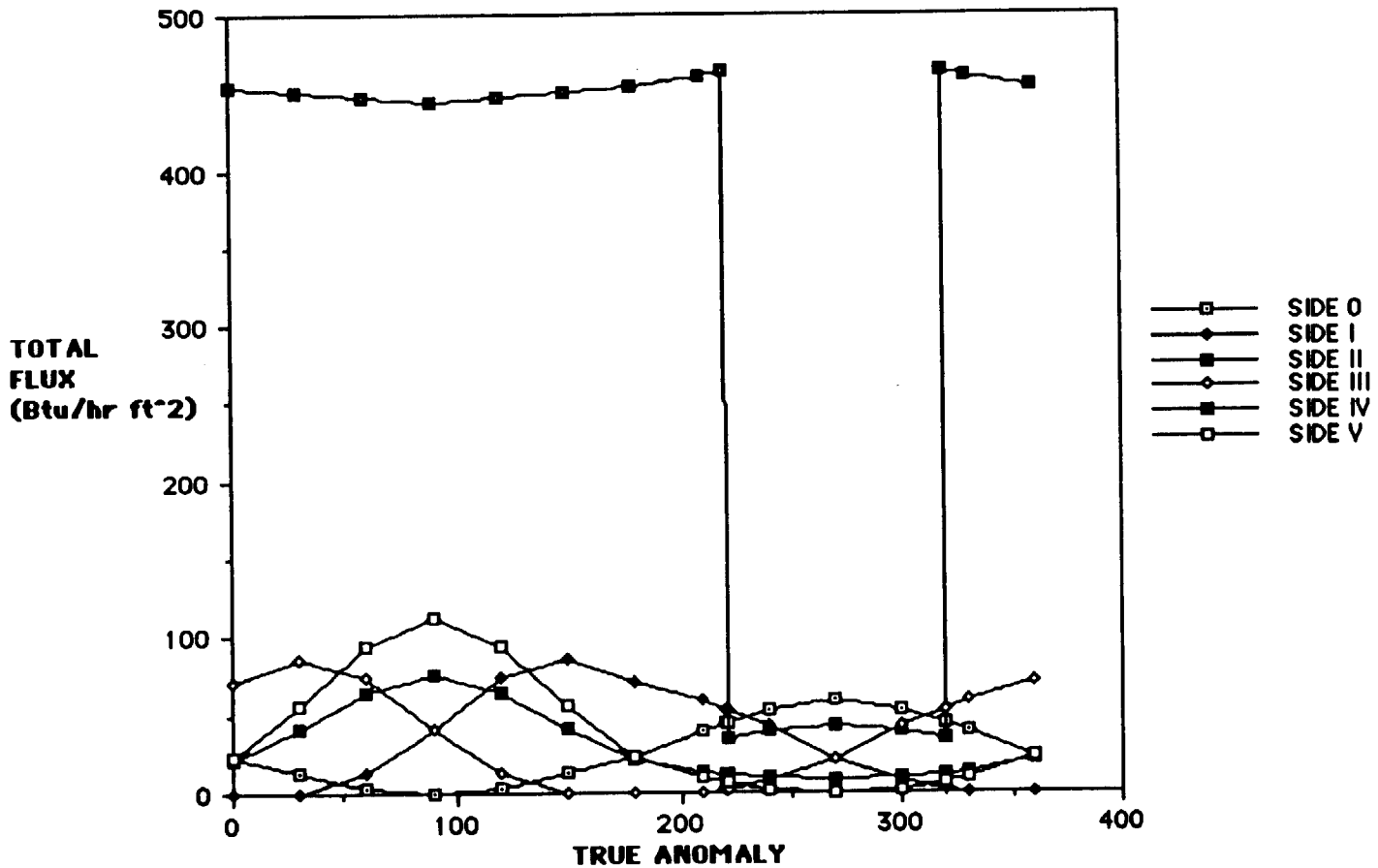

CASE XIV: TOTAL FLUX

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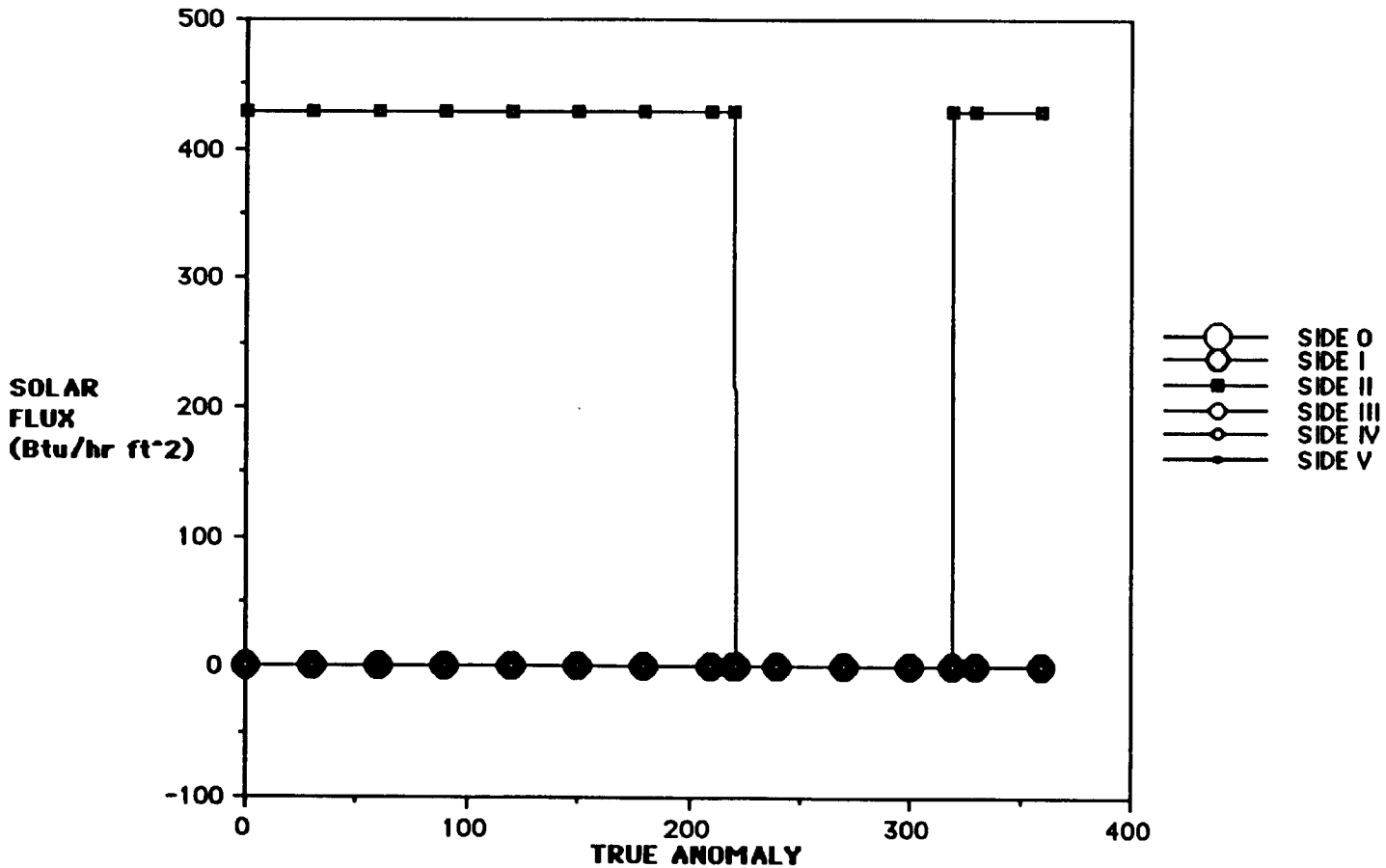

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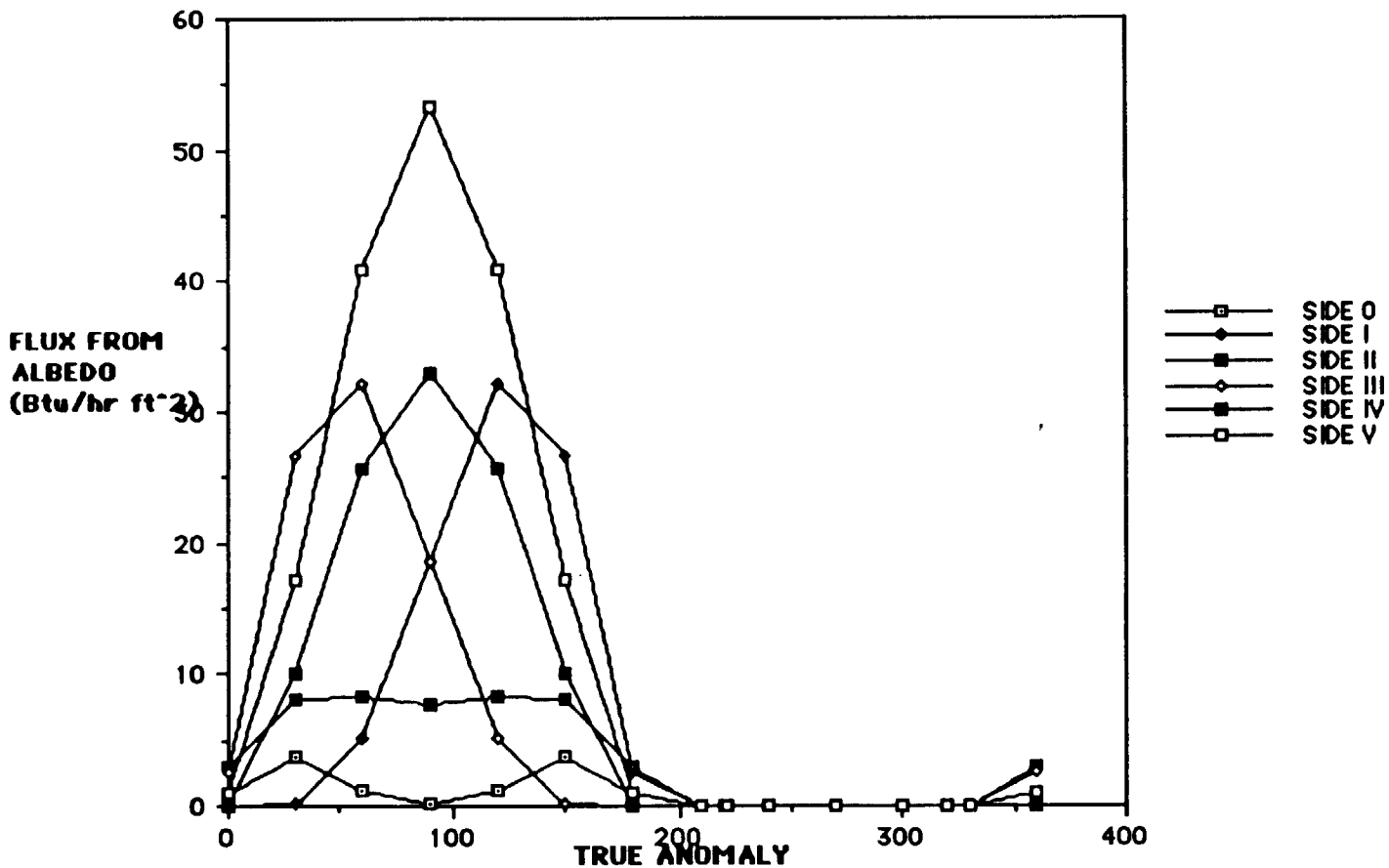

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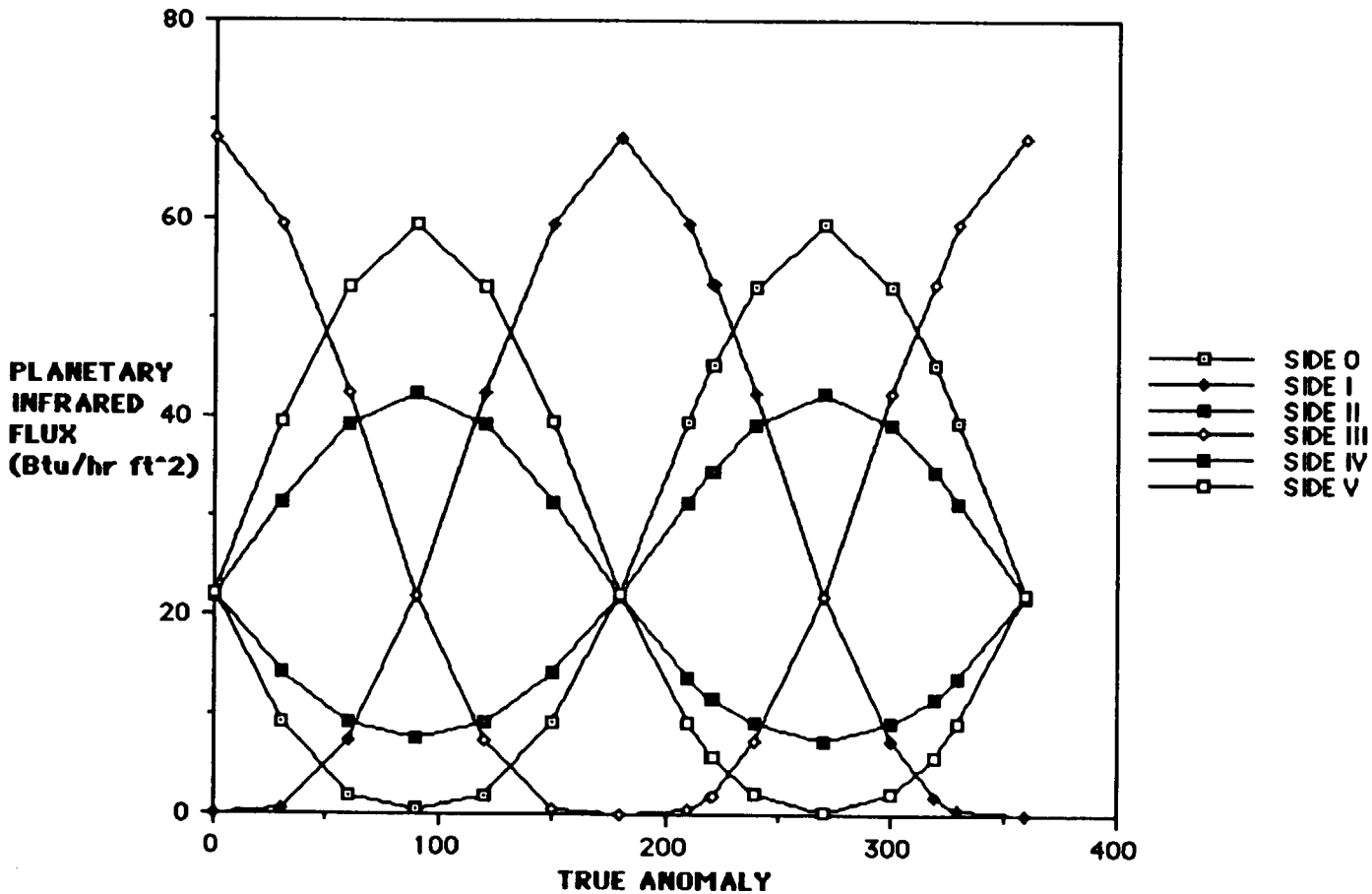

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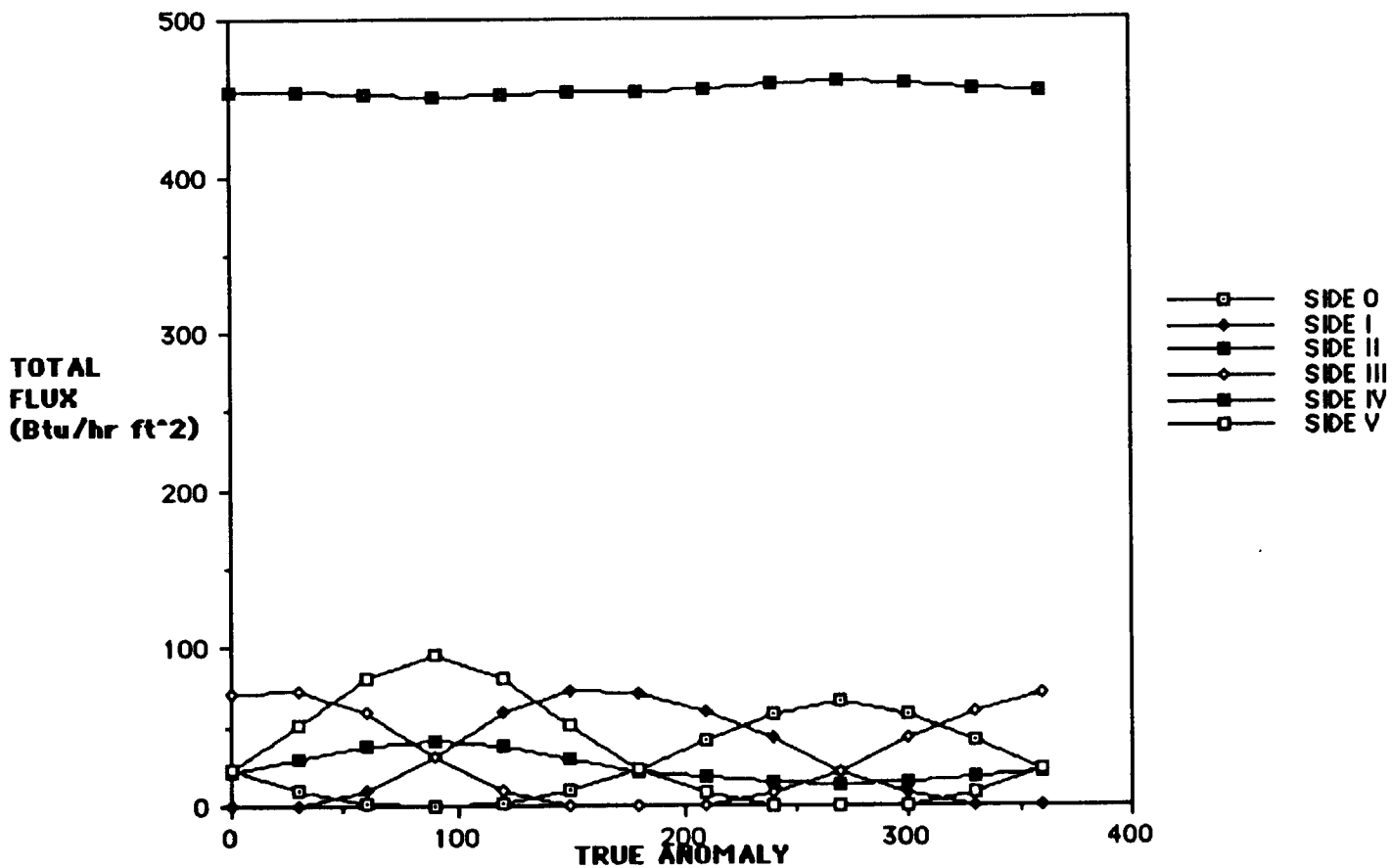

CASE XV: TOTAL FLUX

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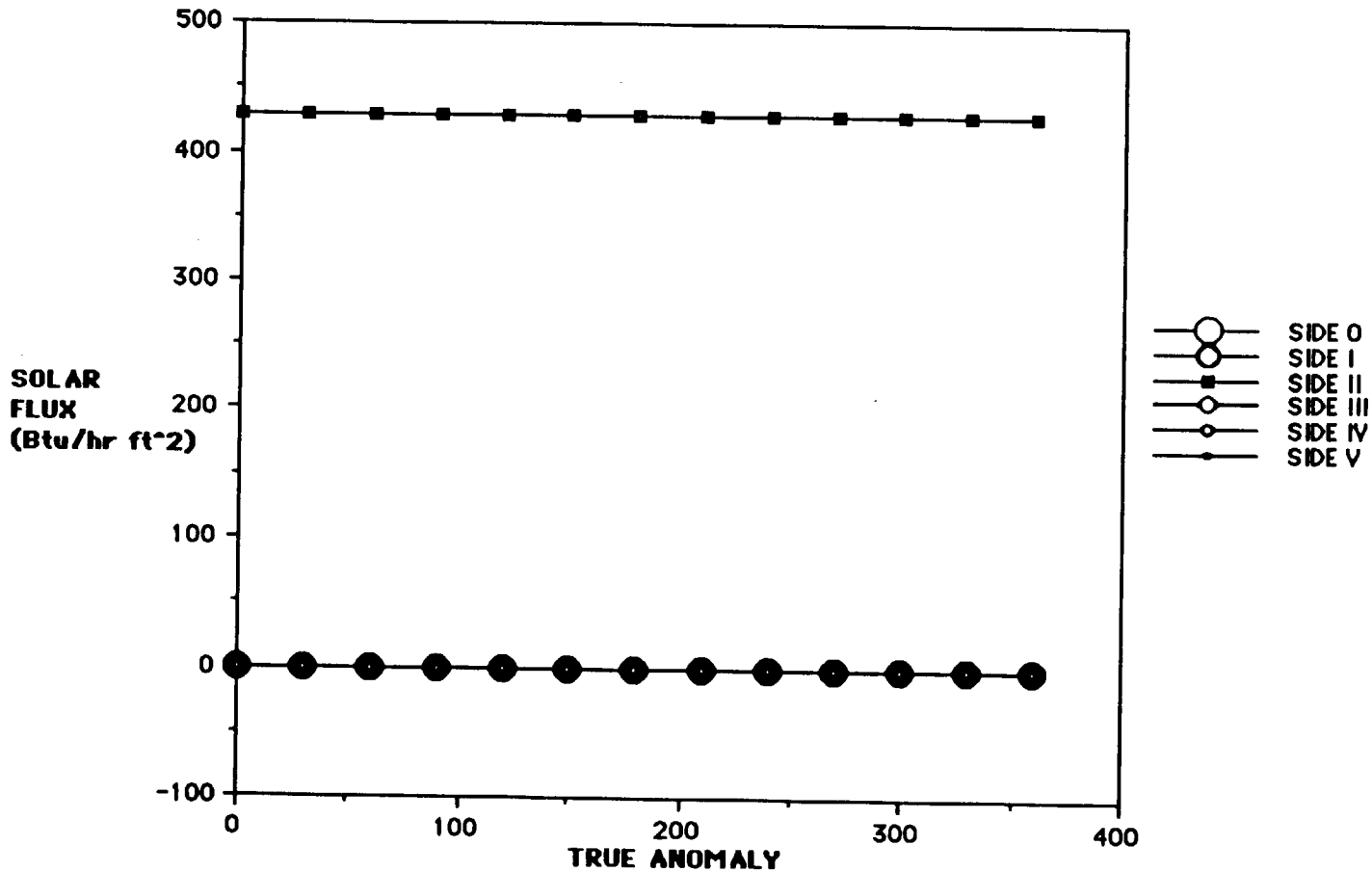

CASE XV: SOLAR FLUX

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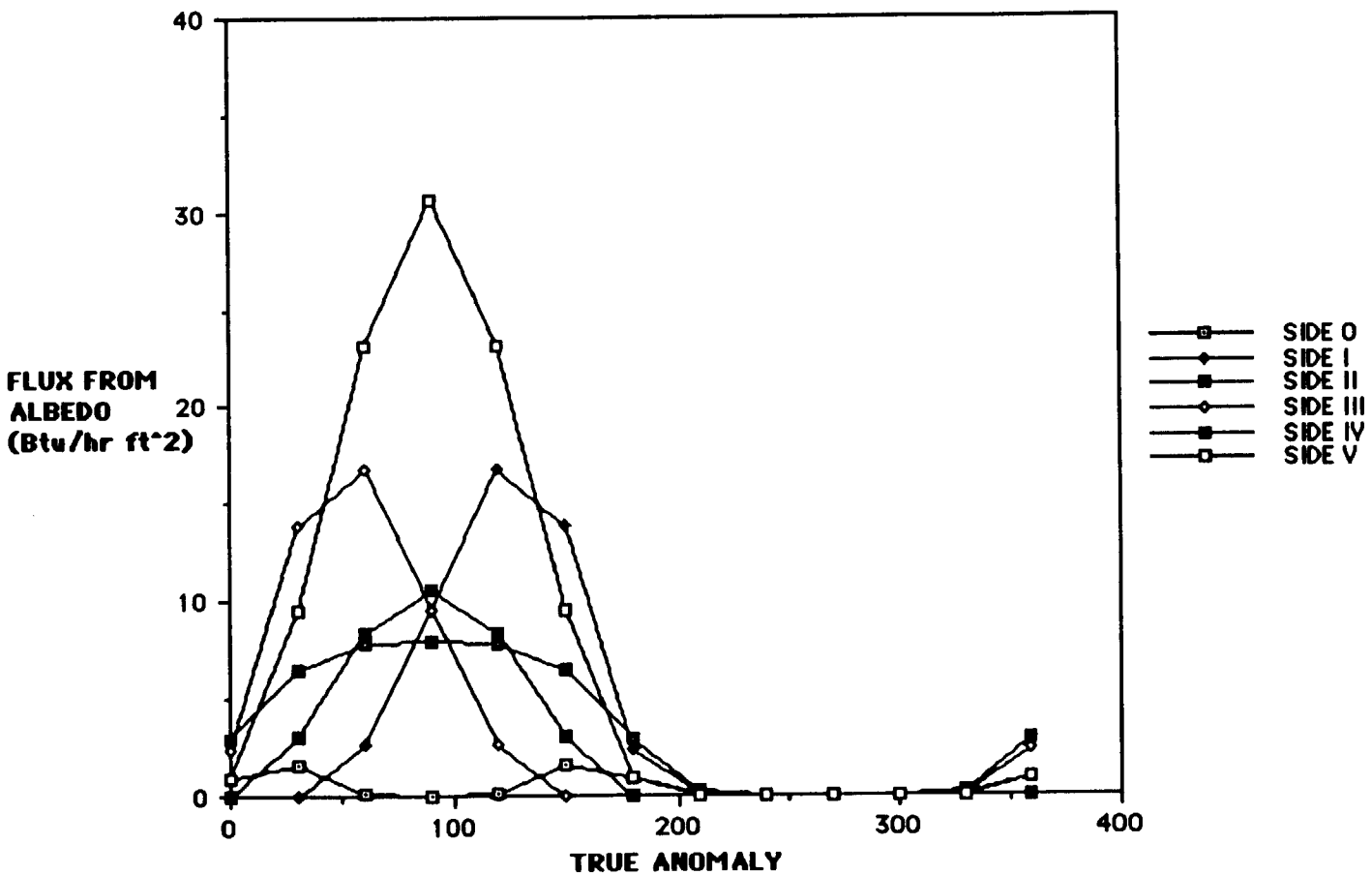

CASE XV: ALBEDO FLUX

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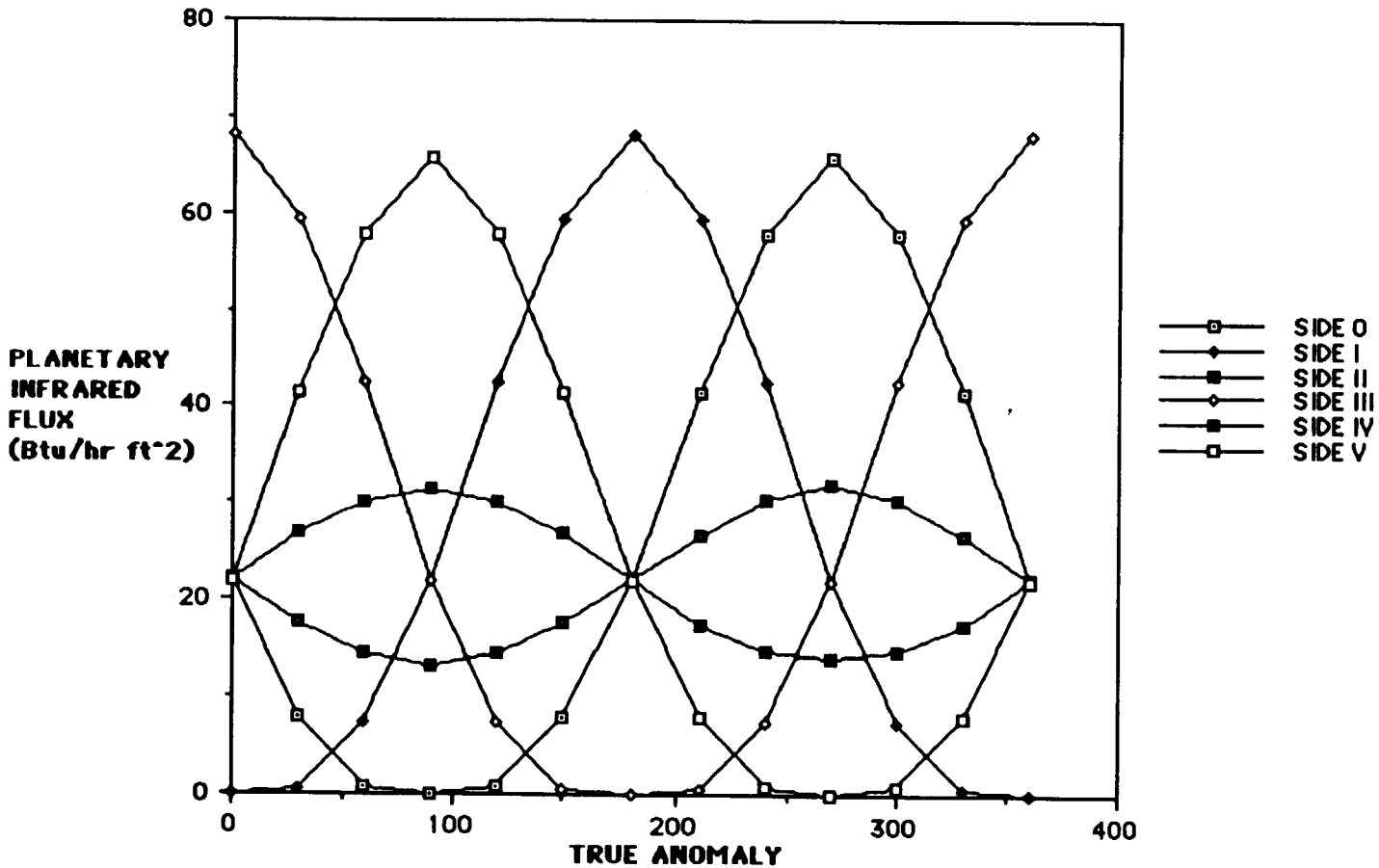

CASE XV: PLANETARY FLUX

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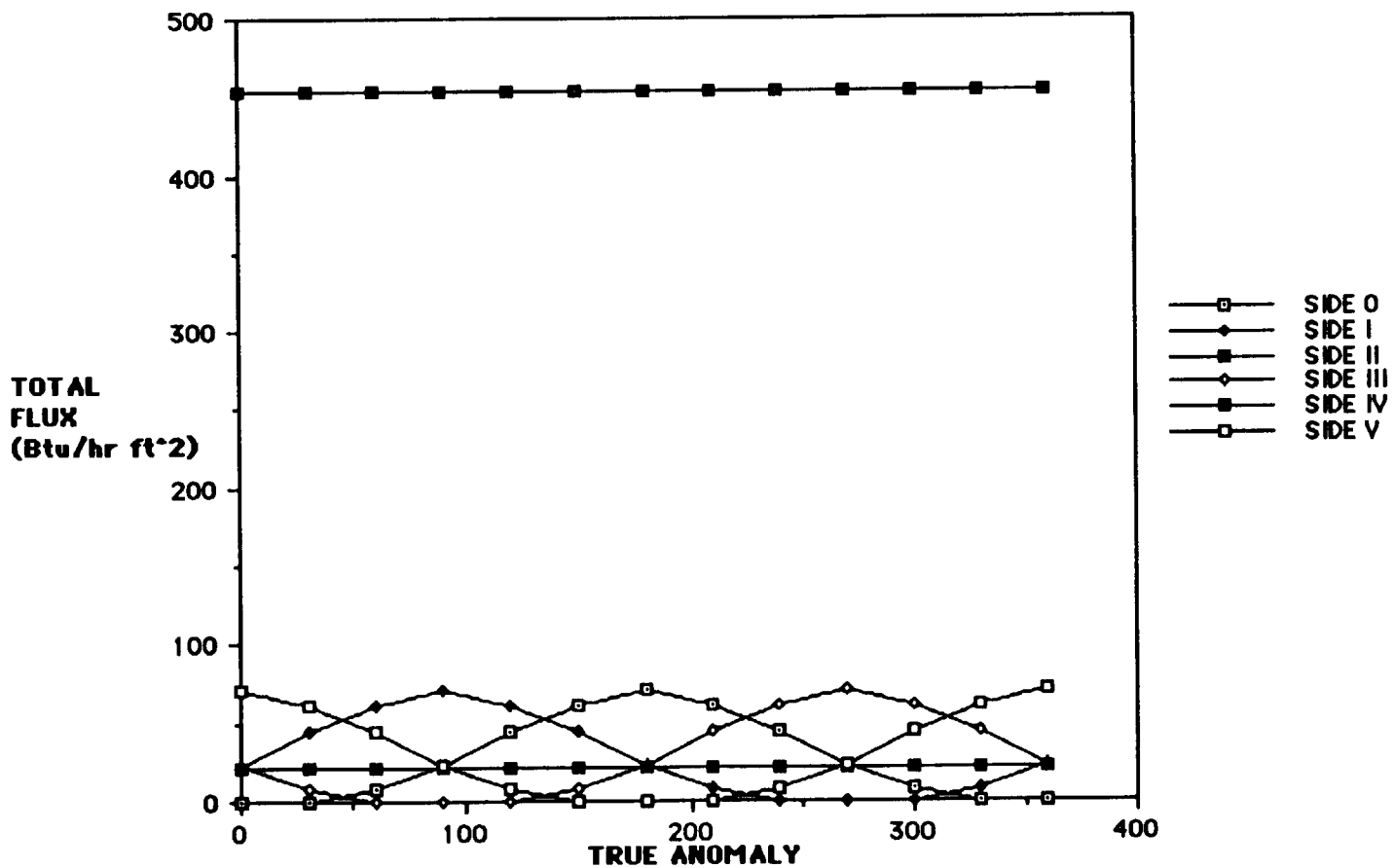

CASE XVI: TOTAL FLUX

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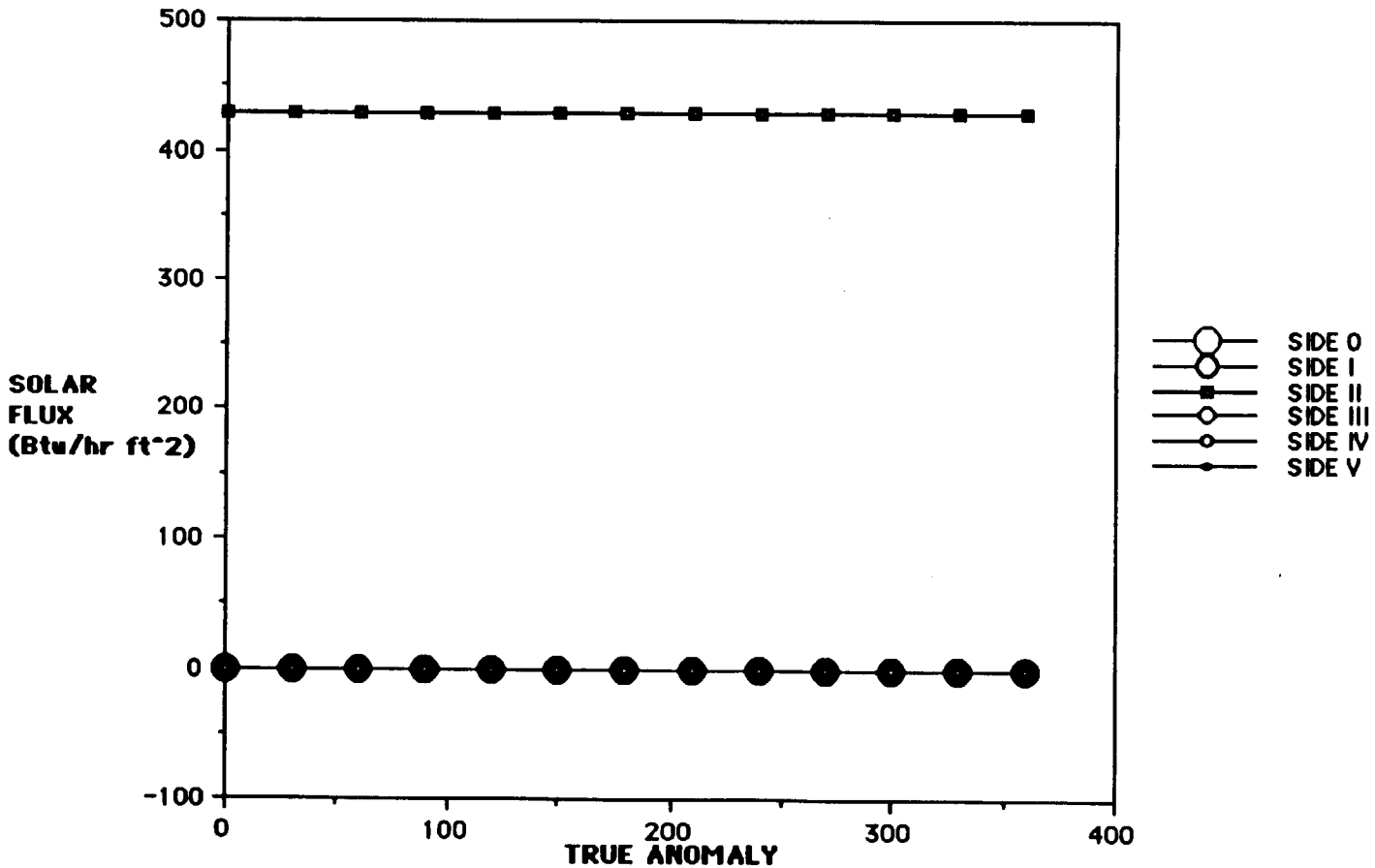

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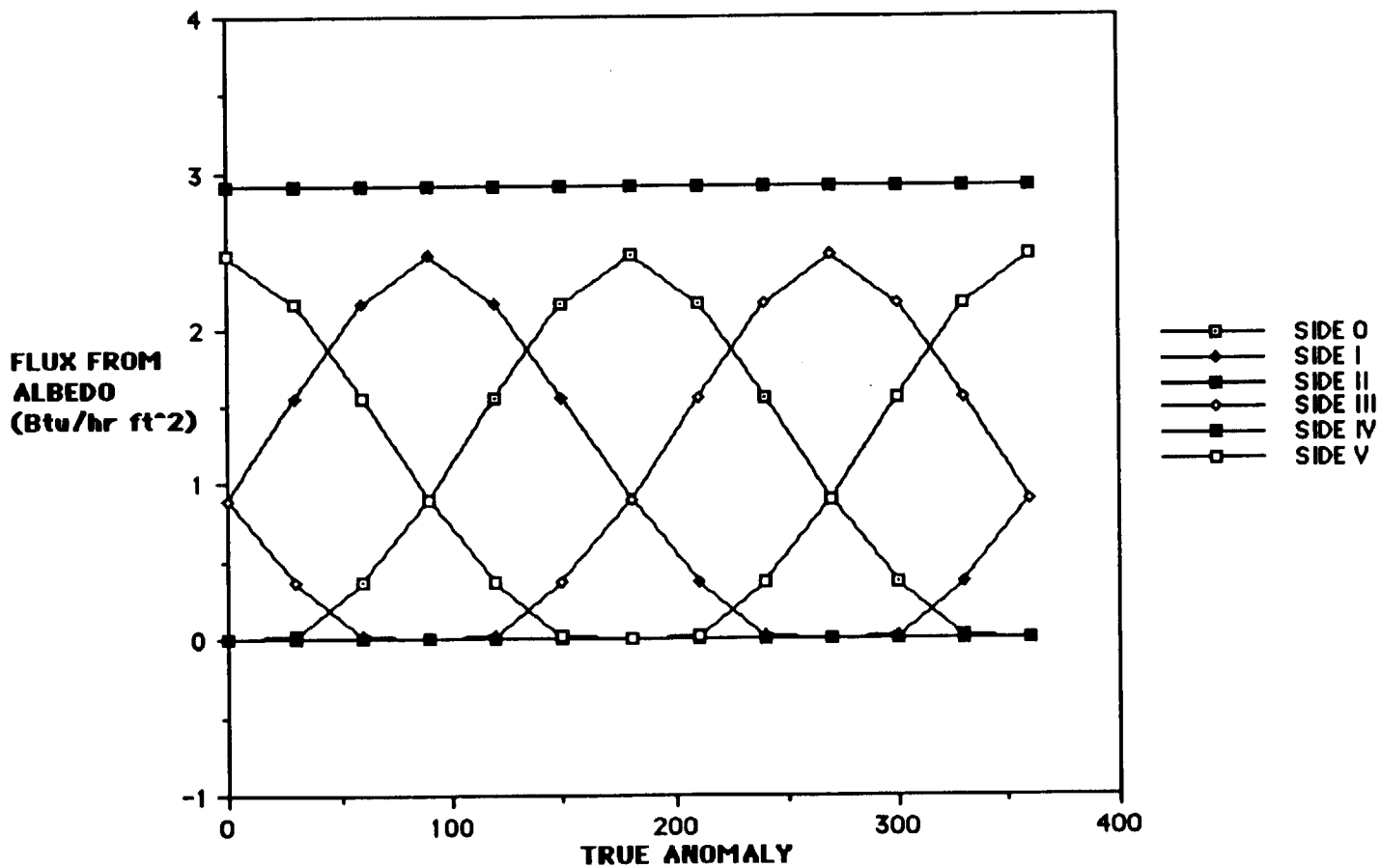

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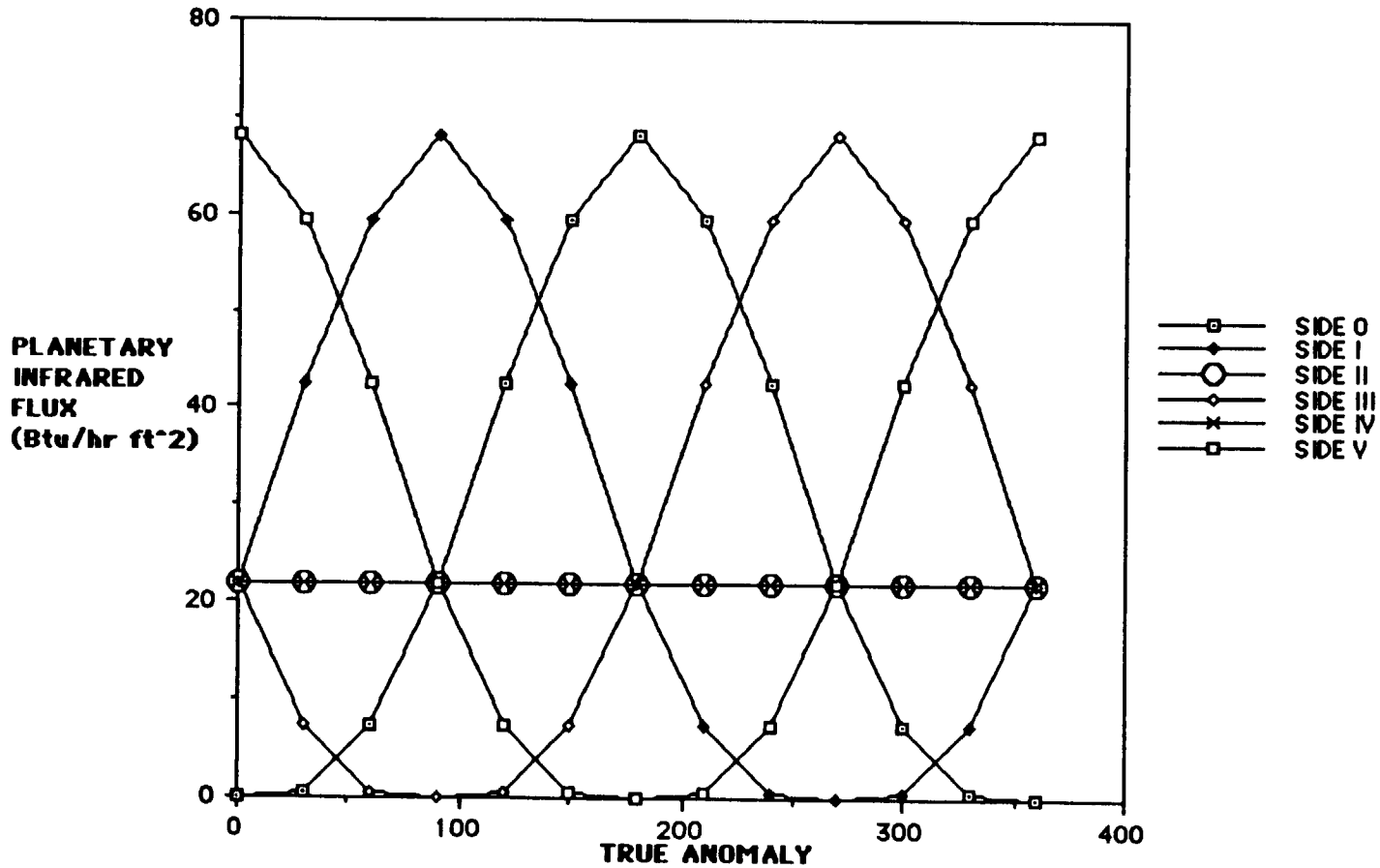

CASE XVI: PLANETARY FLUX

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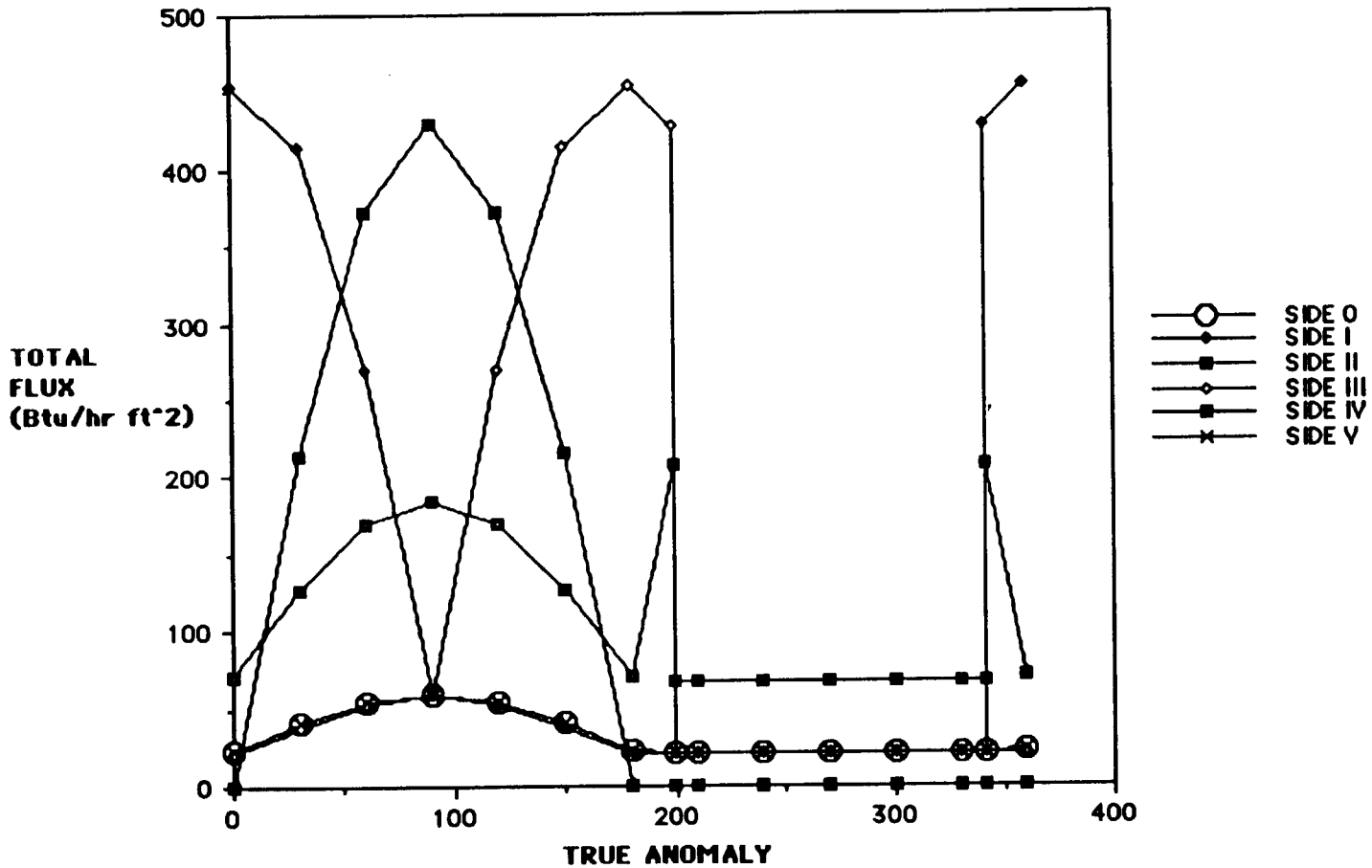

CASE XVII: TOTAL FLUX

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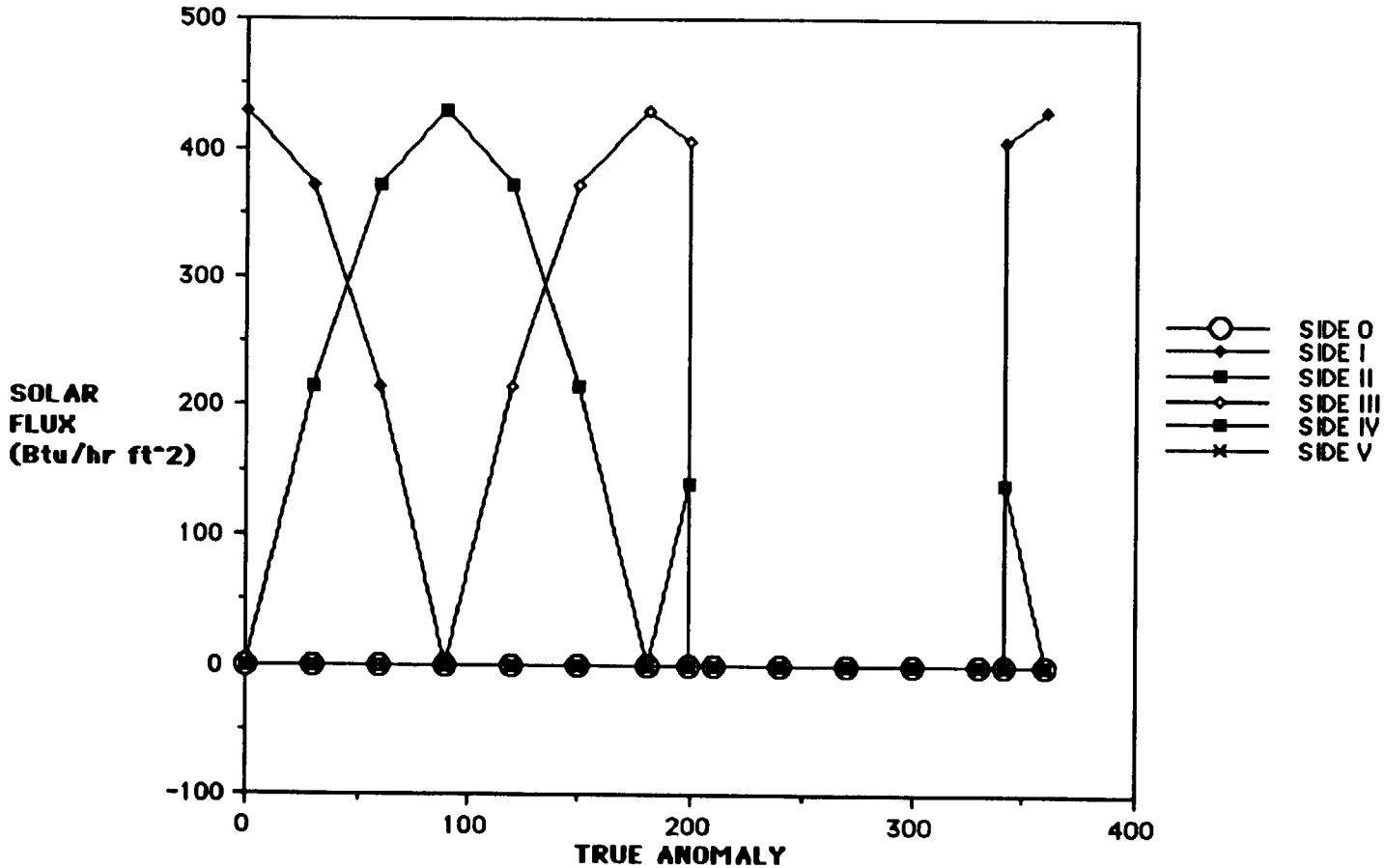

CASE XVII: SOLAR FLUX

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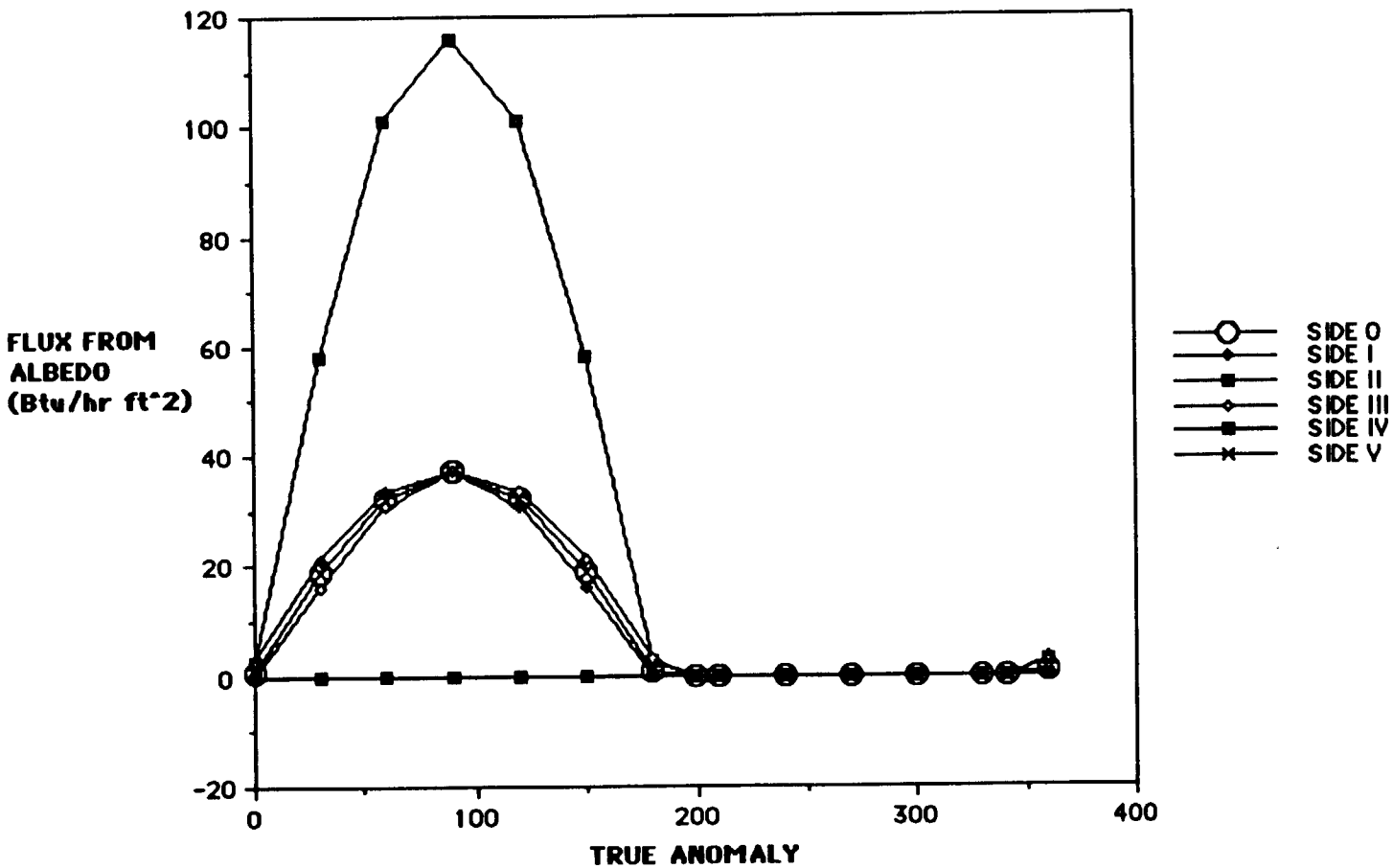
EARTH ORIENTED



CASE XVII: ALBEDO FLUX

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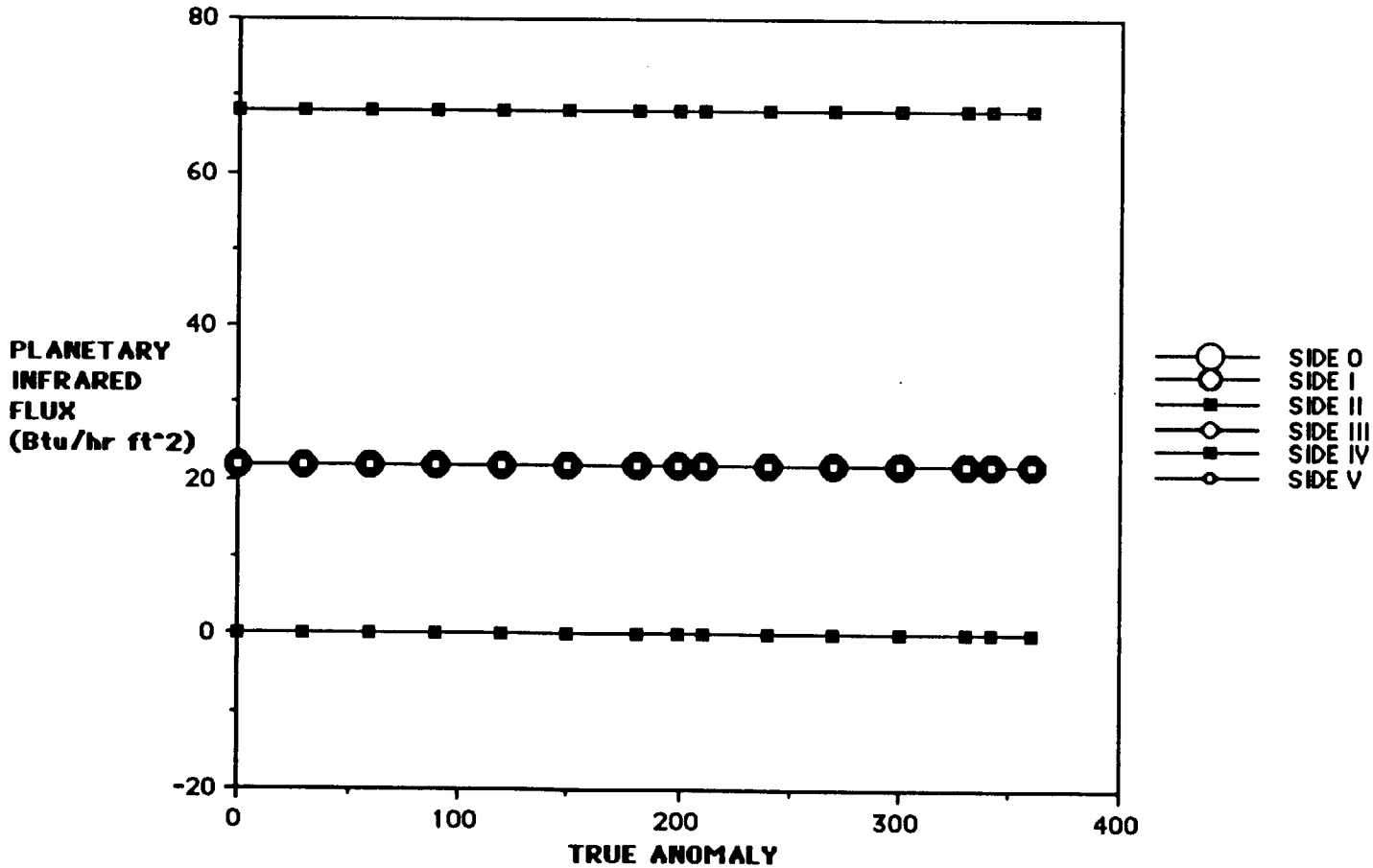

CASE XVII: PLANETARY FLUX

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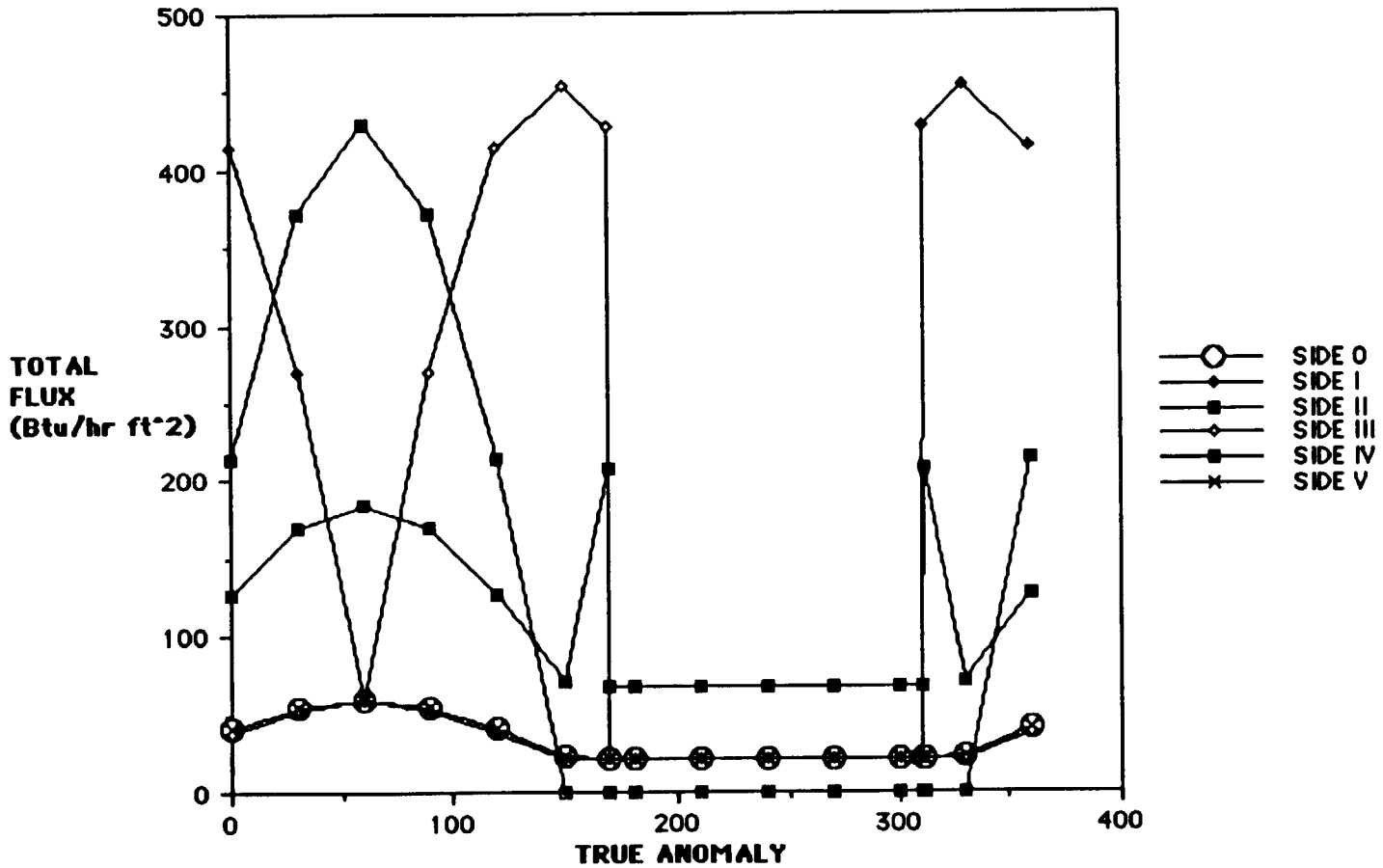

CASE XVIII: TOTAL FLUX

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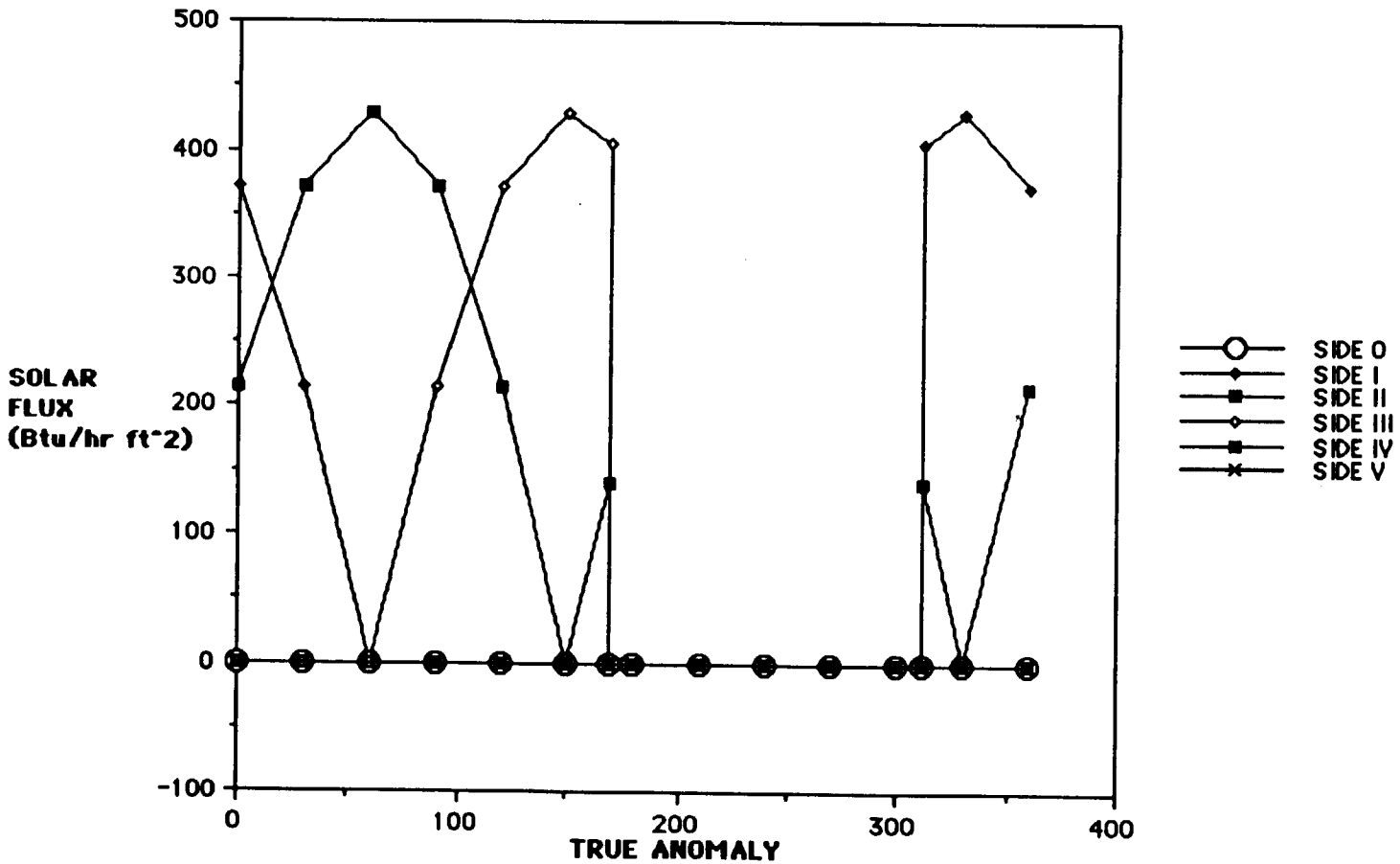

CASE XVIII: SOLAR FLUX

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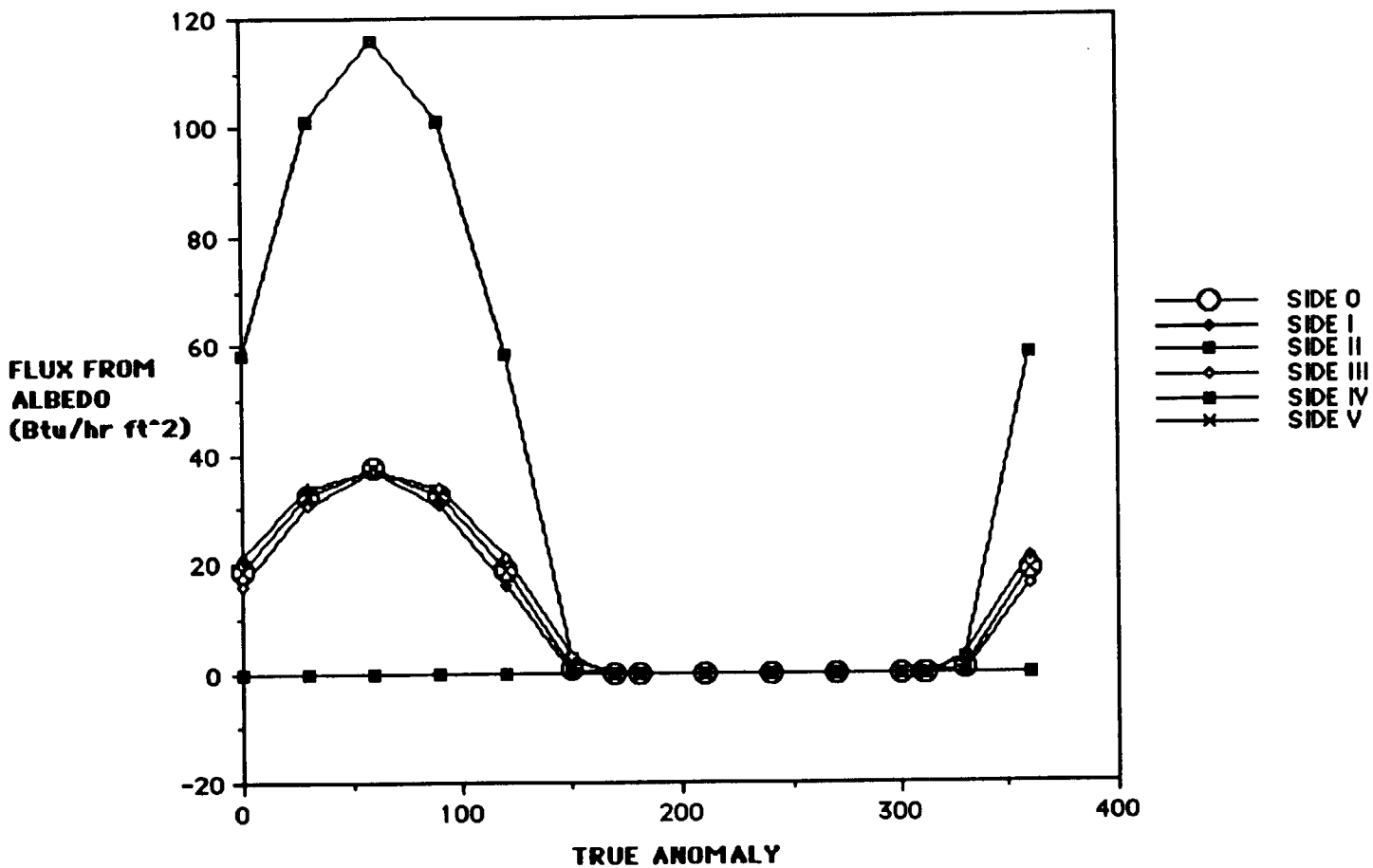

CASE XVIII: ALBEDO FLUX

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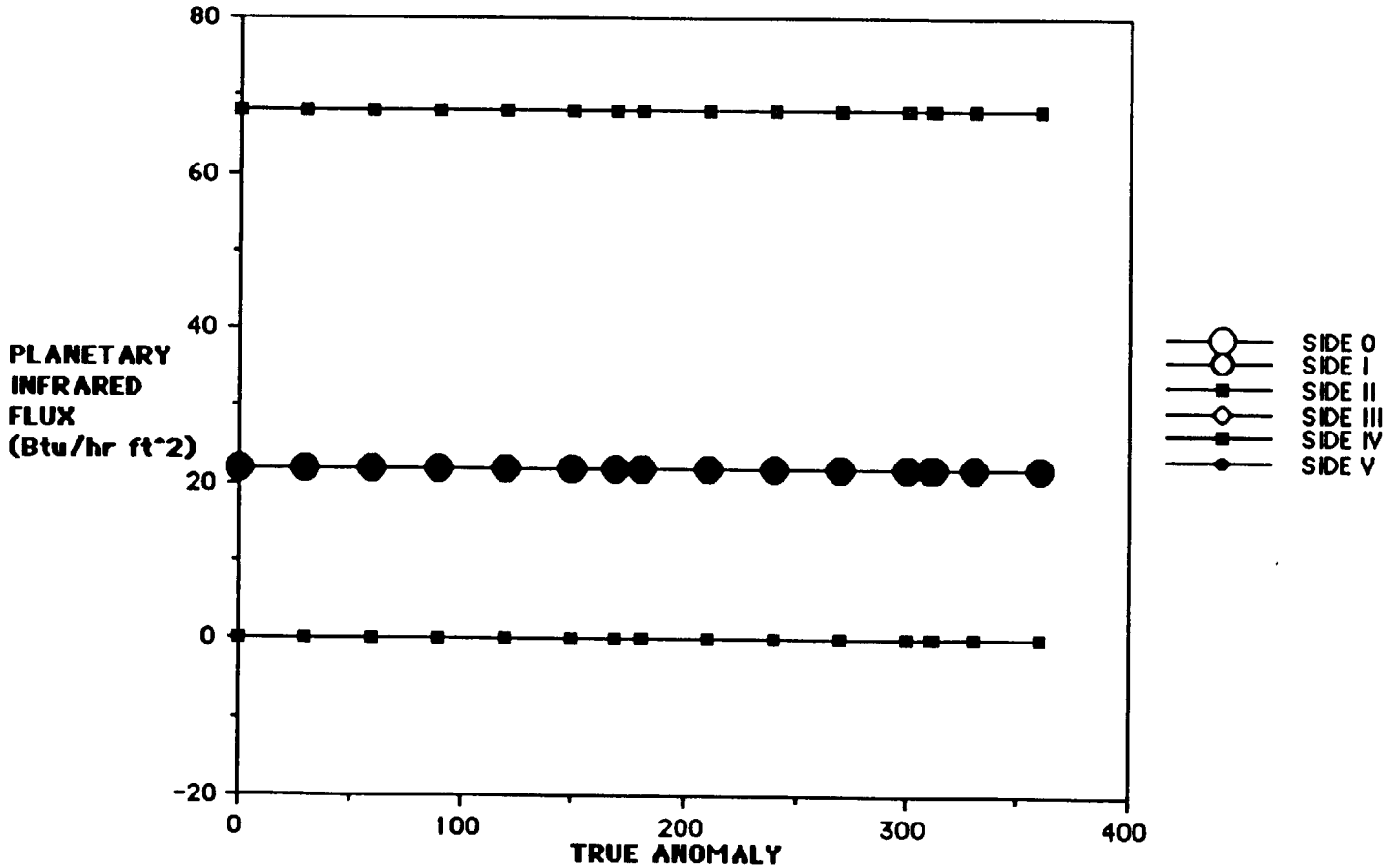

CASE XVIII: PLANETARY FLUX

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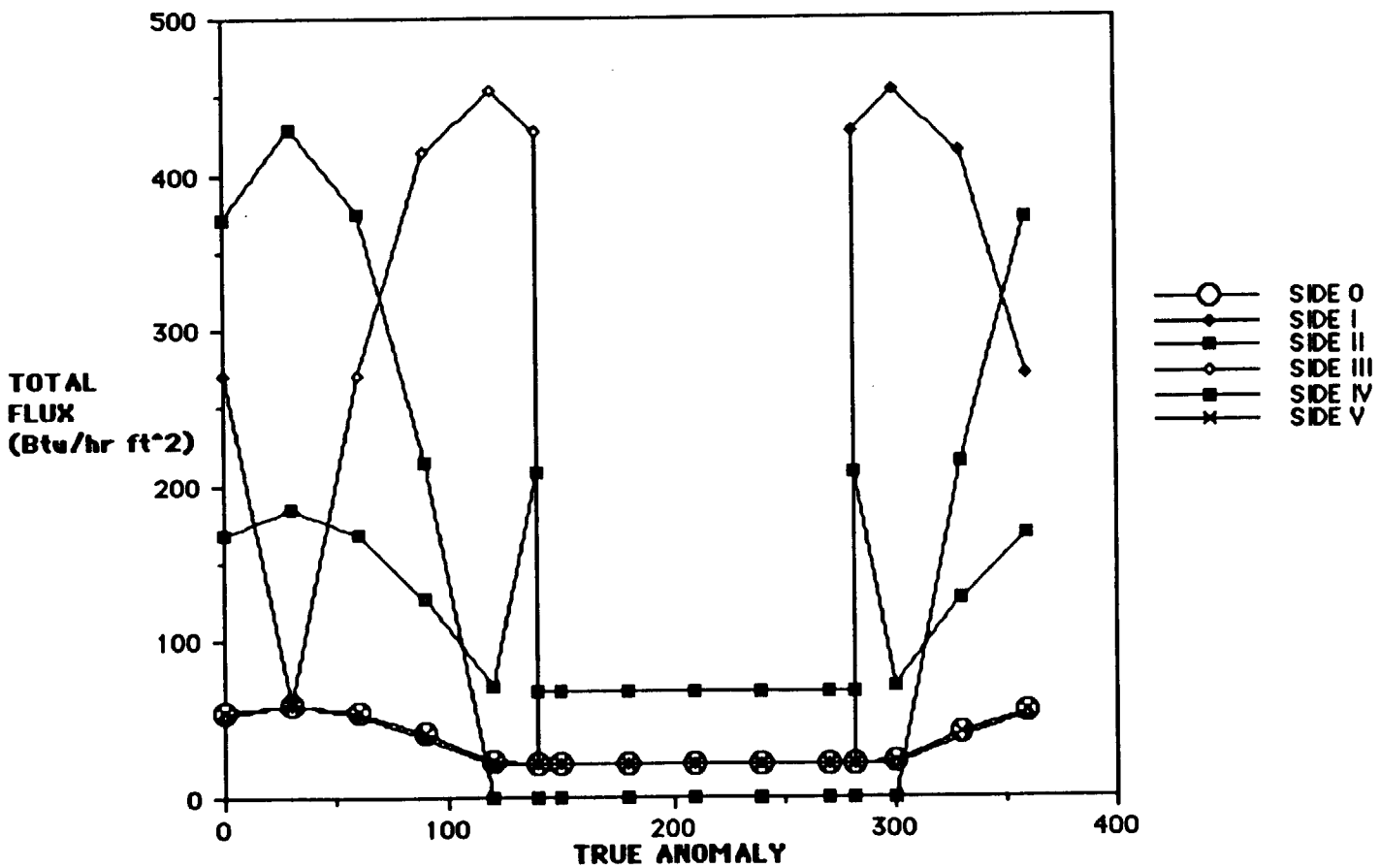

CASE XIX: TOTAL FLUX

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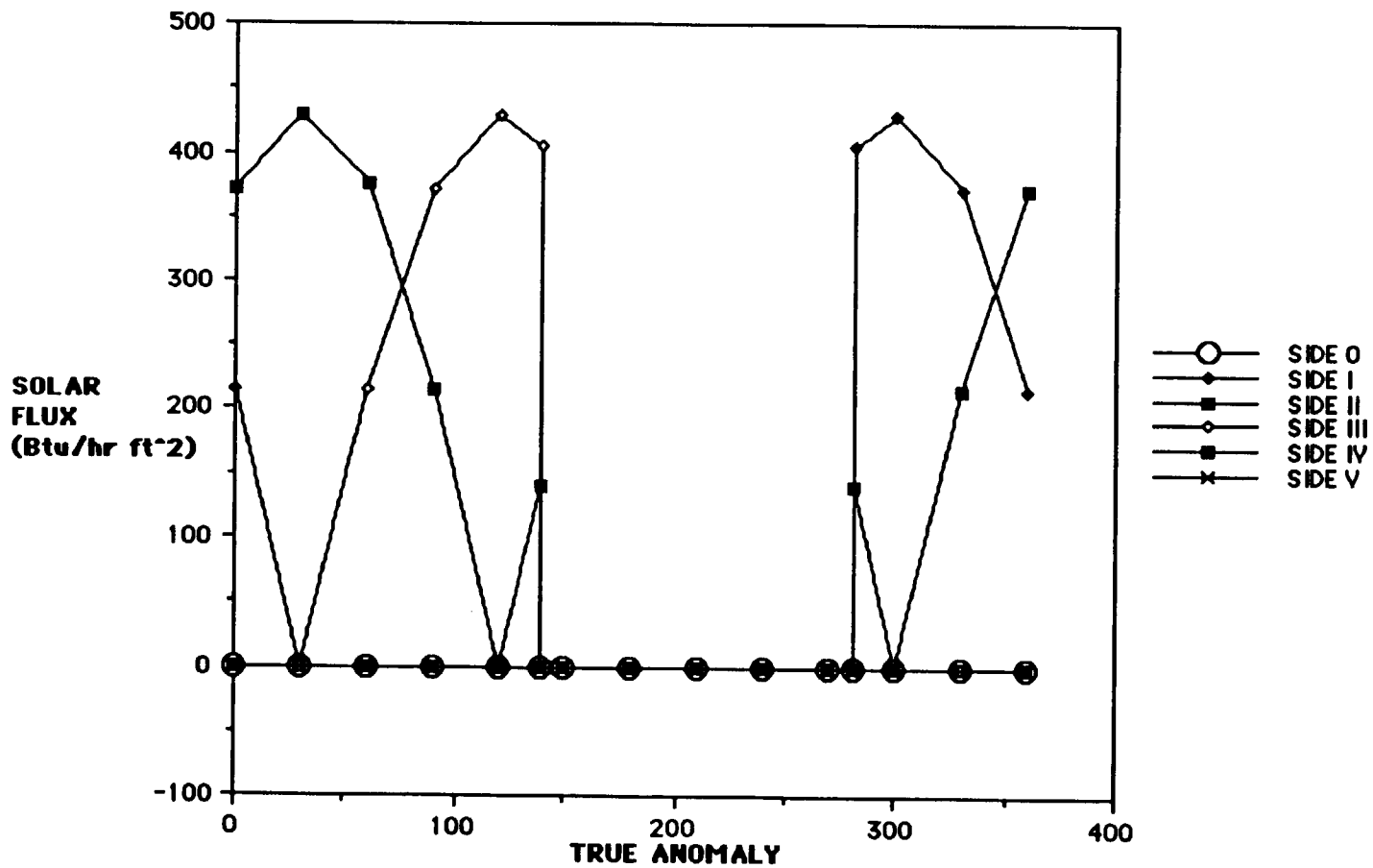

CASE XIX: SOLAR FLUX

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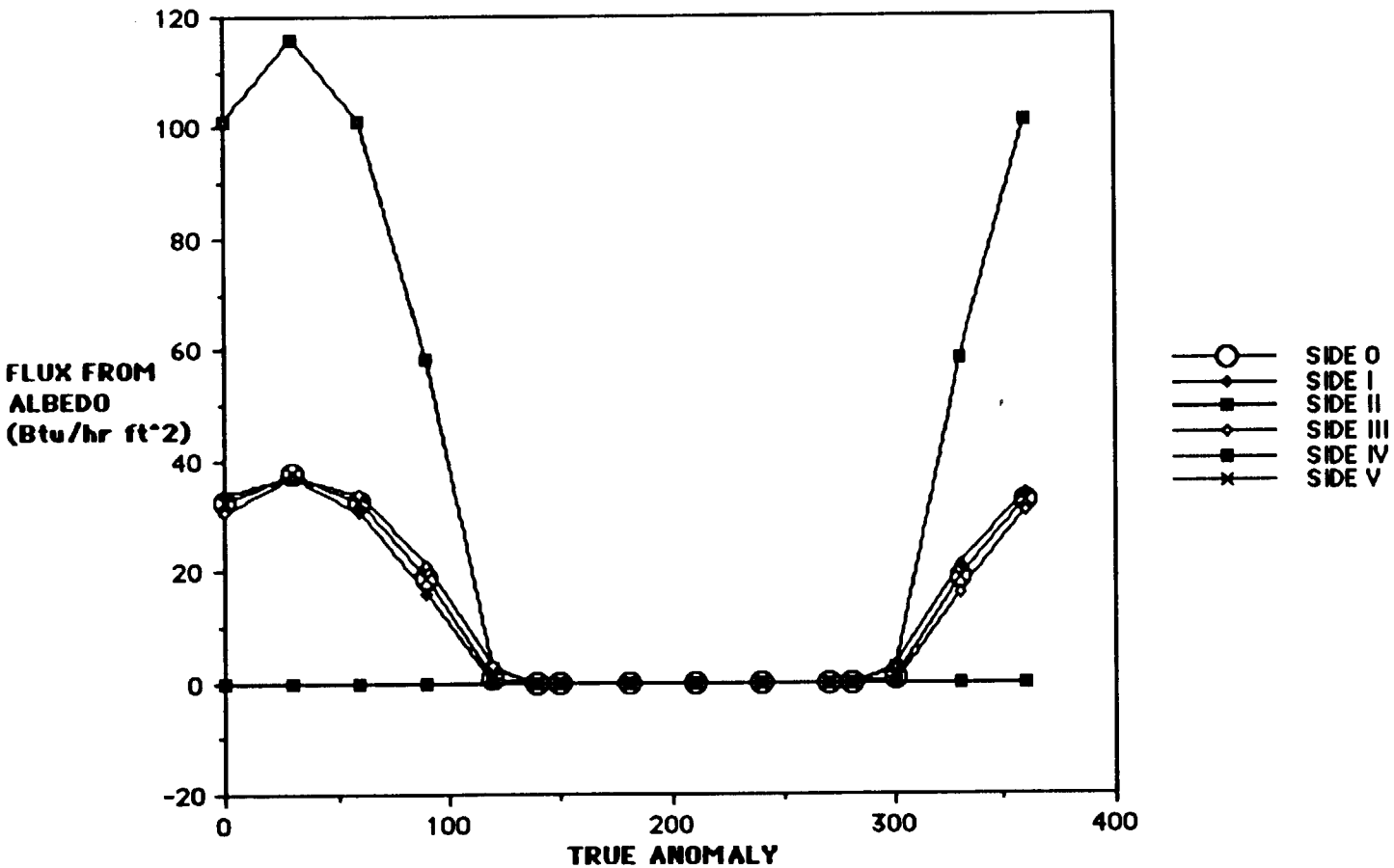

CASE XIX: ALBEDO FLUX

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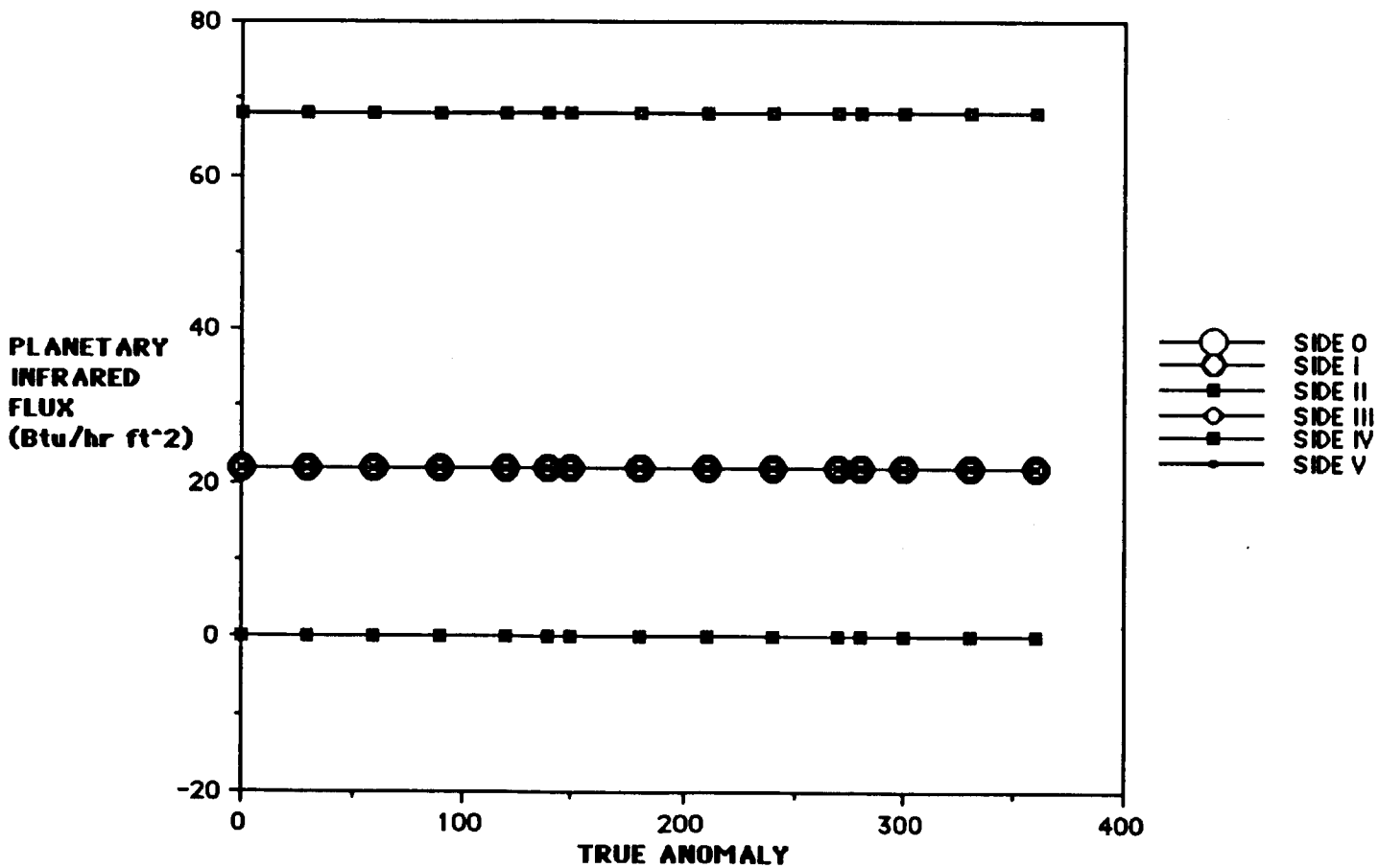

CASE XIX: PLANETARY FLUX

ALTITUDE=200nmi
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EARTH ORIENTED

Introduction to Chapter 5

N-Dimensional Branching Networks, 1-Dimensional Fluid Flow

Because many engineering problems involve heat transfer, thermodynamics, and flow of fluids, chapter five includes solution techniques for common fluid flow problems, using one-dimensional (Bernouli) equations, in network analyses. Through the versatility of the SINDA code, and through the use of analogies and linearization techniques, complex branching networks representing physical systems can be analyzed with reasonable accuracy. This chapter also includes examples related to transient concentrations of gas mixtures, and simulation of two-phase flows. While these examples do not strictly fall into the thermal analysis category, they are important illustrations of code versatility and analytical technique.

Section one gives a detailed discussion of the formulation of fluid network problems, and illustrates solution of steady state problems. Equations for simple flow of fluids are given and methods of linearization are shown. Both incompressible and compressible flows are considered. Analogies are developed so that these systems can be modeled in SINDA For steady state solutions, a unique procedure is given which allows convergence of the set of highly nonlinear flow equations. This technique is quite versatile, and allows quick convergence for n-dimensional branching networks.

Section 2 is an extension of these techniques to simulate transient pressurization events in compressible fluids. The formulation used requires use of the ideal gas law and assumes isothermal conditions. For many engineering problems, a conjugate fluid/thermal analysis, including heat transfer and any appropriate thermodynamic realtionships, can be simulated through these techniques.

Section 3 is included as a specific example of an engineering problem, related to the Shuttle program, utilizing many of the techniques illustrated in the first two sections. The analysis involves a conjugate fluid/thermal analysis, and requires parallel networks in SINDA. This is an important illustration of hydraulic system analysis (incompressible flow) for fluids with highly nonlinear properties. Simulations of several operating conditions and boundary conditions are shown, illustrating potential physical responses. This example illustrates great analytical flexibility.

During the Shuttle program, detecting and understanding cryogenic leaks within critical vehicle compartments, has been a major concern. Section four shows a simple closed form solution for description of gas mixture concentrations. A numerical model is then shown, which extends the analysis capability to predict concentrations during ascent, and can simulate several leaks simultaneously. For single constituent constant leak rates, the closed form and numerical solutions are in close agreement. The numerical analysis makes use of the SINDA code as an analytical framework, providing structured data sets, automated compile, link, and run features, and well defined transient analysis capability. Again, this example illustrates the versatility of network analysis codes.

Section five gives an example that relates thermodynamics and simple fluid flow, for systems with saturated, two-phase fluids. This is an important example because it illustrates the ability to compute "rough-order-of-magnitude" solutions for complex phenomena. Two-phase fluid properties are calculated via homogeneity, and standard pipe flow (Darcy) equations are solved for parallel flows with unequal heat distribution. A pressure balancing technique is utilized. While this example is highly idealized, such simulations are quite useful in understanding system response trends, and can many times become useful prediction tools if adequate data exists for model correlation.

Section six is included to illustrate several numerical techniques available to predict venting of compartments. This is important for payloads in the shuttle payload bay. This example shows a coupled solution by way of a code called FLAP, which solves the time dependent mass and energy conservation equation. Also illustrated are simplifying assumptions which can be used to quickly bound the couple solution. These include an isentropic and an isothermal solution using the SINDA code. Comparisons are given for the various techniques.

Again, this chapter illustrates the versatility and power of the network analysis technique and the SINDA code in particular. Also, the detailed development of analogies for physical systems is believed to be an excellent teaching tool for beginning analysts. Finally, the convergence techniques illustrated here have not been published elsewhere, and may prove to be useful in future engineering design analyses, where n-dimensional fluid systems can be described through use of characteristic dimensions and loss coefficients.

CHAPTER 5: N-DIMENSIONAL FLUID NETWORKS

SECTION 1: 1-D Network, Incompressible and Compressible Flow

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A. Preface to the Problem:

This section is included to present a resistance-capacitance (R-C) network approach for modeling simple fluid flow problems which can be coupled to thermal network problems. The following is a suggested approach for modeling N-dimensional branching fluid flow networks. The governing equations for pipe flow and flow through orifices are developed for incompressible flow (both laminar and turbulent regimes) and for compressible flow. Methods for linearizing the governing equations and a suggested approach for obtaining converged solutions are given. Specific examples are included for 1-D networks for both liquid and vapor.

The goals of this section are as follows:

(1) To understand the linearization methodology for the simple fluid system equations

(2) To understand the three step approach for obtaining convergence of highly non-linear network equations

(3) To understand the analogies for programming fluid network problems within SINDA

(4) To run the given sample fluid network problems for the various boundary conditions to learn the capabilities and limitations of the SINDA code

II. General Formulation of N-Dimensional Network Problems:

A. Mathematical Model:

Incompressible Fluid Flow in a Pipe

Flow in a pipe is always accompanied by friction between fluid particles rubbing against one another, and consequently, by a loss of energy available for doing work; there must be a pressure drop in the direction of flow. The general equation for the pressure drop in a pipe, known as Darcy's formula, is

$$\Delta P = \frac{\rho f L V^2}{144 D 2g}$$

where ΔP is the pressure difference, ρ is the density of the fluid, f is the friction factor, L is the length of pipe, V is the average fluid velocity, D is the diameter of the circular pipe (or hydraulic diameter for non-circular cross-sections) and g is the conversion constant.

The Darcy formula is valid for laminar or turbulent flow of any liquid in a pipe. With suitable restrictions, the Darcy formula may be used when gases and vapors (compressible fluids) are involved.

The Darcy formula can be rationally derived by dimensional analysis, with the exception of the friction factor, f, which must be determined experimentally. The friction factor for laminar flow conditions (**R** < 2000 or 2300 for circular pipe) is a function of Reynolds number only, whereas, for fully turbulent flow (**R** > 4000), it is also a function of the character of the pipe wall.

For incompressible laminar flow, the friction factor is given by

$$f = \frac{64}{\mathbf{R}} = \frac{64\mu}{D\rho V}$$

where μ is the absolute viscosity and **R** is the Reynolds number, based upon diameter or hydraulic diameter.

With the substitution of the friction factor, f, into the Darcy formula, this equation may be used for the solution of laminar flow problems in pipes. It applies to all pipe roughness factors, as the pressure difference in laminar flow is independent of wall roughness. The critical Reynolds number is about 2000 or 2300 for circular pipe, and the transition region is characterized by Reynolds numbers of 2000 to 4000.

In place of the Moody diagram, the following explicit formula for the friction factor, f, may be utilized with the given restrictions

$$f = \frac{1.325}{\left[\ln\left(\frac{\varepsilon}{3.7D} + \frac{5.74}{\mathbf{R}^{0.9}}\right)\right]^2}$$

$$10^{-6} \le \frac{\varepsilon}{D} \le 10^{-2}$$

$$5000 \le \mathbf{R} \le 10^{8}$$

where ε is the roughness height and $\frac{\varepsilon}{D}$ is the relative roughness.

Substituting the appropriate friction factor equation into the Darcy formula for incompressible laminar flow gives

$$\Delta P = \frac{\rho\left(\frac{64\mu}{D\rho V}\right) L V^2}{144 D 2g}$$

$$\Delta P = \frac{\left(\frac{64\mu}{D}\right) LV}{144D2g}$$

$$\Delta P = \frac{64\mu LV}{144D^2 2g}$$

The mean velocity at a given cross-section is given by

$$V = \frac{\dot{m}}{\rho A}$$

where $\dot{m}$ is the mass flowrate and A is the cross-sectional area, as determined by the continuity equation for steady flow.

Substituting the equation for the mean velocity into the Darcy formula gives

$$\Delta P = \frac{64\mu L\left(\frac{\dot{m}}{\rho A}\right)}{144D^2 2g}$$

$$\Delta P = \frac{(4)(64)\mu L\dot{m}}{144D^4 2g\pi\rho}$$

Solving for $\dot{m}$ gives

$$\dot{m} = \frac{dm}{dt} = \frac{144D^4 2g\rho\pi}{256\mu L}(P_1 - P_2)$$

Where P_1 is defined as the upstream pressure and P_2 is defined as the downstream pressure.

Let the laminar "calculated conductor", G_L, be given by

$$G_L = \frac{144D^4 2g\rho\pi}{256\mu L}$$

such that the equation for the mass flowrate, for incompressible laminar flow, becomes

$$\dot{m} = \frac{dm}{dt} = G_L(P_1 - P_2)$$

The mass flowrate equation for incompressible laminar flow is linear with respect to P and the "calculated conductor" is not a function of the dependent variable (pressure).

For incompressible turbulent flow, ΔP is given by

$$\Delta P = \frac{\rho f L \left(\frac{\dot{m}}{\rho A}\right)^2}{144 D 2 g}$$

$$\Delta P = \frac{\rho f L (\dot{m})^2}{144 D 2 g \rho^2 A^2}$$

$$\Delta P = \frac{f L (\dot{m})^2}{144 D 2 g \rho \left(\frac{\pi^2 D^4}{16}\right)}$$

or, finally,

$$\Delta P = \frac{8 f L \dot{m}^2}{144 \pi^2 D^5 \rho g}.$$

Solving for $\dot{m}$ gives

$$\dot{m}^2 = \frac{144 g \rho \pi^2 D^5 \Delta P}{8 f L}$$

or

$$\dot{m} = \sqrt{\frac{144 g \rho \pi^2 D^5 \Delta P}{8 f L}}$$

Let the turbulent "calculated conductor", G_T, be given by

$$G_T = \sqrt{\frac{144 g \rho \pi^2 D^5}{8 f L}}$$

such that the equation for the mass flowrate, for incompressible turbulent flow, becomes

$$\dot{m} = \frac{dm}{dt} = G_T (P_1 - P_2)^{\frac{1}{2}}$$

The mass flowrate equation for incompressible turbulent flow is non-linear with respect to P, the dependent variable (pressure).

Linearizing the equation gives

$$\dot{m} = \frac{dm}{dt} = \frac{G_T}{(P_1 - P_2)^{\frac{1}{2}}}(P_1 - P_2)$$

Incompressible Flow through Nozzles, Orifices and Restrictions

The mass flowrate for incompressible flow through nozzles, orifices and restrictions is given by

$$\dot{m} = C_d A\sqrt{2g(144)\Delta P\rho}$$

where A denotes the cross-sectional discharge area and C_d is the characteristic discharge coefficient.

Let the restrictions "calculated conductor", G_R, be given by

$$G_R = C_d A\sqrt{2g(144)\rho}$$

such that the equation for the mass flowrate, for incompressible flow through restrictions, becomes

$$\dot{m} = \frac{dm}{dt} = G_R(P_1 - P_2)^{\frac{1}{2}}$$

The mass flowrate equation for flow through nozzles, orifices and restrictions is non-linear with respect to P, the dependent variable (pressure).

Linearizing the equation gives

$$\dot{m} = \frac{dm}{dt} = \frac{G_R}{(P_1 - P_2)^{\frac{1}{2}}}(P_1 - P_2)$$

Compressible Fluid Flow in Pipes

An accurate determination of the pressure drop for a compressible fluid flow through a pipe requires knowledge of the relationship between pressure and specific volume; this relationship is not easily determined for each particular problem. The usual extremes considered include adiabatic and isothermal flows. Adiabatic flow is usually assumed in short, "perfectly insulated" pipe. Such is consistent with the adiabatic flow assumption since no heat is transferred to or from the pipe, excepting the minute amount of heat generated by friction, which is added to the flow.

Isothermal flow, or flow at constant temperature, is often assumed, partly for convenience. More often isothermal flow is assumed because it is closer to fact in piping practice. The complete isothermal formulation is given by

$$\dot{m}^2 = \left[\frac{144\rho g A^2}{\frac{fL}{D} + 2\ln\left(\frac{P_1}{P_2}\right)}\right]\left(\frac{P_1^2 - P_2^2}{P_1}\right)$$

$$\dot{m} = \left[\frac{144\rho g A^2}{\frac{fL}{D} + 2\ln\left(\frac{P_1}{P_2}\right)}\right]^{\frac{1}{2}}\left(\frac{P_1^2 - P_2^2}{P_1}\right)^{\frac{1}{2}}$$

or

$$\dot{m} = \left[\frac{144\rho g A^2}{\frac{fL}{D} + 2\ln\left(\frac{P_1}{P_2}\right)}\right]^{\frac{1}{2}}\left[\frac{(P_1 + P_2)(P_1 - P_2)}{P_1}\right]^{\frac{1}{2}}$$

Let the "calculated conductor", G_C, for compressible isothermal flow in a pipe be given by

$$G_C = \left[\frac{144\rho g A^2}{\frac{fL}{D} + 2\ln\left(\frac{P_1}{P_2}\right)}\right]^{\frac{1}{2}}$$

such that the equation for the mass flowrate for compressible isothermal flow through pipes becomes

$$\dot{m} = \frac{dm}{dt} = G_C\left(\frac{P_1 + P_2}{P_1}\right)^{\frac{1}{2}}(P_1 - P_2)^{\frac{1}{2}}$$

The mass flowrate equation for compressible isothermal flow in a pipe is non-linear with respect to P, and the "calculated conductor" is a function of the dependent variable (pressure).

Linearizing the equation gives

$$\dot{m} = \frac{dm}{dt} = G_C\left[\frac{(P_1 + P_2)}{P_1(P_1 - P_2)}\right]^{\frac{1}{2}}(P_1 - P_2)$$

The mass flow equation for compressible isothermal pipe flow is developed on the basis of these assumptions:

(1) Isothermal flow
(2) No mechanical work is done on or by the system
(3) Steady flow

(4) The gas behaves as an ideal gas
(5) The velocity may be represented by the average velocity at a cross section
(6) The friction factor is constant along the pipe
(7) The pipe line is straight and horizontal between end points

Compressible Flow through Nozzles, Orifices and Restrictions

The semi-empirical isentropic equation for compressible flow through nozzles, orifices, and restrictions is given by

$$\dot{m} = C_d Y A \sqrt{2g144\rho(P_1 - P_2)}$$

where the expansion factor Y, for orifices, is given by

$$Y = 1 - \left[0.41 + 0.35\left(\frac{A_{throat}}{A_{inlet}}\right)^2\right]\left(\frac{P_1 - P_2}{kP_1}\right)$$

where A_{throat} is the area of the orifice or nozzle throat, and A_{inlet} is the area of approach, and k is the ratio of specific heats.

If the diameter ratio β is given by

$$\beta = \sqrt{\frac{A_{throat}}{A_{inlet}}}$$

then the expansion factor Y can be rewritten as

$$Y = 1 - \left[0.41 + 0.35\beta^4\right]\left(\frac{P_1 - P_2}{kP_1}\right)$$

Substituting the expansion factor Y into the mass flowrate equation gives

$$\dot{m} = C_d A(2g144\rho)^{\frac{1}{2}}(P_1 - P_2)^{\frac{1}{2}}\left[1 - \left(0.41 + 0.35\beta^4\right)\left(\frac{P_1 - P_2}{kP_1}\right)\right]$$

Let the restrictions "calculated conductor" be given by

$$G_{CD} = C_d A(2g144\rho)^{\frac{1}{2}}\left[1 - \left(0.41 + 0.35\beta^4\right)\left(\frac{P_1 - P_2}{kP_1}\right)\right]$$

The mass flowrate equation for compressible flow through an orifice then becomes

$$\dot{m} = G_{CD}(P_1 - P_2)^{\frac{1}{2}}$$

The mass flowrate equation for compressible flow through nozzles, orifices and restrictions is non-linear with respect to P and the "calculated conductor" is a function of the dependent variable (pressure).

Linearizing the equation gives

$$\dot{m} = \frac{G_{CD}}{(P_1 - P_2)^{\frac{1}{2}}}(P_1 - P_2)$$

Choked Flow Conditions

The maximum velocity of a compressible fluid in a pipe is limited by the velocity at which a pressure wave may be propagated through the fluid medium. This velocity is the speed of sound in the fluid. Since recognizing that the mass flowrate of fluid through a pipe is given by the product of fluid density, mean velocity, and cross-sectional flow area; continuity requires that a decrease in fluid density be accompanied by an increase in mean flow velocity. This statement is made under the assumption that the cross-sectional area of the pipe is constant. Generally, because pressure decreases in the direction of flow through the pipe, the maximum velocity is expected at the downstream end of the pipe. If the pressure drop is sufficiently high, the exit velocity will reach the velocity of sound. Further decrease in the outlet pressure will not be felt upstream because the pressure wave can only travel at sonic velocity, and the "signal" will never translate upstream. The added pressure drop, obtained by lowering the outlet pressure after the maximum discharge has already been reached takes place beyond the end of the pipe.

The maximum possible velocity in the pipe is sonic velocity, which is given by

$$V_{max} = \sqrt{kgRT} = \sqrt{\frac{kgP_1 144}{\rho}}$$

and the maximum mass flowrate is given by

$$\dot{m}_{max} = \rho A\sqrt{\frac{kgP_1 144}{\rho}} = A\sqrt{kg\rho P_1 144}$$

where k is the ratio of the constant pressure to constant volume specific heat, R is the individual gas constant and T is the absolute temperature. The critical pressure for which choked flow conditions will exist is defined as follows

$$P_{crit} = P_{source}\left(\frac{2}{k+1}\right)^{\left(\frac{k}{k-1}\right)}$$

Any reduction in downstream pressure below P_{crit} will not result in an increase in flow rate. The critical pressure ratio is defined as follows

$$r = \frac{P_{crit}}{P_{source}}$$

Choked flow equations must be formulated from the maximum velocity and mass flow relations. For a network analysis, however, we would like to have $\dot{m}_{choked}$ as a function of downstream pressure. We may write

$$\dot{m}_{choked} = G_{choked}(P_1 - P_2)$$

where G_{choked} is a choked flow conductor which may be defined as follows. The semi-empirical isentropic equation developed above for nozzles and orifices may be used with the following restrictions.

1. Y, expansion factor defined with $P_2 = P_{crit}$
2. G_{CD}, calculated with $P_2 = P_{crit}$
3. Flow equation normalized based on actual downstream pressure P_2

$$Y = 1 - \left[0.41 + 0.35\beta^4\right]\left(\frac{P_1 - P_{crit}}{kP_1}\right)$$

Substituting the expansion factor Y for choked flow

$$G_{CD} = C_d A(2g144\rho)^{\frac{1}{2}}(P_1 - P_{crit})^{\frac{1}{2}}\left[1 - \left(0.41 + 0.35\beta^4\right)\left(\frac{P_1 - P_{crit}}{kP_1}\right)\right]$$

Normalizing the equation with respect to the actual downstream pressure gives

$$\dot{m}_{choked} = \frac{G_{CD}}{(P_1 - P_2)}(P_1 - P_2)$$

therefore

$$G_{choked} = \frac{G_{CD}}{(P_1 - P_2)}$$

The above formulation will satisfy continuity and limit the mass flowrate, below the critical pressure ratio.

B. Linearization Methodology for Non-Linear Equations

The following non-linear algebraic equation is used to illustrate a linearization and under-relaxation scheme.

Let

$$x^2 = 16$$

where $x = x^*$.

The linearized equation is given by

$$x x^* = 16$$

The variable x^* can be a function of the variable x. Suppose we now make an initial guess at x^* and solve for x.

If $x^*_{old} = 1$ then

$$x = \frac{16}{1}$$

Since $x^* = x$, then $x^*_{new} = 16$ and the next calculation of x^*_{new} will lead to $x^*_{new} = 1$. No progress toward a solution is possible. An under-relaxation scheme is then used to converge to a solution.

Suppose now that

$$x = (1 - \alpha)\, x^*_{old} + \alpha x^*_{new}$$

where $\alpha = 0.50$ is the under-relaxation factor.

Four iterations are required to converge to the correct solution, x = 4.0.

C. Solution Procedure for N-Dimensional Fluid Networks

To solve a set of linearized equations requires some knowledge of the solution for convergence because the linearized conductors include dependent variables. The following three steps outline the procedure for solving a multi-dimensional fluid network, involving turbulent pipe and orifice flows.

(1) To start the solution, solve a set of linear incompressible, but physically unrealistic network equations.

(2) Use this solution as a starting point for the linearized incompressible flow equations.

(3) If the problem is compressible, then follow with a solution of linearized compressible flow equations.

To illustrate the procedure, the following linear incompressible equations for turbulent pipe and orifice flows are solved

$$\dot{m} = \frac{dm}{dt} = G_T (P_1 - P_2)$$

where $G_T = \sqrt{\dfrac{144 g \rho \pi^2 D^5}{8 f L}}$

and

$$\dot{m} = \frac{dm}{dt} = G_R (P_1 - P_2)$$

where $G_R = C_d A\sqrt{2g(144)\rho}$

The mass flowrates will be in error by a significant amount, but the pressures will be reasonable. The problem is now solved using the linearized incompressible flow equations and the previous solution as the initial condition.

$$\dot{m} = \frac{dm}{dt} = \frac{G_T}{(P_1 - P_2)^{\frac{1}{2}}}(P_1 - P_2)$$

$$\dot{m} = \frac{dm}{dt} = \frac{G_R}{(P_1 - P_2)^{\frac{1}{2}}}(P_1 - P_2)$$

After solving these equations the mass flowrates and pressures will then be reasonable. For compressible flow problems, the following linearized equations are used and the linearized conductors are updated for each iteration.

$$\dot{m} = \frac{dm}{dt} = G_C\left[\frac{(P_1 + P_2)}{P_1(P_1 - P_2)}\right]^{\frac{1}{2}}(P_1 - P_2)$$

where

$$G_C = \left[\frac{144\rho g A^2}{\frac{fL}{D} + 2\ln\left(\frac{P_1}{P_2}\right)}\right]^{\frac{1}{2}}$$

and

$$\dot{m} = \frac{dm}{dt} = \frac{G_{CD}}{(P_1 - P_2)^{\frac{1}{2}}}(P_1 - P_2)$$

where

$$G_{CD} = C_d A(2g144\rho)^{\frac{1}{2}}\left[1 - \left(0.41 + 0.35\beta^4\right)\left(\frac{P_1 - P_2}{kP_1}\right)\right]$$

The critical pressure ratio is used to check for choked conditions. For each compressible flow problem with choked flow conditions, the mass flowrate is given by

$$\dot{m}_{choked} = C_d A(2g144\rho)^{\frac{1}{2}}\frac{(P_1 - P_{crit})^{\frac{1}{2}}}{(P_1 - P_2)}\left[1 - \left(0.41 + 0.35\beta^4\right)\left(\frac{P_1 - P_{crit}}{kP_1}\right)\right](P_1 - P_2)$$

<u>Transient (Isothermal) Pressurization</u>

If transient pressurization is of interest, the compressible flow equations can be extended with the ideal gas law.

The ideal gas law is given by

$$m = \frac{PV}{RT}$$

differentiating

$$\dot{m} = \frac{dm}{dt} = \frac{V}{RT}\frac{dP}{dt} - \frac{VP}{RT^2}\frac{dT}{dt}$$

For cases where the change in temperature with time is slow, or for systems where the change in temperature is insignificant (isothermal), dT/dt can be assumed to be zero, giving

$$\dot{m} = \frac{dm}{dt} = \frac{V}{RT}\frac{dP}{dt}$$

Combining with any of the resistance equations gives

$$\frac{V}{RT}\frac{dP}{dt} = G_{linearized}\ \Delta P$$

Thus a fluid capacitance for a transient analysis can be defined in the form

$$c = \frac{V}{RT}$$

resulting in

$$c\frac{dP}{dT} = G_{linearized}\left(P_1 - P_2\right)$$

where it may be noted that small time steps will generally be required.

This formulation assumes that the temperature is constant. For problems where temperature changes are involved, due either to heat transfer or thermodynamics, then coupled analyses are required. Coupled networks can be incorporated in SINDA for incompressible flow, and for isothermal compressible flow. An example of coupled networks is given in Chapter 5, Section 3 (for incompressible flow). Also, Chapter 5, Section 6 illustrates the effects of various assumptions (including isentropic, isothermal, and solutions with heat transfer) for venting analyses. Fully coupled solutions for mass and energy conservation are given.

D. N-Dimensional Fluid Network Solution with SINDA

The above mentioned networks can be defined and solved in SINDA with the following analogies:

(1) Temperature translates into Pressure

(2) Heat Rate translates into Mass Flowrate

(3) $\frac{kA}{\Delta x}$, hA, $\sigma\varepsilon FA$ translates into Linearized Flow Conductors

(4) Capacitance translates into $\frac{V}{RT}$ (gas storage, isothermal)

The solutions can be linked to transient heat transfer problems, yielding coupled conjugate solutions. Three example problems illustrate the solution techniques discussed. These example problems include:

(1) 1-D Fluid Network, Incompressible Flow

(2) 1-D Fluid Network, Compressible Flow

(3) 1-D Fluid Network, Compressible Flow with Choked Flow Conditions

The programming is not optimized, but intended to be explicit so that beginning code users can easily follow the logic. All solutions were generated on a PC, using single precision. Greater accuracy can be obtained with a 64-bit machine. This is important for networks with low resistance (high stiffness).

III. Flow Analysis for a 1-D Fluid Network, Incompressible Flow

A. Statement of the Problem:

Consider the 1-D fluid network shown in Figure 1. The pipe is 6 in long. The diameters of the pipe and orifices are 0.50 in. Fluid (water) flows from the high pressure side, at 200 psia, to the low pressure side, at 14.7 psia. Determine the steady state pressure and mass flowrate distributions through the fluid network.

B. Schematic of 1-D Fluid Network, Incompressible Flow

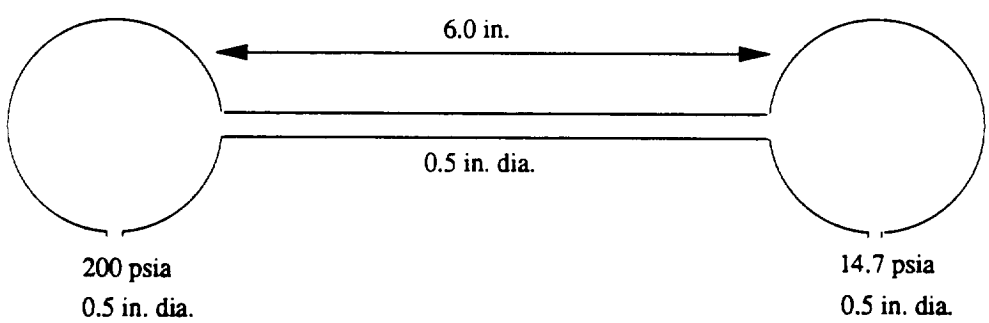


Figure 1. Schematic of 1-D Fluid Network

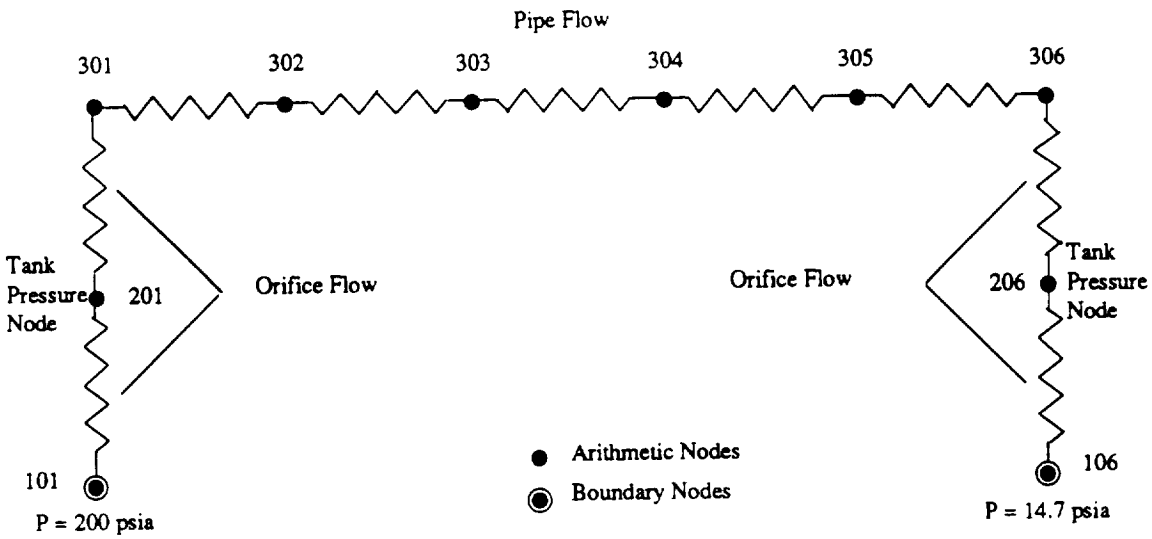


Figure 2. Schematic of 1-D Fluid Resistance Network

C. Given:

(1) Hydraulic diameter of pipe is 0.5 in
(2) Hydraulic diameter of orifices are 0.5 in
(3) Pipe length is 6 in
(4) High pressure side is 200 psia
(5) Low pressure side is 14.7 psia

D. Find:

Steady state pressure and mass flowrate distribution through the 1-D fluid network

IV. Analysis:

A. Discretization:

The analysis is performed assuming steady state fluid flow. The fluid network is modeled using two boundary nodes and eight arithmetic nodes, as shown in Figure 2.

Negative capacitances designate arithmetic nodes while negative node numbers designate boundary nodes. For a steady state analysis, it should be noted that capacitance is of no importance and has arbitrarily been assigned a value of one. The total number of nodes used to model the problem is ten and the nodes are labeled as shown in Figure 2.

B. The Input Deck:

This section is included to explain how information in the statement of the problem is conveyed to SINDA and to present an accompanying flowchart (see Figure 3) and a corresponding input deck. The input deck, provided on the following pages, is a "Gaski" SINDA deck.

The input deck comprises of nine major "blocks"; these include the TITLE block, the NODE DATA block, the CONDUCTOR DATA block, the CONSTANTS DATA block, the ARRAY DATA block, the EXECUTION block, the VARIABLES 1 block, the VARIABLES 2 block, and the OUTPUT block.

For this problem, two boundary nodes and eight arithmetic nodes have been used to define the 1-D fluid resistance network. Also, seventeen (dummy) boundary nodes have been defined as storage locations for the total mass and mass flowrates data.

Nine conductor sets have been defined as well as nine (dummy) conductor sets for mass flowrate information purposes.

Thirteen control constants have been identified including DTIMEI, DTIMEH, NLOOP, TIMEND, OUTPUT, ARLXCA, DRLXA, BALENG, TIMEO, DAMPA, DAMPD, NDIM, and ITEST. The reader is directed to the Gaski SINDA users manual for further information regarding these and other control constants used by SINDA.

Two array data sets have been defined. These array data sets define the pressure vs density and viscosity vs temperature relationships for water.

The EXECUTION block contains information that directly controls program execution. The solution scheme is identified in this block. The SNHOSD selection which corresponds to a steady state analysis (Explicit Taylor Series Double Precision) is used for this problem.

The VARIABLES 1 block includes various user supplied subroutines to calculate the conductor values for orifice and pipe flows (incompressible and compressible flow) as well as the mass flowrates. The subroutines utilize the equations derived in Mathematical Model (Section II, part A) for calculating these conductor and mass flowrate values.

The OUTPUT CALLS block determines what parameters are to be printed. Only the steady state nodal pressures and mass flowrates are of interest in the present analysis. User defined subroutines which convert pressure and mass flowrate data into the "T-type" format are included to print the desired data.

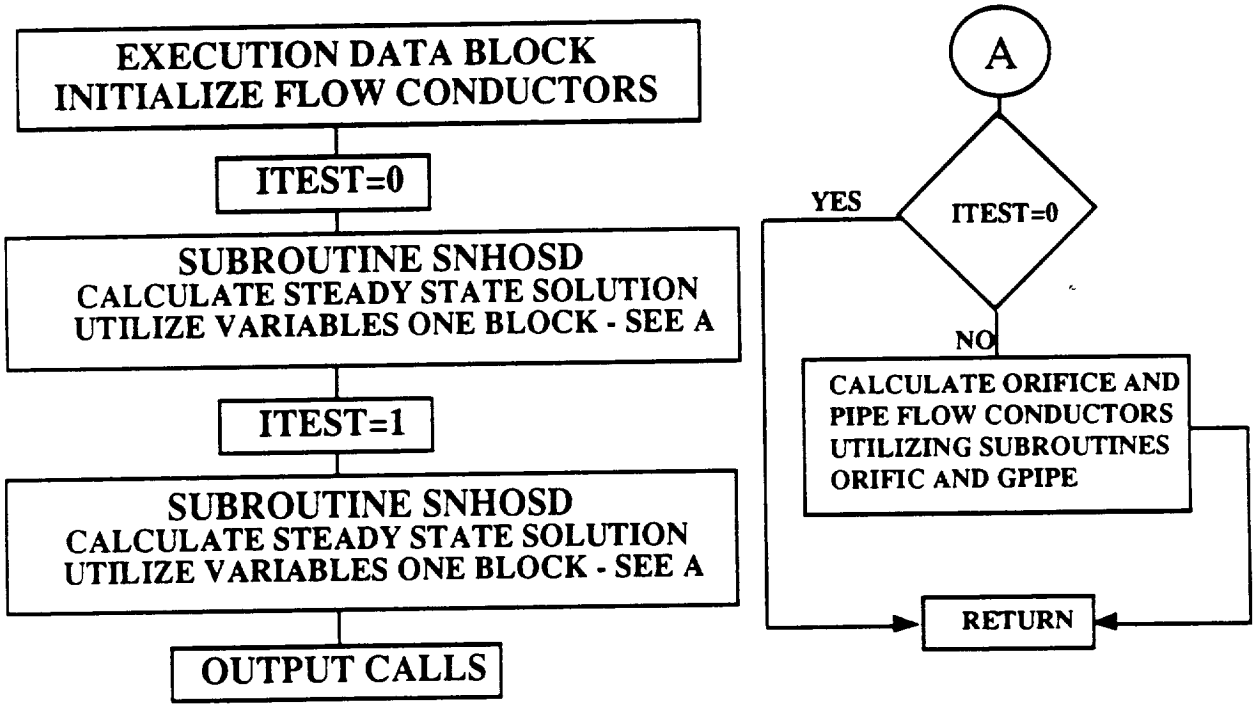


Figure 3. SINDA Solution Procedure, Controlled in the Execution Block

SINDA INPUT LISTING

```
        BCD 3THERMAL LPCS
        BCD 9INCOMPRESSIBLE FLOW, 1D NETWORK
        END
C
        BCD 3NODE DATA
C
            1, 0.0, 1.0
            2, 0.0, 1.0
            -3, 0.0, 1.0
C
           -101,200.0,1.0 $ PRES BOUNDARY
           -106,14.7,1.0 $ PRES BOUNDARY
C
           201, 200.0, -1.0 $ PRES AT FIRST CAVITY
           206, 200.0, -1.0 $ PRES AT FIRST CAVITY
C
           301, 200.0, -1.0 $ PRES AT SECOND CAVITY
           302, 200.0, -1.0 $ PRES AT SECOND CAVITY
           303, 200.0, -1.0 $ PRES AT SECOND CAVITY
           304, 200.0, -1.0 $ PRES AT SECOND CAVITY
           305, 200.0, -1.0 $ PRES AT SECOND CAVITY
           306, 200.0, -1.0 $ PRES AT SECOND CAVITY
C
C FLOW RATE STORAGE LOCATION
C
           -1001, 0.0, 1.0
           -1006, 0.0, 1.0
C
           -2001, 0.0, 1.0
           -2006, 0.0, 1.0
C
           -4001, 0.0, 1.0
           -4002, 0.0, 1.0
           -4003, 0.0, 1.0
           -4004, 0.0, 1.0
           -4005, 0.0, 1.0
C
       END
C
       BCD 3CONDUCTOR DATA
C
           1, 1, 2, 1.0
           2, 2, 3, 1.0
C
           101, 101, 201, 0.0
           106, 106, 206, 0.0
C
           201, 201, 301, 0.0
           206, 206, 306, 0.0
C
C
           401, 301, 302, 0.0
           402, 302, 303, 0.0
           403, 303, 304, 0.0
           404, 304, 305, 0.0
           405, 305, 306, 0.0
C
       END
C
       BCD 3CONSTANTS DATA
```

```
          DTIMEI,0.1
          DTIMEH,0.1
          NLOOP,5000
C
          TIMEND,0.0
          OUTPUT,0.2
C
          ARLXCA,.01
          DRLXCA,.01
          BALENG,.01
          TIMEO,0.0
          DAMPA,0.5
          DAMPD,0.5
          NDIM,1000
          ITEST,0
          301,0.
          302,0.
          303,0.
          304,0.
          305,0.
          306,0.
          1301,0.
          1302,0.
          1303,0.
          1304,0.
          1305,0.
          1306,0.
C
      END
C
      BCD 3ARRAY DATA
          1 $ PRES VS RHO (H2O) AT 2460 DEG R
          14.7, 62.4
          600.0, 62.4
          END
C
          2 $ VISCOSITY H20 VS TEMP
          32.0, 1.2E-3
          100.0, 0.458E-3
          600.0, 0.058E-3
          END
      END
C
      BCD 3EXECUTION
C
C INITIALIZE FLOW CONDUCTORS
C
M     PAVG=AMAX1(T101,T201)
M     CALL D1DEG1(PAVG,A1,RHO)
M     RGAS=1545./18.
M     TEMP=80.
M     AREA=(3.14159*(0.5/12.)**2)/4.0
M     GK=1.329
M     G101=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M     PAVG=AMAX1(T106,T206)
M     CALL D1DEG1(PAVG,A1,RHO)
M     RGAS=1545./18.
M     TEMP=80.
M     AREA=(3.14159*(0.5/12.)**2)/4.0
M     G106=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M     PAVG=AMAX1(T201,T301)
M     CALL D1DEG1(PAVG,A1,RHO)
```

```
M       RGAS=1545./18.
M       TEMP=80.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G201=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=80.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G206=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=80.
M       DIA=0.5/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G401=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G402=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G403=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G404=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G405=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
```

```
C
C  FIRST SOLUTION USES LINEAR (UNREALISTIC) FLOW CONDUCTORS
C
F       ITEST=0
F       NLOOP=2000
F       CALL SNHOSD
C
C  SECOND SOLUTION USES FIRST SOLUTION AS A STARTING POINT, AND
C  LINEARIZES FLOW CONDUCTORS IN VARIABLES 1, TO GET PROPER SOLUTION
C
F       ITEST=1
F       NLOOP=2000
F       CALL SNHOSD
C
        END
        BCD 3VARIABLES 1
C
C
C CALC ORIFICE FLOW CONDUCTORS
C
F       IF(ITEST.EQ.0)GO TO 40
C
M       PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=80.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=80.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=80.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=80.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
```

```
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=80.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
C
C CALC MDOTS
C
M 40    CALL XMDOT(T101,T201,G101,T1001)
M       CALL XMDOT(T106,T206,G106,T1006)
C
M       CALL XMDOT(T201,T301,G201,T2001)
M       CALL XMDOT(T206,T306,G206,T2006)
C
```

```
M       CALL XMDOT(T301,T302,G401,T4001)
M       CALL XMDOT(T302,T303,G402,T4002)
M       CALL XMDOT(T303,T304,G403,T4003)
M       CALL XMDOT(T304,T305,G404,T4004)
M       CALL XMDOT(T305,T306,G405,T4005)
C
F 100   CONTINUE
C
C
F       RETURN
F       END
C
F       SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
F       RETURN
F       END
C
F       SUBROUTINE ORIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)/SQRT(ABS(PUP-PDN))
F       RETURN
F 2     GCOND=0.0
F       RETURN
F       END
C
F       SUBROUTINE GPIPE(RHO,AREA,XL,DIA,FFACT,PUP,PDN,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
F       GCOND=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
F       GCOND=GCOND/SQRT(ABS(PUP-PDN))
F       RETURN
F 2     GCOND=0.0
C
C       RETURN
C       END
C
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
C CALC MDOTS
C
M       CALL XMDOT(T101,T201,G101,T1001)
M       CALL XMDOT(T106,T206,G106,T1006)
C
M       CALL XMDOT(T201,T301,G201,T2001)
M       CALL XMDOT(T206,T306,G206,T2006)
C
M       CALL XMDOT(T301,T302,G401,T4001)
M       CALL XMDOT(T302,T303,G402,T4002)
M       CALL XMDOT(T303,T304,G403,T4003)
M       CALL XMDOT(T304,T305,G404,T4004)
M       CALL XMDOT(T305,T306,G405,T4005)
C
C
C
```

```
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC,ITEST
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $           8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $           8H RELXCC(I6,2H)=1PE12.5,/,
F     $           18X,8H ITEST =I6)
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       J=1
F       L=3
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 15
F       J=L+1
F       L=L+3
F       GO TO 5
F15     CONTINUE
CF       END
C
C       RETURN
        END
        BCD 3END OF DATA
```

V. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are given on the following pages. Nodal pressures and mass flowrates are printed in psia and lb/sec, respectively. Some items to note in the SINDA output are (1) SINDA iteratively solves for the pressure distributions, (2) the mass flowrates are saved in temperature locations of the (dummy) nodes 1001-4005 and (3) there are at least two sets of output for each solution, the initial condition and solution results. Figure 4 shows the steady state nodal pressures and the mass flowrates through the 1-D fluid resistance network using linearized incompressible flow equations.

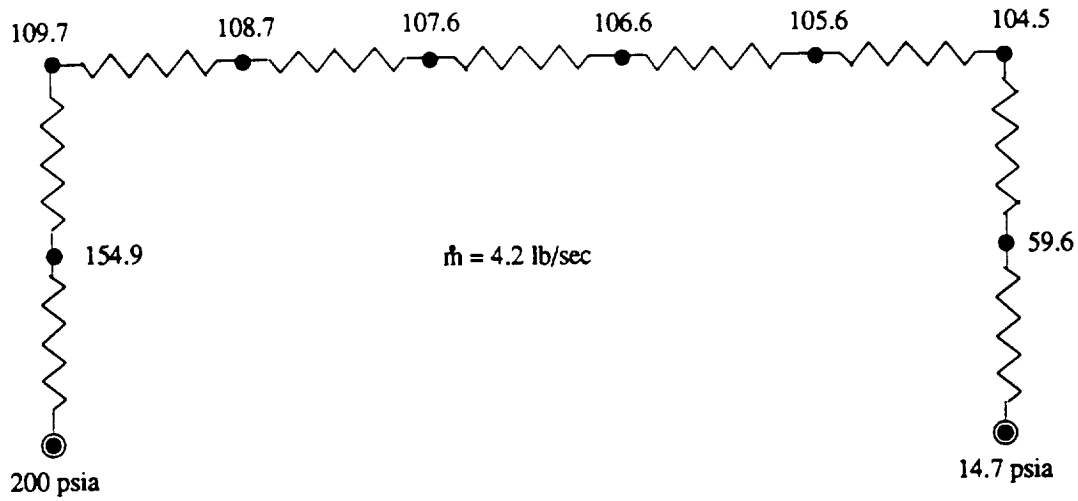


Figure 4. Steady State Nodal Pressures and Mass Flowrates for 1-D Resistance Fluid Network Using Linearized Incompressible Flow Equations

VI. Closing Comments:

While this example illustrates a simple one dimensional problem for incompressible flow, the techniques can be easily extended to branching networks, with many parallel flow passages. These branching networks would be difficult to evaluate through hand calculations. Also, through the use of analogies, these networks can be coupled to thermal networks in SINDA. Chapter 5, Section 3 shows a coupled hydraulic/thermal network.

SINDA OUTPUT LISTING

```
 (C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK
ANALYSIS ASSOCIATES, INC. - PAGE      1

    COPMRESSIBLE FLOW, 1D NETWORK

 *** NOTE *** SNHOSD REQUIRES      20 DYNAMIC STORAGE LOCATIONS OUT OF     951 AVAILABLE ***

 **********
 TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                   ITEST =      0

 T     1=       .00000  T     2=       .00000  T   201=   200.00000
 T   206=    200.00000  T   301=    200.00000  T   302=   200.00000
 T   303=    200.00000  T   304=    200.00000  T   305=   200.00000
 T   306=    200.00000  T     3=       .00000  T   101=   200.00000
 T   106=     14.70001  T  1001=       .00000  T  1006=   115.32150
 T  2001=       .00000  T  2006=       .00000  T  4001=       .00000
 T  4002=       .00000  T  4003=       .00000  T  4004=       .00000
 T  4005=       .00000

 SNHOSD RUN, ARLXCA=0.10000E-01, DRLXCA=0.10000E-01, BALENG=0.10000E-01, BENODE=0.50000E-02,
NLOOP=   2000

 *** NOTE *** RELAXATION CRITERIA HAS BEEN MET WITH LOOPCT =      69

     ENGBAL = -.101192      AT LOOPCT =      69
```

```
**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(    302)=-8.85010E-03
                   ITEST =      0

T      1=       .00000  T      2=       .00000  T    201=   162.64400
T    206=     52.21863  T    301=    125.28030  T    302=   118.18212
T    303=    111.05822  T    304=    103.89263  T    305=    96.85168
T    306=     89.73370  T      3=       .00000  T    101=   200.00000
T    106=     14.70001  T   1001=     23.24853  T   1006=    23.34972
T   2001=     23.25331  T   2006=     23.34752  T   4001=    23.28243
T   4002=     23.36692  T   4003=     23.50365  T   4004=    23.09485
T   4005=     23.34750

*** NOTE *** SYSTEM ENERGY BALANCE CRITERIA HAS BEEN MET, ENGBAL =-0.949669E-02, LOOPCT =
94

    EBNODE(     302)=-0.920868E-02 AT LOOPCT=      94

**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(    303)=-2.74658E-03
                   ITEST =      0

T      1=       .00000  T      2=       .00000  T    201=   162.56430
T    206=     52.15100  T    301=    125.12854  T    302=   118.02460
T    303=    110.91784  T    304=    103.81270  T    305=    96.70728
T    306=     89.60156  T      3=       .00000  T    101=   200.00000
T    106=     14.70001  T   1001=     23.29813  T   1006=    23.30763
T   2001=     23.29813  T   2006=     23.30737  T   4001=    23.30145
T   4002=     23.31066  T   4003=     23.30546  T   4004=    23.30626
T   4005=     23.30726

*** NOTE *** NODAL ENERGY BALANCE CRITERIA HAS BEEN MET, EBNODE(     301)=-0.286484E-02,
LOOPCT =      96

**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(    301)=-1.58691E-03
                   ITEST =      0

T      1=       .00000  T      2=       .00000  T    201=   162.56384
T    206=     52.15070  T    301=    125.12610  T    302=   118.02191
T    303=    110.91723  T    304=    103.81213  T    305=    96.70673
T    306=     89.60101  T      3=       .00000  T    101=   200.00000
T    106=     14.70001  T   1001=     23.29840  T   1006=    23.30744
T   2001=     23.29939  T   2006=     23.30721  T   4001=    23.30225
T   4002=     23.30385  T   4003=     23.30526  T   4004=    23.30626
T   4005=     23.30726
1(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK
ANALYSIS ASSOCIATES, INC. - PAGE      2

    COPMRESSIBLE FLOW, 1D NETWORK

*** NOTE *** SNHOSD REQUIRES      20 DYNAMIC STORAGE LOCATIONS OUT OF     951 AVAILABLE ***

**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                   ITEST =      1

T      1=       .00000  T      2=       .00000  T    201=   162.56384
T    206=     52.15070  T    301=    125.12610  T    302=   118.02191
T    303=    110.91723  T    304=    103.81213  T    305=    96.70673
```

```
T   306=    89.60101  T     3=       .00000  T   101=   200.00000
T   106=    14.70001  T  1001=     3.80786  T  1006=     3.80859
T  2001=     3.80794  T  2006=     3.80858  T  4001=    10.92825
T  4002=    10.92863  T  4003=    10.92896  T  4004=    10.92919
T  4005=    10.92943

SNHOSD RUN, ARLXCA=0.10000E-01, DRLXCA=0.10000E-01, BALENG=0.10000E-01, BENODE=0.50000E-02,
NLOOP=   2000

*** NOTE *** RELAXATION CRITERIA HAS BEEN MET WITH LOOPCT =     105

    ENGBAL =  .134535     AT LOOPCT =     105

**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(     0)= 0.00000E-01
                   TEMPCC(     0)= 0.00000E-01 RELXCC(   303)= 8.36182E-03
                   ITEST =     1

T     1=      .00000  T     2=       .00000  T   201=   153.51562
T   206=    58.27802  T   301=   107.03660  T   302=   105.97420
T   303=   106.07300  T   304=   103.91820  T   305=   102.88201
T   306=   101.92220  T     3=       .00000  T   101=   200.00000
T   106=    14.70001  T  1001=     4.24310  T  1006=     4.10857
T  2001=     4.24281  T  2006=     4.11398  T  4001=     4.22191
T  4002=      .39542  T  4003=     8.71851  T  4004=     4.21886
T  4005=     3.90939

*** NOTE *** SYSTEM ENERGY BALANCE CRITERIA HAS BEEN MET, ENGBAL = 0.998497E-02, LOOPCT =
542

    EBNODE(    303)= 0.429916E-02 AT LOOPCT=     542

*** NOTE *** NODAL ENERGY BALANCE CRITERIA HAS BEEN MET, EBNODE(    303)= 0.429916E-02,
LOOPCT =    542

**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(     0)= 0.00000E-01
                   TEMPCC(     0)= 0.00000E-01 RELXCC(   304)= 1.03760E-03
                   ITEST =     1

T     1=      .00000  T     2=       .00000  T   201=   154.86250
T   206=    59.62085  T   301=   109.72700  T   302=   108.68830
T   303=   107.64971  T   304=   106.61330  T   305=   105.57860
T   306=   104.54360  T     3=       .00000  T   101=   200.00000
T   106=    14.70001  T  1001=     4.18123  T  1006=     4.17118
T  2001=     4.18113  T  2006=     4.17127  T  4001=     4.17867
T  4002=     4.17842  T  4003=     4.17412  T  4004=     4.17068
T  4005=     4.17117
```

VII. Flow Analysis for a 1-D Fluid Network, Compressible Flow

A. Statement of the Problem:

Consider the 1-D fluid network shown in Figure 5. The geometry is identical to that of the previous example. For this problem however, assume that steam is flowing through the system at a constant temperature of 2460 R. The pressure boundary conditions are 600 psia at the inlet and 200 psia at the exit.

B. Schematic of 1-D Fluid Network, Compressible Flow

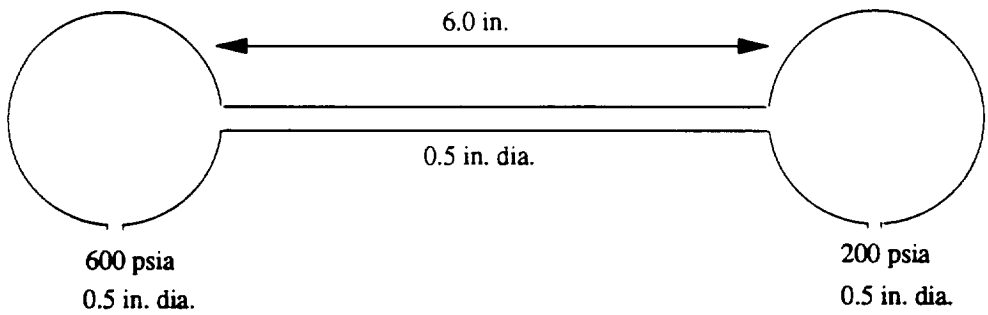


Figure 5. Schematic of 1-D Fluid Network

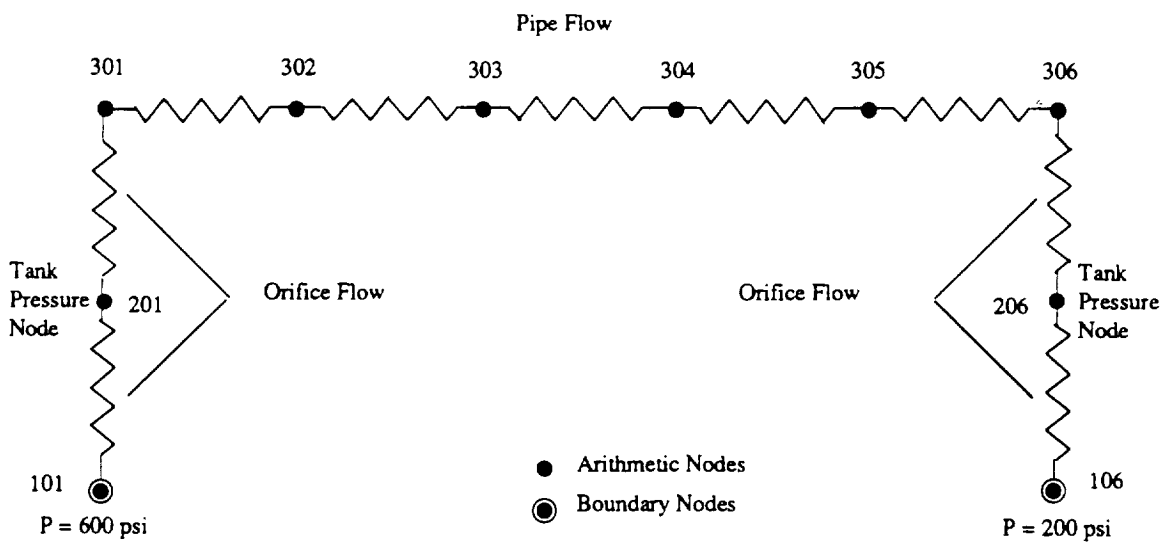


Figure 6. 1-D Fluid R-C Network

C. Given:

(1) Hydraulic diameters of pipe is 0.5 in
(2) Hydraulic diameters of orifices are 0.5 in
(3) Pipe length is 6 in
(4) Upstream pressure boundary condition is 600 psia
(5) Downstream pressure boundary condition is 200 psia

D. Find:

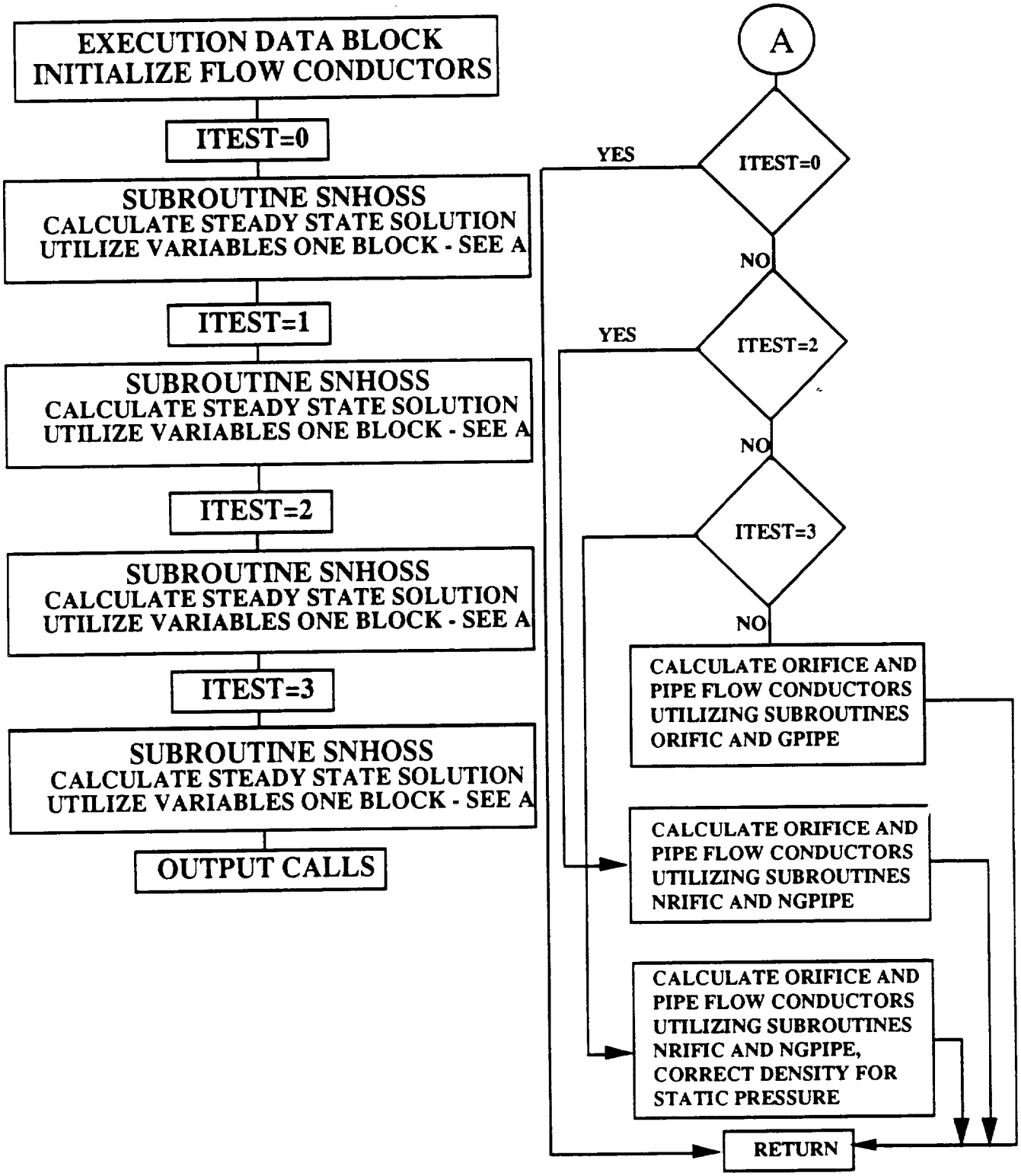
Steady state pressure and mass flowrate distribution through the 1-D fluid network

VIII. Analysis:

A. Discretization:

Same as previous example

B. The Input Deck: Flow chart of logic blocks



SINDA INPUT LISTING

```
        BCD 3THERMAL LPCS
        BCD 9COPMRESSIBLE FLOW, 1D NETWORK
        END
C
        BCD 3NODE DATA
C
            1, 0.0, 1.0
            2, 0.0, 1.0
            -3, 0.0, 1.0
C
           -101,600.0,1.0 $ PRES BOUNDARY
           -106,200.0,1.0 $ PRES BOUNDARY
C
           201, 200.0, -1.0 $ PRES AT FIRST CAVITY
           206, 200.0, -1.0 $ PRES AT FIRST CAVITY
C
           301, 200.0, -1.0 $ PRES AT SECOND CAVITY
           302, 200.0, -1.0 $ PRES AT SECOND CAVITY
           303, 200.0, -1.0 $ PRES AT SECOND CAVITY
           304, 200.0, -1.0 $ PRES AT SECOND CAVITY
           305, 200.0, -1.0 $ PRES AT SECOND CAVITY
           306, 200.0, -1.0 $ PRES AT SECOND CAVITY
C
C FLOW RATE STORAGE LOCATION
C
           -1001, 0.0, 1.0
           -1006, 0.0, 1.0
C
           -2001, 0.0, 1.0
           -2006, 0.0, 1.0
C
           -4001, 0.0, 1.0
           -4002, 0.0, 1.0
           -4003, 0.0, 1.0
           -4004, 0.0, 1.0
           -4005, 0.0, 1.0
C
        END
C
        BCD 3CONDUCTOR DATA
C
           1, 1, 2, 1.0
           2, 2, 3, 1.0
C
           101, 101, 201, 0.0
           106, 106, 206, 0.0
C
           201, 201, 301, 0.0
           206, 206, 306, 0.0
C
C
           401, 301, 302, 0.0
           402, 302, 303, 0.0
           403, 303, 304, 0.0
           404, 304, 305, 0.0
           405, 305, 306, 0.0
C
        END
C
        BCD 3CONSTANTS DATA
```

```
          DTIMEI,0.1
          DTIMEH,0.1
          NLOOP,5000
C
          TIMEND,0.0
          OUTPUT,0.2
C
          ARLXCA,.001
          DRLXCA,.001
          BALENG,.001
          TIMEO,0.0
          DAMPA,0.5
          DAMPD,0.5
          NDIM,1000
          ITEST,0
          301,0.
          302,0.
          303,0.
          304,0.
          305,0.
          306,0.
          1301,0.
          1302,0.
          1303,0.
          1304,0.
          1305,0.
          1306,0.
C
      END
C
      BCD 3ARRAY DATA
          1 $ PRES VS RHO (H2O) AT 2460 DEG R
          60.0, 0.0410
          80.0, 0.0546
          100.0, 0.0683
          120.0, 0.0819
          140.0, 0.0956
          160.0, 0.1093
          180.0, 0.1229
          200.0, 0.1366
          225.0, 0.1537
          250.0, 0.1708
          275.0, 0.1879
          300.0, 0.2042
          500.0, 0.34
          600.0, 0.4102
          1000.0, 0.68
          2000.0, 1.37
          4000.0, 2.76
          END
C
          2 $ VISCOSITY H20 VS TEMP
          2060., 2.58E-5
          2460., 3.03E-5
          2960., 3.58E-5
          3460., 4.0E-5
          END
      END
C
      BCD 3EXECUTION
C
F     OPEN(3,FILE="CH5S1P600.WRT",STATUS="UNKNOWN")
C
C INITIALIZE FLOW CONDUCTORS
```

```
C
M       PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       G101=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G106=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G201=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G206=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=2460.
M       DIA=0.5/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G401=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G402=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G403=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
```

```
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G404=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G405=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
F       ITEST=0
F       NLOOP=2000
F       CALL SNHOSS
C
F       ITEST=1
F       NLOOP=2000
F       CALL SNHOSS
C
F       ITEST=2
F       NLOOP=2000
F       CALL SNHOSS
C
C
F       ITEST=3
F       NLOOP=5000
F       CALL SNHOSS
C
        END
        BCD 3VARIABLES 1
C
M        EQUIVALENCE (XK301,VEL301),(XK1301,RHO301)
M        EQUIVALENCE (XK302,VEL302),(XK1302,RHO302)
M        EQUIVALENCE (XK303,VEL303),(XK1303,RHO303)
M        EQUIVALENCE (XK304,VEL304),(XK1304,RHO304)
M        EQUIVALENCE (XK305,VEL305),(XK1305,RHO305)
M        EQUIVALENCE (XK306,VEL306),(XK1306,RHO306)
C
C CALC ORIFICE FLOW CONDUCTORS
C
F       IF(ITEST.EQ.0)GO TO 40
F       IF(ITEST.EQ.2)GO TO 50
F       IF(ITEST.EQ.3)GO TO 150
C
M       PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
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```
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
```

```
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
F       GO TO 40
C
M 50    PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO301=RHO
M       VEL301=T4001/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
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```
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO302=RHO
M       VEL302=T4002/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO303=RHO
M       VEL303=T4003/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO304=RHO
M       VEL304=T4004/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO305=RHO
M       VEL305=T4005/RHO/AREA
M       RHO306=RHO
M       VEL306=T4005/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
```

```
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
F       GO TO 40
C
M150    PAVG=(T101)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=T206
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PSTAT=T301-RHO301*VEL301*VEL301/(2.0*32.2*144.)
M       PAVG=(T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PSTAT=T306-RHO306*VEL306*VEL306/(2.0*32.2*144.)
M       PAVG=(PSTAT)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(PSTAT,A1,RHO306)
M       VEL306=T4005/RHO306/AREA
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT1=T301-RHO301*VEL301*VEL301/(2.0*32.2*144.)
M       PSTAT2=T302-RHO302*VEL302*VEL302/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO301)
M       VEL301=T4001/RHO301/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT2=T303-RHO303*VEL303*VEL303/(2.0*32.2*144.)
M       PSTAT1=T302-RHO302*VEL302*VEL302/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO302)
```

```
M       VEL302=T4002/RHO302/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT1=T303-RHO303*VEL303*VEL303/(2.0*32.2*144.)
M       PSTAT2=T304-RHO304*VEL304*VEL304/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO303)
M       VEL303=T4003/RHO303/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT2=T305-RHO305*VEL305*VEL305/(2.0*32.2*144.)
M       PSTAT1=T304-RHO304*VEL304*VEL304/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PAVG,A1,RHO304)
M       VEL304=T4004/RHO304/AREA
M       CALL D1DEG1(PSTAT1,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT1=T305-RHO305*VEL305*VEL305/(2.0*32.2*144.)
M       PSTAT2=T306-RHO306*VEL306*VEL306/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO305)
M       VEL305=T4005/RHO305/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
C CALC MDOTS
C
M 40    CALL XMDOT(T101,T201,G101,T1001)
```

```
M       CALL XMDOT(T106,T206,G106,T1006)
C
M       CALL XMDOT(T201,T301,G201,T2001)
M       CALL XMDOT(T206,T306,G206,T2006)
C
M       CALL XMDOT(T301,T302,G401,T4001)
M       CALL XMDOT(T302,T303,G402,T4002)
M       CALL XMDOT(T303,T304,G403,T4003)
M       CALL XMDOT(T304,T305,G404,T4004)
M       CALL XMDOT(T305,T306,G405,T4005)
C
F 100   CONTINUE
C
F       RETURN
F       END
C
F       SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
F       RETURN
F       END
C
F       SUBROUTINE ORIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)/SQRT(ABS(PUP-PDN))
F       RETURN
F 2     GCOND=0.0
F       RETURN
F       END
C
F       SUBROUTINE GPIPE(RHO,AREA,XL,DIA,FFACT,PUP,PDN,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
F       GCOND=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
F       GCOND=GCOND/SQRT(ABS(PUP-PDN))
F       RETURN
F 2     GCOND=0.0
F       RETURN
F       END
C
F       SUBROUTINE NRIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
C
F       PUP1=PUP
F       PDN1=PDN
C
F       PS1=PUP
F       PS2=PDN
F       IF(PUP.GT.PDN)GO TO 1
F       PUP1=PS2
F       PDN1=PS1
F 1     CONTINUE
C
F       GK=1.329
C
F       PRATIO=(2.0/(GK+1.0))**(GK/(GK-1.0))
F       PCRIT=PUP1*PRATIO
F       BETA=0.0
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PCRIT)/(GK*PUP1)
F       GMAX=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GMAX=GMAX*Y*SQRT(PUP1-PCRIT)
```

```
F       GMAX=GMAX/(PUP1-PDN1)
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PDN1)/(GK*PUP1)
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GCOND=GCOND*Y/SQRT(PUP1-PDN1)
C
F       IF(PDN1/PUP1.LT.PRATIO)GCOND=AMIN1(GMAX,GCOND)
C
F       RETURN
F 2     GCOND=0.0
C
F       RETURN
F       END
C
F       SUBROUTINE NGPIPE(RHO,AREA,XL,DIA,FFACT,PUP,PDN,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
C
F       PUP1=PUP
F       PDN1=PDN
C
F       PS1=PUP
F       PS2=PDN
F       IF(PUP.GT.PDN)GO TO 1
F       PUP1=PS2
F       PDN1=PS1
F 1     CONTINUE
C
F       GCOND=(144.*RHO*32.2*AREA**2)
F       GCOND=GCOND/((FFACT*XL/DIA)+2.*ALOG(PUP1/PDN1))
F       GCOND=SQRT(GCOND)
F       GCOND=GCOND*SQRT((PUP+PDN)/(PUP1*ABS(PUP-PDN)))
C
F       RETURN
F 2     GCOND=0.0
C       RETURN
C       END
C
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
C CALC MDOTS
C
M       CALL XMDOT(T101,T201,G101,T1001)
M       CALL XMDOT(T106,T206,G106,T1006)
C
M       CALL XMDOT(T201,T301,G201,T2001)
M       CALL XMDOT(T206,T306,G206,T2006)
C
M       CALL XMDOT(T301,T302,G401,T4001)
M       CALL XMDOT(T302,T303,G402,T4002)
M       CALL XMDOT(T303,T304,G403,T4003)
M       CALL XMDOT(T304,T305,G404,T4004)
M       CALL XMDOT(T305,T306,G405,T4005)
C
C FOUR COLUMN OUTPUT ROUTINE, STNDRD
C
```

```
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(3,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC,ITEST,LOOPCT
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $           8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $           8H RELXCC(I6,2H)=1PE12.5,/,
F     $           18X,8H ITEST =I6,/,
F     $           18X,8H LOOPCT=I6)
C
C FOUR COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(3,100)
F 100   FORMAT(1H )
F       J=1
F       L=4
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(3,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(4(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 15
F       J=L+1
F       L=L+4
F       GO TO 5
F15     CONTINUE
CF       END
C
C       RETURN
        END
        BCD 3END OF DATA
```

IX. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are given on the following pages. Nodal pressures and mass flowrates are printed in psia and lb/sec, respectively. Figure 7 shows the steady state nodal pressures and mass flowrates through the 1-D resistance fluid network using linearized incompressible flow equations.

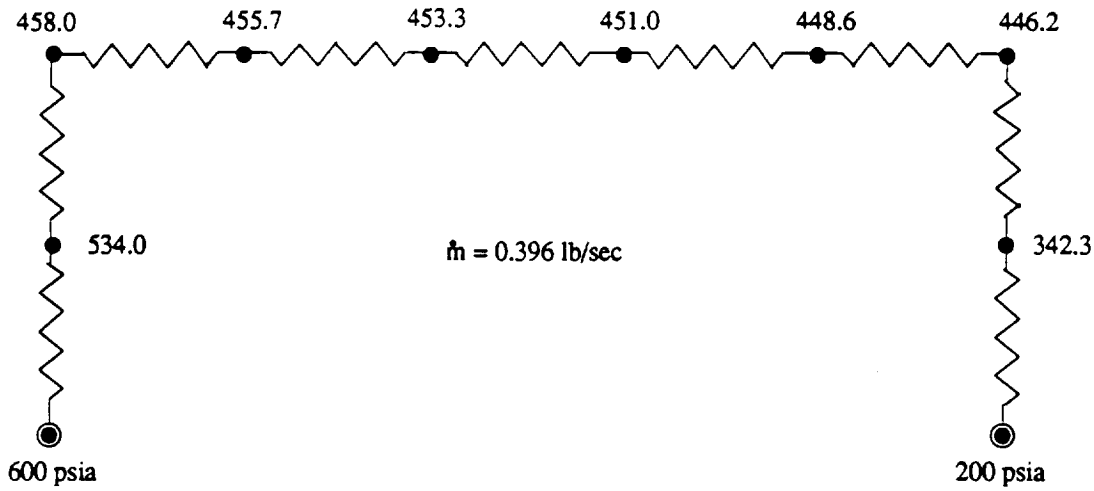


Figure 7. Steady State Nodal Pressures and Mass Flowrates for 1-D Resistance Fluid Network Using Linearized Compressible Flow Equations

X. Closing Comments:

One difference in this example relative to the previous example involves the calculation of static pressure for determination of density. This was not necessary in the previous example because the fluid was incompressible (density not a function of pressure). In this example static pressure is calculated in the variables block, for proper determination of density. Differentiation between static and dynamic pressure may become necessary in branching, compressible pipe flow, for proper determination of flowrate and fluid properties.

SINDA OUTPUT LISTING

```
**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                   ITEST =      0
                   LOOPCT=      0

T      1=       .00000  T      2=       .00000  T    201=   200.00000  T    206=   200.00000
T    301=    200.00000  T    302=    200.00000  T    303=   200.00000  T    304=   200.00000
T    305=    200.00000  T    306=    200.00000  T      3=       .00000  T    101=   600.00000
T    106=    200.00000  T   1001=     20.18368  T   1006=       .00000  T   2001=       .00000
T   2006=       .00000  T   4001=       .00000  T   4002=       .00000  T   4003=       .00000
T   4004=       .00000  T   4005=       .00000

**********
TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(    305)=-7.93457E-04
                   ITEST =      0
                   LOOPCT=    111

T      1=       .00000  T      2=       .00000  T    201=   549.00130  T    206=   288.39044
T    301=    460.62650  T    302=    443.85852  T    303=   427.09010  T    304=   410.32090
T    305=    393.55090  T    306=    376.78020  T      3=       .00000  T    101=   600.00000
T    106=    200.00000  T   1001=      2.57335  T   1006=      2.57379  T   2001=      2.57334
T   2006=      2.57377  T   4001=      2.57334  T   4002=      2.57341  T   4003=      2.57353
```

```
T  4004=     2.57364  T  4005=     2.57377

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      1
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   549.00130  T   206=   288.39044
T   301=   460.62650  T   302=   443.85852  T   303=   427.09010  T   304=   410.32090
T   305=   393.55090  T   306=   376.78020  T     3=      .00000  T   101=   600.00000
T   106=   200.00000  T  1001=      .36035  T  1006=      .32845  T  2001=      .45318
T  2006=      .37501  T  4001=     1.18959  T  4002=     1.16779  T  4003=     1.14558
T  4004=     1.12293  T  4005=     1.09981

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(    301)= 9.15527E-04
                  ITEST =      1
                  LOOPCT=    594

T     1=      .00000  T     2=      .00000  T   201=   527.28302  T   206=   331.73060
T   301=   444.23291  T   302=   441.95980  T   303=   439.67610  T   304=   437.38210
T   305=   435.07702  T   306=   432.76160  T     3=      .00000  T   101=   600.00000
T   106=   200.00000  T  1001=      .43029  T  1006=      .42963  T  2001=      .43028
T  2006=      .42963  T  4001=      .43014  T  4002=      .43004  T  4003=      .42990
T  4004=      .42981  T  4005=      .42964

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      2
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   527.28302  T   206=   331.73060
T   301=   444.23291  T   302=   441.95980  T   303=   439.67610  T   304=   437.38210
T   305=   435.07702  T   306=   432.76160  T     3=      .00000  T   101=   600.00000
T   106=   200.00000  T  1001=      .41420  T  1006=      .37700  T  2001=      .40937
T  2006=      .39869  T  4001=      .39881  T  4002=      .39844  T  4003=      .39803
T  4004=      .39766  T  4005=      .39722

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(    303)= 9.15527E-04
                  ITEST =      2
                  LOOPCT=    492

T     1=      .00000  T     2=      .00000  T   201=   532.47010  T   206=   344.78143
T   301=   454.42970  T   302=   452.20642  T   303=   449.97131  T   304=   447.72320
T   305=   445.46044  T   306=   443.18414  T     3=      .00000  T   101=   600.00000
T   106=   200.00000  T  1001=      .40026  T  1006=      .39968  T  2001=      .40026
T  2006=      .39968  T  4001=      .40015  T  4002=      .39995  T  4003=      .39983
T  4004=      .39981  T  4005=      .39968

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      3
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   532.47010  T   206=   344.78143
T   301=   454.42970  T   302=   452.20642  T   303=   449.97131  T   304=   447.72320
T   305=   445.46044  T   306=   443.18414  T     3=      .00000  T   101=   600.00000
T   106=   200.00000  T  1001=      .40026  T  1006=      .39968  T  2001=      .40026
```

```
T  2006=      .38567  T  4001=      .38671  T  4002=      .38640  T  4003=      .38616
T  4004=      .38600  T  4005=      .38574

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(     0)= 0.00000E-01
                 TEMPCC(     0)= 0.00000E-01 RELXCC(   301)= 9.15527E-04
                 ITEST =     3
                 LOOPCT=   342

T     1=      .00000  T     2=      .00000  T   201=   533.98800  T   206=   342.33502
T   301=   458.01380  T   302=   455.68371  T   303=   453.33624  T   304=   450.97253
T   305=   448.59190  T   306=   446.19354  T     3=      .00000  T   101=   600.00000
T   106=   200.00000  T  1001=      .39605  T  1006=      .39547  T  2001=      .39605
T  2006=      .39547  T  4001=      .39591  T  4002=      .39585  T  4003=      .39571
T  4004=      .39558  T  4005=      .39546
```

XI. Flow Analysis for a 1-D Fluid Network, Compressible Flow with Choked Flow Conditions

A. Statement of the Problem:

Consider the 1-D fluid network shown in Figure 9. The geometry is identical to that of the previous example. For this problem however, assume that steam is flowing through the system at a constant temperature of 2460 R. The pressure boundary conditions are 400 psia at the inlet and 14.7 psia at the exit. In this example choked flow will occur somewhere in the network.

B. Schematic of 1-D Fluid Network, Compressible Flow

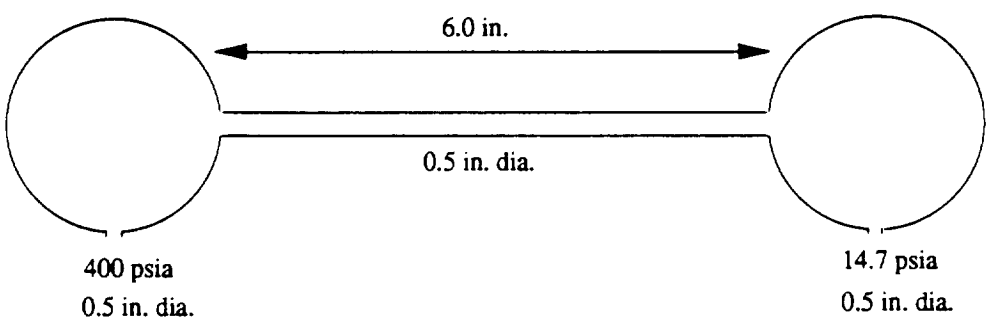


Figure 8. Schematic of 1-D Fluid Network

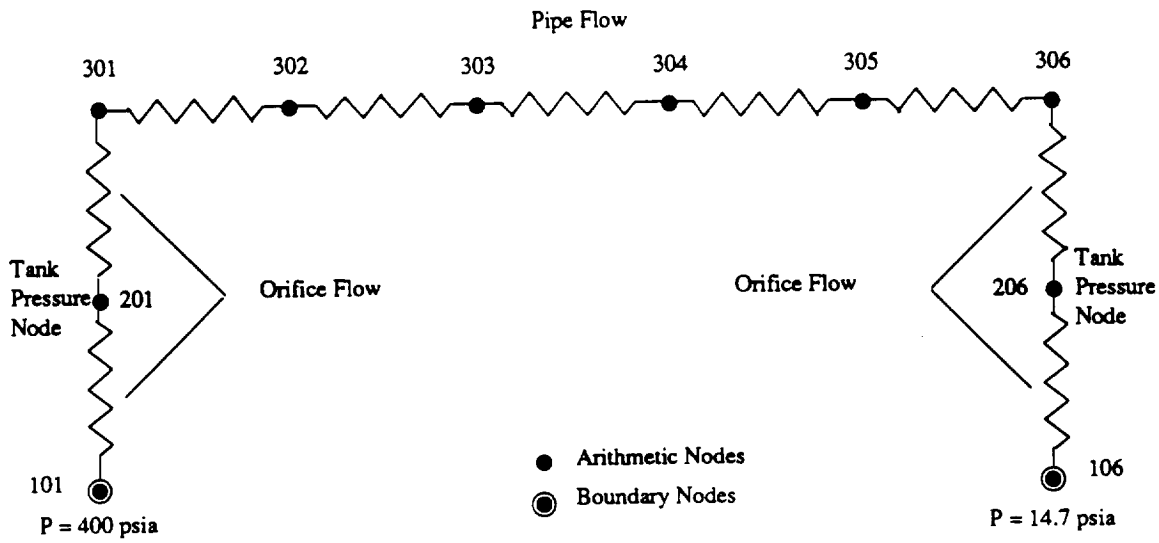


Figure 9. 1-D Fluid R-C Network

C. Given:

(1) Hydraulic diameters of pipes are 0.5 in
(2) Hydraulic diameters of orifices are 0.5 in
(3) Pipe length is 6 in
(4) Upstream pressure boundary condition is 400 psia
(5) Downstream pressure boundary condition is 14.7 psia

D. Find:

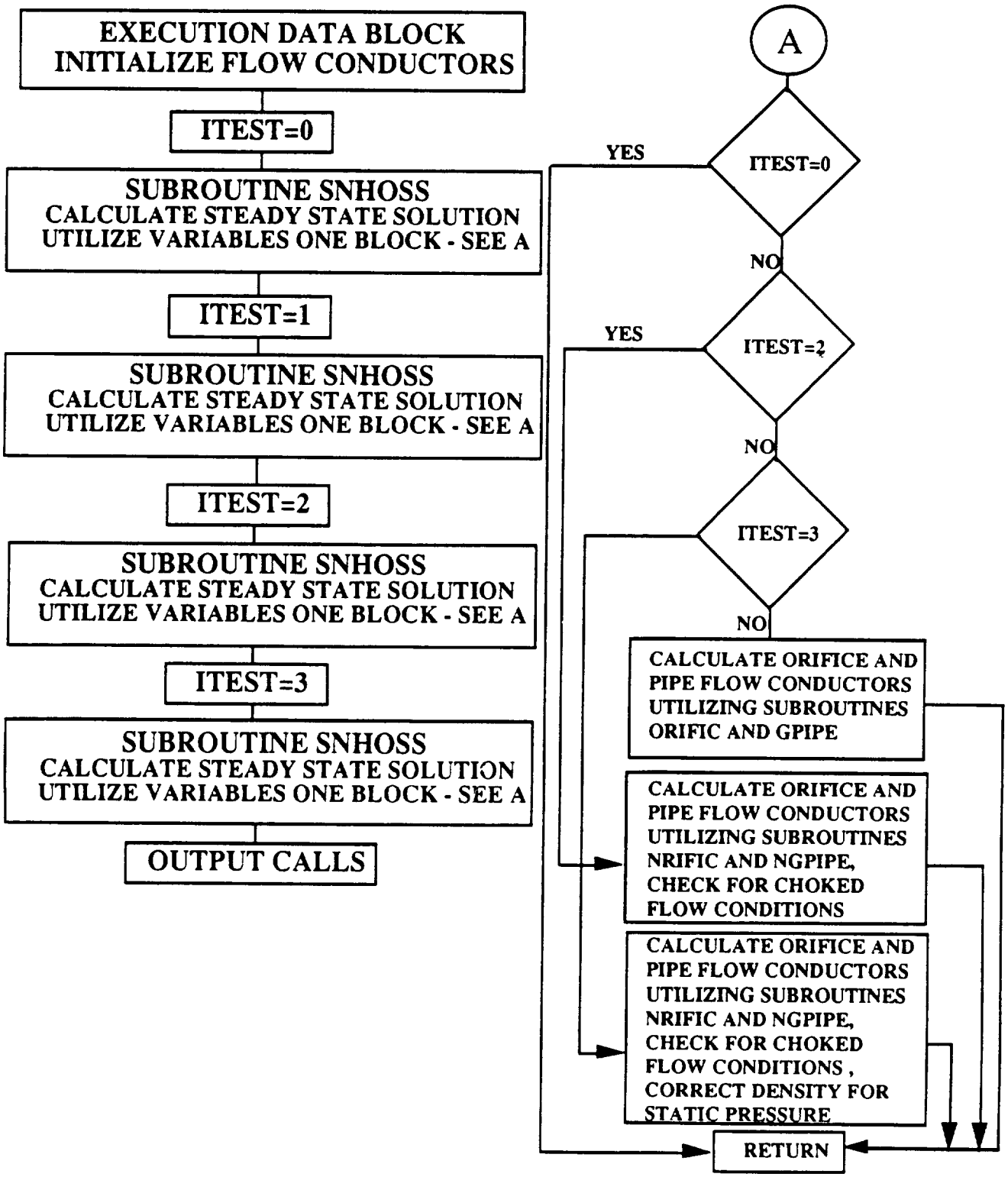
Steady state pressure and mass flowrate distribution through the 1-D fluid network

XII. Analysis:

A. Discretization:

Same as previous example

B. The Input Deck: Flow chart for logic blocks



SINDA INPUT LISTING

```
      BCD 3THERMAL LPCS
      BCD 9COPMRESSIBLE FLOW, 1D NETWORK
      END
C
      BCD 3NODE DATA
C
           1, 0.0, 1.0
           2, 0.0, 1.0
           -3, 0.0, 1.0
C
          -101,400.0,1.0 $ PRES BOUNDARY
          -106,14.7,1.0 $ PRES BOUNDARY
C
          201, 400.0, -1.0 $ PRES AT FIRST CAVITY
          206, 400.0, -1.0 $ PRES AT FIRST CAVITY
C
          301, 400.0, -1.0 $ PRES AT SECOND CAVITY
          302, 400.0, -1.0 $ PRES AT SECOND CAVITY
          303, 400.0, -1.0 $ PRES AT SECOND CAVITY
          304, 400.0, -1.0 $ PRES AT SECOND CAVITY
          305, 400.0, -1.0 $ PRES AT SECOND CAVITY
          306, 400.0, -1.0 $ PRES AT SECOND CAVITY
C
C FLOW RATE STORAGE LOCATION
C
          -1001, 0.0, 1.0
          -1006, 0.0, 1.0
C
          -2001, 0.0, 1.0
          -2006, 0.0, 1.0
C
          -4001, 0.0, 1.0
          -4002, 0.0, 1.0
          -4003, 0.0, 1.0
          -4004, 0.0, 1.0
          -4005, 0.0, 1.0
C
      END
C
      BCD 3CONDUCTOR DATA
C
          1, 1, 2, 1.0
          2, 2, 3, 1.0
C
          101, 101, 201, 0.0
          106, 106, 206, 0.0
C
          201, 201, 301, 0.0
          206, 206, 306, 0.0
C
C
          401, 301, 302, 0.0
          402, 302, 303, 0.0
          403, 303, 304, 0.0
          404, 304, 305, 0.0
          405, 305, 306, 0.0
C
      END
C
      BCD 3CONSTANTS DATA
```

```
            DTIMEI,0.1
            DTIMEH,0.1
            NLOOP,5000
C
            TIMEND,0.0
            OUTPUT,0.2
C
            ARLXCA,.001
            DRLXCA,.001
            BALENG,.001
            TIMEO,0.0
            DAMPA,0.5
            DAMPD,0.5
            NDIM,1000
            ITEST,0
            301,0.
            302,0.
            303,0.
            304,0.
            305,0.
            306,0.
            1301,0.
            1302,0.
            1303,0.
            1304,0.
            1305,0.
            1306,0.
C
        END
C
        BCD 3ARRAY DATA
            1 $ PRES VS RHO (H2O) AT 2460 DEG R
            60.0, 0.0410
            80.0, 0.0546
            100.0, 0.0683
            120.0, 0.0819
            140.0, 0.0956
            160.0, 0.1093
            180.0, 0.1229
            200.0, 0.1366
            225.0, 0.1537
            250.0, 0.1708
            275.0, 0.1879
            300.0, 0.2042
            500.0, 0.34
            600.0, 0.4102
            1000.0, 0.68
            2000.0, 1.37
            4000.0, 2.76
            END
C
            2 $ VISCOSITY H20 VS TEMP
            2060., 2.58E-5
            2460., 3.03E-5
            2960., 3.58E-5
            3460., 4.0E-5
            END
        END
C
        BCD 3EXECUTION
C
F       OPEN(3,FILE="CH5S1P400.WRT",STATUS="UNKNOWN")
C
C INITIALIZE FLOW CONDUCTORS
```

```
C
M       PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       G101=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G106=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G201=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       G206=0.6*AREA*SQRT(2.*32.2*144.*RHO)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=2460.
M       DIA=0.5/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G401=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G402=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G403=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
```

```
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G404=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       FFACT=0.05
M       G405=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
C
F       ITEST=0
F       NLOOP=2000
F       CALL SNHOSS
C
F       ITEST=1
F       NLOOP=2000
F       CALL SNHOSS
C
F       ITEST=2
F       NLOOP=2000
F       CALL SNHOSS
C
C
F       ITEST=3
F       NLOOP=5000
F       CALL SNHOSS
C
        END
        BCD 3VARIABLES 1
C
M        EQUIVALENCE (XK301,VEL301),(XK1301,RHO301)
M        EQUIVALENCE (XK302,VEL302),(XK1302,RHO302)
M        EQUIVALENCE (XK303,VEL303),(XK1303,RHO303)
M        EQUIVALENCE (XK304,VEL304),(XK1304,RHO304)
M        EQUIVALENCE (XK305,VEL305),(XK1305,RHO305)
M        EQUIVALENCE (XK306,VEL306),(XK1306,RHO306)
C
C CALC ORIFICE FLOW CONDUCTORS
C
F       IF(ITEST.EQ.0)GO TO 40
F       IF(ITEST.EQ.2)GO TO 50
F       IF(ITEST.EQ.3)GO TO 150
C
M       PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
```

```
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL ORIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
```

```
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL GPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
F       GO TO 40
C
M 50    PAVG=AMAX1(T101,T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=AMAX1(T106,T206)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PAVG=AMAX1(T201,T301)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PAVG=AMAX1(T206,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T301,T302)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO301=RHO
M       VEL301=T4001/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
```

```
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T302,T303)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO302=RHO
M       VEL302=T4002/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T303,T304)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO303=RHO
M       VEL303=T4003/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T304,T305)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO304=RHO
M       VEL304=T4004/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PAVG=AMAX1(T305,T306)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RHO305=RHO
M       VEL305=T4005/RHO/AREA
M       RHO306=RHO
M       VEL306=T4005/RHO/AREA
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
```

```
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
F       GO TO 40
C
M150    PAVG=(T101)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,T1001,G101)
C
M       PAVG=T206
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,T1006,G106)
C
M       PSTAT=T301-RHO301*VEL301*VEL301/(2.0*32.2*144.)
M       PAVG=(T201)
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,T2001,G201)
C
M       PSTAT=T306-RHO306*VEL306*VEL306/(2.0*32.2*144.)
M       PAVG=(PSTAT)
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(PSTAT,A1,RHO306)
M       VEL306=T4005/RHO306/AREA
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL NRIFIC(RHO,AREA,RGAS,TEMP,T206,T306,GK,T2006,G206)
C
C CALC PIPE FLOW CONDUCTORS
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT1=T301-RHO301*VEL301*VEL301/(2.0*32.2*144.)
M       PSTAT2=T302-RHO302*VEL302*VEL302/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO301)
M       VEL301=T4001/RHO301/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4001*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T301,T302,T4001,G401)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT2=T303-RHO303*VEL303*VEL303/(2.0*32.2*144.)
M       PSTAT1=T302-RHO302*VEL302*VEL302/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
```

```
M       CALL D1DEG1(PSTAT1,A1,RHO302)
M       VEL302=T4002/RHO302/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4002*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T302,T303,T4002,G402)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT1=T303-RHO303*VEL303*VEL303/(2.0*32.2*144.)
M       PSTAT2=T304-RHO304*VEL304*VEL304/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO303)
M       VEL303=T4003/RHO303/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4003*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T303,T304,T4003,G403)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT2=T305-RHO305*VEL305*VEL305/(2.0*32.2*144.)
M       PSTAT1=T304-RHO304*VEL304*VEL304/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PAVG,A1,RHO304)
M       VEL304=T4004/RHO304/AREA
M       CALL D1DEG1(PSTAT1,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4004*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T304,T305,T4004,G404)
C
M       TEMP=2460.
M       DIA=0.50/12.
M       AREA=(3.14159*DIA**2)/4.
M       PSTAT1=T305-RHO305*VEL305*VEL305/(2.0*32.2*144.)
M       PSTAT2=T306-RHO306*VEL306*VEL306/(2.0*32.2*144.)
M       PAVG=(PSTAT1)
M       CALL D1DEG1(PSTAT1,A1,RHO305)
M       VEL305=T4005/RHO305/AREA
M       CALL D1DEG1(PAVG,A1,RHO)
M       CALL D1DEG1(TEMP,A2,XMU)
M       XL=1.0/12.0
M       REY=T4005*DIA/(AREA*XMU)
M       IF(REY.EQ.0.0)REY=64.
M       IF(REY.LT.2000.)FFACT=64./REY
M       IF(REY.GT.2000.)FFACT=0.032
M       CALL NGPIPE(RHO,AREA,XL,DIA,FFACT,T305,T306,T4005,G405)
C
C CALC MDOTS
C
```

```
M 40    CALL XMDOT(T101,T201,G101,T1001)
M       CALL XMDOT(T106,T206,G106,T1006)
C
M       CALL XMDOT(T201,T301,G201,T2001)
M       CALL XMDOT(T206,T306,G206,T2006)
C
M       CALL XMDOT(T301,T302,G401,T4001)
M       CALL XMDOT(T302,T303,G402,T4002)
M       CALL XMDOT(T303,T304,G403,T4003)
M       CALL XMDOT(T304,T305,G404,T4004)
M       CALL XMDOT(T305,T306,G405,T4005)
C
F 100   CONTINUE
C
C
F       RETURN
F       END
C
F       SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
F       RETURN
F       END
C
F       SUBROUTINE ORIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)/SQRT(ABS(PUP-PDN))
F       RETURN
F 2     GCOND=0.0
F       RETURN
F       END
C
F       SUBROUTINE GPIPE(RHO,AREA,XL,DIA,FFACT,PUP,PDN,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
F       GCOND=SQRT(RHO*3.14159**2*DIA**5*144.*32.2/(8.*FFACT*XL))
F       GCOND=GCOND/SQRT(ABS(PUP-PDN))
F       RETURN
F 2     GCOND=0.0
F       RETURN
F       END
C
F       SUBROUTINE NRIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
C
F       PUP1=PUP
F       PDN1=PDN
C
F       PS1=PUP
F       PS2=PDN
F       IF(PUP.GT.PDN)GO TO 1
F       PUP1=PS2
F       PDN1=PS1
F 1     CONTINUE
C
F       GK=1.329
C
F       PRATIO=(2.0/(GK+1.0))**(GK/(GK-1.0))
F       PCRIT=PUP1*PRATIO
F       BETA=0.0
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PCRIT)/(GK*PUP1)
```

```
F       GMAX=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GMAX=GMAX*Y*SQRT(PUP1-PCRIT)
F       GMAX=GMAX/(PUP1-PDN1)
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PDN1)/(GK*PUP1)
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GCOND=GCOND*Y/SQRT(PUP1-PDN1)
C
F       IF(PDN1/PUP1.LT.PRATIO)GCOND=AMIN1(GMAX,GCOND)
C
F       RETURN
F 2     GCOND=0.0
C
F       RETURN
F       END
C
F       SUBROUTINE NGPIPE(RHO,AREA,XL,DIA,FFACT,PUP,PDN,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
C
F       PUP1=PUP
F       PDN1=PDN
C
F       PS1=PUP
F       PS2=PDN
F       IF(PUP.GT.PDN)GO TO 1
F       PUP1=PS2
F       PDN1=PS1
F 1     CONTINUE
C
F       GCOND=(144.*RHO*32.2*AREA**2)
F       GCOND=GCOND/((FFACT*XL/DIA)+2.*ALOG(PUP1/PDN1))
F       GCOND=SQRT(GCOND)
F       GCOND=GCOND*SQRT((PUP+PDN)/(PUP1*ABS(PUP-PDN)))
C
F       RETURN
F 2     GCOND=0.0
C       RETURN
C       END
C
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
C CALC MDOTS
C
M       CALL XMDOT(T101,T201,G101,T1001)
M       CALL XMDOT(T106,T206,G106,T1006)
C
M       CALL XMDOT(T201,T301,G201,T2001)
M       CALL XMDOT(T206,T306,G206,T2006)
C
M       CALL XMDOT(T301,T302,G401,T4001)
M       CALL XMDOT(T302,T303,G402,T4002)
M       CALL XMDOT(T303,T304,G403,T4003)
M       CALL XMDOT(T304,T305,G404,T4004)
M       CALL XMDOT(T305,T306,G405,T4005)
C
```

```
C FOUR COLUMN OUTPUT ROUTINE, STNDRD
C
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(3,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC,ITEST,LOOPCT
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $          8H RELXCC(I6,2H)=1PE12.5,/,
F     $          18X,8H ITEST =I6,/,
F     $          18X,8H LOOPCT=I6)
C
C FOUR COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(3,100)
F 100   FORMAT(1H )
F       J=1
F       L=4
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(3,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(4(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 15
F       J=L+1
F       L=L+4
F       GO TO 5
F15     CONTINUE
CF       END
C
C       RETURN
        END
        BCD 3END OF DATA
```

IX. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are given on the following pages. Nodal pressures and mass flowrates are printed in psia and lb/sec, respectively. Figure 10 shows the steady state nodal pressures and mass flowrates through the 1-D resistance fluid network using linearized incompressible flow equations.

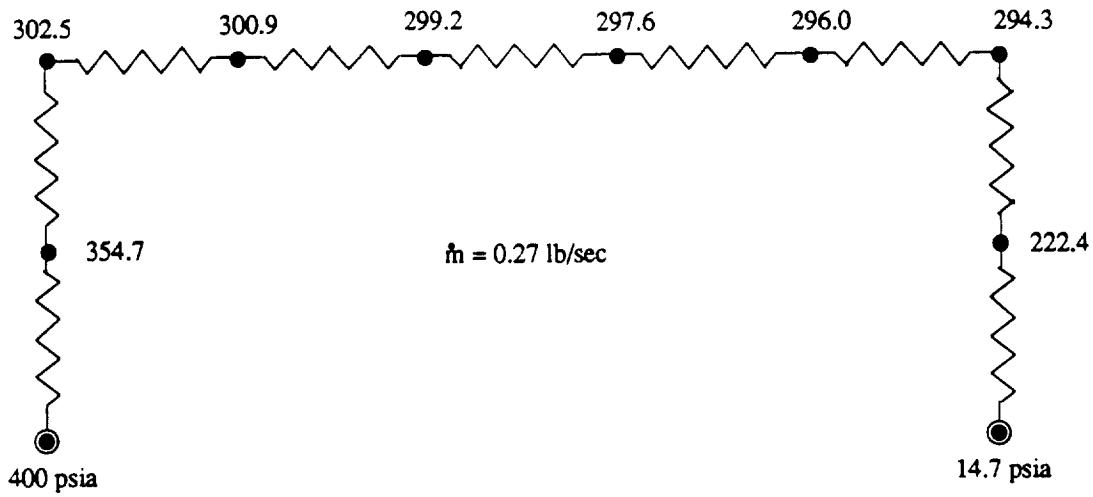


Figure 10. Steady State Nodal Pressures and Mass Flowrates for 1-D Resistance Fluid Network Using Linearized Compressible Flow Equations

XIII. Closing Comments:

Note that the flow conditions are choked at the downstream exit to atmospheric pressure, controlling the system flow rate. Other system pressures adjust to accommodate this flow. By evaluating the results of successive solutions given in this example, the user can evaluate the errors in the pressure field and flow rate calculations for the assumptions of incompressible flow, and the errors incurred by failing to account for dynamic and static pressures in property determination. These differences can become significant in many engineering problems and must always be checked.

SINDA OUTPUT LISTING

```
**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      0
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   400.00000  T   206=   400.00000
T   301=   400.00000  T   302=   400.00000  T   303=   400.00000  T   304=   400.00000
T   305=   400.00000  T   306=   400.00000  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .00000  T  1006=    15.83455  T  2001=      .00000
T  2006=      .00000  T  4001=      .00000  T  4002=      .00000  T  4003=      .00000
T  4004=      .00000  T  4005=      .00000

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(    302)= 7.32422E-04
                  ITEST =      0
                  LOOPCT=    111

T     1=      .00000  T     2=      .00000  T   201=   322.13060  T   206=    92.54962
T   301=   244.26180  T   302=   229.48800  T   303=   214.71490  T   304=   199.94260
T   305=   185.17100  T   306=   170.39990  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=     3.20018  T  1006=     3.19936  T  2001=     3.20015
T  2006=     3.19939  T  4001=     3.19998  T  4002=     3.19983  T  4003=     3.19967
```

```
T  4004=     3.19951  T  4005=     3.19939

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      1
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   322.13060  T   206=    92.54962
T   301=   244.26180  T   302=   229.48800  T   303=   214.71490  T   304=   199.94260
T   305=   185.17100  T   306=   170.39990  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .36265  T  1006=      .17475  T  2001=      .32551
T  2006=      .23714  T  4001=      .81497  T  4002=      .78989  T  4003=      .76399
T  4004=      .73719  T  4005=      .70934

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(    301)=-9.15527E-04
                  ITEST =      1
                  LOOPCT=    603

T     1=      .00000  T     2=      .00000  T   201=   339.20200  T   206=   162.95214
T   301=   267.52801  T   302=   265.44262  T   303=   263.34430  T   304=   261.23004
T   305=   259.09860  T   306=   256.95050  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .32044  T  1006=      .32004  T  2001=      .32045
T  2006=      .32004  T  4001=      .32046  T  4002=      .32019  T  4003=      .32013
T  4004=      .32014  T  4005=      .32007

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      2
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   339.20200  T   206=   162.95214
T   301=   267.52801  T   302=   265.44262  T   303=   263.34430  T   304=   261.23004
T   305=   259.09860  T   306=   256.95050  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .30542  T  1006=      .19520  T  2001=      .29956
T  2006=      .28392  T  4001=      .28669  T  4002=      .28605  T  4003=      .28554
T  4004=      .28507  T  4005=      .28453

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(    201)=-9.15527E-04
                  ITEST =      2
                  LOOPCT=    642

T     1=      .00000  T     2=      .00000  T   201=   353.71530  T   206=   224.53784
T   301=   300.17053  T   302=   298.63620  T   303=   297.09313  T   304=   295.54060
T   305=   293.97991  T   306=   292.41050  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .26961  T  1006=      .26898  T  2001=      .26961
T  2006=      .26898  T  4001=      .26947  T  4002=      .26936  T  4003=      .26930
T  4004=      .26912  T  4005=      .26898

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01
                  ITEST =      3
                  LOOPCT=      0

T     1=      .00000  T     2=      .00000  T   201=   353.71530  T   206=   224.53784
T   301=   300.17053  T   302=   298.63620  T   303=   297.09313  T   304=   295.54060
T   305=   293.97991  T   306=   292.41050  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .26961  T  1006=      .26898  T  2001=      .26961
```

```
T  2006=      .25952  T  4001=      .26045  T  4002=      .26027  T  4003=      .26012
T  4004=      .25986  T  4005=      .25960

**********
TIME=      .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                  TEMPCC(      0)= 0.00000E-01 RELXCC(    301)= 9.76563E-04
                  ITEST =      3
                  LOOPCT=    276

T     1=      .00000  T     2=      .00000  T   201=   354.68621  T   206=   222.37792
T   301=   302.47110  T   302=   300.85880  T   303=   299.23431  T   304=   297.59912
T   305=   295.95251  T   306=   294.29351  T     3=      .00000  T   101=   400.00000
T   106=    14.70001  T  1001=      .26698  T  1006=      .26639  T  2001=      .26697
T  2006=      .26639  T  4001=      .26682  T  4002=      .26677  T  4003=      .26662
T  4004=      .26650  T  4005=      .26639
```

XIV. References:

Streeter, Victor L. and Wylie, Benjamin E.; Fluid Mechanics; 7th Edition; Copyright 1979 by McGraw-Hill Book Company; New York

Crane Co.; Flow of Fluids Through Valves, Fittings, and Pipe; Technical Paper No. 410; Copyright 1976; by Crane Co.

White, Frank M.; Fluid Mechanics; 2nd Edition; Copyright 1979 by McGraw-Hill Book Company; New York; pp. 551-554

CHAPTER 5: N-DIMENSIONAL BRANCHING NETWORKS

SECTION 2: Transient (Isothermal) Pressurization of a 1-D Fluid Network, Compressible Flow

ANALYSIS CODE: SINDA (Gaski Version)

Following is an extension of the previous examples illustrating transient pressurization, assuming isothermal conditions and the ideal gas law. The difference in modeling technique involves derivation of a fluid capacitance, utilization of diffusion nodes in the SINDA network, and use of a transient solution routine. Analyses of this type will typically require small time steps. Long term transient results should compare favorably with steady state techniques discussed previously. The flow areas and hydraulic diameters are assumed to be known, and were not rigorously developed. The intent is to show programming technique and code versatility.

I. Identification of the Problem

A. Statement of the Problem

Consider again a 1-D fluid network as shown in Figure 1. Assume that at time zero the two boundary conditions are instantaneously applied. Determine the transient response of the fluid network.

B. Given:

(1) The tank volumes are 4 cu. ft.
(2) Hydraulic diameter of orifices are 0.5 in.
(3) High pressure boundary is 600.0 psia
(4) Low pressure boundary is 200.0 psia
(5) Initial system pressures are 200 psia

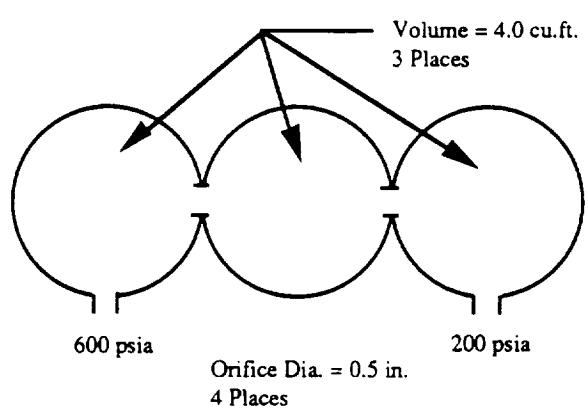


Figure 1. Schematic of One Dimensional Tank Pressurization

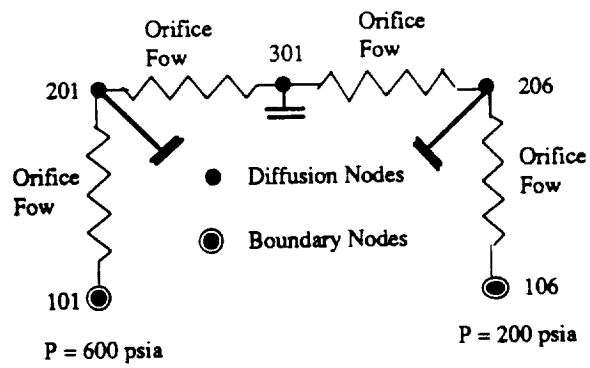


Figure 2. Resistance-Capacitance (R-C) Network for 1-D Schematic

D. Find:

The transient response of the network fluid pressures and flow rates.

II. Formulation of the Problem:

A. Simplifying Assumptions:

(1) Constant, known fluid temperature

B. Initial/Boundary Conditions:

(1) Initial Pressure = 200 psia
(2) Upstream Boundary = 600 psia applied at time = 0 sec.
(3) Downstream Boundary = 200 psia, constant with time

C. Discretization:

The analysis is performed for transient compressible fluid flow. This was discussed briefly in Chapter 5 Section 1 paragraph II(C). This formulation requires knowledge of the fluid temperature for calculation of fluid capacitance. In this example temperature is known and assumed to be constant. In many real engineering problems fluid temperature will be a function of both heat transfer and thermodynamics. Solution of problems of this type require a coupled thermal network and definition of any appropriate thermodynamic functions. See details given in the following section for coupled networks (with incompressible flow).

The fluid network is modeled using three diffusion nodes and two boundary nodes, as shown in Figure 2. Capacitances (V/RT) are calculated in the EXECUTION and VARIABLE's blocks prior to each time step. This is done to illustrate the required procedure for temperature varying problems (since temperature does not vary here, the calculation could be performed only once). Note, if large temperature changes occur, the formulation of equations used here is inappropriate. The error which can be incurred is a violation of mass conservation. If temperature changes are small this is insignificant. Conductors are also calculated prior to each time step. This is required because fluid density is a function of pressure, which changes with time.

III. Analysis:

A. The Input Deck:

This section is included to explain how the information in the statement of the problem is conveyed to SINDA, and to show the corresponding flow chart (see Figure 3). The input deck shown in the following is a "Gaski" SINDA deck.

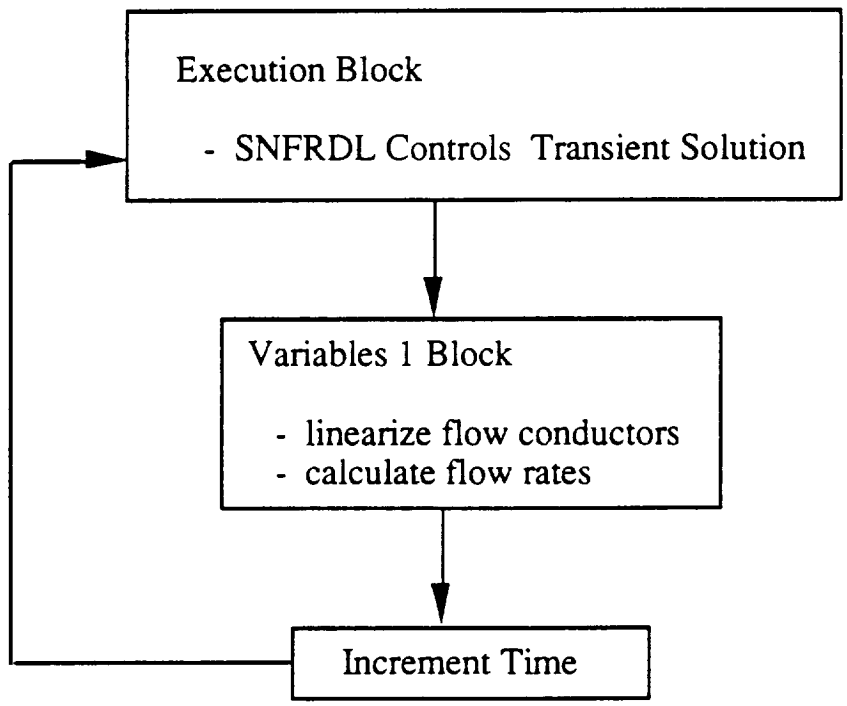


Figure 3. Solution Technique in SINDA

```
      BCD 3THERMAL LPCS
      BCD 9COPMRESSIBLE FLOW, 1D NETWORK
      END
C
      BCD 3NODE DATA
C
           1, 0.0, 1.0
           2, 0.0, 1.0
           -3, 0.0, 1.0
C
          -101,600.0,1.0 $ PRES BOUNDARY
          -106,200.0,1.0 $ PRES BOUNDARY
C
          201, 200.0, 1.0 $ PRES AT FIRST CAVITY
          206, 200.0, 1.0 $ PRES AT FIRST CAVITY
C
          301, 200.0, 1.0 $ PRES AT SECOND CAVITY
C
C FLOW RATE STORAGE LOCATION
C
          -1001, 0.0, 1.0
          -1006, 0.0, 1.0
C
          -2001, 0.0, 1.0
          -2006, 0.0, 1.0
C
C
          -4001, 0.0, 1.0
C
      END
C
      BCD 3CONDUCTOR DATA
C
          1, 1, 2, 1.0
          2, 2, 3, 1.0
C
          101, 101, 201, 0.0
          106, 106, 206, 0.0
C
          201, 201, 301, 0.0
          206, 206, 301, 0.0
C
C FLOW RATE STORAGE LOCATION
C
          1001, 101, 101, 0.0
          1006, 106, 106, 0.0
C
          2001, 201, 201, 0.0
          2006, 206, 206, 0.0
C
C
          4001, 301, 301, 0.0
C
      END
C
      BCD 3CONSTANTS DATA
```

```
            DTIMEI,1.E-6
            DTIMEH,1.E-6
            NLOOP,1000
C
            TIMEND,0.0
            OUTPUT,10.E-6
C
            ARLXCA,.001
            DRLXCA,.001
C            BALENG,.001
            TIMEO,0.0
            DAMPA,0.5
            DAMPD,0.5
            NDIM,1000
            ITEST,0
C
        END
C
        BCD 3ARRAY DATA
            1 $ PRES VS RHO (H2O) AT 2460 DEG R
            60.0, 0.0410
            80.0, 0.0546
            100.0, 0.0683
            120.0, 0.0819
            140.0, 0.0956
            160.0, 0.1093
            180.0, 0.1229
            200.0, 0.1366
            225.0, 0.1537
            250.0, 0.1708
            275.0, 0.1879
            300.0, 0.2042
            400.0, 0.2734
            500.0, 0.3418
            600.0, 0.4102
            END
C
        END
C
        BCD 3EXECUTION
C
F       OPEN(3,FILE="NEWTANK1DA.PLT",STATUS="UNKNOWN")
F       WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F     2 FORMAT(I6/,50(I6,31X,I6,/))
C
F       TIMEO=0.0
F       DTIMEI=1.E-2
F       DTIMEH=1.E-2
F       OUTPUT=0.1
F       TIMEND=20.00
F       CALL SNFRDL
C
        END
        BCD 3VARIABLES 1
C
C CALC ORIFICE FLOW CONDUCTORS
C
M 50    PAVG=(T101+T201)/2.0
```

```
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,G1001,G101)
C
M       PAVG=(T106+T206)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,G1006,G106)
C
M       PAVG=(T201+T301)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,G2001,G201)
C
M       PAVG=(T206+T301)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T206,T301,GK,G2006,G206)
C
M       C201=144.*4.0/(TEMP*RGAS)
M       C206=144.*4.0/(TEMP*RGAS)
M       C301=144.*4.0/(TEMP*RGAS)
C
C CALC MDOTS
C
M 40    CALL XMDOT(T101,T201,G101,G1001)
M       CALL XMDOT(T106,T206,G106,G1006)
C
M       CALL XMDOT(T201,T301,G201,G2001)
M       CALL XMDOT(T206,T301,G206,G2006)
C
F 100   CONTINUE
C
F       RETURN
F       END
C
F       SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
F       RETURN
F       END
C
C
F       SUBROUTINE IRIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
C
F       PUP1=PUP
F       PDN1=PDN
```

```
C
F       PS1=PUP
F       PS2=PDN
F       IF(PUP.GT.PDN)GO TO 1
F       PUP1=PS2
F       PDN1=PS1
F 1     CONTINUE
C
F       GK=1.329
C
F       PRATIO=(2.0/(GK+1.0))**(GK/(GK-1.0))
F       PCRIT=PUP1*PRATIO
F       BETA=0.0
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PCRIT)/(GK*PUP1)
F       GMAX=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GMAX=GMAX*Y*SQRT(PUP1-PCRIT)
F       GMAX=GMAX/(PUP1-PDN1)
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PDN1)/(GK*PUP1)
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GCOND=GCOND*Y/SQRT(PUP1-PDN1)
C
F       IF(PDN1/PUP1.LT.PRATIO)GCOND=AMIN1(GMAX,GCOND)
C
F       RETURN
F 2     GCOND=0.0
C
CF       RETURN
CF       END
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
C CALC MDOTS
C
M 40    CALL XMDT(T101,T201,G101,T1001)
M       CALL XMDT(T106,T206,G106,T1006)
C
M       CALL XMDT(T201,T301,G201,T2001)
M       CALL XMDT(T206,T301,G206,T2006)
C
C GENERATE PLOT FILE
C
F       WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F    1  FORMAT(E10.3,/,7F12.3,/,7F12.3,/,7F12.3)
C
C RETURN IF TIME INCREMENT NOT SATISFIED
C
F          TIMCHK=TIMEO*1.001
M         IF(AMOD(TIMCHK,1.0).GT.0.08)RETURN
C
```

```
C FOUR COLUMN OUTPUT ROUTINE, STNDRD
C
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $           8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $           8H RELXCC(I6,2H)=1PE12.5)
C
C FOUR COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       J=1
F       L=4
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(4(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 15
F       J=L+1
F       L=L+4
F       GO TO 5
F 15    CONTINUE
F       RETURN
F       END
C
F       SUBROUTINE XMDT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
C       RETURN
        END
        BCD 3END OF DATA
```

As discussed previously the input deck is comprised of nine major blocks. These include the TITLE block, the NODE DATA block, the CONDUCTOR DATA block, the ARRAY DATA block, the EXECUTION block, the VARIABLES 1 block, the VARIABLES 2 block, and the OUTPUT CALLS block. The blocks are similar to those presented earlier, with the exception of diffusion nodes replacing arithmetic nodes in the fluid network, and the use of a transient solution routine.

Again, the EXECUTION block contains information which directly controls program execution. The solution scheme is identified in this block. The SNFRDL explicit forward differencing transient solution routine is used. As you can see in the flow chart, the solution procedure here differs from the three step convergence technique used in previous examples. The solution uses linearized conductor values calculated each time step, similar to the techniques described earlier. The

solution then marches through time predicting the pressure field and the distribution of flow.

The VARIABLES blocks are similar to those described earlier. Note that the calculation procedure now forces use of non-linear compressible equations for the transient solution. Convergence to specified criteria (ARLXCA, DRLXCA) should be guaranteed by the forward differencing scheme.

The OUTPUT CALLS block is similar to that used previously. Note that because transient pressures and temperatures are of interest, an additional plot file is defined in the EXECUTION block. The OUTPUT CALLS block then writes to this file at each output interval for post run plotting.

IV. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are presented on the following pages. Figure 4 shows the transient plot of node pressures versus time. Figure 5 shows the transient distribution of flow rates. Note that both the long term transient pressures and flow rates converge to constant values. Because networks of this type sometimes have low flow resistance (high stiffness), inaccuracies can occur, especially in steady state solutions. When this occurs, solution on a 64 bit machine is recommended.

V. Closing Comments:

The analogies utilized for this example are quite useful as learning tools for inexperienced code users. Because flow rate, mass (gas) storage, and pressure are easily understood and observed, the analyst can easily relate to the analytical model and results. Additionally, the analyst can understand better the more abstract variables such as thermal capacitance, energy storage, and heat rate which are used in thermal networks.

The user is again cautioned against using these analytical techniques where thermodynamic processes cause large fluid temperature changes. At best these techniques give rough order of magnitude results for non-isothermal processes. The dynamics and thermodynamics of compressible fluid flow is quite complex and must be addressed with appropriate physical laws for given phenomena.

VI. References

Crane Co.; Flow of Fluids Through Valves, Fittings, and Pipes; Technical Paper No. 410; Copyright 1976; by Crane Co.

White, Frank M.; Fluid Mechanics; 2nd Edition; Copyright 1979 by McGraw-Hill Book Company; New York; pp. 551-554

Sutton, George P.; Rocket Propulsion Elements; 5th Edition; Copyright 1986 by John Wiley & Sons, Inc.; New York; pp. 36-56

Van Wylen, Gordon J. and Sonntag, Richard E.; Fundamentals of Classical Thermodynamics; Second Edition; Copyright 1973 by John Wiley & Sons, Inc.; New York; pp. 607-630

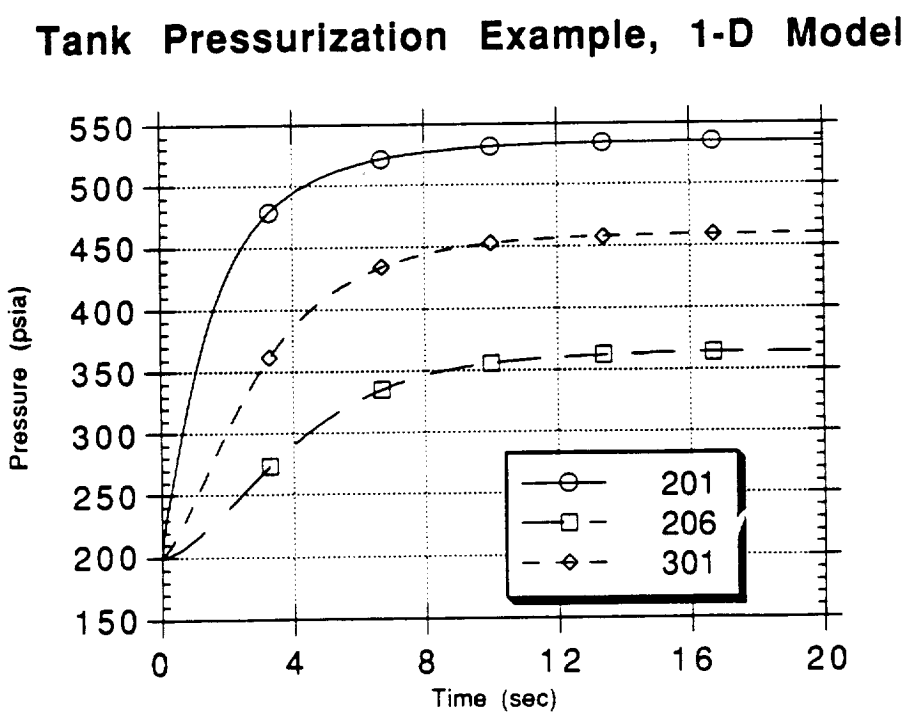


Figure 4. Transient Pressure Response

Tank Pressurization Example, 1-D Model

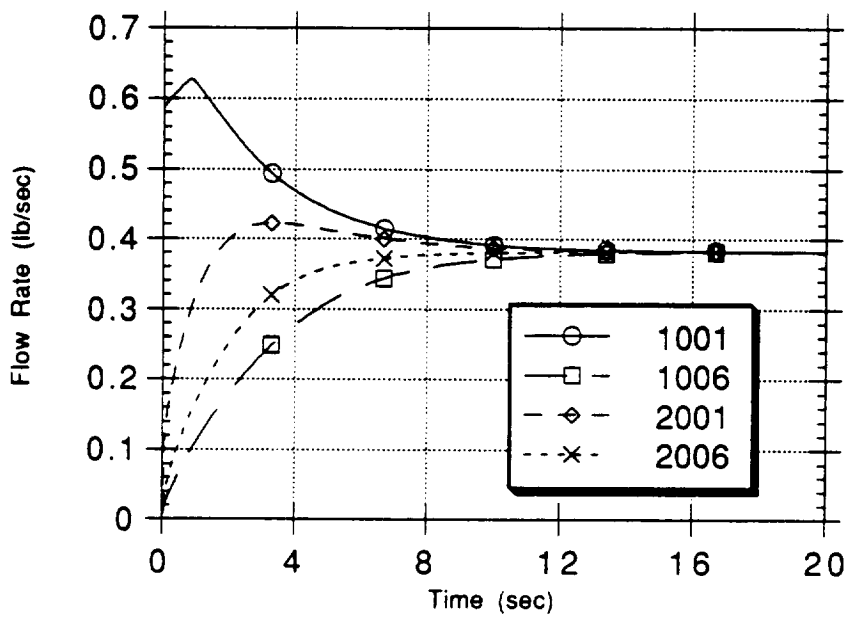


Figure 5. Transient Flow Rates

TRANSIENT OUTPUT

```
 (C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK
ANALYSIS ASSOCIATES, INC. - PAGE      1

     COPMRESSIBLE FLOW, 1D NETWORK

 *** NOTE *** SNFRDL REQUIRES      18 DYNAMIC STORAGE LOCATIONS OUT OF     974 AVAILABLE ***
              TIMEND=  20.000     , CSGFAC=  1.0000     , DTIMEI= 0.10000E-01, NLOOP =
1000
              TIMEO =  .00000     , OUTPUT=  .10000     , DTIMEH= 0.10000E-01, DTIMEL=  .00000
              ARLXCA= 0.10000E-02, ATMPCA= 0.10000E+09, DRLXCA= 0.10000E-02, DTMPCA=
0.10000E+09

 **********
 TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                   TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01

 T      1=       .00000  T      2=       .00000  T    201=   200.00000  T    206=   200.00000
 T    301=    200.00000  T      3=       .00000  T    101=   600.00000  T    106=   200.00000
 T   1001=       .58703  T   1006=       .00000  T   2001=       .00000  T   2006=       .00000
 T   4001=       .00000

 *WARN* GSUM IS ZERO, ACT NODE     206 IS UNCONNECTED AT TIME   .00000

 *WARN* GSUM IS ZERO, ACT NODE     301 IS UNCONNECTED AT TIME   .00000

 **********
 TIME=      1.00000          DTIMEU= 5.00000E-03 CSGMIN(    206)= 2.06964E-01
                   TEMPCC(    201)= 5.57500E-01 RELXCC(      0)= 0.00000E-01
```

```
T     1=       .00000  T     2=       .00000  T   201=   343.21970  T   206=   214.15950
T   301=   244.72880  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .62111  T  1006=       .10962  T  2001=      .31920  T  2006=      .16625
T  4001=       .00000

**********
TIME=     2.00000          DTIMEU= 5.00000E-03 CSGMIN(   206)= 3.14306E-01
                  TEMPCC(   201)= 2.96465E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   426.16241  T   206=   238.24322
T   301=   301.34851  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .55955  T  1006=       .17947  T  2001=      .39884  T  2006=      .25156
T  4001=       .00000

**********
TIME=     3.00000          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.68760E-01
                  TEMPCC(   301)= 2.09764E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   469.96972  T   206=   265.14813
T   301=   349.76700  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .50659  T  1006=       .23449  T  2001=      .42090  T  2006=      .30692
T  4001=       .00000

**********
TIME=     4.00000          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.29527E-01
                  TEMPCC(   301)= 1.46258E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   493.98443  T   206=   290.29492
T   301=   385.15222  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .46877  T  1006=       .27715  T  2001=      .41972  T  2006=      .34025
T  4001=       .00000

**********
TIME=     5.00002          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.03416E-01
                  TEMPCC(   301)= 9.87230E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   508.21790  T   206=   311.09130
T   301=   409.36334  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .44247  T  1006=       .30887  T  2001=      .41221  T  2006=      .35855
T  4001=       .00000

**********
TIME=     6.00005          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.85957E-01
                  TEMPCC(   206)= 6.77323E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   517.20760  T   206=   326.95532
T   301=   425.65673  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .42404  T  1006=       .33160  T  2001=      .40447  T  2006=      .36838
T  4001=       .00000

**********
TIME=     7.00007          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.74171E-01
                  TEMPCC(   206)= 4.83451E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   523.09420  T   206=   338.47973
T   301=   436.63024  T     3=       .00000  T   101=   600.00000  T   106=   200.00000
T  1001=       .41108  T  1006=       .34751  T  2001=      .39811  T  2006=      .37375
T  4001=       .00000

**********
TIME=     8.00009          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.66166E-01
                  TEMPCC(   206)= 3.37884E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   527.02030  T   206=   346.61660
```

```
T   301=   444.04730  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .40202  T  1006=      .35849  T  2001=      .39332  T  2006=      .37683
T  4001=      .00000

**********
TIME=     9.00012          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.60718E-01
                   TEMPCC(   206)= 2.33768E-02 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   529.66241  T   206=   352.27030
T   301=   449.07190  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .39571  T  1006=      .36597  T  2001=      .38984  T  2006=      .37865
T  4001=      .00000

**********
TIME=    10.00014          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.57003E-01
                   TEMPCC(   206)= 1.60717E-02 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   531.44860  T   206=   356.17132
T   301=   452.48450  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .39134  T  1006=      .37104  T  2001=      .38737  T  2006=      .37976
T  4001=      .00000

**********
TIME=    11.00016          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.54470E-01
                   TEMPCC(   206)= 1.10010E-02 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   532.66010  T   206=   358.84720
T   301=   454.80430  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38834  T  1006=      .37450  T  2001=      .38564  T  2006=      .38047
T  4001=      .00000

**********
TIME=    12.00018          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.52744E-01
                   TEMPCC(   206)= 7.51089E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   533.48260  T   206=   360.67584
T   301=   456.38092  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38627  T  1006=      .37685  T  2001=      .38444  T  2006=      .38093
T  4001=      .00000

**********
TIME=    13.00021          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.51570E-01
                   TEMPCC(   206)= 5.11609E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   534.04113  T   206=   361.92360
T   301=   457.45230  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38486  T  1006=      .37845  T  2001=      .38361  T  2006=      .38123
T  4001=      .00000

**********
TIME=    14.00023          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.50771E-01
                   TEMPCC(   206)= 3.48254E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   534.42053  T   206=   362.77294
T   301=   458.18040  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38389  T  1006=      .37954  T  2001=      .38305  T  2006=      .38143
T  4001=      .00000

**********
TIME=    15.00025          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.50228E-01
                   TEMPCC(   206)= 2.36864E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   534.67820  T   206=   363.35083
T   301=   458.67480  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
```

```
T  1001=      .38324  T  1006=      .38028  T  2001=      .38266  T  2006=      .38156
T  4001=      .00000

**********
TIME=    16.00027          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.49859E-01
                   TEMPCC(   206)= 1.60968E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   534.85321  T   206=   363.74370
T   301=   459.01060  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38279  T  1006=      .38078  T  2001=      .38240  T  2006=      .38165
T  4001=      .00000

**********
TIME=    17.00028          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.49608E-01
                   TEMPCC(   206)= 1.09441E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   534.97180  T   206=   364.01062
T   301=   459.23864  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38249  T  1006=      .38112  T  2001=      .38222  T  2006=      .38171
T  4001=      .00000

**********
TIME=    18.00028          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.49438E-01
                   TEMPCC(   206)= 7.42786E-04 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   535.05242  T   206=   364.19213
T   301=   459.39350  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38228  T  1006=      .38135  T  2001=      .38210  T  2006=      .38175
T  4001=      .00000

**********
TIME=    19.00029          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.49322E-01
                   TEMPCC(   206)= 5.04131E-04 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   535.10730  T   206=   364.31530
T   301=   459.49853  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38214  T  1006=      .38151  T  2001=      .38202  T  2006=      .38178
T  4001=      .00000

**********
TIME=    20.00000          DTIMEU= 4.70924E-03 CSGMIN(   201)= 2.49244E-01
                   TEMPCC(   206)= 3.23043E-04 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   535.14430  T   206=   364.39890
T   301=   459.57000  T     3=      .00000  T   101=   600.00000  T   106=   200.00000
T  1001=      .38204  T  1006=      .38162  T  2001=      .38196  T  2006=      .38180
T  4001=      .00000
```

Appendix to Section 2: Further Examples

The following is identical to the previous example except that the boundary and initial conditions have been changed (high pressure is 400 psia, low pressure 14.7 psia, initial condition 14.7 psia). The results show the transient response. The change in profile with time is a result of choked flow conditions in the system. As before, the network converges to a steady state condition.

I. Identification of the Problem:

A. Statement of the Problem:

(same)

B. Given:

(1) The tank volumes are 4 cu. ft.
(2) Hydraulic diameter of orifices are 0.5 in.
(3) High Pressure Boundary is 400 psia
(4) Low Pressure Boundary is 14.7 psia
(5) Initial System Pressure, 14.7 psia

C. Schematic of the 1-D Fluid Network:

(same, with new boundary conditions)

D. Find:

(same)

II. Formulation of the Problem:

A. Simplifying Assumptions:

(same)

B. Initial/Boundary Conditions:

(1) Initial Pressure = 14.7 psia
(2) Upstream Boundary = 400 psia, applied at time = 0 sec.
(3) Downstream Boundary = 14.7 psia

C. Descretization:

(same)

III. Analysis:

A. The Input Deck:

(same, with new boundary conditions)

SINDA INPUT LISTING

```
      BCD 3THERMAL LPCS
      BCD 9COPMRESSIBLE FLOW, 1D NETWORK
      END
C
      BCD 3NODE DATA
C
           1, 0.0, 1.0
           2, 0.0, 1.0
           -3, 0.0, 1.0
C
```

```
          -101,400.0,1.0 $ PRES BOUNDARY
          -106,14.7,1.0 $ PRES BOUNDARY
C
          201, 14.7, 1.0 $ PRES AT FIRST CAVITY
          206, 14.7, 1.0 $ PRES AT FIRST CAVITY
C
          301, 14.7, 1.0 $ PRES AT SECOND CAVITY
C
C FLOW RATE STORAGE LOCATION
C
          -1001, 0.0, 1.0
          -1006, 0.0, 1.0
C
          -2001, 0.0, 1.0
          -2006, 0.0, 1.0
C
C
          -4001, 0.0, 1.0
C
      END
C
      BCD 3CONDUCTOR DATA
C
          1, 1, 2, 1.0
          2, 2, 3, 1.0
C
          101, 101, 201, 0.0
          106, 106, 206, 0.0
C
          201, 201, 301, 0.0
          206, 206, 301, 0.0
C
C FLOW RATE STORAGE LOCATION
C
          1001, 101, 101, 0.0
          1006, 106, 106, 0.0
C
          2001, 201, 201, 0.0
          2006, 206, 206, 0.0
C
C
          4001, 301, 301, 0.0
C
      END
C
      BCD 3CONSTANTS DATA
          DTIMEI,1.E-6
          DTIMEH,1.E-6
          NLOOP,1000
C
          TIMEND,0.0
          OUTPUT,10.E-6
C
          ARLXCA,.001
          DRLXCA,.001
C          BALENG,.001
          TIMEO,0.0
          DAMPA,0.5
```

```
            DAMPD,0.5
            NDIM,1000
            ITEST,0
C
        END
C
        BCD 3ARRAY DATA
            1 $ PRES VS RHO (H2O) AT 2460 DEG R
            60.0, 0.0410
            80.0, 0.0546
            100.0, 0.0683
            120.0, 0.0819
            140.0, 0.0956
            160.0, 0.1093
            180.0, 0.1229
            200.0, 0.1366
            225.0, 0.1537
            250.0, 0.1708
            275.0, 0.1879
            300.0, 0.2042
            400.0, 0.2734
            500.0, 0.3418
            600.0, 0.4102
            END
C
        END
C
        BCD 3EXECUTION
C
F       OPEN(3,FILE="NEWTANK1DB.PLT",STATUS="UNKNOWN")
F       WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F     2 FORMAT(I6/,50(I6,31X,I6,/))
C
F       TIMEO=0.0
F       DTIMEI=1.E-2
F       DTIMEH=1.E-2
F       OUTPUT=0.1
F       TIMEND=20.00
F       CALL SNFRDL
C
        END
        BCD 3VARIABLES 1
C
C CALC ORIFICE FLOW CONDUCTORS
C
M 50    PAVG=(T101+T201)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       GK=1.329
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T101,T201,GK,G1001,G101)
C
M       PAVG=(T106+T206)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
```

```
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T106,T206,GK,G1006,G106)
C
M       PAVG=(T201+T301)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T201,T301,GK,G2001,G201)
C
M       PAVG=(T206+T301)/2.0
M       CALL D1DEG1(PAVG,A1,RHO)
M       RGAS=1545./18.
M       TEMP=2460.
M       AREA=(3.14159*(0.5/12.)**2)/4.0
M       CALL IRIFIC(RHO,AREA,RGAS,TEMP,T206,T301,GK,G2006,G206)
C
M       C201=144.*4.0/(TEMP*RGAS)
M       C206=144.*4.0/(TEMP*RGAS)
M       C301=144.*4.0/(TEMP*RGAS)
C
C CALC MDOTS
C
M 40    CALL XMDOT(T101,T201,G101,G1001)
M       CALL XMDOT(T106,T206,G106,G1006)
C
M       CALL XMDOT(T201,T301,G201,G2001)
M       CALL XMDOT(T206,T301,G206,G2006)
C
F 100   CONTINUE
C
F       RETURN
F       END
C
F       SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
F       RETURN
F       END
C
C
F       SUBROUTINE IRIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F       IF(PUP.EQ.PDN)GO TO 2
C
F       PUP1=PUP
F       PDN1=PDN
C
F       PS1=PUP
F       PS2=PDN
F       IF(PUP.GT.PDN)GO TO 1
F       PUP1=PS2
F       PDN1=PS1
F 1     CONTINUE
C
F       GK=1.329
C
F       PRATIO=(2.0/(GK+1.0))**(GK/(GK-1.0))
F       PCRIT=PUP1*PRATIO
```

```
F       BETA=0.0
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PCRIT)/(GK*PUP1)
F       GMAX=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GMAX=GMAX*Y*SQRT(PUP1-PCRIT)
F       GMAX=GMAX/(PUP1-PDN1)
C
F       Y=1.-(0.41+0.35*BETA**4)*(PUP1-PDN1)/(GK*PUP1)
F       GCOND=0.6*AREA*SQRT(2.*32.2*144.*RHO)
F       GCOND=GCOND*Y/SQRT(PUP1-PDN1)
C
F       IF(PDN1/PUP1.LT.PRATIO)GCOND=AMIN1(GMAX,GCOND)
C
F       RETURN
F 2     GCOND=0.0
C
CF       RETURN
CF       END
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT    /
C
C CALC MDOTS
C
M 40    CALL XMDT(T101,T201,G101,T1001)
M       CALL XMDT(T106,T206,G106,T1006)
C
M       CALL XMDT(T201,T301,G201,T2001)
M       CALL XMDT(T206,T301,G206,T2006)
C
C GENERATE PLOT FILE
C
F       WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F    1  FORMAT(E10.3,/,7F12.3,/,7F12.3,/,7F12.3)
C
C RETURN IF TIME INCREMENT NOT SATISFIED
C
F          TIMCHK=TIMEO*1.001
M         IF(AMOD(TIMCHK,1.0).GT.0.08)RETURN
C
C FOUR COLUMN OUTPUT ROUTINE, STNDRD
C
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
```

```
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $           8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $           8H RELXCC(I6,2H)=1PE12.5)
C
C FOUR COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       J=1
F       L=4
F    5  IF(L.LT.NNT)GO TO 10
F       L=NNT
F   10  WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(4(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 15
F       J=L+1
F       L=L+4
F       GO TO 5
F 15    CONTINUE
F       RETURN
F       END
C
F       SUBROUTINE XMDT(PUP,PDN,GCOND,XM)
C
F       XM=GCOND*ABS(PUP-PDN)
C       RETURN
        END
        BCD 3END OF DATA
```

IV. Presentation and Discussion of Results:

A. Presentation of Results:

Results obtained from SINDA are shown on the following pages. Figure 6 shows the transient response of node pressures. Figure 7 shows the transient distribution of flow rates. Again the long term transient pressures and flow rates converge to constant (steady state) values. The transient profile (response) is somewhat different from the previous example. This is due to the potential for choked flow conditions in the network. The long term transient (steady state) results show the flow choked across the final flow restriction, to the downstream boundary condition. The 1-D system flow rate is controlled at this position in the network, and other system pressures adjust to accommodate this flow.

V. Closing Comments:

(none)

VI. References:

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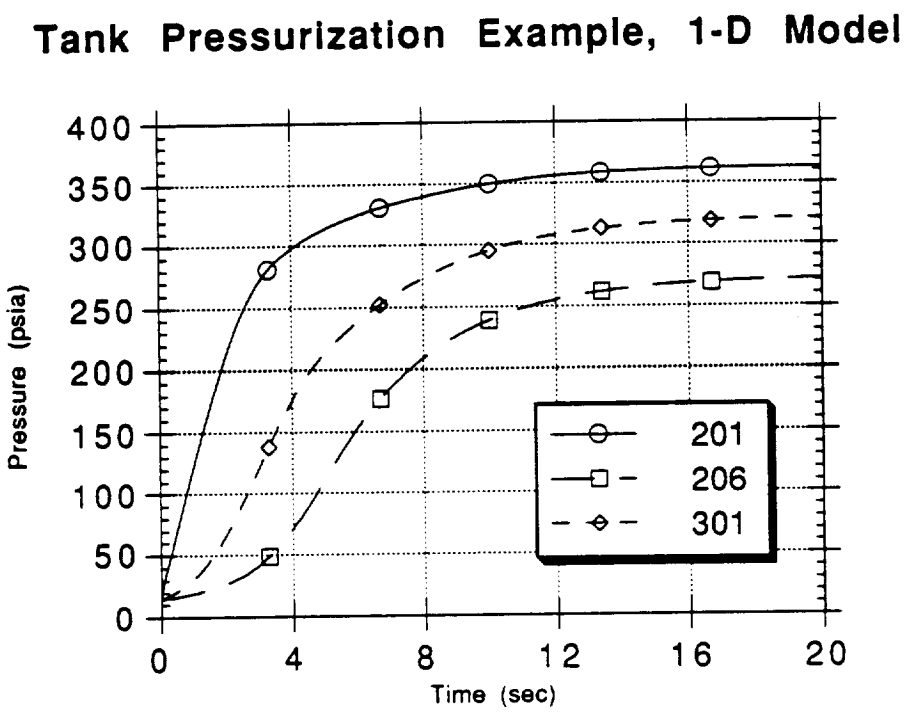

Figure 6. Transient Pressure Response with Choked Flow

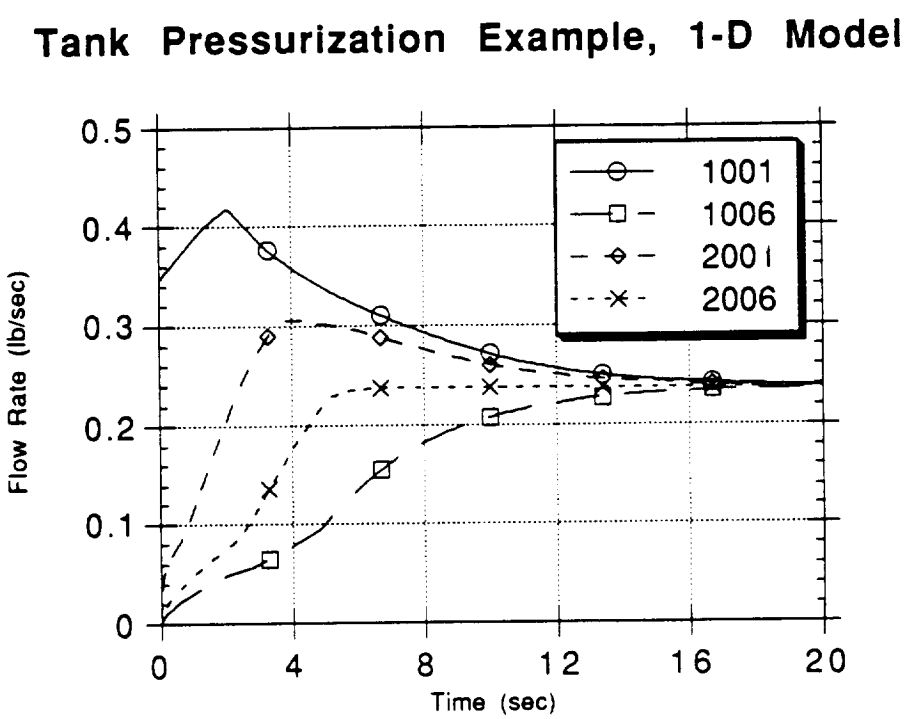

Figure 7. Transient Flow Rates with Choked Flow

TRANSIENT OUTPUT

```
 (C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK
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     COPMRESSIBLE FLOW, 1D NETWORK

 *** NOTE *** SNFRDL REQUIRES      18 DYNAMIC STORAGE LOCATIONS OUT OF     974 AVAILABLE ***
              TIMEND=  20.000     , CSGFAC=  1.0000     , DTIMEI= 0.10000E-01, NLOOP =
1000
              TIMEO =  .00000     , OUTPUT=  .10000     , DTIMEH= 0.10000E-01, DTIMEL=  .00000
              ARLXCA= 0.10000E-02, ATMPCA= 0.10000E+09, DRLXCA= 0.10000E-02, DTMPCA=
0.10000E+09

 **********
 TIME=       .00000          DTIMEU= 0.00000E-01 CSGMIN(      0)= 0.00000E-01
                    TEMPCC(      0)= 0.00000E-01 RELXCC(      0)= 0.00000E-01

 T      1=       .00000  T      2=       .00000  T    201=    14.70000  T    206=    14.70000
 T    301=     14.70000  T      3=       .00000  T    101=   400.00000  T    106=    14.70000
 T   1001=       .34497  T   1006=       .00000  T   2001=       .00000  T   2006=       .00000
 T   4001=       .00000

 *WARN* GSUM IS ZERO, ACT NODE     206 IS UNCONNECTED AT TIME   .00000

 *WARN* GSUM IS ZERO, ACT NODE     301 IS UNCONNECTED AT TIME   .00000

 **********
 TIME=      1.00000          DTIMEU= 5.00000E-03 CSGMIN(    206)= 2.43973E-01
                    TEMPCC(    201)= 4.98385E-01 RELXCC(      0)= 0.00000E-01

 T      1=       .00000  T      2=       .00000  T    201=   121.54553  T    206=    19.10849
 T    301=     31.00314  T      3=       .00000  T    101=   400.00000  T    106=    14.70001
 T   1001=       .38605  T   1006=       .03124  T   2001=       .11531  T   2006=       .04872
 T   4001=       .00000

 **********
 TIME=      2.00000          DTIMEU= 5.00000E-03 CSGMIN(    206)= 4.72233E-01
                    TEMPCC(    201)= 3.91398E-01 RELXCC(      0)= 0.00000E-01

 T      1=       .00000  T      2=       .00000  T    201=   210.54580  T    206=    27.34601
 T    301=     66.82684  T      3=       .00000  T    101=   400.00000  T    106=    14.70001
 T   1001=       .41692  T   1006=       .04868  T   2001=       .20446  T   2006=       .07609
 T   4001=       .00000

 **********
 TIME=      3.00000          DTIMEU= 5.00000E-03 CSGMIN(      2)= 5.00000E-01
                    TEMPCC(    301)= 2.86322E-01 RELXCC(      0)= 0.00000E-01

 T      1=       .00000  T      2=       .00000  T    201=   270.06170  T    206=    42.03870
 T    301=    121.22710  T      3=       .00000  T    101=   400.00000  T    106=    14.70001
 T   1001=       .38579  T   1006=       .06033  T   2001=       .27489  T   2006=       .11910
 T   4001=       .00000

 **********
 TIME=      4.00000          DTIMEU= 5.00000E-03 CSGMIN(    201)= 4.54753E-01
                    TEMPCC(    301)= 2.37594E-01 RELXCC(      0)= 0.00000E-01

 T      1=       .00000  T      2=       .00000  T    201=   297.59790  T    206=    70.96954
 T    301=    175.64540  T      3=       .00000  T    101=   400.00000  T    106=    14.70001
 T   1001=       .35798  T   1006=       .07833  T   2001=       .30523  T   2006=       .17605
 T   4001=       .00000
```

```
**********
TIME=      5.00002          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.94670E-01
                   TEMPCC(   206)= 2.24145E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   313.58264  T   206=   112.15290
T   301=    213.49163  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .33715  T  1006=       .10108  T  2001=      .30132  T  2006=      .22296
T  4001=       .00000

**********
TIME=      6.00005          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.56548E-01
                   TEMPCC(   206)= 1.83164E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   324.60943  T   206=   153.46893
T   301=    238.00732  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .32029  T  1006=       .13606  T  2001=      .29466  T  2006=      .23560
T  4001=       .00000

**********
TIME=      7.00007          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.26940E-01
                   TEMPCC(   206)= 1.37017E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   332.97521  T   206=   185.36730
T   301=    257.50120  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .30585  T  1006=       .16313  T  2001=      .28533  T  2006=      .23759
T  4001=       .00000

**********
TIME=      8.00009          DTIMEU= 5.00000E-03 CSGMIN(   201)= 3.02829E-01
                   TEMPCC(   206)= 1.00454E-01 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   339.82380  T   206=   208.93591
T   301=    273.23020  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .29281  T  1006=       .18305  T  2001=      .27585  T  2006=      .23765
T  4001=       .00000

**********
TIME=      9.00012          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.83455E-01
                   TEMPCC(   206)= 7.35650E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   345.45670  T   206=   226.19510
T   301=    285.65210  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .28112  T  1006=       .19765  T  2001=      .26731  T  2006=      .23764
T  4001=       .00000

**********
TIME=     10.00014          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.68328E-01
                   TEMPCC(   206)= 5.38895E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   349.97802  T   206=   238.83720
T   301=    295.18444  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .27104  T  1006=       .20837  T  2001=      .26015  T  2006=      .23767
T  4001=       .00000

**********
TIME=     11.00016          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.56779E-01
                   TEMPCC(   206)= 3.94380E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   353.48583  T   206=   248.09650
T   301=    302.34730  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .26273  T  1006=       .21623  T  2001=      .25442  T  2006=      .23767
T  4001=       .00000

**********
```

```
TIME=    12.00018          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.48092E-01
                   TEMPCC(   206)= 2.86833E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   356.13653  T   206=   254.85070
T   301=    307.66424  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .25614  T  1006=       .22196  T  2001=      .24993  T  2006=      .23756
T  4001=       .00000

**********
TIME=    13.00021          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.41645E-01
                   TEMPCC(   206)= 2.08347E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   358.10491  T   206=   259.76141
T   301=    311.56680  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .25106  T  1006=       .22613  T  2001=      .24648  T  2006=      .23745
T  4001=       .00000

**********
TIME=    14.00023          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.36913E-01
                   TEMPCC(   206)= 1.50840E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   359.54724  T   206=   263.32312
T   301=    314.40560  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .24723  T  1006=       .22915  T  2001=      .24389  T  2006=      .23735
T  4001=       .00000

**********
TIME=    15.00025          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.33467E-01
                   TEMPCC(   206)= 1.08837E-02 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   360.59440  T   206=   265.89764
T   301=    316.45880  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .24439  T  1006=       .23133  T  2001=      .24197  T  2006=      .23725
T  4001=       .00000

**********
TIME=    16.00027          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.30971E-01
                   TEMPCC(   206)= 7.83321E-03 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   361.35083  T   206=   267.75274
T   301=    317.93860  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .24230  T  1006=       .23291  T  2001=      .24056  T  2006=      .23716
T  4001=       .00000

**********
TIME=    17.00028          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.29170E-01
                   TEMPCC(   206)= 5.62588E-03 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   361.89532  T   206=   269.08640
T   301=    319.00213  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .24078  T  1006=       .23404  T  2001=      .23953  T  2006=      .23710
T  4001=       .00000

**********
TIME=    18.00028          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.27875E-01
                   TEMPCC(   206)= 4.03237E-03 RELXCC(     0)= 0.00000E-01

T     1=       .00000  T     2=       .00000  T   201=   362.28613  T   206=   270.04330
T   301=    319.76464  T     3=       .00000  T   101=   400.00000  T   106=    14.70001
T  1001=       .23969  T  1006=       .23485  T  2001=      .23879  T  2006=      .23704
T  4001=       .00000

**********
TIME=    19.00029          DTIMEU= 5.00000E-03 CSGMIN(   201)= 2.26946E-01
```

```
                TEMPCC(   206)= 2.88746E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   362.56620  T   206=   270.72890
T   301=   320.31103  T     3=      .00000  T   101=   400.00000  T   106=    14.70001
T  1001=      .23889  T  1006=      .23543  T  2001=      .23825  T  2006=      .23700
T  4001=      .00000

**********
TIME=    20.00000         DTIMEU= 4.70924E-03 CSGMIN(   201)= 2.26280E-01
                TEMPCC(   206)= 1.94587E-03 RELXCC(     0)= 0.00000E-01

T     1=      .00000  T     2=      .00000  T   201=   362.76650  T   206=   271.21923
T   301=   320.70160  T     3=      .00000  T   101=   400.00000  T   106=    14.70001
T  1001=      .23832  T  1006=      .23585  T  2001=      .23786  T  2006=      .23697
T  4001=      .00000
```

CHAPTER 5: N-DIMENSIONAL BRANCHING NETWORKS, 1-DIMENSIONAL FLUID FLOW

SECTION 3: Coupled (Conjugate) Fluid/Thermal Analysis

ANALYSIS CODE: SINDA (Gaski Version)

I. Identification of the Problem:

A. Preface to the Problem:

The Space Shuttle Main Engine's Main Fuel Valve Actuator (MFVA), during development, exhibited marginal prelaunch thermal conditioning. Eventually, a heater was added to compensate for the loss of heat to the cryogenic valve. Extensive thermal analysis was needed to correctly size the heater, and to predict the outcome of a possible heater failure. The following is a simplified version of the thermal/hydraulic analysis. Linearized incompressible flow equations are solved, as described earlier in Chapter 5.

Hydraulic power is provided for operation of five valve actuators in the propellant feed system (oxidizer preburner oxidizer, fuel preburner oxidizer, main oxidizer, main fuel, and chamber coolant valves). Servoactuators mounted to the propellant valves convert vehicle-supplied hydraulic fluid pressure to rotary motion of the actuator shaft. The amount of rotation is a function of electrical input.

Two servovalves are integral with each servoactuator as shown in Figure 1. The servovalves translate the electrical command signal from the engine controller, to position the valve actuator. The dual servovalves provide redundancy, thereby permitting a single servovalve failure with no change in actuator performance. A fail-operate servoswitch is used to (automatically) select the redundant servovalve, upon failure of a single servovalve. A fail-safe servoswitch is used to hydraulically lock the servoactuator upon failure of both servovalves.

A heater, installed on the MFV actuator neck, maintains the hydraulic fluid temperature at an acceptable level.

Dual rotary variable differential transformers (RVDTs) are connected to the actuator shaft and return electrical signals to the controller which in turn, interprets the signal and determines the position of the actuator.

Any or all of the actuators may be pneumatically operated should emergency conditions warrant rapid closure of the propellant valves. Pneumatic sequence valves, in the oxidizer and fuel preburner actuators, provide the proper closing sequence of the propellant valves during an emergency shutdown condition. A pneumatic sequence valve in the chamber coolant-valve actuator is used to determine engine post-shutdown purges.

Normal operating specifications for the hydraulic actuators are given in Table 1.

Table 1. Hydraulic Actuator Operating Specifications.

Supply Pressure, psig	2700 to 3100
Return Pressure, psig	200 nominal
	250 maximum
Flowrates, gpm	
Steady State	2.5 minimum
Transient	12

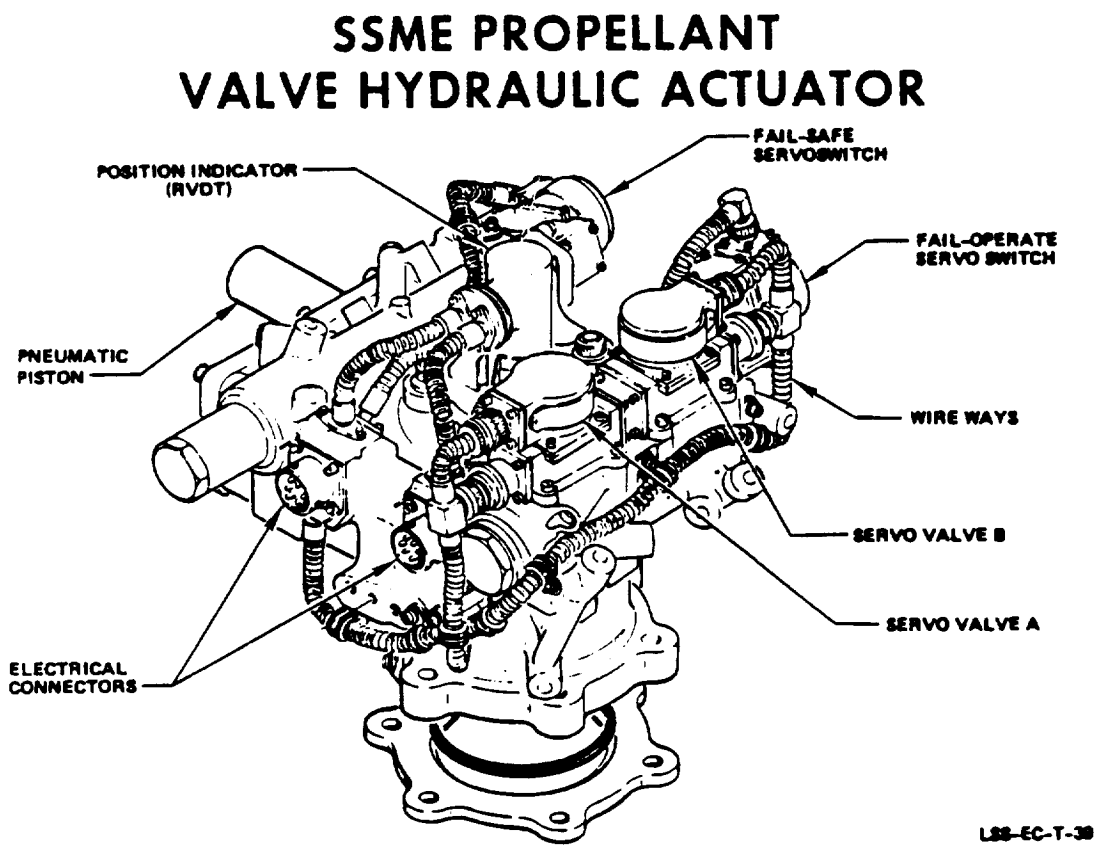

Figure 1. Typical Hydraulic Actuator

The main fuel valve, pictured in Figure 2, is a hydraulically actuated ball valve with a 2.5 inch diameter propellant flow passage. The valve is flange-mounted and is located between the high-pressure fuel duct and the coolant distribution manifold to the thrust chamber nozzle. The valve permits (or stops) the flow of fuel to the thrust chamber coolant circuits, the low pressure fuel turbopump turbine, hot gas manifold coolant circuit, oxidizer preburner, fuel preburner and the three augmented spark igniters. Valve position is determined by commands from the engine controller.

The valve contains two major (moving) components including the integral ball/shaft/cams and the ball seal retracting mechanism. The ball outlet seal is machined plastic, bellows-loaded-closed seal. The ball seal is placed at the outlet side of the valve such that the valve housing is exposed to liquid hydrogen during engine conditioning (chilldown). Redundant shaft seals, with a (overboard) drain cavity located between them, prevent leakage along the shaft during engine operation. Inlet and outlet throttling sleeves align the flow to minimize turbulence and the resultant pressure loss. Ball seal wear is minimized by cams and a cam follower assembly that displaces the seal away from the ball following the first few degrees of ball rotation.

Geometry of Main Fuel Valve

Flow Passage Dimensions, inches	2.500
Ball Diameter, inches	5.125
Shaft Diameter (seal), inches	1.875
Valve Length, inches	10.25

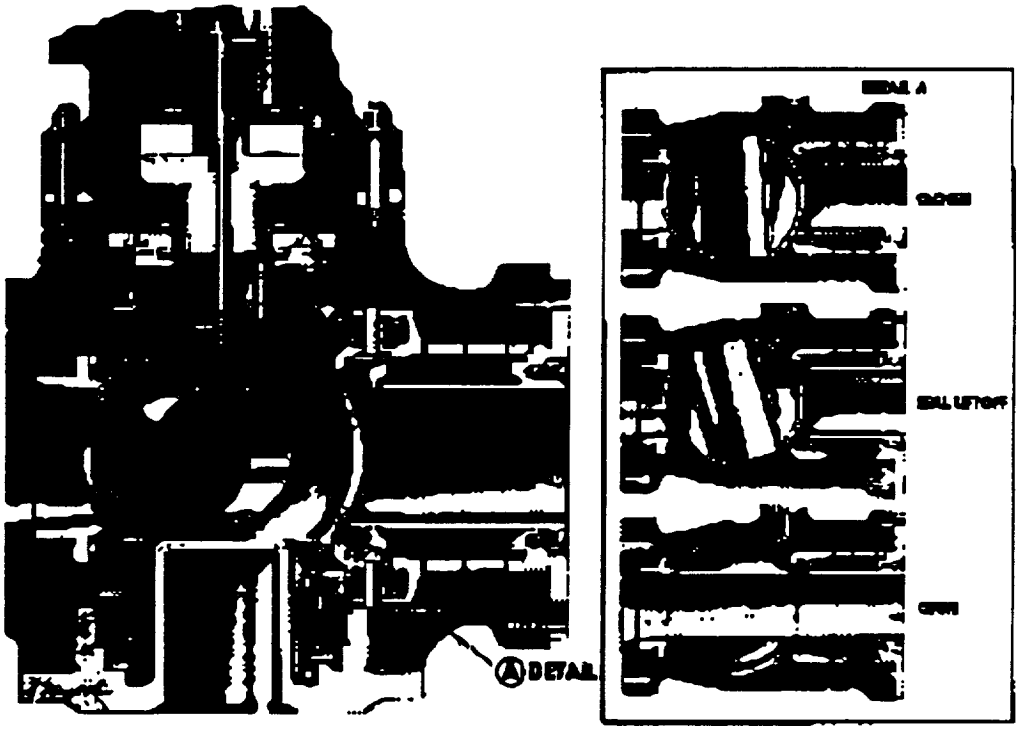

Figure 2. Main Fuel Valve Actuator

B. Statement of the Problem:

Following is an example of a coupled (conjugate) thermal model with an incompressible branching network (fluid) analysis that was used to evaluate the heat loss problem addressed in this chapter. Previously discussed techniques (Sections 1 and 2) for linearizing the flow conductors are used to solve the pressure field. Transient thermal/flow conditions are simulated.

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In order to understand the solution of the problem, the following steps should be taken:

1. Understand the thermal and fluid networks in the model.

2. Understand the method of coupling the solutions and the logic required.

3. Understand the heat transfer coefficient calculations and the fluid heat transfer calculations.

4. Run the model for various supply pressures and temperatures. Observe the sensitivity of the system response to small changes. Observe the variation in fluid viscosity as a function of temperature. Also, observe the effect on system response from viscosity.

5. Examine the effects of cryogenic heat leak, heater power, and Joule-Thompson heating.

II. Formulation of the Problem:

A. Discretization:

Each servo is modeled as a single orifice. The helical flow passages are intended to warm critical seals in the actuator neck. These passages are modeled as simple pipes. The fluid network analysis is coupled to the heat transfer analysis within SINDA. The flow conductances are linearized and the flow is solved at each time step. A schematic is shown in Figure 3a. A schematic of the simplified thermal model is depicted in Figure 3b.

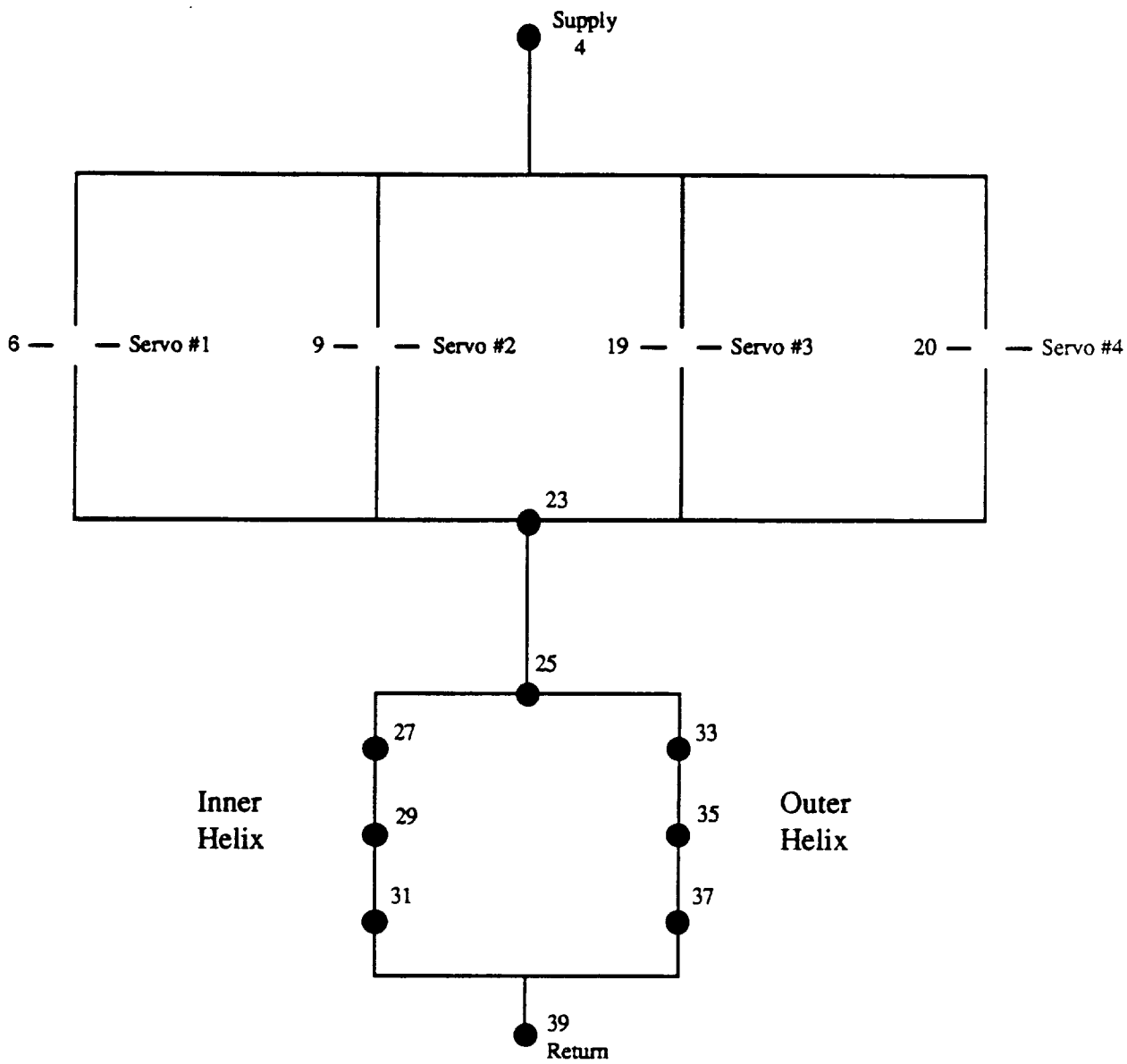

Figure 3a. Simplified Fluid Model During Prelaunch

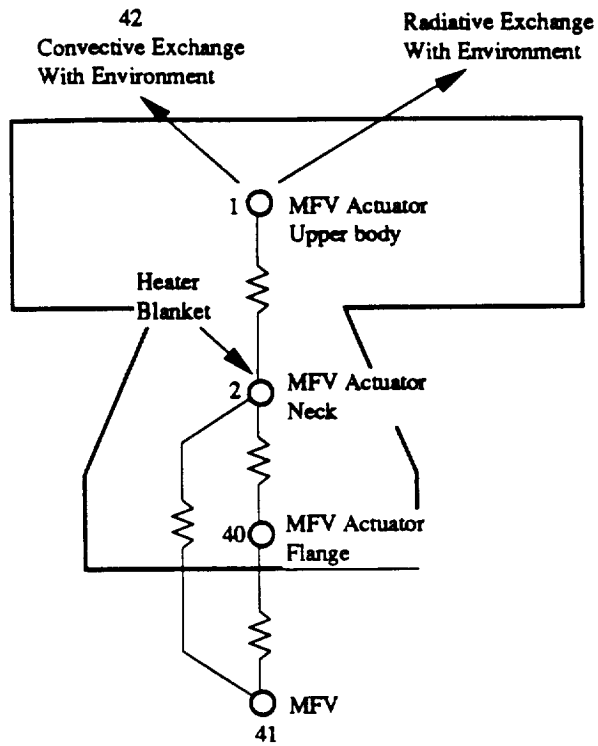

Figure 3b. MFV Actuator
Simplified Thermal Model

The fluid model and the thermal model interface with one another. The MFV actuator upper body is connected to the helix return. Also, it is connected to servos 1-4 and the helix inlet. The inner helix and the outer helix are joined to the MFV actuator neck.

III. Solution of the Problem:

Development of the input deck is the focus of this section. Individual blocks of code are discussed in some detail.

A. Input Deck:

1. The Node Data

The input deck consists of nine parts and the listing is attached. Comments are scattered throughout the listing that point out significant programming techniques.

Nodes 41 (ball valve) and 42 shown in Figure 3b (convective exchange with environment) are modeled as boundary nodes, while the temperature nodes (oil nodes) in Figure 3a are modeled as arithmetic nodes.

Flow pressure is modeled with nodes 100 (pressure inlet), 102 (pressure outlet), and 101 (pressure out of the servos to the helix). Nodes 100 and 102 are boundary nodes. Node 101 is an arithmetic node.

Flow rates are calculated using dummy boundary nodes 1101 through 1107. Nodes 1101 through 1104 correspond to servos 1 through 4. Nodes 1106 and 1105 correspond to the inner helix (oil node 29) and to the outer helix (oil node 35). Node 1107 is a sum of the inner and outer helix flow rates.

2. The Conductor Data

Figure 3a shows the flow paths that are connected by one way conductors. Conductors 101 to 104 are for servos 1 through 4. Conductors 105 and 106 are for the inner and outer helix respectively.

The heat transfer coefficients between the oil and the internal surfaces of the MFV actuator upper body and the MFV actuator neck are calculated using the following expression:

$$Nu = \left[3.66 + \frac{0.0668 \, Re \, Pr \, (D/L)}{1.0 + 0.04 \, [Re \, Pr \, (D/L)]^{2/3}} \right] \left(\frac{\mu_f}{\mu_\omega} \right)^{0.14}$$

Where:

Nu = Nusselt number
Pr = Prandtl number
Re = Reynolds number
D = Flow passage hydraulic diameter
L = Flow passage length
μ_f = Viscosity of fluid at fluid temperature
μ_w = Viscosity of fluid at wall temperature

The following table lists the geometry of internal passages within the valve that was used to calculate heat transfer coefficients between the oil and the surfaces.

Connector Number	Starting Node	Ending Node	Hydraulic Diamter(in)	Line Length(in)
9	1	4	0.180	24.
10	1	6	0.120	1.5
11	1	9	0.120	1.5
12	1	19	0.120	1.5
13	1	20	0.120	1.5
14	1	23	0.120	4.0
15	1	25	0.120	4.0
16	2	27	0.069	20.4
17	2	29	0.069	20.4
18	2	31	0.069	20.4
19	2	33	0.072	22.6
20	2	35	0.072	22.6
21	2	37	0.072	22.6

3. Constants Data Block:

The constants data block contains data which controls execution. The constants may be user defined such as JTEST or SINDA-defined, such as NDIM. This deck contains two user-defined constants (ITEST and JTEST) and twelve SINDA-defined constants. The two user-defined constants are used as flags. The twelve SINDA-defined constants include,

a. DTIMEI — User input DTIMEU (Computational time step used) for implicit type solutions.

b. DTIMEH — Maximum DTIMEU allowed.

c. NLOOP — Number of iterative loops allowed.

d.TIMEND — Transient problem termination time.

e. OUTPUT — Output time interval for activating output calls.

f. ARLXCA — Arithmetic relaxation allowed.

g. DRLXCA — Diffusion relaxation allowed.

h. TIMEO — Time at start of calculation.

i. DAMPA — Damping factor used in specific arithmetic calculations.

j. DAMPD — Damping factor used in specific diffusion calculations.

k. BALENG — System energy balance allowed.

l. NDIM — Special constant used to allocate dynamic storage space for thermal problems.

4. Array Input Block:

The array input block contains information regarding the change in physical properties with temperature. Hydraulic fluid density, absolute viscosity, hydraulic fluid specific heat, hydraulic fluid Prandtl number, and thermal conductivity are the properties that are temperature dependent in this model.

5. Execution Data Block:

The execution data block contains information that controls execution. A transient solution was used.

6. Variables 1 Data Block:

VARIABLES 1 data block preforms necessary pre-solution calculations. The flow conductors and fluid convection must be determined in VARIABLES 1. This includes the flow network simulation as discussed in Chapter 5. Also, the heat transfer through the fluid must be calculated, using SINDA's one-way conductor option. Finally, the heat transfer from the fluid to the solid body must be calculated using standard heat transfer coefficient correlations.

For cases where APU start is simulated, Joule-Thompson heating can be added. This is accomplished for incompressible flow as given below

$$\dot{q} = \frac{\dot{m}\Delta P}{\rho}$$

In this analysis, when throttling hydraulic fluid across several thousand PSID, this term becomes significant, and should be included. For this analysis, units must be converted to BTU/sec.

7. Variables 2 Data Block:

For each computational interval the execution subroutines call VARIABLES 2 and then checks control constant BACKUP to see if the user has requested that the previous solution be repeated.

B. The SINDA Model:

This section contains an input deck and the corresponding output. The hydraulic supply temperature is 80 °F and the supply pressure is 400 PSID. The supply temperature and the supply pressure are the parameters that were varied to produce the results that are discussed in Section IV. Simulations of the heat input from the actuator neck heater blanket, the APU start pressure, and Joule Thompson heating are included. These sections are not active in this configuration. However, if a section needs to be activated the instructions are contained in the model.

Model Input

```
      BCD 3THERMAL LPCS
      BCD 9TEST, PC-SINDA
      END
C
      BCD 3NODE DATA
C
C MFVA NODES
C
          1, 100.0, 4.05228 $ MFVA UPPER BODY
          2, 100.0, 0.332207 $ MFVA NECK
          40, 100.0, 0.161935 $ MFVA FLANGE
          -41, -420.0, 1.0 $ BALL VALVE TEMP
          -42, 30.0, 1.0 $ CONVECTIVE BOUNDARY
C
          99,14.8,-420.0 $ MFV
C
C OIL NODES
C
C**VARY SUPPLY TEMPERATURE PARAMETRICALLY
C
          -999, 80.0, 1.0 $ HYD SUPPLY TEMP
          4, 100.0, -1.7067E-2
          6, 100.0, -1.14E-3
          9, 100.0, -1.1486E-3
          12, 100.0, -5.027E-3
          15, 100.0, -9.3189E-5
          19, 100.0, -1.1486E-3
          20, 100.0, -1.1486E-3
          23, 100.0, -3.2075E-3
          25, 100.0, -9.5763E-4
          27, 100.0, -1.097E-3
          29, 100.0, -1.097E-3
          31, 100.0, -1.097E-3
          33, 100.0, -1.3E-3
          35, 100.0, -1.3E-3
          37, 100.0, -1.3E-3
          39, 100.0, 0.34937
C

C**VARY SUPPLY PRESSURE PARAMETRICALLY
C
          -100, 400.0, 1.0 $ PRES BOUNDARY
           101, 250.0, -1.0 $ PRES OUT OF SERVOS
          -102, 100.0, 1.0 $ RETURN PRES
C
          -1101, 0.0, 1.0 $ FLOWS IN GPM
          -1102, 0.0, 1.0
          -1103, 0.0, 1.0
          -1104, 0.0, 1.0
          -1105, 0.0, 1.0
          -1106, 0.0, 1.0
          -1107, 0.0, 1.0
C
      END
C
      BCD 3CONDUCTOR DATA
C
C THERMAL CONDUCTORS
C
          1, 40, 2, 4.8678E-3
          2, 1, 2, 6.3756E-3
```

```
            3, 40, 42, 3.809E-5
            4, 2, 42, 5.372E-5
            5, 1, 42, 8.205E-4
            6, 1, 39, 2.163E-4
            7, 40, 99, 5.0134E-4
            8, 2, 99, 5.8E-5
            108, 41, 99, 0.031772
C
C CONVECTION, INTERNAL
C
            9, 1, 4, 0.0
            10, 1, 6, 0.0
            11, 1, 9, 0.0
            12, 1, 19, 0.0
            13, 1, 20, 0.0
            14, 1, 23, 0.0
            15, 1, 25, 0.0
            16, 2, 27, 0.0
            17, 2, 29, 0.0
            18, 2, 31, 0.0
            19, 2, 33, 0.0
            20, 2, 35, 0.0
            21, 2, 37, 0.0
            22, 1, 12, 7.814E-6
            23, 1, 15, 4.986E-5
C
C MDOT CP CONNECTORS
C
            24, -999, 4, 0.0
            25, -4, 6, 0.0
            26, -4, 9, 0.0
            27, -4, 19, 0.0
            28, -4, 20, 0.0
            29, -6, 23, 0.0
            30, -9, 23, 0.0
            31, -19, 23, 0.0
            32, -20, 23, 0.0
            33, -23, 25, 0.0
            34, -25, 27, 0.0
            35, -27, 29, 0.0
            36, -29, 31, 0.0
            37, -31, 39, 0.0
            38, -25, 33, 0.0
            39, -33, 35, 0.0
            40, -35, 37, 0.0
            41, -37, 39, 0.0
C
            101, 100, 101, 0.0 $ FLOW COND SERVO1
            102, 100, 101, 0.0 $ FLOW COND SERVO2
            103, 100, 101, 0.0 $ FLOW COND SERVO3
            104, 100, 101, 0.0 $ FLOW COND SERVO4
C
            105, 101, 102, 0.0 $ FLOW CONDUCTOR INNER HELIX
            106, 101, 102, 0.0 $ FLOW CONDUCTOR OUTER HELIX
C
        END
C
        BCD 3CONSTANTS DATA
            DTIMEI,20.0
            DTIMEH,20.0
            NLOOP,1000
C
            TIMEND,0.0
            OUTPUT,0.2
```

```
C
          ARLXCA,.01
          DRLXCA,.01
          TIMEO,0.0
          DAMPA,0.5
          DAMPD,0.5
          BALENG,0.001
          NDIM,200
          ITEST,0
          JTEST,0
C
      END
C
      BCD 3ARRAY DATA
C
          1 $ HYD FLUID RHO VS TEMP
          -100.0, 56.9
          300.0, 47.3
          END
C
C**VISCOSITY CHANGES SEVERAL ORDERS OF MAGNITUDE,
C**GREATLY AFFECTING PRESSURE DISTRIBUTION AND FLOW RATE
C
          2 $ ABS VISCOSITY (CENTIPOISE)
          -100.0, 2.E+5
          -65.0, 1.2E+4
          -60.0, 7.25E+3
          -50.0, 3.8E+3
          -40.0, 1.9E+3
          -30.0, 1.0E+3
          -20.0, 5.9E+2
          -10.0, 3.25E+2
          0.0, 2.2E+2
          10.0, 1.3E+2
          20.0, 1.E+2
          30.0, 7.2E+1
          40.0, 53.0
          50.0, 40.0
          60.0, 30.0
          70.0, 22.0
          80.0, 20.0
          90.0, 15.0
          100.0, 12.0
          150.0, 6.0
          200.0, 3.2
          250.0, 2.0
          275.0, 1.7
          END $ 1CP = 0.000672 LB/FT-SEC
C
          3 $ SPECIFIC HEAT, HYD FLUID
          -100.0, 0.402
          300.0, 0.597
          END
C
          4 $ HYD FLUID PRANDTL NUMBER
          -65.0, 1.E+5
          -60.0, 7.1E+4
          -50.0, 3.2E+4
          -40.0, 1.8E+4
          -30.0, 1.0E+4
          -20.0, 6.0E+3
          -10.0, 3.6E+3
          0.0, 2.2E+3
          10.0, 1.6E+3
```

```
            20.0, 1.05E+3
            30.0, 8.0E+2
            40.0, 6.0E+2
            50.0, 4.6E+2
            60.0, 3.6E+2
            70.0, 3.0E+2
            80.0, 2.3E+2
            90.0, 2.0E+2
            100.0, 1.5E+2
            150.0, 80.0
            200.0, 50.0
            250.0, 33.0
            275.0, 30.0
            END
C
            5 $ THERMAL CONDUCTIVITY BTU/HR-FT-F
            -100.0, 0.1083
            287.0, 0.082
            END
C
        END
C
        BCD 3EXECUTION
C
F       OPEN(3,FILE="EMLFLT.PLT",STATUS="UNKNOWN")
F       WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F    2 FORMAT(I6/,250(I6,31X,I6/))
C
C CALC SERVO1 CONDUCTORS
C
M       CALL D1DEG1(T6,A1,RHO)
C**FLOW CONSTANTS DERIVED FROM EXPERIMENTAL DATA
C
M       G101=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
C
C CALC SERVO2 CONDUCTORS
C
M       CALL D1DEG1(T9,A1,RHO)
M       G102=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
C
C CALC SERVO3 CONDUCTORS
C
M       CALL D1DEG1(T19,A1,RHO)
M       G103=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
C
C CALC SERVO4 CONDUCTORS
C
M       CALL D1DEG1(T20,A1,RHO)
M       G104=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
C
C CALC FLOWS THROUGH HELIX
C
M       CALL D1DEG1(T29,A1,RHO)
M       CALL D1DEG1(T29,A2,XMU)
M       XMU=XMU*0.000672
M       XXL=20.391/12.
M       REY=100.
M       DH=0.65E-2
M       IF(REY.LT.1500.)FFACT=64./REY
M       IF(REY.GE.1500.)FFACT=0.3164/(REY**0.25)
M       G105=SQRT(RHO*3.14159**2*DH**5*144.*32.2/(8.*FFACT*XXL))
C
C CALC FLOWS THROUGH HELIX
C
```

```
M       CALL D1DEG1(T35,A1,RHO)
M       CALL D1DEG1(T35,A2,XMU)
M       XMU=XMU*0.000672
M       XXL=22.591/12.
C**CRITICAL PARAMETERS DERIVED FROM EXPERIMENTAL DATA
C
M       DH=0.65E-2
M       REY=100.
M       IF(REY.LT.1500.)FFACT=64./REY
M       IF(REY.GE.1500.)FFACT=0.3164/(REY**0.25)
M       G106=SQRT(RHO*3.14159**2*DH**5*144.*32.2/(8.*FFACT*XXL))
C
M       ITEST=0
M       CALL SNHOSD
F       ITEST=1
M       TIMEND=7200.
M       OUTPUT=100.
F       CALL SNFRDL
C
        END
        BCD 3VARIABLES 1
C
M       IF(ITEST.EQ.0)GO TO 900
C
F       DO 20 I=1,15

C**A CHECK FOR CONVERGENCE CAN BE ADDED TO SPEED UP
C
C CALC SERVO1 CONDUCTORS
C
M       CALL D1DEG1(T6,A1,RHO)
M       GR=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
M       G101=GR/SQRT(T100-T101)
C
C CALC SERVO2 CONDUCTORS
C
M       CALL D1DEG1(T9,A1,RHO)
M       GR=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
M       G102=GR/SQRT(T100-T101)
C
C CALC SERVO3 CONDUCTORS
C
M       CALL D1DEG1(T19,A1,RHO)
M       GR=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
M       G103=GR/SQRT(T100-T101)
C
C CALC SERVO4 CONDUCTORS
C
M       CALL D1DEG1(T20,A1,RHO)
M       GR=0.25*0.6*1.44111E-6*SQRT(2.*32.2*144.*RHO)
M       G104=GR/SQRT(T100-T101)
C
C CALC FLOWS THROUGH HELIX
C
M       CALL D1DEG1(T29,A1,RHO)
M       CALL D1DEG1(T29,A2,XMU)
M       XMU=XMU*0.000672
M       XXL=20.391/12.
M       XMDOT=G105*(T101-T102)
M       AREA=.0385*.31/144.
M       REY=XMDOT*1.427E-3/(XMU*AREA)
M       IF(REY.LT.1500.)FFACT=64./REY
M       IF(REY.GE.1500.)FFACT=0.3164/(REY**0.25)
M       DH=0.65E-2
```

```
M       G105=SQRT(RHO*3.14159**2*DH**5*144.*32.2/(8.*FFACT*XXL))
M       G105=G105/SQRT(T101-T102)
C
C CALC FLOWS THROUGH HELIX
C
M       CALL D1DEG1(T35,A1,RHO)
M       CALL D1DEG1(T35,A2,XMU)
M       XMU=XMU*0.000672
M       XXL=20.391/12.
M       XMDOT=G106*(T101-T102)
M       AREA=0.041*0.31/144.
M       REY=XMDOT*1.509E-3/(XMU*AREA)
M       IF(REY.LT.1500.)FFACT=64./REY
M       IF(REY.GE.1500.)FFACT=0.3164/(REY**0.25)
M       DH=0.65E-2
M       G106=SQRT(RHO*3.14159**2*DH**5*144.*32.2/(8.*FFACT*XXL))
M       G106=G106/SQRT(T101-T102)
C
CM       WRITE(6,15)G101,G102,G103,G104,G105,G106
CM 15    FORMAT(1X,6(F12.6,1X))
C
F 20    CONTINUE
C
F900    CONTINUE
C
C THERMAL NETWORK CALCULATIONS
C
C       CALCULATE MDOTS AND FLOW CONDUCTORS
C
M       XMDOT1=G101*(T100-T101)
M       CALL D1DEG1(T4,A3,CP)
M       G25=XMDOT1*CP
C
M       XMDOT2=G102*(T100-T101)
M       CALL D1DEG1(T4,A3,CP)
M       G26=XMDOT2*CP
C
M       XMDOT3=G103*(T100-T101)
M       CALL D1DEG1(T4,A3,CP)
M       G27=XMDOT3*CP
C
M       XMDOT4=G104*(T100-T101)
M       CALL D1DEG1(T4,A3,CP)
M       G28=XMDOT4*CP
C
M       XMDT=XMDOT1+XMDOT2+XMDOT3+XMDOT4
M       CALL D1DEG1(T999,A3,CP)
M       G24=XMDT*CP
C
M       CALL D1DEG1(T6,A3,CP)
M       G29=XMDOT1*CP
C
M       CALL D1DEG1(T9,A3,CP)
M       G30=XMDOT2*CP
C
M       CALL D1DEG1(T19,A3,CP)
M       G31=XMDOT3*CP
C
M       CALL D1DEG1(T20,A3,CP)
M       G32=XMDOT4*CP
C
M       CALL D1DEG1(T23,A3,CP)
M       G33=XMDT*CP
C
```

```
M       XMDOT5=G105*(T101-T102)
M       CALL D1DEG1(T25,A3,CP)
M       G34=XMDOT5*CP
C
M       CALL D1DEG1(T27,A3,CP)
M       G35=XMDOT5*CP
C
M       CALL D1DEG1(T29,A3,CP)
M       G36=XMDOT5*CP
C
M       CALL D1DEG1(T31,A3,CP)
M       G37=XMDOT5*CP
C
M       XMDOT6=G106*(T101-T102)
M       CALL D1DEG1(T25,A3,CP)
M       G38=XMDOT6*CP
C
M       CALL D1DEG1(T33,A3,CP)
M       G39=XMDOT6*CP
C
M       CALL D1DEG1(T35,A3,CP)
M       G40=XMDOT6*CP
C
M       CALL D1DEG1(T37,A3,CP)
M       G41=XMDOT6*CP
C
C CALC INTERNAL CONVECTION
C
M       CALL D1DEG1(T4,A4,XPR)
M       CALL D1DEG1(T4,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.18/12.
M       XXL=24.0/12.
M       REY=4.0*XMDT/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T4,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G9=XHC*AREA
C
M       CALL D1DEG1(T6,A4,XPR)
M       CALL D1DEG1(T6,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.12/12.
M       XXL=1.5/12.
M       REY=4.0*XMDOT1/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T6,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G10=XHC*AREA
C
M       CALL D1DEG1(T9,A4,XPR)
M       CALL D1DEG1(T9,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
```

```
M       XMUW=XMUW*0.000672
M       DH=0.12/12.
M       XXL=1.5/12.
M       REY=4.0*XMDOT2/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T9,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G11=XHC*AREA
C
M       CALL D1DEG1(T19,A4,XPR)
M       CALL D1DEG1(T19,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.12/12.
M       XXL=1.5/12.
M       REY=4.0*XMDOT3/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T19,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G12=XHC*AREA
C
M       CALL D1DEG1(T20,A4,XPR)
M       CALL D1DEG1(T20,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.12/12.
M       XXL=1.5/12.
M       REY=4.0*XMDOT4/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T20,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G13=XHC*AREA
C
M       CALL D1DEG1(T23,A4,XPR)
M       CALL D1DEG1(T23,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.12/12.
M       XXL=4.0/12.
M       REY=4.0*XMDT/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T23,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G14=XHC*AREA
C
M       CALL D1DEG1(T25,A4,XPR)
M       CALL D1DEG1(T25,A2,XMUF)
M       CALL D1DEG1(T1,A2,XMUW)
M       XMUF=XMUF*0.000672
```

```
M       XMUW=XMUW*0.000672
M       DH=0.12/12.
M       XXL=4.0/12.
M       REY=4.0*XMDT/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T25,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G15=XHC*AREA
C
M       CALL D1DEG1(T27,A4,XPR)
M       CALL D1DEG1(T27,A2,XMUF)
M       CALL D1DEG1(T2,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.069/12.
M       XXL=20.4/12./3.
M       REY=4.0*XMDOT5/(3.   39*DH*XMUF)
M       XNU=.0668*REY*XPR*    XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XM   XMUW)**0.14
M       CALL D1DEG1(T27,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G16=XHC*AREA
C
M       CALL D1DEG1(T29,A4,XPR)
M       CALL D1DEG1(T29,A2,XMUF)
M       CALL D1DEG1(T2,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.069/12.
M       XXL=20.4/12./3.
M       REY=4.0*XMDOT5/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T29,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G17=XHC*AREA
C
M       CALL D1DEG1(T31,A4,XPR)
M       CALL D1DEG1(T31,A2,XMUF)
M       CALL D1DEG1(T2,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.069/12.
M       XXL=20.4/12./3.
M       REY=4.0*XMDOT5/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T31,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G18=XHC*AREA
C
M       CALL D1DEG1(T33,A4,XPR)
M       CALL D1DEG1(T33,A2,XMUF)
M       CALL D1DEG1(T2,A2,XMUW)
M       XMUF=XMUF*0.000672
```

```
M       XMUW=XMUW*0.000672
M       DH=0.072/12.
M       XXL=22.6/12./3.
M       REY=4.0*XMDOT6/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T33,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G19=XHC*AREA
C
M       CALL D1DEG1(T35,A4,XPR)
M       CALL D1DEG1(T35,A2,XMUF)
M       CALL D1DEG1(T2,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.072/12.
M       XXL=22.6/12./3.
M       REY=4.0*XMDOT6/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T35,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G20=XHC*AREA
C
M       CALL D1DEG1(T37,A4,XPR)
M       CALL D1DEG1(T37,A2,XMUF)
M       CALL D1DEG1(T2,A2,XMUW)
M       XMUF=XMUF*0.000672
M       XMUW=XMUW*0.000672
M       DH=0.072/12.
M       XXL=22.6/12./3.
M       REY=4.0*XMDOT6/(3.14159*DH*XMUF)
M       XNU=.0668*REY*XPR*(DH/XXL)/(1.+.04*(REY*XPR*(DH/XXL))**.6667)
M       XNU=(3.66+XNU)*(XMUF/XMUW)**0.14
M       CALL D1DEG1(T37,A5,XCOND)
M       XCOND=XCOND/3600.
M       XHC=XNU*XCOND/DH
M       AREA=3.14159*DH*XXL
M       G21=XHC*AREA
C
F1000   CONTINUE
C
C**HEAT INPUT FROM ACTUATOR HEATER BLANKET
C**TO ACTIVATE THIS OPTION REMOVE COMMENTS
CM       Q2=Q2+300.*3.413/3600.
C
M       IF(T39.LT.10.)GO TO 400
M       IF(JTEST.EQ.1)GO TO 400
CM       G7=5.0134E-4
CM       G8=5.8E-5
M       G108=.031772
M       GO TO 450
C
C**SIMULATED APU START PRESSURES
C**TO ACTIVATE THIS OPTION REMOVE COMMENTS
C
CM400    T100=3000.
CM       T102=250.
CM       CALL D1DEG1(T6,A1,RHO)
C
```

```
C**JOULE-THOMPSON HEATING
C**TO ACTIVATE THIS OPTION REMOVE COMMENTS
C
CM      Q6=Q6+G101*(T100-T101)*((T100-T101)*144.)*0.001285/RHO
CM      CALL D1DEG1(T9,A1,RHO)
CM      Q9=Q9+G102*(T100-T101)*((T100-T101)*144.)*0.001285/RHO
CM      CALL D1DEG1(T19,A1,RHO)
CM      Q19=Q19+G103*(T100-T101)*((T100-T101)*144.)*0.001285/RHO
CM      CALL D1DEG1(T20,A1,RHO)
CM      Q20=Q20+G104*(T100-T101)*((T100-T101)*144.)*0.001285/RHO
M400   G108=0.

C**CAN BE USED TO SIMULATE LIQUID HYDROGEN
C**RECIRCULATION PUMP CYCLIC OPERATION
C**TO ACTIVATE THIS OPTION REMOVE COMMENTS
C**AND COMMENT OUT PREVIOUS STATEMENT 400

C
CM400   G7=5.013E-4/5.0
CM      G8=5.8E-5/5.0
M      JTEST=1
M450   CONTINUE
C
       END
C
       BCD 3VARIABLES 2
       END
C
       BCD 3OUTPUT CALLS
C
F      DATA HT/4HT   /
C
C FLOW RATES IN GPM
C
M      CALL D1DEG1(T6,A1,RHO)
M      T1101=60.*G101*(T100-T101)/RHO/0.1337
M      CALL D1DEG1(T9,A1,RHO)
M      T1102=60.*G102*(T100-T101)/RHO/0.1337
M      CALL D1DEG1(T19,A1,RHO)
M      T1103=60.*G103*(T100-T101)/RHO/0.1337
M      CALL D1DEG1(T20,A1,RHO)
M      T1104=60.*G104*(T100-T101)/RHO/0.1337
M      CALL D1DEG1(T29,A1,RHO)
M      T1105=60.*G105*(T101-T102)/RHO/0.1337
M      CALL D1DEG1(T35,A1,RHO)
M      T1106=60.*G106*(T101-T102)/RHO/0.1337
M      T1107=T1106+T1105
C
C
F      WRITE(3,1)TIMEO,(T(I),I=1,NNT)
F    1 FORMAT(E10.3/,250(7F12.3/))
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
F      IF(NPAGE.EQ.0 .OR. NLINE.GE.56)CALL TPLIN
F      J=LNODE+NCSGMN
F      I1=NX(J)
F      IF(J.LE.LNODE)I1=0
F      J=LNODE+NDTMPC
F      I2=NX(J)
F      IF(J.LE.LNODE)I2=0
F      J=LNODE+NARLXC
F      I3=NX(J)
F      IF(J.LE.LNODE)I3=0
```

```
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $          8H RELXCC(I6,2H)=1PE12.5)
F       NLINE=NLINE+4
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       NLINE=NLINE+1
F       J=1
F       L=3
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F       IF(NLINE.LE.56)GO TO 15
F       CALL TPLIN
F       WRITE(6,100)
F  15   NLINE=NLINE+1
F       IF(L.EQ.NNT)RETURN
F       J=L+1
F       L=L+3
F       GO TO 5
F       END
C
C THREE COLUMN OUTPUT PAGE ROUTINE
C
F       SUBROUTINE TPLIN
F       WRITE(6,100)
F 100   FORMAT(/////,1X,'GASKI PC-SINDA, THREE COLUMN OUTPUT',/)
F       CALL TOPLIN
C       RETURN
        END
        BCD 3END OF DATA
```

Model Output

```
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    TEST, PC-SINDA

*** NOTE *** SNHOSD REQUIRES      42 DYNAMIC STORAGE LOCATIONS OUT OF     109 AVAILABLE ***

**********
TIME=      0.00000          DTIMEU= 0.00000E+00 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T      1=    100.00000  T      2=    100.00000  T     40=    100.00000
T     39=    100.00000  T     99=     14.79999  T      4=    100.00000
T      6=    100.00000  T      9=    100.00000  T     12=    100.00000
T     15=    100.00000  T     19=    100.00000  T     20=    100.00000
T     23=    100.00000  T     25=    100.00000  T     27=    100.00000
T     29=    100.00000  T     31=    100.00000  T     33=    100.00000
T     35=    100.00000  T     37=    100.00000  T    101=    250.00000
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.19414
T   1102=      0.19414  T   1103=      0.19414  T   1104=      0.19414
T   1105=      2.30394  T   1106=      2.18888  T   1107=      4.49282

SNHOSD RUN, ARLXCA=0.10000E-01, DRLXCA=0.10000E-01, BALENG=0.10000E-02, BENODE=0.50000E-03, NLOOP=    1000

*** NOTE *** RELAXATION CRITERIA HAS BEEN MET WITH LOOPCT =      11

    ENGBAL =-0.104769E-05 AT LOOPCT =      11

*** NOTE *** SYSTEM ENERGY BALANCE CRITERIA HAS BEEN MET, ENGBAL =-0.104769E-05, LOOPCT =      11

    EBNODE(      39)=-0.134280E-05 AT LOOPCT=      11

*** NOTE *** NODAL ENERGY BALANCE CRITERIA HAS BEEN MET, EBNODE(      39)=-0.134280E-05, LOOPCT =      11

**********
TIME=      0.00000          DTIMEU= 0.00000E+00 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(     12)=-2.44141E-04

T      1=     64.53101  T      2=     53.17072  T     40=     9.83337
T     39=     76.44141  T     99=   -412.48600  T      4=    79.34534
T      6=     79.08533  T      9=     79.08533  T     12=    64.53101
T     15=     64.53101  T     19=     79.08533  T     20=    79.08533
T     23=     78.88922  T     25=     78.69537  T     27=    77.97424
T     29=     77.26886  T     31=     76.57928  T     33=    77.89990
T     35=     77.12372  T     37=     76.36670  T    101=   144.21080
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.32789
T   1102=      0.32789  T   1103=      0.32789  T   1104=      0.32789
T   1105=      0.67202  T   1106=      0.63842  T   1107=      1.31044
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    TEST, PC-SINDA

*** NOTE *** SNFRDL REQUIRES      37 DYNAMIC STORAGE LOCATIONS OUT OF     109 AVAILABLE ***
             TIMEND=  7200.0    , CSGFAC=  1.0000    , DTIMEI=  20.000    , NLOOP =        1000
             TIMEO = 0.00000    , OUTPUT=  100.00    , DTIMEH=  20.000    , DTIMEL= 0.00000
             ARLXCA= 0.10000E-01, ATMPCA= 0.10000E+09, DRLXCA= 0.10000E-01, DTMPCA= 0.10000E+09

**********
TIME=      0.00000          DTIMEU= 0.00000E+00 CSGMIN(      0)= 0.00000E+00
                     TEMPCC(      0)= 0.00000E+00 RELXCC(      0)= 0.00000E+00

T      1=     64.53101  T      2=     53.17072  T     40=     9.83337
T     39=     76.44141  T     99=   -412.48600  T      4=    79.34534
T      6=     79.08533  T      9=     79.08533  T     12=    64.53101
T     15=     64.53101  T     19=     79.08533  T     20=    79.08533
T     23=     78.88922  T     25=     78.69537  T     27=    77.97424
T     29=     77.26886  T     31=     76.57928  T     33=    77.89990
T     35=     77.12372  T     37=     76.36670  T    101=   144.21080
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.02060
T   1102=      0.02060  T   1103=      0.02060  T   1104=      0.02060
T   1105=      0.01510  T   1106=      0.01497  T   1107=      0.03008

**********
TIME=    100.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.42721E+01
                     TEMPCC(     39)=-2.04367E+00 RELXCC(    101)= 0.00000E+00

T      1=     61.62268  T      2=     38.22379  T     40=    -1.73752
T     39=     65.43909  T     99=   -412.69230  T      4=    75.79657
T      6=     74.21826  T      9=     74.21826  T     12=    61.62268
T     15=     61.62268  T     19=     74.21826  T     20=    74.21826
T     23=     73.09015  T     25=     72.05475  T     27=    66.47211
T     29=     61.78217  T     31=     57.83459  T     33=    66.08667
T     35=     61.13770  T     37=     57.02173  T    101=   233.53530
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.01656
T   1102=      0.01656  T   1103=      0.01656  T   1104=      0.01656
T   1105=      0.03334  T   1106=      0.03253  T   1107=      0.06587

**********
TIME=    200.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.43833E+01
                     TEMPCC(     39)=-9.79067E-01 RELXCC(    101)= 0.00000E+00

T      1=     58.06744  T      2=     33.89685  T     40=    -6.52771
T     39=     58.85760  T     99=   -412.77430  T      4=    74.96661
T      6=     73.07281  T      9=     73.07281  T     12=    58.06744
T     15=     58.06744  T     19=     73.07281  T     20=    73.07281
T     23=     71.71790  T     25=     70.47357  T     27=    64.46130
T     29=     59.39722  T     31=     55.10504  T     33=    64.02472
T     35=     58.65826  T     37=     54.17542  T    101=   240.38310
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.01618
T   1102=      0.01618  T   1103=      0.01618  T   1104=      0.01618
```

```
T  1105=     0.03265  T  1106=     0.03167  T  1107=     0.06432
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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     TEST, PC-SINDA

 **********
 TIME=   300.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.44449E+01
                    TEMPCC(     1)=-6.63700E-01 RELXCC(   101)= 0.00000E+00

 T     1=    54.66205  T     2=    30.67325  T    40=    -9.61835
 T    39=    55.18976  T    99=  -412.82800  T     4=    74.16016
 T     6=    71.95929  T     9=    71.95929  T    12=    54.66205
 T    15=    54.66205  T    19=    71.95929  T    20=    71.95929
 T    23=    70.38342  T    25=    68.94312  T    27=    62.64459
 T    29=    57.31232  T    31=    52.79614  T    33=    62.18463
 T    35=    56.53259  T    37=    51.81546  T   101=   247.01610
 T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
 T   100=   400.00000  T   102=   100.00000  T  1101=     0.01584
 T  1102=     0.01584  T  1103=     0.01584  T  1104=     0.01584
 T  1105=     0.03195  T  1106=     0.03098  T  1107=     0.06293

 **********
 TIME=   400.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.45050E+01
                    TEMPCC(     1)=-6.19105E-01 RELXCC(   101)= 0.00000E+00

 T     1=    51.47830  T     2=    27.78140  T    40=   -12.29584
 T    39=    52.52777  T    99=  -412.87470  T     4=    73.39465
 T     6=    70.90186  T     9=    70.90186  T    12=    51.47833
 T    15=    51.47830  T    19=    70.90186  T    20=    70.90186
 T    23=    69.12366  T    25=    67.50604  T    27=    60.96747
 T    29=    55.40674  T    31=    50.69934  T    33=    60.48999
 T    35=    54.59656  T    37=    49.68060  T   101=   252.80540
 T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
 T   100=   400.00000  T   102=   100.00000  T  1101=     0.01554
 T  1102=     0.01554  T  1103=     0.01554  T  1104=     0.01554
 T  1105=     0.03132  T  1106=     0.03039  T  1107=     0.06171

 **********
 TIME=   500.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.45589E+01
                    TEMPCC(     1)=-5.77408E-01 RELXCC(   101)= 0.00000E+00

 T     1=    48.50934  T     2=    25.09799  T    40=   -14.77039
 T    39=    50.28470  T    99=  -412.91790  T     4=    72.67639
 T     6=    69.90894  T     9=    69.90894  T    12=    48.50934
 T    15=    48.50934  T    19=    69.90894  T    20=    69.90894
 T    23=    67.94946  T    25=    66.16626  T    27=    59.40356
 T    29=    53.63361  T    31=    48.74570  T    33=    58.90173
 T    35=    52.78796  T    37=    47.67892  T   101=   257.92110
 T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
 T   100=   400.00000  T   102=   100.00000  T  1101=     0.01527
 T  1102=     0.01527  T  1103=     0.01527  T  1104=     0.01527
 T  1105=     0.03076  T  1106=     0.02985  T  1107=     0.06061

 **********
 TIME=   600.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.46007E+01
                    TEMPCC(     1)=-5.39045E-01 RELXCC(   101)= 0.00000E+00

 T     1=    45.73856  T     2=    22.60388  T    40=   -17.06848
 T    39=    48.24652  T    99=  -412.95800  T     4=    72.00769
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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     TEST, PC-SINDA

 T     6=    69.00079  T     9=    69.00079  T    12=    45.73856
 T    15=    45.73856  T    19=    69.00079  T    20=    69.00079
 T    23=    66.87213  T    25=    64.93396  T    27=    57.93591
 T    29=    51.96692  T    31=    46.90228  T    33=    57.41699
 T    35=    51.09290  T    37=    45.80066  T   101=   262.53880
 T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
 T   100=   400.00000  T   102=   100.00000  T  1101=     0.01502
 T  1102=     0.01502  T  1103=     0.01502  T  1104=     0.01502
 T  1105=     0.03024  T  1106=     0.02936  T  1107=     0.05960

 **********
 TIME=   700.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.46378E+01
                    TEMPCC(     1)=-5.03539E-01 RELXCC(   101)= 0.00000E+00

 T     1=    43.15100  T     2=    20.27481  T    40=   -19.21121
 T    39=    46.34760  T    99=  -412.99540  T     4=    71.37402
 T     6=    68.14404  T     9=    68.14404  T    12=    43.15100
 T    15=    43.15100  T    19=    68.14404  T    20=    68.14404
 T    23=    65.85620  T    25=    63.77246  T    27=    56.54926
 T    29=    50.39099  T    31=    45.15964  T    33=    56.00818
 T    35=    49.47885  T    37=    44.01196  T   101=   266.78170
 T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
 T   100=   400.00000  T   102=   100.00000  T  1101=     0.01478
 T  1102=     0.01478  T  1103=     0.01478  T  1104=     0.01478
 T  1105=     0.02978  T  1106=     0.02887  T  1107=     0.05864

 **********
 TIME=   800.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.46763E+01
                    TEMPCC(     1)=-4.71575E-01 RELXCC(   101)= 0.00000E+00

 T     1=    40.73083  T     2=    18.07813  T    40=   -21.22546
 T    39=    44.54037  T    99=  -413.03060  T     4=    70.75867
```

```
T     6-     67.31494  T     9-     67.31494  T    12-     40.73080
T    15-     40.73083  T    19-     67.31494  T    20-     67.31494
T    23-     64.87494  T    25-     62.65247  T    27-     55.20886
T    29-     48.86078  T    31-     43.47092  T    33-     54.62085
T    35-     47.86469  T    37-     42.22229  T   101-    271.55770
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01450
T  1102-      0.01450  T  1103-      0.01450  T  1104-      0.01450
T  1105-      0.02930  T  1106-      0.02821  T  1107-      0.05751

**********
TIME=   900.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.47097E+01
                     TEMPCC(      1)=-4.43226E-01 RELXCC(    101)= 0.00000E+00

T     1-     38.45935  T     2-     16.00885  T    40-    -23.12674
T    39-     42.79626  T    99-   -413.06380  T     4-     70.17151
T     6-     66.52594  T     9-     66.52594  T    12-     38.45935
T    15-     38.45935  T    19-     66.52594  T    20-     66.52594
T    23-     63.94238  T    25-     61.58899  T    27-     53.92316
T    29-     47.38086  T    31-     41.83630  T    33-     53.32007
T    35-     46.36041  T    37-     40.55936  T   101-    276.28070
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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     TEST, PC-SINDA

T   100-    400.00000  T   102-    100.00000  T  1101-      0.01423
T  1102-      0.01423  T  1103-      0.01423  T  1104-      0.01423
T  1105-      0.02874  T  1106-      0.02769  T  1107-      0.05643

**********
TIME=  1000.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.47390E+01
                     TEMPCC(      1)=-4.17165E-01 RELXCC(    101)= 0.00000E+00

T     1-     36.32233  T     2-     14.06686  T    40-    -24.91132
T    39-     41.14133  T    99-   -413.09490  T     4-     69.63782
T     6-     65.80334  T     9-     65.80334  T    12-     36.32233
T    15-     36.32233  T    19-     65.80334  T    20-     65.80334
T    23-     63.08508  T    25-     60.60858  T    27-     52.72760
T    29-     45.99829  T    31-     40.30505  T    33-     52.10980
T    35-     44.95401  T    37-     38.99664  T   101-    280.49140
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01399
T  1102-      0.01399  T  1103-      0.01399  T  1104-      0.01399
T  1105-      0.02824  T  1106-      0.02722  T  1107-      0.05545

**********
TIME=  1100.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.47643E+01
                     TEMPCC(      1)=-3.92850E-01 RELXCC(    101)= 0.00000E+00

T     1-     34.31009  T     2-     12.24063  T    40-    -26.58832
T    39-     39.57321  T    99-   -413.12420  T     4-     69.14185
T     6-     65.12628  T     9-     65.12628  T    12-     34.31009
T    15-     34.31009  T    19-     65.12628  T    20-     65.12628
T    23-     62.27893  T    25-     59.68372  T    27-     51.59625
T    29-     44.68835  T    31-     38.84921  T    33-     50.96417
T    35-     43.62115  T    37-     37.51093  T   101-    284.30460
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01377
T  1102-      0.01377  T  1103-      0.01377  T  1104-      0.01377
T  1105-      0.02777  T  1106-      0.02678  T  1107-      0.05455

**********
TIME=  1200.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.47871E+01
                     TEMPCC(      1)=-3.70165E-01 RELXCC(    101)= 0.00000E+00

T     1-     32.41455  T     2-     10.51804  T    40-    -28.16879
T    39-     38.07855  T    99-   -413.15180  T     4-     68.66791
T     6-     64.47980  T     9-     64.47980  T    12-     32.41455
T    15-     32.41455  T    19-     64.47980  T    20-     64.47980
T    23-     61.50970  T    25-     58.79675  T    27-     50.51199
T    29-     43.43433  T    31-     37.45435  T    33-     49.86618
T    35-     42.34531  T    37-     36.09100  T   101-    287.81230
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01356
T  1102-      0.01356  T  1103-      0.01356  T  1104-      0.01356
T  1105-      0.02733  T  1106-      0.02637  T  1107-      0.05370

**********
TIME=  1300.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.48254E+01
                     TEMPCC(      1)=-3.49418E-01 RELXCC(    101)= 0.00000E+00

T     1-     30.62714  T     2-      8.87384  T    40-    -29.66800
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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     TEST, PC-SINDA

T    39-     36.65884  T    99-   -413.17800  T     4-     68.21497
T     6-     63.86243  T     9-     63.86243  T    12-     30.62714
T    15-     30.62714  T    19-     63.86243  T    20-     63.86243
T    23-     60.77533  T    25-     57.95007  T    27-     49.50958
T    29-     42.29507  T    31-     36.19672  T    33-     48.84479
T    35-     41.18051  T    37-     34.80478  T   101-    290.98330
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
```

```
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01337
T  1102-     0.01337  T  1103-     0.01337  T  1104-     0.01337
T  1105-     0.02694  T  1106-     0.02600  T  1107-     0.05293

**********
TIME-  1400.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.48764E+01
                     TEMPCC(     1)--3.30872E-01 RELXCC(   101)- 0.00000E+00

T     1-    28.93655  T     2-     7.29932  T    40-   -31.11038
T    39-    35.37341  T    99-  -413.20320  T     4-    67.80084
T     6-    63.29724  T     9-    63.29724  T    12-    28.93655
T    15-    28.93655  T    19-    63.29724  T    20-    63.29724
T    23-    60.10211  T    25-    57.17242  T    27-    48.60474
T    29-    41.27966  T    31-    35.08057  T    33-    47.93088
T    35-    40.14951  T    37-    33.66876  T   101-   293.65490
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01320
T  1102-     0.01320  T  1103-     0.01320  T  1104-     0.01320
T  1105-     0.02660  T  1106-     0.02568  T  1107-     0.05228

**********
TIME-  1500.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.49239E+01
                     TEMPCC(     1)--3.13708E-01 RELXCC(   101)- 0.00000E+00

T     1-    27.33444  T     2-     5.80481  T    40-   -32.47720
T    39-    34.18445  T    99-  -413.22710  T     4-    67.41321
T     6-    62.76831  T     9-    62.76831  T    12-    27.33444
T    15-    27.33444  T    19-    62.76831  T    20-    62.76831
T    23-    59.46881  T    25-    56.44116  T    27-    47.74976
T    29-    40.31720  T    31-    34.02069  T    33-    47.02148
T    35-    39.09146  T    37-    32.49246  T   101-   296.45040
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01302
T  1102-     0.01302  T  1103-     0.01302  T  1104-     0.01302
T  1105-     0.02634  T  1106-     0.02520  T  1107-     0.05154

**********
TIME-  1600.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.49684E+01
                     TEMPCC(     1)--2.98540E-01 RELXCC(   101)- 0.00000E+00

T     1-    25.81213  T     2-     4.37103  T    40-   -33.78564
T    39-    33.02481  T    99-  -413.24990  T     4-    67.01849
T     6-    62.23181  T     9-    62.23181  T    12-    25.81213
T    15-    25.81213  T    19-    62.23181  T    20-    62.23181
T    23-    58.82635  T    25-    55.70184  T    27-    46.87708
T    29-    39.32962  T    31-    32.93619  T    33-    46.09091
T    35-    38.00299  T    37-    31.28522  T   101-   299.68810
```

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    TEST, PC-SINDA

T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01281
T  1102-     0.01281  T  1103-     0.01281  T  1104-     0.01281
T  1105-     0.02601  T  1106-     0.02467  T  1107-     0.05068

**********
TIME-  1700.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.50089E+01
                     TEMPCC(     1)--2.85341E-01 RELXCC(   101)- 0.00000E+00

T     1-    24.35953  T     2-     2.99088  T    40-   -35.04538
T    39-    31.86121  T    99-  -413.27200  T     4-    66.61340
T     6-    61.68353  T     9-    61.68353  T    12-    24.35953
T    15-    24.35953  T    19-    61.68353  T    20-    61.68353
T    23-    58.17157  T    25-    54.95044  T    27-    45.96686
T    29-    38.28485  T    31-    31.78738  T    33-    45.17181
T    35-    36.94455  T    37-    30.12167  T   101-   303.21370
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01258
T  1102-     0.01258  T  1103-     0.01258  T  1104-     0.01258
T  1105-     0.02552  T  1106-     0.02424  T  1107-     0.04977

**********
TIME-  1800.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.50456E+01
                     TEMPCC(     1)--2.73077E-01 RELXCC(   101)- 0.00000E+00

T     1-    22.96991  T     2-     1.66827  T    40-   -36.25336
T    39-    30.70679  T    99-  -413.29310  T     4-    66.21613
T     6-    61.14661  T     9-    61.14661  T    12-    22.96991
T    15-    22.96988  T    19-    61.14661  T    20-    61.14661
T    23-    57.53082  T    25-    54.21570  T    27-    45.07623
T    29-    37.26315  T    31-    30.66544  T    33-    44.27304
T    35-    35.91077  T    37-    28.98865  T   101-   306.52430
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01236
T  1102-     0.01236  T  1103-     0.01236  T  1104-     0.01236
T  1105-     0.02506  T  1106-     0.02383  T  1107-     0.04890

**********
TIME-  1900.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.50791E+01
                     TEMPCC(     1)--2.61544E-01 RELXCC(   101)- 0.00000E+00

T     1-    21.63940  T     2-     0.40070  T    40-   -37.41095
T    39-    29.57401  T    99-  -413.31330  T     4-    65.82825
T     6-    60.62311  T     9-    60.62311  T    12-    21.63940
T    15-    21.63940  T    19-    60.62311  T    20-    60.62311
T    23-    56.90637  T    25-    53.50012  T    27-    44.20740
T    29-    36.26660  T    31-    29.57251  T    33-    43.39603
T    35-    34.90216  T    37-    27.88477  T   101-   309.61710
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01215
```

```
T  1102-     0.01215  T  1103-     0.01215  T  1104-     0.01215
T  1105-     0.02363  T  1106-     0.02344  T  1107-     0.04807
```

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TEST, PC-SINDA

```
**********
TIME=  2000.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.51118E+01
                   TEMPCC(     1)=-2.50715E-01 RELXCC(   101)= 0.00000E+00

T     1-    20.36453  T     2-    -0.81702  T    40-   -38.52182
T    39-    28.46857  T    99-  -413.33270  T     4-    65.44977
T     6-    60.11279  T     9-    60.11279  T    12-    20.36453
T    15-    20.36453  T    19-    60.11279  T    20-    60.11279
T    23-    56.29797  T    25-    52.80341  T    27-    43.36499
T    29-    35.30298  T    31-    28.51944  T    33-    42.54572
T    35-    33.92682  T    37-    26.81900  T   101-   312.49910
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01196
T  1102-     0.01196  T  1103-     0.01196  T  1104-     0.01196
T  1105-     0.02422  T  1106-     0.02307  T  1107-     0.04729

**********
TIME=  2100.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.51436E+01
                   TEMPCC(     1)=-2.40508E-01 RELXCC(   101)= 0.00000E+00

T     1-    19.14182  T     2-    -1.98749  T    40-   -39.59024
T    39-    27.40039  T    99-  -413.35140  T     4-    65.08429
T     6-    59.61682  T     9-    59.61682  T    12-    19.14182
T    15-    19.14185  T    19-    59.61682  T    20-    59.61682
T    23-    55.70782  T    25-    52.12842  T    27-    42.55219
T    29-    34.37555  T    31-    27.50726  T    33-    41.72537
T    35-    32.98828  T    37-    25.79474  T   101-   313.15230
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01178
T  1102-     0.01178  T  1103-     0.01178  T  1104-     0.01178
T  1105-     0.02384  T  1106-     0.02272  T  1107-     0.04656

**********
TIME=  2200.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.51728E+01
                   TEMPCC(     1)=-2.30826E-01 RELXCC(   101)= 0.00000E+00

T     1-    17.96851  T     2-    -3.11111  T    40-   -40.61588
T    39-    26.36594  T    99-  -413.36930  T     4-    64.73004
T     6-    59.13373  T     9-    59.13373  T    12-    17.96851
T    15-    17.96851  T    19-    59.13373  T    20-    59.13373
T    23-    55.13391  T    25-    51.47284  T    27-    41.76111
T    29-    33.47263  T    31-    26.52206  T    33-    40.92676
T    35-    32.07422  T    37-    24.79755  T   101-   317.63370
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01160
T  1102-     0.01160  T  1103-     0.01160  T  1104-     0.01160
T  1105-     0.02347  T  1106-     0.02239  T  1107-     0.04586

**********
TIME=  2300.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.51997E+01
                   TEMPCC(     1)=-2.21644E-01 RELXCC(   101)= 0.00000E+00

T     1-    16.84213  T     2-    -4.19034  T    40-   -41.60080
T    39-    25.36096  T    99-  -413.38650  T     4-    64.38434
```

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TEST, PC-SINDA

```
T     6-    58.66266  T     9-    58.66266  T    12-    16.84213
T    15-    16.84213  T    19-    58.66266  T    20-    58.66266
T    23-    54.57458  T    25-    50.83435  T    27-    40.98993
T    29-    32.59265  T    31-    25.56250  T    33-    40.14807
T    35-    31.18335  T    37-    23.82651  T   101-   319.96160
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01144
T  1102-     0.01144  T  1103-     0.01144  T  1104-     0.01144
T  1105-     0.02312  T  1106-     0.02208  T  1107-     0.04520

**********
TIME=  2400.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.52243E+01
                   TEMPCC(     1)=-2.12926E-01 RELXCC(   101)= 0.00000E+00

T     1-    15.76022  T     2-    -5.22720  T    40-   -42.54709
T    39-    24.38330  T    99-  -413.40300  T     4-    64.04718
T     6-    58.20355  T     9-    58.20355  T    12-    15.76022
T    15-    15.76022  T    19-    58.20355  T    20-    58.20355
T    23-    54.02985  T    25-    50.21280  T    27-    40.23874
T    29-    31.73593  T    31-    24.62903  T    33-    39.38437
T    35-    30.31140  T    37-    22.87787  T   101-   322.14980
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01128
T  1102-     0.01128  T  1103-     0.01128  T  1104-     0.01128
T  1105-     0.02280  T  1106-     0.02178  T  1107-     0.04457

**********
TIME=  2500.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.52496E+01
                   TEMPCC(     1)=-2.04773E-01 RELXCC(   101)= 0.00000E+00

T     1-    14.72046  T     2-    -6.22900  T    40-   -43.45773
```

```
T    39=    23.42899  T    99=  -413.41890  T     4=    63.71344
T     6=    57.74988  T     9=    57.74988  T    12=    14.72046
T    15=    14.72046  T    19=    57.74988  T    20=    57.74988
T    23=    53.49219  T    25=    49.59872  T    27=    39.49725
T    29=    30.89435  T    31=    23.71506  T    33=    38.59708
T    35=    29.40073  T    37=    21.88312  T   101=   324.39900
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01111
T  1102=     0.01111  T  1103=     0.01111  T  1104=     0.01111
T  1105=     0.02250  T  1106=     0.02138  T  1107=     0.04388

**********
TIME=  2600.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.52761E+01
                   TEMPCC(     1)=-1.98496E-01 RELXCC(   101)= 0.00000E+00

T     1=    13.71603  T     2=    -7.21689  T    40=   -44.35263
T    39=    22.46176  T    99=  -413.43460  T     4=    63.35034
T     6=    57.25940  T     9=    57.25940  T    12=    13.71603
T    15=    13.71603  T    19=    57.25940  T    20=    57.25940
T    23=    52.91370  T    25=    48.93924  T    27=    38.72537
T    29=    30.03812  T    31=    22.79849  T    33=    37.71991
T    35=    28.37592  T    37=    20.76340  T   101=   327.06980
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
```

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TEST, PC-SINDA

```
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01091
T  1102=     0.01091  T  1103=     0.01091  T  1104=     0.01091
T  1105=     0.02225  T  1106=     0.02082  T  1107=     0.04308

**********
TIME=  2700.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.53047E+01
                   TEMPCC(    39)=-2.02393E-01 RELXCC(   101)= 0.00000E+00

T     1=    12.73932  T     2=    -8.19394  T    40=   -45.23505
T    39=    21.46964  T    99=  -413.45000  T     4=    62.96783
T     6=    56.74487  T     9=    56.74487  T    12=    12.73932
T    15=    12.73932  T    19=    56.74487  T    20=    56.74487
T    23=    52.30878  T    25=    48.25183  T    27=    37.87549
T    29=    29.07410  T    31=    21.75687  T    33=    36.82874
T    35=    27.34808  T    37=    19.64261  T   101=   330.04210
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01067
T  1102=     0.01067  T  1103=     0.01067  T  1104=     0.01067
T  1105=     0.02181  T  1106=     0.02033  T  1107=     0.04214

**********
TIME=  2800.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.53276E+01
                   TEMPCC(    39)=-2.13646E-01 RELXCC(   101)= 0.00000E+00

T     1=    11.78220  T     2=    -9.16235  T    40=   -46.11154
T    39=    20.42136  T    99=  -413.46540  T     4=    62.55200
T     6=    56.18835  T     9=    56.18835  T    12=    11.78220
T    15=    11.78217  T    19=    56.18835  T    20=    56.18835
T    23=    51.65695  T    25=    47.51392  T    27=    36.95532
T    29=    28.02982  T    31=    20.63162  T    33=    35.90558
T    35=    26.30347  T    37=    18.46271  T   101=   333.22960
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01042
T  1102=     0.01042  T  1103=     0.01042  T  1104=     0.01042
T  1105=     0.02127  T  1106=     0.01987  T  1107=     0.04115

**********
TIME=  2900.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.53483E+01
                   TEMPCC(    39)=-2.18601E-01 RELXCC(   101)= 0.00000E+00

T     1=    10.84076  T     2=   -10.11682  T    40=   -46.97678
T    39=    19.33655  T    99=  -413.48050  T     4=    62.13092
T     6=    55.62579  T     9=    55.62579  T    12=    10.84076
T    15=    10.84076  T    19=    55.62579  T    20=    55.62579
T    23=    50.99908  T    25=    46.77017  T    27=    36.03128
T    29=    26.98404  T    31=    19.49323  T    33=    34.97876
T    35=    25.25784  T    37=    17.28912  T   101=   336.25410
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01018
T  1102=     0.01018  T  1103=     0.01018  T  1104=     0.01018
T  1105=     0.02076  T  1106=     0.01944  T  1107=     0.04019

**********
TIME=  3000.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.53827E+01
                   TEMPCC(    39)=-2.11530E-01 RELXCC(   101)= 0.00000E+00

T     1=     9.91351  T     2=   -11.07010  T    40=   -47.83640
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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TEST, PC-SINDA

```
T    39=    18.25497  T    99=  -413.49550  T     4=    61.71802
T     6=    55.07428  T     9=    55.07428  T    12=     9.91351
T    15=     9.91351  T    19=    55.07428  T    20=    55.07428
T    23=    50.35428  T    25=    46.04132  T    27=    35.18640
T    29=    26.05884  T    31=    18.45685  T    33=    34.13495
T    35=    24.33655  T    37=    16.26974  T   101=   338.90210
```

```
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.00997
T  1102-     0.00997  T  1103-     0.00997  T  1104-     0.00997
T  1105-     0.02031  T  1106-     0.01905  T  1107-     0.03936

**********
TIME-  3100.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.54154E+01
                     TEMPCC(    39)--1.93870E-01 RELXCC(   101)- 0.00000E+00

T     1-     8.99774  T     2-   -11.99225  T    40-   -48.67856
T    39-    17.24567  T    99-  -413.51030  T     4-    61.40491
T     6-    54.65338  T     9-    54.65338  T    12-     8.99774
T    15-     8.99774  T    19-    54.65338  T    20-    54.65338
T    23-    49.85831  T    25-    45.47580  T    27-    34.50378
T    29-    25.28922  T    31-    17.57751  T    33-    33.44983
T    35-    23.56406  T    37-    15.39566  T   101-   341.03230
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.00980
T  1102-     0.00980  T  1103-     0.00980  T  1104-     0.00980
T  1105-     0.01995  T  1106-     0.01874  T  1107-     0.03869

**********
TIME-  3200.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.54453E+01
                     TEMPCC(    39)--1.79136E-01 RELXCC(   101)- 0.00000E+00

T     1-     8.09787  T     2-   -12.87900  T    40-   -49.48599
T    39-    16.32428  T    99-  -413.52440  T     4-    61.12122
T     6-    54.27106  T     9-    54.27106  T    12-     8.09787
T    15-     8.09787  T    19-    54.27106  T    20-    54.27106
T    23-    49.40390  T    25-    44.95682  T    27-    33.86902
T    29-    24.56720  T    31-    16.75113  T    33-    32.81046
T    35-    22.83572  T    37-    14.56870  T   101-   342.83790
T    41-  -420.00000  T    4[illegible]    30.00000  T   999-    80.00000
T   100-   400.00000  T    1[illegible]    30.00000  T  1101-     0.00965
T  1102-     0.00965  T   11[illegible]     0.00965  T  1104-     0.00965
T  1105-     0.01963  T   11[illegible]     0.01846  T  1107-     0.03809

**********
TIME-  3300.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.54730E+01
                     TEMPCC(     1)--1.74602E-01 RELXCC(   101)- 0.00000E+00

T     1-     7.21719  T     2-   -13.74405  T    40-   -50.27136
T    39-    15.45248  T    99-  -413.53810  T     4-    60.83636
T     6-    53.88770  T     9-    53.88770  T    12-     7.21719
T    15-     7.21719  T    19-    53.88770  T    20-    53.88770
T    23-    48.94870  T    25-    44.43756  T    27-    33.23163
T    29-    23.84180  T    31-    15.92365  T    33-    32.16803
T    35-    22.10352  T    37-    13.74026  T   101-   344.56140
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

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    TEST, PC-SINDA

T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.00951
T  1102-     0.00951  T  1103-     0.00951  T  1104-     0.00951
T  1105-     0.01932  T  1106-     0.01819  T  1107-     0.03750

**********
TIME-  3400.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.54988E+01
                     TEMPCC(     1)--1.70853E-01 RELXCC(   101)- 0.00000E+00

T     1-     6.35547  T     2-   -14.59137  T    40-   -51.04004
T    39-    14.60379  T    99-  -413.55150  T     4-    60.54749
T     6-    53.49957  T     9-    53.49957  T    12-     6.35547
T    15-     6.35547  T    19-    53.49957  T    20-    53.49957
T    23-    48.48859  T    25-    43.91345  T    27-    32.58765
T    29-    23.10968  T    31-    15.09198  T    33-    31.51892
T    35-    21.36472  T    37-    12.90784  T   101-   346.22910
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.00936
T  1102-     0.00936  T  1103-     0.00936  T  1104-     0.00936
T  1105-     0.01901  T  1106-     0.01792  T  1107-     0.03693

**********
TIME-  3500.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.55231E+01
                     TEMPCC(     1)--1.67264E-01 RELXCC(   101)- 0.00000E+00

T     1-     5.51202  T     2-   -15.42221  T    40-   -51.79361
T    39-    13.76566  T    99-  -413.56470  T     4-    60.25500
T     6-    53.10724  T     9-    53.10724  T    12-     5.51202
T    15-     5.51202  T    19-    53.10724  T    20-    53.10724
T    23-    48.02417  T    25-    43.38522  T    27-    31.93854
T    29-    22.37253  T    31-    14.25775  T    33-    30.86456
T    35-    20.62091  T    37-    12.07309  T   101-   347.84140
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.00922
T  1102-     0.00922  T  1103-     0.00922  T  1104-     0.00922
T  1105-     0.01871  T  1106-     0.01765  T  1107-     0.03636

**********
TIME-  3600.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.55460E+01
                     TEMPCC(    39)--1.66228E-01 RELXCC(   101)- 0.00000E+00

T     1-     4.68604  T     2-   -16.23724  T    40-   -52.53275
T    39-    12.93289  T    99-  -413.57760  T     4-    59.95966
T     6-    52.71167  T     9-    52.71167  T    12-     4.68604
T    15-     4.68604  T    19-    52.71167  T    20-    52.71167
T    23-    47.55637  T    25-    42.85385  T    27-    31.28571
T    29-    21.63214  T    31-    13.42310  T    33-    30.20636
T    35-    19.87390  T    37-    11.23795  T   101-   349.39610
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
```

```
T   100=   400.00000  T   102=   100.00000  T  1101=     0.00908
T  1102=     0.00908  T  1103=     0.00908  T  1104=     0.00908
T  1105=     0.01842  T  1106=     0.01739  T  1107=     0.03581
```

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TEST, PC-SINDA

```
**********
TIME=  3700.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.55652E+01
                     TEMPCC(    39)=-1.69039E-01 RELXCC(   101)= 0.00000E+00

T     1=     3.87683  T     2=   -17.03772  T    40=   -53.25775
T    39=    12.09610  T    99=  -413.59030  T     4=    59.64441
T     6=    52.29498  T     9=    52.29498  T    12=     3.87683
T    15=     3.87686  T    19=    52.29498  T    20=    52.29498
T    23=    47.06723  T    25=    42.30136  T    27=    30.61511
T    29=    20.87766  T    31=    12.57953  T    33=    29.50681
T    35=    19.01956  T    37=    10.30399  T   101=   351.00210
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.00893
T  1102=     0.00893  T  1103=     0.00893  T  1104=     0.00893
T  1105=     0.01814  T  1106=     0.01708  T  1107=     0.03521

**********
TIME=  3800.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.55854E+01
                     TEMPCC(    39)=-1.72407E-01 RELXCC(   101)= 0.00000E+00

T     1=     3.08179  T     2=   -17.83246  T    40=   -53.97565
T    39=    11.23907  T    99=  -413.60280  T     4=    59.31122
T     6=    51.85657  T     9=    51.85657  T    12=     3.08179
T    15=     3.08182  T    19=    51.85657  T    20=    51.85657
T    23=    46.55414  T    25=    41.72382  T    27=    29.92075
T    29=    20.10190  T    31=    11.71857  T    33=    28.77661
T    35=    18.12955  T    37=     9.35855  T   101=   352.63780
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.00878
T  1102=     0.00878  T  1103=     0.00878  T  1104=     0.00878
T  1105=     0.01786  T  1106=     0.01675  T  1107=     0.03461

**********
TIME=  3900.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.56050E+01
                     TEMPCC(    39)=-1.75294E-01 RELXCC(   101)= 0.00000E+00

T     1=     2.29849  T     2=   -18.62009  T    40=   -54.68811
T    39=    10.37100  T    99=  -413.61530  T     4=    58.96851
T     6=    51.40671  T     9=    51.40671  T    12=     2.29849
T    15=     2.29849  T    19=    51.40671  T    20=    51.40671
T    23=    46.02872  T    25=    41.13339  T    27=    29.20148
T    29=    19.25403  T    31=    10.79031  T    33=    28.03561
T    35=    17.23416  T    37=     8.43237  T   101=   354.27660
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.00862
T  1102=     0.00862  T  1103=     0.00862  T  1104=     0.00862
T  1105=     0.01754  T  1106=     0.01644  T  1107=     0.03399

**********
TIME=  4000.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.56228E+01
                     TEMPCC(    40)= 2.22799E+01 RELXCC(    99)= 0.00000E+00

T     1=     1.52475  T     2=   -18.13885  T    40=   -32.97415
T    39=     9.47742  T    99=   -31.43582  T     4=    58.60431
```

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TEST, PC-SINDA

```
T     6=    50.93048  T     9=    50.93048  T    12=     1.52475
T    15=     1.52475  T    19=    50.93048  T    20=    50.93048
T    23=    45.47418  T    25=    40.51230  T    27=    28.69272
T    29=    18.80124  T    31=    10.43942  T    33=    27.54901
T    35=    16.83209  T    37=     8.18866  T   101=   355.96550
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.00846
T  1102=     0.00846  T  1103=     0.00846  T  1104=     0.00846
T  1105=     0.01720  T  1106=     0.01615  T  1107=     0.03335

**********
TIME=  4100.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.51338E+01
                     TEMPCC(    40)= 3.47650E+00 RELXCC(   101)= 0.00000E+00

T     1=     2.58484  T     2=     2.19702  T    40=    -2.08881
T    39=    12.22675  T    99=    -1.64435  T     4=    60.04492
T     6=    52.76172  T     9=    52.76172  T    12=     2.58484
T    15=     2.58484  T    19=    52.76172  T    20=    52.76172
T    23=    47.55096  T    25=    42.77689  T    27=    34.75055
T    29=    28.12970  T    31=    22.74463  T    33=    34.07755
T    35=    27.04260  T    37=    21.42212  T   101=   340.73470
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01025
T  1102=     0.01025  T  1103=     0.01025  T  1104=     0.01025
T  1105=     0.02073  T  1106=     0.01980  T  1107=     0.04053

**********
TIME=  4200.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.48687E+01
                     TEMPCC(    40)= 1.33933E+00 RELXCC(   101)= 0.00000E+00
```

```
T     1-      5.54205  T     2-      9.39392  T    40-      7.63583
T    39-     18.72662  T    99-      7.81815  T     4-     62.19098
T     6-     55.58051  T     9-     55.58051  T    12-      5.54205
T    15-      5.54205  T    19-     55.58051  T    20-     55.58051
T    23-     50.82977  T    25-     46.43762  T    27-     39.32797
T    29-     33.42490  T    31-     28.59146  T    33-     38.79160
T    35-     32.55139  T    37-     27.53720  T   101-    321.50540
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01155
T  1102-      0.01155  T  1103-      0.01155  T  1104-      0.01155
T  1105-      0.02324  T  1106-      0.02251  T  1107-      0.04574

**********
TIME=  4300.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.47650E+01
                     TEMPCC(    39)= 9.77573E-01 RELXCC(   101)= 0.00000E+00

T     1-      8.91226  T     2-     13.61856  T    40-     12.48740
T    39-     24.20920  T    99-     12.60471  T     4-     63.25116
T     6-     57.02197  T     9-     57.02197  T    12-      8.91226
T    15-      8.91226  T    19-     57.02197  T    20-     57.02197
T    23-     52.54047  T    25-     48.40286  T    27-     41.82175
T    29-     36.34909  T    31-     31.84937  T    33-     41.32852
T    35-     35.54071  T    37-     30.86835  T   101-    312.08440
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
```

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    TEST, PC-SINDA

T   100-    400.00000  T   102-    100.00000  T  1101-      0.01213
T  1102-      0.01213  T  1103-      0.01213  T  1104-      0.01213
T  1105-      0.02443  T  1106-      0.02365  T  1107-      0.04808

**********
TIME=  4400.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.46997E+01
                     TEMPCC(    39)= 7.70624E-01 RELXCC(   101)= 0.00000E+00

T     1-     12.28351  T     2-     17.06253  T    40-     16.07205
T    39-     28.41501  T    99-     16.17477  T     4-     64.16669
T     6-     58.27612  T     9-     58.27612  T    12-     12.28351
T    15-     12.28351  T    19-     58.27612  T    20-     58.27612
T    23-     54.03711  T    25-     50.13022  T    27-     44.00198
T    29-     38.89600  T    31-     34.67593  T    33-     43.54126
T    35-     38.13773  T    37-     33.75070  T   101-    304.03800
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01267
T  1102-      0.01267  T  1103-      0.01267  T  1104-      0.01267
T  1105-      0.02553  T  1106-      0.02471  T  1107-      0.05023

**********
TIME=  4500.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.46387E+01
                     TEMPCC(    39)= 6.70095E-01 RELXCC(   101)= 0.00000E+00

T     1-     15.55344  T     2-     20.29468  T    40-     19.33820
T    39-     31.96512  T    99-     19.43738  T     4-     65.15411
T     6-     59.62744  T     9-     59.62744  T    12-     15.55344
T    15-     15.55341  T    19-     59.62744  T    20-     59.62744
T    23-     55.64618  T    25-     51.97314  T    27-     46.20248
T    29-     41.38525  T    31-     37.39005  T    33-     45.79565
T    35-     40.71588  T    37-     36.56772  T   101-    295.55160
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01320
T  1102-      0.01320  T  1103-      0.01320  T  1104-      0.01320
T  1105-      0.02650  T  1106-      0.02586  T  1107-      0.05236

**********
TIME=  4600.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.45936E+01
                     TEMPCC(     1)= 6.18208E-01 RELXCC(   101)= 0.00000E+00

T     1-     18.70013  T     2-     23.32715  T    40-     22.41171
T    39-     35.00388  T    99-     22.50665  T     4-     65.97089
T     6-     60.74707  T     9-     60.74707  T    12-     18.70013
T    15-     18.70010  T    19-     60.74707  T    20-     60.74707
T    23-     56.98883  T    25-     53.52014  T    27-     48.07455
T    29-     43.52072  T    31-     39.74393  T    33-     47.69284
T    35-     42.89157  T    37-     38.96948  T   101-    289.67210
T    41-   -420.00000  T    42-     30.00000  T   999-     80.00000
T   100-    400.00000  T   102-    100.00000  T  1101-      0.01354
T  1102-      0.01354  T  1103-      0.01354  T  1104-      0.01354
T  1105-      0.02719  T  1106-      0.02655  T  1107-      0.05374

**********
TIME=  4700.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.45426E+01
                     TEMPCC(     1)= 5.89585E-01 RELXCC(   101)= 0.00000E+00

T     1-     21.70547  T     2-     26.19336  T    40-     25.30679
```

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    TEST, PC-SINDA

T    39-     37.66299  T    99-     25.39877  T     4-     66.70953
T     6-     61.75537  T     9-     61.75537  T    12-     21.70547
T    15-     21.70551  T    19-     61.75537  T    20-     61.75537
T    23-     58.20148  T    25-     54.92102  T    27-     49.78894
T    29-     45.49066  T    31-     41.92148  T    33-     49.42953
```

```
T    35=    44.89716  T    37=    41.19186  T   101=   284.13130
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01388
T  1102=     0.01388  T  1103=     0.01388  T  1104=     0.01388
T  1105=     0.02787  T  1106=     0.02722  T  1107=     0.05510

**********
TIME=  4800.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.44863E+01
                     TEMPCC(     1)= 5.61334E-01 RELXCC(   101)= 0.00000E+00

T     1=    24.56833  T     2=    28.91577  T    40=    28.05414
T    39=    40.07080  T    99=    28.14349  T     4=    67.40045
T     6=    62.69958  T     9=    62.69958  T    12=    24.56833
T    15=    24.56836  T    19=    62.69958  T    20=    62.69958
T    23=    59.33710  T    25=    56.23328  T    27=    51.38614
T    29=    47.32813  T    31=    43.95325  T    33=    51.04959
T    35=    46.76996  T    37=    43.26529  T   101=   278.63950
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01420
T  1102=     0.01420  T  1103=     0.01420  T  1104=     0.01420
T  1105=     0.02854  T  1106=     0.02787  T  1107=     0.05641

**********
TIME=  4900.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.44333E+01
                     TEMPCC(     1)= 5.33746E-01 RELXCC(   101)= 0.00000E+00

T     1=    27.29202  T     2=    31.49496  T    40=    30.66113
T    39=    42.28436  T    99=    30.74762  T     4=    68.04102
T     6=    63.57617  T     9=    63.57617  T    12=    27.29202
T    15=    27.29202  T    19=    63.57617  T    20=    63.57617
T    23=    60.39038  T    25=    57.45135  T    27=    52.87372
T    29=    49.04596  T    31=    45.85785  T    33=    52.55652
T    35=    48.51950  T    37=    45.20801  T   101=   273.23940
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01451
T  1102=     0.01451  T  1103=     0.01451  T  1104=     0.01451
T  1105=     0.02917  T  1106=     0.02849  T  1107=     0.05767

**********
TIME=  5000.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.43926E+01
                     TEMPCC(     1)= 5.06765E-01 RELXCC(   101)= 0.00000E+00

T     1=    29.87958  T     2=    33.92804  T    40=    33.12204
T    39=    44.34756  T    99=    33.20563  T     4=    68.63641
T     6=    64.39185  T     9=    64.39185  T    12=    29.87958
T    15=    29.87958  T    19=    64.39185  T    20=    64.39185
T    23=    61.36462  T    25=    58.57990  T    27=    54.25830
T    29=    50.64783  T    31=    47.63782  T    33=    53.96582
T    35=    50.16348  T    37=    47.03836  T   101=   267.97840
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

```
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    TEST, PC-SINDA

T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01481
T  1102=     0.01481  T  1103=     0.01481  T  1104=     0.01481
T  1105=     0.02973  T  1106=     0.02912  T  1107=     0.05885

**********
TIME=  5100.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.43558E+01
                     TEMPCC(     1)= 4.78746E-01 RELXCC(   101)= 0.00000E+00

T     1=    32.32974  T     2=    36.21719  T    40=    35.43906
T    39=    46.24451  T    99=    35.51981  T     4=    69.19489
T     6=    65.15808  T     9=    65.15808  T    12=    32.32974
T    15=    32.32974  T    19=    65.15808  T    20=    65.15808
T    23=    62.28046  T    25=    59.64056  T    27=    55.54541
T    29=    52.12402  T    31=    49.27618  T    33=    55.27283
T    35=    51.67322  T    37=    48.71771  T   101=   263.93060
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01502
T  1102=     0.01502  T  1103=     0.01502  T  1104=     0.01502
T  1105=     0.03014  T  1106=     0.02958  T  1107=     0.05973

**********
TIME=  5200.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.43164E+01
                     TEMPCC(     1)= 4.51583E-01 RELXCC(   101)= 0.00000E+00

T     1=    34.64142  T     2=    38.37616  T    40=    37.62350
T    39=    48.00488  T    99=    37.70157  T     4=    69.71899
T     6=    65.87750  T     9=    65.87750  T    12=    34.64142
T    15=    34.64142  T    19=    65.87750  T    20=    65.87750
T    23=    63.14044  T    25=    60.63373  T    27=    56.75397
T    29=    53.51227  T    31=    50.81641  T    33=    56.49658
T    35=    53.08643  T    37=    50.29031  T   101=   260.11090
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01523
T  1102=     0.01523  T  1103=     0.01523  T  1104=     0.01523
T  1105=     0.03057  T  1106=     0.03000  T  1107=     0.06057

**********
TIME=  5300.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.42739E+01
                     TEMPCC(     1)= 4.25544E-01 RELXCC(   101)= 0.00000E+00

T     1=    36.82095  T     2=    40.40912  T    40=    39.68115
T    39=    49.64053  T    99=    39.75665  T     4=    70.21307
T     6=    66.55347  T     9=    66.55347  T    12=    36.82095
T    15=    36.82092  T    19=    66.55347  T    20=    66.55347
T    23=    63.94727  T    25=    61.56122  T    27=    57.88232
T    29=    54.80847  T    31=    52.25189  T    33=    57.63898
T    35=    54.40582  T    37=    51.75433  T   101=   256.43730
```

```
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01543
T  1102-     0.01543  T  1103-     0.01543  T  1104-     0.01543
T  1105-     0.03097  T  1106-     0.03041  T  1107-     0.06138
```



```
**********
TIME=  5400.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.42441E+01
                   TEMPCC(     1)= 4.00460E-01 RELXCC(   101)= 0.00000E+00

T     1-    38.87292  T     2-    42.31696  T    40-    41.61450
T    39-    51.17343  T    99-    41.68738  T     4-    70.69226
T     6-    67.20074  T     9-    67.20074  T    12-    38.87292
T    15-    38.87289  T    19-    67.20074  T    20-    67.20074
T    23-    64.71558  T    25-    62.44122  T    27-    58.95648
T    29-    56.04370  T    31-    53.61938  T    33-    58.72662
T    35-    55.66309  T    37-    53.14868  T   101-   252.83620
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01562
T  1102-     0.01562  T  1103-     0.01562  T  1104-     0.01562
T  1105-     0.03137  T  1106-     0.03080  T  1107-     0.06217

**********
TIME=  5500.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.42150E+01
                   TEMPCC(     1)= 3.76372E-01 RELXCC(   101)= 0.00000E+00

T     1-    40.80289  T     2-    44.10800  T    40-    43.42911
T    39-    52.61243  T    99-    43.49951  T     4-    71.14221
T     6-    67.80939  T     9-    67.80939  T    12-    40.80292
T    15-    40.80289  T    19-    67.80939  T    20-    67.80939
T    23-    65.43829  T    25-    63.26910  T    27-    59.96387
T    29-    57.20026  T    31-    54.89880  T    33-    59.74640
T    35-    56.83997  T    37-    54.45288  T   101-   249.36550
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01580
T  1102-     0.01580  T  1103-     0.01580  T  1104-     0.01580
T  1105-     0.03174  T  1106-     0.03117  T  1107-     0.06291

**********
TIME=  5600.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.41839E+01
                   TEMPCC(     1)= 3.53243E-01 RELXCC(   101)= 0.00000E+00

T     1-    42.61475  T     2-    45.79349  T    40-    45.13513
T    39-    53.96558  T    99-    45.20346  T     4-    71.57727
T     6-    68.39783  T     9-    68.39783  T    12-    42.61472
T    15-    42.61475  T    19-    68.39783  T    20-    68.39783
T    23-    66.13654  T    25-    64.06818  T    27-    60.92212
T    29-    58.29572  T    31-    56.10760  T    33-    60.71729
T    35-    57.95520  T    37-    55.68536  T   101-   245.97560
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01598
T  1102-     0.01598  T  1103-     0.01598  T  1104-     0.01598
T  1105-     0.03210  T  1106-     0.03153  T  1107-     0.06363

**********
TIME=  5700.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.41524E+01
                   TEMPCC(     1)= 3.31408E-01 RELXCC(   101)= 0.00000E+00

T     1-    44.31500  T     2-    47.37491  T    40-    46.73795
T    39-    55.23199  T    99-    46.80402  T     4-    71.98145
```



```
T     6-    68.94525  T     9-    68.94525  T    12-    44.31497
T    15-    44.31500  T    19-    68.94525  T    20-    68.94525
T    23-    66.78656  T    25-    64.81232  T    27-    61.81342
T    29-    59.31543  T    31-    57.23340  T    33-    61.61871
T    35-    58.99194  T    37-    56.83228  T   101-   242.73790
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01615
T  1102-     0.01615  T  1103-     0.01615  T  1104-     0.01615
T  1105-     0.03244  T  1106-     0.03187  T  1107-     0.06431

**********
TIME=  5800.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.41217E+01
                   TEMPCC(     1)= 3.10708E-01 RELXCC(   101)= 0.00000E+00

T     1-    45.90948  T     2-    48.85596  T    40-    48.23975
T    39-    56.41229  T    99-    48.30368  T     4-    72.35681
T     6-    69.45447  T     9-    69.45447  T    12-    45.90945
T    15-    45.90948  T    19-    69.45447  T    20-    69.45447
T    23-    67.39154  T    25-    65.50525  T    27-    62.64282
T    29-    60.26355  T    31-    58.28040  T    33-    62.45844
T    35-    59.95776  T    37-    57.90094  T   101-   239.66920
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01630
T  1102-     0.01630  T  1103-     0.01630  T  1104-     0.01630
T  1105-     0.03274  T  1106-     0.03220  T  1107-     0.06494

**********
TIME=  5900.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.40926E+01
```

```
                    TEMPCC(      1)= 2.90860E-01 RELXCC(    101)= 0.00000E+00

T      1=     47.40326  T      2=     50.23874  T     40=     49.64349
T     39=     57.50208  T     99=     49.70523  T      4=     72.70050
T      6=     69.92151  T      9=     69.92151  T     12=     47.40329
T     15=     47.40326  T     19=     69.92151  T     20=     69.92151
T     23=     67.94708  T     25=     66.14227  T     27=     63.40369
T     29=     61.12872  T     31=     59.23724  T     33=     63.23041
T     35=     60.84259  T     37=     58.88196  T    101=    237.25620
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.01642
T   1102=      0.01642  T   1103=      0.01642  T   1104=      0.01642
T   1105=      0.03295  T   1106=      0.03246  T   1107=      0.06542

**********
TIME=   6000.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.40686E+01
                    TEMPCC(      1)= 2.71834E-01 RELXCC(    101)= 0.00000E+00

T      1=     48.80008  T      2=     51.52792  T     40=     50.95245
T     39=     58.51013  T     99=     51.01218  T      4=     73.01721
T      6=     70.35785  T      9=     70.35785  T     12=     48.80008
T     15=     48.80008  T     19=     70.35785  T     20=     70.35785
T     23=     68.46515  T     25=     66.73560  T     27=     64.11743
T     29=     61.94299  T     31=     60.13873  T     33=     63.95221
T     35=     61.67023  T     37=     59.80017  T    101=    235.07250
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
```

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     TEST, PC-SINDA

T    100=    400.00000  T    102=    100.00000  T   1101=      0.01653
T   1102=      0.01653  T   1103=      0.01653  T   1104=      0.01653
T   1105=      0.03318  T   1106=      0.03269  T   1107=      0.06587

**********
TIME=   6100.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.40431E+01
                    TEMPCC(      1)= 2.53917E-01 RELXCC(    101)= 0.00000E+00

T      1=     50.10504  T      2=     52.73224  T     40=     52.17456
T     39=     59.44995  T     99=     52.23236  T      4=     73.31165
T      6=     70.76642  T      9=     70.76642  T     12=     50.10504
T     15=     50.10504  T     19=     70.76642  T     20=     70.76642
T     23=     68.94971  T     25=     67.29010  T     27=     64.78400
T     29=     62.70313  T     31=     60.97687  T     33=     64.62628
T     35=     62.44281  T     37=     60.65503  T    101=    232.99570
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.01663
T   1102=      0.01663  T   1103=      0.01663  T   1104=      0.01663
T   1105=      0.03339  T   1106=      0.03290  T   1107=      0.06629

**********
TIME=   6200.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.40175E+01
                    TEMPCC(      1)= 2.36914E-01 RELXCC(    101)= 0.00000E+00

T      1=     51.32315  T      2=     53.85712  T     40=     53.31592
T     39=     60.32556  T     99=     53.37207  T      4=     73.59137
T      6=     71.15411  T      9=     71.15411  T     12=     51.32315
T     15=     51.32315  T     19=     71.15411  T     20=     71.15411
T     23=     69.40948  T     25=     67.81604  T     27=     65.41296
T     29=     63.41809  T     31=     61.76343  T     33=     65.26215
T     35=     63.16919  T     37=     61.45569  T    101=    231.02060
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.01673
T   1102=      0.01673  T   1103=      0.01673  T   1104=      0.01673
T   1105=      0.03359  T   1106=      0.03311  T   1107=      0.06669

**********
TIME=   6300.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.39929E+01
                    TEMPCC(      1)= 2.21001E-01 RELXCC(    101)= 0.00000E+00

T      1=     52.45959  T      2=     54.90674  T     40=     54.38171
T     39=     61.14319  T     99=     54.43616  T      4=     73.85211
T      6=     71.51544  T      9=     71.51544  T     12=     52.45959
T     15=     52.45959  T     19=     71.51544  T     20=     71.51544
T     23=     69.83826  T     25=     68.30670  T     27=     65.99945
T     29=     64.08453  T     31=     62.49652  T     33=     65.85492
T     35=     63.84613  T     37=     62.20184  T    101=    229.14940
T     41=   -420.00000  T     42=     30.00000  T    999=     80.00000
T    100=    400.00000  T    102=    100.00000  T   1101=      0.01683
T   1102=      0.01683  T   1103=      0.01683  T   1104=      0.01683
T   1105=      0.03377  T   1106=      0.03330  T   1107=      0.06707

**********
TIME=   6400.00000          DTIMEU= 2.00000E+01 CSGMIN(      2)= 2.39693E+01
                    TEMPCC(      1)= 2.06040E-01 RELXCC(    101)= 0.00000E+00

T      1=     53.51941  T      2=     55.88501  T     40=     55.37518
```

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     TEST, PC-SINDA

T     39=     61.90442  T     99=     55.42804  T      4=     74.09412
T      6=     71.85077  T      9=     71.85077  T     12=     53.51941
T     15=     53.51941  T     19=     71.85077  T     20=     71.85077
T     23=     70.23822  T     25=     68.76416  T     27=     66.54590
```

```
T    29-    64.70544  T    31-    63.17938  T     3-    66.40735
T    35-    64.47681  T    37-    62.89679  T     1-   227.38630
T    41-  -420.00000  T    42-    30.00000  T    99-    80.00000
T   100-   400.00000  T   102-   100.00000  T    11-     0.01691
T  1102-     0.01691  T  1103-     0.01691  T   104-     0.01691
T  1105-     0.03395  T  1106-     0.03348  T   107-     0.06743

**********
TIME-  6500.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.39465E+01
                   TEMPCC(     1)- 1.91997E-01 RELXCC(   101)- 0.00000E+00

T     1-    54.50714  T     2-    56.79657  T    40-    56.30096
T    39-    62.61346  T    99-    56.35236  T     4-    74.31897
T     6-    72.16223  T     9-    72.16223  T    12-    54.50714
T    15-    54.50714  T    19-    72.16223  T    20-    72.16223
T    23-    70.61230  T    25-    69.19165  T    27-    67.05597
T    29-    65.28436  T    31-    63.81573  T    33-    66.92279
T    35-    65.06482  T    37-    63.54443  T   101-   225.72130
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01699
T  1102-     0.01699  T  1103-     0.01699  T  1104-     0.01699
T  1105-     0.03411  T  1106-     0.03364  T  1107-     0.06776

**********
TIME-  6600.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.39247E+01
                   TEMPCC(     1)- 1.78851E-01 RELXCC(   101)- 0.00000E+00

T     1-    55.42731  T     2-    57.64514  T    40-    57.16309
T    39-    63.27289  T    99-    57.21307  T     4-    74.52765
T     6-    72.45129  T     9-    72.45129  T    12-    55.42731
T    15-    55.42731  T    19-    72.45129  T    20-    72.45129
T    23-    70.95953  T    25-    69.58056  T    27-    67.52966
T    29-    65.82220  T    31-    64.40704  T    33-    67.40161
T    35-    65.61115  T    37-    64.14624  T   101-   224.15680
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01707
T  1102-     0.01707  T  1103-     0.01707  T  1104-     0.01707
T  1105-     0.03427  T  1106-     0.03380  T  1107-     0.06807

**********
TIME-  6700.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.39039E+01
                   TEMPCC(     1)- 1.66541E-01 RELXCC(   101)- 0.00000E+00

T     1-    56.28436  T     2-    58.43475  T    40-    57.96545
T    39-    63.88550  T    99-    58.01410  T     4-    74.72137
T     6-    72.71960  T     9-    72.71960  T    12-    56.28436
T    15-    56.28436  T    19-    72.71960  T    20-    72.71960
T    23-    71.28174  T    25-    69.95709  T    27-    67.96967
T    29-    66.32202  T    31-    64.95673  T    33-    67.84625
T    35-    66.11859  T    37-    64.70544  T   101-   222.68900
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

TEST, PC-SINDA

```
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01714
T  1102-     0.01714  T  1103-     0.01714  T  1104-     0.01714
T  1105-     0.03441  T  1106-     0.03395  T  1107-     0.06836

**********
TIME-  6800.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.38839E+01
                   TEMPCC(     1)- 1.54986E-01 RELXCC(   101)- 0.00000E+00

T     1-    57.08209  T     2-    59.16943  T    40-    58.71185
T    39-    64.45465  T    99-    58.75934  T     4-    74.90131
T     6-    72.96869  T     9-    72.96869  T    12-    57.08209
T    15-    57.08209  T    19-    72.96869  T    20-    72.96869
T    23-    71.58087  T    25-    70.30145  T    27-    68.38025
T    29-    66.78784  T    31-    65.46863  T    33-    68.26123
T    35-    66.59174  T    37-    65.22638  T   101-   221.31040
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01721
T  1102-     0.01721  T  1103-     0.01721  T  1104-     0.01721
T  1105-     0.03455  T  1106-     0.03409  T  1107-     0.06863

**********
TIME-  6900.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.38649E+01
                   TEMPCC(     1)- 1.44189E-01 RELXCC(   101)- 0.00000E+00

T     1-    57.82434  T     2-    59.85284  T    40-    59.40637
T    39-    64.98425  T    99-    59.45264  T     4-    75.06824
T     6-    73.19977  T     9-    73.19977  T    12-    57.82434
T    15-    57.82434  T    19-    73.19977  T    20-    73.19977
T    23-    71.85834  T    25-    70.62189  T    27-    68.76215
T    29-    67.22107  T    31-    65.94464  T    33-    68.64709
T    35-    67.03156  T    37-    65.71063  T   101-   220.01460
T    41-  -420.00000  T    42-    30.00000  T   999-    80.00000
T   100-   400.00000  T   102-   100.00000  T  1101-     0.01727
T  1102-     0.01727  T  1103-     0.01727  T  1104-     0.01727
T  1105-     0.03467  T  1106-     0.03421  T  1107-     0.06889

**********
TIME-  7000.00000          DTIMEU- 2.00000E+01 CSGMIN(     2)- 2.38483E+01
                   TEMPCC(     1)- 1.34102E-01 RELXCC(   101)- 0.00000E+00

T     1-    58.51471  T     2-    60.48773  T    40-    60.05188
T    39-    65.47626  T    99-    60.09711  T     4-    75.22321
T     6-    73.41425  T     9-    73.41425  T    12-    58.51471
T    15-    58.51471  T    19-    73.41425  T    20-    73.41425
T    23-    72.11578  T    25-    70.91913  T    27-    69.11700
T    29-    67.62396  T    31-    66.38757  T    33-    69.00574
```

```
T    35=    67.44073  T    37=    66.16132  T   101=   218.80110
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01733
T  1102=     0.01733  T  1103=     0.01733  T  1104=     0.01733
T  1105=     0.03479  T  1106=     0.03433  T  1107=     0.06913
```

GASKI PC-SINDA, THREE COLUMN OUTPUT

TEST, PC-SINDA

```
**********
TIME=  7100.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.38336E+01
                   TEMPCC(     1)= 1.24669E-01 RELXCC(   101)= 0.00000E+00

T     1=    59.15668  T     2=    61.07721  T    40=    60.65125
T    39=    65.93384  T    99=    60.69543  T     4=    75.36694
T     6=    73.61322  T     9=    73.61322  T    12=    59.15668
T    15=    59.15668  T    19=    73.61322  T    20=    73.61322
T    23=    72.35468  T    25=    71.19501  T    27=    69.44672
T    29=    67.99854  T    31=    66.79932  T    33=    69.33899
T    35=    67.82111  T    37=    66.58032  T   101=   217.66360
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01738
T  1102=     0.01738  T  1103=     0.01738  T  1104=     0.01738
T  1105=     0.03490  T  1106=     0.03445  T  1107=     0.06935

**********
TIME=  7200.00000          DTIMEU= 2.00000E+01 CSGMIN(     2)= 2.38198E+01
                   TEMPCC(     1)= 1.15866E-01 RELXCC(   101)= 0.00000E+00

T     1=    59.75336  T     2=    61.62476  T    40=    61.20795
T    39=    66.35870  T    99=    61.25122  T     4=    75.50037
T     6=    73.79779  T     9=    73.79779  T    12=    59.75336
T    15=    59.75336  T    19=    73.79779  T    20=    73.79779
T    23=    72.57623  T    25=    71.45081  T    27=    69.75250
T    29=    68.34595  T    31=    67.18140  T    33=    69.64795
T    35=    68.17383  T    37=    66.96887  T   101=   216.60090
T    41=  -420.00000  T    42=    30.00000  T   999=    80.00000
T   100=   400.00000  T   102=   100.00000  T  1101=     0.01743
T  1102=     0.01743  T  1103=     0.01743  T  1104=     0.01743
T  1105=     0.03500  T  1106=     0.03455  T  1107=     0.06955
```

IV. Presentation and Discussion of Results:

A. Presentation of Unprocessed Results:

Graphical representation of the transient thermal analysis, results are presented in this section. Temperatures corresponding to the nodes labeled in Figures 3a and 3b are calculated at discrete time steps, over a period of two hours. Transient temperature distributions across the inner helix, outer helix, and servoactuators may be obtained from these data.

B. Discussion of Results:

Hydraulic oil inlet (Node 4) and outlet (Node 39) temperatures are plotted, as functions of time, in Figure 4. The figure was generated by plotting the temperatures of nodes 4 and 39, for an elapsed time of one hour. For a supply temperature of 100F, it is clear that the temperatures become relatively constant within one hour and that actuator freezing is not a problem. It was further shown, however, that the actuator thermal condition is highly sensitive to Δ P and to the supply temperature. This sensitivity is a result of the non-linear change in fluid viscosity, as the temperature drops.

The flow in the helix is susceptable to freezing when supply temperature is decreased to 80F; this is shown in Figures 5a and 5b. Addition of a 300 W strip heater at the actuator neck alleviates the freezing problem, as evidenced by the transient temperature and flowrate profiles shown in Figures 5c and 5d, respectively. In the event that a heater fails during prelaunch, thermal conditioning may be accomplished through cyclic operation of the liquid hydrogen recirculation pump as indicated in Figures 5e and 5f. This allows a vapor pocket to form at the ball valve inlet, greatly reducing the cryogenic heat leak. If proper propellant and engine conditioning can be achieved, a launch scrub might be avoided. In Figure 5e it is shown that by reducing the cryogenic heat leak by a factor of a factor of five, (simulating turning the liquid hydrogen recirculation pump off), thermal conditioning recovers within one hour. Cylic operation of the liquid hydrogen recirculation pump could avoid a launch scrub. In Figure 5f it is demonstrated that cyclic recirculation pump operation allows flow recovery before actuator freezing.

When a APU start is simulated thermal conditioning after T-5 min is not a problem because hydraulic pressure is increased to 3000 PSI at the APU start, and the thermal response is rapid. This is demonstrated in Figures 6a and 6b The fluid temperature and the fluid flow recover within one or two minutes. This demonstrates that engine start could be achieved easily from the MFVA outlet temperature of 10 Deg F at APU start. (The MFVA must be above 35 Deg F at engine start).

While the simulation in Figures 6a and 6b did not include throttling work to the fluid or slewing of the actuator piston, Figures 7a and 7b show the thermal response where the effects of Joule Thompson heating are included. Joule Thompson heating is significant when throttling over large pressure ranges. The response rates are rapid.

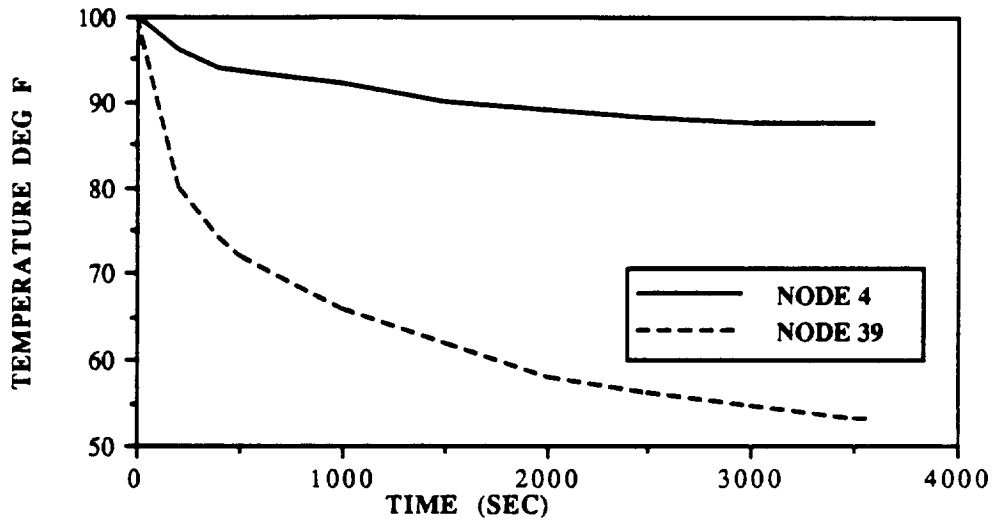


Figure 4. Hydraulic inlet (Node 4) and outlet (Node 39) temperatures. The actuator ΔP is 400 PSID and the supply temperature is 100 Deg F.

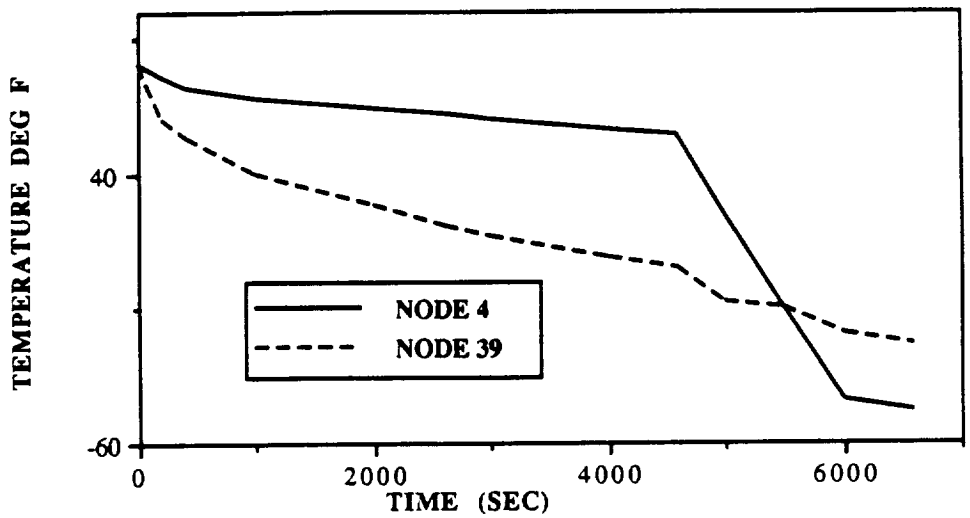


Figure 5a. Hydraulic inlet (Node 4) and outlet (Node 39) temperatures with freeze conditions. The actuator ΔP is 300 PSID and the supply temperature is 80 Deg F.

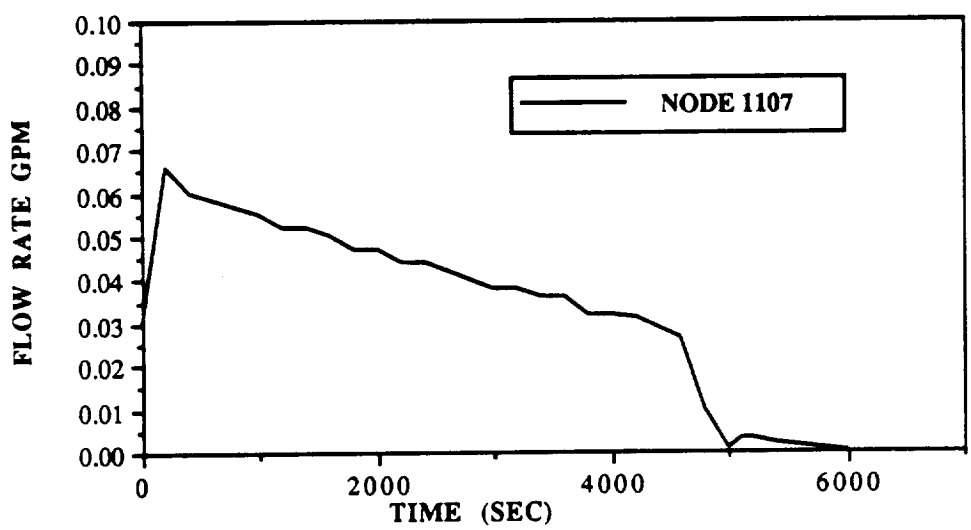


Figure 5b. Helix flow rate (Node 1107) during transient actuator freeze. The actuator ΔP is 300 PSID and the supply temperature is 80 Deg F.

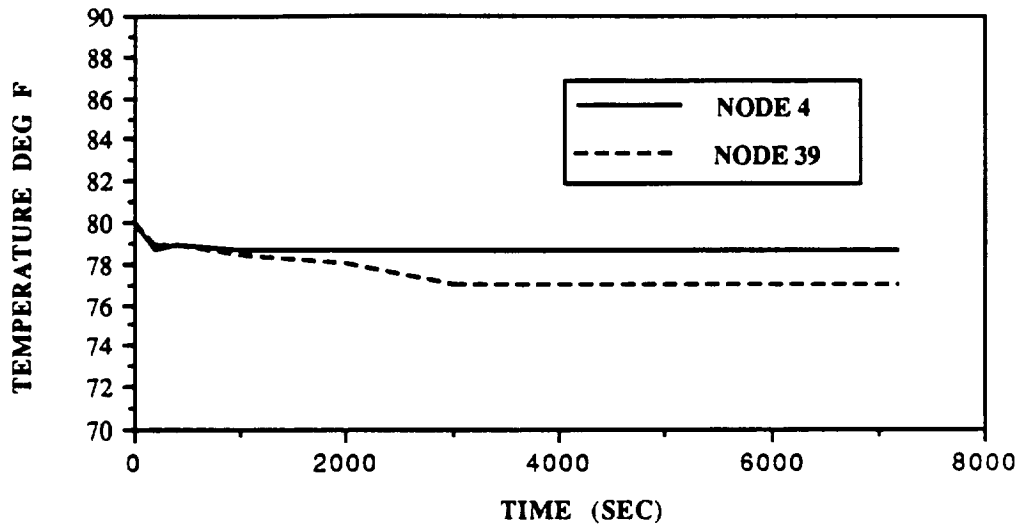


Figure 5c. Hydraulic inlet (Node 4) and outlet (Node 39) temperatures when heater is present. The actuator ΔP is 300 PSID, the supply temperature is 80 Deg F and the heater power is 300 W.

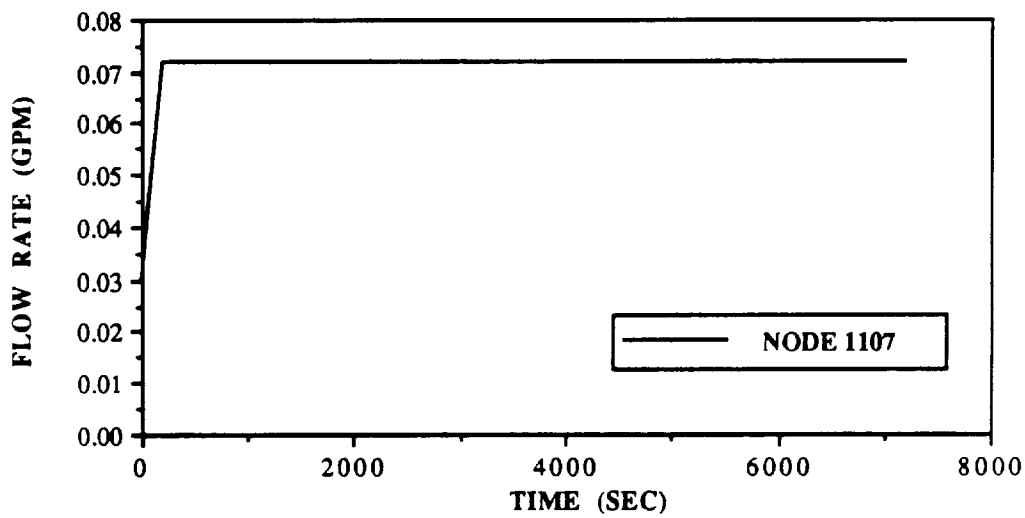


Figure 5d. Helix flow rate (Node 1107) when heater is present. The actuator ΔP is 300 PSID, the supply temperature is 80 Deg F and the heater power is 300 W.

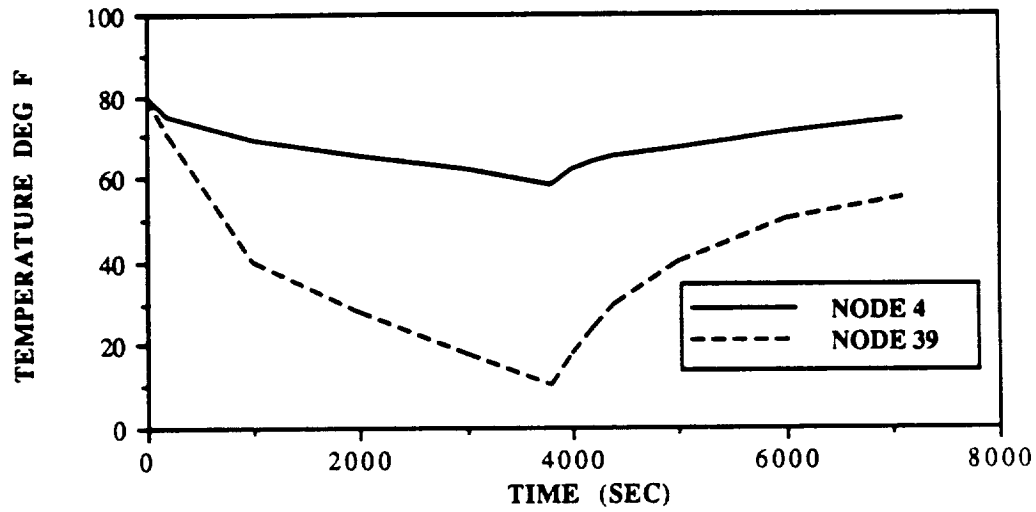


Figure 5e. Hydraulic inlet (Node 4) and outlet (Node 39) temperatures with simulated cyclic liquid hydrogen recirculation pump operation. The actuator ΔP is 300 PSID and the supply temperature is 80 Deg F.

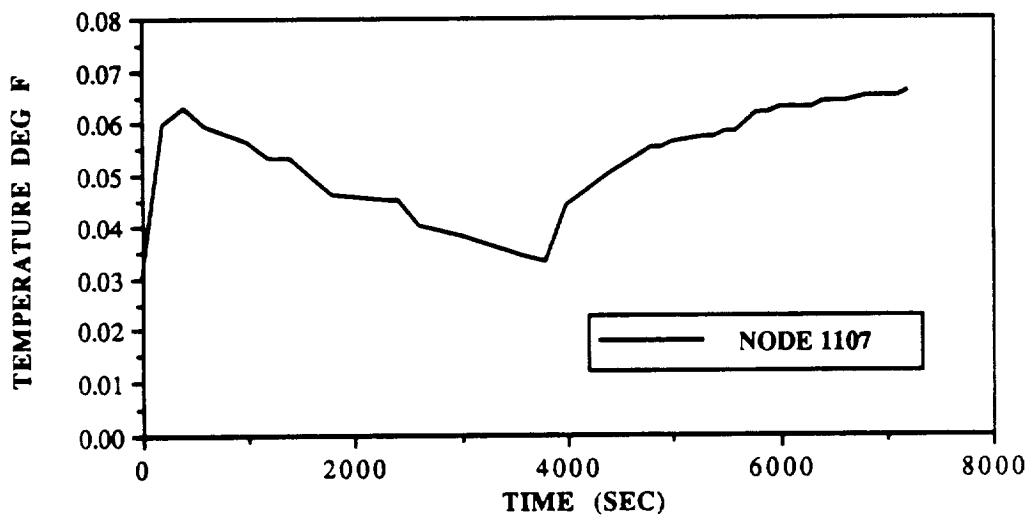


Figure 5f. Helix flow rate (Node 1107) with simulated cyclic liquid hydrogen recirculation pump operation. The actuator ΔP is 300 PSID and the supply temperature is 80 Deg F.

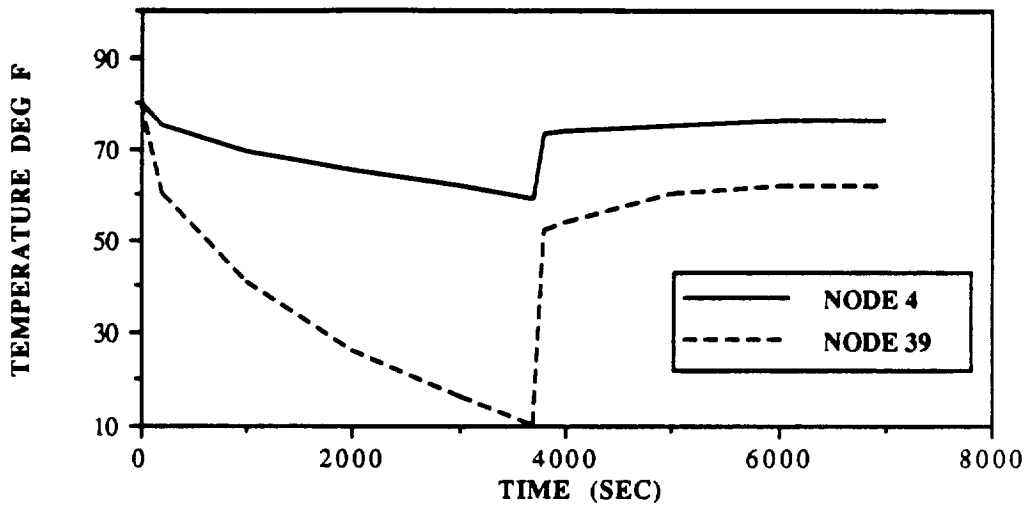


Figure 6a. Hydraulic inlet (Node 4) and outlet (Node 39) temperatures with an APU start simulation. The supply temperature is constant and there is no throttling energy.

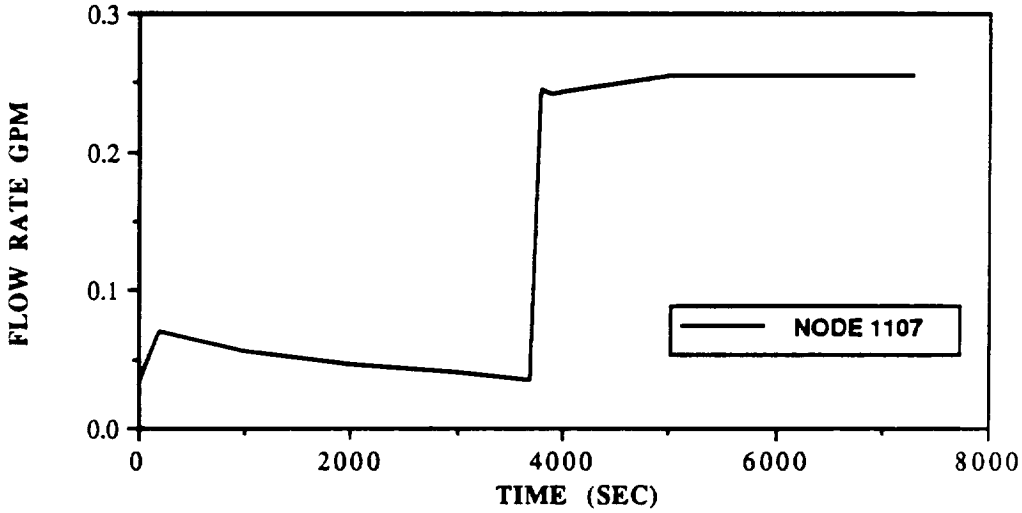


Figure 6b. Helix flow rate (Node 1107) with an APU start simulation. This is a transient response. The supply temperature is constant and there is no throttling energy.

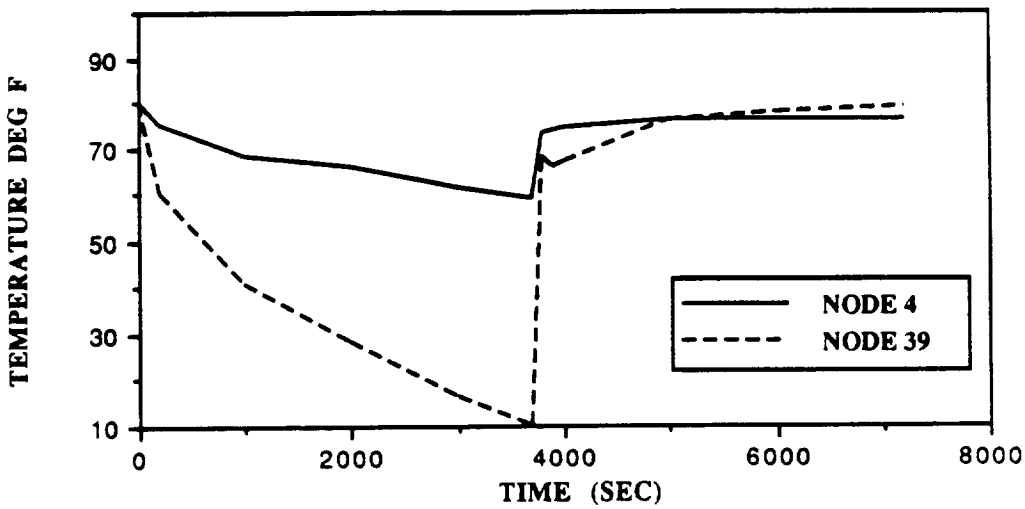


Figure 7a. Hydraulic inlet (Node 4) and outlet (Node 39) temperatures with Joule Thompson heating. This is a transient response with throttling.

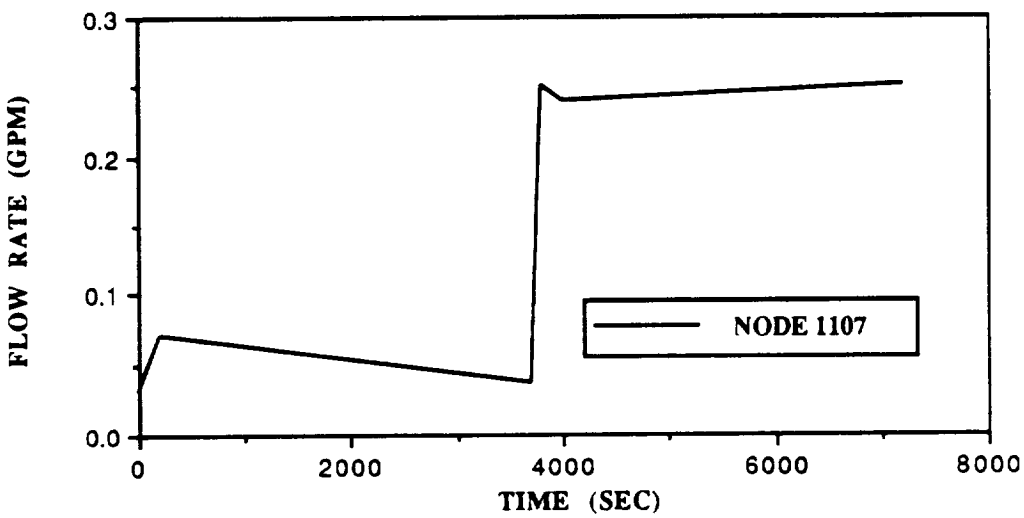


Figure 7b. Helix flow rate (Node 1107) recovery with Joule Thompson heating. This is a transient response with throttling.

CHAPTER 5. N-DIMENSIONAL BRANCHING NETWORK, 1-DIMENSIONAL FLUID FLOW

SECTION 4: Hazardous Gas Concentration in Oxygen/Hydrogen Systems

ANALYSIS CODE: SINDA

Following is an example of a problem worked during the Shuttle program, to understand the steady-state and transient response of gas concentrations. The application for this work includes both prediction and understanding of data collected for each Shuttle launch on the hazardous gas detection system. Primarily, the gas mixture concentrations are of interest in the Orbiter aft compartment both prior to and during flight. The presence of both oxygen and hydrogen systems dictates strict leak detection requirements and active inerting of compartments (inert gas purges) prior to flight. The safety approach includes prevention of fuel concentrations, prevention of oxygen concentrations, and elimination of any ignition source.

Background

The Space Shuttle Orbiter aft compartment houses the three Space Shuttle Main Engines, all propellant feed and conditioning systems, and associated fill and drain systems required by the vehicle. Leakage of volatile fuels in closed compartments is quite dangerous, so safety precautions are required. Real-time monitoring of gas concentrations by mass spectrometers is also required. A schematic of the compartment is given in Figure 1.

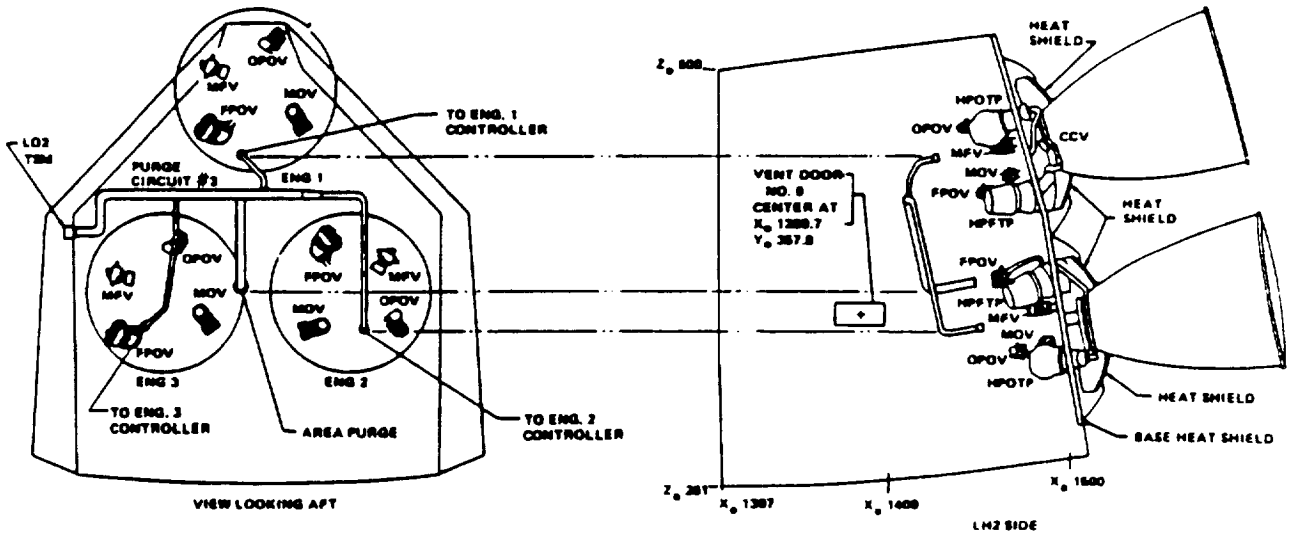


Figure 1. Space Shuttle Orbiter Aft Compartment

Detection of leaks and preventions of hazards was of engineering concern throughout the Shuttle development program. Understanding of leak characteristics, however, became extremely important during preparation for STS-6, when hydrogen leakage in the aft compartment was detected during the 20 second (on-pad) flight readiness firing. Location of this leak (a cracked weld in an SSME high pressure fuel line) required weeks of

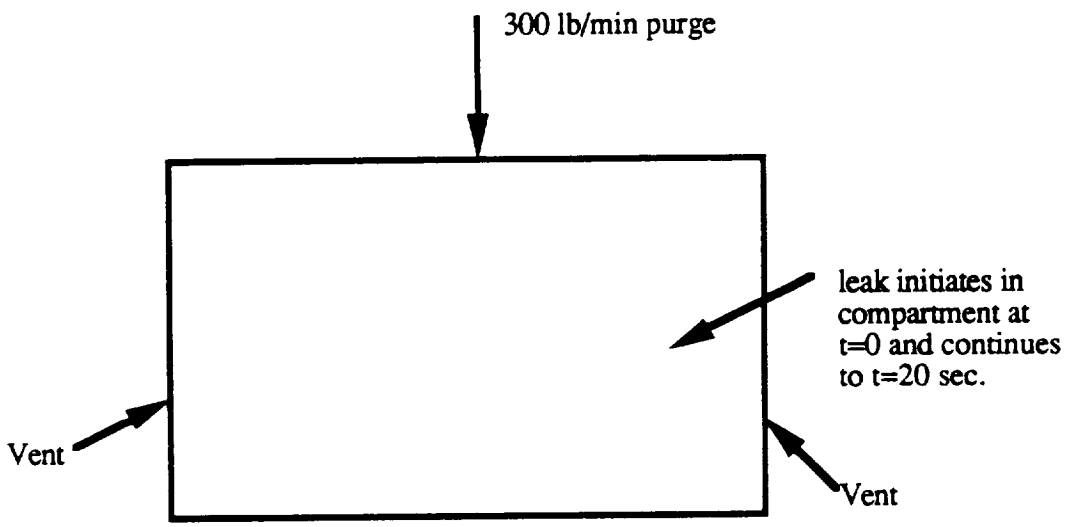
troubleshooting, testing, and data analysis. The analysis described here was utilized during that investigation to define the magnitude of leakage and the flight hazard. Closed form solutions for transient simulations are included.

I. Identification of the Problem.

A. Statement of the Problem.

Consider a single compartment of a given volume, containing both oxygen and hydrogen systems, and continuously purged with nitrogen at a given flow rate. Assume that the gas concentration is 100% nitrogen at time zero and that at engine ignition (time zero) a fuel (hydrogen) leak initiates. If the firing lasts 20 seconds, and the leak terminates with the end of firing, find the transient concentration of hydrogen gas in the compartment. The nitrogen purge is constant at 300 lb/min before, during, and after firing.

B. Schematic



C. Given

1. N_2 Purge rate, 300 lb/min
2. Compartment Volume, 4550 ft^3
3. H_2 Leak Rate Parametrically Evaluated
4. 20 second firing (constant leak rate)

D. Find

1. The transient H_2 concentration during firing
2. The transient H_2 concentration decay after firing

II. Formulation of the Problem

A. Simplifying Assumptions

1. The volume of hydrogen in the compartment is much less than the total compartment volume
2. The compartment pressure, temperature, and density remain constant during and after firing.
3. The H_2 leak rate is much less than the compartment purge rate.
4. The compartment mixture is uniform throughout

B. Initial/Boundary Conditions

1. Aft Compartment initially inert
2. N_2 Purge Rate, 300 lb/min

III. Mathematical Formulation

Let V_{H2} be the volume of H_2 in the compartment at time t

then,

$$\frac{dV_{H2}}{dt} = \text{Volumetric Rate } H_2 \text{ in - Volumetric Rate } H_2 \text{ out}$$

$$\text{Volumetric Rate } H_2 \text{ in} = \text{Leak Rate} = LR_{H2}$$

$$\text{Volumetric Rate } H_2 \text{ out} = \left[\frac{V_{H2}}{V_{Compartment}}\right]\left[\begin{array}{c}\text{Total Flow}\\ \text{Leaving}\\ \text{Compartment}\end{array}\right]$$

assuming flow leaving compartment is purge rate (because we have assumed LR<< Purge Rate)

$$\text{Volumetric Rate } H_2 \text{ out} = \left[\frac{V_{H2}}{4550\ ft^3}\right]\left[\frac{300\ lb/min}{.07\frac{lb}{ft^3}}\right]\left[\frac{min}{60\ sec}\right]$$

$$\text{Volumetric Rate } H_2 \text{ out} = 0.0157\ V_{H2}$$

and

$$\frac{dV_{H2}}{dt} = LR_{H2} - 0.0157\ V_{H2}$$

separating and solving,

$$\frac{dV_{H2}}{LR_{H2} - 0.0157\ V_{H2}} = dt$$

$$\text{let } u = LR_{H2} - 0.0157\ V_{H2}$$

$$du = -0.0157\ dV_{H2}$$

$$\int \frac{du}{u} = \ln u$$

$$\left(\frac{1}{-0.0157}\right) \ln (LR_{H2} - 0.0157\ V_{H2}\ ) = t + c$$

at $t = o,\ V_{H2} = 0$

$$\therefore\ c = \left(\frac{1}{-0.0157}\right) \ln LR_{H2}$$

$$\ln (LR_{H2} - 0.0157\ V_{H2}) - \ln LR_{H2} = -0.0157t$$

$$\ln \left(\frac{LR_{H2} - 0.0157\ V_{H2}}{LR_{H2}}\right) = -0.0157t$$

$$\frac{LR_{H2} - 0.0157\ V_{H2}}{LR_{H2}} = e^{-0.0157t}$$

solving for V_{H2}

$$-0.0157\ V_{H2} = LR_{H2}\, e^{-0.0157} - LR_{H2}$$

$$V_{H2} = \frac{LR_{H2}\left(1 - e^{-0.0157t}\right)}{0.0157} \qquad (1)$$

Equation (1) describes the volumetric concentration of hydrogen with time during firing. Typically, the concentration is described in parts per million (ppm). For example, if a leak rate of H_2 of a magnitude of 100,000 SCIM (standard cubic inches per minute) exists during a 20 second firing, the concentration would be determined as follows:

$$LR_{H2} = 100{,}000\ \text{SCIM} = 0.96\ \frac{ft^3}{sec}$$

$$V_{H2} = \frac{0.96\left[1 - e^{(-0.0157)(20.0)}\right]}{0.0157}$$

$$V_{H2} = 16.5\ ft$$

$$H_2\ \text{Concentration} = \frac{V_{H2}}{V_{compartment}} = \frac{16.5}{4550.0} = 3.626 \times 10^{-3}$$

In PPM

$$H_2\ \text{Concentration} = \left(3.626 \times 10^{-3}\right)\left(1.0 \times 10^{6}\right)$$

$$H_2\ \text{Concentration} = 3626\ ppm$$

Therefore, at the end of a 20 second firing, with a constant leak of 100,000 SCIM, the H_2 concentration in the aft compartment should be 3626 ppm.

The decay of H_2 after firing can also be derived. This, of course, assumes that at the end of firing, the leak stops. After firing at elapsed time t_e;

$$\frac{dV_{H2}}{dt_e} = \text{Volumetric Rate } H_2 \text{ in} - \text{Volumetric Rate } H_2 \text{ out}$$

$$\text{Volumetric Rate } H_2 \text{ in} = 0$$

$$\text{Volumetric Rate } H_2 \text{ out} = \left(\frac{V_{H2}}{4550}\right)\left(\frac{300 \text{ lb/min}}{.07 \frac{\text{lb}}{\text{ft}^3}}\right)\left(\frac{\text{min}}{60 \text{ sec}}\right)$$

$$\text{Volumetric Rate } H_2 \text{ out} = 0.0157\ V_{H2}$$

therefore,

$$\frac{dV_{H2}}{dt_e} = -0.0157\ V_{H2}$$

$$\frac{dV_{H2}}{V_{H2}} = -0.0157\ dt_e$$

$$\ln V_{H2} = -0.0157\ t_e + c$$

at the end of firing, $t_e = 0$, $V_{H2} = (V_{H2})_{max}$ where $(V_{H2})_{max}$ is determined from equation (1) at t = 20 sec., end of firing.

then,

$$c = \ln (V_{H2})_{max}$$

and,

$$\ln (V_{H2}) = \ln (V_{H2})_{max} - 0.0157\ t_e$$

$$\ln\left[\frac{V_{H2}}{(V_{H2})_{max}}\right] = -0.0157\ t_e$$

$$V_{H2} = (V_{H2})_{max}\ e^{-0.0157\ t_e}$$

to equate to time t, from the beginning of the firing,

let t_f = firing duration

then,

$$t_e = t - t_f$$

and,

$$V_{H2} = (V_{H2})_{max}\, e^{-0.0157\,(t - t_f)} \qquad (2)$$

Therefore, for a flight readiness firing, the transient volume of hydrogen in the Orbiter aft compartment can be described as follows:

$$V_{H2} = \frac{LR_{H2}\left(1 - e^{-0.0157\,t}\right)}{0.0157},\ 0 \le t \le t_f$$

$$V_{H2} = (V_{H2})_{max}\, e^{-0.0157(t - t_f)},\ t_f \le t < \alpha$$

Equation (2) describes the transient decay of H_2 after firing, assuming the leak stops at engine shutdown, and the purge continues at a constant value throughout time. Using the example given above for the transient concentration during firing, $(V_{H2})_{max}$ = 3626 ppm, and the volume of H_2, V_{H2} = 16.5 ft_3 at t = 20. To find the concentration of H_2 at t = 100 sec., equation (2) can be used as follows:

$$V_{H2} = 16.5\, e^{-0.0157(t - t_f)}$$

$$V_{H2} = 16.5\, e^{-0.0157(100 - 20)}$$

$$V_{H2} = 4.7\ ft^3$$

$$H_2 \text{ Concentration} = \left(\frac{4.7}{4550}\right)\left(10^6\right) = 1033 \text{ ppm}$$

IV. Presentation and Discussion of Results

The formulations given above have been programmed and the transient concentration of hydrogen has been plotted for parametric leaks, during a 20 second firing. These calculations, while fairly simple and straight forward, have been quite useful in determining "rough order-of-magnitude" leak rates during the Shuttle program. The methods can be used for other compartments, given that the simplifying assumptions are realistic. It is interesting to note that leak rates can be estimated from knowledge of either the concentration increase or decay with time.

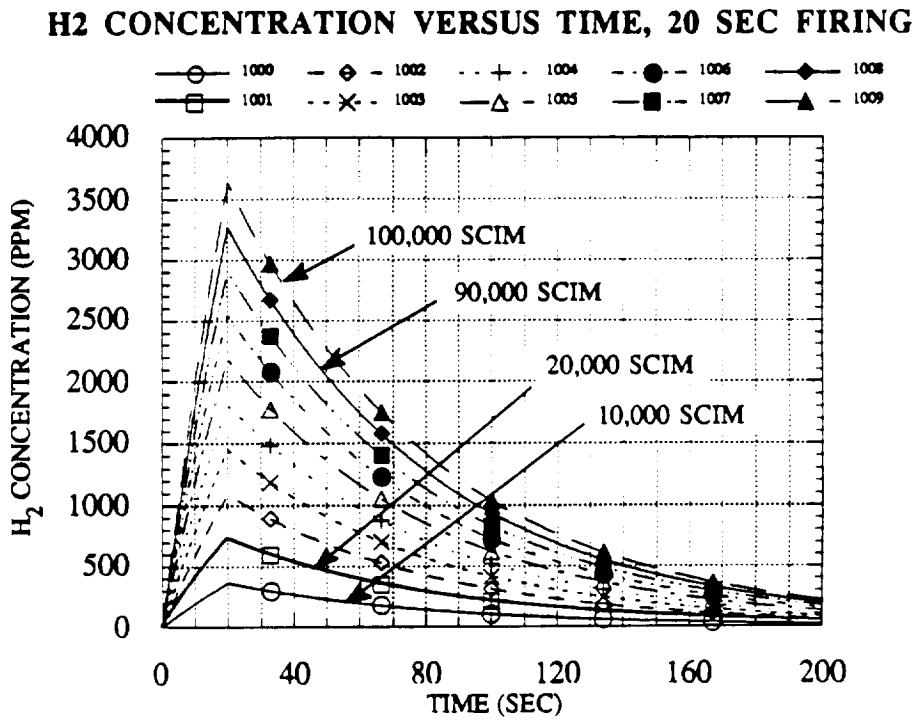


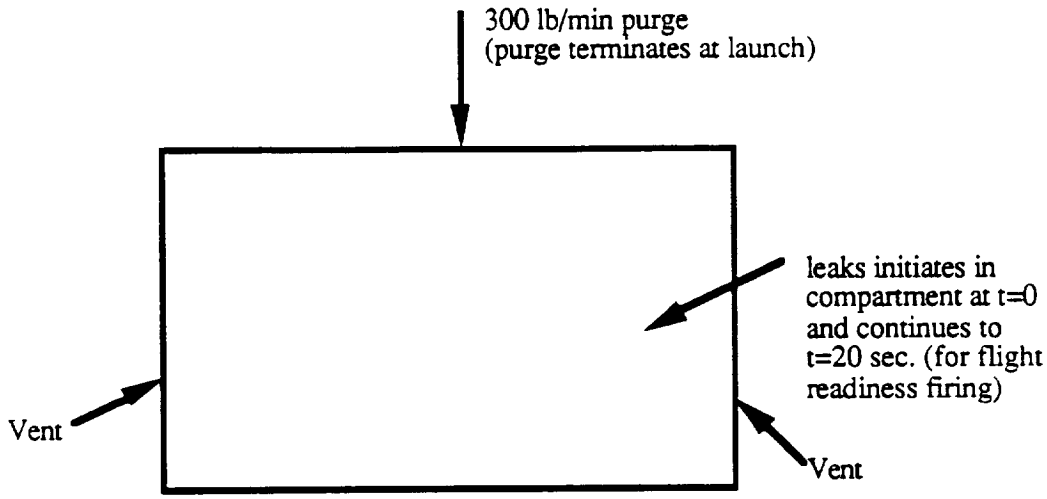
Figure 2. Flight Readiness Firing Simulation

V. Numerical Solution

A. Statement of the Problem

Because the problem discussed above can be complicated by leakage of both hydrogen and oxygen, and because simulation of leaks during assent is of interest, a numerical model was generated using the SINDA code as a programming aid. The model utilizes the ideal gas law and calculates concentrations based upon mass fractions. The model is capable of solving the simple flight readiness firing program discussed above, but is also capable of simulating mixture gas concentrations during flight. Mass concentrations of nitrogen, oxygen, and hydrogen are tracked numerically. Flight simulations require the ascent pressure profile versus time, and also require the knowledge of vent areas for the aft compartment.

B. Schematic.



C. Given

1. N_2 Purge Rate 300 lb/min prior to flight
2. N_2 Purge Rate 0 during flight
3. Compartment Volume, 4550 ft^3
4. Compartment Vent Area, 312 in^2
5. Ascent Pressure Profile given versus time

D. Find

1. Numerical Simulation of Flight Readiness firing discussed above
2. Parametric (transient) H_2 gas concentrations during flight
3. Simulation of oxygen leakage during flight

VI. Formulation of the Problem

A. Simplifying Assumptions

1. The compartment mixture is uniform

B. Initial/Boundary Conditions

1. Prior to Flight Purge Rate = 300 lb/min
2. During flight Purge Rate = 0 lb/min
3. Ambient Pressure initially = 14.7 psia
4. Ascent Pressure Profile given versus time

VII. Mathematical Formulation (Numerical Modal)

A. Presentation of Results

The model was run for several different boundary conditions to simulate different operating conditions. Shown in figure 3 is a transient response for a flight readiness firing, similar to the previous discussion. Figure 4 shows the transient response of H_2 concentration during ascent for a constant leak rate of hydrogen.

Note that for a constant leak rate, with no purge, the H_2 concentration must eventually approach 100%. While flammability is normally a concern for concentrations above 4% H_2, flame propagation is not typically considered a problem below 1 psia. This compartment pressure occurs prior to 100 seconds into flight (typical ascent profile). The flammability limit versus flight time is also shown on figure 4. Figure 5 shows an ascent simulation of both oxygen and hydrogen leaks. Again, the period of interest is prior to 100 seconds flight time.

IX. Closing Comments

This example is a very good illustration of the power of simplified hand calculations, and the extensions possible through numerical analysis. This particular problem, H_2 leakage, has been and continues to be a major concern for the Shuttle program.

X. References

Spiegel, Murray R., Applied Differential Equation, 1958, Prentice Hall, Inc., New Jersey, pp. 89-91.

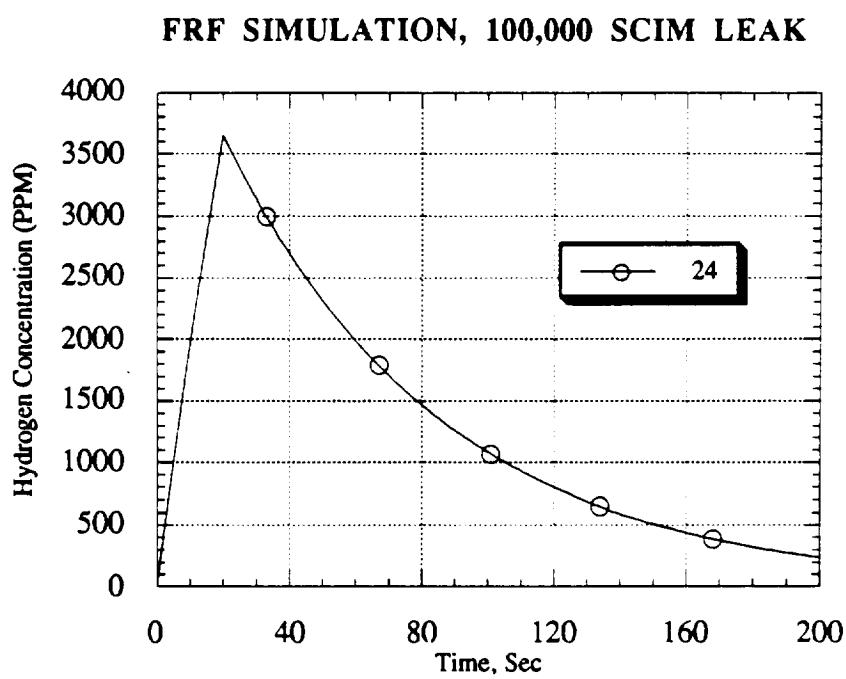


Figure 3. Numerical Results for Flight Readiness Firing

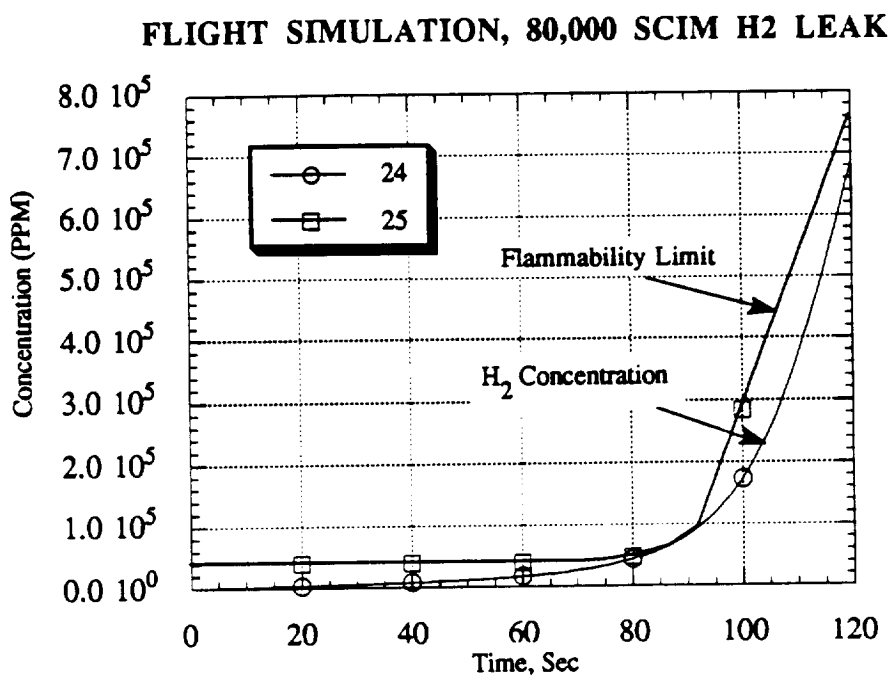


Figure 4. Hydrogen Concentration Versus Flight Time Compared To Flammability Limit

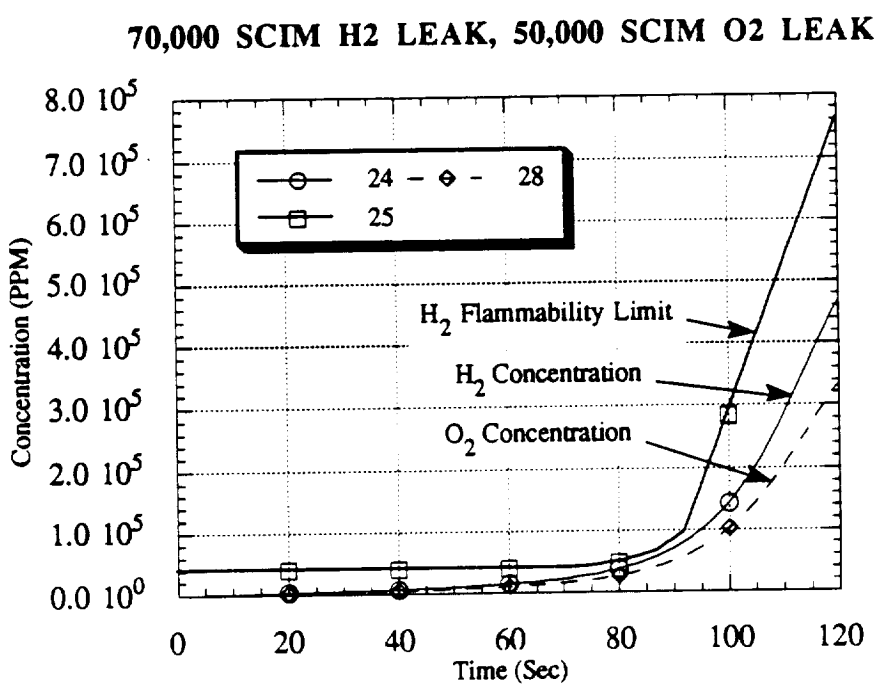


Figure 5. Simultaneous Simulation of H_2 and O_2 Leakage

Numerical Model Listing, Flight Readiness Firing Simulation

```
BCD 3THERMAL LPCS
BCD 9 AFT COMPARTMENT PURGE/VENT/HAZ GAS MODEL
END
BCD 3NODE DATA
    1000,70.0,1.0 $DUMMY NODE
    -1,20.0,1.0 $MOL FRACTION O2
    -2, 0.0,1.0 $MOL FRACTION H2
    -3,80.0,1.0 $MOL FRACTION N2
    -4,2116.0,1.0 $INTERNAL PRESSURE
    -5,2116.0,1.0 $EXTERNAL PRESSURE
    -6,0.,0.0       $DELTA P
    -7,0.0,1.0    $CAVITY TOTAL DENSITY
    -11,0.0,1.0   $N2 FLOW LBM/MIN
    -12,0.0,1.0   $H2 FLOW SCIM
    -13,0.0,1.0   $O2 FLOW SCIM
    -20,0.0,1.0   $TOTAL FLOW OUT LBM/MIN
    -21,0.0,1.0   $N2 FLO OUT
    -22,0.0,1.0   $H2 FLO OUT LBM/MIN
    -23,0.0,1.0   $O2 FLO OUT LBM/MIN
    -24,0.0,1.0   $ PPP H2
    -25,0.0,1.0 $ FLAM LIM
    -26,0.0,1.0 $ %FLAM LIM
END
BCD 3CONDUCTOR DATA
    1000,1000,1,10.0 $DUMMY CONNECTOR
END
BCD 3CONSTANTS DATA
    DTIMEH,0.01
    TIMEO,0.0
    DAMPA,0.5
    DAMPD,0.5
    DRLXCA= 0.001
    ARLXCA= 0.001
    NLOOP= 50
    NDIM=250
    DTIMEI= 0.01
    OUTPUT= 1.0
    TIMEND= 210.
    JTEST,0     $ OUTPUT FLAG
    KTEST,0     $
    8,530.      $ H2 TEMP. (DEG R)
    15, 00.0E-6    $ INITIAL H2 CONCONCENTRATION
GEN 101,60,1, 0.0 $ DUMMY VARIABLES
END
BCD 3ARRAY DATA
    1 $TIME VS EXT PRESS (STS14) PSF
    0.,2110.
    1000.,2110.
    END
    6     $TIME VS. AFT COMPARTMENT TEMP
    0.000,  70.0
    1000.000,  70.0
    END
    2     $N2 PURGE
    0.0,300.,1000.0,300.
    END
    3     $H2 LEAK RATE (SCIM)
    0.0,0.0,9.999,0.0
    10.0,100000.,30.,100000.,30.01,0.,1000.,0.
    END
```

```
          4    $O2 LEAK RATE (SCIM)
          0.,0.,300.,0.
          END
          10   $ H2 FLAM LIMIT
          0.,40000.,72.,40000.,76.,42500.,78.,46000.,81.,50000.
                  87.,65000.,92.,95000.,130.,1000000.
          END
          11   $ TIME VS. PRESS
          0.,2110.
          1000.,2110.
          END
       END
       BCD 3EXECUTION
C
F      OPEN(3,FILE="AFT.PLT",STATUS="UNKNOWN")
F      WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F    2 FORMAT(I6/,50(I6,31X,I6/))
C
F      CALL FWDBKL
C
       END
       BCD 3VARIABLES 1
C
M      EQUIVALENCE (XK101,RHOB),(XK102,CPO2),(XK103,CPN2)
M      EQUIVALENCE (XK104,CPH2),(XK105,CVO2),(XK106,CVN2)
M      EQUIVALENCE (XK107,CVH2),(XK108,RO2),(XK109,RN2)
M      EQUIVALENCE (XK110,RH2),(XK111,RAIR),(XK112,TN2)
M      EQUIVALENCE (XK113,TO2),(XK114,TH2),(XK115,V),(XK116,CD)
M      EQUIVALENCE (XK117,PEXT),(XK118,PII),(XK119,PIO)
M      EQUIVALENCE (XK120,PEXTO),(XK121,XH2I),(XK122,XO2I)
M      EQUIVALENCE (XK159,XN2I),(XK123,YMN2O),(XK124,YMO2O)
M      EQUIVALENCE (XK125,YMH2O),(XK126,YMGO),(XK127,CVBMB)
M      EQUIVALENCE (XK128,TB),(XK129,TBO),(XK130,RBMG),(XK131,RB)
M      EQUIVALENCE (XK132,XCH2X),(XK133,VH2X),(XK134,TAFT)
M      EQUIVALENCE (XK135,WN2I),(XK136,WH2I),(XK137,WO2I)
M      EQUIVALENCE (XK138,AEXIT),(XK139,XP2),(XK140,WBO),(XK141,WBOM)
M      EQUIVALENCE (XK142,YMG),(XK143,WRATIO),(XK144,WN2O)
M      EQUIVALENCE (XK145,WH2O),(XK146,WO2O),(XK147,XMG)
M      EQUIVALENCE (XK148,YMFN2),(XK149,YMFH2),(XK150,YMFO2)
M      EQUIVALENCE (XK151,CPBWB),(XK152,PI),(XK153,CVBMBO)
M      EQUIVALENCE (XK154,XN2),(XK155,XH2),(XK156,XO2),(XK157,VH2IX)
M      EQUIVALENCE (XK158,VH2OX)
C
M      CALL D1DEG1(TIMEO,A10,T25)
M      T26=T25/10000.
M      IF (TIMEO.NE.0.0) GO TO 10
C
C INITIALIZE VARIABLES
C
F      RHOB=.050
F      CPO2=.219
F      CPN2=.248
F      CPH2=3.42
F      CVO2=.156
F      CVN2=.177
F      CVH2=2.43
F      RO2=1545.4/32.
F      RN2=1545.4/28.
F      RH2=1545.4/2.
F      RAIR=1545.4/29.
F      TN2=530.
F      TO2=530.
M      TH2=XK8
F      V=4550.0
```

```
F       CD=0.6
M       PEXT=A(1+2)
F       PII=14.696*144
F       PIO=PEXT
F       PEXTO=PEXT
M       XH2I=XK15
F       XO2I=00.E-6
F       XN2I=1-XH2I-XO2I
F       YMN2O=XN2I*PIO*V/RN2/TN2
F       YMO2O=XO2I*PIO*V/RO2/TO2
F       YMH2O=XH2I*PIO*V/RH2/TH2
F       YMGO=YMN2O+YMO2O+YMH2O
F       CVBMB=YMO2O*CVO2+YMH2O*CVH2+YMN2O*CVN2
F       TB=(CVN2*YMN2O*TN2+CVH2*YMH2O*TH2+CVO2*YMO2O*TO2)/CVBMB
F       TBO=TB
F       RBMG=RH2*YMH2O+RN2*YMN2O+RO2*YMO2O
F       RB=RBMG/YMGO
F       XCH2X=XH2I
F       VH2X=XCH2X*V
F 10    CONTINUE
M       CALL D1DEG1(TIMEO,A6,TAFT)
F       TAFT=TAFT+459.6
M       CALL D1DEG1(TIMEO,A1,PEXT)
M       CALL D1DEG1(TIMEO,A2,WN2I)
F       WN2I=WN2I/60.
C
C LOOK UP LEAK RATE
C
M 11    CALL D1DEG1(TIMEO,A3,WH2I)
F       WH2I=WH2I*PII/RH2/530./1728./60.
M       CALL D1DEG1(TIMEO,A4,WO2I)
F       WO2I=WO2I*PII/RO2/530./1728./60.
F       AEXIT=(285.0+27.0)/144.
F       XP2=PEXT/PIO
C
C CALCULATE FLOWS
C
F 12    WBO=CD*AEXIT*SQRT(ABS(64.4*RHOB*PIO*1.4/.4*(XP2**(2./1.4)
F     1 -XP2**(2.4/1.4))))
F       IF (PIO.LE.PEXT) WBO=-WBO
F       WBOM=CD*AEXIT*PIO*SQRT(32.2*1.4/RB*(2./2.4)**(2.4/.4)/TAFT)
C
C CHECK FOR CHOKED FLOW CONDITIONS
C
F       IF (XP2.LE.0.5283) WBO=WBOM
F       ICHPT=0
F       GO TO 14
F 13    CONTINUE
F       YMG=PEXT*V/RB/TAFT
F       WBO=(YMGO-YMG)/DTIMEU
F       IF(ICHPT.EQ.1)STOP
F       ICHPT=1
F 14    CONTINUE
F       WRATIO=WBO/WBOM
F       WN2O=WBO*YMFN2
F       WH2O=WBO*YMFH2
F       WO2O=WBO*YMFO2
C
C DETERMINE NEW CONCENTRATIONS
C
F       YMG=YMGO+DTIMEU*(WN2I+WH2I+WO2I-WBO)
F       YMN2=YMN2O+DTIMEU*(WN2I-WN2O)
F       YMH2=YMH2O+DTIMEU*(WH2I-WH2O)
F       YMO2=YMO2O+DTIMEU*(WO2I-WO2O)
```

```
F       XMG=YMN2+YMH2+YMO2
F       YMFN2=YMN2/YMG
F       YMFH2=YMH2/YMG
F       YMFO2=YMO2/YMG
F       CPBWB=WO2I*CPO2+WN2I*CPN2+WH2I*CPH2
F       CVBMB=YMO2*CVO2+YMH2*CVH2+YMN2*CVN2
F       RBMG=RH2*YMH2+RN2*YMN2+RO2*YMO2
F       RB=RBMG/YMG
F       TB=(CVN2*YMN2*TN2+CVH2*YMH2*TH2+CVO2*YMO2*TO2)/CVBMB
F       PI=RBMG*TAFT/V
F       RHOB=PI/RB/TAFT
F       XP2=PI-PEXT
F       IF(PEXT.LT.PEXTO.AND.PI+1.E-2.LT.PEXT) GO TO 13
F       YMGO=YMG
F       PIO=PI
F       PEXTO=PEXT
F       CVBMBO=CVBMB
F       YMN2O=YMN2
F       YMO2O=YMO2
F       YMH2O=YMH2
F       XN2=YMFN2*RN2/RB
F       XH2=YMFH2*RH2/RB
F       XO2=YMFO2*RO2/RB
C
M       CALL D1DEG1(TIMEO,A3,WH2I)
F       VH2IX=WH2I/1728/60*DTIMEU*PII/PEXT*TAFT/530.
F       VH2OX=VH2IX*XCH2X
F       VH2X=VH2X+VH2IX-VH2OX
F       XCH2X=VH2X/V
F       IF(XO2.LE.0.0) XO2=1.E-6
M       T1=ALOG10(100.*XO2)
F       IF(XH2.LE.0.0) XH2=1.E-6
M       T2=ALOG10(100.*XH2)
F       IF(XN2.LE.0.0) XN2=1.E-6
M       T3=ALOG10(100.*XN2)
M       T4=(PEXT/144.)
M       IF(PEXT.LE.0.0) PEXT=A(1+2)
M       T5=ALOG10(PEXT/144.)
M       T6=(PI-PEXT)/144.
M       T7=100.*XH2
M       T24=T7*10000.
M       T11=100.*XO2
M       T12=100.*XN2
M       T20=PI/144.
M       IF(PI.LE.0.0) PI=A(1+2)
M       T21=ALOG10(PI/144)
M       T22=WBO*60.
M       T23=100.*XCH2X
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
F       TIMEN=TIMEN-10.0
F       TIMEO=TIMEO-10.0
F       TIMEM=TIMEM-10.0
C
F       WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F     1 FORMAT(E10.3/,50(7F12.3/))
```

```
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $          8H RELXCC(I6,2H)=1PE12.5)
F       NLINE=NLINE+4
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       NLINE=NLINE+1
F       J=1
F       L=3
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 6
F       J=L+1
F       L=L+3
F       GO TO 5
F 6     CONTINUE
F       TIMEN=TIMEN+10.0
F       TIMEO=TIMEO+10.0
F       TIMEM=TIMEM+10.0
        END
        BCD 3END OF DATA
```

Numerical Model Listing, Flight Simulation

```
BCD 3THERMAL LPCS
 BCD 9 AFT COMPARTMENT FLIGHT SIMULATION
 END
 BCD 3NODE DATA
     1000,70.0,1.0 $DUMMY NODE
     -1,20.0,1.0 $MOL FRACTION O2
     -2, 0.0,1.0 $MOL FRACTION H2
     -3,80.0,1.0 $MOL FRACTION N2
     -4,2116.0,1.0 $INTERNAL PRESSURE
     -5,2116.0,1.0 $EXTERNAL PRESSURE
     -6,0.,0.0       $DELTA P
     -7,0.0,1.0    $CAVITY TOTAL DENSITY
     -11,0.0,1.0   $N2 FLOW LBM/MIN
     -12,0.0,1.0   $H2 FLOW SCIM
     -13,0.0,1.0   $O2 FLOW SCIM
     -20,0.0,1.0   $TOTAL FLOW OUT LBM/MIN
     -21,0.0,1.0   $N2 FLO OUT
     -22,0.0,1.0   $H2 FLO OUT LBM/MIN
     -23,0.0,1.0   $O2 FLO OUT LBM/MIN
     -24,0.0,1.0   $ PPP H2
     -25,0.0,1.0 $ FLAM LIM
     -26,0.0,1.0 $ %FLAM LIM
     -28,0.0,1.0 $ PPM O2
 END
 BCD 3CONDUCTOR DATA
     1000,1000,1,10.0 $DUMMY CONNECTOR
 END
 BCD 3CONSTANTS DATA
     DTIMEH,0.05
     TIMEO,0.0
     DAMPA,0.5
     DAMPD,0.5
     DRLXCA= 0.001
     ARLXCA= 0.001
     NLOOP= 50
     NDIM=250
     DTIMEI= 0.05
     OUTPUT= 1.0
     TIMEND= 120.
     JTEST,0     $ OUTPUT FLAG
     KTEST,0     $
     8,530.      $ H2 TEMP. (DEG R)
     15, 00.0E-6    $ INITIAL H2 CONCONCENTRATION
 GEN 101,60,1, 0.0 $ DUMMY VARIABLES
 END
 BCD 3ARRAY DATA
     1 $TIME VS EXT PRESS (STS14) PSF
     0.,2110.
     5.,2096.
     10.,2045.
     15.,1956.
     20.,1832.
     25.,1677.
     30.,1502.
     35.,1317.
     40.,1133.
     45.,955.
     50.,787.
```

```
            55.,634.
            60.,495.
            65.,373.
            70.,269.
            75.,186.
            80.,124.
            85.,80.8
            90.,51.42
            95.,32.25
            100.,19.95
            105.,12.25
            110.,7.51
            115.,4.63
            120.,2.91
            124.91,1.88
            130.,1.2
            END
            6    $TIME VS. AFT COMPARTMENT TEMP(STS6 DB-V38T9272A)
             -10.000,  74.435,   -5.000,  74.435,     .000,  77.863
               5.000,  74.531,   10.000,  76.078,  15.000,  74.435
              20.000,  74.047,   25.000,  69.302,  30.000,  67.458
              35.000,  63.956,   40.000,  58.782,  45.000,  53.488
              50.000,  49.749,   55.000,  46.390,  60.000,  51.523
              65.000,  55.061,   70.000,  56.923,  75.000,  54.323
              80.000,  51.621,   85.000,  53.391,  90.000,  55.158
              95.000,  56.923,  100.000,  58.685, 105.000,  60.445
             110.000,  62.202,  115.000,  63.956
            END
            2    $N2 PURGE
            -20.,300.,0.,0.,300.,0.
            END
            3    $H2 LEAK RATE (SCIM)
            0.,70000.,300.,70000.
            END
            4    $O2 LEAK RATE (SCIM)
            0.,50000.,300.,50000.
            END
            10   $ H2 FLAM LIMIT
            0.,40000.,72.,40000.,76.,42500.,78.,46000.,81.,50000.
                    87.,65000.,92.,95000.,130.,1000000.
            END
            11   $ TIME VS. PRESS
            0.,2110.,5.,2096.,10.,2045.
            15.,1956.,20.,1832.,25.,1677.
            30.,1502.,35.,1317.,40.,1133.
            45.,955.,50.,787.,55.,634.,60.,495.
            65.,373.,70.,269.,75.,186.,80.,124.
            85.,80.8,90.,51.42,95.,32.25,100.,19.95
            105.,12.25,110.,7.51,115.,4.63,120.,2.91
            124.91,1.88,130.,1.2
            END
        END
        BCD 3EXECUTION
C
F       OPEN(3,FILE="EMLFLT.PLT",STATUS="UNKNOWN")
F       WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F     2 FORMAT(I6/,50(I6,31X,I6/))
C
F       CALL FWDBKL
C
        END
        BCD 3VARIABLES 1
C
M       EQUIVALENCE (XK101,RHOB),(XK102,CPO2),(XK103,CPN2)
```

```
M       EQUIVALENCE (XK104,CPH2),(XK105,CVO2),(XK106,CVN2)
M       EQUIVALENCE (XK107,CVH2),(XK108,RO2),(XK109,RN2)
M       EQUIVALENCE (XK110,RH2),(XK111,RAIR),(XK112,TN2)
M       EQUIVALENCE (XK113,TO2),(XK114,TH2),(XK115,V),(XK116,CD)
M       EQUIVALENCE (XK117,PEXT),(XK118,PII),(XK119,PIO)
M       EQUIVALENCE (XK120,PEXTO),(XK121,XH2I),(XK122,XO2I)
M       EQUIVALENCE (XK159,XN2I),(XK123,YMN2O),(XK124,YMO2O)
M       EQUIVALENCE (XK125,YMH2O),(XK126,YMGO),(XK127,CVBMB)
M       EQUIVALENCE (XK128,TB),(XK129,TBO),(XK130,RBMG),(XK131,RB)
M       EQUIVALENCE (XK132,XCH2X),(XK133,VH2X),(XK134,TAFT)
M       EQUIVALENCE (XK135,WN2I),(XK136,WH2I),(XK137,WO2I)
M       EQUIVALENCE (XK138,AEXIT),(XK139,XP2),(XK140,WBO),(XK141,WBOM)
M       EQUIVALENCE (XK142,YMG),(XK143,WRATIO),(XK144,WN2O)
M       EQUIVALENCE (XK145,WH2O),(XK146,WO2O),(XK147,XMG)
M       EQUIVALENCE (XK148,YMFN2),(XK149,YMFH2),(XK150,YMFO2)
M       EQUIVALENCE (XK151,CPBWB),(XK152,PI),(XK153,CVBMBO)
M       EQUIVALENCE (XK154,XN2),(XK155,XH2),(XK156,XO2),(XK157,VH2IX)
M       EQUIVALENCE (XK158,VH2OX)
C
CF       WRITE(6,5557)YMFO2
CF5557   FORMAT(1X,F15.7)
C
M       CALL D1DEG1(TIMEO,A10,T25)
M       T26=T25/10000.
M       IF (TIMEO.NE.0.0) GO TO 10
C
C INITIALIZE VARIABLES
C
F       RHOB=.050
F       CPO2=.219
F       CPN2=.248
F       CPH2=3.42
F       CVO2=.156
F       CVN2=.177
F       CVH2=2.43
F       RO2=1545.4/32.
F       RN2=1545.4/28.
F       RH2=1545.4/2.
F       RAIR=1545.4/29.
F       TN2=530.
F       TO2=530.
M       TH2=XK8
F       V=4550.0
F       CD=0.6
M       PEXT=A(1+2)
F       PII=14.696*144
F       PIO=PEXT
F       PEXTO=PEXT
M       XH2I=XK15
F       XO2I=00.E-6
F       XN2I=1-XH2I-XO2I
F       YMN2O=XN2I*PIO*V/RN2/TN2
F       YMO2O=XO2I*PIO*V/RO2/TO2
F       YMH2O=XH2I*PIO*V/RH2/TH2
F       YMGO=YMN2O+YMO2O+YMH2O
F       CVBMB=YMO2O*CVO2+YMH2O*CVH2+YMN2O*CVN2
F       TB=(CVN2*YMN2O*TN2+CVH2*YMH2O*TH2+CVO2*YMO2O*TO2)/CVBMB
F       TBO=TB
F       RBMG=RH2*YMH2O+RN2*YMN2O+RO2*YMO2O
F       RB=RBMG/YMGO
F       XCH2X=XH2I
F       VH2X=XCH2X*V
F 10    CONTINUE
M       CALL D1DEG1(TIMEO,A6,TAFT)
```

```
F       TAFT=TAFT+459.6
M       CALL D1DEG1(TIMEO,A1,PEXT)
M       CALL D1DEG1(TIMEO,A2,WN2I)
F       WN2I=WN2I/60.
C
C LOOK UP LEAK RATE
C
M 11    CALL D1DEG1(TIMEO,A3,WH2I)
F       WH2I=WH2I*PII/RH2/530./1728./60.
M       CALL D1DEG1(TIMEO,A4,WO2I)
F       WO2I=WO2I*PII/RO2/530./1728./60.
F       AEXIT=(285.0+27.0)/144.
F       XP2=PEXT/PIO
C
C CALCULATE FLOWS
C
F 12    WBO=CD*AEXIT*SQRT(ABS(64.4*RHOB*PIO*1.4/.4*(XP2**(2./1.4)
F     1 -XP2**(2.4/1.4))))
F       IF (PIO.LE.PEXT) WBO=-WBO
F       WBOM=CD*AEXIT*PIO*SQRT(32.2*1.4/RB*(2./2.4)**(2.4/.4)/TAFT)
C
C CHECK FOR CHOKED FLOW CONDITIONS
C
F       IF (XP2.LE.0.5283) WBO=WBOM
F       ICHPT=0
F       GO TO 14
F 13    CONTINUE
F       YMG=PEXT*V/RB/TAFT
F       WBO=(YMGO-YMG)/DTIMEU
F       IF(ICHPT.EQ.1)STOP
F       ICHPT=1
F 14    CONTINUE
F       WRATIO=WBO/WBOM
C
CF       WRITE(6,5556)WN2O,WH2O,WO2O
C
F       WN2O=WBO*YMFN2
F       WH2O=WBO*YMFH2
F       WO2O=WBO*YMFO2
C
CF       WRITE(6,5556)WN2O,WH2O,WO2O
C
C DETERMINE NEW CONCENTRATIONS
C
CF       WRITE(6,5557)YMO2
F       YMG=YMGO+DTIMEU*(WN2I+WH2I+WO2I-WBO)
F       YMN2=YMN2O+DTIMEU*(WN2I-WN2O)
F       YMH2=YMH2O+DTIMEU*(WH2I-WH2O)
F       YMO2=YMO2O+DTIMEU*(WO2I-WO2O)
CF       WRITE(6,5557)YMO2
F       XMG=YMN2+YMH2+YMO2
F       YMFN2=YMN2/YMG
F       YMFH2=YMH2/YMG
F       YMFO2=YMO2/YMG
F       CPBWB=WO2I*CPO2+WN2I*CPN2+WH2I*CPH2
F       CVBMB=YMO2*CVO2+YMH2*CVH2+YMN2*CVN2
F       RBMG=RH2*YMH2+RN2*YMN2+RO2*YMO2
F       RB=RBMG/YMG
F       TB=(CVN2*YMN2*TN2+CVH2*YMH2*TH2+CVO2*YMO2*TO2)/CVBMB
F       PI=RBMG*TAFT/V
F       RHOB=PI/RB/TAFT
F       XP2=PI-PEXT
F       IF(PEXT.LT.PEXTO.AND.PI+1.E-2.LT.PEXT) GO TO 13
F       YMGO=YMG
```

```
F       PIO=PI
F       PEXTO=PEXT
F       CVBMBO=CVBMB
F       YMN2O=YMN2
F       YMO2O=YMO2
F       YMH2O=YMH2
F       XN2=YMFN2*RN2/RB
F       XH2=YMFH2*RH2/RB
F       XO2=YMFO2*RO2/RB
CF       WRITE(6,5556)XN2,XH2,XO2
CF       WRITE(6,5556)YMFN2,YMFH2,YMFO2
CF       WRITE(6,5556)RN2,RH2,RO2
F5556   FORMAT(1X,3F16.7)
C
M       CALL D1DEG1(TIMEO,A3,WH2I)
F       VH2IX=WH2I/1728/60*DTIMEU*PII/PEXT*TAFT/530.
F       VH2OX=VH2IX*XCH2X
F       VH2X=VH2X+VH2IX-VH2OX
F       XCH2X=VH2X/V
F       IF(XO2.LE.0.0) XO2=1.E-6
M       T1=ALOG10(100.*XO2)
F       IF(XH2.LE.0.0) XH2=1.E-6
M       T2=ALOG10(100.*XH2)
F       IF(XN2.LE.0.0) XN2=1.E-6
M       T3=ALOG10(100.*XN2)
M       T4=(PEXT/144.)
M       IF(PEXT.LE.0.0) PEXT=A(1+2)
M       T5=ALOG10(PEXT/144.)
M       T6=(PI-PEXT)/144.
M       T7=100.*XH2
M       T24=T7*10000.
M       T28=XO2*1000000.
M       T11=100.*XO2
M       T12=100.*XN2
M       T20=PI/144.
M       IF(PI.LE.0.0) PI=A(1+2)
M       T21=ALOG10(PI/144)
M       T22=WBO*60.
M       T23=100.*XCH2X
C
        END
C
        BCD 3VARIABLES 2
        END
C
        BCD 3OUTPUT CALLS
C
F       DATA HT/4HT   /
C
F       WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F     1 FORMAT(E10.3/,50(7F12.3/))
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
F       J=LNODE+NCSGMN
F       I1=NX(J)
F       IF(J.LE.LNODE)I1=0
F       J=LNODE+NDTMPC
F       I2=NX(J)
F       IF(J.LE.LNODE)I2=0
F       J=LNODE+NARLXC
F       I3=NX(J)
F       IF(J.LE.LNODE)I3=0
F       WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
```

```
F   9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F     $          8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F     $          8H RELXCC(I6,2H)=1PE12.5)
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F       WRITE(6,100)
F 100   FORMAT(1H )
F       J=1
F       L=3
F   5   IF(L.LT.NNT)GO TO 10
F       L=NNT
F  10   WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F       IF(L.EQ.NNT)GO TO 6
F       J=L+1
F       L=L+3
F       GO TO 5
F 6     CONTINUE
        END
        BCD 3END OF DATA
```

CHAPTER 5. N-DIMENSIONAL BRANCHING NETWORKS, 1-DIMENSIONAL FLUID FLOW

SECTION 5: Pressure Balancing, Techniques for Saturated (Two-Phase) Flows

ANALYSIS CODE: SINDA

A common problem encountered by thermal analysts involves a saturated fluid and the potential for two-phase flow. This is especially true in cryogenic systems. Simulation of heat transfer and flow distribution is quite complex and sometimes impractical other than for bulk (average) conditions. The example that follows illustrates simple assumptions and techniques for determining steady state flow distributions in parallel flow passages with unequal flow resistances. These non-uniform flow distributions could be caused by geometry, but in this example are caused by non-uniform heating, to a saturated fluid. The non-uniform heating causes unequal amounts of vapor in the flow, resulting in unequal flow losses and mass flow rates. The simple solution technique is referred to as pressure balancing. Given the downstream pressure, total flow, and heat distribution, the upstream pressure can be determined by iterating until the sum of flows in parallel legs just equals the system total flow (hence pressure balancing). The assumption which allows calculation of fluid properties in the two-phase regime is usually called homogeneity. That is the bulk fluid properties can be calculated as the mass averaged sum of the liquid and vapor properties (based upon fluid quality). These very simple assumptions can lead to understanding of complex flow systems, not necessarily precise simulations, but fundamental understanding of key relationships and variables significantly affecting system response.

I. Identification of the Problem

A. State of the Problem

Consider the flow schematic given below. Saturated fluid flows in 13 parallel passages between two plenums. Heat is added non-uniformly to the fluid in the parallel flow channels. The total flow and heat distribution are given (parametrically). The upstream pressure and local flow rates are calculated. This type of problem could be encountered in a tube and shell heat exchanger.

B. Schematic

Figure 1. Perspective View of Flow Passages

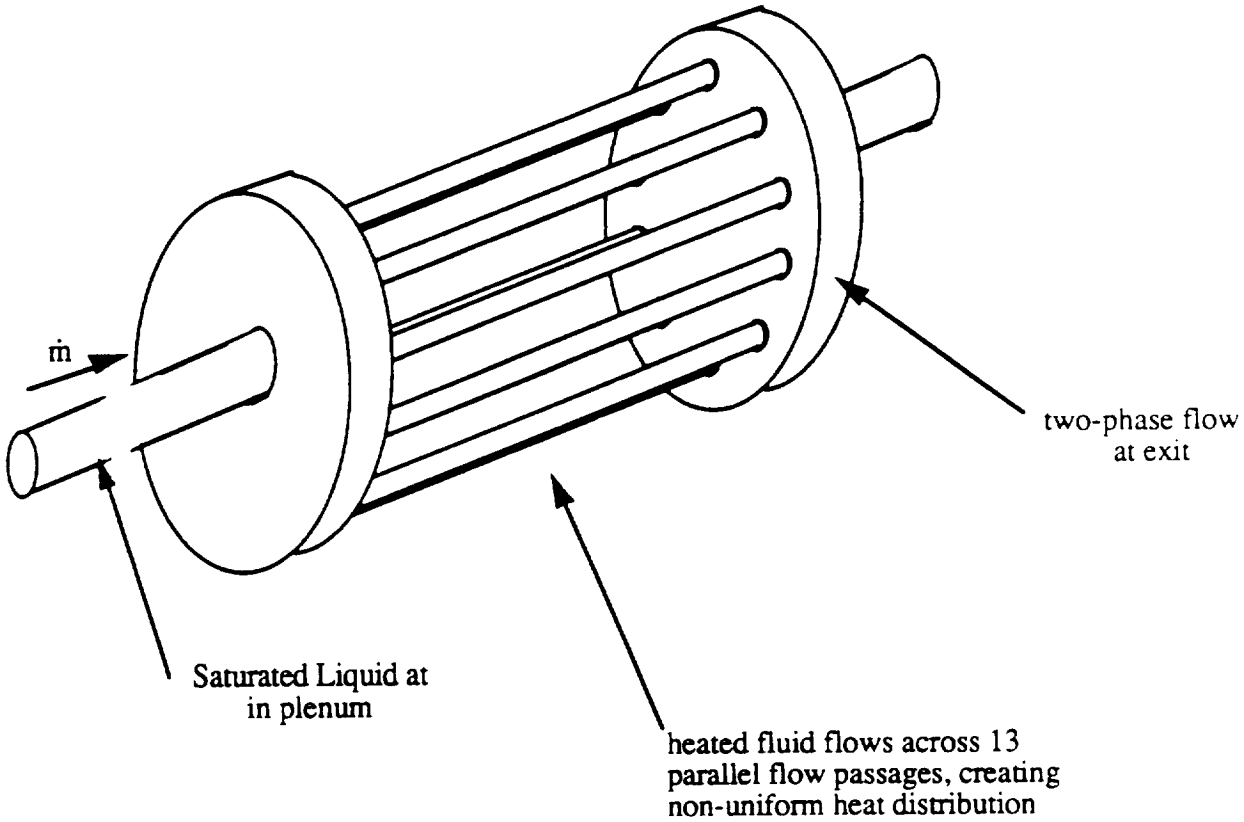
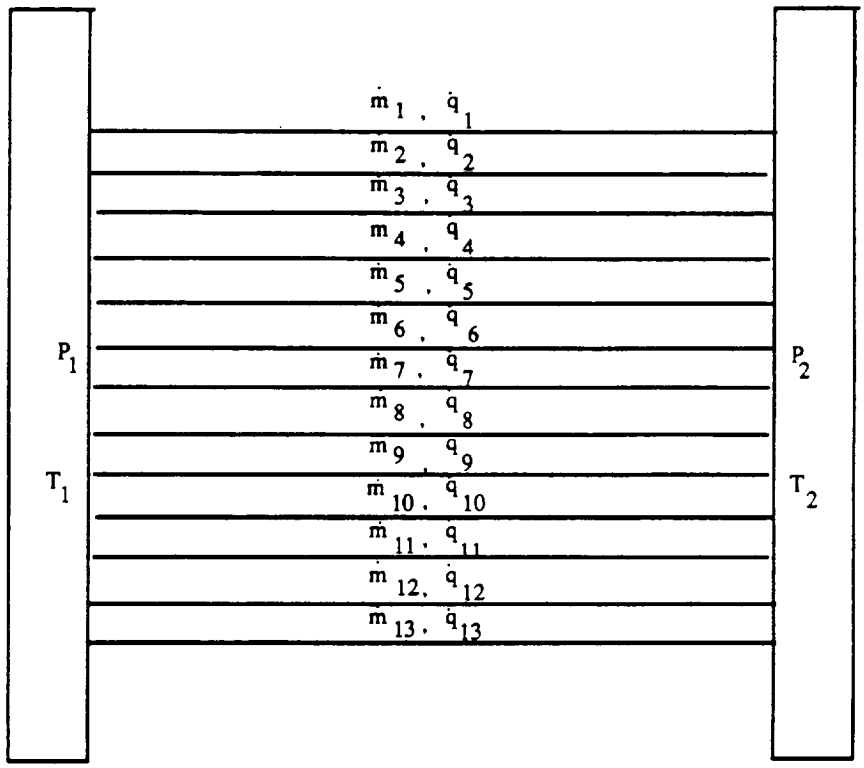


Figure 2. Schematic Representation of Flow Passages



C. Given

1. Flow geometry Area = .016 in^2, Dia = 0.09", Length = .375"
2. Downstream Pressure
3. Total Flow rate
4. Distribution of heat (see figure 2)
5. Fluid is saturated

D. Find

1. The distribution of flow
2. The upstream pressure and total pressure drop
3. The fluid quality in each channel
4. The percent vapor by volume in each channel

II. Formulation of the Problem

A. Simplifying Assumptions

1. Fluid density is calculated via homogeneity

$$v = v_l + x\, v_{lg}$$

B. Initial/Boundary Conditions

1. Downstream Pressure
2. Fluid is saturated
3. Constant/known heat load for each channel

III. Mathematical Formulation

The problem was formulated and programmed using SINDA as a programming aid. The program is versatile and can include parametric variations in flow rate, heat distribution, or pressure. The example given here is for a downstream pressure of 300 psia. As stated earlier, the program, through pressure balancing, the assumption of homogeneous properties, and given distribution of heat, calculates local flows, local quality, and total pressure drop. A very simple iteration scheme is used to solve for the upstream pressure which matches the parametric system flow rate.

IV. Presentation and Discussion of Results

Figure 1 shows the given distribution of heat. Figures 2, 3, and 4 show the calculated local fluid quality, local percent vapor by volume, and local mass flow rate for the parallel flow passages. Here, total flow is varied parametrically.

CIRCUMFERENTIAL VARIATION IN HEATING

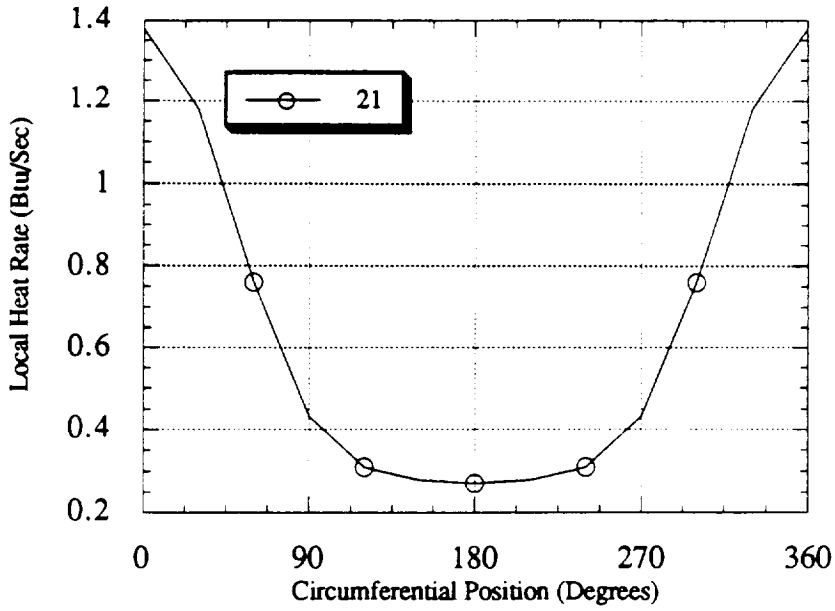


Figure 3. Circumferential Heat Distribution

V. Closing Comments

This simple example illustrates two useful techniques for approaching complex problems. The analyst may at first feel that homogeneous properties are an over simplification of complex physical phenomena. This is true for precise predictions of performance, but for gaining parametric insight into system response, trends, and key variables, this assumption is quite useful. When faced with a seemingly impossible problem, the analyst is advised to proceed based upon simplifying assumptions. The insight gained nearly always leads to more detailed and accurate simulations, identification of appropriate test requirements, or realistic engineering understanding of expected or observed system response.

VI. References

Van Waylen, Gordon J., and Sonntag, Richard E., Fundamentals of Classical Thermodynamics, Copyright - 1973, Johy Wiley and Sons, Inc., pp. 52-58

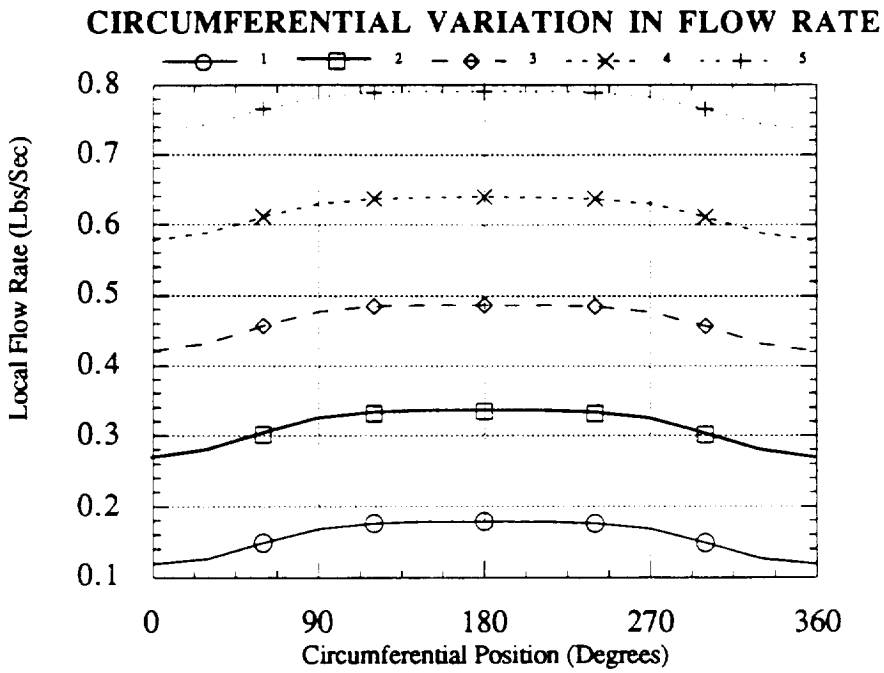


Figure 4. Local Flow Rate Variation

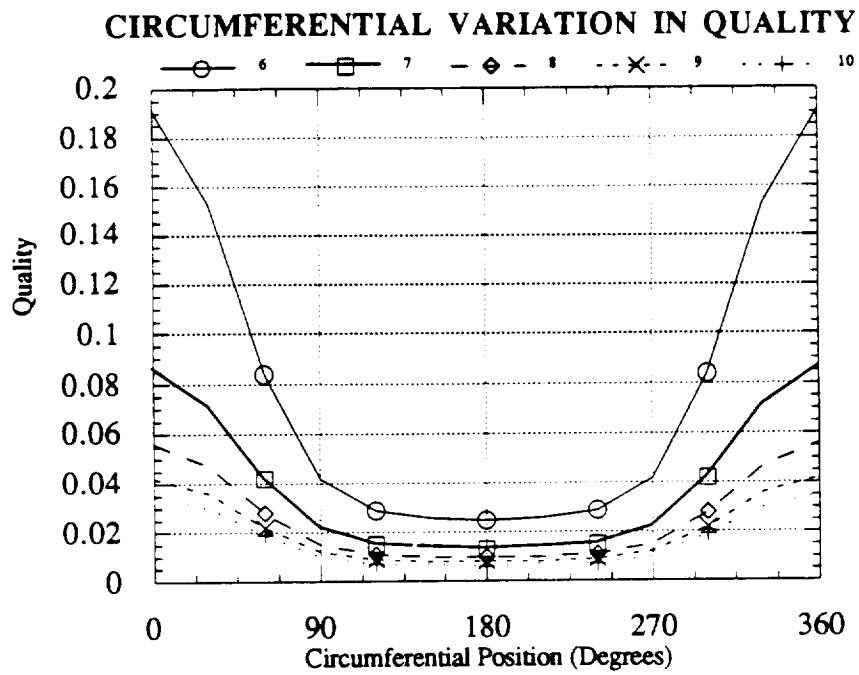


Figure 5. Local Quality

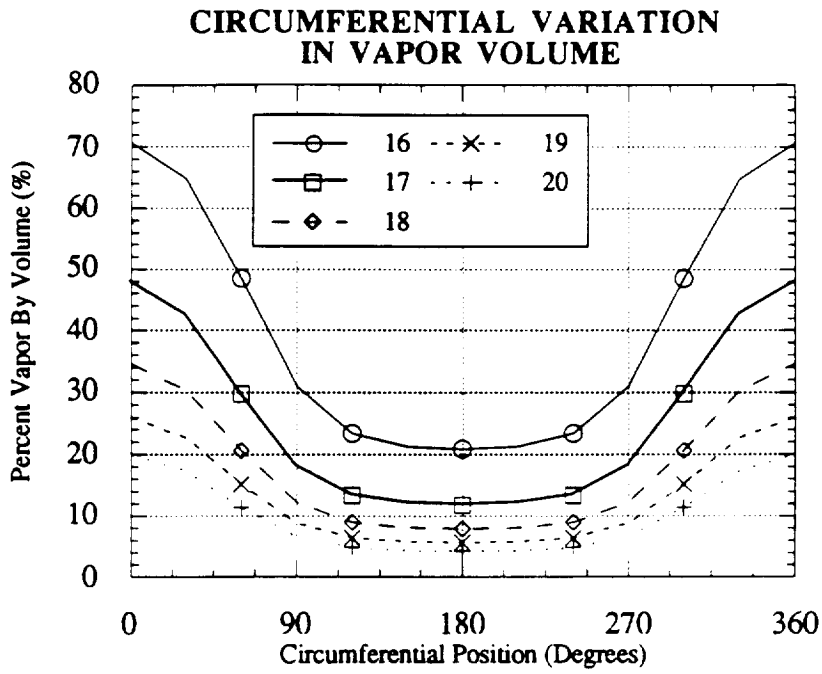


Figure 6. Percent Vapor By Volume

OUTPUT LISTING

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PRESSURE BALANCE, TWO PHASE FLOW

POS	P1	P2	MDOT TOT	MDOT LOC	QUAL	VVAP/VLIQ
1	306.20	300.00	2.00	0.1186	0.19	2.41
2	306.20	300.00	2.00	0.1272	0.15	1.84
3	306.20	300.00	2.00	0.1482	0.08	0.94
4	306.20	300.00	2.00	0.1679	0.04	0.45
5	306.20	300.00	2.00	0.1758	0.03	0.31
6	306.20	300.00	2.00	0.1780	0.03	0.27
7	306.20	300.00	2.00	0.1784	0.02	0.26
8	306.20	300.00	2.00	0.1780	0.03	0.27
9	306.20	300.00	2.00	0.1758	0.03	0.31
10	306.20	300.00	2.00	0.1679	0.04	0.45
11	306.20	300.00	2.00	0.1482	0.08	0.94
12	306.20	300.00	2.00	0.1272	0.15	1.84
13	306.20	300.00	2.00	0.1186	0.19	2.41

POS	P1	P2	MDOT TOT	MDOT LOC	QUAL	VVAP/VLIQ
1	319.90	300.00	4.00	0.2667	0.09	0.92
2	319.90	300.00	4.00	0.2776	0.07	0.74
3	319.90	300.00	4.00	0.3022	0.04	0.43
4	319.90	300.00	4.00	0.3234	0.02	0.22
5	319.90	300.00	4.00	0.3315	0.02	0.15
6	319.90	300.00	4.00	0.3336	0.01	0.14
7	319.90	300.00	4.00	0.3341	0.01	0.13
8	319.90	300.00	4.00	0.3336	0.01	0.14
9	319.90	300.00	4.00	0.3315	0.02	0.15
10	319.90	300.00	4.00	0.3234	0.02	0.22
11	319.90	300.00	4.00	0.3022	0.04	0.43
12	319.90	300.00	4.00	0.2776	0.07	0.74
13	319.90	300.00	4.00	0.2667	0.09	0.92

POS	P1	P2	MDOT TOT	MDOT LOC	QUAL	VVAP/VLIQ
1	341.30	300.00	6.00	0.4205	0.06	0.53
2	341.30	300.00	6.00	0.4318	0.05	0.44
3	341.30	300.00	6.00	0.4565	0.03	0.26
4	341.30	300.00	6.00	0.4771	0.02	0.14
5	341.30	300.00	6.00	0.4849	0.01	0.10
6	341.30	300.00	6.00	0.4869	0.01	0.09
7	341.30	300.00	6.00	0.4873	0.01	0.09
8	341.30	300.00	6.00	0.4869	0.01	0.09
9	341.30	300.00	6.00	0.4849	0.01	0.10
10	341.30	300.00	6.00	0.4771	0.02	0.14
11	341.30	300.00	6.00	0.4565	0.03	0.26
12	341.30	300.00	6.00	0.4318	0.05	0.44
13	341.30	300.00	6.00	0.4205	0.06	0.53

POS	P1	P2	MDOT TOT	MDOT LOC	QUAL	VVAP/VLIQ
1	371.10	300.00	8.00	0.5767	0.04	0.35
2	371.10	300.00	8.00	0.5875	0.04	0.29
3	371.10	300.00	8.00	0.6110	0.02	0.18
4	371.10	300.00	8.00	0.6302	0.01	0.10
5	371.10	300.00	8.00	0.6374	0.01	0.07
6	371.10	300.00	8.00	0.6393	0.01	0.06
7	371.10	300.00	8.00	0.6397	0.01	0.06
8	371.10	300.00	8.00	0.6393	0.01	0.06
9	371.10	300.00	8.00	0.6374	0.01	0.07
10	371.10	300.00	8.00	0.6302	0.01	0.10

11	371.10	300.00	8.00	0.6110	0.02	0.18
12	371.10	300.00	8.00	0.5875	0.04	0.29
13	371.10	300.00	8.00	0.5767	0.04	0.35

POS	P1	P2	MDOT TOT	MDOT LOC	QUAL	VVAP/VLIQ
1	410.31	300.00	10.00	0.7340	0.04	0.25
2	410.31	300.00	10.00	0.7440	0.03	0.21
3	410.31	300.00	10.00	0.7654	0.02	0.13
4	410.31	300.00	10.00	0.7828	0.01	0.07
5	410.31	300.00	10.00	0.7892	0.01	0.05
6	410.31	300.00	10.00	0.7909	0.01	0.05
7	410.31	300.00	10.00	0.7912	0.01	0.04
8	410.31	300.00	10.00	0.7909	0.01	0.05
9	410.31	300.00	10.00	0.7892	0.01	0.05
10	410.31	300.00	10.00	0.7828	0.01	0.07
11	410.31	300.00	10.00	0.7654	0.02	0.13
12	410.31	300.00	10.00	0.7440	0.03	0.21
13	410.31	300.00	10.00	0.7340	0.04	0.25

```
      BCD 3THERMAL LPCS
      BCD 9PRESSURE BALANCE, TWO PHASE FLOW
      END
C
      BCD 3NODE DATA
          -1, 0.0, 1.0 $ MDOT LOCAL
          -2, 0.0, 1.0 $
          -3, 0.0, 1.0 $
          -4, 0.0, 1.0 $
          -5, 0.0, 1.0 $
          -6, 0.0, 1.0 $
          -7, 0.0, 1.0 $
          -8, 0.0, 1.0 $
          -9, 0.0, 1.0 $
          -10, 0.0, 1.0 $
          -11, 0.0, 1.0 $
          -12, 0.0, 1.0 $
          -13, 0.0, 1.0 $
C
          -201, 0.0, 1.0 $ LOCAL QUALITY
          -202, 0.0, 1.0 $
          -203, 0.0, 1.0 $
          -204, 0.0, 1.0 $
          -205, 0.0, 1.0 $
          -206, 0.0, 1.0 $
          -207, 0.0, 1.0 $
          -208, 0.0, 1.0 $
          -209, 0.0, 1.0 $
          -210, 0.0, 1.0 $
          -211, 0.0, 1.0 $
          -212, 0.0, 1.0 $
          -213, 0.0, 1.0 $
C
          -301, 0.0, 1.0 $ VOL VAPOR/VOL LIQ
          -302, 0.0, 1.0 $
          -303, 0.0, 1.0 $
          -304, 0.0, 1.0 $
          -305, 0.0, 1.0 $
          -306, 0.0, 1.0 $
          -307, 0.0, 1.0 $
          -308, 0.0, 1.0 $
          -309, 0.0, 1.0 $
          -310, 0.0, 1.0 $
          -311, 0.0, 1.0 $
          -312, 0.0, 1.0 $
          -313, 0.0, 1.0 $
C
          -501, 0.0, 1.0 $
          -502, 0.0, 1.0 $
          -503, 0.0, 1.0 $
          -504, 0.0, 1.0 $
          -505, 0.0, 1.0 $
          -506, 0.0, 1.0 $
          -507, 0.0, 1.0 $
          -508, 0.0, 1.0 $
          -509, 0.0, 1.0 $
          -510, 0.0, 1.0 $
          -511, 0.0, 1.0 $
          -512, 0.0, 1.0 $
          -513, 0.0, 1.0 $
C
```

```
            -100, 0.0, 1.0 $ PRES 1
            -101, 0.0, 1.0 $ PRES 2
            -102, 0.0, 1.0 $ MDOT TOTAL
            -103, 0.0, 1.0 $
C
            1001,0.0,1.0 $ DUMMY
            1002,0.0,1.0
C
        GEN -1201,13,1, 0.0,1.0 $
        GEN -2201,13,1, 0.0,1.0 $
        GEN -3201,13,1, 0.0,1.0 $
        GEN -5201,13,1, 0.0,1.0 $
C
        GEN -1401,13,1, 0.0,1.0 $
        GEN -2401,13,1, 0.0,1.0 $
        GEN -3401,13,1, 0.0,1.0 $
        GEN -5401,13,1, 0.0,1.0 $
C
        GEN -1601,13,1, 0.0,1.0 $
        GEN -2601,13,1, 0.0,1.0 $
        GEN -3601,13,1, 0.0,1.0 $
        GEN -5601,13,1, 0.0,1.0 $
C
        GEN -1801,13,1, 0.0,1.0 $
        GEN -2801,13,1, 0.0,1.0 $
        GEN -3801,13,1, 0.0,1.0 $
        GEN -5801,13,1, 0.0,1.0 $
C
        GEN -2001,13,1, 0.0,1.0 $
        GEN -3001,13,1, 0.0,1.0 $
        GEN -4001,13,1, 0.0,1.0 $
        GEN -6001,13,1, 0.0,1.0 $
C
        END
C
        BCD 3CONDUCTOR DATA
C
            1,1001,1002,1.0
C
        END
C
        BCD 3CONSTANTS DATA
            DTIMEI,1.E-5
            DTIMEH,1.E-5
            NLOOP,100
C
            TIMEND,.1
            OUTPUT,1.E-5
C
            ARLXCA,.01
            DRLXCA,.01
            TIMEO,0.0
            DAMPA,0.5
            DAMPD,0.5
            NDIM,1000
C
        END
C
        BCD 3ARRAY DATA
C
            1 $ POSITION VS FRICTIONAL HEAT LOAD (BTU/SEC)
            1.0, 1.13
            2.0, 0.93
            3.0, 0.51
```

```
          4.0, 0.18
          5.0, 0.059
          6.0, 0.028
          7.0, 0.021
          8.0, 0.028
          9.0, 0.059
          10.0, 0.18
          11.0, 0.51
          12.0, 0.93
          13.0, 1.13
          END
          2 $ PRES VS LIQUID SPECIFIC VOLUME AT SATURATION
          150.0, 0.01647
          200.0, 0.01709
          250.0, 0.01770
          300.0, 0.01832
          350.0, 0.01896
          400.0, 0.01964
          450.0, 0.02039
          500.0, 0.02122
          END
          3 $ PRES VS VAPOR SPECIFIC VOLUME AT SATURATION
          150.0, 0.40132
          200.0, 0.29991
          250.0, 0.23731
          300.0, 0.19450
          350.0, 0.16316
          400.0, 0.13903
          450.0, 0.11970
          500.0, 0.10366
          END
          4 $ PRES VS HFG
          150.0, 74.40
          200.0, 70.11
          250.0, 66.05
          300.0, 62.08
          350.0, 58.13
          400.0, 54.14
          450.0, 50.01
          500.0, 45.66
          END
C
      END
C
      BCD 3EXECUTION
C
F     OPEN(3,FILE="TPF.PLT",STATUS="UNKNOWN")
F     NWRT=21
F     WRITE(3,12)NWRT,(I,I=1,21)
F 12  FORMAT(I6/,250(I6,31X,I6/))
C
F     XMCHK=0.
C
F 1   XMCHK=XMCHK+2.0
C
M     CALL D1DEG1(1.0,A1,QZ1)
M     CALL D1DEG1(2.0,A1,QZ2)
M     CALL D1DEG1(3.0,A1,QZ3)
M     CALL D1DEG1(4.0,A1,QZ4)
M     CALL D1DEG1(5.0,A1,QZ5)
M     CALL D1DEG1(6.0,A1,QZ6)
M     CALL D1DEG1(7.0,A1,QZ7)
M     CALL D1DEG1(8.0,A1,QZ8)
M     CALL D1DEG1(9.0,A1,QZ9)
```

```
M       CALL D1DEG1(10.0,A1,QZ10)
M       CALL D1DEG1(11.0,A1,QZ11)
M       CALL D1DEG1(12.0,A1,QZ12)
M       CALL D1DEG1(13.0,A1,QZ13)
F       QFAC=1.0
F       QDIV=1.0
F       QADD=0.251
F       QZ1=QFAC*QZ1/QDIV+QADD
F       QZ2=QFAC*QZ2/QDIV+QADD
F       QZ3=QFAC*QZ3/QDIV+QADD
F       QZ4=QFAC*QZ4/QDIV+QADD
F       QZ5=QFAC*QZ5/QDIV+QADD
F       QZ6=QFAC*QZ6/QDIV+QADD
F       QZ7=QFAC*QZ7/QDIV+QADD
F       QZ8=QFAC*QZ8/QDIV+QADD
F       QZ9=QFAC*QZ9/QDIV+QADD
F       QZ10=QFAC*QZ10/QDIV+QADD
F       QZ11=QFAC*QZ11/QDIV+QADD
F       QZ12=QFAC*QZ12/QDIV+QADD
F       QZ13=QFAC*QZ13/QDIV+QADD
C
F       PR1=302.0
F       PR2=300.0
C
C TOTAL FLOW RATE LB.SEC
C
F       XMST=0.1*XMCHK/13.0
F       XMDT1=XMST
F       XMDT2=XMST
F       XMDT3=XMST
F       XMDT4=XMST
F       XMDT5=XMST
F       XMDT6=XMST
F       XMDT7=XMST
F       XMDT8=XMST
F       XMDT9=XMST
F       XMDT10=XMST
F       XMDT11=XMST
F       XMDT12=XMST
F       XMDT13=XMST
C
F 10    CONTINUE
M       CALL D1DEG1(PR1,A4,XHFG)
F       XVAP1=QZ1/XHFG
F       XVAP2=QZ2/XHFG
F       XVAP3=QZ3/XHFG
F       XVAP4=QZ4/XHFG
F       XVAP5=QZ5/XHFG
F       XVAP6=QZ6/XHFG
F       XVAP7=QZ7/XHFG
F       XVAP8=QZ8/XHFG
F       XVAP9=QZ9/XHFG
F       XVAP10=QZ10/XHFG
F       XVAP11=QZ11/XHFG
F       XVAP12=QZ12/XHFG
F       XVAP13=QZ13/XHFG
C
F       XQAL1=XVAP1/XMDT1
F       XQAL2=XVAP2/XMDT2
F       XQAL3=XVAP3/XMDT3
F       XQAL4=XVAP4/XMDT4
F       XQAL5=XVAP5/XMDT5
F       XQAL6=XVAP6/XMDT6
F       XQAL7=XVAP7/XMDT7
```

```
F       XQAL8=XVAP8/XMDT8
F       XQAL9=XVAP9/XMDT9
F       XQAL10=XVAP10/XMDT10
F       XQAL11=XVAP11/XMDT11
F       XQAL12=XVAP12/XMDT12
F       XQAL13=XVAP13/XMDT13
C
F       IF(XQAL1.GT.1.0)XVAP1=XMDT1
F       IF(XQAL2.GT.1.0)XVAP2=XMDT2
F       IF(XQAL3.GT.1.0)XVAP3=XMDT3
F       IF(XQAL4.GT.1.0)XVAP4=XMDT4
F       IF(XQAL5.GT.1.0)XVAP5=XMDT5
F       IF(XQAL6.GT.1.0)XVAP6=XMDT6
F       IF(XQAL7.GT.1.0)XVAP7=XMDT7
F       IF(XQAL8.GT.1.0)XVAP8=XMDT8
F       IF(XQAL9.GT.1.0)XVAP9=XMDT9
F       IF(XQAL10.GT.1.0)XVAP10=XMDT10
F       IF(XQAL11.GT.1.0)XVAP11=XMDT11
F       IF(XQAL12.GT.1.0)XVAP12=XMDT12
F       IF(XQAL13.GT.1.0)XVAP13=XMDT13
C
F       IF(XQAL1.GT.1.0)XQAL1=1.0
F       IF(XQAL2.GT.1.0)XQAL2=1.0
F       IF(XQAL3.GT.1.0)XQAL3=1.0
F       IF(XQAL4.GT.1.0)XQAL4=1.0
F       IF(XQAL5.GT.1.0)XQAL5=1.0
F       IF(XQAL6.GT.1.0)XQAL6=1.0
F       IF(XQAL7.GT.1.0)XQAL7=1.0
F       IF(XQAL8.GT.1.0)XQAL8=1.0
F       IF(XQAL9.GT.1.0)XQAL9=1.0
F       IF(XQAL10.GT.1.0)XQAL10=1.0
F       IF(XQAL11.GT.1.0)XQAL11=1.0
F       IF(XQAL12.GT.1.0)XQAL12=1.0
F       IF(XQAL13.GT.1.0)XQAL13=1.0
C
M       CALL D1DEG1(PR1,A2,VLIQ)
M       CALL D1DEG1(PR1,A3,VVAP)
F       VLG=VVAP-VLIQ
C
F       V1=VLIQ+VLG*XQAL1
F       V2=VLIQ+VLG*XQAL2
F       V3=VLIQ+VLG*XQAL3
F       V4=VLIQ+VLG*XQAL4
F       V5=VLIQ+VLG*XQAL5
F       V6=VLIQ+VLG*XQAL6
F       V7=VLIQ+VLG*XQAL7
F       V8=VLIQ+VLG*XQAL8
F       V9=VLIQ+VLG*XQAL9
F       V10=VLIQ+VLG*XQAL10
F       V11=VLIQ+VLG*XQAL11
F       V12=VLIQ+VLG*XQAL12
F       V13=VLIQ+VLG*XQAL13
C
F       CALL DELP(PR1,PR2,V1,XMDT1)
F       CALL DELP(PR1,PR2,V2,XMDT2)
F       CALL DELP(PR1,PR2,V3,XMDT3)
F       CALL DELP(PR1,PR2,V4,XMDT4)
F       CALL DELP(PR1,PR2,V5,XMDT5)
F       CALL DELP(PR1,PR2,V6,XMDT6)
F       CALL DELP(PR1,PR2,V7,XMDT7)
F       CALL DELP(PR1,PR2,V8,XMDT8)
F       CALL DELP(PR1,PR2,V9,XMDT9)
F       CALL DELP(PR1,PR2,V10,XMDT10)
F       CALL DELP(PR1,PR2,V11,XMDT11)
```

```
F       CALL DELP(PR1,PR2,V12,XMDT12)
F       CALL DELP(PR1,PR2,V13,XMDT13)
C
F       XMDTS=XMDT1+XMDT2+XMDT3+XMDT4+XMDT5+XMDT6+XMDT7
F       XMDTS=XMDTS+XMDT8+XMDT9+XMDT10+XMDT11+XMDT12+XMDT13
C
F       IF(XMDTS.GT.XMCHK)GO TO 20
F       PR1=PR1+0.1
F       GO TO 10
C
M 20    T1=XMDT1
M       T2=XMDT2
M       T3=XMDT3
M       T4=XMDT4
M       T5=XMDT5
M       T6=XMDT6
M       T7=XMDT7
M       T8=XMDT8
M       T9=XMDT9
M       T10=XMDT10
M       T11=XMDT11
M       T12=XMDT12
M       T13=XMDT13
C
M       T201=XQAL1
M       T202=XQAL2
M       T203=XQAL3
M       T204=XQAL4
M       T205=XQAL5
M       T206=XQAL6
M       T207=XQAL7
M       T208=XQAL8
M       T209=XQAL9
M       T210=XQAL10
M       T211=XQAL11
M       T212=XQAL12
M       T213=XQAL13
C
M       T301=XVAP1*VVAP/(AMAX1((XMDT1-XVAP1),0.0001)*VLIQ)
M       T302=XVAP2*VVAP/(AMAX1((XMDT2-XVAP2),0.0001)*VLIQ)
M       T303=XVAP3*VVAP/(AMAX1((XMDT3-XVAP3),0.0001)*VLIQ)
M       T304=XVAP4*VVAP/(AMAX1((XMDT4-XVAP4),0.0001)*VLIQ)
M       T305=XVAP5*VVAP/(AMAX1((XMDT5-XVAP5),0.0001)*VLIQ)
M       T306=XVAP6*VVAP/(AMAX1((XMDT6-XVAP6),0.0001)*VLIQ)
M       T307=XVAP7*VVAP/(AMAX1((XMDT7-XVAP7),0.0001)*VLIQ)
M       T308=XVAP8*VVAP/(AMAX1((XMDT8-XVAP8),0.0001)*VLIQ)
M       T309=XVAP9*VVAP/(AMAX1((XMDT9-XVAP9),0.0001)*VLIQ)
M       T310=XVAP10*VVAP/(AMAX1((XMDT10-XVAP10),0.0001)*VLIQ)
M       T311=XVAP11*VVAP/(AMAX1((XMDT11-XVAP11),0.0001)*VLIQ)
M       T312=XVAP12*VVAP/(AMAX1((XMDT12-XVAP12),0.0001)*VLIQ)
M       T313=XVAP13*VVAP/(AMAX1((XMDT13-XVAP13),0.0001)*VLIQ)
C
M      T501=XVAP1*VVAP/(AMAX1((XMDT1-XVAP1),1.E-5)*VLIQ+XVAP1*VVAP)
M      T502=XVAP2*VVAP/(AMAX1((XMDT2-XVAP2),1.E-5)*VLIQ+XVAP2*VVAP)
M      T503=XVAP3*VVAP/(AMAX1((XMDT3-XVAP3),1.E-5)*VLIQ+XVAP3*VVAP)
M      T504=XVAP4*VVAP/(AMAX1((XMDT4-XVAP4),1.E-5)*VLIQ+XVAP4*VVAP)
M      T505=XVAP5*VVAP/(AMAX1((XMDT5-XVAP5),1.E-5)*VLIQ+XVAP5*VVAP)
M      T506=XVAP6*VVAP/(AMAX1((XMDT6-XVAP6),1.E-5)*VLIQ+XVAP6*VVAP)
M      T507=XVAP7*VVAP/(AMAX1((XMDT7-XVAP7),1.E-5)*VLIQ+XVAP7*VVAP)
M      T508=XVAP8*VVAP/(AMAX1((XMDT8-XVAP8),1.E-5)*VLIQ+XVAP8*VVAP)
M      T509=XVAP9*VVAP/(AMAX1((XMDT9-XVAP9),1.E-5)*VLIQ+XVAP9*VVAP)
M      T510=XVAP10*VVAP/(AMAX1((XMDT10-XVAP10),1.E-5)*VLIQ+XVAP10*VVAP)
M      T511=XVAP11*VVAP/(AMAX1((XMDT11-XVAP11),1.E-5)*VLIQ+XVAP11*VVAP)
M      T512=XVAP12*VVAP/(AMAX1((XMDT12-XVAP12),1.E-5)*VLIQ+XVAP12*VVAP)
```

```
M      T513=XVAP13*VVAP/(AMAX1((XMDT13-XVAP13),1.E-5)*VLIQ+XVAP13*VVAP)
C
F       IXC=(XMCHK/2.)+0.1
F       GO TO (81,82,83,84,85),IXC
C
F 81    DO 1000 I=1,13
M       T(1201+I-1)=T(1+I-1)
M       T(2201+I-1)=T(201+I-1)
M       T(3201+I-1)=T(301+I-1)
M       T(5201+I-1)=T(501+I-1)*100.
F1000   CONTINUE
C
F 82    DO 1001 I=1,13
M       T(1401+I-1)=T(1+I-1)
M       T(2401+I-1)=T(201+I-1)
M       T(3401+I-1)=T(301+I-1)
M       T(5401+I-1)=T(501+I-1)*100.
F1001   CONTINUE
C
F 83    DO 1002 I=1,13
M       T(1601+I-1)=T(1+I-1)
M       T(2601+I-1)=T(201+I-1)
M       T(3601+I-1)=T(301+I-1)
M       T(5601+I-1)=T(501+I-1)*100.
F1002   CONTINUE
C
F 84    DO 1003 I=1,13
M       T(1801+I-1)=T(1+I-1)
M       T(2801+I-1)=T(201+I-1)
M       T(3801+I-1)=T(301+I-1)
M       T(5801+I-1)=T(501+I-1)*100.
F1003   CONTINUE
C
F 85    DO 1004 I=1,13
M       T(2001+I-1)=T(1+I-1)
M       T(3001+I-1)=T(201+I-1)
M       T(4001+I-1)=T(301+I-1)
M       T(6001+I-1)=T(501+I-1)*100.
F1004   CONTINUE
C
M       T501=T501*100.
M       T502=T502*100.
M       T503=T503*100.
M       T504=T504*100.
M       T505=T505*100.
M       T506=T506*100.
M       T507=T507*100.
M       T508=T508*100.
M       T509=T509*100.
M       T510=T510*100.
M       T511=T511*100.
M       T512=T512*100.
M       T513=T513*100.
C
M       T100=PR1
M       T101=PR2
M       T103=T100-T101
M       T102=XMCHK
F       TIMEN=XMCHK
F       TIMEO=XMCHK
F       TIMEM=XMCHK
C
F       CALL OUTCAL
C
```

```
F       IF(XMCHK.GT.9.9)GO TO 99
F       GO TO 1
C
F 99    CONTINUE
C
F       DO 90 I=1,13
F       TIME=I
F       TIME=((TIME-1.0)/12.)*360.
M       TX2=T(1201+I-1)
M       TX4=T(1401+I-1)
M       TX6=T(1601+I-1)
M       TX8=T(1801+I-1)
M       TX10=T(2001+I-1)
M       QX2=T(2201+I-1)
M       QX4=T(2401+I-1)
M       QX6=T(2601+I-1)
M       QX8=T(2801+I-1)
M       QX10=T(3001+I-1)
M       VX2=T(3201+I-1)
M       VX4=T(3401+I-1)
M       VX6=T(3601+I-1)
M       VX8=T(3801+I-1)
M       VX10=T(4001+I-1)
M       VVX2=T(5201+I-1)
M       VVX4=T(5401+I-1)
M       VVX6=T(5601+I-1)
M       VVX8=T(5801+I-1)
M       VVX10=T(6001+I-1)
F       XI=I
M       CALL D1DEG1(XI,A1,QZZ)
F       QZZ=QZZ+0.251
F       WRITE(3,11)TIME,TX2,TX4,TX6,TX8,TX10,
F     1 QX2,QX4,QX6,QX8,QX10,
F     1 VX2,VX4,VX6,VX8,VX10,
F     1 VVX2,VVX4,VVX6,VVX8,VVX10,
F     1 QZZ
F 11    FORMAT(E10.3/,250(7F12.3/))
F 90    CONTINUE
C
F       RETURN
F       END
C
F       SUBROUTINE DELP(PUP,PDN,V,XMDT)
F       AREA=0.20988/13.0
F       XL=0.375
F       D=.09
F       XMDT=AREA*SQRT(((PUP-PDN)*2.*32.2*12.)/(4.*.06*(XL/D)*V*1728.))
C
C       RETURN
C
        END
C
        BCD 3VARIABLES 1
C
        END
C
        BCD 3VARIABLES 2
C
        END
C
        BCD 3OUTPUT CALLS
F       WRITE(6,10)
F 10  FORMAT(/,1X,'  POS     P1          P2        MDOT TOT  MDOT LOC ',
F     * '   QUAL   VVAP/VLIQ')
```

```
F       DO 40 I=1,13
M       WRITE(6,30)I,T100,T101,T102,T(1+I-1),T(201+I-1),T(301+I-1)
F 30    FORMAT(1X,I4,F10.2,F10.2,F10.2,F10.4,F10.2,F10.2)
F 40    CONTINUE
C
CF       CALL TDUMP
C
        END
        BCD 3END OF DATA
```

SECTION 6: Venting of an Electronic Box, in the Space Shuttle Cargo Bay, During Ascent

ANALYSIS CODE: FLAP / SINDA

I. Identification of the Problem:

A. Statement of the Problem:

Consider an electronic box located in the space shuttle cargo bay. During the ascent phase of a space shuttle flight, the pressure in the cargo bay decreases, at a rapid rate. Vent holes are usually provided to equalize the pressure between the inside and outside of the box, in order to avoid any deformation of the box. Vent hole sizes must be determined by performing the transient flow and thermal analyses.

B. Schematic:

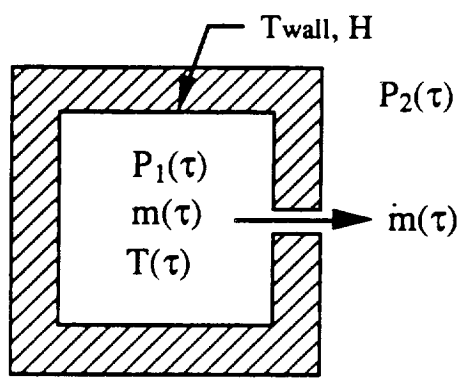

Figure 1. Schematic of Transient Depressurization of the Box

C. Given:

The following data is given for this problem:

1. The pressure history, within the cargo bay, is provided in the following table:

Time (sec)	Pressure (psia)
0	14.70
10	14.40
20	13.20
30	11.30
40	9.00
50	6.75
60	4.40
70	2.80
80	1.50
90	0.50

100 0.25

2. The volume of the box is 500 cubic inches and the diameter of the (single) vent hole is 0.05 inch. The initial temperature, within the box, is 70 °F.

3. The following thermo-physical data for air are used:

   Specific heat at constant volume, c_v = 0.17 BTU/lbm-°F
   Gas constant, R = 53.20 lbf-ft/lbm-°R
   Discharge coefficient for orifice, C_D = 1.00

D. Find:

The transient distribution of pressure, mass, and temperature, in the box, during the period of ascent.

II. Formulation of the Problem:

Two different formulations are described in this chapter. A finite-volume based procedure that is used to solve the transient mass and energy conservation equations is described. The results of the finite-volume procedure are compared with the results of a finite-difference procedure (of SINDA), for isothermal and isentropic conditions.

A. Governing Equations:

Finite-Volume Procedure:

During the ascent phase of a space shuttle flight, the pressure inside the cargo bay decreases, due to venting of the contained air to the atmosphere. The electronic box, located inside the cargo bay, must vent to equalize the pressure between the inside and outside of the box. A pressure difference still exists between the inside and outside of the box, since the pressure in the orbiter falls more rapidly than the rate of airflow (through the vent hole) allows. In order to mathematically represent the physical process, the box has been regarded as a control volume which loses or gains mass from the surroundings (i.e., cargo bay), through the vent hole.

Mass Conservation Equation

The time-dependent mass and energy conservation equations are derived for the control volume. Flow through the vent hole is modeled by either the formulation derived in reference 2 for incompressible flow through nozzles, orifices, and restrictions or by the orifice flow equation described in the following section.

The mass conservation equation can be written as

$$m_{\tau+\Delta\tau} = m_\tau - \dot{m}_{\tau+\Delta\tau}\Delta\tau \qquad (1)$$

where m_τ and $m_{\tau+\Delta\tau}$ denote the resident mass of air, in the box, at time τ and $\tau+\Delta\tau$, respectively. The mass flowrate, $\dot{m}_{\tau+\Delta\tau}$, through the vent hole at time $\tau+\Delta\tau$, is determined from the incompressible flow equation through nozzles, orifices, and restrictions (see Reference 2).

For the orifice flow equation (see Reference 1), the flow through the vent hole is a function of pressure ratio, P_2/P_1, and is given by

$$\dot{m}_v = C_D \frac{A_2 P_1}{\sqrt{T_1}} \sqrt{\frac{2\gamma g}{(\gamma-1)R}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{\gamma}} - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma+1}{\gamma}}\right]} \tag{2}$$

The critical pressure ratio, r_{pc}, is given by

$$r_{pc} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma+1}} \tag{3}$$

Energy Conservation Equation

The energy conservation equation can be written as

$$(mu)_{\tau+\Delta\tau} = (mu)_\tau - \dot{m}_{\tau+\Delta\tau}\Delta\tau h_\tau + HA\Delta\tau(T_{wall} - T_{\tau+\Delta\tau}) \tag{4}$$

The expression for the internal energy at the current time step consists of three terms. The first term on the right hand side of equation (4) represents the energy at the previous time step. The amount of energy leaving the control volume, during the current time step is represented by the second term in the equation. The third term represents the heat transfer, from the wall, to the fluid. Omission of the third term in equation (4) corresponds to an isentropic process. An isothermal case may be modeled by setting H equal to a large value, which leads to

$$T_{\tau+\Delta\tau} = T_{wall} = T_\tau$$

Equation of State

During transient depressurization, it is assumed that thermodynamic equilibrium exists. Therefore, the equation of state for an ideal gas is used to compute the pressure in the box.

$$P_{1_{\tau+\Delta\tau}} = \frac{m_{\tau+\Delta\tau} R T_{\tau+\Delta\tau}}{V} \tag{5}$$

where R is the gas constant; $T_{\tau+\Delta\tau}$ is the temperature at time, $\tau+\Delta\tau$, and is determined from the internal energy

$$T_{\tau+\Delta\tau} = \frac{u_{\tau+\Delta\tau}}{c_v} \tag{6}$$

Finite-Difference Procedure (SINDA):

The transient depressurization (venting) problem was also modeled using the network analyzer, SINDA. The transient pressure distribution was calculated for isothermal and isentropic formulations.

Isothermal Formulation

The mass conservation equation is similar to that developed for the finite-volume formulation. The energy conservation equation was obtained using the assumption of constant temperature

$$T_{1_{\tau+\Delta\tau}} = T_{1_\tau} \tag{7}$$

During depressurization, it is assumed that a state of thermodynamic equilibrium exists. The derivation of equations is based upon the ideal gas law and the assumption of isothermal conditions.

Isentropic Formulation

The mass conservation equation is similar to that presented in the finite-volume formulation. Instead of solving the energy conservation equation, the isentropic relationship has been used to determine the thermodynamic states of the resident mass. A constant-entropy assumption was made

$$s_{1_{\tau+\Delta\tau}} = s_{1_\tau} \tag{8}$$

The pressure is determined with knowledge of two state variables, at any given time, during the depressurization process. Thus,

$$P_{1_{\tau+\Delta\tau}} = f(s,\rho)$$

Entropy (s) is known, and density (ρ) is determined at each time step, as a function of the volume and remaining mass, within the volume. Similarily, temperature is determined from the following equation.

$$T_{1_{\tau+\Delta\tau}} = f(s,\rho)$$

B. Initial and Boundary Conditions:

Since this is a transient problem, at least one initial condition must be specified. The initial temperature and pressure in the box are 70 °F and 14.7 psia, respectively. The cargo bay pressure, $P_2(\tau)$, is the only boundary condition required for this analysis and is tabulated in Section I C.

C. Solution Procedure:

Finite-Volume Formulation (FLAP)

The governing equations (Eqns. 1 through 6) are solved using an iterative numerical method. The solution steps are as follows:

1. Initially (at $\tau = 0$) set

$$P_1 = 14.7 \text{ psia}$$
$$T_1 = 530 \text{ °R}$$

2. Calculate resident mass of box at $\tau = 0$;

$$m = \frac{P_1 V_1}{RT_1}$$

3. Move to a new time;

$$\tau = \tau + \Delta\tau$$

4. Obtain $P_2(\tau)$, from cargo bay pressure history. The pressure is linearly interpolated from the given table.

5. Begin the iteration loop for the current time.

6. Calculate resident mass, $m_{\tau+\Delta\tau}$, from mass conservation equation (Eqn. 1).

7. Calculate internal energy from energy conservation equation (Eqn. 6).

8. Calculate temperature in the box from equation (8).

9. Calculate pressure in the box from the equation of state (Eqn. 7).

10. Calculate the difference in the resident mass and internal energy, between successive iterations.

11. If the percent difference is larger than a pre-specified small number (convergence criterion for this problem is set to 1.0 E-05), then the iteration loop (steps 6 to 10) are repeated until the convergence criterion is satisfied.

12. After the convergence criteria is satisfied, proceed to the next time and repeat steps 4 to 11, until the end time is reached.

Since the mass flow equation is non-linear, it is necessary to introduce under-relaxation in the solution procedure. In the present scheme, the internal energy is under-relaxed, according to the relation

$$u = (1 - \alpha)u_{old} + \alpha u_{new}$$

For a given iteration, a weighted average of the new and old values is used. A low value of the under-relaxation parameter, α, implies larger damping of the solution.

The iterative solution procedure is incorporated into a FORTRAN code, listed at the end of this section. The code runs (interactively) on an IBM PC. A flow diagram for the code is shown in Figure 2. This code is an adaptation of the FLAP code that was developed to analyze pressurization and depressurization, during the propellant burn of the Solid Rocket Motor (see Reference 1).

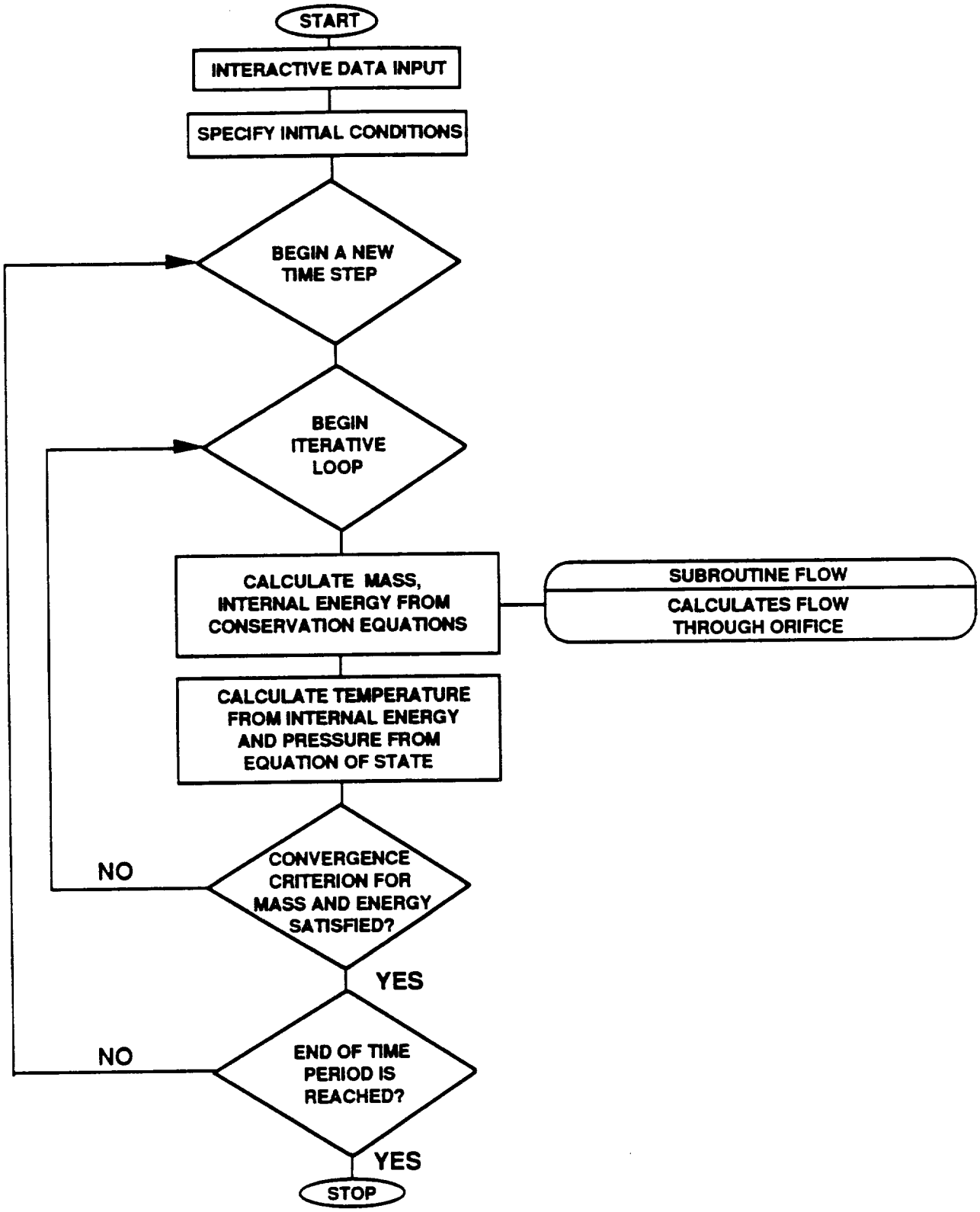

Figure 2. Flow Diagram for Venting Calculation

Finite-Difference Formulation (SINDA)

Isentropic Formulation:

The governing equations are solved using a linearized differencing scheme, incorporated into the computer code, SINDA. The solution steps are as follows:

1. Initially (at $\tau = 0$) set

   $P_1 = 14.7$ psia
   $T_1 = 530$ °R

2. Calculate resident mass of box at $\tau = 0$;

   $m = \rho * \text{volume}$

3. Move to a new time;

   $\tau = \tau + \Delta\tau$

4. Obtain $P_2(\tau)$, from cargo bay pressure history. The pressure is linearly interpolated from the given table.

5. Calculate flowrate of mass leaving the control volume.

6. Calculate the mass remaining in the volume.

7. Calculate the new density in the volume.

8. Calculate pressure in the box, given density and entropy.

9. Calculate temperature in the box, given density and entropy.

10. Repeat steps 3 to 9 until end time is reached.

Isothermal Formulation:

The governing equations are solved using a linearized differencing scheme, incorporated into the computer code, SINDA. The solution steps are as follows:

1. Initially (at $\tau = 0$) set

   $P_1 = 14.7$ psia
   $T_1 = 530$ °R

2. Calculate the capacitance associated with the contents of the control volume;

   $$C = \frac{V}{RT}$$

3. Move to a new time;

$$\tau = \tau + \Delta\tau$$

4. Obtain $P_2(\tau)$ from cargo bay pressure history. The pressure is linearly interpolated from the given table.

5. Calculate flowrate of mass leaving the control volume.

6. Solve the linearized differential equation for pressure.

7. Repeat steps 3 to 6 until end time is reached.

D. Presentation and Discussion of Results:

Finite-Volume Procedure (FLAP):

Numerical Parameters

The accuracy of the numerical solution depends upon the time step and the convergence criterion. Parametric studies were performed to determine the optimum time step and convergence criterion. The optimum time step was found to be 1 millisecond. The criterion used to determine the time step was the maximum pressure difference, observed during the period of ascent. Any further reduction in the time step did not significantly affect the calculated pressure difference. The same procedure was followed to determine the optimum convergence criterion. The optimum convergence criterion was found to be 1.0 E-05, for the present problem.

It should be mentioned that there are two fundamental methods of solving transient thermal and flow problems. The first method, called the explicit method, uses values from the previous time step to determine the variables at the current time step. Alternatively, an implicit method is one in which the variables are determined from values at the current time step. Since the governing equations are coupled, an iterative procedure is required to simultaneously satisfy them. In general, the explicit method requires much smaller time steps than an implicit method. The present solution scheme uses an implicit method.

Sample Results

The predicted pressure distribution, inside and outside the box, is depicted in Figure 3. The pressure inside the box does not decrease as rapidly as does the pressure in the cargo bay. Therefore, a pressure differential exists during the period of ascent. The predicted pressure drop, across the vent, is shown in Figure 4. In both figures, comparisons are made for three cases; these include isentropic, isothermal, and for wall-to-fluid heat transfer. The isothermal formulation gives the largest predicted pressure differential whereas the isentropic formulation gives the lowest pressure differential. The case in which a finite heat loss was considered led to an intermediate value (i.e., between two extremes). The mass flowrate from the box is shown in Figure 5. The predicted change in temperature, for fluid within the box, is shown in Figure 6. The temperature remains constant during the isothermal process. For the isentropic process, the temperature reduces rapidly, due to expansion. In the case of heat transfer from the wall, the fluid temperature does not reduce to the extent observed in the case of isentropic expansion.

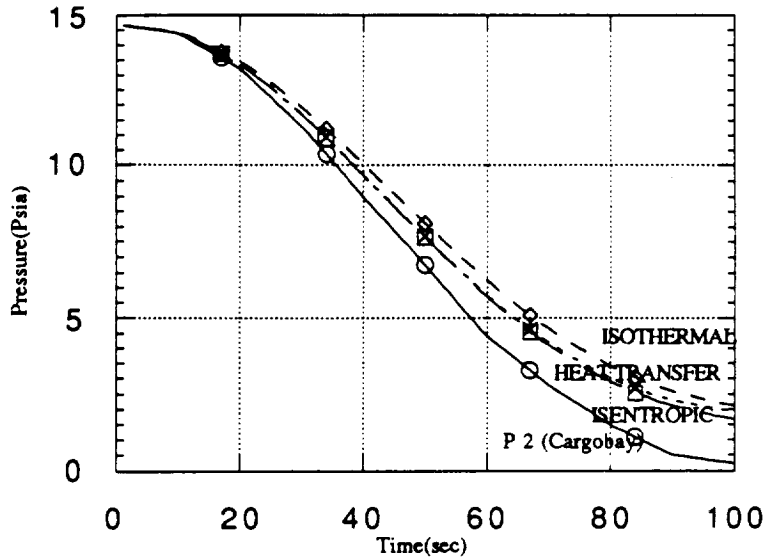

Figure 3. Predicted pressure distribution in the box and given pressure history in the cargo bay; Box Volume = 500 in^3; Vent hole diameter = .05 in

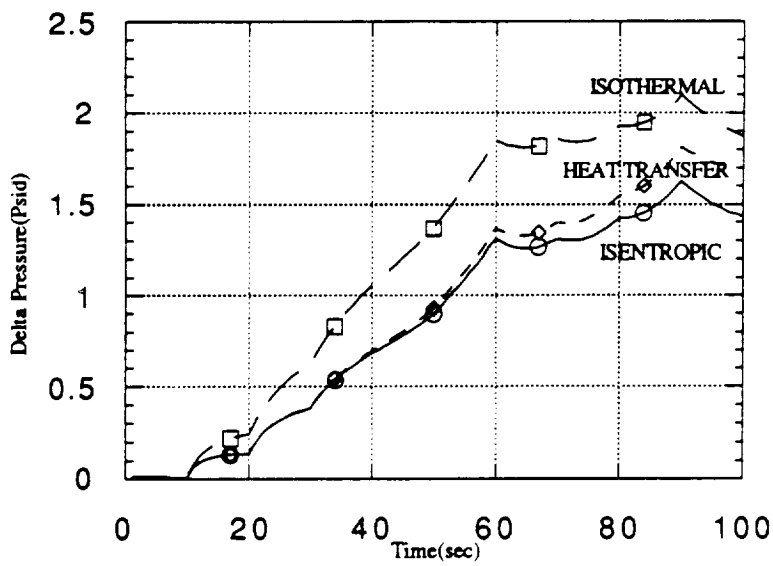

Figure 4. The predicted distribution of pressure difference between the box and the cargo bay during the launch; Box volume = 500 in^3; Vent hole diameter = .05 in

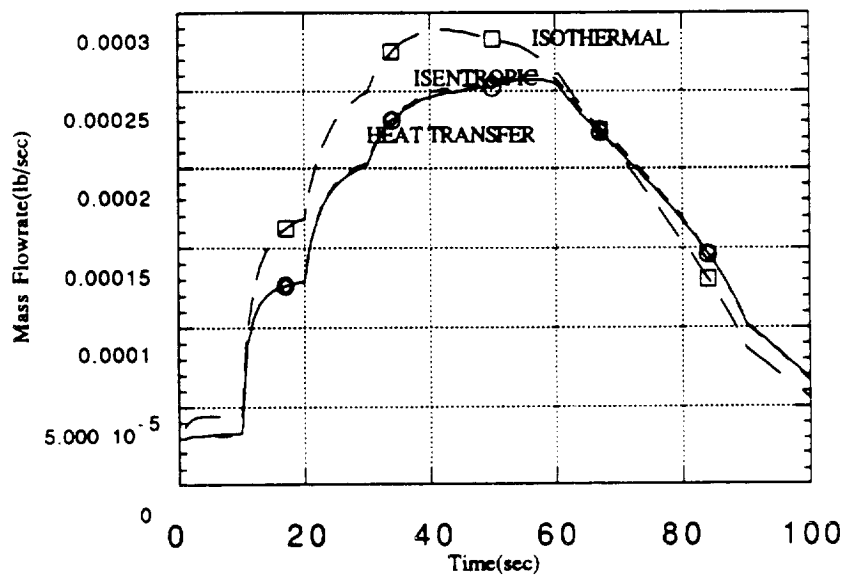

Figure 5. The predicted distribution of mass flowrate from the box during the first 100 seconds after lift-off; Box volume = 500 in^3; Vent hole diameter = .05 in

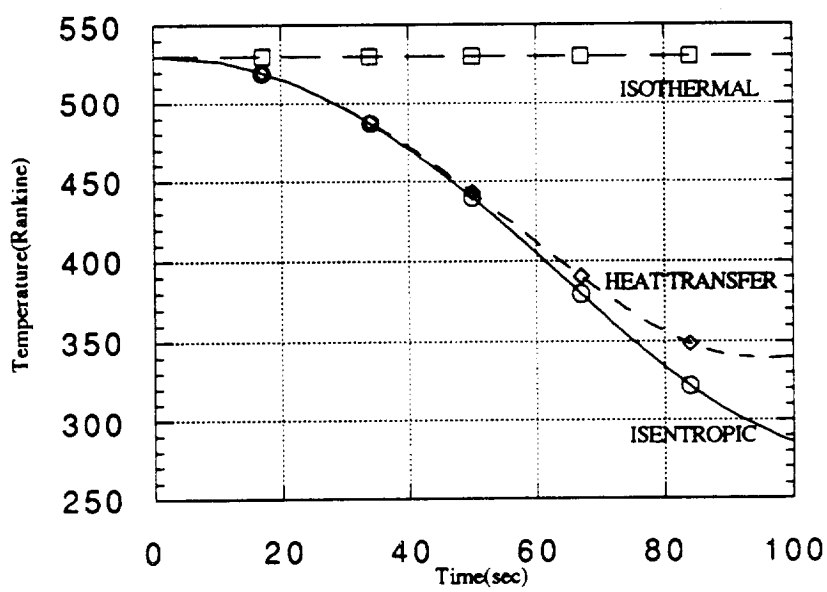

Figure 6. The predicted air temperature inside the box during the first 100 seconds after lift-off; Box volume = 500 in^3; Vent hole diameter = .05 in

Parametric Studies

Parametric studies were performed to investigate the effect of vent hole diameter and box volume on the maximum pressure difference. The effect of vent hole diameter on the maximum pressure difference is shown in Figure 7. The pressure difference diminishes with the increase of vent hole diameter. The effect of box volume is illustrated in Figure 8. For a given vent hole diameter size, the pressure difference increases with the volume.

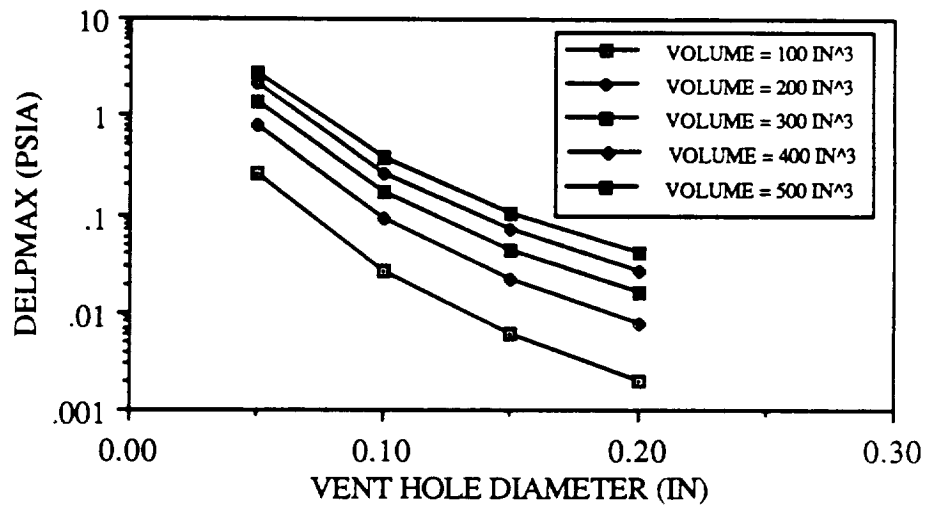

Figure 7. Venting of electronic box in the space shuttle; effect of vent hole size on pressure differential

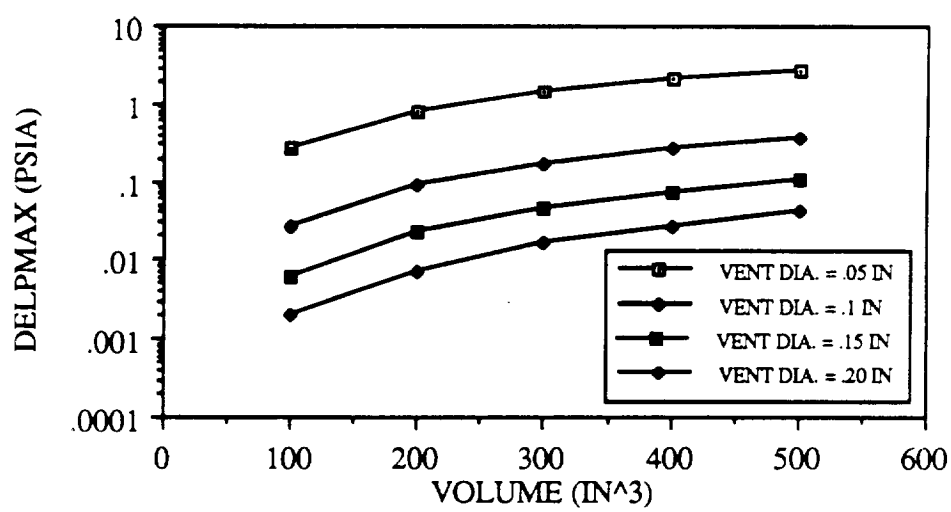

Figure 8. Venting of electronic box in the space shuttle; effect of box volume on pressure differential

FLAP OUTPUT

FINITE-VOLUME FORMULATION

TWALL	=	5.300E+02 DEG R
HC	=	5.000E-02 BTU/HR-FT**2-F
AREA	=	1.000E+02 IN**2
VOLUME	=	5.000E+02 IN**3
DIA	=	5.000E-02 IN
TIME STEP	=	1.000E-03 SEC

TAU	P1	P2	DELP	T1	EMDOT	EM1	MACH	ITER
1.000E+00	1.468E+01	1.467E+01	6.903E-03	5.298E+02	2.985E-05	2.170E-02	2.592E-02	2
2.000E+00	1.465E+01	1.464E+01	7.522E-03	5.295E+02	3.114E-05	2.167E-02	2.709E-02	2
3.000E+00	1.462E+01	1.461E+01	7.540E-03	5.291E+02	3.116E-05	2.164E-02	2.715E-02	2
4.000E+00	1.459E+01	1.458E+01	7.560E-03	5.288E+02	3.118E-05	2.160E-02	2.721E-02	2
5.000E+00	1.456E+01	1.455E+01	7.579E-03	5.285E+02	3.119E-05	2.157E-02	2.728E-02	2
6.000E+00	1.453E+01	1.452E+01	7.597E-03	5.282E+02	3.120E-05	2.154E-02	2.734E-02	2
7.000E+00	1.450E+01	1.449E+01	7.619E-03	5.279E+02	3.123E-05	2.151E-02	2.740E-02	2
8.000E+00	1.447E+01	1.446E+01	7.659E-03	5.276E+02	3.129E-05	2.148E-02	2.750E-02	2
9.000E+00	1.444E+01	1.443E+01	7.739E-03	5.273E+02	3.143E-05	2.145E-02	2.768E-02	2
1.000E+01	1.441E+01	1.440E+01	7.882E-03	5.270E+02	3.169E-05	2.141E-02	2.796E-02	2
1.100E+01	1.434E+01	1.428E+01	6.300E-02	5.263E+02	8.927E-05	2.135E-02	7.933E-02	2
1.200E+01	1.425E+01	1.416E+01	9.019E-02	5.253E+02	1.064E-04	2.125E-02	9.528E-02	2
1.300E+01	1.415E+01	1.404E+01	1.061E-01	5.242E+02	1.151E-04	2.113E-02	1.038E-01	2
1.400E+01	1.404E+01	1.392E+01	1.162E-01	5.231E+02	1.200E-04	2.102E-02	1.090E-01	2
1.500E+01	1.392E+01	1.380E+01	1.229E-01	5.219E+02	1.231E-04	2.090E-02	1.126E-01	2
1.600E+01	1.381E+01	1.368E+01	1.277E-01	5.206E+02	1.251E-04	2.077E-02	1.153E-01	2
1.700E+01	1.369E+01	1.356E+01	1.313E-01	5.194E+02	1.264E-04	2.065E-02	1.174E-01	2
1.800E+01	1.357E+01	1.344E+01	1.343E-01	5.181E+02	1.274E-04	2.052E-02	1.193E-01	2
1.900E+01	1.346E+01	1.332E+01	1.365E-01	5.169E+02	1.280E-04	2.039E-02	1.208E-01	2
2.000E+01	1.334E+01	1.320E+01	1.389E-01	5.156E+02	1.287E-04	2.026E-02	1.224E-01	2
2.100E+01	1.321E+01	1.301E+01	1.989E-01	5.142E+02	1.531E-04	2.012E-02	1.474E-01	2
2.200E+01	1.306E+01	1.282E+01	2.420E-01	5.126E+02	1.679E-04	1.996E-02	1.637E-01	2
2.300E+01	1.290E+01	1.263E+01	2.746E-01	5.108E+02	1.778E-04	1.979E-02	1.756E-01	2
2.400E+01	1.274E+01	1.244E+01	3.002E-01	5.090E+02	1.848E-04	1.960E-02	1.849E-01	2
2.500E+01	1.257E+01	1.225E+01	3.211E-01	5.071E+02	1.900E-04	1.942E-02	1.926E-01	2
2.600E+01	1.240E+01	1.206E+01	3.387E-01	5.051E+02	1.940E-04	1.922E-02	1.993E-01	2
2.700E+01	1.222E+01	1.187E+01	3.539E-01	5.031E+02	1.971E-04	1.903E-02	2.053E-01	2
2.800E+01	1.205E+01	1.168E+01	3.674E-01	5.011E+02	1.996E-04	1.883E-02	2.108E-01	2
2.900E+01	1.187E+01	1.149E+01	3.798E-01	4.990E+02	2.017E-04	1.863E-02	2.160E-01	2
3.000E+01	1.169E+01	1.130E+01	3.913E-01	4.969E+02	2.035E-04	1.843E-02	2.211E-01	2
3.099E+01	1.151E+01	1.107E+01	4.382E-01	4.948E+02	2.135E-04	1.822E-02	2.361E-01	2
3.199E+01	1.132E+01	1.084E+01	4.784E-01	4.925E+02	2.213E-04	1.800E-02	2.491E-01	2
3.299E+01	1.113E+01	1.061E+01	5.137E-01	4.901E+02	2.273E-04	1.778E-02	2.608E-01	2
3.399E+01	1.093E+01	1.038E+01	5.453E-01	4.877E+02	2.322E-04	1.755E-02	2.714E-01	2
3.499E+01	1.073E+01	1.015E+01	5.743E-01	4.852E+02	2.362E-04	1.731E-02	2.815E-01	2
3.599E+01	1.052E+01	9.922E+00	6.013E-01	4.827E+02	2.396E-04	1.707E-02	2.911E-01	2
3.699E+01	1.032E+01	9.692E+00	6.270E-01	4.801E+02	2.424E-04	1.683E-02	3.006E-01	2
3.799E+01	1.011E+01	9.462E+00	6.517E-01	4.775E+02	2.448E-04	1.659E-02	3.099E-01	2
3.899E+01	9.908E+00	9.232E+00	6.759E-01	4.748E+02	2.469E-04	1.634E-02	3.193E-01	2
3.999E+01	9.702E+00	9.002E+00	6.998E-01	4.721E+02	2.488E-04	1.610E-02	3.288E-01	2
4.099E+01	9.496E+00	8.777E+00	7.190E-01	4.693E+02	2.497E-04	1.585E-02	3.373E-01	2
4.199E+01	9.291E+00	8.553E+00	7.388E-01	4.666E+02	2.505E-04	1.560E-02	3.461E-01	2
4.299E+01	9.087E+00	8.328E+00	7.595E-01	4.638E+02	2.514E-04	1.535E-02	3.553E-01	2
4.399E+01	8.884E+00	8.103E+00	7.808E-01	4.609E+02	2.521E-04	1.509E-02	3.649E-01	2
4.499E+01	8.681E+00	7.878E+00	8.031E-01	4.581E+02	2.529E-04	1.484E-02	3.750E-01	2
4.599E+01	8.479E+00	7.653E+00	8.262E-01	4.552E+02	2.535E-04	1.459E-02	3.855E-01	2
4.699E+01	8.278E+00	7.428E+00	8.503E-01	4.523E+02	2.541E-04	1.434E-02	3.965E-01	2
4.799E+01	8.079E+00	7.203E+00	8.755E-01	4.494E+02	2.547E-04	1.408E-02	4.081E-01	2
4.898E+01	7.880E+00	6.978E+00	9.019E-01	4.464E+02	2.552E-04	1.383E-02	4.203E-01	2
4.998E+01	7.683E+00	6.754E+00	9.294E-01	4.434E+02	2.557E-04	1.357E-02	4.332E-01	2
5.098E+01	7.486E+00	6.519E+00	9.676E-01	4.404E+02	2.571E-04	1.331E-02	4.491E-01	2

TAU	P1	P2	DELP	T1	EMDOT	EM1	MACH	ITER
5.198E+01	7.291E+00	6.284E+00	1.007E+00	4.373E+02	2.582E-04	1.306E-02	4.657E-01	2
5.298E+01	7.096E+00	6.049E+00	1.047E+00	4.342E+02	2.591E-04	1.280E-02	4.829E-01	2
5.398E+01	6.902E+00	5.814E+00	1.087E+00	4.311E+02	2.598E-04	1.254E-02	5.010E-01	2
5.498E+01	6.709E+00	5.579E+00	1.130E+00	4.279E+02	2.602E-04	1.228E-02	5.200E-01	2
5.598E+01	6.518E+00	5.344E+00	1.173E+00	4.248E+02	2.603E-04	1.202E-02	5.401E-01	2
5.698E+01	6.328E+00	5.110E+00	1.219E+00	4.216E+02	2.602E-04	1.176E-02	5.614E-01	2
5.798E+01	6.141E+00	4.875E+00	1.266E+00	4.183E+02	2.599E-04	1.150E-02	5.840E-01	2
5.898E+01	5.956E+00	4.640E+00	1.316E+00	4.151E+02	2.593E-04	1.124E-02	6.080E-01	2
5.998E+01	5.772E+00	4.405E+00	1.367E+00	4.118E+02	2.583E-04	1.098E-02	6.337E-01	2
6.098E+01	5.593E+00	4.244E+00	1.350E+00	4.085E+02	2.528E-04	1.072E-02	6.408E-01	2
6.198E+01	5.420E+00	4.084E+00	1.336E+00	4.053E+02	2.477E-04	1.047E-02	6.491E-01	2
6.298E+01	5.252E+00	3.924E+00	1.328E+00	4.022E+02	2.429E-04	1.023E-02	6.591E-01	2
6.398E+01	5.089E+00	3.764E+00	1.325E+00	3.990E+02	2.384E-04	9.988E-03	6.708E-01	2
6.498E+01	4.930E+00	3.604E+00	1.326E+00	3.960E+02	2.342E-04	9.751E-03	6.843E-01	2
6.598E+01	4.776E+00	3.444E+00	1.332E+00	3.930E+02	2.301E-04	9.519E-03	6.998E-01	2
6.697E+01	4.626E+00	3.284E+00	1.342E+00	3.900E+02	2.263E-04	9.291E-03	7.171E-01	2
6.797E+01	4.480E+00	3.124E+00	1.356E+00	3.870E+02	2.225E-04	9.067E-03	7.366E-01	2
6.897E+01	4.338E+00	2.964E+00	1.374E+00	3.841E+02	2.188E-04	8.846E-03	7.582E-01	2
6.997E+01	4.201E+00	2.804E+00	1.396E+00	3.813E+02	2.150E-04	8.629E-03	7.822E-01	2
7.097E+01	4.067E+00	2.674E+00	1.393E+00	3.784E+02	2.103E-04	8.416E-03	7.979E-01	2
7.197E+01	3.937E+00	2.544E+00	1.394E+00	3.757E+02	2.058E-04	8.208E-03	8.154E-01	2
7.297E+01	3.812E+00	2.414E+00	1.399E+00	3.730E+02	2.013E-04	8.005E-03	8.352E-01	2
7.397E+01	3.691E+00	2.284E+00	1.407E+00	3.704E+02	1.969E-04	7.806E-03	8.574E-01	2
7.497E+01	3.574E+00	2.154E+00	1.420E+00	3.678E+02	1.925E-04	7.611E-03	8.824E-01	2
7.597E+01	3.461E+00	2.024E+00	1.437E+00	3.653E+02	1.880E-04	7.421E-03	9.102E-01	2
7.697E+01	3.352E+00	1.894E+00	1.458E+00	3.629E+02	1.834E-04	7.235E-03	9.412E-01	2
7.797E+01	3.247E+00	1.764E+00	1.483E+00	3.605E+02	1.787E-04	7.054E-03	9.758E-01	2
7.897E+01	3.146E+00	1.634E+00	1.512E+00	3.583E+02	1.738E-04	6.878E-03	1.014E+00	2
7.997E+01	3.049E+00	1.504E+00	1.545E+00	3.561E+02	1.685E-04	6.707E-03	1.058E+00	2
8.097E+01	2.956E+00	1.403E+00	1.553E+00	3.540E+02	1.633E-04	6.541E-03	1.089E+00	2
8.197E+01	2.868E+00	1.303E+00	1.564E+00	3.520E+02	1.579E-04	6.380E-03	1.124E+00	2
8.297E+01	2.783E+00	1.203E+00	1.580E+00	3.502E+02	1.524E-04	6.225E-03	1.163E+00	2
8.397E+01	2.703E+00	1.103E+00	1.599E+00	3.484E+02	1.466E-04	6.075E-03	1.208E+00	2
8.496E+01	2.627E+00	1.004E+00	1.623E+00	3.468E+02	1.405E-04	5.932E-03	1.258E+00	2
8.596E+01	2.555E+00	9.036E-01	1.651E+00	3.453E+02	1.340E-04	5.795E-03	1.315E+00	2
8.696E+01	2.488E+00	8.036E-01	1.684E+00	3.440E+02	1.270E-04	5.664E-03	1.380E+00	2
8.796E+01	2.426E+00	7.037E-01	1.722E+00	3.428E+02	1.193E-04	5.541E-03	1.456E+00	2
8.896E+01	2.369E+00	6.037E-01	1.765E+00	3.419E+02	1.108E-04	5.426E-03	1.546E+00	2
8.996E+01	2.317E+00	5.038E-01	1.813E+00	3.412E+02	1.013E-04	5.320E-03	1.653E+00	2
9.096E+01	2.270E+00	4.760E-01	1.794E+00	3.406E+02	9.769E-05	5.220E-03	1.677E+00	2
9.196E+01	2.226E+00	4.510E-01	1.775E+00	3.402E+02	9.433E-05	5.124E-03	1.700E+00	2
9.296E+01	2.183E+00	4.260E-01	1.757E+00	3.398E+02	9.095E-05	5.032E-03	1.725E+00	2
9.396E+01	2.142E+00	4.010E-01	1.741E+00	3.395E+02	8.753E-05	4.942E-03	1.752E+00	2
9.496E+01	2.104E+00	3.760E-01	1.728E+00	3.393E+02	8.408E-05	4.856E-03	1.783E+00	2
9.596E+01	2.068E+00	3.510E-01	1.717E+00	3.392E+02	8.057E-05	4.774E-03	1.816E+00	2
9.696E+01	2.034E+00	3.260E-01	1.708E+00	3.393E+02	7.700E-05	4.695E-03	1.854E+00	2
9.796E+01	2.002E+00	3.011E-01	1.701E+00	3.394E+02	7.334E-05	4.620E-03	1.895E+00	2
9.896E+01	1.972E+00	2.761E-01	1.696E+00	3.396E+02	6.959E-05	4.549E-03	1.941E+00	2
9.996E+01	1.945E+00	2.511E-01	1.694E+00	3.399E+02	6.571E-05	4.481E-03	1.994E+00	2

SUMMARY RESULTS

FREE VOLUME(IN**3)	=	500.00
HOLE SIZE(IN)	=	.05
MAXIMUM PRESSURE DIFFERENCE(PSI)	=	1.8154
TIME OF OCCURENCE(SEC)	=	90.0002

FLAP FORTRAN CODE LISTING

```
C*********************************************************************
C   FLAP IS A COMPUTER PROGRAM TO ANALYSE DEPRESSURIZATION OF AN
C   ELECTRONIC BOX IN THE SPACELAB. DURING THE ASCENT OF THE SPACE
C   SHUTTLE, PRESSURE IN THE SPACELAB REDUCES AT A RAPID RATE. THE
C   ELECTRONIC BOXES ARE PROVIDED WITH HOLES TO EQUALIZE PRESSURE
C   BETWEEN INSIDE AND OUTSIDE OF THE BOX TO AVOID STRUCTURAL DEFORMATION
C   OF THE BOX. THE ORBITER PAYLOAD BAY PRESSURE HISTORY IS PROVIDED IN
C   THE FOLLOWING TABLE
C
C   TIME(SEC)  PRESSURE(PSIA)
C
C      0        14.70
C     10        14.40
C     20        13.20
C     30        11.30
C     40         9.00
C     50         6.75
C     60         4.40
C     70         2.80
C     80         1.50
C     90         0.50
C    100         0.25
C
C   FLAP INCLUDES THREE DIFFERENT FORMULATIONS
C
C   OPTION - 1  FINITE VOLUME FORMULATION
C   OPTION - 2  ISENTROPIC FORMULATION
C   OPTION - 3  ISOTHERMAL FORMULATION
C*********************************************************************
C
C   VARIABLES
C
C   P1          - PRESSURE INSIDE THE BOX,PSIA
C   P2          - PRESSURE IN THE CARGO BAY,PSIA
C   T1          - TEMPERATURE INSIDE THE BOX,R
C   U1          - INTERNAL ENERGY OF AIR IN THE BOX,BTU/LBM
C   EM1         - MASS OF AIR IN THE BOX AT CURRENT TIME STEP,LBM
C   EMP         - MASS OF AIR IN THE BOX AT PREVIOUS TIMESTEP,LBM
C   EMDOT       - MASS FLOWRATE OF AIR,LBM/SEC
C   V1          - VOLUME OF THE BOX,IN**3
C   DOR         - VENT HOLE DIAMETER,IN
C   AREA1       - SURFACE AREA,IN**2
C   TWALL       - WALL TEMPERATURE,R
C   CD          - DISCHARGE COEFFICIENT
C   CV          - CONSTANT VOLUME SPECIFIC HEAT(BTU/LBM - R)
C   R           - GAS CONSTANT,LBF-FT/LBM-R
C   CC          - CONVERGENCE CRITERION
C   NITER       - MAXIMUM NUMBER OF ITERATIONS
C   RELAXM      - UNDER-RELAXATION PARAMETER FOR MASS
C   RELAXP      - UNDER-RELAXATION PARAMETER FOR PRESSURE
C   RELAXU      - UNDER-RELAXATION PARAMETER FOR INTERNAL ENERGY
C*********************************************************************
      DIMENSION TIME(20),PORBIT(20),DPODT(20)
      LOGICAL CHOCKED
      INTEGER OPTION
      CHARACTER*3 ANS
C
C   CHAPTER 1  INPUT DATA
C
      DATA PAI/3.14159/
      DATA T1INIT,T2INIT,P1INIT/70.,70.,14.7/
```

```
      DATA CP,CV,CD,R,GRAVC/0.24,0.17,1.,53.2,32.2/
      DATA NZONE/11/
      DATA NITER,CC/50,1.E-06/
      DATA RELAXM,RELAXP,RELAXU/3*1./
      DATA GAMA/1.4/
      DATA HC/0./
        DATA (TIME(I),I=1,11)/0.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
        DATA (PORBIT(I),I=1,11)/14.7,14.4,13.2,11.3,9.,6.75,4.4,2.8,1.5,
     &              0.5,0.25/
      OPEN(UNIT=70,FILE='VENTC.OUT',STATUS='UNKNOWN')
      PRINT *,'INPUT OPTION FOR FORMULATION'
      PRINT *,'1 - FINITE VOLUME FORMULATION'
      PRINT *,'2 - ISENTROPIC FORMULATION'
      PRINT *,'3 - ISOTHERMAL FORMULATION'
      READ(5,*) OPTION
      PRINT *,'INPUT OPTION FOR MDOT FORMULATION'
      PRINT *,'1 - FLAP MDOT FORMULATION'
      PRINT *,'2 - SINDA MDOT FORMULATION'
      READ(5,*) MDOTOPT
      PRINT *,'INPUT FREE VOLUME OF THE BOX IN CUBIC INCHES'
      READ(5,*) V1IN
      IF (OPTION.EQ.1) THEN
      PRINT *,'FLOW IS ADIABATIC? (Y OR N) '
      READ(5,10) ANS
   10 FORMAT(A1)
       IF(ANS.EQ.'Y') GO TO 15
        PRINT *,'INPUT HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-F)'
        READ(5,*) HC
        PRINT *,'INPUT WALL TEMPERATURE'
        READ(5,*) TWALL
        PRINT *,'INPUT SURFACE AREA OF THE BOX IN SQUARE INCHES'
        READ(5,*) AREAIN
       ENDIF
   15 PRINT *,'INPUT HOLE SIZE IN INCH'
      READ(5,*) DOR
      PRINT *,'INPUT PRINT INTERVAL'
      READ(5,*) NPSTEP
       V1=V1IN/1728.
      AREA1=AREAIN/144.
      AOR=PAI*DOR*DOR/(4.*144.)
C
C   CHAPTER 2  INITIAL CONDITION
C
      TAU=0.
      P1=P1INIT
      T1=T1INIT+460.
      U1=CV*T1
      T2=T2INIT+460.
      U2=CV*T2
      PRINT *,'INPUT TIME STEP,DTAU(SEC)'
      READ(5,*) DTAU
      PRINT *,'INPUT FINAL TIME(TAUF)'
      READ(5,*) TAUF
       EM1=P1*144.*V1/(R*T1)
      SV1=V1/EM1
      P1P=P1
      U1P=U1
      T1P=T1
      SV1P=SV1
C   PRINT INPUT VARIABLES
      WRITE(70,20) V1IN,DOR,DTAU
20    FORMAT(2X,'VOLUME = ',1PE12.3,' IN**3'/,
     &       2X,'DIA    = ',1PE12.3/,' IN',
     &       2X,'TIME STEP = ',1PE12.3,' SEC'//)
```

```
      IF(OPTION.EQ.1) WRITE(70,25)
      IF(OPTION.EQ.2) WRITE(70,28)
      IF(OPTION.EQ.3) WRITE(70,29)
25    FORMAT(2X,'FINITE VOLUME FORMULATION'//)
28    FORMAT(2X,'ISENTROPIC FORMULATION'//)
29    FORMAT(2X,'ISOTHERMAL FORMULATION'//)
      IF(OPTION.EQ.1 .AND. ANS.NE.'Y') WRITE(70,250) TWALL,HC,AREAIN
250   FORMAT(2X,'TWALL = ', 1PE12.3,' DEG R'/,
     &      2X,'HC    = ',1PE12.3,' BTU/HR-FT**2-F'/,
     &      2X,'AREA  = ',1PE12.3,' IN**2' //)
C     CONVERT UNITS OF HEAT TRANSFER COEFFICIENT
      HC=HC/3600.
C
C     CHAPTER 3  TIME MARCHING
C
      WRITE(70,30)
30    FORMAT(5X,'TAU',9X,'P1',10X,'P2',7X,'DELP',9X,'T1',
     &      5X,'EMDOT',7X,'EM1',8X,'MACH',4X,'ITER')
300   TAU=TAU+DTAU
      ISTEP=ISTEP+1
      EMP=EM1
      DO 310 I = 2,NZONE
       DPODT(I)=(PORBIT(I)-PORBIT(I-1))/(TIME(I)-TIME(I-1)`
       IF(TAU.LE.TIME(I).AND.TAU.GT.TIME(I-1)) IZONE=I
310   CONTINUE
      P2=PORBIT(IZONE-1)+DPODT(IZONE)*(TAU-TIME(IZONE-1))
C
C     ITERATION LOOP IN THE TIME STEP
C
      ITER=0
320   ITER=ITER+1
       RHO1=P1*144./(R*T1)
       RHO2=P2*144./(R*T2)
C     CHECK FOR DELP
      IF(P1.GT.P2) THEN
       PU=P1
       PD=P2
       RHOU=RHO1
       DELP=P1-P2
       FACT=1.
      ELSE
       PU=P2
       PD=P1
       RHOU=RHO2
       DELP=P2-P1
       FACT=-1.
      ENDIF
C
C     CALCULATE FLOWRATE
C
      CALL FLOW(DOR,CD,P1,P2,T1,GAMA,R,RHOU,EMDOT,MDOTOPT)
C
C     CHAPTER 3  MASS CONSERVATION
C
      EM1OLD=EM1
      EM1=EMP-EMDOT*DTAU*FACT
      EM1=(1.-RELAXM)*EM1OLD+RELAXM*EM1
      SV1=V1/EM1
      FACT1=(PU/PD)**((GAMA-1.)/GAMA)-1.
      FACT2=(2./(GAMA-1.))
      EMACH=SQRT(FACT2*FACT1)
      DELM=ABS(EM1OLD-EM1)/EM1
C
C     CHAPTER 4  ENERGY CONSERVATION
```

```
C
      IF(OPTION.EQ.1) GO TO 40
      IF(OPTION.EQ.2) GO TO 45
      IF(OPTION.EQ.3) GO TO 48
C   ENTHALPY FORMULATION
40    ATR=EMP
      ACON1=EMDOT*DTAU
      AP=EM1
       H1P=U1P+P1P*144.*SV1P/778.
      U1OLD=U1
      U1=(ATR*U1P-ACON1*H1P+HC*AREA1*(TWALL-T1)*DTAU)/AP
      U1=(1.-RELAXU)*U1OLD+RELAXU*U1
      T1=U1/CV
      DELU1=ABS(U1OLD-U1)/U1
       P1=EM1*R*T1/(V1*144.)
      ERROR=AMAX1(DELM,DELU1)
      GO TO 50
C   ISENTROPIC FORMULATION
45    P1OLD=P1
       P1=EM1*R*T1/(V1*144.)
      T1OLD=T1
      T1=T1P*(P1/P1P)**((GAMA-1.)/GAMA)
      DIFP=ABS(P1OLD-P1)/P1OLD
      DIFT=ABS(T1OLD-T1)/T1OLD
      ERROR=AMAX1(DIFP,DIFT)
      GO TO 50
C   ISOTHERMAL FORMULATION
C
48    P1OLD=P1
       P1=EM1*R*T1/(V1*144.)
      T1=T1P
      DIFP=ABS(P1OLD-P1)/P1OLD
      ERROR=AMAX1(DELM,DIFP)
C
50    CONTINUE
      IF(ITER.GT.NITER) GO TO 600
      IF(ITER.LT.2.OR.ERROR.GE.CC) GO TO 320
C
C   CHAPTER 6  DECIDE
C
 600 CONTINUE
      IF(ITER.GT.NITER) WRITE(70,625) NITER,DELM,DELU1
 625 FORMAT(5X,'**** W A R N I N G ****'/,
     &      5X,'SOLUTION DID NOT CONVERGE IN ',I4,' ITERATIONS'/,
     &      5X,'DELM= ',1PE12.3,5X,'DELU1= ',1PE12.3)
      P1P=P1
      U1P=U1
      T1P=T1
      SV1P=SV1
      EMP=EM1
      IF(MOD(ISTEP,NPSTEP).EQ.0)
     & WRITE(70,650) TAU,P1,P2,DELP,T1,EMDOT,EM1,EMACH,ITER
 650 FORMAT(1P8E11.3,I4)
C   DETERMINE DPMAX
      IF(DELP.GT.DPMAX) THEN
       DPMAX=DELP
       TAUMAX=TAU
      ENDIF
      IF(TAU.LT.TAUF) GO TO 300
      WRITE(70,670) V1IN,DOR,DPMAX,TAUMAX
 670 FORMAT(15X,'SUMMARY RESULTS'/,
     &      15X,'_______________'/,
     &      5X,'FREE VOLUME(IN**3)          =',F8.2/,
     &      5X,'HOLE SIZE(IN)               =',F8.2/,
```

```
     &      5X,'MAXIMUM PRESSURE DIFFERENCE(PSI)= ',F8.4,/,
     &      5X,'TIME OF OCCURENCE(SEC)        = ',F8.4,/,)
      STOP
      END
      SUBROUTINE FLOW(D2,CD,P1,P2,T1,GAMA,RGAS,RHOU,EMDOT,MDOTOPT)
C
C  THIS SUBROUTINE CALCUALTES FLOW RATE THROUGH ORIFICE AND NOZZLE
C
C  VARIABLES
C
C  D2 - DIAMETER, IN
C  CD - DISCHARGE COEFFICIENT
C  T1 - UPSTREAM TEMPERATURE, R
C  P1 - UPSTREAM PIPE/PLENUM PRESSURE, PSIA
C  P2 - THROAT OR VENA CONTRACTA PRESSURE, PSIA
C  RP - PRESSURE RATIO, P2/P1
C  MDOTOPT - MDOT FORMULATION (FLAP OR SINDA) OPTION
C  EMDOT - MASS FLOWRATE (LB/SEC)
C  A2 - THROAT AREA, IN**2
C  RGAS - GAS CONSTANT FT-LBF/LBM*R
      REAL K
      CHARACTER*3,ANS
       DATA PAI, GRAV/3.14159,32.174/
       A2 = PAI*D2*D2/4.
       RP = P2/P1
       PU=P1
       IF(MDOTOPT.EQ.1)THEN
       FACT1=CD*A2*PU/SQRT(T1)
       FACT2=2.*GAMA*GRAV/((GAMA-1.)*RGAS)
       FACT3=ABS(RP**(2./GAMA)-RP**((GAMA+1)/GAMA))
       EMDOT=FACT1*(FACT2*FACT3)**0.5
       ELSE
       BETA=0.0
        A2=A2/144.
        Y=1.-(0.41+0.35*BETA**4)*(PU-P2)/(GAMA*PU)
        GCOND=CD*A2*SQRT(2.*32.174*144.*RHOU)
       GCOND=GCOND*Y/SQRT(PU-P2)
       EMDOT=GCOND*ABS(PU-P2)
       ENDIF
       RETURN
       END
```

Finite Difference Procedure (SINDA):

Isentropic Formulation:

The results of the analysis are given in the figures below

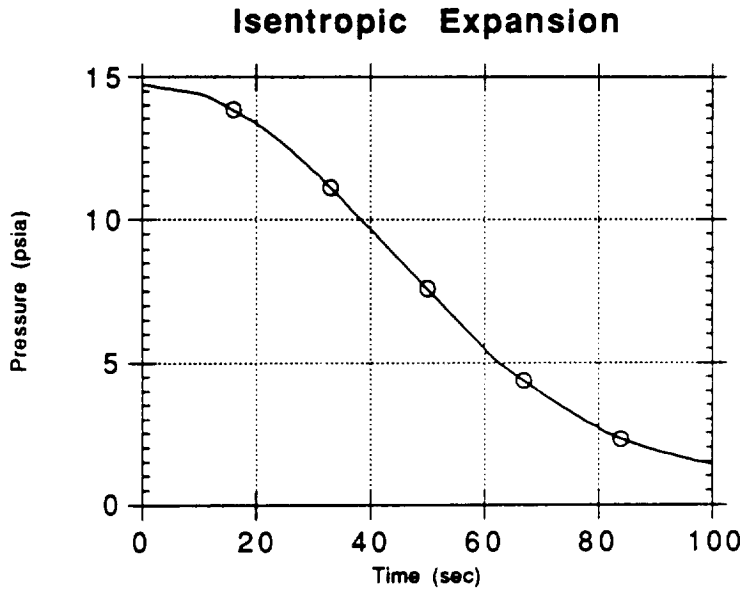

Figure 9. Predicted pressure distribution in the box, Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

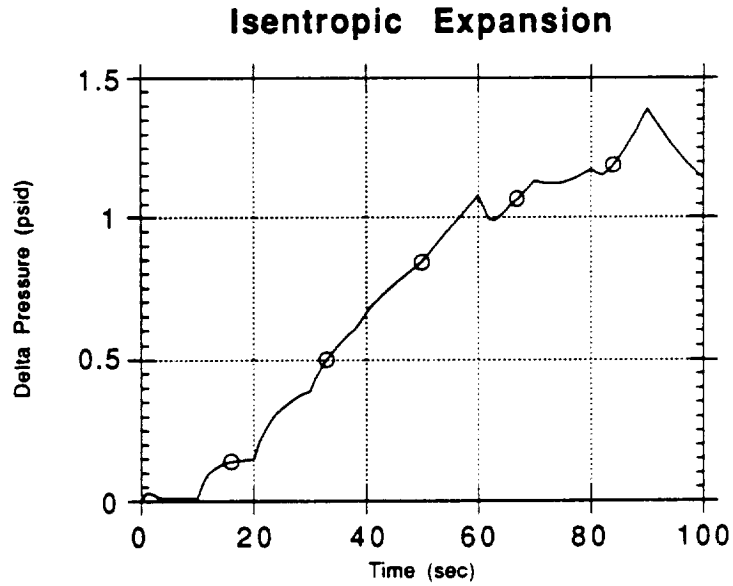

Figure 10. Predicted distribution of pressure difference between the box and the cargo bay; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

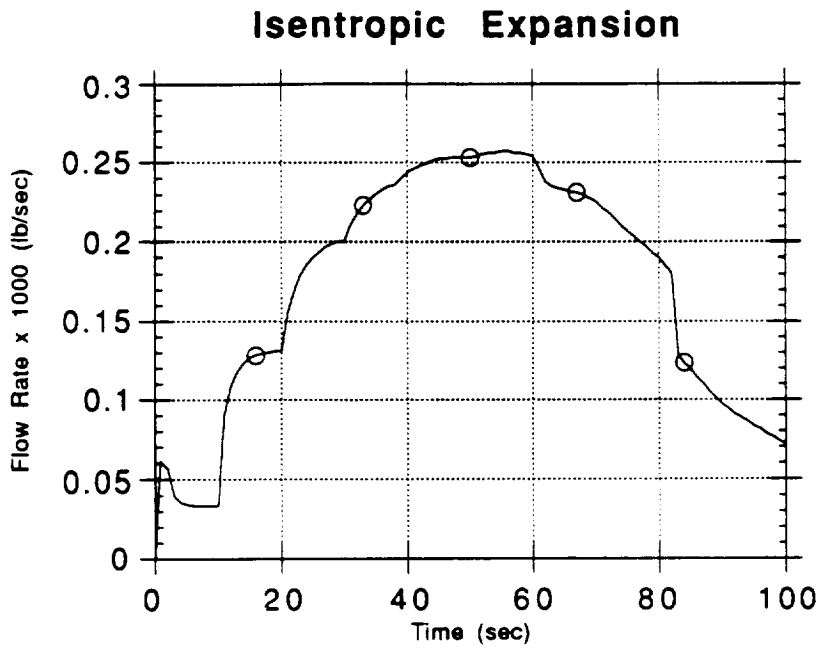

Figure 11. Predicted distribution of mass flowrate from the box during the first 100 seconds after lift-off; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

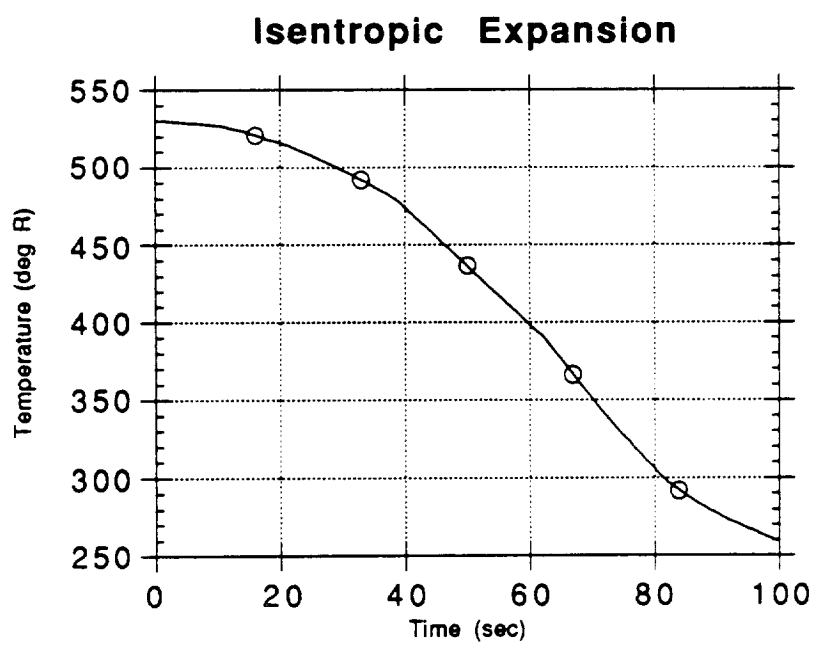

Figure 12. Predicted air temperature inside the box during the first 100 seconds after lift-off; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

SINDA ISENTROPIC MODEL LISTING

```
        BCD 3THERMAL LPCS
    BCD 9VENTING DURING ASCENT, ISENTROPIC
    END
C
    BCD 3NODE DATA
C
        1, 0.0, 1.0
        2, 0.0, 1.0
        -3, 0.0, 1.0
C
       -106,14.7,1.0 $ PRES BOUNDARY
C
       -206, 14.7, 1.0 $ PRES AT FIRST CAVITY
C
C FLOW RATE STORAGE LOCATION
C
       -1006, 0.0, 1.0
C
C GAS TEMP
C
       -2006, 530.0, 1.0
C
       -3006, 0.0, 1.0
C
    END
C
    BCD 3CONDUCTOR DATA
C
       1, 1, 2, 1.0
       2, 2, 3, 1.0
C
       106, 106, 206, 0.0
C
C FLOW RATE STORAGE LOCATION
C
    END
C
    BCD 3CONSTANTS DATA
      DTIMEI,1.E-6
      DTIMEH,1.E-6
      NLOOP,1000
C
      TIMEND,0.0
      OUTPUT,10.E-6
C
      ARLXCA,.01
      DRLXCA,.01
      TIMEO,0.0
      DAMPA,0.5
      DAMPD,0.5
      NDIM,100
      ITEST,0
       998,0.0
C
    END
C
    BCD 3ARRAY DATA
      1 $ RHO
          4, 1.0, 5.0, 10.0, 14.7
          200.0, 0.01307, 0.06558, 0.1318, 0.1946
          300.0, 0.008704, 0.04357, 0.08728, 0.12840
          400.0, 0.006526, 0.03625, 0.06509, 0.09605
```

```
      500.0, 0.005221, 0.02611, 0.05222, 0.07676
      560.0, 0.004662, 0.02331, 0.04662, 0.06851
    END
C
    101 $ GAS CONSTANT ARRAY
      4, 1.0, 5.0, 10.0, 14.7
      300.0, 55.14, 55.14, 55.14, 55.14
      400.0, 55.14, 55.14, 55.14, 55.14
      500.0, 55.14, 55.14, 55.14, 55.14
      560.0, 55.16, 55.16, 55.16, 55.16
    END
C
    203 $ ENTROPY ARRAY
      4, 1.0, 5.0, 10.0, 14.7
      200.0, 1.579, 1.465, 1.415, 1.387
      300.0, 1.680, 1.566, 1.516, 1.489
      400.0, 1.752, 1.637, 1.588, 1.561
      500.0, 1.807, 1.693, 1.643, 1.616
      560.0, 1.835, 1.721, 1.672, 1.644
    END
C
    301 $ RATIO OF SPECIFIC HEATS WITH PRESSURE
      1.0, 1.40
      5.0, 1.40
      10.0, 1.40
      14.7, 1.40
    END
C
    501 $ BOUNDARY PRES VS TIME
      0.0, 14.7
      10.0, 14.4
      20.0, 13.2
      30.0, 11.3
      40.0, 9.0
      50.0, 6.75
      60.0, 4.4
      70.0, 2.8
      80.0, 1.5
      90.0, 0.5
      100.0, 0.25
    END
C
    701 $ DENSITY VS PRES AT S=1.631
      0.01066,1.0
      0.03349,5.0
      0.05441,10.0
      0.07240,14.7
    END
C
    702 $ DENSITY VS TEMP AT S=1.631
      0.01066,245.0
      0.03349,390.0
      0.05441,480.0
      0.07240,530.0
    END
C
   END
C
   BCD 3EXECUTION
C
F  OPEN(3,FILE="v2c2.plt",STATUS="UNKNOWN")
F  WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F 2 FORMAT(I6/,5(I6,31X,I6,/),I6,31X,I6)
C
```

```
F    TIMEO=0.0
F    DTIMEI=0.001
F    DTIMEH=0.001
F    OUTPUT=1.0
F    TIMEND=100.0
C
F     DTIMEU=0.001
C
F      VOL=500.0/(12.**3)
M     CALL D2DEG1(T206,T2006,A1,RHO)
M     CALL D2DEG1(T206,T2006,A101,RGAS)
M    XK998=RHO*VOL
C
F   CALL SNFRDL
C
    END
    BCD 3VARIABLES 1
C
C CALC ORIFICE FLOW CONDUCTORS
C
M   CALL D1DEG1(TIMEN,A501,T106)
C
M    PAVG=T206
M    CALL D1DEG1(PAVG,A301,GK)
F    ENTRPY=1.631
M    CALL CENTH(ENTRPY,T206,A203,T2006)
M    CALL D2DEG1(T206,T2006,A101,RGAS)
M      AREA=(3.14159*(0.05/12.)**2)/4.
M    CALL D2DEG1(PAVG,T2006,A1,RHO)
M     CALL IRIFIC(RHO,AREA,RGAS,T2006,T106,T206,GK,T1006,G106)
C
C CALC MDOTS
C
F     VOL=500.0/(12.**3)
C
M     CALL XMDOT(T106,T206,G106,T1006)
C
M     XK998=XK998-T1006*DTIMEU
C
M    RHO=XK998/VOL
M    CALL D1DEG1(RHO,A701,T206)
M    CALL D1DEG1(RHO,A702,T2006)
C
F   RETURN
F   END
C
F   SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F   XM=GCOND*ABS(PUP-PDN)
F   RETURN
F   END
C
C
F   SUBROUTINE CENTH(ENTH,PRES,ARR,TEMP)
C
F     DIMENSION ARR(1)
C
C THIS ROUTINE INTERPOLATES FOR TEMPERATURE, BASED UPON ENTHALPY
C AND PRESSURE
C
F   ICOUNT=0
F   TGLOW=200.0
F   TGHIGH=570.0
F 1  TG=(TGLOW+TGHIGH)/2.0
```

```
F     ICOUNT=ICOUNT+1
F     CALL D2DEG1(PRES,TG,ARR(1),EN)
F     ENCALC=EN-ENTH
F     IF(ABS(ENCALC).LT.1.E-4)GO TO 10
F     IF(ICOUNT.GT.1000)GO TO 10
F     IF(EN.LT.ENTH)TGLOW=TG
F     IF(EN.GE.ENTH)TGHIGH=TG
F     GO TO 1
F10   TEMP=TG
F     RETURN
F     END
C
C
F     SUBROUTINE IRIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F     IF(PUP.EQ.PDN)GO TO 2
C
F     PUP1=PUP
F     PDN1=PDN
C
F     PS1=PUP
F     PS2=PDN
F     IF(PUP.GT.PDN)GO TO 1
F     PUP1=PS2
F     PDN1=PS1
F 1   CONTINUE
C
F     BETA=0.0
F      Y=1.-(0.41+0.35*BETA**4)*(PUP1-PDN1)/(GK*PUP1)
C
F     GMAX=1.0*AREA*SQRT(144.*GK*32.2*RHO)/SQRT(AMAX1(PUP,PDN))
F     GMAX=Y*GMAX*PUP1/(ABS(PUP-PDN))
C
F      GCOND=1.0*AREA*SQRT(2.*32.2*144.*RHO)
F     GCOND=GCOND*Y/SQRT(PUP1-PDN1)
C
F      PRATIO=(2.0/(GK+1.0))**(GK/(GK-1.0))
F     IF(PDN1/PUP1.LT.PRATIO)GCOND=AMIN1(GMAX,GCOND)
C
F     RETURN
F 2   GCOND=0.0
C     RETURN
C     END
C
C
      END
C
      BCD 3VARIABLES 2
      END
C
      BCD 3OUTPUT CALLS
C
F     DATA HT/4HT  /
C
C
C CALC MDOTS
C
M      T3006=T206-T106
M      CALL XMDOT(T106,T206,G106,T1006)
M       T1006=T1006*1000.
C
F     WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F     1   FORMAT(E10.3/,7F12.6,/,7F12.6,/,7F12.6)
C
```

```
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
F     J=LNODE+NCSGMN
F     I1=NX(J)
F     IF(J.LE.LNODE)I1=0
F     J=LNODE+NDTMPC
F     I2=NX(J)
F     IF(J.LE.LNODE)I2=0
F     J=LNODE+NARLXC
F     I3=NX(J)
F     IF(J.LE.LNODE)I3=0
F     WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F  9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F   $        8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F   $        8H RELXCC(I6,2H)=1PE12.5)
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F     WRITE(6,100)
F 100  FORMAT(1H )
F     J=1
F     L=3
F  5  IF(L.LT.NNT)GO TO 10
F     L=NNT
F  10  WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101   FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F     IF(L.EQ.NNT)go to 15
F     J=L+1
F     L=L+3
F     GO TO 5
F 15  CONTINUE
M       T1006=T1006/1000.
C     RETURN
C     END
C
      END
      BCD 3END OF DATA
```

Isothermal Formulation:

The results of the analysis are given in the figures below

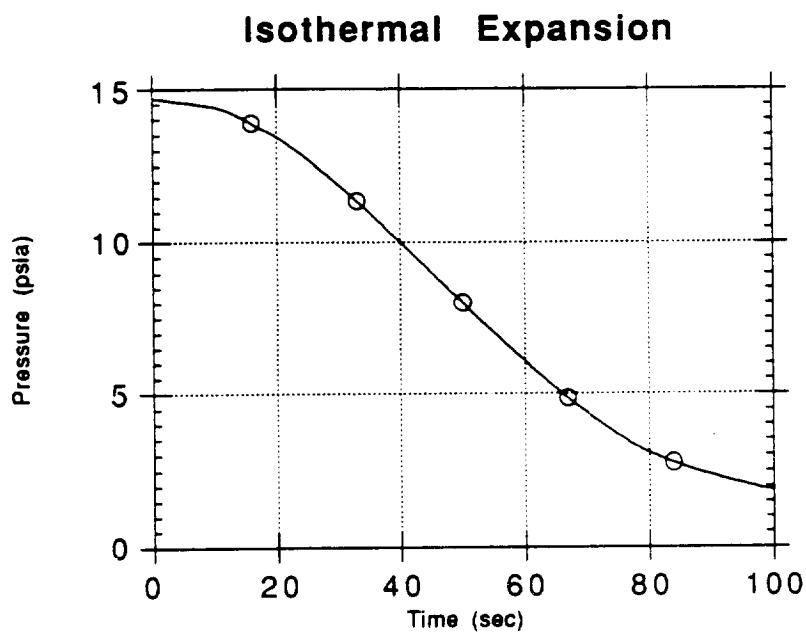

Figure 13. Predicted pressure distribution in the box; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

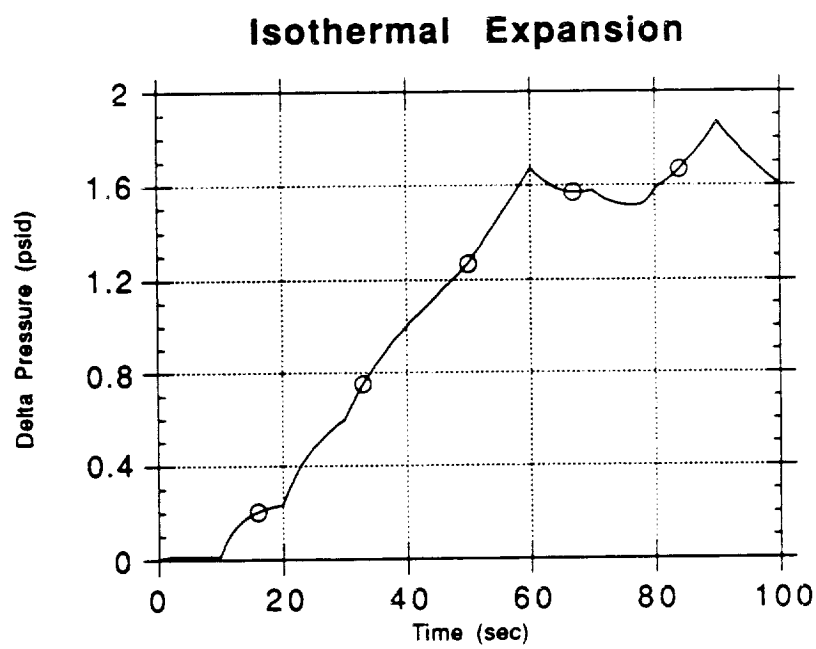

Figure 14. Predicted distribution of pressure difference between the box and the cargo bay; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

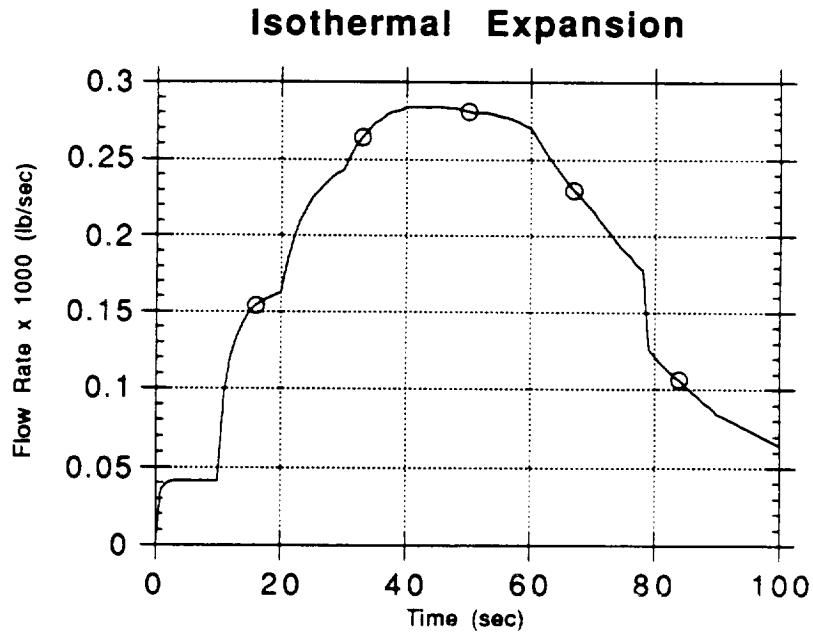

Figure 15. Predicted distribution of mass flowrate from the box during the first 100 seconds after lift-off; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

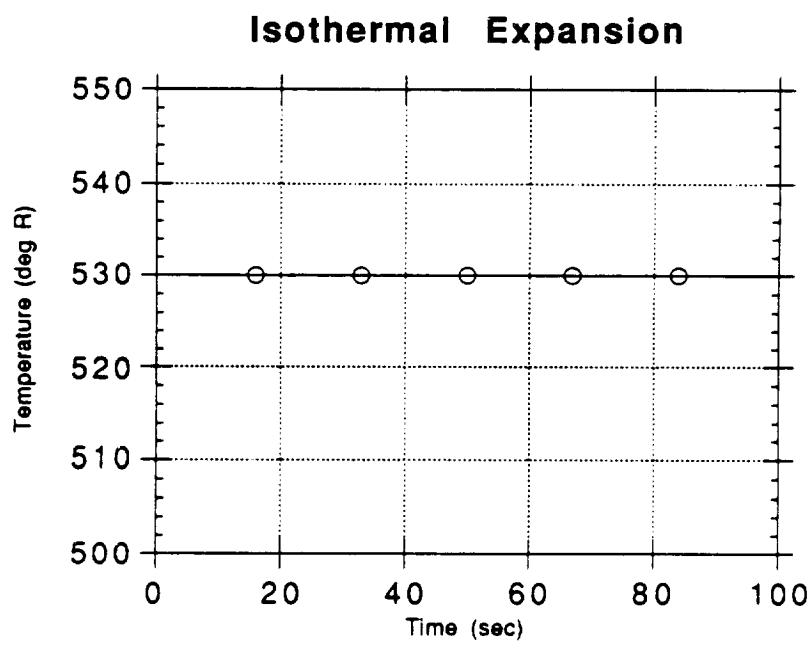

Figure 16. Predicted air temperature inside the box during the first 100 seconds after lift-off; Box volume = 500 in^3; Vent hole diameter = 0.05 in; C_D = 1.00

SINDA ISOTHERMAL MODEL LISTING

```
        BCD 3THERMAL LPCS
    BCD 9VENTING DURING ASCENT, ISOTHERMAL
    END
C
    BCD 3NODE DATA
C
        1, 0.0, 1.0
        2, 0.0, 1.0
        -3, 0.0, 1.0
C
       -106,14.7,1.0 $ PRES BOUNDARY
C
       206, 14.7, 1.0 $ PRES AT FIRST CAVITY
C
C FLOW RATE STORAGE LOCATION
C
        -1006, 0.0, 1.0
C
C GAS TEMP
C
        -2006, 530.0, 1.0
C
        -3006, 0.0, 1.0
C
    END
C
    BCD 3CONDUCTOR DATA
C
        1, 1, 2, 1.0
        2, 2, 3, 1.0
C
        106, 106, 206, 0.0
C
C FLOW RATE STORAGE LOCATION
C
    END
C
    BCD 3CONSTANTS DATA
       DTIMEL,1.E-6
       DTIMEH,1.E-6
       NLOOP,1000
C
       TIMEND,0.0
       OUTPUT,10.E-6
C
       ARLXCA,.01
       DRLXCA,.01
       TIMEO,0.0
       DAMPA,0.5
       DAMPD,0.5
       NDIM,100
       ITEST,0
C
    END
C
    BCD 3ARRAY DATA
C
        1 $ RHO
           4, 1.0, 5.0, 10.0, 14.7
           200.0, 0.01307, 0.06558, 0.1318, 0.1946
           300.0, 0.008704, 0.04357, 0.08728, 0.12840
           400.0, 0.006526, 0.03625, 0.06509, 0.09605
```

```
        500.0, 0.005221, 0.02611, 0.05222, 0.07676
        560.0, 0.004662, 0.02331, 0.04662, 0.06851
      END
C
      101 $ GAS CONSTANT ARRAY
        4, 1.0, 5.0, 10.0, 14.7
        300.0, 55.14, 55.14, 55.14, 55.14
        400.0, 55.14, 55.14, 55.14, 55.14
        500.0, 55.14, 55.14, 55.14, 55.14
        560.0, 55.16, 55.16, 55.16, 55.16
      END
C
      301 $ RATIO OF SPECIFIC HEATS WITH PRESSURE
        1.0, 1.40
        5.0, 1.40
        10.0, 1.40
        14.7, 1.40
      END
C
      501 $ BOUNDARY PRES VS TIME
        0.0, 14.7
        10.0, 14.4
        20.0, 13.2
        30.0, 11.3
        40.0, 9.0
        50.0, 6.75
        60.0, 4.4
        70.0, 2.8
        80.0, 1.5
        90.0, 0.5
        100.0, 0.25
      END
C
    END
C
    BCD 3EXECUTION
C
F    OPEN(3,FILE="v2c1iso.plt",STATUS="UNKNOWN")
F    WRITE(3,2)NNT,(NX(LNODE+I),I=1,NNT)
F   2 FORMAT(I6/,5(I6,31X,I6,/),I6,31X,I6)
C
F    TIMEO=0.0
F    DTIMEI=0.01
F    DTIMEH=0.01
F    OUTPUT=1.0
F    TIMEND=100.0
F    DTIMEU=0.01
C
M    CALL D2DEG1(T206,T2006,A101,RGAS)
M     VOL=500.*((1./12.)**3)
M     C206=144.*VOL/(RGAS*T2006)
C
F    CALL SNFRDL
C
    END
    BCD 3VARIABLES 1
C
C CALC ORIFICE FLOW CONDUCTORS
C
M    CALL D1DEG1(TIMEN,A501,T106)
C
M    CALL D1DEG1(T206,A301,GK)
C
M    CALL D2DEG1(T206,T2006,A101,RGAS)
```

```
M       AREA=(3.14159*(0.05/12.)**2)/4.
M     CALL D2DEG1(T206,T2006,A1,RHO)
M      CALL IRIFIC(RHO,AREA,RGAS,T2006,T106,T206,GK,T1006,G106)
C
C CALC MDOTS
C
M     CALL XMDOT(T106,T206,G106,T1006)
C
F    RETURN
F    END
C
F    SUBROUTINE XMDOT(PUP,PDN,GCOND,XM)
C
F    XM=GCOND*ABS(PUP-PDN)
F    RETURN
F    END
C
F    SUBROUTINE IRIFIC(RHO,AREA,RGAS,TEMP,PUP,PDN,GK,XM,GCOND)
C
F    IF(PUP.EQ.PDN)GO TO 2
C
F    PUP1=PUP
F    PDN1=PDN
C
F    PS1=PUP
F    PS2=PDN
F    IF(PUP.GT.PDN)GO TO 1
F    PUP1=PS2
F    PDN1=PS1
F 1  CONTINUE
C
F    BETA=0.0
F     Y=1.-(0.41+0.35*BETA**4)*(PUP1-PDN1)/(GK*PUP1)
C
F    GMAX=1.0*AREA*SQRT(144.*GK*32.2*RHO)/SQRT(AMAX1(PUP,PDN))
F    GMAX=Y*GMAX*PUP1/(ABS(PUP-PDN))
C
F     GCOND=1.0*AREA*SQRT(2.*32.2*144.*RHO)
F    GCOND=GCOND*Y/SQRT(PUP1-PDN1)
C
F     PRATIO=(2.0/(GK+1.0))**(GK/(GK-1.0))
F    IF(PDN1/PUP1.LT.PRATIO)GCOND=AMIN1(GMAX,GCOND)
C
F    RETURN
F 2  GCOND=0.0
C    RETURN
C    END
C
C
    END
C
    BCD 3VARIABLES 2
C
    END
C
    BCD 3OUTPUT CALLS
C
F    DATA HT/4HT  /
C
C
C CALC MDOTS
C
M     CALL XMDOT(T106,T206,G106,T1006)
M      T1006=T1006*1000.
```

```
C
M       T3006=T206-T106
C
F     WRITE(3,1)TIMEN,(T(I),I=1,NNT)
F   1   FORMAT(E10.3/,7F12.6,/,7F12.6,/,7F12.6)
C
C THREE COLUMN OUTPUT ROUTINE, STNDRD
C
F     J=LNODE+NCSGMN
F     I1=NX(J)
F     IF(J.LE.LNODE)I1=0
F     J=LNODE+NDTMPC
F     I2=NX(J)
F     IF(J.LE.LNODE)I2=0
F     J=LNODE+NARLXC
F     I3=NX(J)
F     IF(J.LE.LNODE)I3=0
F     WRITE(6,9)TIMEN,DTIMEU,I1,CSGMIN,I2,DTMPCC,I3,ARLXCC
F 9   FORMAT(/,11H **********/6H TIME=F12.5,8X,8H DTIMEU=1PE12.5,
F  $        8H CSGMIN(I6,2H)=1PE12.5,/,18X,8H TEMPCC(I6,2H)=1PE12.5,
F  $        8H RELXCC(I6,2H)=1PE12.5)
C
C THREE COLUMN OUTPUT ROUTINE, TPRNTX
C
F     WRITE(6,100)
F 100 FORMAT(1H )
F     J=1
F     L=3
F  5  IF(L.LT.NNT)GO TO 10
F     L=NNT
F 10  WRITE(6,101) (HT,NX(I+LNODE),T(I),I = J,L)
F 101  FORMAT(3(1X,A1,I6,1H=,F12.5,1X))
F     IF(L.EQ.NNT)go to 15
F     J=L+1
F     L=L+3
F     GO TO 5
F 15  CONTINUE
M       T1006=T1006/1000.
C     RETURN
C     END
C
      END
      BCD 3END OF DATA
```

Comparison of Results:

Figure 17 shows the results of a comparison of the predicted pressure differential, obtained using the two analysis codes (i.e., FLAP and SINDA). Both codes employed the isentropic formulation. The overall agreement was good. The observed discrepancies was attributed to the difference in thermo-physical property data. The flow equation as described in reference 2 was incorporated into both the FLAP and SINDA models. FLAP used the ideal gas law to calculate the thermo-dynamic property; SINDA used property values from the Gas Table. Predicted temperatures, during the period of ascent, are compared in Figure 18. The temperatures are consistent with the predicted pressure distribution, as shown in the previous figure. Since SINDA predicted a lower pressure in the box, the predicted temperatures were also lower, as compared to the FLAP predictions.

The results for the isothermal expansion are compared in Figure 19. The predicted pressure differentials were higher than those reported for the isentropic expansion. Isothermal venting showed a larger pressure differential because energy was added to the fluid, during the expansion

process, as a result of heat transfer from the wall. Since the cargo bay pressure remained the same, in both cases the pressure in the box remained higher and caused a larger pressure differential. The observed differences between FLAP and SINDA results were due to the differences noted above.

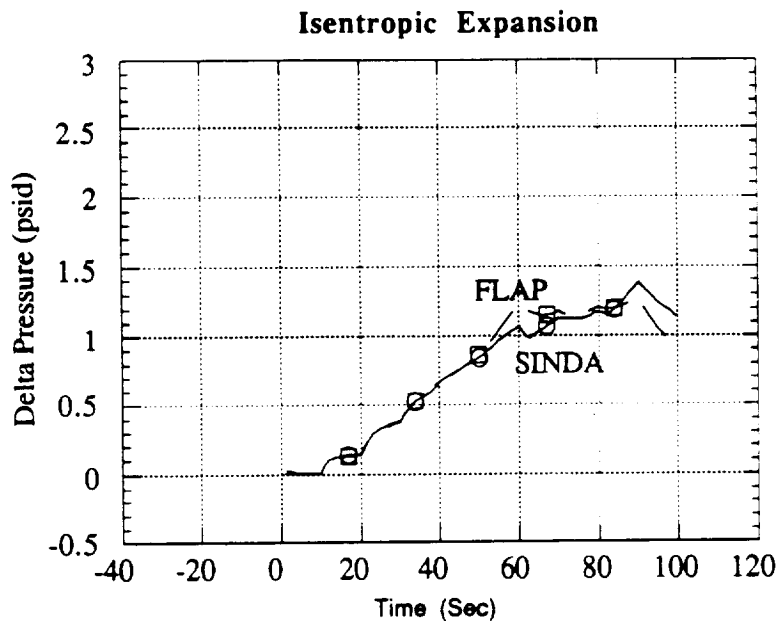

Figure 17. Comparison of predicted pressure differential between FLAP and SINDA for isentropic formulation

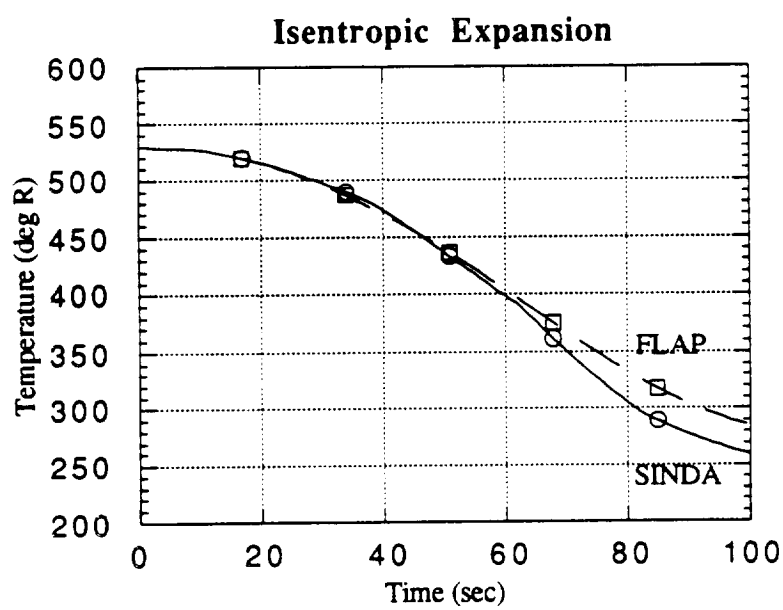

Figure 18. Comparison of predicted temperatures between FLAP and SINDA for isentropic formulation

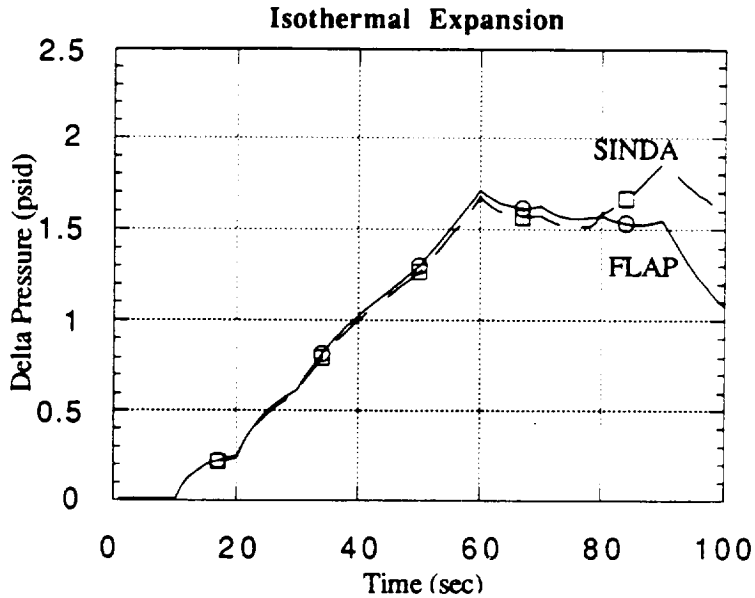

Figure 19. Comparison of predicted pressure differential between FLAP and SINDA for isothermal formulation

E. Closing Comments:

In this section, two numerical procedures were developed to analyze the venting problem in a spacecraft. A finite-volume procedure for solving the transient (mass and energy) conservation equations was incorporated into the FLAP code. A finite-difference based model was developed using the network analyzer code, SINDA. The results of both analyses were compared. Reasonable agreement between the two solutions was noted. It has also been shown that, the isothermal and isentropic formulations produce the upper and lower bounds of the solution. In the presence of heat transfer, from the wall to the fluid, the solution was found to be within the limits of the two extremes. The isothermal formulation can be used to determine the worst case design conditions. Additionally, the SINDA formulation can be extended to multiple volumes, venting in series or in parallel.

IV. References:

1.0 Sverdrup Technology Inc., Colbert, R. F., Ghaffarian, B., Majumdar, A. K., A Computer Program to Perform Flow and Thermal Analysis During Pressurization of the 70-LB Test Motor (FLAP Version 2.1), Prepared for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Contract No. NAS 8-37814, TN-SvT-MD5.1/90-006, November 1990.

2.0 Thermal Analysis Workbook, Chapter 5, Thermal Analysis Branch, George C. Marshall Space Flight Center

3.0 B. W. Anderson, The Analysis and Design of Pneumatic Systems, Robert E. Kreiger Publishing Company, 1967

Introduction to Chapter 6

Thermal Protection Systems

During design of the External Tank (ET) and Solid Rocket Booster (SRB), a design code was required to size thermal protection systems (TPS) required for ascent and reentry aerodynamic heating. To accomplish this, along with extensive material testing, an analysis code was developed to use with SINDA, to determine material thickness requirements to meet structural temperature limits. This code, called ABL, was designed to utilize aerodynamic heating environments, and through empirical relationships, evaluate material ablation, along with standard simulation of heat storage and heat transfer. The example included here shows how to use the ABL code with SINDA, and also gives a detailed numerical formulation of the analytical techniques used in the code. The techniques illustrated here were essential during design and are still utilized by the ET and SRB contractors to evaluate TPS requirements and changes.

CHAPTER 6: THERMAL PROTECTION SYSTEMS

SECTION 1: Aeroheating Temperature Analysis

ANALYSIS CODE : SINDA (Gaski Version)

I. Identification of the Problem

A. Statement of the Problem

It has been proposed to make the nose cone of the HLLV from AISI 347 Stainless Steel. It is necessary to predict the surface temperature of the plate to determine if a thermal protection system will be required.

B. Schematic

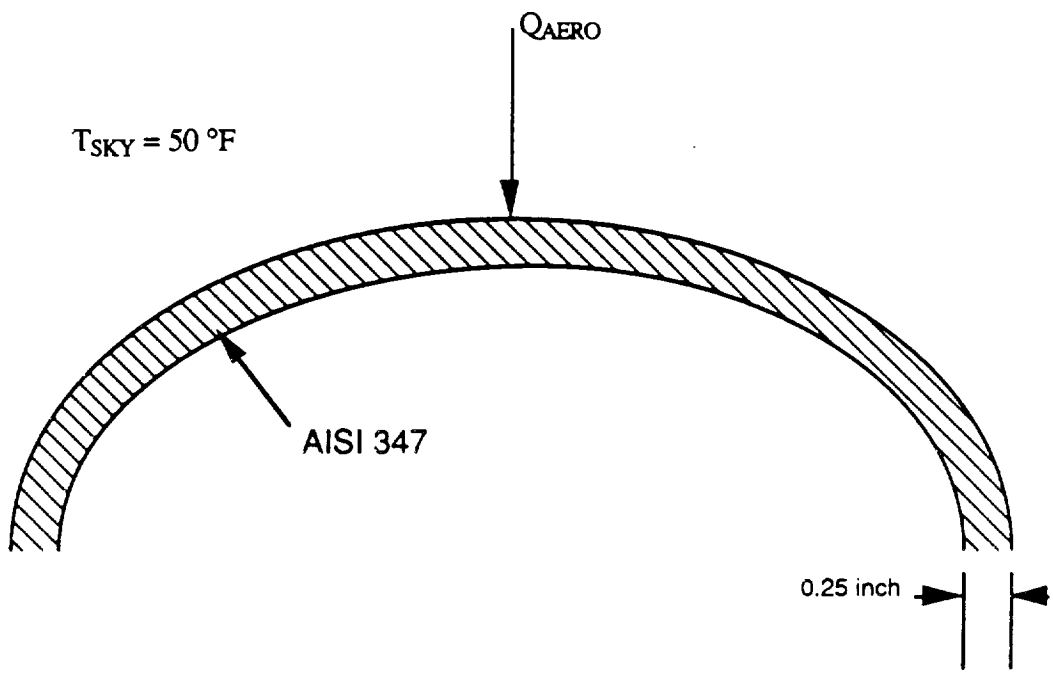

Fig. 1 Cross Section

C. Given

The following data is available for this problem:

1. The material properties are constant
2. The sky temperature is assumed to be 50 °F
3. The initial temperature of the material is 80 °F
4. The material will be 0.25 in. thick
5. The maximum surface temperature is 600 °F
6. The aeroheating environment will be presented in the form of equations and arrays.

a. Equations

For time ≤ 50.0 seconds

$$Hc = 0.001 + 0.00198 * time$$
$$Hrec = 100.0$$

For time > 50.0 seconds

$$Hc = 0.1 - 2.828E\text{-}4 * (time - 50.0)$$
$$Hrec = 100.0 + 2.0 * (time - 50.0)$$

where:

Hc = Film Coefficient, $\frac{h}{Cp}$ $\left(\frac{lbm}{ft^2 * sec}\right)$

h = Heat Transfer Coefficient $\left(\frac{BTU}{ft^2 * sec}\right)$

Cp = Specific Heat $\left(\frac{Btu}{lbm\ °R}\right)$

$Hrec$ = Recovery Enthalpy $\left(\frac{Btu}{lbm}\right)$

$Hwall$ = Wall Enthalpy $\left(\frac{Btu}{lbm}\right)$

$Qaero$ = Aerodynamic Heating rate $\left(\frac{Btu}{sec}\right)$

T_{WALL} = Wall Temperature (°F)

T_{REC} = Recovery Temperature (°F)

b. Arrays

The arrays given will be time, film coefficient, and recovery enthalpy for a particular body point

D. Find

Find the surface temperature for the first 400 seconds of ascent.

II. Formulation of the Problem

A. Theoretical Basis

For convection

$$Q_{AERO} = A * h * (T_{REC} - T_{WALL})$$

Assume Area(A) = 1.0

Since $\Delta H = Cp\Delta T$, assuming H = 0 @ T = 0

This may be rewritten as

$$Q_{aero} = \frac{h}{Cp}(H_{REC} - H_{WALL})$$

and $H_{wall} = CpTsurf$

The specific heat of air is given by the following function

$$Cp_{air} = 9.786E\text{-}6T_{surf} + 0.2345 + \frac{1.57}{T_{surf}} + \frac{943.6}{T_{surf}^2}$$

Thus

$$H_{wall} = 9.786E\text{-}6T_{surf}^2 + 0.2345T_{surf} + 1.57 + \frac{943.6}{T_{surf}}$$

A. SINDA Problem Formulation

A one-dimensional finite difference model can be constructed as :

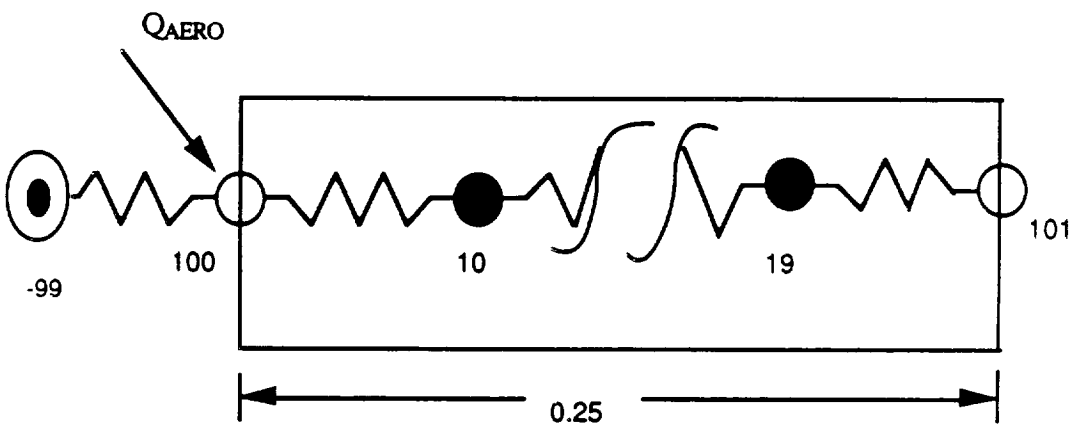

Figure 2. Finite Difference Model

III. Computer Solution Techniques

SINDA INPUT LISTING
Array Model

```
      BCD 3THERMAL LPCS
      BCD 9HLLV NOSE CAP
C*****************************************************************************
```

```
C*  This is a simple 1-D model of a proposed nose cone for the          *
C*  HLLV.  It is composed of AISI 347 Stainless Steel.  The                *
C*  aeroheating environment is presented in the form of arrays.        *
C*  This is the general form in which data may be presented; one        *
C*  array is the film coefficient(HC), one is the time,  and a third      *
C*  is the recovery enthalpy(HR).  The initial temperature of the       *
C*  metal is assumed to be 80 °F and the sky temperature is 50 °F.  *
C*****************************************************************************
      END
C-----------------------------------------------------------------------------
      BCD 3NODE DATA
C  Generate two arithmetic nodes on the outside of the plate
      GEN 100,2,1,80.0,-1.0
C
C  Generate fifteen diffusion nodes on the inside of the plate
      GEN 5,15,1,80.0,7.927E-2
C
C  Provide a boundary node in the free stream environment
          -99,50.0,0.0
      END
C-----------------------------------------------------------------------------
      BCD 3CONDUCTOR DATA
C  Generate the conductance between the diffusion nodes with
C  temperature varying conductance
      SIM 56,14,1,5,1,6,1,A150,720.0
C
C  Generate the conductance in the arithmetic nodes with
C  temperature varying conductance
      SIV 1005,100,5,A150,1440.0
      SIV 19101,19,101,A150,1440.0
C
C  Provide the conductance of the boundary node to the surface
          -99100,99,100,1.1903E-13
C
      END
C-----------------------------------------------------------------------------
      BCD 3CONSTANTS DATA
          OUTPUT=10.0       $ time of each output
          TIMEO=0.0           $ starting time
          NLOOP=500         $ allowable loops for convergence
          CSGFAC=1.0         $ reduces time step; always > 1
          DRLXCA=0.01       $ diffusion relaxation
          ARLXCA=0.01       $ arithmetic relaxation
          NDIM=1000           $ size of storage array
          TIMEND=400.0      $ completion time
      END
C-----------------------------------------------------------------------------
      BCD 3ARRAY DATA
C  Provide storage space for combined arrays
          300,SPACE,62,END
          400,SPACE,62,END
C
C  TIME,  BODY POINT 100
          1100        $  Array number 1100
            0.0,  10.0,  20.0,  30.0,  40.0
            50.0, 60.0,  70.0,  80.0,  90.0
            100.0, 110.0, 120.0, 130.0, 140.0
            150.0, 160.0, 170.0, 180.0, 190.0
            210.0, 230.0, 250.0, 270.0, 290.0
            310.0, 330.0, 350.0, 370.0, 390.0
            400.0
          END
C
C   FILM  COEFFICENT BODY POINT 100
```

```
            2100          $  Array number 2100
              0.001,     0.0208,     0.0406,     0.0604,     0.0802
              0.100,     0.0917,     0.094344,   0.091516,   0.088688
              0.08586,   0.083032,   0.080204,   0.077376,   0.074548
              0.07172,   0.068892,   0.066064,   0.063236,   0.060408
              0.054752,  0.049096,   0.043440,   0.037784,   0.032128
              0.026472,  0.020816,   0.015160,   0.009504,   0.003848
              0.00102
            END
C
C  RECOVERY ENTHALPY BODY POINT 100
            3100           $  Array number 3100
              100.0,    100.0,    100.0,    100.0,   100.0
              100.0,    120.0,    140.0,    160.0,   180.0
              200.0,    220.0,    240.0,    260.0,   280.0
              300.0,    320.0,    340.0,    360.0,   380.0
              420.0,    460.0,    500.0,    540.0,   580.0
              620.0,    660.0,    700.0,    740.0,   780.0
              800.0
            END
C
C    TEMP vs. CONDUCTIVITY(k) (BTU/sec-ft-F)
            150           $  Array number 150
              80.0, 2.2792E-03
              260.0, 2.536E-03
              620.0, 3.5151E-03
              1340.0, 3.9645E-03
            END
        END
C-----------------------------------------------------------------------------
        BCD 3EXECUTION
C
C  Join time array with film coefficient array and recovery enthalpy
C  array.  This will allow for linear interpolation with respect to
C  time of the film coefficient and enthalpy.
C
M       CALL JOIN(31,A(1100+1),A(2100+1),A(300+1))  $Hc ARRAY
M       CALL JOIN(31,A(1100+1),A(3100+1),A(400+1))  $Hr ARRAY
C
C    Transient Solution Technique
F       CALL SNFRDL
C  SNFRDL is an explicit solution technique to work with ABL
        END
C-----------------------------------------------------------------------------
        BCD 3VARIABLES 1
C  Determine the heat input for the given time
C
C  TSURF  : Surface temperature at given time
C  TIME   : Given Time
C  HWALL  : Wall Enthalpy
C  HC     : Film Coefficient
C  HR     : Recovery Enthalpy
C  Q100   : Heat input at surface
C
M       TSURF=T100+460.0
M       TIME=TIMEO
F       HWALL = 0.2345*TSURF+9.786E-6*TSURF**2+943.6/TSURF-1.57
M       CALL D1DEG1(TIME,A300,HC)  $ Linear interpolation for HC
M       CALL D1DEG1(TIME,A400,HR)  $ Linear interpolation for HR
M       Q100 = HC*(HR-HWALL)
C
        END
C-----------------------------------------------------------------------------
        BCD 3VARIABLES 2
```

```
      END
C-----------------------------------------------------------------------
      BCD 3OUTPUT CALLS
C    Print out temperature data
F     CALL TPRINT
      END
C-----------------------------------------------------------------------
      BCD 3END OF DATA
```

SINDA INPUT LISTING
Mathematical Equation Model

```
      BCD 3THERMAL LPCS
      BCD 9HLLV NOSE CAP
C*****************************************************************************
C*  This is a simple 1-D model of a proposed nose cone for the              *
C*  HLLV.  It is composed of AISI 347 Stainless Steel.  The                 *
C*  aeroheating environment is approximated by a film coefficient(HC)       *
C*  and Recovery Enthalpy(HR( of HC = 0.001+0.00198*time and                *
C*  Hr = 100.0 for time <= 50.0.  For time > 50.0;                          *
C*  HC = 0.1-2.828e-4*(time-50.0) and Hr = 100+2*(time-50.0).               *
C*  The initial temperature of the metal is assumed to be 80 °F and         *
C*  the sky temperature is 50 °F.                                           *
C*****************************************************************************
C
      END
C-----------------------------------------------------------------------
      BCD 3NODE DATA
C  Generate two arithmetic nodes on the outside of the plate
      GEN 100,2,1,80.0,-1.0
C
C  Generate fifteen diffusion nodes on the inside of the plate
      GEN 5,15,1,80.0,7.927E-2
C
C  Provide a boundary node in the free stream environment
          -99,50.0,0.0
      END
C-----------------------------------------------------------------------
      BCD 3CONDUCTOR DATA
C  Generate the conductance between the diffusion nodes with
C  temperature varying conductance
      SIM 56,14,1,5,1,6,1,A150,720.0
C
C  Generate the conductance in the arithmetic nodes with
C  temperature varying conductance
      SIV 1005,100,5,A150,1440.0
      SIV 19101,19,101,A150,1440.0
C
C  Provide the conductance of the boundary node to the surface
          -99100,99,100,1.1903E-13
C
      END
C-----------------------------------------------------------------------
      BCD 3CONSTANTS DATA
          OUTPUT=10.0        $ time of each output
          TIMEO=0.0          $ starting time
          NLOOP=500          $ allowable loops for convergence
          CSGFAC=1.0         $ reduces time step; always > 1
          DRLXCA=0.01        $ diffusion relaxation
          ARLXCA=0.01        $ arithmetic relaxation
          NDIM=1000          $ size of array storage
          TIMEND=400.0       $ completion time
```

```
      END
C-----------------------------------------------------------------------------------------
      BCD 3ARRAY DATA
C
C     TEMP vs. CONDUCTIVITY(k) (BTU/sec-ft-F)
         150                $ Array number 150
           80.0, 2.2792E-03
           260.0, 2.536E-03
           620.0, 3.5151E-03
           1340.0, 3.9645E-03
         END
      END
C-----------------------------------------------------------------------------------------
      BCD 3EXECUTION
C
C    Transient Solution Technique
F     CALL SNFRDL
C  SNFRDL is an explicit solution technique to work with ABL
      END
C-----------------------------------------------------------------------------------------
      BCD 3VARIABLES 1
C  Determine the heat input for the given time
C
C  TSURF       : Surface temperature at given time
C  TIME        : Given Time
C  HWALL       : Wall Enthalpy
C  HC          : Film Coefficient
C  HREC          Recovery Enthalpy
C  Q100        : Heat input at surface
C
M     TSURF= T100+460.0
M     TIME = TIMEO
F     HWALL = 0.2345*TSURF+9.786E-6*TSURF**2+943.6/TSURF-1.57
C
F     IF (TIME.LE.50.0) THEN
F         HC = 0.001+0.00198*TIME
F         HREC = 100.0
F     ELSE
F         HC = 0.1-(2.828E-4)*(TIME-50.0)
F         HREC = 100.0+2.0*(TIME-50.0)
F     END IF
M     Q100 = HC*(HREC-HWALL)
C
      END
C-----------------------------------------------------------------------------------
      BCD 3VARIABLES 2
      END
C-----------------------------------------------------------------------------------
      BCD 3OUTPUT CALLS
C   Print out Temperature Data
F     CALL TPRINT
      END
C-----------------------------------------------------------------------------------
      BCD 3END OF DATA
```

IV. RESULTS

The temperature on the outer surface of the stainless steel exceeds 1300 degrees Fahrenheit. This is more than twice the design criteria and therefore a TPS will be necessary. The two solution techniques produced similar results as demonstrated below.

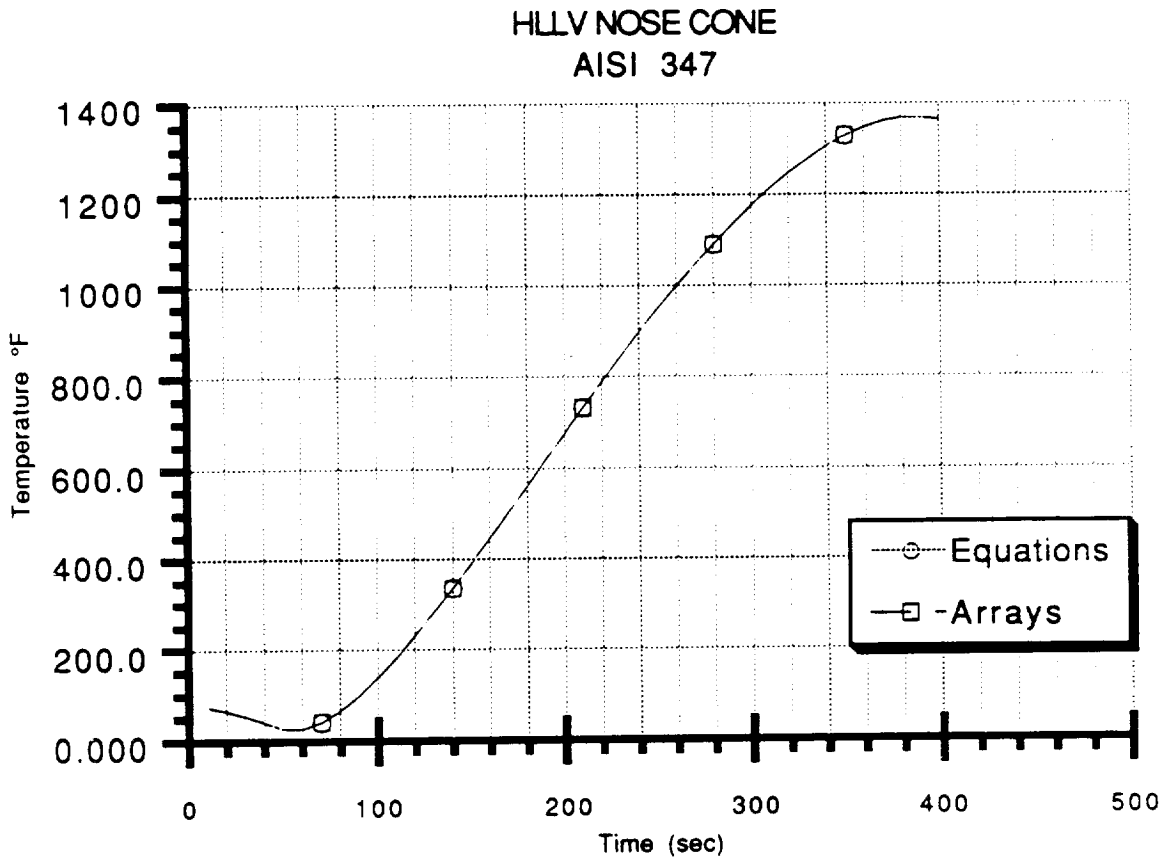

Fig. 3

CHAPTER 6. THERMAL PROTECTION SYSTEMS

SECTION 2: Vehicle Thermal Protection System Design Analysis Methods

ANALYSIS CODE: FORTRAN, SINDA (Gaski Version) with ABL Routine

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I. Identification of the Problem

A. Statement of the Problem

The nose cone of a launch vehicle is to be protected from ascent aeroheating by SLA-561, an ablative material. An analyst has suggested a thickness of 1/2 inch. Will this keep the aluminum skin temperature below 300°F? Determine the aluminum skin temperature rise for time up to 400 seconds using two different methods:

1. Finite Difference FORTRAN Model.
2. SINDA with ABL Subroutine.

B. Schematic

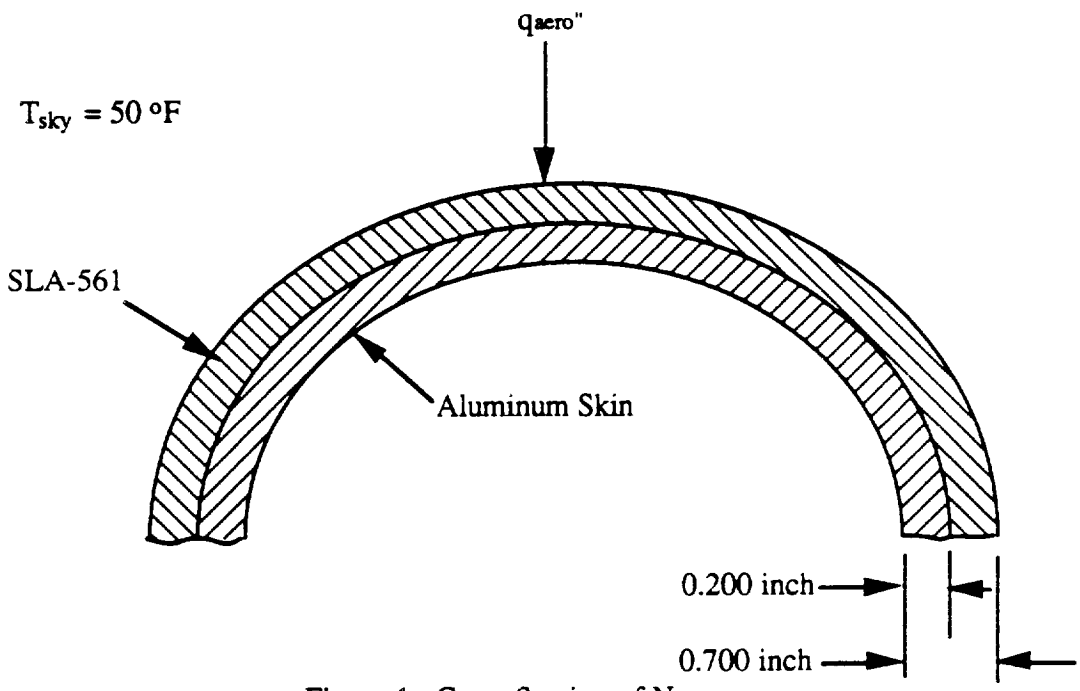


Figure 1. Cross Section of Nosecone

C. Given

The following data is available for this problem:

1. The material properties are constant.
2. The sky temperature is 50 °F

3. The recovery enthalpy:

$$h_r = 100, \left(\frac{Btu}{lbm}\right), \text{ for time} \le 50 \text{ seconds}$$

$$h_r = 100 + 2.0*(\text{time}-50), \left(\frac{Btu}{lbm}\right), \text{ for time} > 50 \text{ seconds}$$

4. The film coefficient:

$$\frac{h}{C_p} = 0.001 + 0.00198*\text{time} \quad \left(\frac{lbm}{ft^2*sec}\right), \text{ for time} \le 50 \text{ sec}$$

$$\frac{h}{C_p} = 0.1 - (2.828e\text{-}4)*(\text{time}-50), \left(\frac{lbm}{ft^2*sec}\right), \text{ for time} > 50 \text{ sec}$$

5. The aluminum skin is 0.200 inch thick
6. The initial temperature of the skin and SLA-561 is 80°F
7. The SLA-561 is 0.500 inch thick
8. The SLA-561 material ablation characteristics

D. Find

The aluminum skin temperature for the first 400 seconds of ascent.

II. Formulation of the Problem

A. FORTRAN Problem Formulation

A one-dimensional finite difference model can be constructed as:

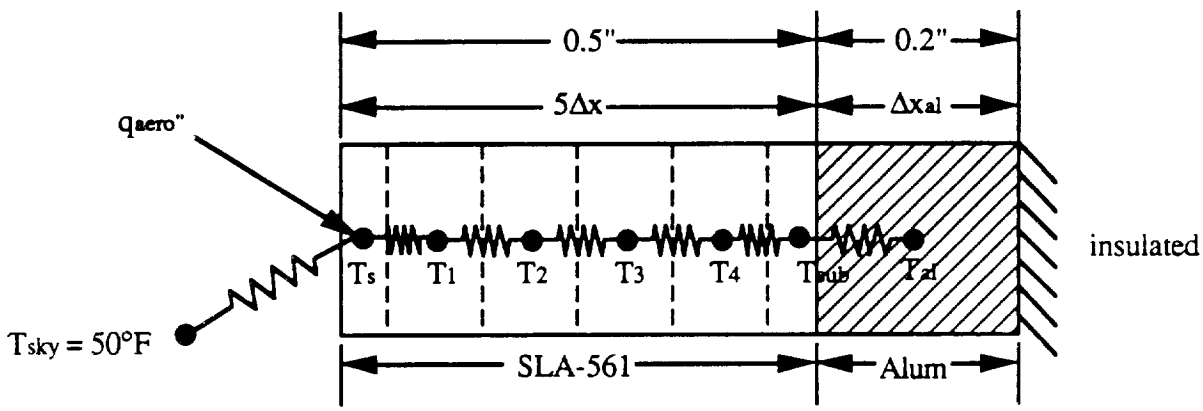


Figure 2. Seven Node Thermal Network

The differential equation for node s can be written as:

$$\rho C_p \frac{\Delta x}{2} A \frac{dT_s}{dt} = R(T_{sky}-T_s) + A\frac{k}{\Delta x}(T_1-T_s) + q''_{aero}A$$

where:

ρ = density
T_i=temperature of node i
C_p = specific heat
Δx = length increment
A = area

t = time
k = thermal conductivity
$R = \sigma \epsilon F(T^2_{sky} - T^2_s)(T_1 - T_s)$
σ = Stephan-Boltzman constant
ϵ = emissivity
F = view factor

Note: Material ablation will be discussed later.

If unit area is assumed, then:

$$\frac{dT_s}{dt} = \frac{2}{\rho C_p \Delta x}\left[R(T_{sky} - T_s) + \frac{k}{\Delta x}(T_1 - T_s) + q''_{aero}\right]$$

In difference form:

$$\frac{\Delta T_s}{\Delta t} = -\frac{2}{\rho C_p \Delta x}\left[R(T_{sky} - (T_s + \Delta T_s)) + \frac{k}{\Delta x}(T_1 - (T_s + \Delta T_s)) + q''_{aero}\right]$$

$$\Delta T_s = \frac{\frac{2\Delta t}{\rho C_p \Delta x}R(T_{sky} - T_s) + 2Fo(T_1 - T_s) + \frac{2\Delta t}{\rho C_p \Delta x}q''_{aero}}{1 + \frac{2\Delta t R}{\rho C_p \Delta x} + 2Fo}$$

where:

$$Fo = \text{Fourier number}, \left(\frac{k\Delta t}{\rho C_p \Delta x^2}\right)$$

The diffenential equation for node 1 can be written as:

$$\rho C_p \Delta x A \frac{dT_1}{dt} = A\frac{k}{\Delta x}(T_s - T_1) + A\frac{k}{\Delta x}(T_2 - T_1)$$

Assuming unit area and resolving into difference form:

$$\Delta T_1 = Fo(T_s - (T_1 - \Delta T_1)) + Fo(T_2 - (T_1 - \Delta T_1))$$

$$\Delta T_1 = \frac{Fo(T_s + T_2 - 2T_1)}{1 + 2Fo}$$

For any interior node, (1,2,3,4), the difference equation can be wriiten as:

$$\Delta T_i = \frac{Fo(T_{i-1} + T_{i+1} - 2T_i)}{1 + 2Fo}$$

The differential equation for node sub can be written as:

$$\rho C_p \frac{\Delta x}{2} A \frac{dT_{sub}}{dt} = A \frac{k}{\Delta x}(T_4 - T_{sub}) + A \frac{k_{al}}{\frac{\Delta x_{al}}{2}}(T_{al} - T_{sub})$$

where:

k_{al} = Conductivity of Aluminum
Δx_{al} = Length increment of Aluminum

Assuming unit area, and resolving into difference form:

$$\Delta T_{sub} = 2\,Fo\left(T_4 - \left(T_{sub} - \Delta T_{sub}\right)\right) + \frac{4k_{al}\Delta t}{\rho C_p \Delta x \Delta x_{al}}\left(T_{al} - \left(T_{sub} - \Delta T_{sub}\right)\right)$$

$$\Delta T_{sub} = \frac{2Fo(T_4 - T_{sub}) + \frac{4k_{al}\Delta t}{\rho C_p \Delta x \Delta x_{al}}(T_{al} - T_{sub})}{1 + 2Fo + \frac{4k_{al}\Delta t}{\rho C_p \Delta x \Delta x_{al}}}$$

Finally, the differential equation for the aluminum can be written as:

$$\rho_{al} C_{p_{al}} \frac{\Delta x_{al}}{2} A \frac{dT_{al}}{dt} = A \frac{k_{al}}{\frac{\Delta x_{al}}{2}}(T_{sub} - T_{al})$$

Assuming unit area and putting into difference form:

$$\Delta T_{al} = \frac{Fo_{al}(T_{sub} - T_{al})}{1 + 2Fo_{al}}$$

where:

$$Fo_{al} = \text{Fourier number for aluminum}, \left(\frac{k_{al}\Delta t}{\rho_{al} C_{p\text{-}al} \Delta x_{al}^2}\right)$$

The solution method for this system of equations is a simple "march through" using the old values of temperature to find the new temperature increment. Differencing solutions were discussed in detail in Chapter 2, Section 3.

This problem is unique because the SLA-561 material ablates, causing the length increment to change. The SLA-561 material will begin to recess at a temperature of 990°F. The recession rate has been determined experimentally to be:

$$\dot{r} = 1.10E\text{-}6 * Q_{cw}^{1.81} \left(\frac{ft}{sec}\right)$$

where:

Q_{cw} = Cold Wall Heating Rate

(Wall enthalpy is calculated using a wall temperature of 0.0°F)

To avoid stability problems the time step used in this explicit solution must be kept small. The stability criterion for a one-dimensional interior node is:

$$Fo \leq 0.5$$

B. SINDA Model Formulation

The SINDA model of the nose cone is a simple one dimensional model calling the ABL subroutine.

C. ABL Documentation

Subroutines ABL provides for the simulation of an ablating TPS material based on empirical recession correlations. The ablator thermal network, figure 3, consists of a thin skin diffusion node which is located on the TPS surface, and a core diffusion node which is located in the middle of the TPS material. The thin skin surface node is subjected to user specified environmental heating data. It behaves as a normal, transiently responding, diffusion node if its temperature is below the ablation temperature. If the computed thin skin temperature is above the ablation temperature for a given time step, then the following operations are performed:

1. a recession rate is computed based on instantaneous cold wall heating rate,

2. the thin skin nodal temperature is set to the ablation (recession) temperature.

3. conduction path lengths are adjusted accordingly based on the computed recession distance, and

4. the thermal capacitance of the core node is adjusted to reflect the change in ablator thickness.

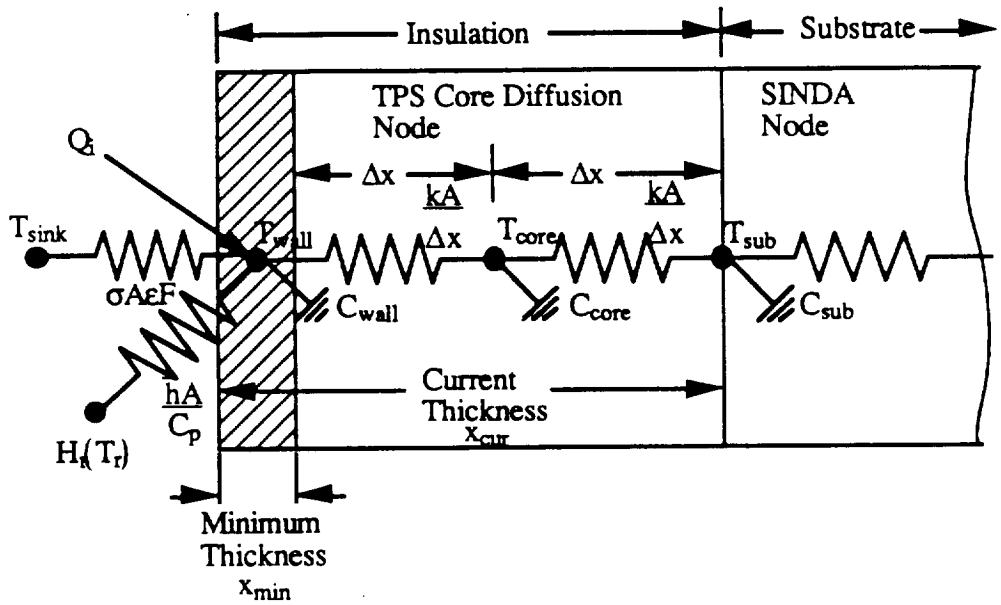


Figure 3. TPS Thermal Ablator Network

The TPS core node is allowed to conduct heat to/from both the thin skin and SINDA "substrate" node. Provisions are made to allow for nonlinear heat conduction and storage in the TPS via specification of temperature dependent material properties.

To invoke the ABL routine, the following modified FORTRAN statement is placed in the VARIABLES 2 operation block:

M CALL ABL (Axx),

where, Axx = SINDA reference to the ABL working array

ABL Inputs

The ABL working array serves to (1) define the physical parameters that describes the TPS material, (2) direct the method of solution used internally by ABL, and (3) define the locations of material and heating data. The ABL working array is entered into the 3ARRAY DATA block. The contents of the array are given in Table 1.

The current Vax ABL routine (i.e., Version 1.0) is specifically designed to use the USBI environment files. These files are formatted with time as the independent variable and convective film coefficient, recovery enthalpy, and incident plume radiation as dependent variables. Since the USBI environment data files are all structured the same (QMODE = -301), the routine is currently configured to read only the data files that fall in this category. In future versions, if alternate methods of heating data input are required, simple modifications to the calculation procedure contained in the subroutines GETQ1 and GETQ2 must be performed.

Item 14 in the ABL working array is the material array number. The material array is also input in the 3ARRAY DATA block and serves to define TPS

material properties such as specific heating, thermal conductivity, and recession constants. The specific entries in the material array are given in Table 2. Item 7 in the material array is the material mode specifier. For this input, there are six options enabled in this version of ABL. If a material mode of -1 is specified, then the first 11 entries in the material array are required. When using this option, thermally dependent TPS material properties are calculated via simple linear expressions across the anticipated temperature range. If a two material mode is specified, then the ABL working array requires 25 entires. If a material mode of -3 is specified, then the material array requires 36 inputs (see Table 2). Material mode -2 is used for the heat of ablation option. A positive material mode provides the option to suppress negative aeroheating loads in recession calculations. The anticipated temperature range is banded into three regions which are defined by lower and upper temperature limits. Thermal dependent properties of the TPS material, figure 4, are computed per specific coefficients that are defined local to each temperature region.

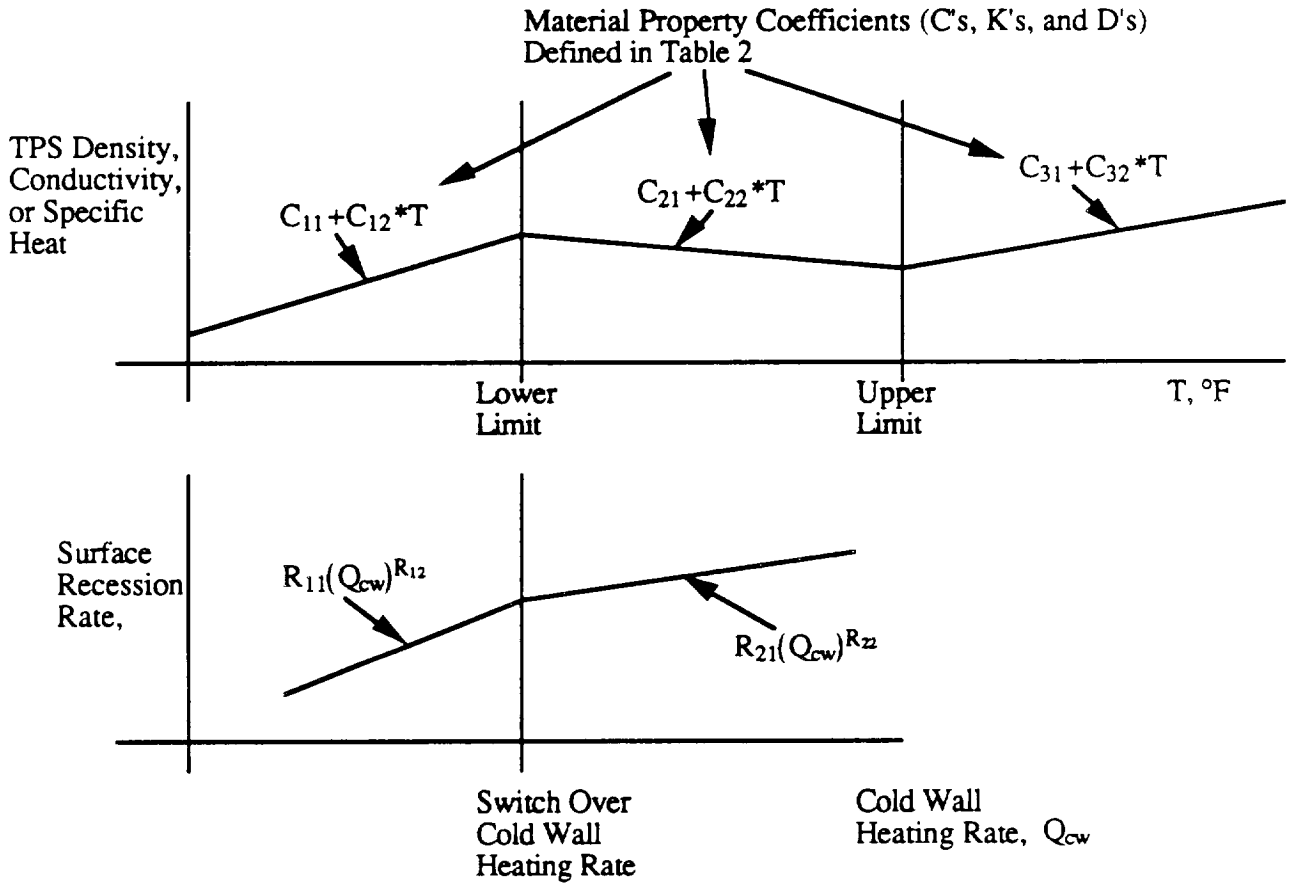


Figure 4. Thermal Dependency of Material Properties

Using material mode -3, the TPS recession constants are defined for two cold wall heat rate regions (see figure 4). The switch over heat rate is a user specified quantity (item 12 in Table 2). If the computer cold wall heat rate is greater than the specified limit, then the secondary recession constants are used in the recession calculations.

ABL Output

To obtain ABL diagnostic output, the following call is placed into 3OUTPUT CALLS:

M CALL ABLOUT (Axx)

where: Axx is the ABL working array

Provided as output are TPS surface/core nodal temperatures, minimum nodal time constant (DTMX), current/ablated thicknesses, hot/cold wall heating rates, and material status indicators. Nodal time constants are computed for the thin skin, core, and the substrate nodes. A test is performed to determine which is the fastest thermally responding node (i.e., the minimum DTMX). The ABL internal time step is then computed as approximately 75 percent of this value.

The hot wall environmental heating rates are computed per the following relatioships:

$$Q_{rad}=\sigma A\varepsilon f\left(T^4_{sink}-T^4_{wall}\right)$$

$$Q_i=A(Q_{plume})$$

$$Q_{aero}=\frac{\bar{h}A}{C_p}(H(T_r)-H(T_{wall}))$$

$$Q_{hw}=Q_{rad}+(Q_{aero}+Q_i)Q_{factor}$$

If the TPS surface temperature is at or above the specified recession temperature, then a surface recession rate is computed based on the cold wall heating rate. The basic relationships used in this calculation are given:

$$Q_i=A(Q_{plume})$$

$$Q_{aero}=MAX\left[0.0,\frac{\bar{h}A}{C_p}(H(T_r)-H(T_{wall}))\right]$$

$$Q_{cw}=(Q_{aero}+Q_i)Q_{factor}$$

$$\dot{r}=R_{ij}(Q_{cw})^{R_k}$$

In the recession calculations, if the aerodynamic heating rate is negative (i.e., cooling the TPS surface), then this quantity is set to zero. This operation is indicated by the MAX () function in the above expression.

The material status indicators in the ABL output have the following meaning:

Status 1. . . . . normal TPS simulation
Status 2 . . . . . bondline temperature exceeded, environments now imposed on the substrate material,

Status 3 . . . . . all TPS material has ablated, environments are now imposed on substrate material.

Operational Characteristics of Vax-ABL Version 1.0

(1) Explicit SINDA numerical solution routines are recommended but are not necessary. If an implicit routine is used, make sure your input time step is no more than 3 to 4 times the substrate CSGMIN. Model sensitivity to the input time step should be checked.

(2) Use of boundary nodes to store TPS thickness is possible but not recommended. A problem surface when the solution routine adds/subtracts 460.0 to all temperature locations. For example, if the minimum TPS thickness is 0.0002 inch, then adding 4600 results in 460.0002 in the storage location. When 460.0 is subtracted from this location, the result may be 0.00178. The reason for the difference is that the Vax can only compute about 5 to 6 significant digits of accuracy in single precision mode. The fractional part of the "Rankine" value is beyond the credible resolution of 32 bit arithmetic.

(3) When specifying material properties per the -3 material mode, make sure the functional values are approximately continuous at the temperature change-over limits. Large discontinuities in the material properties can cause instabilities in the ABL solution routine.

(4) Entry 17 in Table 1 is the minimum TPS node thickness. This is the thickness of the thin skin node. Be sure this quantity is no larger than about 1 percent of the total TPS thickness. The routine stops the ablation simulation when the TPS core node is 2 times the thickness of the thin skin node.

(5) The QMODE specifier (item 8 in the ABL working array is disabled thus inputs in this location are ignored.

(6) Actual node numbers greater than 4096 (i.e, 2^{12}) cannot be used in ABL. This constraint of course precludes using ABL with SINDA models larger than 4096 nodes as well.

Location	Description	Type	I/O Status
1	SINDA Substrate Node Number (Actual Reference)	Integer	Input
2	Used Internally	Real	Leave blank
3	Used Internally	Real	
4	Radiative Coefficient	Real	Input
5	TPS Surface Area	Real	Input
6	Radiative sink temperature or SINDA node that contains data value (actual node number) T_{sink}	Real/Int.	Input
7	Computed smallest insulation nodal time constant, DTMX	Real	Leave blank/out
8	QMODE (Note that only QMODE -301 is enabled)	Integer	Input
9	Q factor or array number of Q_{factor} vs. time (doublet array input)	Real/Int.	Input
10	Array number of plume radiation (Q_i) vs. time (doublet array input)	Integer	Input
11	Singlet time array number	Integer	Input
12	Singlet recovery enthalpy array number	Integer	Input
13	Singlet film coefficient array number	Integer	Input
14	Material array number	Integer	Input
15	Initial TPS thickness or SINDA boundary node (dummy location) that contains the data value , x_{init}	Real/Int.	Input

16	Current TPS thickness or SINDA boundary node (dummy location)that contains the data value, x_{cur}	Real/Int.	Leave blank/out
17	MinimumTPS thickness or SINDA boundary node (dummy location)that contains the data value, x_{min}	Real/Int.	Input
18	Initial TPS surface temperature or SINDA boundary node (dummy location)that contains the data value, T_{wall}	Real/Int.	Input
19	Initial TPS core temperature or SINDA boundary node (dummy location)that contains the data value, T_{core}	Real/Int.	Input
20	Material array number, outer material	Integer	Input
21	Initial TPS thickness or SINDA boundary node (dummy location) that contains the data value , x_{init2}	Real/Int.	Input
22	Current TPS thickness or SINDA boundary node (dummy location)that contains the data value, x_{cur2}	Real/Int.	Leave blank/out
23	MinimumTPS thickness or SINDA boundary node (dummy location)that contains the data value, x_{min2}	Real/Int.	Input
24	Initial TPS surface temperature or SINDA boundary node (dummy location)that contains the data value, T_{wall2}	Real/Int.	Input
25	Initial TPS core temperature or SINDA boundary node (dummy location)that contains the data value, T_{core2}	Real/Int.	Input

Table 1. ABL working array storage locations

Location	Description	Type	I/O Status
1	TPS Density	Real	Input
2	TPS Specific heat constant, C_{11}	Real	Input
3	TPS Specific heat constant, C_{12}	Real	Input
4	TPS Thermal conductivity constant, k_{11}	Real	Input
5	TPS Thermal conductivity constant, k_{12}	Real	Input
6	Bondline temperature limit, °F	Real	Input
7	Material mode	Integer	Input
8	Recession (ablation) temperature, °F	Real	Input
9	Fixed (cold wall) temperature, °F	Real	Input
10	First recession equation coefficient, R_{11}	Real	Input
11	First recession equation exponent, R_{12}	Real	Input
12	Fixed wall heat rate to begin using second recession equation	Real	Input
13	Recession temperature for second recession equation	Real	Input
14	Blank	Leave blank	
15	Second recession coefficient, R_{21}	Real	Input
16	Second recession exponent, R_{22}	Real	Input
17	TPS density constant, D_{11}	Real	Input
18	TPS density constant, D_{12}	Real	Input
19	Density lower temperature limit, °F	Real	Input
20	TPS density constant, D_{21}	Real	Input
21	TPS density constant, D_{22}	Real	Input
22	Density upper temperature limit, °F	Real	Input
23	TPS density constant, D_{31}	Real	Input
24	TPS density constant, D_{32}	Real	Input
25	Specific heat lower temperature limit, °F	Real	Input
26	TPS Specific heat constant, C_{21}	Real	Input
27	TPS Specific heat constant, C_{22}	Real	Input
28	Specific heat upper temperature limit, °F	Real	Input
29	TPS Specific heat constant, C_{31}	Real	Input
30	TPS Specific heat constant, C_{32}	Real	Input
31	Thermal conductivity lower temperature limit, °F	Real	Input
32	TPS Thermal conductivity constant, k_{21}	Real	Input
33	TPS Thermal conductivity constant, k_{22}	Real	Input
34	Thermal conductivity upper temperature limit, °F	Real	Input
35	TPS Thermal conductivity constant, k_{31}	Real	Input
36	TPS Thermal conductivity constant, k_{32}	Real	Input

Table 2. ABL material array storage locations

List of Symbols

Q_{rad}	TPS net surface radiative heat rate to the environment, Btu/sec
T_{sink}	effective radiative sink temperature, °F
T_{wall}	TPS wall (surface) temperature, °F
T_{core}	TPS core temperature, °F
T_{sub}	SINDA substrate temperature, °F
Q_i	imposed heat rate on TPS wall node, Btu/sec
Q_{plume}	incident plume radiation heat flux rate, Btu/sec/ft^2
Q_{aero}	aerodynamic heating rate, Btu/sec
$\bar{h}$	average convective film coefficient, Btu/ft^2/sec/R
C_p	air specific heat, Btu/lbm/R
$H(T_r)$	recovery enthalpy, Btu/lbm
$H(T_{wall})$	wall enthalpy, Btu/lbm
MAX	selects the algebraic maximum of the input arguments
Q_{hw}	hot wall heat load, Btu/sec
Q_{factor}	Q factor
x_{cur}	current TPS thickness, ft
x_{init}	initial TPS thickness, ft
x_{min}	minimum TPS thickness, ft
T_{cw}	cold wall temperature, °F
C_{wall}	TPS thin skin node thermal capacitance, Btu/R
C_{core}	TPS core node thermal capacitance, Btu/R
R_{ij}	TPS recession coefficient
R_{ik}	TPS recession exponent

III. Problem Solution

A. FORTRAN Code Listing

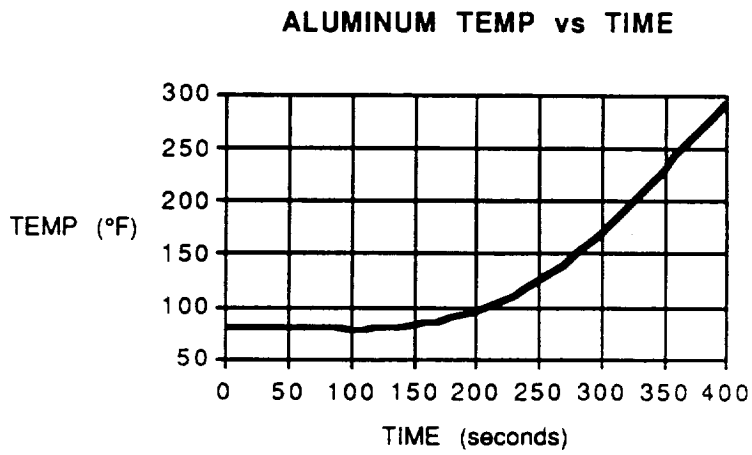
```
C   THIS PROGRAM WILL MODEL SLA-561 ABLATIVE MATERIAL ON
C   A 0.200IN THICK ALUMINUM SUBSTRATE.  THE ALUMINUM
C   TEMPERATURE WILL BE PREDICTED FOR A RUN TIME OF 400
C   SECONDS WITH A VARIABLE HEAT RATE APPLIED TO THE ABLATIVE
C   MATERIAL AND RADIATION EXCHANGE WITH A 50 DEG F ENVIRONMENT.
C
        DELTIME = 0.01
        RHOSLA  = 16.0
        DXSLA   = 4.167E-2/5
        CPSLA   = 0.34
        CONSLA  = 2.444E-5
        RHOCPA  = 40.0
        CONAL   = 2.000E-2
        DXAL    = 1.667E-2
        TINF    = 510.0
        TSURF   = 540.0
        T1      = 540.0
        T2      = 540.0
        T3      = 540.0
        T4      = 540.0
        TSUB    = 540.0
        TAL     = 540.0
        TIME    = 0.0
        J       = 5
        I       = 999
        ABLOSS  = 0.0
        WRITE(11,50)
50      FORMAT('TIME',4X,'ALUM TEMP',4X,'SURF T',4X'MATERIAL LOSS')
C
C   SOLVE FOR RADIATION CONDUCTOR
C
100     R = 4.285E-13 * (TINF**2-TSURF**2) * (TINF+TSURF)
C
C
C   CALCULATE FOURIER NUMBERS
C
        FOSLA = DELTIME*CONSLA/(RHOSLA*CPSLA*DXSLA**2)
        FOAL  = DELTIME*CONAL/(RHOCPA*DXAL**2)
C
C   SOLVE FILM COEF AND RECOVERY ENTHALPY
C
        IF (TIME .LE. 50) THEN
          FC = 0.001 + 0.00198*TIME
          HREC = '00.0
        END IF
        IF ( TIME .GT. 50) THEN
          FC = 0.1 -(2.828E-4) * (TIME-50.0)
          HREC = 100.0 + 2.0 * (TIME-50.0)
        END IF
C
C   SOLVE HEATING RATES
C
        HWALL = 0.2345*TSURF+9.786E-6*TSURF**2+943.6/TSURF-1.57
        HCWALL = 0.2345*460.0+9.786E-6*460.0**2+943.6/460.0-1.57
        Q = FC*(HREC-HWALL)
        QCW = FC*(HREC-HCWALL)
```

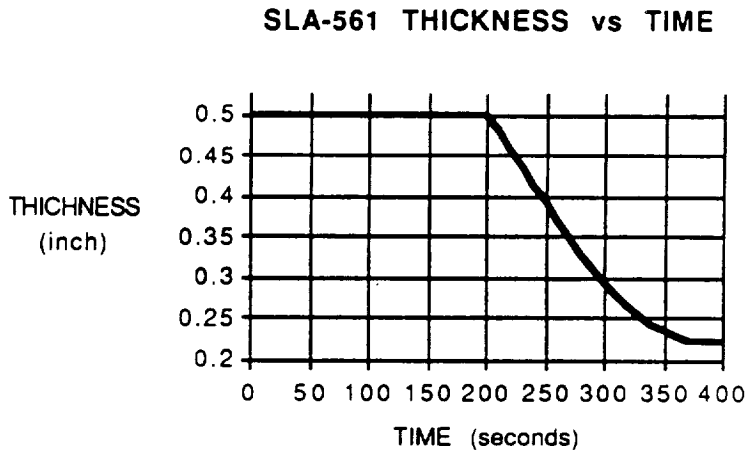
```
C
C   SOLVE TEMP INCREMENTS
C
        A = (2*DELTIME*R)/(RHOSLA*CPSLA*DXSLA)
        B = (2*DELTIME)/(RHOSLA*CPSLA*DXSLA)
        C = ABS(A)*(TINF-TSURF)+B*Q+2*FOSLA*(T1-TSURF)
        D = 1+A+2*FOSLA
        DTSURF = C/D
C
        DT1 = FOSLA*(TSURF+T2-2*T1)/(1+2*FOSLA)
        DT2 = FOSLA*(T1+T3-2*T2)/(1+2*FOSLA)
        DT3 = FOSLA*(T2+T4-2*T3)/(1+2*FOSLA)
        DT4 = FOSLA*(T3+TSUB-2*T4)/(1+2*FOSLA)
C
        A = 4*CONAL*DELTIME/(RHOSLA*CPSLA*DXSLA*DXAL)
        B = 2*FOSLA*(T4-TSUB)+A*(TAL-TSUB)
        C = 1+2*FOSLA+A
        DTSUB = B/C
C
        DTAL = 2*FOAL*(TSUB-TAL)/(1+2*FOAL)
C
C   INCREMENT TEMPS AND TIME
C
        TSURF = TSURF+DTSURF
        IF (TSURF .GE. 1450) TSURF=1450.0
        T1 = T1+DT1
        T2 = T2+DT2
        T3 = T3+DT3
        T4 = T4+DT4
        TSUB = TSUB+DTSUB
        TAL = TAL+DTAL
        TIME = TIME+DELTIME
        I = I+1
C
C   CHECK TIME AND WRITE TEMPS
C
        IF (TIME .GE. 401) GO TO 500
        IF ( I .EQ. 1000 ) GO TO 250
        TF = TAL - 460.0
        GO TO 350
250     WRITE(11,300),TIME,TF,TSURF,ABLOSS
300     FORMAT(F6.2,2X,F10.4,2X,F10.4,2X,F10.4)
        I = 0
350     CONTINUE
C
C   CHECK FOR ABLATION AND CHANGE TPS THICKNESS
C
        IF (TSURF .GE. 1450.0) THEN
          ABLOSS = ABLOSS+((1.1E-6*QCW**1.81)*DELTIME)
          DXSLA = (J*DXSLA-(1.1E-6*QCW**1.81*DELTIME))/J
          GO TO 100
        END IF
        GO TO 100
500     CONTINUE
        END
```

B. FORTRAN Output

TIME	ALUM TEMP	SURF T	MATERIAL LOSS
0.01	80.0000	539.9868	0.0000
10.01	80.0000	475.2087	0.0000
20.01	80.0000	439.2649	0.0000
30.01	79.9483	428.5745	0.0000
40.01	79.8032	424.1151	0.0000
50.01	79.5510	421.7969	0.0000
60.01	79.1900	490.5258	0.0000
70.01	78.7339	567.0659	0.0000
80.01	78.2456	643.5966	0.0000
90.01	77.8204	719.5480	0.0000
100.01	77.5463	794.6028	0.0000
110.02	77.5093	868.5078	0.0000
120.02	77.7778	941.0299	0.0000
130.02	78.4035	1011.9357	0.0000
140.01	79.4272	1080.9640	0.0000
150.01	80.8741	1147.9370	0.0000
160.00	82.7622	1212.6405	0.0000
170.00	85.1023	1274.8676	0.0000
179.99	87.8952	1334.4210	0.0000
189.98	91.1423	1391.1144	0.0000
199.98	94.8339	1444.7742	0.0000
209.97	99.0440	1450.0000	0.0016
219.97	103.9432	1450.0000	0.0035
229.96	109.5919	1450.0000	0.0054
239.96	116.0066	1450.0000	0.0073
249.95	123.1741	1450.0000	0.0091
259.95	131.0663	1450.0000	0.0109
269.96	139.6486	1450.0000	0.0127
279.97	148.8866	1450.0000	0.0144
289.98	158.7478	1450.0000	0.0159
299.99	169.1983	1450.0000	0.0173
310.00	180.1980	1450.0000	0.0186
320.01	191.7037	1450.0000	0.0198
330.02	203.6571	1450.0000	0.0208
340.03	215.9847	1450.0000	0.0216
350.04	228.6013	1450.0000	0.0222
360.05	241.4095	1450.0000	0.0227
370.06	254.2880	1450.0000	0.0231
380.07	267.1544	1450.0000	0.0233
390.08	279.8741	1375.0325	0.0233
400.09	291.7511	1188.6919	0.0233

C. Graph of FORTRAN Results





D. SINDA Input Listing:

```
C
      BCD 3THERMAL LPCS
      BCD 9SHUTTLE-C NOSE CAP TPS MODEL
C
C  This is a simple 1-D SINDA model of a body point on
C  the Shuttle-C nose cap. The aeroheating environments were
C  given as FC = 0.001+0.00198*t and Hr = 100 for t <= 50.
C  FC = 0.1 - 2.828e-4*(t-50) and Hr = 100 + 2*(t-50)
C  for t > 50.The SINDA subroutine ABL will be called
C  in this model. The aluminum substrate will be modeled as a
C  flat plate, 1 square foot in area.  The skin thickness was
C  assumed to be 0.200 in. and the ablative material 0.5 in. thick.
C  Initial temperatures were taken as 80 deg F for the skin
C  and ablative material.  The sky temp. was assumed to be 50 deg F.
C
      END
C
      BCD 3NODE DATA
C
          150,80.0,0.333 $SUBSTRATE NODE 0.100 IN. THICK, To = 80 F
          250,80.0,0.333 $INTERIOR SUBSTRATE NODE
          -500,50.0,1.0          $AMBIENT SINK TEMP. =  50 DEG F
C
      END
C
      BCD 3SOURCE DATA
C
      END
C
      BCD 3CONDUCTOR DATA
C
          151,150,250,1.0 $CONDUCTIVITY HIGH TO REDUCE TO ONE NODE
C
      END
C
      BCD 3CONSTANTS DATA
C
          OUTPUT = 10.0
          TIMEO  = 0.0
          NLOOP  = 500
          CSGFAC = 4.0
          DRLXCA = 0.1
          ARLXCA = 0.1
          NDIM   = 40
          TIMEND = 400.0
C
      END
C
      BCD 3ARRAY DATA
C
C*****************************************************************
C                    MATERIAL PROPERTY ARRAYS
C*****************************************************************
C
C
C
          5                  $SLA-561 MATERIAL PROP. FROM UTC
          16.0,0.34,0.0,2.444E-5,0.0,400.0,-1,990.0,0.0,1.10E-6
          1.81
          END  $ EMISSIVITY = 0.9
C
C
C*****************************************************************
```

```
C              AEROHEATING ENVIRONMENT DATA BELOW
C*********************************************************************
C
C     TIME, BODY POINT 100
          1100
             0.0,    10.0,    20.0,    30.0,    40.0
            50.0,    60.0,    70.0,    80.0,    90.0
           100.0,   110.0,   120.0,   130.0,   140.0
           150.0,   160.0,   170.0,   180.0,   190.0
           210.0,   230.0,   250.0,   270.0,   290.0
           310.0,   330.0,   350.0,   370.0,   390.0
           400.0
          END$
C
C     HEAT COEFFICIENT BODY POINT 100
          2100
           0.001,       0.0208,      0.0406,      0.0604,      0.0802
           0.100,       0.09717,     0.094344,    0.091516,    0.088688
           0.08586,     0.083032,    0.080204,    0.077376,    0.074548
           0.07172,     0.068892,    0.066064,    0.063236,    0.060408
           0.054752,    0.049096,    0.043440,    0.037784,    0.032128
           0.026472,    0.020816,    0.015160,    0.009504,    0.003848
           0.00102
          END$
C
C     RECOVERY ENTHALPY BODT POINT 100
          3100
            100.0,   100.0,   100.0,   100.0,   100.0
            100.0,   120.0,   140.0,   160.0,   180.0
            200.0,   220.0,   240.0,   260.0,   280.0
            300.0,   320.0,   340.0,   360.0,   380.0
            420.0,   460.0,   500.0,   540.0,   580.0
            620.0,   660.0,   700.0,   740.0,   780.0
            800.0
          END$
C
C       PLUME INPINGEMENT, ALL BODY POINTS
          4100
           0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0
           0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0
           0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0
           0.0,    0.0,    0.0,    0.0
          END
C
C
          35,SPACE,62,END
C
C
C*************************************************************
C  Ablation array: 1 TPS ABL working array format
C*************************************************************
C
          50  $
          150,,,4.285E-13,1.0,500,,-301,1.0,35,1100,3100,2100,5
          0.0417,,.0004,80.,80.,END
C
C
      END
      BCD 3EXECUTION
C
M     CALL JOIN(31,A(1100+1),A(4100+1),A(35+1)) $COMBINE SINGLET ARRAYS
F     CALL SNADE
C
      END
```

```
C
        BCD 3VARIABLES 1
C
        END
C
        BCD 3VARIABLES 2
C
M       CALL ABL(A50)
C
        END
C
        BCD 3OUTPUT CALLS
            TPRINT
            TDUMP
C
M       CALL ABLOUT(A50)
C
        END
C
        BCD 3END OF DATA
```

E. SINDA Output Listing:

```
(C) COPYRIGHT 1982,1983,1984,1985,1986,1987  J.D.GASKI  SINDA/1987/ANSI 1.31 NETWORK ANALYSIS ASSOCIATES, INC. - PAGE      1

   SHUTTLE-C NOSE CAP TPS MODEL

*** NODE *** SPACE REQUIRES      9 DYNAMIC STORAGE LOCATIONS OUT OF      22 AVAILABLE ***
            TIMEND=  400.00    , CSGFNO= 4.0000    , DTIMEI= 0.00000E+00, NLOOP =          500
            TIMED = 0.00000E+00, OUTPUT= 10.000    , DTIMEH= 0.10000E+09, DTIMEL= 0.00000E+00
            ARLXCA= 0.10000    , ATMPCA= 0.10000E+09, DRLXCA= 0.10000    , DTMPCA= 0.10000E+09

 ================
TIME= 0.00000E+00, DTIMEU= 0.00000E+00, CSGMIN(      0)= 0.00000E+00, ATMPCC(      0)= 0.00000E+00, DTMPCC(      0)= 0.00000E+00
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   80.0000 T   250 =   80.0000 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.00000    Q-HH=  -0.03711    Q-ABL=   0.00000      T-SUB=  80.00
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=   80.00   T-CORE1=   80.00      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 1.00000E+01, DTIMEU= 5.02000E-01, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 5.92041E-03
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   79.9801 T   250 =   79.9848 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.34985    Q-HH=  -0.11543    Q-ABL=   0.00000      T-SUB=  79.98
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  -17.87   T-CORE1=   76.69      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 2.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 4.67529E-02
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   79.9110 T   250 =   79.9309 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.19758    Q-HH=  -0.12052    Q-ABL=   0.00000      T-SUB=  79.91
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  -29.78   T-CORE1=   71.81      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 3.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 7.50732E-02
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   79.7379 T   250 =   79.7695 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.13806    Q-HH=  -0.11958    Q-ABL=   0.00000      T-SUB=  79.74
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  -34.38   T-CORE1=   67.05      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 4.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 1.01196E-01
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   79.4880 T   250 =   79.5302 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.10613    Q-HH=  -0.11691    Q-ABL=   0.00000      T-SUB=  79.49
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  -36.82   T-CORE1=   62.57      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 5.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 1.24505E-01
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   79.1687 T   250 =   79.2206 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.08621    Q-HH=  -0.11368    Q-ABL=   0.00000      T-SUB=  79.17
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  -38.32   T-CORE1=   58.44      XCUR=  0.04170      XABL = 0.00000
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   SHUTTLE-C NOSE CAP TPS MODEL

 ================
TIME= 6.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 1.36534E-01
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   78.7964 T   250 =   78.8522 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.08838    Q-HH=  -0.00223    Q-ABL=   0.93070      T-SUB=  78.80
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=   40.13   T-CORE1=   56.61      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 7.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 1.22525E-01
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   78.4296 T   250 =   78.4752 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.09065    Q-HH=  0.08622     Q-ABL=   2.79051      T-SUB=  78.43
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  118.06   T-CORE1=   58.84      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 8.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 8.75854E-02
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   78.1332 T   250 =   78.1678 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.09302    Q-HH=  0.16905     Q-ABL=   4.53718      T-SUB=  78.13
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  194.77   T-CORE1=   64.66      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 9.00000E+01, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)= 3.32642E-02
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   77.9655 T   250 =   77.9772 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.09546    Q-HH=  0.24664     Q-ABL=   6.17073      T-SUB=  77.97
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  270.20   T-CORE1=   73.67      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 1.00000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.77197E-02
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =   77.9745 T   250 =   77.9567 T   500 =   50.0000 T
ABL NODE      150       STATUS  1 0 2        DTMH=  0.09797    Q-HH=  0.31927     Q-ABL=   7.69117      T-SUB=  77.97
 XCUR2=  0.00000        XABL2=  0.00000    T-SURF1=  344.26   T-CORE1=   85.48      XCUR=  0.04170      XABL = 0.00000

 ================
TIME= 1.10000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-1.22742E-01
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00
```

```
T   150 =   78.2034 T   250 =   78.1504 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.10059    Q-HN=  0.38721   Q-ABL=  9.09848     T-SUB=  78.20
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  416.79   T-CORE1=  99.76     XCUR=  0.04170     XABL = 0.00000
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   SHUTTLE-C NOSE CAP TPS MODEL

 ================
TIME= 1.20000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-2.19543E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   78.6892 T   250 =   78.5963 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.10327    Q-HN=  0.45059   Q-ABL= 10.39267     T-SUB=  78.69
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  487.64   T-CORE1= 116.20     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 1.30000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.26477E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   79.4611 T   250 =   79.3242 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.10606    Q-HN=  0.50959   Q-ABL= 11.57375     T-SUB=  79.46
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  556.63   T-CORE1= 134.51     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 1.40000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.41101E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   80.5435 T   250 =   80.3593 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.10896    Q-HN=  0.56429   Q-ABL= 12.64170     T-SUB=  80.54
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  623.60   T-CORE1= 154.41     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 1.50000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-5.62378E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   81.9587 T   250 =   81.7246 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.11192    Q-HN=  0.61475   Q-ABL= 13.59653     T-SUB=  81.96
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  688.34   T-CORE1= 175.68     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 1.60000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-6.88599E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   83.7210 T   250 =   83.4351 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.11504    Q-HN=  0.66106   Q-ABL= 14.43825     T-SUB=  83.72
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  750.70   T-CORE1= 198.06     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 1.70000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-8.18059E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   85.8419 T   250 =   85.5029 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.11829    Q-HN=  0.70327   Q-ABL= 15.16684     T-SUB=  85.84
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  810.48   T-CORE1= 221.35     XCUR=  0.04170     XABL = 0.00000
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   SHUTTLE-C NOSE CAP TPS MODEL

 ================
TIME= 1.80000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-9.50317E-01
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   88.3278 T   250 =   87.9346 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.12166    Q-HN=  0.74137   Q-ABL= 15.78231     T-SUB=  88.33
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  867.52   T-CORE1= 245.35     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 1.90000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-1.08331E+00
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   91.1852 T   250 =   90.7376 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.12525    Q-HN=  0.77547   Q-ABL= 16.28467     T-SUB=  91.19
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  921.66   T-CORE1= 269.85     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 2.00000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-1.21582E+00
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   94.4160 T   250 =   93.9140 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.12904    Q-HN=  0.80557   Q-ABL= 16.67390     T-SUB=  94.42
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  972.74   T-CORE1= 294.69     XCUR=  0.04170     XABL = 0.00000

 ================
TIME= 2.10000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-1.37964E+00
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =   98.0525 T   250 =   97.4813 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.13367    Q-HN=  1.43740   Q-ABL= 16.95001     T-SUB=  98.05
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  980.00   T-CORE1= 319.63     XCUR=  0.04050     XABL = 0.00120

 ================
TIME= 2.20000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-1.58093E+00
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =  102.2246 T   250 =  101.5699 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.13890    Q-HN=  2.30530   Q-ABL= 17.11301     T-SUB= 102.22
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  980.00   T-CORE1= 344.34     XCUR=  0.03864     XABL = 0.00306

 ================
TIME= 2.30000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-1.79620E+00
   LOOPCT=    0                                                     , ARUXCC(      0)= 0.00000E+00, DRUXCC(      0)= 0.00000E+00

T   150 =  107.0009 T   250 =  106.2563 T   500 =   50.0000 T
ABL NODE     150        STATUS  1 0 2        DTMN=  0.14456    Q-HN=  3.06007   Q-ABL= 17.16288     T-SUB= 107.00
 XCUR2=  0.00000        XABL2=  0.00000   T-SURF1=  980.00   T-CORE1= 368.74     XCUR=  0.03675     XABL = 0.00495
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   SHUTTLE-C NOSE CAP TPS MODEL
```

```
****************
TIME= 2.40000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-2.02722E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  112.4303 T    250 =  111.5892 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.15057    Q-HN=   3.70173    Q-AEL=  17.09963      T-SUB= 112.43
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  392.72      XCUR=  0.03487      XAEL = 0.00603

****************
TIME= 2.50000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-2.27205E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  118.5651 T    250 =  117.6210 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.15708    Q-HN=   4.23027    Q-AEL=  16.92327      T-SUB= 118.57
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  416.16      XCUR=  0.03301      XAEL = 0.00869

****************
TIME= 2.60000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-2.53027E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  125.4531 T    250 =  124.4003 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.16410    Q-HN=   4.64569    Q-AEL=  16.63378      T-SUB= 125.45
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  438.88      XCUR=  0.03119      XAEL = 0.01051

****************
TIME= 2.70000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-2.80042E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  133.1398 T    250 =  131.9730 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.17158    Q-HN=   4.94798    Q-AEL=  16.23117      T-SUB= 133.14
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  460.68      XCUR=  0.02945      XAEL = 0.01225

****************
TIME= 2.80000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.07463E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  141.6658 T    250 =  140.3823 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.17979    Q-HN=   5.13716    Q-AEL=  15.71545      T-SUB= 141.67
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  481.35      XCUR=  0.02779      XAEL = 0.01391

****************
TIME= 2.90000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.35010E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  151.0496 T    250 =  149.6489 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.18875    Q-HN=   5.21322    Q-AEL=  15.08650      T-SUB= 151.05
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  500.70      XCUR=  0.02623      XAEL = 0.01547
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   SHUTTLE-C NOSE CAP TPS MODEL

****************
TIME= 3.00000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.62024E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  161.2911 T    250 =  159.7754 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.19844    Q-HN=   5.17615    Q-AEL=  14.34463      T-SUB= 161.29
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  518.57      XCUR=  0.02480      XAEL = 0.01680

****************
TIME= 3.10000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.87201E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  172.3748 T    250 =  170.7504 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.20802    Q-HN=   5.02597    Q-AEL=  13.48954      T-SUB= 172.37
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  534.85      XCUR=  0.02350      XAEL = 0.01820

****************
TIME= 3.20000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.09888E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  184.2514 T    250 =  182.5286 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.22152    Q-HN=   4.76267    Q-AEL=  12.52134      T-SUB= 184.25
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  549.55      XCUR=  0.02236      XAEL = 0.01934

****************
TIME= 3.30000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.29523E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  196.8401 T    250 =  195.0321 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.23612    Q-HN=   4.38624    Q-AEL=  11.44001      T-SUB= 196.84
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  562.75      XCUR=  0.02137      XAEL = 0.02033

****************
TIME= 3.40000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.45038E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  210.0338 T    250 =  208.1581 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.25106    Q-HN=   3.89670    Q-AEL=  10.24557      T-SUB= 210.03
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  574.61      XCUR=  0.02054      XAEL = 0.02116

****************
TIME= 3.50000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.55914E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  223.7085 T    250 =  221.7830 T    500 =   50.0000 T
AEL NODE     150         STATUS  1 0 2        DTMN=  0.28805    Q-HN=   3.29404    Q-AEL=   8.93800      T-SUB= 223.71
  XCUR2= 0.00000         XAEL2= 0.00000    T-SURF1=  990.00   T-CORE1=  585.33      XCUR=  0.01988      XAEL = 0.02182
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   SHUTTLE-C NOSE CAP TPS MODEL

****************
TIME= 3.60000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ADMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.62573E+00
   LOOPCT=    0                                                     , ARDUCC(      0)= 0.00000E+00, DRUCC(      0)= 0.00000E+00

T   150 =  237.7125 T    250 =  235.7590 T    500 =   50.0000 T
```
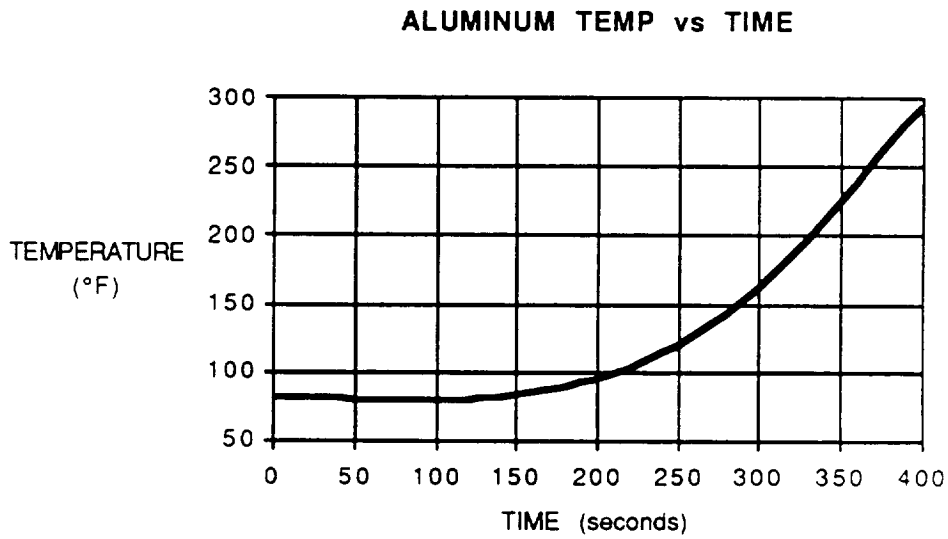
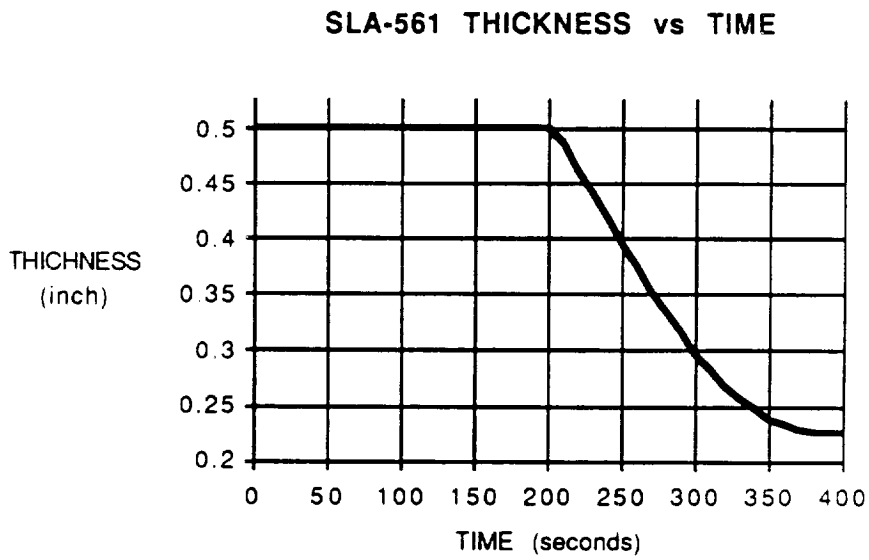

```
ABL NODE      150        STATUS  1 0 2        DTMM=  0.29159    Q-HM=  2.57826   Q-ABL=  7.51731     T-SUB= 237.71
  XCUR2= 0.00000         XABL2= 0.00000   T-SURF1=  990.00  T-CORE1=  595.12     XCUR= 0.01938      XABL = 0.02232

****************
TIMB= 3.70000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.64252E+00
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =  251.8991 T    250 =  249.9364 T    500 =   50.0000 T
ABL NODE      150        STATUS  1 0 2        DTMM=  0.31867    Q-HM=  1.74935   Q-ABL=  5.98350     T-SUB= 251.90
  XCUR2= 0.00000         XABL2= 0.00000   T-SURF1=  990.00  T-CORE1=  604.19     XCUR= 0.01903      XABL = 0.02267

****************
TIMB= 3.80000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.62390E+00
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =  266.1067 T    250 =  264.1550 T    500 =   50.0000 T
ABL NODE      150        STATUS  1 0 2        DTMM=  0.35422    Q-HM=  0.91591   Q-ABL=  4.33658     T-SUB= 266.11
  XCUR2= 0.00000         XABL2= 0.00000   T-SURF1=  974.24  T-CORE1=  612.42     XCUR= 0.01884      XABL = 0.02286

****************
TIMB= 3.90000E+02, DTIMEU= 1.00400E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-4.36098E+00
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =  279.9488 T    250 =  278.1160 T    500 =   50.0000 T
ABL NODE      150        STATUS  1 0 2        DTMM=  0.43248    Q-HM=  0.57435   Q-ABL=  2.57653     T-SUB= 279.95
  XCUR2= 0.00000         XABL2= 0.00000   T-SURF1=  839.74  T-CORE1=  603.92     XCUR= 0.01884      XABL = 0.02286

****************
TIMB= 4.00000E+02, DTIMEU= 1.00397E+00, CSGMIN(    150)= 3.33000E-01, ATMPCC(      0)= 0.00000E+00, DTMPCC(    150)=-3.73151E+00
   LOOPCT=     0                                                    , ARLXCC(      0)= 0.00000E+00, DRLXCC(      0)= 0.00000E+00

T   150 =  292.4404 T    250 =  290.8862 T    500 =   50.0000 T
ABL NODE      150        STATUS  1 0 2        DTMM=  0.57265    Q-HM=  0.03015   Q-ABL=  0.70337     T-SUB= 292.44
  XCUR2= 0.00000         XABL2= 0.00000   T-SURF1=  604.24  T-CORE1=  564.94     XCUR= 0.01884      XABL = 0.02286
```

F. Graphs of SINDA Output





IV. References:

Bryan, D., M., "Description of the Vax-ABL Ablation Simulation Subroutine", MSFC Memo ED64 90-41.

Introduction to Chapter 7

Solid Rocket Motor Nozzle Analysis

Analysis of Solid Rocket Motor (SRM) internal insulation and components involves complex physical phenomena. These include convective heating, plume radiation, ablation chemistry, heat transfer, and energy storage. Analytical representation of these phenomena has typically been accomplished through use of several analytical codes. These codes usually involve expansion of a plume to describe a flowfield, use of a boundary layer code to define the wall heat transfer, and use of charring material code to account for the ablation chemistry and the material thermal response. The descriptions included here include several state-of-the-art codes developed by ACUREX Corporation to provide design capability for these complex phenomena for solid rocket motor materials. The codes given here are well established and typically use 1-D techniques. Use of these codes will provide first order design material thickness requirements for SRM insulations and nozzle materials.

CHAPTER 7: SOLID ROCKET MOTOR NOZZLE ANALYSIS

SECTION 1. DESCRIPTION OF 1-DIMENSIONAL TECHNIQUES

Introduction

In order to predict solid rocket motor nozzle ablation, both aerothermal and heat transfer analyses must be performed. The ACUREX Corporation has developed several computer codes which are used to perform these analyses. The Aerotherm Chemical Equilibrium (ACE), Momentum, and Energy Integral Technique (MEIT) codes are used to establish the internal nozzle aerothermal environments for subsequent use in the Charring Material Thermal Response and Ablation (CMA) program, which is used for the ablation and heat transfer analysis. A brief description of these codes is presented in Section A below, while the nozzle analysis procedure is discussed in Section B. A CMA sample problem of the RSRM Nozzle throat analysis is included in the Appendix.

A. ACUREX CORPORATION COMPUTER CODE DESCRIPTION

ACE

This code is used to calculate the motor chamber combustion gas products, exhaust gas thermodynamic properties, and the subsequent 1-D isentropic nozzle flow expansion at user specified pressure points or Mach numbers along the nozzle wall. ACE is also used to generate nozzle liner surface thermochemistry and boundary layer "edge" gas Mollier tables. These sets of thermodynamic property tables are used in the CMA and MEIT codes, respectively. The surface thermochemistry tables are used to calculate the pyrolysis generation and liner ablation rates at the nozzle surface. These tables contain several pairs of pyrolysis gas and corresponding surface char generation rates. The Mollier tables are thermodynamic properties of the combustion gas products at the outer edge of the boundary layer and are used as input data for the MEIT program.

Required ACE input data for the chamber and subsequent 1-D nozzle expansion solutions include:

1. Propellant elemental composition and heat of formation data
2. Chamber thermodynamic state variables (Tc and Pc)
3. Nozzle gas expansion locations (either a series of pressure points, covering the expected operating range of the nozzle , or mach numbers)
4. JANNAF thermodynamic property data

MEIT

This code is used to calculate the convection heating environment (gas film coefficients and recovery enthalpies) along the nozzle wall. These surface heating boundary conditions are used directly in the CMA program. Required data inputs to the code include values of Cm/Ch, the mass to heat transfer coefficient ratio of the propellant combustion gas products, Gamma (Cp/Cv), and ACE-generated Mollier tables. A table of nozzle body points, along with associated "edge" gas properties (pressure, enthalpy, velocity, and temperature), are also included in the input file. The MEIT body points are taken from the nozzle contour dimensions listed in Appendix A. The Cm/Ch value, Gamma, and "edge" gas properties are taken from the ACE 1-D nozzle expansion output. MEIT output lists in the thermodynamic properties at the wall surface for each body point, along with recovery enthalpies and film coefficients. The recovery enthalpy and film coefficient data can then be plotted as a function of nozzle axial length to obtain the heating distribution along the nozzle surface.

CMA

The CMA code is a 1-D finite-difference heat transfer program used to predict nozzle liner erosion and char depths, along with in-depth temperature profiles. Material property data used with CMA include: Arrhenius kinetic rate constants, density, specific heat, and thermal conductivity for both virgin and char material states, pyrolysis gas enthalpy, and ACE-generated surface thermochemistry (ablation) tables. Other miscellaneous input data includes: nodal thicknesses, program time constants, resin volume or mass percent, and the MEIT-calculated recovery enthalpies and film coefficients. CMA output consists of erosion, char, and pyrolysis depths and rates, surface heat fluxes, and nodal temperatures along with their decomposition states. The decomposition states indicate the degree of heat penetration through the composite material.

Edge Gas Property FORTRAN Routine (EDGEPROP.FOR)

EDGEPROP.FOR is a FORTRAN computer program which aids the analyst in preparing the MEIT body point table. EDGEPROP.FOR program extracts the edge gas properties from the ACE 1-D gas expansion run and interpolates this data to the desired MEIT body point locations.

B. NOZZLE AEROTHERMAL/ABLATION ANALYSIS PROCEDURE

Step 1. ACE Nozzle Flow Analysis and MEIT Edge Gas Properties

a. Run ACE expansion w/propellant composition, chamber pressure and either chamber temperature of propellant enthalpy as the two thermodynamic state variables to obtain the chamber solution. Include nozzle expansion pressures, from chamber to atmospheric, to obtain 1-D isentropic flow profile.

b. Run EDGEPROP.FOR, using the EDGEPROP.DAT output file created from step a. above and RSRMNOZCORD.DAT file, to interpolate edge gas properties from ACE run to the body points contained in the RSRMNOZCORD.DAT file. Output files are NOZGEOM.DAT and EDGEPROP.OUT. Use the EDGEPROP.OUT file as direct input for the MEIT body point table data.

c. Plot Qrad vs. axial length from the output data of step b. above. This plot gives the radiative heating distribution along the nozzle wall, and will be used in the CMA function of time tables.

d. Plot the edge gas properties (pressure,velocity,enthalpy,and temperature) from the EDGEPROP.OUT file vs. the nozzle axial length to obtain gas property distributions thru the nozzle.

Step 2. ACE Mollier and Surface Thermochemistry Table Generation

a. Mollier tables: Run ACE code, using a propellant composition without aluminum and corresponding oxygen content required to form aluminum oxide, at a series of pressures and temperatures covering the operating conditions of the nozzle. Use Pc and Tc as the two thermodynamic state variables for the chamber solution. Within each pressure sub-table, include expansion calculations at 500°K thru 4000°K in 500°K increments. This will create a set of thermodynamic property tables of the boundary layer gas as a function of temperature at several nozzle pressure stations. The resulting ACE output is tabularized and formatted so that it can be used directly in the MEIT input data file.

b. Surface thermochemistry tables: Run ACE using the same propellant composition as in step a. above. Include the elemental compositions for the pyrolysis gas and the surface char in addition to propellant composition. Use the same thermodynamic conditions for the chamber solution in step a. above. The edge gas conditions (Pe and Te) for the nozzle station to be analyzed with CMA need to be identified from the plots in Step 1d. Once the edge pressure has been established, expand the gas from the chamber to this new pressure in 500°K temperature increments, from 500°K to 4000°K. Include card sets for pyrolysis gas and char rates so ablation tables can be created at the specified nozzle station edge pressure. The output surface thermochemistry tables are written into a file labeled ACEOUTPT.PCH and can be inserted directly into the surface thermochemistry table section of the CMA input file.

Step 3. MEIT Boundary Layer Analysis

a. Run MEIT code using ACE Mollier tables created form Step 2a above and the nozzle body point data from the EDGEPROP.OUT file created in Step 1. Additional MEIT inputs include GAMMA (Cp/Cv) and Cm/Ch ratio for the propellant exhaust gas. These values are obtained from the ACE expansion run in Step 1. GAMMA can be found directly in the ACE output, while Cm/Ch (mass to heat transfer coefficients ratio) is calculated as follows: Cm/Ch = (Le) **0.667 = (Pr/Sc) **0.667. Values for Pr and Sc numbers are taken directly from the ACE expansion output from step 1. Typical values for GAMMA and Cm/Ch, for the shuttle PBAN propellant, are 1.2 and 0.70, respectively. MEIT output includes tables of both the wall and viscous boundary layer gas properties at each of the specified body points.

b. Plot the film coefficients and recovery enthalpies vs. the nozzle axial length to obtain the boundary layer heating distribution through the nozzle. This plot will be used to determine the surface heating boundary conditions for the CMA program section.

Step 4. CMA Heat Transfer/Ablation Analysis

a. This is the final step in the ablation analysis procedure. Run CMA using output data from the previous three steps and include the 1-D nozzle liner nodal grid. Additional code inputs are the nozzle liner material Arrhenius kinetic rate constants and thermal properties, pyrolysis gas enthalpy, general program time constants, and nozzle surface heating boundary conditions computed in step 3.

b. Output data consists of the current erosion, char, and pyrolysis depths and their rates, along with the nodal temperatures and decomposition states. Integrated totals for the surface and in-depth heat fluxes are also included. This output data is printed at every print interval specified in the input file.

FIGURE 5. NOZZLE ANALYSIS PROCEDURE

Step 1. ACE Expansion

Specify the chamber pressure, fuel elemental compsoition and heat of formation and run 1-D isentropic expansion to deifn the nozzle flow environment.

Notes:
1. It is sometimes convenient to use isentropic expansion gas tables with the appropriate gamma (e.g., 1.12) and the nozzle geometry to estimate what pressure at corresponding expansion ratios are desired.
2. This run is made with aluminum included in the fuel composition.

Step 2. Organization of ACE Expansion Data

Based upon the nzzle geometry and the output form the ACE expansion identify the velocity, edge pressure, temperature, etc., at several locations on the nozzle wall

Step 3. ACE Edge Gas & Mollier Data

Construct MEIT gas thermochemistry and transport property tables (Mollier Tables) using the ACE program.

Notes:
1. Use temperature and pressure as determined in Step 2 for the ACe calculations (closed system).
2. Eliminate Al_2O_3 from ACE runs for boundary layer gas analysis.

Step 4. MEIT Boundary Layer

Calculate transfer coefficients and recovery enthalpy for initial geometry and average pressure.

Step 5. ACE Surface Thermochemistry

Construct surface thermochemistry using ACE. Requires edge gas, kpyrolysis gas and char composition.

Notes:
1. Use corresponding temperature and pressure determined from Step 2 for each location desired.
2. Eliminate Al_2O_3 from runs (open system).

Step 6. CMA Material Response Calculation

Run CMA based upon transfer coefficients obtained from Step 4 and thermochemistry based upon Step 5.

Notes:

1. Make the transfer coefficients a function of time based upon the pressure trace.

2. Radiation is based upon local static temperatur from Step 2.

Step 7. Erosion Effect on boundary Layer Analysis

Based upon the results of Step 6 (total erosion) determine if a boundary layer analysis is required for the eroded geometry. Return to Step 4 and repeat for the final geometry and average pressure if requried.

Step 8. Average the Transfer Coefficients

Average the heat transfer coefficients for the initial and final geometry (normal to the surface) and make time dependent based upon the pressure trace.

Step 9 GASKET Surface Thermochemistry

Run GASKET or ACE for surface thermochemistry input into ASTHMA.

Note: Generally Gasket is to be used with ASTHMA.

Step 10. ASTHMA Material Response Calculation

Run ASTHMA for the surface recession and indepth temperature maps to be used in a thermo-structural analysis.

References

1. "User's Manual, Aerotherm Chemical Equilibrium (ACE81) Computer Program." Acurex Corporation, Aerotherm Division, Moutain View, California, August 1981

2. "User's Manual, Momentum/Energy Integral Technique (MEIT81)." Acurex Corporation, Aerotherm Division, Mountain View, California, August 1981

3. User's Manual, Aerotherm Charring Material Thermal Response and Ablation Program (CMA), Version 3." Acurex Corporation, Aerotherm Division, Mountain View, California, December 1975

APPENDIX

Table of Contents

1. PBAN TP-H1148 Shuttle Propellant Specification Sheet

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9. Sample ACE Surface Thermochemistry Input File

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11. Sample CMA Input File for RSRM Nozzle Throat Problem

12. Sample CMA Output for RSRM Throat Problem @ 120 Seconds

13. CMA Results for RSRM Nozzle Throat Problem

TP-H-1148

Manufacturer: Thiokol Corporation, Wasatch Division, Brigham City, Utah
Composition Type: AP/PBAN/Al
Std Sea Level Theoretical Isp: 2 568 N•s/kg (261.9 s)
Burn Rate at 6.9 MPa (1000 psia) and 298 K (77 F): 11 mm/s (0.43 in./s)
Pressure Exponent, n, in th Burn Rate Equation: 0.33
Density Measured at 298 K (77 F): 1.76 Mg/m^3 (0.0635 $lbm/in.^3$)
Chamber Flame Temperature at 6.9 Mpa (1000 psia): 3 428 K (5711 F)
Usage: Space Shuttle SRM

PROPELLANT COMPOSITION

Empirical Formula: $C_{0.9406}H_{3.7176}O_{2.4396}N_{0.6263}Al_{0.5930}Cl_{0.5952}Fe_{0.0009}$

Constituent	Source	Nominal Wt%
Ammonium perchlorate	Kerr McGee and Pacific Engineering	69.82
PBAN binder and curing agent	American Synthetic and Dow Chemical	14.0
Aluminum	Alcan and Alcoa	16.0
Iron Oxide	Charles Pfizer	0.18

BALLISTIC PROPERTIES

r, mm/s = $5.807P^{0.33}$ at 298 K from P = 1.4 to 11.7 MPa

(in./s = $0.04424P^{0.33}$ at 77 F from P = 200 to 1700 psia)

K_n = $4\ 770P^{0.67}$ at 298 K from P = 1.4 to 11.7 MPa

(= $170P^{0.67}$ at 77 F from P = 200 to 1700 psia)

σ_p = 0.13 %/K (0.7 %/F)

π_K = 0.20 %/K (0.11 %/F)

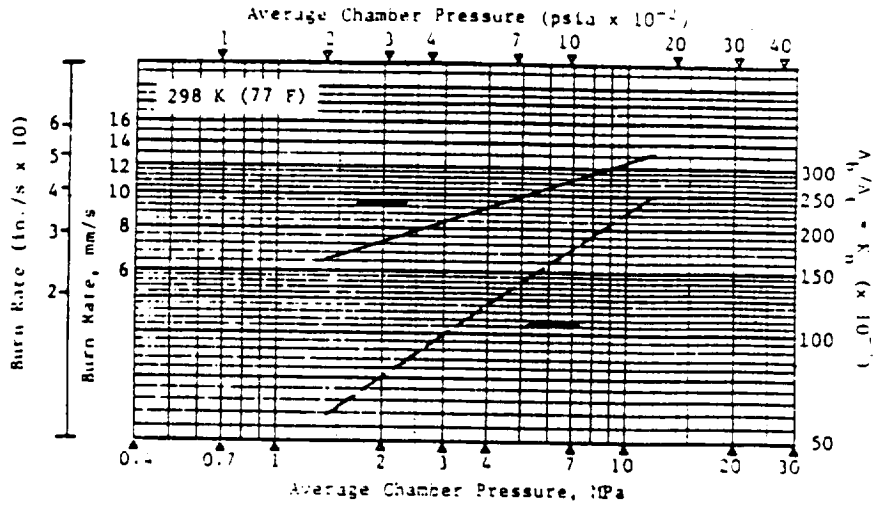
I°_{sps} = 2 568 N•s/kg (261.9 s); standard sea level optimum expansion

I°_{spd} = 2 471 N•s/kg (252.0 s); expansion from P = 4.5 MPa (650 psia) to P_{amb} = 0.085 MPa (12.4 psia), ε = 6.86, α = 12.4°

I_{spd} = 2 378 N•s/kg (242.5 s); conditions as above, m_p = 502 Mg (1.11 Mlbm), 124 s action time

c* = 1 572 m/s (5156 ft/s); standard sea level optimum expansion

TP-H-1148



THERMODYNAMIC PROPERTIES

ΔH_{ex} -5 156 kJ/kg (-1232.2 cal/g)

$\Delta H_{f(298)}$ = -1 853 kJ/kg (-442.8 cal/g)

Exhaust products; expansion form 6.9 to 0.10 MPa; *moles/100 grams*

Component	Chamber	Exit Compn.	Component	Chamber	Exit Compn.
CO_2	0.0617	0.0851	Al_2O_3	0.2829	0.2965(s)
CO	0.8789	0.8555			
H_2O	0.5429	0.5221	Total Products	3.5153	3.4162
H_2	0.9779	1.0374			
N_2	0.3115	0.3126			
HCl	0.5220	0.5860			

		Chamber	Frozen Exit Compn.	Equilibrium Exit Compn.
Pressure	MPa	6.895	0.101	0.101
Pressure	(psia)	(1000)	(14.70)	(14.70)
Temperature	K	3 430	1 799	2 154
Temperature	(F)	(5714)	(2778)	(3417)
c_p (total products)	kJ/(kg•K)	3.428	1.849	1.913
c_p (gases)	kJ/(kg•K)	2.000	1.832	1.901
Mean MW (total products)	kg/kmol	28.447	28.447	29.272
Mean MW (gases)	kg/kmol	20.245	20.245	20.424
Specific Heat Ratio, γ		1.1392	1.1881	1.1828

MECHANICAL AND PHYSICAL PROPERTIES

Uniaxial Tensile Properties:

T, K (F)	E, MPa (psi)	σ_m, MPa (psi)	ε_m, %	σ_b, MPa (psi)	ε_b, %
336 (145)	3.0 (440)	0.48 (69)	26		32
297 (75)	4.6 (660)	0.79 (115)	43		44
255 (0)	44.9 (6510)	2.72 (395)	34		40

Properllant Density at 298 K (77 F): 1.76 Mg/m^3 (0.0635 $lbm/in.^3$)
Thermal Coeff Linear Expandion: 9.49×10^{-5} m/(m•K)
(5.27×10^{-5} in./(in. °F))
Thermal Conductivity: 0.381 W/(m•K) (0.220 Btu/(h•ft•F))
Heat Capacity, cp: 1.2 kJ/(kg•K) (0.29 Btu/(lbm•F))
Glass Transition Temperature: 206 K (-89 F)
Poisson's Ratio: ~0.5 at low strains or under pressure
Additional mechanical property data available from manufacturer:

SENSITIVITY AND STABILITY

DOT-ICC Shipping Classification: Propellant Explosive (solid) Class B
Military Storage Hazard Classification: Class 1.3 (formerly Class 2)

No. 8 Blasting Cap Test: ignited and burned
Ignition and Unconfined Buring Test: burned rapidly without explosion
Thermal Stability: stable beyond 48 h in 348 K (167 F) oven
Card Gap Test: no fire at zero cards
Impact Sensitivity: 11 cm for the ABL impact test
Autoignition Temperature: approximately 478 K (400 F)
Friction Sensitivity: 2.29 MPa (331.6 psi) at 2.4 m/s (8 ft/s) in the ABL sliding friction test
Spark Sensitivity: greater than 6.25 J for the ABL electrostatic discharge test

Manufacturing

Cost of Raw Mix-Ready Ingredients: about $1.68/kg ($0.76/lbm)
Sequence of Operations: prepare premix (HP polymer, ECA, aluminum, and iron oxide); grind selected lots of oxidizer and blend with unground oxidizer; mix ingredients (premix first then add oxidizer); vacuum cast propellant within 8 hours of ECA addition at no less than 322 K (120 F); cure propellant
Mixer Type: Baker Perkins, 2.3 m^3 (600 gal)
Mix Temperature: 336 $\pm$ 6 K (145 $\pm$ 10 F)
Mix Pressure: ambient
End-of-Mix Viscosity: 1 500 $N \cdot s/m^2$ (15 kp); Brookfield TD spindle, 1 rpm
Pot Life: 8 hours
Casting Method: vacuum
Cure Time: 96 $\pm$ 4 hours
Cure Temperatrure: 330 $\pm$ 6 K (135 $\pm$ 10 F)
Cure Atmosphere: ambient air

Approximate Total Production to Date: over 4.5 Gg (10 Mlbm)
Propellant Usage: Space Shuttle Solid Rocket Motors (SRM)

REFERENCES

1. CPIA/M2 Questionnaire from Thiokol Corporation, Wasatch Division, Brigham City, Utah, completed by C. A. Saderholm, 26 October 1979, UNCLASSIFIED.

SRM THERMOCHEMICAL PROPERTIES

CHAMBER CONDITIONS, TP-H1148 PROPELLANT

Property	Chamber Pressure, psia		
	665	880	915
Flame Temperature, °R	6064	6103	6108
Characteristic Velocity, ft/sec	5152	5159	5160
Sonic Velocity, ft/sec	3498	3508	3509
Density, lbm/ft³	.2866	.3778	.3926
Enthalpy, BTU/lbm	-790.0	-790.0	-790.0
Molecular Weight	28.04	28.11	28.12
Frozen Specific Heat, BTU/lbm°R	.4735	.4736	.4737
Specific Heat Ratio	1.138	1.140	1.140
Weight Fraction Condensed	.2877	.2881	.2882
Viscosity, lbm/sec ft	6.189E-5	6.222E-5	6.222E-5
Thermal Conductivity, BTU/sec ft°F	6.222E-5	6.249E-5	6.249E-5
Prandtl Number	.4777	.4786	.4787

SRM THERMOCHEMICAL DATA

TEMPERATURE AND PRESSURE SPECIFIED

TP-H1148 PROPELLANT

PRESSURE = 700 psia

Rev. 7/29/86

TEMPERATURE, °R	500	1000	1500	2000	2500	3000	3500	4000	4187	4190	4500	5000	5500	6000
ENTHALPY, BTU/lbm	-3533*	-3358*	-3168*	-2967*	-2758	-2546	-2340	-2129	-2048	-1912	-1763	-1505	-1210	-849
DENSITY, lbm/ft³	3.799*	1.899*	1.266*	.9496*	.7597	.6296	.5395	.4719	.4508	.4504	.4190	.3759	.3391	.3060
MOLECULAR WEIGHT	29.12*	29.12*	29.12*	29.12*	29.12	28.96	28.95	28.94	28.93	28.93	28.91	28.81	28.59	28.14
FROZEN SPECIFIC HEAT BTU/lbm°R	.330*	.368*	.392*	.411*	.4253	.4387	.4499	.4593	.4624	.4624	.4670	.4732	.4778	.4803
SPECIFIC HEAT RATIO	1.197*	1.197*	1.197*	1.197*	1.197	1.202	1.198	1.192	1.189	1.173	1.168	1.159	1.148	1.140
SONIC VELOCITY ft/sec	1011*	1430*	1751*	2022*	2261	2489	2684	2862	2925	2906	3007	3162	3314	3476
VISCOSITY lbm/sec ft	1.06E-5*	1.72E-5*	2.28E-5*	2.79E-5*	3.26E-5	3.71E-5	4.14E-5	4.55E-5	4.70E-5	4.71E-5	4.96E-5	5.36E-5	5.75E-5	6.14E-5
THERMAL CONDUCTIVITY BTU/sec ft°F	.704E-5*	1.77E-5*	1.80E-5*	2.31E-5*	2.79E-5	3.27E-5	3.74E-5	4.22E-5	4.39E-5	4.39E-5	4.69E-5	5.16E-5	5.64E-5	6.16E-5
PRANDTL NUMBER	.497*	.497*	.497*	.497*	.497	.497	.497	.496	.495	.495	.494	.491	.487	.479

* Estimated values for frozen equilibrium below 2500°R.

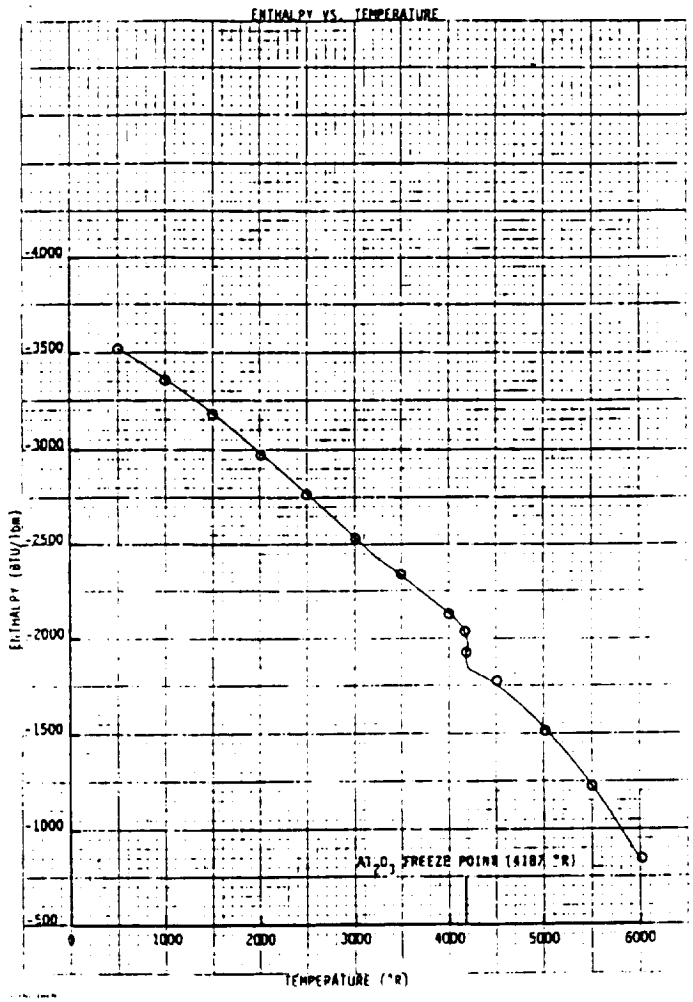


Figure A-1. TP-H1148 Propellant Enthalpy Data

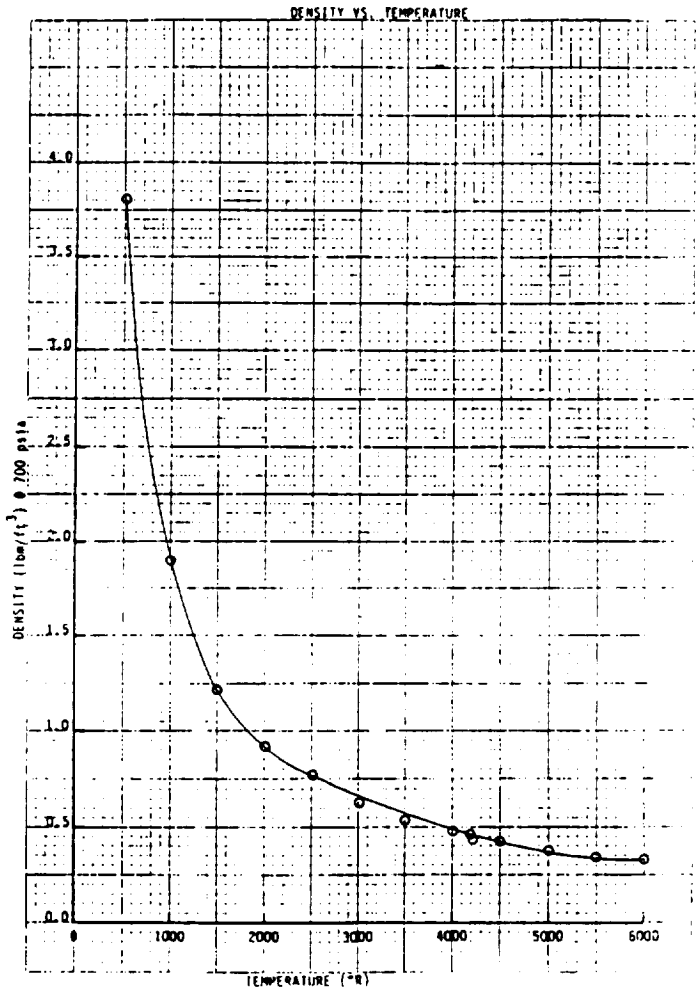


Figure A-2. TP-H1148 Exhaust Gas Density

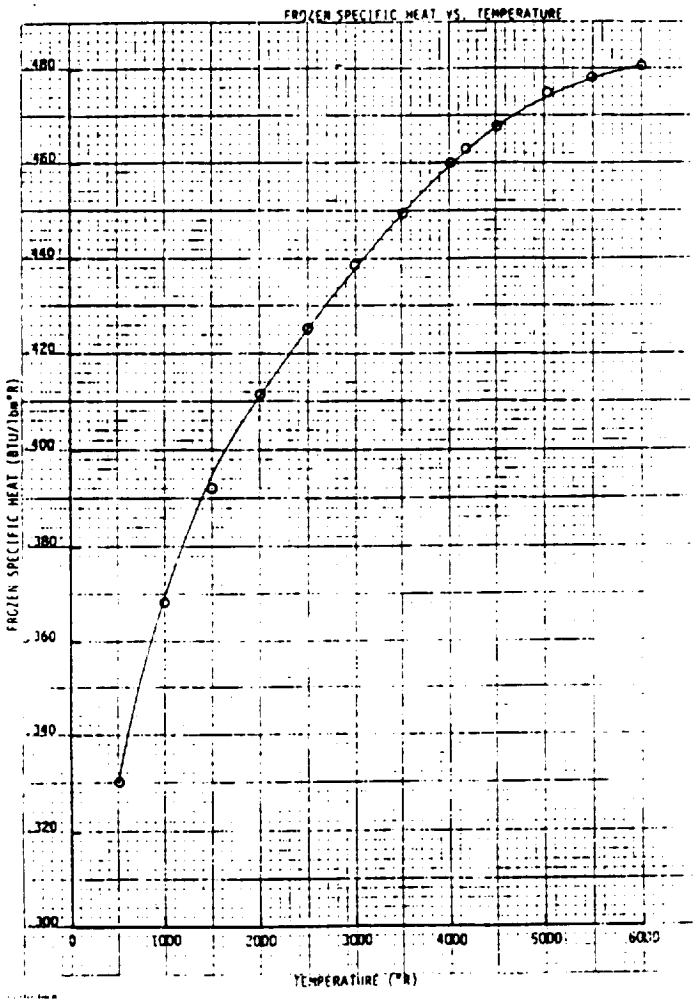


Figure A-3. TP-H1148 Exhaust Gas Frozen Specific Heat Data

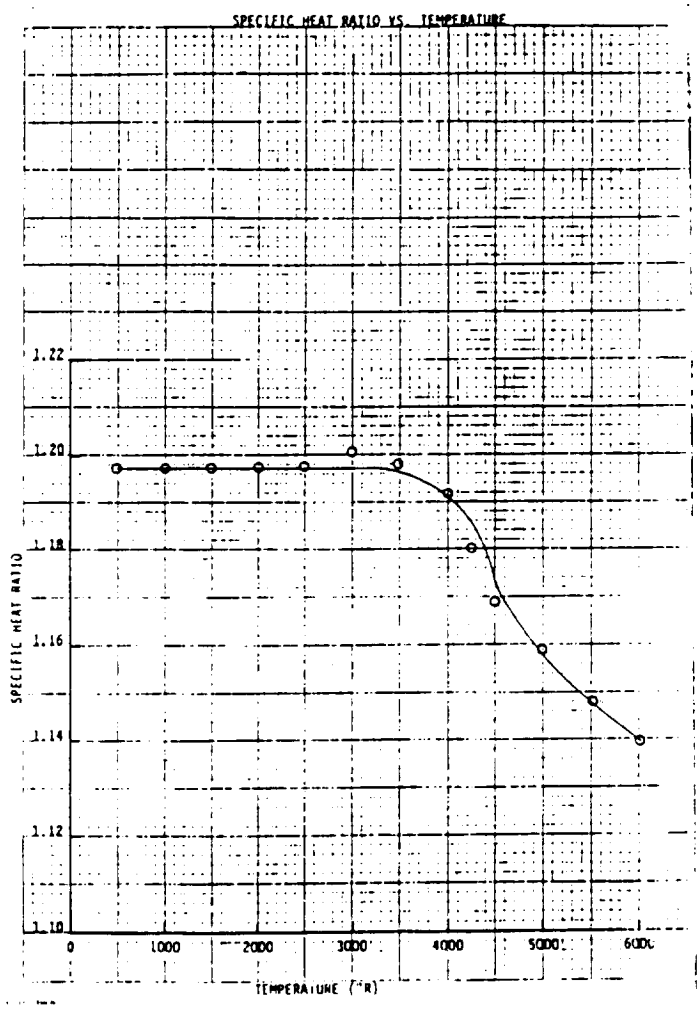


Figure A-4. TP-H1148 Exhaust Gas (c_p/c_v) Data

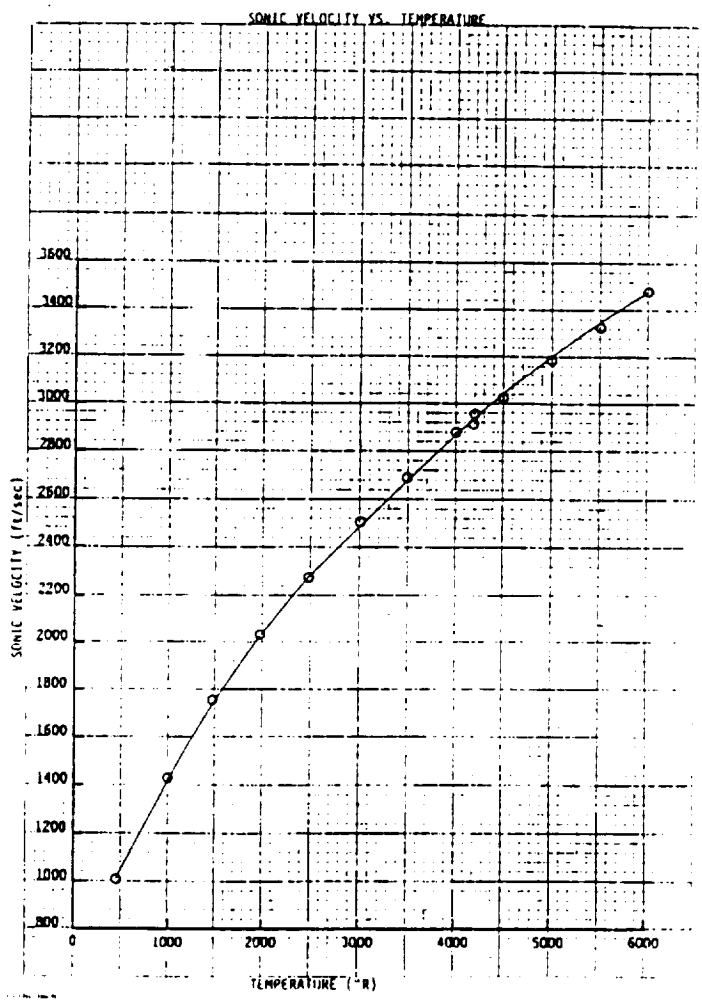


Figure A-5. TP-H1148 Exhaust Gas Velocity Data

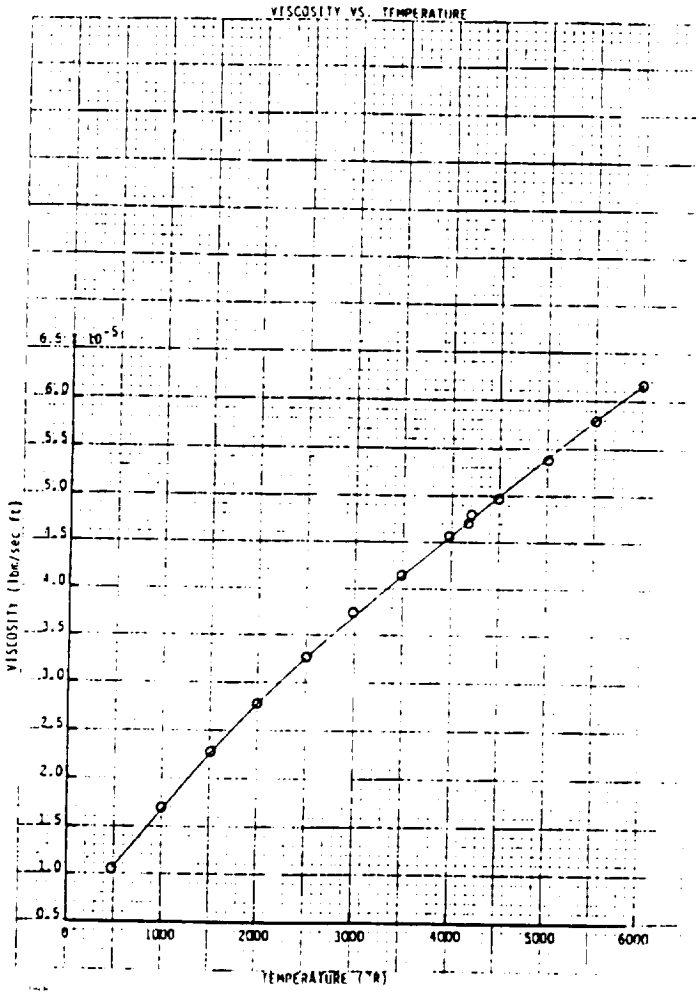


Figure A-6. TP-H1148 Exhaust Gas Viscosity Data

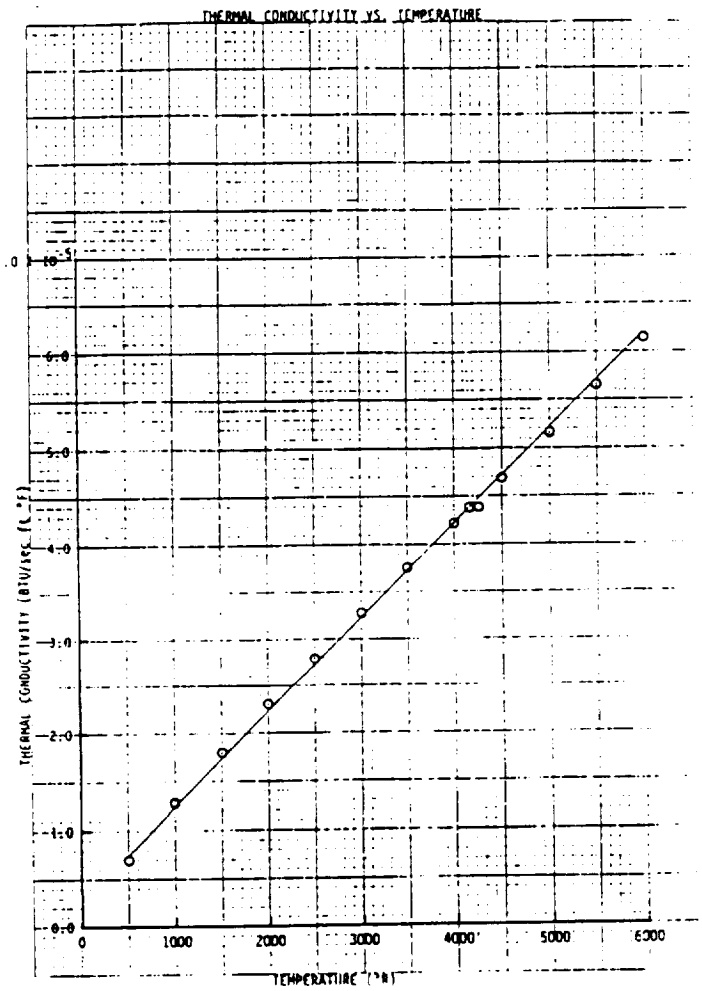


Figure A-7. TP-H1148 Exhaust Gas Thermal Conductivity Data

SAMPLE ACE 1-D GAS EXPANSION INPUT FILE

```
2110200000  -442.8   44.9100                                                W/ AL
  6
  1 HYDROGEN     1.008      3.7176
  6 CARBON       12.011     0.9406
  7 NITROGEN     14.007     0.6263
  8 OXYGEN       16.000     2.4396
 13 ALUMINUM     26.982     0.5930
 17 CHLORINE     35.457     0.5952
  1 13  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-31-65                      AL
 779999+5 134609+5 496502+1 150657-5 131121+5 508439+2   500  30001   -0AL
 779999+5 134609+5 312594+1 351550-3 711361+7 508439+2  3000  60001   -0AL
  1 13  1 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-70                      ALCL
-122999+5 244289+5 891805+1 120132-3-670614+5 750079+2   500  30001   -0ALCL
-122999+5 244289+5 570569+1 770196-3 112924+8 750079+2  3000  60001   -0ALCL
  1  8  1 13  1 17  0  0  0  0  0  0  0  0JANAF 9-30-64                      ALOCL
-831999+5 391989+5 148267+2 227137-4-340874+6 920439+2   500  30001   -0ALOCL
-831999+5 391989+5 149028+2 226154-6-418574+6 920439+2  3000  60001   -0ALOCL
  1 13  2 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-76                      ALCL2
-669999+5 370869+5 138734+2 160949-4-159267+6 100374+3   500  30001   -0ALCL2
-669999+5 370869+5 125438+2 295986-3 425017+7 100374+3  3000  60001   -0ALCL2
  1 13  3 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-70                      ALCL3
-139699+6 528089+5 198357+2 104018-4-287810+6 119441+3   500  30001   -0ALCL3
-139699+6 528089+5 198722+2-586807-7-333436+6 119441+3  3000  60001   -0ALCL3
  1  1  1 13  0  0  0  0  0  0  0  0  0  0JANAF 6-30-63                      ALH
 619999+5 233869+5 848520+1 290683-3-344314+6 638289+2   500  30001   -0ALH
 619999+5 233869+5 893421+1 161058-3-885559+6 638289+2  3000  60001   -0ALH
  1  1  1  8  1 13  0  0  0  0  0  0  0  0JANAF 3-31-64                      HALO
 799999+4 367339+5 142307+2 194411-3-989569+6 803549+2   500  30001   -0HALO
 799999+4 367339+5 148970+2 940074-6-176296+7 803549+2  3000  60001   -0HALO
  1  1  1  8  1 13  0  0  0  0  0  0  0  0JANAF 12-31-67                     ALOH
-429999+5 342169+5 124338+2 661096-3-945888+6 781239+2   500  30001   -0ALOH
-429999+5 342169+5 148035+2 122056-4-475356+7 781239+2  3000  60001   -0ALOH
  1  1  2  8  1 13  0  0  0  0  0  0  0  0JANAF 12-31-68                     ALO2H
-109999+6 480479+5 177228+2 577861-3-949069+6 989729+2   500  30001   -0ALO2H
-109999+6 480479+5 197892+2 101311-4-421799+7 989729+2  3000  60001   -0ALO2H
  1  7  1 13  0  0  0  0  0  0  0  0  0  0JANAF 3-31-67                      ALN
 103999+6 238989+5 886620+1 112887-3-205779+6 703649+2   500  30001   -0ALN
 103999+6 238989+5 894268+1 907595-4-296632+6 703649+2  3000  60001   -0ALN
  1  8  1 13  0  0  0  0  0  0  0  0  0  0JANAF 6-30-75                      ALO
 163999+5 268389+5 879942+1 840987-3-381510+6 733019+2   500  30001   -0ALO
 163999+5 268389+5 103441+2 397942-4 734815+7 733019+2  3000  60001   -0ALO
  2  8  1 13  0  0  0  0  0  0  0  0  0  0JANAF 12-31-75                     ALO2
-448999+5 390949+5 147051+2 892775-4-359395+6 909680+2   500  30001   -0ALO2
-448999+5 390949+5 138529+2 309675-3 135904+7 909680+2  3000  60001   -0ALO2
  2 13  6 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-70                     AL2CL6
-309639+6 116231+6 436560+2 178556-4-617932+6 211224+3   500  30001   -0AL2CL6
-309639+6 116231+6 437197+2-306876-6-700437+6 211224+3  3000  60001   -0AL2CL6
  1  8  2 13  0  0  0  0  0  0  0  0  0  0JANAF 6-30-75                     AL2O
-311999+5 392859+5 148018+2 296756-4-305033+6 941839+2   500  30001   -0AL2O
-311999+5 392859+5 149023+2 202488-6-413765+6 941839+2  3000  60001   -0AL2O
  2  8  2 13  0  0  0  0  0  0  0  0  0  0JANAF 12-31-75                    AL2O2
-103999+6 520269+5 197602+2 326500-4-532649+6 109054+3   500  30001   -0AL2O2
-103999+6 520269+5 198679+2 507231-6-634362+6 109054+3  3000  60001   -0AL2O2
  1  6  0  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-78                      C
 171290+6 135490+5 475422+1 136154-3 477661+5 492859+2  500. 3000.1   0.C
 171290+6 135490+5 526471+1 591146-4-246649+7 492859+2 3000. 6000.1   0.C
  1  6  1 13  0  0  0  0  0  0  0  0  0  0JANAF 6-30-63                      ALC
 164799+6 241579+5 890488+1 118746-3-154083+6 734939+2   500  30001   -0ALC
 164799+6 241579+5 894309+1 107540-3-195424+6 734939+2  3000  60001   -0ALC
  1  6  1 17  0  0  0  0  0  0  0  0  0  0JANAF 12-31-69                     CCL
```

```
 119999+6 240369+5 886319+1 123479-3-167740+6 736239+2   500  30001   -0CCL
 119999+6 240369+5 799088+1 305875-3 275835+7 736239+2  3000  60001   -0CCL
  1  6  1  7  1 17  0  0  0  0  0  0  0  0JANAF 6-30-66                 CLCN
 329699+5 386679+5 139310+2 546534-3-563894+6 876289+2   500  30001   -0CLCN
 329699+5 386679+5 148789+2 275279-3-177143+7 876289+2  3000  60001   -0CLCN
  1  6  1  8  1 17  0  0  0  0  0  0  0  0JANAF 12-31-65                COCL
-149999+5 355119+5 132788+2 179746-3-468979+6 926619+2   500  30001   -0COCL
-149999+5 355119+5 139033+2 904403-6-126068+7 926619+2  3000  60001   -0COCL
  1  6  2 17  0  0  0  0  0  0  0  0  0  0JANAF 12-31-68                CCL2
 569999+5 400499+5 157165+2-576849-4-967723+6 956129+2   500  30001   -0CCL2
 569999+5 400499+5 146617+2-637118-4 868863+7 956129+2  3000  60001   -0CCL2
  1  6  1  8  2 17  0  0  0  0  0  0  0  0JANAF 6-30-61                 COCL2
-525999+5 505949+5 192076+2 189961-3-814729+6 108898+3   500  30001   -0COCL2
-525999+5 505949+5 198672+2 576139-6-163797+7 108898+3  3000  60001   -0COCL2
  1  6  3 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-70                 CCL3
 189999+5 519119+5 197241+2 431230-4-562656+6 113773+3   500  30001   -0CCL3
 189999+5 519119+5 198686+2 417960-6-710006+6 113773+3  3000  60001   -0CCL3
  1  6  4 17  0  0  0  0  0  0  0  0  0  0JANAF 12-31-68                CCL4
-229399+5 677009+5 257013+2 384994-4-673995+6 130035+3   500  30001   -0CCL4
-229399+5 677009+5 258333+2-576306-7-820719+6 130035+3  3000  60001   -0CCL4
  1  1  1  6  0  0  0  0  0  0  0  0  0  0JANAF 12-31-67                 CH
 141999+6 234649+5 770879+1 742295-3-366107+6 622730+2   500  30001   -0CH
 141999+6 234649+5 957141+1 114436-3-177529+6 622730+2  3000  60001   -0CH
  1  1  1  6  1 17  0  0  0  0  0  0  0  0JANAF 12-31-69                CHCL
 800000+5 371449+5 154230+2-202582-3-153304+7 850309+2   500  30001   -0CHCL
 800000+5 371449+5 142262+2-204166-5 382389+7 850309+2  3000  60001   -0CHCL
  1  1  1  6  3 17  0  0  0  0  0  0  0  0JANAF 12-31-68                CHCL3
-246599+5 634159+5 238042+2 557900-3-131324+7 121121+3   500  30001   -0CHCL3
-246599+5 634159+5 257796+2 655418-5-420591+7 121121+3  3000  60001   -0CHCL3
  1  1  1  6  1  7  0  0  0  0  0  0  0  0JANAF 12-31-69                 HCN
 322999+5 348819+5 122242+2 827499-3-780380+6 754299+2   500  30001   -0HCN
 322999+5 348819+5 153475+2 916422-6-657290+7 754299+2  3000  60001   -0HCN
  1  1  1  6  1  7  1  8  0  0  0  0  0  0JANAF 12-31-70                HNCO
-243000+5 462169+5 167336+2 849015-3-114054+7 929410+2   500  30001   -0HNCO
-243000+5 462169+5 197621+2 134322-4-583626+7 929410+2  3000  60001   -0HNCO
  1  1  1  6  1  8  0  0  0  0  0  0  0  0JANAF 12-31-70                 HCO
 103999+5 329069+5 119701+2 588660-3-865359+6 793569+2   500  30001   -0HCO
 103999+5 329069+5 137513+2 988685-4-367160+7 793569+2  3000  60001   -0HCO
  2  1  1  6  0  0  0  0  0  0  0  0  0  0JANAF 12-31-72                 CH2
 923499+5 322429+5 111580+2 865376-3-793202+6 713430+2   500  30001   -0CH2
 923499+5 322429+5 143325+2 261296-5-606953+7 713430+2  3000  60001   -0CH2
  2  1  1  6  2 17  0  0  0  0  0  0  0  0JANAF 12-31-68                CH2CL2
-228299+5 594999+5 219342+2 107013-2-183302+7 110159+3   500  30001   -0CH2CL2
-228299+5 594999+5 257256+2 132132-4-741819+7 110159+3  3000  60001   -0CH2CL2
  2  1  1  6  1  8  0  0  0  0  0  0  0  0JANAF 3-31-61                 CH2O
-276999+5 437909+5 159035+2 110254-2-172990+7 848879+2   500  30001   -0CH2O
-276999+5 437909+5 197832+2 110168-4-717564+7 848879+2  3000  60001   -0CH2O
  3  1  1  6  0  0  0  0  0  0  0  0  0  0JANAF 6-30-69                 CH3
 348199+5 426489+5 144785+2 146135-2-131973+7 785059+2   500  30001   -0CH3
 348199+5 426489+5 196808+2 242331-4-933770+7 785059+2  3000  60001   -0CH3
  3  1  1  6  1 17  0  0  0  0  0  0  0  0JANAF 6-30-72                CH3CL
-199999+5 560019+5 200818+2 157608-2-220583+7 973909+2   500  30001   -0CH3CL
-199999+5 560019+5 256680+2 203427-4-104769+8 973909+2  3000  60001   -0CH3CL
  3  1  1  6  1  7  1  8  0  0  0  0  0  0NIEMCZYK 7-77                HCONH2
-444999+5 105684+6 600508+1 201496-1-109761+6 131424+3  300.  600.1  -0.HCONH2
-444999+5 766186+5 165892+2 790081-2-127429+7 117508+3  600. 1000.1  -0.HCONH2
  4  1  1  6  0  0  0  0  0  0  0  0  0  0JANAF 3-31-61                 CH4
-178949+5 530789+5 183426+2 205381-2-243980+7 825970+2   500  30001   -0CH4
-178949+5 530789+5 256285+2 252135-4-132409+8 825970+2  3000  60001   -0CH4
  4  1  1  6  1  8  0  0  0  0  0  0  0  0NIEMCZYK 7-77                CH3OH
-480999+5 941808+5 513323+1 180190-1 193049+5 121536+3  100.  500.1  -0.CH3OH
-480999+5 759224+5 118369+2 102852-1-689898+6 112834+3  500. 1000.1  -0.CH3OH
  1  6  1  7  0  0  0  0  0  0  0  0  0  0JANAF 6-30-69                  CN
 103999+6 232479+5 706816+1 994584-3-107243+6 669759+2   500  30001   -0CN
```

```
 103999+6 232479+5 126220+2-176667-3-184680+8 669759+2  3000  60001   -0CN
  1  6  1  7  1  8  0  0  0  0  0  0  0  0JANAF 12-31-70                NCO
 380999+5 369719+5 140152+2 254634-3-802338+6 850019+2   500  30001   -0NCO
 380999+5 369719+5 143527+2 110941-3 401765+5 850019+2  3000  60001   -0NCO
  1  6  2  7  0  0  0  0  0  0  0  0  0  0JANAF 6-30-66                 CNN
 139699+6 363729+5 132941+2 442563-3-628614+6 845750+2   500  30001   -0CNN
 139699+6 363729+5 148648+2 471251-5-294282+7 845750+2  3000  60001   -0CNN
  1  6  2  7  0  0  0  0  0  0  0  0  0  0JANAF 12-31-70                NCN
 112999+6 376839+5 143922+2 147751-3-715342+6 844280+2   500  30001   -0NCN
 112999+6 376839+5 143685+2 102651-3 715086+6 844280+2  3000  60001   -0NCN
  1  6  1  8  0  0  0  0  0  0  0  0  0  0JANAF 9-30-65                 CO
-264169+5 223569+5 808732+1 281527-3-332124+6 653699+2   500  30001   -0CO
-264169+5 223569+5 885923+1 582009-4-124951+7 653699+2  3000  60001   -0CO
  1  6  2  8  0  0  0  0  0  0  0  0  0  0JANAF 9-30-65                 CO2
-940539+5 365349+5 135296+2 479823-3-865470+6 798480+2   500  30001   -0CO2
-940539+5 365349+5 144884+2 176547-3-130622+7 798480+2  3000  60001   -0CO2
  2  6  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-31-69                C2
 200223+6 246779+5 789088+1 633093-3 133501+6 685590+2   500  30001   -0C2
 200223+6 246779+5 843360+1 447514-3 259636+6 685590+2  3000  60001   -0C2
  5  1  2  6  1 17  0  0  0  0  0  0  0  0NIEMCZYK 7-77               C2H5CL
-266799+5 128967+6 116530+2 220735-1-290565+6 156283+3  300.  600.1  -0.C2H5CL
-266799+5 126578+6 683101+1 237771-1 107736+7 154435+3  600. 1000.1  -0.C2H5CL
  2  6  2 17  0  0  0  0  0  0  0  0  0  0JANAF 12-31-68               C2CL2
 500999+5 532019+5 199014+2 271742-3-698873+6 108544+3   500  30001   -0C2CL2
 500999+5 532019+5 208490+2 203938-5-194539+7 108544+3  3000  60001   -0C2CL2
  2  6  4 17  0  0  0  0  0  0  0  0  0  0JANAF 9-30-67               C2CL4
-297000+4 818459+5 311781+2 178046-3-118192+7 148902+3   500  30001   -0C2CL4
-297000+4 818459+5 317124+2 148875-4-158505+7 148902+3  3000  60001   -0C2CL4
  2  6  6 17  0  0  0  0  0  0  0  0  0  0JANAF 9-30-67               C2CL6
-320799+5 114604+6 443638+2-298302-3-142167+7 189725+3   500  30001   -0C2CL6
-320799+5 114604+6 432178+2-581721-4 240940+7 189725+3  3000  60001   -0C2CL6
  1  1  2  6  0  0  0  0  0  0  0  0  0  0JANAF 3-31-67                 C2H
 113999+6 356029+5 116307+2 125237-2-574681+6 773270+2   500  30001   -0C2H
 113999+6 356029+5 181256+2-233191-3-189183+8 773270+2  3000  60001   -0C2H
  1  1  2  6  1 17  0  0  0  0  0  0  0  0JANAF 12-31-68               C2HCL
 510999+5 501439+5 182285+2 715469-3-936029+6 977529+2   500  30001   -0C2HCL
 510999+5 501439+5 207770+2 108663-4-484796+7 977529+2  3000  60001   -0C2HCL
  2  1  2  6  0  0  0  0  0  0  0  0  0  0JANAF 3-31-61                 C2H2
 541900+5 482569+5 163735+2 152555-2-117225+7 849689+2   500  30001   -0C2H2
 541900+5 482569+5 206959+2 341577-3-810609+7 849689+2  3000  60001   -0C2H2
  3  1  2  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61               C2H3
 659250+5 562430+5 230065+2 691322-3-499095+7 965150+2  500. 3000.1   0.C2H3
 659250+5 562430+5 239033+2 331771-3-335425+7 965150+2 3000. 5000.1   0.C2H3
  4  1  2  6  0  0  0  0  0  0  0  0  0  0JANAF 9-30-65                 C2H4
 125399+5 674339+5 240524+2 211827-2-291835+7 101424+3   500  30001   -0C2H4
 125399+5 674339+5 315712+2 276043-4-141400+8 101424+3  3000  60001   -0C2H4
  4  1  2  6  1  8  0  0  0  0  0  0  0  0JANAF 9-30-65                C2H4O
-125799+5 813209+5 297487+2 219803-2-361636+7 117209+3   500  30001   -0C2H4O
-125799+5 813209+5 375345+2 274370-4-150829+8 117209+3  3000  60001   -0C2H4O
  6  1  2  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61               C2H6
-203200+5 892710+5 484236+2-169721-2-193680+8 119447+3  500. 3000.1   0.C2H6
-203200+5 892710+5 393119+2 764877-3-383891+7 119447+3 3000. 5000.1   0.C2H6
  2  6  1  7  0  0  0  0  0  0  0  0  0  0JANAF 3-31-67                 C2N
 133000+6 384599+5 146553+2 722952-4-542127+6 866270+2   500  30001   -0C2N
 133000+6 384599+5 145950+2 590928-4 356595+6 866270+2  3000  60001   -0C2N
  2  6  2  7  0  0  0  0  0  0  0  0  0  0JANAF 3-31-61                C2N2
 738699+5 511069+5 189679+2 533418-3-102762+7 985480+2   500  30001   -0C2N2
 738699+5 511069+5 208302+2 453329-5-350879+7 985480+2  3000  60001   -0C2N2
  2  6  1  8  0  0  0  0  0  0  0  0  0  0JANAF 9-30-66                 C2O
 684999+5 386079+5 142061+2 468192-3-780511+6 864460+2   500  30001   -0C2O
 684999+5 386079+5 162297+2-141246-3-253785+7 864460+2  3000  60001   -0C2O
  3  6  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-31-69                C3
 195999+6 309579+5 106821+2 752283-3-557983+6 812359+2   500  30001   -0C3
 195999+6 309579+5 129505+2 166809-3-516560+7 812359+2  3000  60001   -0C3
```

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  3  1  3  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C3H3
 764850+5 709520+5 286929+2 766031-3-548098+7 113604+3  500. 3000.1   0.C3H3
 764850+5 709520+5 291672+2 456238-3-138601+7 113604+3 3000. 5000.1   0.C3H3
  4  1  3  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C3H4
 442940+5 822470+5 372219+2-528861-4-101994+8 120293+3  500. 3000.1   0.C3H4
 442940+5 822470+5 344271+2 578173-3-208515+7 120293+3 3000. 5000.1   0.C3H4
  5  1  3  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C3H5
 324310+5 946210+5 397325+2 958555-3-904683+7 141759+3  500. 3000.1   0.C3H5
 324310+5 946210+5 395073+2 733720-3-949766+6 141759+3 3000. 5000.1   0.C3H5
  3  6  2  8  0  0  0  0  0  0  0  0  0  0JANAF 6-30-68                 C3O2
-223799+5 652989+5 245259+2 649593-3-154570+7 117605+3   500  30001   -0C3O2
-223799+5 652989+5 267877+2 486955-5-449409+7 117605+3  3000  60001   -0C3O2
  4  6  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-31-69                C4
 231999+6 510959+5 194181+2 411017-3-125264+7 948939+2   500  30001   -0C4
 231999+6 510959+5 208450+2 244726-5-306350+7 948939+2  3000  60001   -0C4
  4  1  4  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C4H4
 737050+5 971240+5 398132+2 961427-3-792442+7 139440+3  500. 3000.1   0.C4H4
 737050+5 971240+5 395899+2 720956-3 577880+6 139440+3 3000. 5000.1   0.C4H4
  4  6  2  7  0  0  0  0  0  0  0  0  0  0JANAF 3-31-61                 C4N2
 127499+6 801239+5 298953+2 814914-3-172887+7 133063+3   500  30001   -0C4N2
 127499+6 801239+5 327398+2 621049-5-549402+7 133063+3  3000  60001   -0C4N2
  5  6  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-31-69                C5
 233999+6 653359+5 248817+2 551901-3-169578+7 109128+3   500  30001   -0C5
 233999+6 653359+5 267963+2 382130-5-412893+7 109128+3  3000  60001   -0C5
  6  6  0  0  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C6
 291342+6 772700+5 303965+2 607305-3-475660+7 128958+3  500. 3000.1   0.C6
 291342+6 772700+5 308488+2 643430-4 583350+7 128958+3 3000. 5000.1   0.C6
  6  1  6  6  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C6H6
 197700+5 147317+6 626122+2 117808-2-139277+8 172317+3  500. 3000.1   0.C6H6
 197700+5 147317+6 595572+2 140760-2 737034+7 172317+3 3000. 5000.1   0.C6H6
 12  1  6  6  0  0  0  0  0  0  0  0  0  0NIEMCZYK 7-77                 C6H12
-294299+5 304348+6 244600+2 544248-1-142754+7 276241+3  300.  900.1  -0.C6H12
-294299+5 229289+6 793859+2 102638-1-137241+8 242725+3  900. 1500.1  -0.C6H12
  7  6  0  0  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C7
 292116+6 909770+5 359795+2 669838-3-579638+7 140555+3  500. 3000.1   0.C7
 292116+6 909770+5 355785+2 210202-3 102222+8 140555+3 3000. 5000.1   0.C7
  8  6  0  0  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C8
 344891+6 104684+6 415594+2 733634-3-683462+7 159275+3  500. 3000.1   0.C8
 344891+6 104684+6 402894+2 359448-3 146984+8 159275+3 3000. 5000.1   0.C8
  9  6  0  0  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C9
 340665+6 118391+6 471410+2 796582-3-787328+7 170872+3  500. 3000.1   0.C9
 340665+6 118391+6 450207+2 505033-3 190813+8 170872+3 3000. 5000.1   0.C9
 10  6  0  0  0  0  0  0  0  0  0  0  0  0DUFF BAUER 6/61                C10
 400439+6 132098+6 527202+2 860613-3-891076+7 189592+3  500. 3000.1   0.C10
 400439+6 132098+6 497439+2 651908-3 235109+8 189592+3 3000. 5000.1   0.C10
  1 17  0  0  0  0  0  0  0  0  0  0  0  0JANAF 6-30-72                 CL
 289889+5 140269+5 530429+1-924606-4 637685+5 516209+2   500  30001   -0CL
 289889+5 140269+5 498026+1-147681-5 523459+6 516209+2  3000  60001   -0CL
  1  1  1 17  0  0  0  0  0  0  0  0  0  0JANAF 9-30-64                 HCL
-220629+5 218639+5 744720+1 493509-3-231569+6 623639+2   500  30001   -0HCL
-220629+5 218639+5 889039+1 943852-4-244394+7 623639+2  3000  60001   -0HCL
  1  1  1  8  1 17  0  0  0  0  0  0  0  0JANAF 3-31-79                 HOCL
-177999+5 329780+5 117344+2 582055-3-545546+6 828349+2  500. 3000.1   0.HOCL
-177999+5 329780+5 116669+2 471095-3 305761+7 828349+2 3000. 6000.1   0.HOCL
  1  7  1  8  1 17  0  0  0  0  0  0  0  0JANAF 12-31-72                ONCL
 123599+5 365019+5 132030+2 452651-3-468241+6 921649+2   500  30001   -0ONCL
 123599+5 365019+5 130960+2 437995-3 890661+6 921649+2  3000  60001   -0ONCL
  1  7  2  8  1 17  0  0  0  0  0  0  0  0JANAF 12-31-65                NO2CL
 290000+4 499319+5 191088+2 219635-3-102365+7 105069+3   500  30001   -0NO2CL
 290000+4 499319+5 198643+2 102522-5-192072+7 105069+3  3000  60001   -0NO2CL
  1  8  1 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-61                 CLO
 241919+5 240569+5 888299+1 127572-3-186430+6 740939+2   500  30001   -0CLO
 241919+5 240569+5 894372+1 110077-3-260571+6 740939+2  3000  60001   -0CLO
  2  8  1 17  0  0  0  0  0  0  0  0  0  0JANAF 3-31-61                 CLO2
```

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 249999+5 365779+5 136739+2 243289-3-538722+6 911339+2   500  30001   -0CLO2
 249999+5 365779+5 139074+2 174783-3-790582+6 911339+2  3000  60001   -0CLO2
  2 17  0  0  0  0  0  0  0  0  0  0  0JANAF 9-30-65                    CL2
      0+0 244289+5 880569+1 191785-3-634324+5 737600+2   500  30001   -0CL2
      0+0 244289+5 101178+2-223156-4-609210+7 737600+2  3000  60001   -0CL2
  1  8  2 17  0  0  0  0  0  0  0  0  0JANAF 12-31-65                   CL2O
 209999+5 367229+5 138639+2 136768-4-279167+6 946350+2   500  30001   -0CL2O
 209999+5 367229+5 139100+2 119070-6-327987+6 946350+2  3000  60001   -0CL2O
  1  1  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-77                     H
 521029+5 134229+5 496799+1 000000-0 215212-6 388619+2  500. 3000.1  -0.H
 521029+5 134229+5 496800+1 000000-0-623513-4 388619+2 3000. 6000.1  -0.H
  1  1  1  7  0  0  0  0  0  0  0  0  0JANAF 6-30-77                    NH
 899999+5 218099+5 710740+1 649693-3-157354+6 609410+2  500. 3000.1  -0.NH
 899999+5 218099+5 801875+1 389867-3-134422+7 609410+2 3000. 6000.1  -0.NH
  1  1  1  7  1  8  0  0  0  0  0  0  0JANAF 3-31-63                   HNO
 237999+5 327549+5 119695+2 537664-3-833211+6 783850+2   500  30001   -0HNO
 237999+5 327549+5 138663+2 539053-5-353278+7 783850+2  3000  60001   -0HNO
  1  1  1  7  2  8  0  0  0  0  0  0  0JANAF 6-30-63                   HNO2-C
-183399+5 468799+5 172689+2 705138-3-117299+7 962309+2   500  30001   -0HNO2-C
-183399+5 468799+5 197808+2 112259-4-504517+7 962309+2  3000  60001   -0HNO2-C
  1  1  1  7  2  8  0  0  0  0  0  0  0JANAF 6-30-63                   HNO2-T
-188399+5 468839+5 171983+2 719003-3-111924+7 962879+2   500  30001   -0HNO2-T
-188399+5 468839+5 197715+2 123472-4-519862+7 962879+2  3000  60001   -0HNO2-T
  1  1  1  7  3  8  0  0  0  0  0  0  0JANAF 6-30-63                   HNO3
-320999+5 609120+5 228189+2 819328-3-172706+7 110850+3   500  30001   -0HNO3
-320999+5 609120+5 257308+2 126918-4-615563+7 110850+3  3000  60001   -0HNO3
  1  1  1  8  0  0  0  0  0  0  0  0  0JANAF 6-30-77                    OH
 931799+4 214109+5 696302+1 609272-3-975550+5 613559+2  500. 3000.1  -0.OH
 931799+4 214109+5 870957+1 131643-3-292055+7 613559+2 3000. 6000.1  -0.OH
  1  1  2  8  0  0  0  0  0  0  0  0  0JANAF 9-30-78                   HO2
 499999+3 332089+5 111852+2 100452-2-628452+6 806270+2  500. 3000.1   0.HO2
 499999+3 332089+5 158114+2-166227-3-106542+8 806270+2 3000. 6000.1   0.HO2
  2  1  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-77                    H2
      0+0 212089+5 656932+1 765400-3-137470+5 484659+2  500. 3000.1  -0.H2
      0+0 212089+5 852591+1 278277-3-447076+7 484659+2 3000. 6000.1  -0.H2
  2  1  1  7  0  0  0  0  0  0  0  0  0JANAF 6-30-77                   NH2
 454999+5 310579+5 942154+1 151248-2-521958+6 703739+2  500. 3000.1  -0.NH2
 454999+5 310579+5 164993+2-893848-4-209720+8 703739+2 3000. 6000.1  -0.NH2
  2  1  2  7  0  0  0  0  0  0  0  0  0JANAF 12-31-65                  N2H2-C
 508999+5 437709+5 156544+2 115193-2-154117+7 851030+2   500  30001   -0N2H2-C
 508999+5 437709+5 197427+2 159829-4-766544+7 851030+2  3000  60001   -0N2H2-C
  2  1  1  8  0  0  0  0  0  0  0  0  0JANAF 3-31-79                   H2O
-577949+5 302459+5 941022+1 132433-2-533194+6 684499+2  500. 3000.1   0.H2O
-577949+5 302459+5 136958+2 163815-3-776958+7 684499+2 3000. 6000.1   0.H2O
  2  1  2  8  0  0  0  0  0  0  0  0  0JANAF 12-31-60                  H2O2
-325299+5 447445+5 130278+2 241074-2-418563+6 901209+2   500  10001   -0H2O2
-325299+5 439035+5 140867+2 173487-2-801634+6 897623+2  1000  15001   -0H2O2
  3  1  1  7  0  0  0  0  0  0  0  0  0JANAF 6-30-77                   NH3
-109699+5 418099+5 136323+2 179182-2-134839+7 770309+2  500. 3000.1  -0.NH3
-109699+5 418099+5 215225+2-306997-3-156923+8 770309+2 3000. 6000.1  -0.NH3
  4  1  2  7  0  0  0  0  0  0  0  0  0JANAF 12-31-65                  N2H4
 227899+5 685359+5 239980+2 209617-2-234477+7 108099+3   500  30001   -0N2H4
 227899+5 685359+5 315062+2 355560-4-142821+8 108099+3  3000  60001   -0N2H4
  1  7  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-77                     N
 112974+6 134359+5 491196+1 321849-4 133006+5 480879+2  500. 3000.1  -0.N
 112974+6 134359+5 243846+1 573752-3 765247+7 480879+2 3000. 6000.1  -0.N
  1  7  1  8  0  0  0  0  0  0  0  0  0JANAF 6-30-63                    NO
 215799+5 226999+5 831209+1 226615-3-332452+6 688489+2   500  30001   -0NO
 215799+5 226999+5 893529+1 483657-4-112855+7 688489+2  3000  60001   -0NO
  1  7  2  8  0  0  0  0  0  0  0  0  0JANAF 9-30-64                   NO2
 790999+4 344819+5 131600+2 215749-3-804084+6 847950+2   500  30001   -0NO2
 790999+4 344819+5 139044+2 720659-6-169730+7 847950+2  3000  60001   -0NO2
  1  7  3  8  0  0  0  0  0  0  0  0  0JANAF 12-31-64                   NO3
 169999+5 498219+5 193826+2 142374-3-117716+7 998969+2   500  30001   -0NO3
```

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169999+5 498219+5 198667+2 790840-6-171138+7 998969+2  3000  60001   -0NO3
 2  7  0  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-77                  N2
     0+0 221589+5 793169+1 317727-3-313901+6 637620+2  500. 3000.1  -0.N2
     0+0 221589+5 880163+1 623791-4-124893+7 637620+2 3000. 6000.1  -0.N2
 2  7  1  8  0  0  0  0  0  0  0  0  0  0JANAF 12-31-64                 N2O
196099+5 365529+5 137618+2 322928-3-824997+6 815909+2   500  30001   -0N2O
196099+5 365529+5 148858+2 232427-5-228472+7 815909+2  3000  60001   -0N2O
 2  7  3  8  0  0  0  0  0  0  0  0  0  0JANAF 12-31-64                 N2O3
197999+5 617799+5 235432+2 371736-3-136278+7 123217+3   500  30001   -0N2O3
197999+5 617799+5 248231+2 225890-5-290644+7 123217+3  3000  60001   -0N2O3
 2  7  4  8  0  0  0  0  0  0  0  0  0  0JANAF 9-30-64                  N2O4
217000+4 785969+5 301967+2 459079-3-194385+7 134908+3   500  30001   -0N2O4
217000+4 785969+5 317812+2 182738-5-385850+7 134908+3  3000  60001   -0N2O4
 2  7  5  8  0  0  0  0  0  0  0  0  0  0JANAF 12-31-64                 N2O5
270000+4 915759+5 354580+2 984211-4-169439+7 156719+3   500  30001   -0N2O5
270000+4 915759+5 357466+2 434273-5-175219+7 156719+3  3000  60001   -0N2O5
 3  7  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-31-70                  N3
989999+5 372289+5 141561+2 213893-3-772606+6 839369+2   500  30001   -0N3
989999+5 372289+5 148546+2 868710-5-151836+7 839369+2  3000  60001   -0N3
 1  8  0  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-77                   O
595539+5 135219+5 493024+1 231946-4 375391+5 500939+2  500. 3000.1  -0.O
595539+5 135219+5 449699+1 134471-3 932305+6 500939+2 3000. 6000.1  -0.O
 2  8  0  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-77                  O2
     0+0 234259+5 810351+1 483940-3-246067+6 679629+2  500. 3000.1  -0.O2
     0+0 234259+5 863472+1 323581-3-697247+6 679629+2 3000. 6000.1  -0.O2
 3  8  0  0  0  0  0  0  0  0  0  0  0  0JANAF 6-30-61                  O3
340999+5 360229+5 136204+2 210206-3-639270+6 860920+2   500  30001   -0O3
340999+5 360229+5 139082+2 126252-3-963381+6 860920+2  3000  60001   -0O3
 1 13  0  0  0  0  0  0  0  0  0  0  0  0JANAF 12-65,6-67               AL*
     0+0 328986+5 226022+1 582042-2 325937+6 291707+2   500   9332   3AL*
207199+4 205019+5 758800+1 000000-0-114790-5 259392+2   933  40003   3AL*
 1  8  1 13  1 17  0  0  0  0  0  0  0  0JANAF 3-31-64                 ALOCL*
-189599+6 516427+5 195055+2 252188-3-799723+6 548784+2   500  20002  2ALOCL*
-189599+6 514849+5 203903+2-135854-3-123444+7 548189+2  2000  30002  2ALOCL*
 1 13  3 17  0  0  0  0  0  0  0  0  0  0JANAF 6-30-70                 ALCL3*
-161279+6 810549+5 300000+2 000000-0-198883-5 110588+3   500  10003  1ALCL3*
-161279+6 810549+5 299999+2 000000-0 000000-0 110588+3  1000  15003  1ALCL3*
 1  7  1 13  0  0  0  0  0  0  0  0  0  0JANAF 12-31-62                 ALN*
-759999+5 312367+5 123246+2-477947-4-656239+6 298893+2   500  20002  3ALN*
-759999+5 313049+5 120838+2 794501-4-711146+6 299151+2  2000  30002  3ALN*
 3  8  2 13  0  0  0  0  0  0  0  0  0  0JANAF 6-30-75                 AL2O3-A*
-400499+6 836569+5 295380+2 168122-2-129559+7 783546+2   500  23272  4AL2O3-A*
-383709+6 101606+6 459999+2 000000-0 222822-3 928618+2  2327  40003  4AL2O3-A*
 1  6  0  0  0  0  0  0  0  0  0  0  0  0JANAF 3-31-78                   C*
     0+0 146819+5 543947+1 327572-3-559711+6 122500+2  500. 3000.2  2.C*
     0+0 146819+5 573808+1 240660-3-900570+6 122500+2 3000. 6000.2  2.C*
 3  6  4 13  0  0  0  0  0  0  0  0  0  0JANAF 9-30-65                 AL4C3*
-515499+5 117084+6 419538+2 194794-2-177515+7 114569+3   500  20002  2AL4C3*
-515499+5 116630+6 453636+2 584043-3-450314+7 114398+3  2000  30002  2AL4C3*
 4  1  1  7  1 17  0  0  0  0  0  0  0  0JANAF 9-30-65                 NH4CL*
-751799+5 137240+6 108872+2 239866-1-323895+6 115499+3   500  10002  2NH4CL*
-751799+5 113514+6 315512+2 860337-2-560462+7 105087+3  1000  15002  2NH4CL*
 4  1  1  7  4  8  1 17  0  0  0  0  0  0JANAF 12-31-62                NH4CLO4*
-706899+5 257447+6 253393+2 427791-1-153853+7 216098+3   500  10002  2NH4CLO4*
-706899+5 226287+6 753266+2 134361-1-221828+8 203154+3  1000  15002  2NH4CLO4*

3000100000            -1.0000
3000100000            42.5000
3000100000            42.4000
3000100000            42.3000
3000100000            42.2000
3000100000            42.1000
3000100000            42.0000
3000100000            41.5000
```

3000100000	41.0000
3000100000	40.5000
3000100000	40.0000
3000100000	39.5000
3000100000	39.0000
3000100000	38.5000
3000100000	38.0000
3000100000	37.5000
3000100000	37.0000
3000100000	36.5000
3000100000	36.0000
3000100000	35.0000
3000100000	34.0000
3000100000	33.0000
3000100000	32.0000
3000100000	31.0000
3000100000	30.0000
3000100000	29.0000
3000100000	28.0000
3000100000	27.0000
3000100000	26.0000
3000100000	25.0000
3000100000	20.0000
3000100000	15.0000
3000100000	10.0000
3000100000	5.00000
3000100000	4.00000
3000100000	3.00000
3000100000	2.00000
3000100000	1.75000
3000100000	1.50000
3000100000	1.25000
3000100000	1.00000
3000100000	0.95000
3000100000	0.90000
3000100000	0.85000
3000100000	0.80000
3000100000	0.60000

8

SAMPLE ACE 1-D GAS EXPANSION OUTPUT FILE
(Only Chamber and Throat Solutions Included)

```
1          AEROTHERM CHEMICAL EQUILIBRIUM JOB W/ AL          2110200000
0RELATIVE ELEMENTAL COMPOSITIONS, ATOMIC WTS/UNIT MASS
      HAT.NO.   ELEMENT     ATOMIC WT    COMPONENT 1  COMPONENT 2 COMPONENT 3
         1      HYDROGEN      1.00800     0.0371926    0.0000000    0.0000000
         6      CARBON       12.01100     0.0094102    0.0000000    0.0000000
         7      NITROGEN     14.00700     0.0062658    0.0000000    0.0000000
         8      OXYGEN       16.00000     0.0244069    0.0000000    0.0000000
        13      ALUMINUM     26.98200     0.0059326    0.0000000    0.0000000
        17      CHLORINE     35.45700     0.0059547    0.0000000    0.0000000

     ELEMENT   HYDROGEN    CARBON      NITROGEN    OXYGEN      ALUMINUM    CHLORINE

     BASE SP     ALH         C           ALN         ALOCL       AL          ALCL

1               AEROTHERM CHEMICAL EQUILIBRIUM (ACE) SOLUTION     W/ AL


           CP-FROZEN    CP-EQUIL   DLNM/DLNT   DLNM/DLNP     GAMMA
           0.46994E+00 0.86993E+00-0.30603E+00 0.17224E-01 0.11368E+01

  PROPERTY ROUTINE OUTPUT IN LB-MASS,FT,SEC,BTU,AND DEG-R
    TEMP        VISC        COND        DBAR        PR          SC
  0.61144E+04 0.56501E-04 0.64002E-04 0.29713E-03 0.41487E+00 0.71161E+00
    MU1         MU2        MOL.WT       HTIL       CPTIL       HTIL*
  0.78801E+00 0.20938E+02 0.28325E+02 0.30084E+04 0.80339E+00 0.19289E+04
 ELEMENTAL K AND Z MASS FRACTIONS BY ATOMIC NUMBER . . . .  (GAMEX = 0.667)
      1           6           7           8           13          17
  0.37490E-01 0.11303E+00 0.87765E-01 0.39051E+00 0.16007E+00 0.21113E+00
  0.92962E-01 0.15305E+00 0.11991E+00 0.36396E+00 0.80757E-02 0.26203E+00

          ITERATIONS =   43                        TIME =    0.000 SEC.

   RELATIVE MASSES OF COMPONENTS 1,2 AND 3. 0.10000E+01 0.00000E+00 0.00000E+00
                   MASS CONDENSED/MASS GAS = 0.40367E+00
   TEMP =  6114.3977 DEG R.  =  3396.8876 DEG K.     PRESS =     44.91000 ATM

                                  GAS            CONDENSED       COMPOSITE
  ENTHALPY - BTU/LBM            0.76142E+03     -0.46578E+04     -0.79704E+03
  ENTROPY - BTU/LBM DEG R       0.28298E+01      0.96678E+00      0.22941E+01
  DENSITY - LBM/FT3             0.20294E+00                       0.28486E+00
  MOLECULAR WEIGHT                20.1791         101.9640         28.3248

 CHEMICAL STATE  (MOLE FR. = MOLECULES / TOTAL GAS PHASE MOLECULES).....

     SPECIES   MOLE FR.       SPECIES   MOLE FR.       SPECIES   MOLE FR.       SPECIES   MOLE FR.       SPECIES   MOLE FR.
     AL        0.94010E-04    ALCL      0.40112E-02    ALOCL     0.15139E-02    ALH       0.13633E-04    ALN       0.86876E-
08
     C         0.30708E-08    ALCL2     0.12507E-02    ALCL3     0.15043E-03    HALO      0.40150E-06    ALOH      0.36231E-
03
     ALO2H     0.59961E-03    ALO       0.16880E-03    ALO2      0.30407E-04    AL2CL6    0.17021E-10    AL2O      0.28113E-
04
     AL2O2     0.63685E-05    ALC       0.81193E-11    CCL       0.47394E-09    CLCN      0.27692E-07    COCL      0.10594E-
04
     CCL2      0.56494E-10    COCL2     0.18579E-08    CCL3      0.44374E-13    CCL4      0.13510E-16    CH        0.32027E-
08
     CHCL      0.68127E-09    CHCL3     0.18055E-13    HCN       0.56207E-05    HNCO      0.53655E-06    HCO       0.21803E-
04
     CH2       0.11203E-07    CH2CL2    0.48168E-11    CH2O      0.17087E-05    CH3       0.38080E-07    CH3CL     0.41968E-
09
     HCONH2    0.21329E-09    CH4       0.13490E-07    CH3OH     0.29984E-08    CN        0.12719E-06    NCO       0.43798E-
07
     CNN       0.71320E-12    NCN       0.28515E-10    CO        0.24901E+00    CO2       0.17488E-01    C2        0.24086E-
12
     C2H5CL    0.14941E-14    C2CL2     0.27345E-13    C2CL4     0.20940E-20    C2CL6     0.00000E+00    C2H       0.11961E-
09
     C2HCL     0.79182E-11    C2H2      0.52057E-09    C2H3      0.79865E-12    C2H4      0.42142E-12    C2H4O     0.10954E-
15
     C2H6      0.13862E-15    C2N       0.65226E-11    C2N2      0.28636E-11    C2O       0.12958E-08    C3        0.18944E-
15
     C3H3      0.18762E-15    C3H4      0.10331E-16    C3H5      0.40523E-16    C3O2      0.35935E-11    C4        0.82215E-
22
     C4H4      0.40846E-21    C4N2      0.16082E-20    C5        0.17491E-25    C6        0.00000E+00    C6H6
0.00000E+00
     C6H12     0.00000E+00    C7        0.00000E+00    C8        0.00000E+00    C9        0.00000E+00    C10
0.00000E+00
     CL        0.12815E-01    HCL       0.14730E+00    HOCL      0.78135E-05    ONCL      0.75496E-07    NO2CL     0.48260E-
12
     CLO       0.83611E-05    CLO2      0.10708E-09    CL2       0.24357E-04    CL2O      0.11132E-09    H         0.36218E-
01
     NH        0.28184E-05    HNO       0.11424E-05    HNO2-C    0.10066E-07    HNO2-T    0.11148E-07    HNO3      0.26455E-
12
     OH        0.89790E-02    HO2       0.16395E-05    H2        0.27633E+00    NH2       0.51694E-05    N2H2-C    0.64860E-
09
     H2O       0.15362E+00    H2O2      0.38228E-06    NH3       0.11051E-04    N2H4      0.83582E-12    N         0.58789E-
05
     NO        0.67719E-03    NO2       0.47606E-07    NO3       0.44521E-13    N2        0.88384E-01    N2O       0.78887E-
07
     N2O3      0.69285E-15    N2O4      0.49175E-20    N2O5      0.67448E-24    N3        0.11540E-09    O         0.68443E-
03
     O2        0.14983E-03    O3        0.23617E-10    AL*       0.00000E+00    ALOCL*    0.00000E+00    ALCL3*
0.00000E+00
     ALN*      0.00000E+00    AL2O3-A*  0.79888E-01    C*        0.00000E+00    AL4C3*    0.00000E+00    NH4CL*
0.00000E+00
     NH4CLO4*  0.00000E+00
1          AEROTHERM CHEMICAL EQUILIBRIUM JOB                3000100000

           CP-FROZEN    CP-EQUIL   DLNM/DLNT   DLNM/DLNP     GAMMA
           0.46881E+00 0.80281E+00-0.24626E+00 0.13241E-01 0.11382E+01
```

```
PROPERTY ROUTINE OUTPUT IN LB-MASS,FT,SEC,BTU,AND DEG-R
  TEMP        VISC        COND        DBAR        PR          SC
0.57660E+04 0.54340E-04 0.61012E-04 0.46744E-03 0.41754E+00 0.71137E+00
   MU1         MU2        MOL.WT       HTIL        CPTIL       HTIL*
0.78944E+00 0.20975E+02 0.28547E+02 0.25459E+04 0.79622E+00 0.15863E+04
ELEMENTAL K AND Z MASS FRACTIONS BY ATOMIC NUMBER . ... . (GAMEX = 0.667)
     1           6           7           8          13          17
0.37490E-01 0.11303E+00 0.87765E-01 0.39051E+00 0.16007E+00 0.21113E+00
0.93218E-01 0.15400E+00 0.12068E+00 0.36238E+00 0.50599E-02 0.26467E+00

        ITERATIONS =    7                        TIME =    0.000 SEC.

 RELATIVE MASSES OF COMPONENTS 1,2 AND 3. 0.10000E+01 0.00000E+00 0.00000E+00
                 MASS CONDENSED/MASS GAS = 0.41472E+00
 TEMP =  5765.9994 DEG R.  =  3203.3330 DEG K.     PRESS =     25.90009 ATM

                                GAS          CONDENSED       COMPOSITE
 ENTHALPY - BTU/LBM           0.54614E+03   -0.48149E+04    -0.10254E+04
 ENTROPY - BTU/LBM DEG R      0.28555E+01    0.94032E+00     0.22941E+01
 DENSITY - LBM/FT3            0.12411E+00                    0.17558E+00
 MOLECULAR WEIGHT               20.1785       101.9640        28.5470

ABOVE ARE STATIC PROPERTIES                H-KINETIC =  0.22841E+03 BTU/LBM
 VEL. =   0.3381E+04 FT/SEC   FLUX =  0.59370E+03 LBM/FT2SEC   MACH =   1.00005

CHEMICAL STATE  (MOLE FR. = MOLECULES / TOTAL GAS PHASE MOLECULES).....

    SPECIES   MOLE FR.       SPECIES   MOLE FR.       SPECIES   MOLE FR.       SPECIES   MOLE FR.       SPECIES   MOLE FR.
    AL        0.41122E-04    ALCL      0.25445E-02    ALOCL     0.10098E-02    ALH       0.53070E-05    ALN       0.23117E-
08
    C         0.89079E-09    ALCL2     0.82329E-03    ALCL3     0.11705E-03    HALO      0.14316E-06    ALOH      0.20879E-
03
    ALO2H     0.35434E-03    ALO       0.72202E-04    ALO2      0.12897E-04    AL2CL6    0.70094E-11    AL2O      0.94564E-
05
    AL2O2     0.23370E-05    ALC       0.13017E-11    CCL       0.14132E-09    CLCN      0.13234E-07    COCL      0.60891E-
05
    CCL2      0.18200E-10    COCL2     0.92724E-09    CCL3      0.12872E-13    CCL4      0.35148E-17    CH        0.93061E-
09
    CHCL      0.21726E-09    CHCL3     0.58682E-14    HCN       0.33140E-05    HNCO      0.30266E-06    HCO       0.12088E-
04
    CH2       0.39620E-08    CH2CL2    0.18883E-11    CH2O      0.10161E-05    CH3       0.17277E-07    CH3CL     0.19593E-
09
    HCONH2    0.75278E-10    CH4       0.75091E-08    CH3OH     0.10918E-08    CN        0.51977E-07    NCO       0.18218E-
07
    CNN       0.15864E-12    NCN       0.79575E-11    CO        0.25056E+00    CO2       0.18045E-01    C2        0.42784E-
13
    C2H5CL    0.21808E-15    C2CL2     0.72885E-14    C2CL4     0.35074E-21    C2CL6     0.00000E+00    C2H       0.35028E-
10
    C2HCL     0.25448E-11    C2H2      0.19542E-09    C2H3      0.21222E-12    C2H4      0.13726E-12    C2H4O     0.25077E-
16
    C2H6      0.35184E-16    C2N       0.15730E-11    C2N2      0.87919E-12    C2O       0.42027E-09    C3        0.29081E-
16
    C3H3      0.34741E-16    C3H4      0.19381E-17    C3H5      0.63560E-17    C3O2      0.11527E-11    C4        0.66403E-
23
    C4H4      0.45031E-22    C4N2      0.17987E-21    C5        0.10674E-26    C6        0.00000E+00    C6H6
0.00000E+00
    C6H12     0.00000E+00    C7        0.00000E+00    C8        0.00000E+00    C9        0.00000E+00    C10
0.00000E+00
    CL        0.10757E-01    HCL       0.15363E+00    HOCL      0.45305E-05    ONCL      0.32274E-07    NO2CL     0.12682E-
12
    CLO       0.42755E-05    CLO2      0.30955E-10    CL2       0.17207E-04    CL2O      0.37249E-10    H         0.29396E-
01
    NH        0.12745E-05    HNO       0.54063E-06    HNO2-C    0.38922E-08    HNO2-T    0.43300E-08    HNO3      0.64872E-
13
    OH        0.63598E-02    HO2       0.71969E-06    H2        0.28142E+00    NH2       0.26972E-05    N2H2-C    0.24213E-
09
    H2O       0.15445E+00    H2O2      0.17235E-06    NH3       0.73090E-05    N2H4      0.22697E-12    N         0.27654E-
05
    NO        0.42457E-03    NO2       0.19353E-07    NO3       0.92427E-14    N2        0.89213E-01    N2O       0.37340E-
07
    N2O3      0.10608E-15    N2O4      0.48079E-21    N2O5      0.37311E-25    N3        0.35213E-10    O         0.39307E-
03
    O2        0.85609E-04    O3        0.56657E-11    AL*       0.00000E+00    ALOCL*    0.00000E+00    ALCL3*
0.00000E+00
    ALN*      0.00000E+00    AL2O3-A*  0.82073E-01    C*        0.00000E+00    AL4C3*    0.00000E+00    NH4CL*
0.00000E+00
    NH4CLO4*  0.00000E+00
```

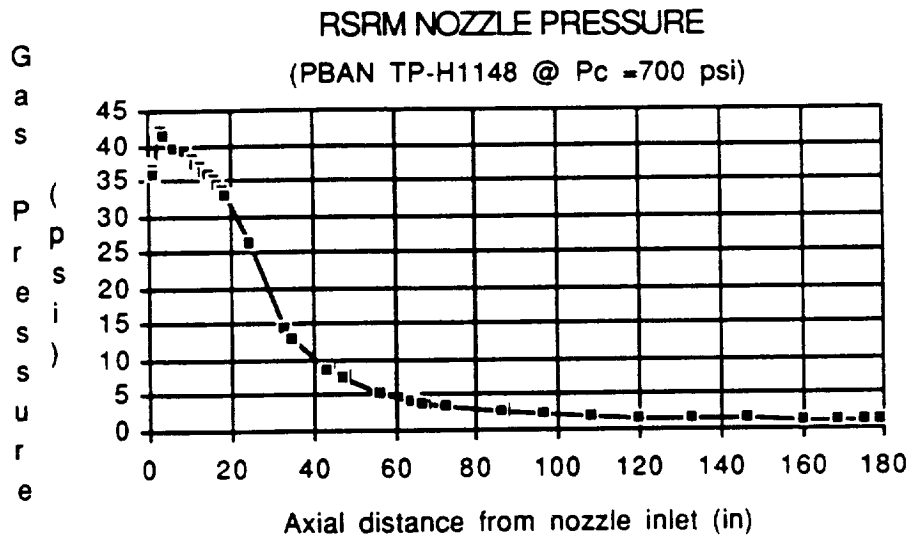

Figure A-1. RSRM Nozzle Gas Pressure Profile

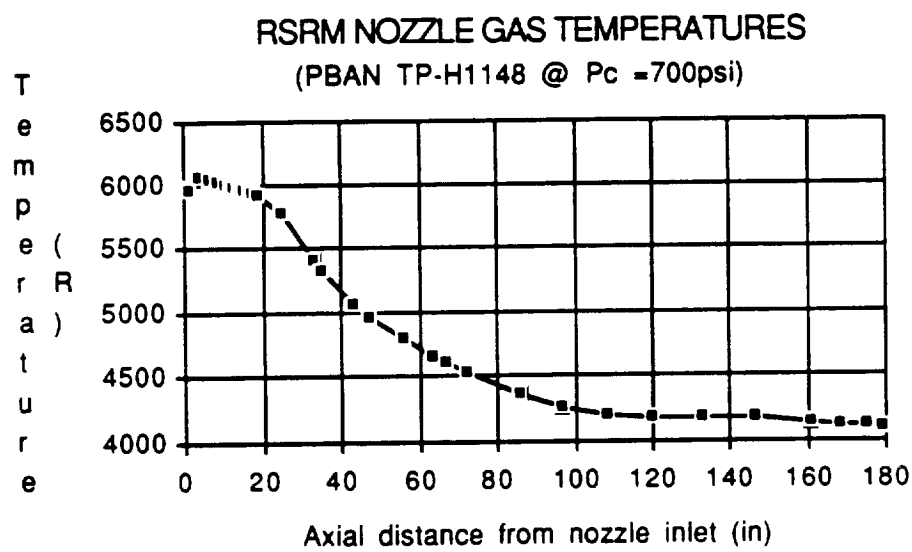

Figure A-2. RSRM Nozzle Gas Temperature Profile

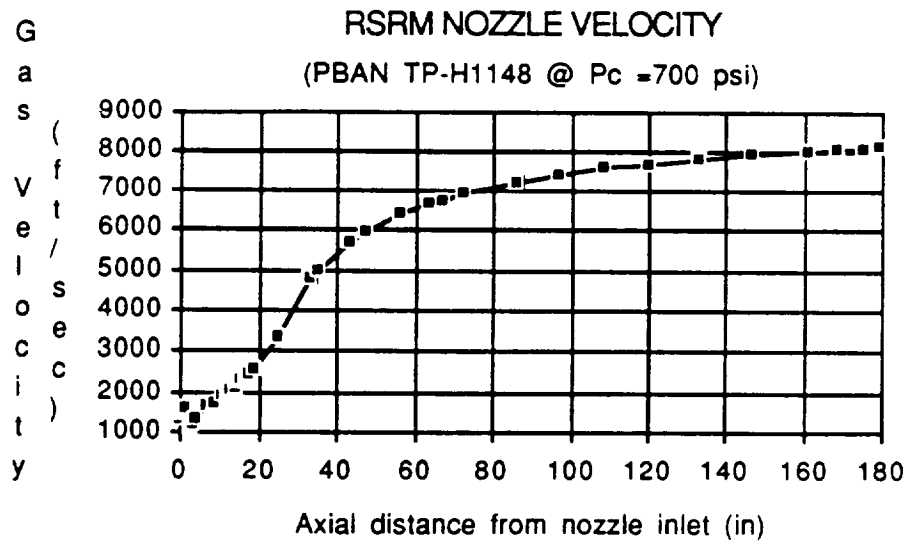

Figure A-3. RSRM Nozzle Velocity Profile

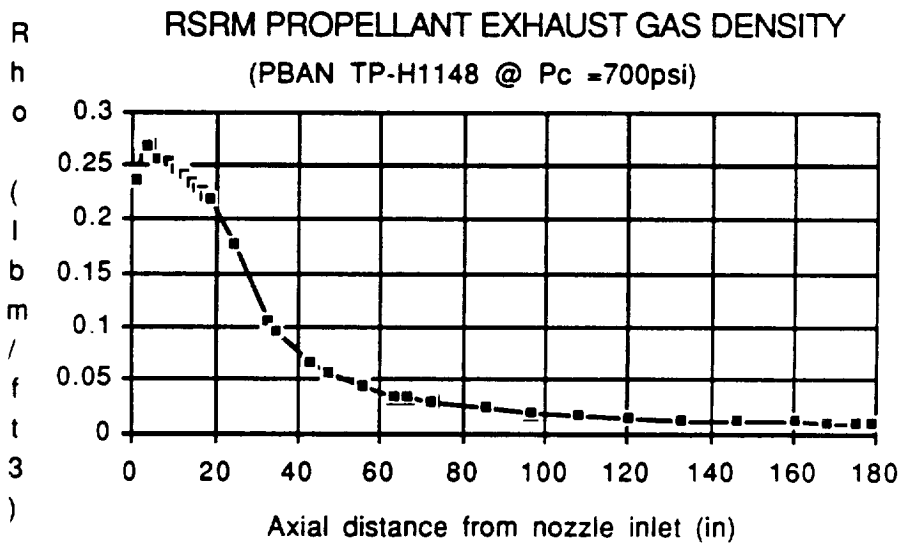

Figure A-4. RSRM Exhaust Gas Density Profile

SAMPLE MEIT INPUT FILE FOR RSRM NOZZLE AEROTHERMAL ANALYSIS

```
 1   1      0.701      1.138      0.00       42.705
                                             2.00
60 1 7 1
1     0.000     41.820     37.027    672.123  1401.972  5969.698     0.000     1.000
1     0.001     40.952     36.690    668.299  1462.033  5963.516     0.000     1.000
1     0.509     39.287     35.978    660.238  1588.620  5950.486     0.000     1.000
1     1.009     38.079     42.461    739.245  1095.079  6078.210     0.000     1.000
1     1.509     37.104     42.169    736.524  1160.432  6073.694     0.000     1.000
1     2.009     36.282     41.882    733.792  1221.044  6069.350     0.000     1.000
1     2.509     35.573     41.604    731.173  1277.885  6065.449     0.000     1.000
1     3.009     34.950     41.328    728.547  1331.708  6061.246     0.000     1.000
1     3.509     34.394     41.059    725.963  1382.856  6056.938     0.000     1.000
1     4.009     33.895     40.790    723.386  1432.179  6052.644     0.000     1.000
1     4.509     33.441     40.531    720.898  1479.346  6048.497     0.000     1.000
1     5.009     33.027     40.264    718.286  1525.608  6044.223     0.000     1.000
1     5.564     32.606     39.976    715.462  1574.896  6039.620     0.000     1.000
1    12.595     28.093     33.611    647.344  2472.282  5929.602     0.000     1.000
1    22.286     26.930     26.085    548.938  3360.181  5770.049     0.000     1.000
1    23.339     26.930     25.000    532.500  3484.000  5744.000     0.000     1.000
1    29.412     28.378     17.063    383.374  4436.846  5502.629     0.000     1.000
1    30.185     28.625     16.280    366.381  4535.205  5475.063     0.000     1.000
1    32.455     29.684     13.872    304.910  4861.294  5374.977     0.000     1.000
1    37.839     32.169     10.116    192.663  5412.008  5191.656     0.000     1.000
1    40.769     33.535      8.940    137.625  5641.069  5098.627     0.000     1.000
1    41.262     33.790      8.743    128.050  5680.439  5082.407     0.000     1.000
1    42.339     34.285      8.373    110.066  5754.386  5051.941     0.000     1.000
1    45.339     35.653      7.429     64.155  5943.167  4974.164     0.000     1.000
1    51.339     38.318      5.872    -11.591  6254.619  4845.845     0.000     1.000
1    57.339     40.874      4.734    -73.842  6501.978  4739.109     0.000     1.000
1    58.492     41.545      4.515    -90.129  6561.875  4710.472     0.000     1.000
1    60.339     42.110      4.339   -103.243  6610.108  4687.412     0.000     1.000
1    61.492     42.766      4.143   -117.833  6663.767  4661.758     0.000     1.000
1    62.339     43.032      4.067   -123.544  6684.773  4651.714     0.000     1.000
1    64.492     43.959      3.829   -144.427  6758.830  4614.400     0.000     1.000
1    70.492     46.272      3.312   -192.490  6927.308  4528.094     0.000     1.000
1    76.492     48.485      2.899   -234.139  7071.129  4452.403     0.000     1.000
1    82.492     50.605      2.583   -273.488  7202.294  4378.939     0.000     1.000
1    88.492     52.639      2.316   -306.836  7313.454  4316.679     0.000     1.000
1    94.492     54.588      2.088   -335.364  7408.548  4263.417     0.000     1.000
1   100.492     56.460      1.905   -356.813  7493.755  4222.432     0.000     1.000
1   106.254     58.257      1.756   -373.256  7570.012  4190.260     0.000     1.000
1   112.492     59.983      1.643   -372.743  7634.698  4189.000     0.000     1.000
1   118.492     61.642      1.544   -371.674  7691.730  4189.000     0.000     1.000
1   121.492     62.446      1.499   -371.182  7717.858  4189.000     0.000     1.000
1   124.492     63.236      1.457   -370.617  7745.471  4189.000     0.000     1.000
1   127.492     64.009      1.418   -370.083  7771.539  4189.000     0.000     1.000
1   130.492     64.769      1.381   -369.578  7796.216  4189.000     0.000     1.000
1   133.492     65.513      1.345   -369.099  7819.593  4189.000     0.000     1.000
1   136.492     66.243      1.312   -368.645  7841.738  4189.000     0.000     1.000
1   139.492     66.957      1.281   -368.215  7862.745  4189.000     0.000     1.000
1   142.492     67.659      1.250   -367.806  7882.711  4189.000     0.000     1.000
1   145.492     68.348      1.220   -372.218  7906.829  4180.259     0.000     1.000
1   148.492     69.022      1.191   -376.487  7929.850  4171.814     0.000     1.000
1   151.492     69.684      1.164   -380.551  7951.766  4163.774     0.000     1.000
1   154.492     70.281      1.139   -384.117  7970.999  4156.719     0.000     1.000
1   157.492     70.970      1.112   -388.131  7992.646  4148.778     0.000     1.000
1   160.492     71.594      1.088   -391.662  8011.685  4141.794     0.000     1.000
1   163.492     72.206      1.065   -395.033  8029.866  4135.125     0.000     1.000
1   166.492     72.807      1.044   -398.261  8047.276  4128.738     0.000     1.000
1   169.492     73.394      1.023   -401.343  8063.897  4122.641     0.000     1.000
```

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1  172.492    73.965     1.003  -404.271  8079.688  4116.848     0.000     1.000
1  174.037    74.532     0.983  -410.195  8097.112  4105.353     0.000     1.000
1  177.492    74.822     0.973  -413.462  8106.095  4099.024     0.000     1.000
  7  7  1
1.0
-0.14888E+04 0.18000E+04 0.20561E+02 0.66954E+00-0.14718E+00 0.25277E-04  0.4121
-0.10712E+04 0.27000E+04 0.20447E+02 0.44140E+00-0.15658E-03 0.32965E-04  0.4284
-0.66611E+03 0.36000E+04 0.20433E+02 0.47158E+00-0.90322E-02 0.39822E-04  0.4331
-0.16210E+03 0.45000E+04 0.20236E+02 0.71596E+00-0.11536E+00 0.46125E-04  0.4299
 0.84685E+03 0.54000E+04 0.19125E+02 0.17238E+01-0.62406E+00 0.52033E-04  0.4083
 0.33081E+04 0.63000E+04 0.16108E+02 0.37450E+01-0.16028E+01 0.57482E-04  0.3550
 0.67555E+04 0.72000E+04 0.13023E+02 0.32851E+01-0.12897E+01 0.62176E-04  0.3087
5.0
-0.16194E+04 0.18000E+04 0.21698E+02 0.15797E+01-0.84843E+00 0.25352E-04  0.4396
-0.10713E+04 0.27000E+04 0.20447E+02 0.44137E+00-0.34918E-03 0.32965E-04  0.4285
-0.66961E+03 0.36000E+04 0.20441E+02 0.45824E+00-0.40570E-02 0.39822E-04  0.4332
-0.21844E+03 0.45000E+04 0.20352E+02 0.57471E+00-0.51869E-01 0.46121E-04  0.4323
 0.46277E+03 0.54000E+04 0.19838E+02 0.10235E+01-0.28473E+00 0.52019E-04  0.4219
 0.18300E+04 0.63000E+04 0.18214E+02 0.21392E+01-0.90992E+00 0.57590E-04  0.3912
 0.43421E+04 0.72000E+04 0.15411E+02 0.32671E+01-0.14944E+01 0.62687E-04  0.3438
10.0
-0.17235E+04 0.18000E+04 0.22699E+02 0.16902E+01-0.97821E+00 0.25399E-04  0.4650
-0.10714E+04 0.27000E+04 0.20448E+02 0.44193E+00-0.10478E-02 0.32965E-04  0.4285
-0.67044E+03 0.36000E+04 0.20443E+02 0.45509E+00-0.28979E-02 0.39822E-04  0.4333
-0.23179E+03 0.45000E+04 0.20380E+02 0.54129E+00-0.36730E-01 0.46120E-04  0.4328
 0.37277E+03 0.54000E+04 0.20014E+02 0.86092E+00-0.20215E+00 0.52014E-04  0.4253
 0.14629E+04 0.63000E+04 0.18823E+02 0.16599E+01-0.66656E+00 0.57595E-04  0.4021
 0.34688E+04 0.72000E+04 0.16492E+02 0.27585E+01-0.12961E+01 0.62801E-04  0.3612
20.0
-0.18346E+04 0.18000E+04 0.23827E+02 0.17238E+01-0.97867E+00 0.25427E-04  0.4926
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 0.30940E+03 0.54000E+04 0.20139E+02 0.74700E+00-0.14334E+00 0.52009E-04  0.4277
 0.12037E+04 0.63000E+04 0.19277E+02 0.13121E+01-0.48019E+00 0.57591E-04  0.4104
 0.27851E+04 0.72000E+04 0.17445E+02 0.22229E+01-0.10397E+01 0.62861E-04  0.3772
40.0
-0.19245E+04 0.18000E+04 0.24843E+02 0.14038E+01-0.78609E+00 0.25438E-04  0.5201
-0.10732E+04 0.27000E+04 0.20464E+02 0.45345E+00-0.13926E-01 0.32967E-04  0.4289
-0.67150E+03 0.36000E+04 0.20446E+02 0.45137E+00-0.16658E-02 0.39822E-04  0.4333
-0.24791E+03 0.45000E+04 0.20414E+02 0.50100E+00-0.18436E-01 0.46118E-04  0.4335
 0.26472E+03 0.54000E+04 0.20229E+02 0.66700E+00-0.10155E+00 0.52006E-04  0.4294
 0.10217E+04 0.63000E+04 0.19610E+02 0.10657E+01-0.34291E+00 0.57584E-04  0.4166
 0.22771E+04 0.72000E+04 0.18223E+02 0.17616E+01-0.79222E+00 0.62885E-04  0.3907
60.0
-0.19668E+04 0.18000E+04 0.25360E+02 0.12432E+01-0.67862E+00 0.25441E-04  0.5353
-0.10754E+04 0.27000E+04 0.20484E+02 0.46801E+00-0.30014E-01 0.32969E-04  0.4295
-0.67173E+03 0.36000E+04 0.20447E+02 0.45077E+00-0.15949E-02 0.39822E-04  0.4334
-0.25088E+03 0.45000E+04 0.20420E+02 0.49362E+00-0.15095E-01 0.46118E-04  0.4337
 0.24497E+03 0.54000E+04 0.20269E+02 0.63171E+00-0.82984E-01 0.52005E-04  0.4302
 0.94154E+03 0.63000E+04 0.19760E+02 0.95716E+00-0.28097E+00 0.57580E-04  0.4194
 0.20479E+04 0.72000E+04 0.18596E+02 0.15391E+01-0.66508E+00 0.62889E-04  0.3973
75.0
-0.19872E+04 0.18000E+04 0.25620E+02 0.11639E+01-0.62292E+00 0.25441E-04  0.5433
-0.10776E+04 0.27000E+04 0.20502E+02 0.48194E+00-0.45382E-01 0.32971E-04  0.4300
-0.67185E+03 0.36000E+04 0.20448E+02 0.45055E+00-0.16459E-02 0.39822E-04  0.4334
-0.25227E+03 0.45000E+04 0.20423E+02 0.49016E+00-0.13538E-01 0.46118E-04  0.4338
 0.23569E+03 0.54000E+04 0.20288E+02 0.61517E+00-0.74255E-01 0.52004E-04  0.4306
 0.90400E+03 0.63000E+04 0.19831E+02 0.90637E+00-0.25166E+00 0.57578E-04  0.4207
 0.19397E+04 0.72000E+04 0.18777E+02 0.14316E+01-0.60188E+00 0.62890E-04  0.4005
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SAMPLE MEIT OUTPUT FILE FOR RSRM NOZZLE AEROTHERMAL ANALYSIS

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MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)


NUMBER OF MATERIALS =   1
CM/CH =    0.70100
ISENTROPIC EXPONENT =    1.13800
THE INITIAL SOLUTION IS THE STAGNATION SOLUTION OF A SPHERE WITH A RADIUS OF  42.705INCHES


MATL            BTS             BTH             BLS             BLH
  1             0.35000         0.35000         0.50000         0.50000


NS = 60
IBRUPT =  1
NREYCR =  7
IPRNT =  1
DLTRAN =    0.00000  INCHES


ABRUPT TRANSITION

FLOW IS TURBULENT
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MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

THERMODYNAMIC TABLE
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PRESSURE = 1.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1488.8000	1800.0000	20.5610	0.000025	0.4121
-1071.2000	2700.0000	20.4470	0.000033	0.4284
-666.1100	3600.0000	20.4330	0.000040	0.4331
-162.1000	4500.0000	20.2360	0.000046	0.4299
846.8500	5400.0000	19.1250	0.000052	0.4083
3308.1000	6300.0000	16.1080	0.000057	0.3550
6755.5000	7200.0000	13.0230	0.000062	0.3087

PRESSURE = 5.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1619.4000	1800.0000	21.6980	0.000025	0.4396
-1071.3000	2700.0000	20.4470	0.000033	0.4285
-669.6100	3600.0000	20.4410	0.000040	0.4332
-218.4400	4500.0000	20.3520	0.000046	0.4323
462.7700	5400.0000	19.8380	0.000052	0.4219
1830.0000	6300.0000	18.2140	0.000058	0.3912
4342.1000	7200.0000	15.4110	0.000063	0.3438

PRESSURE = 10.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1723.5000	1800.0000	22.6990	0.000025	0.4650
-1071.4000	2700.0000	20.4480	0.000033	0.4285
-670.4400	3600.0000	20.4430	0.000040	0.4333
-231.7900	4500.0000	20.3800	0.000046	0.4328
372.7700	5400.0000	20.0140	0.000052	0.4253
1462.9000	6300.0000	18.8230	0.000058	0.4021
3468.8000	7200.0000	16.4920	0.000063	0.3612

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

PRESSURE = 20.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1834.6000	1800.0000	23.8270	0.000025	0.4926
-1071.8000	2700.0000	20.4520	0.000033	0.4286
-671.0500	3600.0000	20.4440	0.000040	0.4333
-241.2300	4500.0000	20.3990	0.000046	0.4332
309.4000	5400.0000	20.1390	0.000052	0.4277
1203.7000	6300.0000	19.2770	0.000058	0.4104
2785.1000	7200.0000	17.4450	0.000063	0.3772

PRESSURE = 40.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1924.5000	1800.0000	24.8430	0.000025	0.5201
-1073.2000	2700.0000	20.4640	0.000033	0.4289
-671.5000	3600.0000	20.4460	0.000040	0.4333
-247.9100	4500.0000	20.4140	0.000046	0.4335
264.7200	5400.0000	20.2290	0.000052	0.4294
1021.7000	6300.0000	19.6100	0.000058	0.4166
2277.1000	7200.0000	18.2230	0.000063	0.3907

PRESSURE = 60.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1966.8000	1800.0000	25.3600	0.000025	0.5353
-1075.4000	2700.0000	20.4840	0.000033	0.4295
-671.7300	3600.0000	20.4470	0.000040	0.4334
-250.8800	4500.0000	20.4200	0.000046	0.4337
244.9700	5400.0000	20.2690	0.000052	0.4302
941.5400	6300.0000	19.7600	0.000058	0.4194
2047.9000	7200.0000	18.5960	0.000063	0.3973

PRESSURE = 75.000ATM

ENTHALPY (BTU/LBM)	TEMPERATURE (DEG R)	MOLECULAR WEIGHT	VISCOSITY (LB/SEC-FT)	PRANDTL NUMBER
-1987.2000	1800.0000	25.6200	0.000025	0.5433
-1077.6000	2700.0000	20.5020	0.000033	0.4300
-671.8500	3600.0000	20.4480	0.000040	0.4334
-252.2700	4500.0000	20.4230	0.000046	0.4338
235.6900	5400.0000	20.2880	0.000052	0.4306
904.0000	6300.0000	19.8310	0.000058	0.4207
1939.7000	7200.0000	18.7770	0.000063	0.4005

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

GENERAL INPUT INFORMATION
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BODY PT NO VELOCITY FT/SEC (J) (UE)	INTEG PT NO (I)	MATL NO (MATL)	STREAM LENGTH INCH (S)	AXIAL LENGTH INCH (Z)	RADIAL LENGTH INCH (R)	BODY ANGLE DEG (THETB)	NORMALIZED ABLATION RATE (BP)	WALL TEMP DEG R (TW)	SURFACE ROUGHNESS MIL (RUFMIL)	---EDGE CONDITION--- PRESSURE ATM (PE)	ENTHALPY BTU/LBM (HE)
1 1401.97	1	1	0.00	0.000	41.820	-89.934	0.000	5969.70	2.000	37.03	672.12
2 1462.03	7	1	0.87	0.001	40.952	-78.638	0.000	5963.52	2.000	36.69	668.30
3 1588.62	9	1	2.61	0.509	39.287	-70.666	0.000	5950.49	2.000	35.98	660.24
4 1095.08	11	1	3.92	1.009	38.079	-65.388	0.000	6078.21	2.000	42.46	739.25
5 1160.43	13	1	5.01	1.509	37.104	-60.905	0.000	6073.69	2.000	42.17	736.52
6 1221.04	15	1	5.97	2.009	36.282	-56.849	0.000	6069.35	2.000	41.88	733.79
7 1277.88	17	1	6.84	2.509	35.573	-53.103	0.000	6065.45	2.000	41.60	731.17
8 1331.71	19	1	7.64	3.009	34.950	-49.696	0.000	6061.25	2.000	41.33	728.55
9 1382.86	21	1	8.39	3.509	34.394	-46.533	0.000	6056.94	2.000	41.06	725.96
10 1432.18	23	1	9.09	4.009	33.895	-43.621	0.000	6052.64	2.000	40.79	723.39
11 1479.35	25	1	9.77	4.509	33.441	-40.958	0.000	6048.50	2.000	40.53	720.90
12 1525.61	27	1	10.42	5.009	33.027	-38.361	0.000	6044.22	2.000	40.26	718.29
13 1574.90	29	1	11.12	5.564	32.606	-33.040	0.000	6039.62	2.000	39.98	715.46
14 2472.28	33	1	19.47	12.595	28.093	-18.749	0.000	5929.60	2.000	33.61	647.34
15 3360.18	38	1	29.23	22.286	26.930	-6.178	0.000	5770.05	2.000	26.08	548.94
16 3484.00	40	1	30.28	23.339	26.930	11.486	0.000	5744.00	2.000	25.00	532.50
17 4436.85	43	1	36.53	29.412	28.378	13.906	0.000	5502.63	2.000	17.06	383.37
18 4535.21	45	1	37.34	30.185	28.625	23.228	0.000	5475.06	2.000	16.28	366.38
19 4861.29	47	1	39.84	32.455	29.684	24.845	0.000	5374.98	2.000	13.87	304.91
20 5412.01	50	1	45.77	37.839	32.169	24.853	0.000	5191.66	2.000	10.12	192.66
21 5641.07	52	1	49.01	40.769	33.535	25.340	0.000	5098.63	2.000	8.94	137.63
22 5680.44	54	1	49.56	41.262	33.790	25.534	0.000	5082.41	2.000	8.74	128.05
23 5754.39	56	1	50.75	42.339	34.285	24.558	0.000	5051.94	2.000	8.37	110.07
24 5943.17	58	1	54.04	45.339	35.653	24.138	0.000	4974.16	2.000	7.43	64.15
25 6254.62	62	1	60.61	51.339	38.318	23.513	0.000	4845.85	2.000	5.87	-11.59
26 6501.98	66	1	67.13	57.339	40.874	24.282	0.000	4739.11	2.000	4.73	-73.84
27 6561.88	68	1	68.46	58.492	41.545	22.392	0.000	4710.47	2.000	4.52	-90.13
28 6610.11	70	1	70.40	60.339	42.110	22.146	0.000	4687.41	2.000	4.34	-103.24
29 6663.77	72	1	71.72	61.492	42.766	24.750	0.000	4661.76	2.000	4.14	-117.83
30 6684.77	74	1	72.61	62.339	43.032	21.686	0.000	4651.71	2.000	4.07	-123.54
31 6758.83	76	1	74.95	64.492	43.959	21.673	0.000	4614.40	2.000	3.83	-144.43
32 6927.31	79	1	81.39	70.492	46.272	20.665	0.000	4528.09	2.000	3.31	-192.49
33 7071.13	82	1	87.78	76.492	48.485	19.854	0.000	4452.40	2.000	2.90	-234.14
34 7202.29	85	1	94.14	82.492	50.605	19.094	0.000	4378.94	2.000	2.58	-273.49
35 7313.45	88	1	100.48	88.492	52.639	18.362	0.000	4316.68	2.000	2.32	-306.84
36 7408.55	91	1	106.79	94.492	54.588	17.662	0.000	4263.42	2.000	2.09	-335.36
37 7493.75	94	1	113.07	100.492	56.460	17.325	0.000	4222.43	2.000	1.90	-356.81
38 7570.01	97	1	119.11	106.254	58.257	16.361	0.000	4190.26	2.000	1.76	-373.26
39 7634.70	101	1	125.58	112.492	59.983	15.461	0.000	4189.00	2.000	1.64	-372.74
40 7691.73	104	1	131.81	118.492	61.642	15.305	0.000	4189.00	2.000	1.54	-371.67
41 7717.86	106	1	134.91	121.492	62.446	14.878	0.000	4189.00	2.000	1.50	-371.18
42 7745.47	108	1	138.01	124.492	63.236	14.601	0.000	4189.00	2.000	1.46	-370.62
43 7771.54	110	1	141.11	127.492	64.009	14.332	0.000	4189.00	2.000	1.42	-370.08
44 7796.22	112	1	144.21	130.492	64.769	14.072	0.000	4189.00	2.000	1.38	-369.58

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

BODY PT NO VELOCITY FT/SEC (J) (UE)	INTEG PT NO (I)	MATL NO (MATL)	STREAM LENGTH INCH (S)	AXIAL LENGTH INCH (Z)	RADIAL LENGTH INCH (R)	BODY ANGLE DEG (THETB)	NORMALIZED ABLATION RATE (BP)	WALL TEMP DEG R (TW)	SURFACE ROUGHNESS MIL (RUFMIL)	---EDGE CONDITION--- PRESSURE ATM (PE)	ENTHALPY BTU/LBM (HE)
45 7819.59	114	1	147.30	133.492	65.513	13.802	0.000	4189.00	2.000	1.35	-369.10
46 7841.74	116	1	150.39	136.492	66.243	13.532	0.000	4189.00	2.000	1.31	-368.65
47 7862.75	118	1	153.47	139.492	66.957	13.279	0.000	4189.00	2.000	1.28	-368.22
48 7882.71	120	1	156.55	142.492	67.659	13.052	0.000	4189.00	2.000	1.25	-367.81
49 7906.83	122	1	159.63	145.492	68.348	12.798	0.000	4180.26	2.000	1.22	-372.22
50 7929.85	124	1	162.70	148.492	69.022	12.553	0.000	4171.81	2.000	1.19	-376.49
51 7951.77	126	1	165.78	151.492	69.684	11.851	0.000	4163.77	2.000	1.16	-380.55
52 7971.00	128	1	168.83	154.492	70.281	12.097	0.000	4156.72	2.000	1.14	-384.12
53 7992.65	130	1	171.91	157.492	70.970	12.344	0.000	4148.78	2.000	1.11	-388.13
54 8011.68	132	1	174.98	160.492	71.594	11.640	0.000	4141.79	2.000	1.09	-391.66
55 8029.87	134	1	178.04	163.492	72.206	11.429	0.000	4135.13	2.000	1.07	-395.03
56 8047.28	136	1	181.10	166.492	72.807	11.200	0.000	4128.74	2.000	1.04	-398.26
57 8063.90	138	1	184.15	169.492	73.394	10.924	0.000	4122.64	2.000	1.02	-401.34
58 8079.69	140	1	187.21	172.492	73.965	14.057	0.000	4116.85	2.000	1.00	-404.27
59 8097.11	142	1	188.83	174.037	74.532	9.726	0.000	4105.35	2.000	0.98	-410.20
60 8106.10	144	1	192.32	177.492	74.822	4.798	0.000	4099.02	2.000	0.97	-413.46

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

VISCOUS FLOW - EDGE PROPERTIES

BODY PT NO (J)	INTEG PT NO (I)	STREAM LENGTH INCH (S)	VELOCITY FT/SEC (UE)	MACH NO (HCAM)	ENTHALPY BTU/LBM (HE)	TEMPERATURE DEG R (TE)	DENSITY LBM/FT3 (ROE)	VISCOSITY LBM/FT-SEC (VISE)	UNIT RE NO 1/FT (URE)
1	1	0.0000	1402.0	0.3430	672.1	5869.0	1.718E-01	5.491E-05	4.385E+06
2	7	0.8680	1462.0	0.3579	668.3	5862.7	1.704E-01	5.487E-05	4.540E+06
3	9	2.6088	1588.6	0.3894	660.2	5849.7	1.675E-01	5.479E-05	4.856E+06
4	11	3.9162	1095.1	0.2653	739.2	5974.4	1.932E-01	5.557E-05	3.807E+06
5	13	5.0119	1160.4	0.2813	736.5	5969.9	1.920E-01	5.554E-05	4.012E+06
6	15	5.9740	1221.0	0.2961	733.8	5965.5	1.908E-01	5.551E-05	4.198E+06
7	17	6.8416	1277.9	0.3100	731.2	5961.2	1.897E-01	5.548E-05	4.370E+06
8	19	7.6404	1331.7	0.3232	728.5	5956.9	1.886E-01	5.546E-05	4.529E+06
9	21	8.3882	1382.9	0.3357	726.0	5952.7	1.875E-01	5.543E-05	4.678E+06
10	23	9.0946	1432.2	0.3478	723.4	5948.6	1.864E-01	5.541E-05	4.819E+06
11	25	9.7699	1479.3	0.3594	720.9	5944.5	1.854E-01	5.538E-05	4.952E+06
12	27	10.4191	1525.6	0.3708	718.3	5940.3	1.843E-01	5.535E-05	5.080E+06
13	29	11.1157	1574.9	0.3830	715.5	5935.8	1.831E-01	5.533E-05	5.213E+06
14	33	19.4705	2472.3	0.6074	647.3	5822.3	1.572E-01	5.462E-05	7.115E+06
15	38	29.2310	3360.2	0.8373	548.9	5674.4	1.255E-01	5.371E-05	7.852E+06
16	40	30.2840	3484.0	0.8702	532.5	5651.4	1.208E-01	5.357E-05	7.859E+06
17	43	36.5272	4436.8	1.1306	383.4	5457.0	8.585E-02	5.236E-05	7.274E+06
18	45	37.3387	4535.2	1.1582	366.4	5436.1	8.227E-02	5.223E-05	7.143E+06
19	47	39.8436	4861.3	1.2534	304.9	5341.0	7.146E-02	5.163E-05	6.729E+06
20	50	45.7734	5412.0	1.4245	192.7	5133.1	5.430E-02	5.027E-05	5.847E+06
21	52	49.0062	5641.1	1.4998	137.6	5035.7	4.897E-02	4.963E-05	5.566E+06
22	54	49.5612	5680.4	1.5129	128.1	5019.1	4.805E-02	4.952E-05	5.512E+06
23	56	50.7466	5754.4	1.5376	110.1	4988.0	4.632E-02	4.932E-05	5.405E+06
24	58	54.0437	5943.2	1.6014	64.2	4909.8	4.179E-02	4.880E-05	5.089E+06
25	62	60.6090	6254.6	1.7084	-11.6	4785.9	3.395E-02	4.799E-05	4.424E+06
26	66	67.1307	6502.0	1.7960	-73.8	4687.2	2.799E-02	4.735E-05	3.843E+06
27	68	68.4647	6561.9	1.8176	-90.1	4662.8	2.684E-02	4.719E-05	3.732E+06
28	70	70.3962	6610.1	1.8351	-103.2	4643.4	2.591E-02	4.706E-05	3.639E+06
29	72	71.7228	6663.8	1.8546	-117.8	4622.0	2.487E-02	4.692E-05	3.531E+06
30	74	72.6106	6684.8	1.8623	-123.5	4613.7	2.446E-02	4.687E-05	3.488E+06
31	76	74.9547	6758.8	1.8896	-144.4	4584.2	2.319E-02	4.667E-05	3.358E+06
32	79	81.3851	6927.3	1.9540	-192.5	4511.6	2.042E-02	4.620E-05	3.062E+06
33	82	87.7802	7071.1	2.0120	-234.1	4435.7	1.819E-02	4.567E-05	2.816E+06
34	85	94.1437	7202.3	2.0688	-273.5	4353.6	1.651E-02	4.510E-05	2.637E+06
35	88	100.4791	7313.5	2.1178	-306.8	4284.4	1.505E-02	4.461E-05	2.467E+06
36	91	106.7877	7408.5	2.1605	-335.4	4225.4	1.376E-02	4.420E-05	2.306E+06
37	94	113.0729	7493.8	2.1970	-356.8	4181.0	1.269E-02	4.389E-05	2.166E+06
38	97	119.1086	7570.0	2.2287	-373.3	4146.8	1.179E-02	4.365E-05	2.045E+06
39	101	125.5810	7634.7	2.2481	-372.7	4144.9	1.104E-02	4.364E-05	1.931E+06
40	104	131.8062	7691.7	2.2649	-371.7	4144.3	1.037E-02	4.363E-05	1.829E+06
41	106	134.9120	7717.9	2.2726	-371.2	4143.9	1.007E-02	4.363E-05	1.781E+06
42	108	138.0143	7745.5	2.2807	-370.6	4143.7	9.788E-03	4.363E-05	1.738E+06
43	110	141.1123	7771.5	2.2884	-370.1	4143.6	9.526E-03	4.363E-05	1.697E+06
44	112	144.2071	7796.2	2.2956	-369.6	4143.3	9.278E-03	4.363E-05	1.658E+06

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

BODY PT NO (J)	INTEG PT NO (I)	STREAM LENGTH INCH (S)	VELOCITY FT/SEC (UE)	MACH NO (HCAM)	ENTHALPY BTU/LBM (HE)	TEMPERATURE DEG R (TE)	DENSITY LBM/FT3 (ROE)	VISCOSITY LBM/FT-SEC (VISE)	UNIT RE NO 1/FT (URE)
45	114	147.2979	7819.6	2.3025	-369.1	4143.1	9.036E-03	4.363E-05	1.620E+06
46	116	150.3855	7841.7	2.3090	-368.6	4142.9	8.814E-03	4.362E-05	1.584E+06
47	118	153.4693	7862.7	2.3152	-368.2	4142.6	8.606E-03	4.362E-05	1.551E+06
48	120	156.5503	7882.7	2.3211	-367.8	4142.3	8.398E-03	4.362E-05	1.518E+06
49	122	159.6284	7906.8	2.3308	-372.2	4133.3	8.215E-03	4.356E-05	1.491E+06
50	124	162.7032	7929.9	2.3401	-376.5	4124.5	8.037E-03	4.350E-05	1.465E+06
51	126	165.7754	7951.8	2.3490	-380.6	4116.2	7.870E-03	4.344E-05	1.441E+06
52	128	168.8342	7971.0	2.3568	-384.1	4108.9	7.715E-03	4.339E-05	1.418E+06
53	130	171.9123	7992.6	2.3656	-388.1	4100.7	7.548E-03	4.333E-05	1.392E+06
54	132	174.9765	8011.7	2.3734	-391.7	4093.4	7.398E-03	4.328E-05	1.370E+06
55	134	178.0383	8029.9	2.3808	-395.0	4086.5	7.254E-03	4.323E-05	1.347E+06
56	136	181.0979	8047.3	2.3879	-398.3	4080.0	7.123E-03	4.318E-05	1.327E+06
57	138	184.1548	8063.9	2.3948	-401.3	4073.7	6.991E-03	4.314E-05	1.307E+06
58	140	187.2086	8079.7	2.4012	-404.3	4067.7	6.864E-03	4.310E-05	1.287E+06
59	142	188.8544	8097.1	2.4099	-410.2	4056.3	6.747E-03	4.302E-05	1.270E+06
60	144	192.3216	8106.1	2.4145	-413.5	4050.1	6.689E-03	4.297E-05	1.262E+06

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

VISCOUS FLOW - WALL AND B. L. RECOVERY PROPERTIES

BODY CF/2 PT NO (J)	INTEG PT NO (I)	STREAM LENGTH INCH (S)	WALL TEMPERATURE DEG R (TW)	WALL ENTHALPY BTU/LBM (HW)	WALL DENSITY LBM/FT3 (ROW)	WALL VISCOSITY LBM/FT-SEC (VISW)	RECOVERY ENTHALPY BTU/LBM (HR)	RECOVERY FACTOR (RECOV)	SENSBL CONV HEAT FLUX BTU/FT2-SEC
1	1	0.0000	5969.7	758.6	1.682E-01	5.554E-05	697.6	0.6558	-6.119E+00
1.000E+30									
2	7	0.8680	5963.5	755.0	1.669E-01	5.550E-05	700.3	0.7548	-5.700E+01
2.612E-03									
3	9	2.6088	5950.5	747.4	1.640E-01	5.542E-05	698.0	0.7548	-3.695E+01
2.181E-03									
4	11	3.9162	6078.2	825.5	1.892E-01	5.621E-05	757.2	0.7548	-5.102E+01
1.287E-03									
5	13	5.0119	6073.7	822.9	1.881E-01	5.618E-05	756.7	0.7548	-4.442E+01
1.276E-03									
6	15	5.9740	6069.4	820.4	1.869E-01	5.615E-05	756.1	0.7548	-4.136E+01
1.318E-03									
7	17	6.8416	6065.4	818.2	1.858E-01	5.613E-05	755.6	0.7548	-3.965E+01
1.357E-03									
8	19	7.6404	6061.2	815.7	1.847E-01	5.610E-05	755.1	0.7548	-3.816E+01
1.394E-03									
9	21	8.3882	6056.9	813.1	1.836E-01	5.608E-05	754.6	0.7548	-3.675E+01
1.428E-03									
10	23	9.0946	6052.6	810.6	1.826E-01	5.605E-05	754.1	0.7548	-3.545E+01
1.463E-03									
11	25	9.7699	6048.5	808.1	1.816E-01	5.603E-05	753.6	0.7548	-3.418E+01
1.495E-03									
12	27	10.4191	6044.2	805.5	1.805E-01	5.600E-05	753.1	0.7548	-3.293E+01
1.525E-03									
13	29	11.1157	6039.6	802.8	1.793E-01	5.597E-05	752.6	0.7548	-3.158E+01
1.558E-03									
14	33	19.4705	5929.6	741.7	1.537E-01	5.529E-05	738.8	0.7548	-2.146E+00
1.980E-03									
15	38	29.2310	5770.0	638.3	1.229E-01	5.430E-05	717.9	0.7548	7.997E+01
1.997E-03									
16	40	30.2840	5744.0	619.9	1.184E-01	5.414E-05	714.2	0.7548	9.533E+01
2.003E-03									
17	43	36.5272	5502.6	431.0	8.493E-02	5.265E-05	678.4	0.7548	2.326E+02
2.015E-03									
18	45	37.3387	5475.1	407.7	8.152E-02	5.248E-05	674.7	0.7548	2.445E+02
2.002E-03									
19	47	39.8436	5375.0	326.7	7.097E-02	5.185E-05	659.3	0.7548	2.782E+02
1.958E-03									
20	50	45.7734	5191.7	232.0	5.363E-02	5.065E-05	632.2	0.7548	2.603E+02
1.803E-03									
21	52	49.0062	5098.6	180.7	4.830E-02	5.004E-05	615.4	0.7548	2.577E+02
1.736E-03									
22	54	49.5612	5082.4	171.6	4.739E-02	4.993E-05	612.5	0.7548	2.572E+02
1.726E-03									
23	56	50.7466	5051.9	154.4	4.567E-02	4.974E-05	607.2	0.7548	2.557E+02
1.705E-03									
24	58	54.0437	4974.2	109.8	4.119E-02	4.923E-05	594.5	0.7548	2.493E+02
1.653E-03									
25	62	60.6090	4845.8	33.4	3.347E-02	4.839E-05	576.0	0.7548	2.295E+02
1.565E-03									
26	66	67.1307	4739.1	-32.6	2.764E-02	4.769E-05	561.4	0.7548	2.096E+02
1.503E-03									
27	68	68.4647	4710.5	-50.7	2.653E-02	4.750E-05	556.9	0.7548	2.068E+02
1.494E-03									
28	70	70.3962	4687.4	-65.6	2.563E-02	4.735E-05	553.4	0.7548	2.035E+02
1.480E-03									
29	72	71.7228	4661.8	-82.5	2.462E-02	4.718E-05	549.6	0.7548	2.005E+02
1.471E-03									
30	74	72.6106	4651.7	-89.3	2.423E-02	4.712E-05	548.1	0.7548	1.988E+02
1.464E-03									
31	76	74.9547	4614.4	-115.6	2.301E-02	4.687E-05	542.4	0.7548	1.960E+02
1.452E-03									
32	79	81.3851	4528.1	-180.1	2.033E-02	4.631E-05	529.3	0.7548	1.880E+02
1.418E-03									
33	82	87.7802	4452.4	-224.2	1.812E-02	4.579E-05	518.3	0.7548	1.756E+02
1.383E-03									
34	85	94.1437	4378.9	-258.9	1.641E-02	4.528E-05	507.3	0.7548	1.638E+02
1.347E-03									
35	88	100.4791	4316.7	-288.5	1.493E-02	4.484E-05	498.6	0.7548	1.529E+02
1.319E-03									
36	91	106.7877	4263.4	-314.0	1.363E-02	4.447E-05	491.5	0.7548	1.425E+02
1.293E-03									
37	94	113.0729	4222.4	-333.6	1.256E-02	4.418E-05	489.4	0.7548	1.338E+02
1.271E-03									
38	97	119.1086	4190.3	-348.9	1.167E-02	4.395E-05	490.5	0.7548	1.265E+02
1.252E-03									
39	101	125.5810	4189.0	-348.0	1.092E-02	4.395E-05	505.8	0.7548	1.200E+02
1.236E-03									
40	104	131.8062	4189.0	-346.5	1.026E-02	4.395E-05	520.0	0.7548	1.141E+02
1.223E-03									
41	106	134.9120	4189.0	-345.8	9.958E-03	4.395E-05	526.6	0.7548	1.114E+02
1.216E-03									
42	108	138.0143	4189.0	-345.2	9.678E-03	4.395E-05	533.6	0.7548	1.090E+02
1.210E-03									
43	110	141.1123	4189.0	-344.5	9.419E-03	4.395E-05	540.2	0.7548	1.066E+02
1.205E-03									
44	112	144.2071	4189.0	-343.9	9.172E-03	4.395E-05	546.5	0.7548	1.044E+02
1.199E-03									

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

BODY CF/2 PT NO (J)	INTEG PT NO (I)	STREAM LENGTH INCH (S)	WALL TEMPERATURE DEG R (TW)	WALL ENTHALPY BTU/LBM (HW)	WALL DENSITY LBM/FT3 (ROW)	WALL VISCOSITY LBM/FT-SEC (VISW)	RECOVERY ENTHALPY BTU/LBM (HR)	RECOVERY FACTOR (RECOV)	SENSBL CONV HEAT FLUX BTU/FT2-SEC
45	114	147.2979	4189.0	-343.3	8.933E-03	4.395E-05	552.4	0.7548	1.022E+02
1.194E-03									
46	116	150.3855	4189.0	-342.7	8.713E-03	4.395E-05	558.1	0.7548	1.001E+02
1.188E-03									
47	118	153.4693	4189.0	-342.1	8.507E-03	4.395E-05	563.5	0.7548	9.813E+01
1.183E-03									
48	120	156.5503	4189.0	-341.5	8.300E-03	4.395E-05	568.7	0.7548	9.613E+01
1.178E-03									
49	122	159.6284	4180.3	-345.8	8.118E-03	4.389E-05	570.0	0.7548	9.455E+01
1.173E-03									
50	124	162.7032	4171.8	-349.9	7.942E-03	4.383E-05	571.3	0.7548	9.295E+01
1.168E-03									
51	126	165.7754	4163.8	-353.8	7.777E-03	4.377E-05	572.6	0.7548	9.144E+01
1.163E-03									
52	128	168.8342	4156.7	-357.3	7.623E-03	4.372E-05	573.7	0.7548	9.001E+01
1.158E-03									
53	130	171.9123	4148.8	-361.1	7.457E-03	4.367E-05	574.9	0.7548	8.851E+01
1.154E-03									
54	132	174.9765	4141.8	-364.5	7.308E-03	4.362E-05	576.0	0.7548	8.709E+01
1.150E-03									
55	134	178.0383	4135.1	-367.8	7.165E-03	4.357E-05	577.0	0.7548	8.572E+01
1.145E-03									
56	136	181.0979	4128.7	-370.9	7.035E-03	4.352E-05	578.0	0.7548	8.447E+01
1.141E-03									
57	138	184.1548	4122.6	-373.9	6.904E-03	4.348E-05	578.9	0.7548	8.317E+01
1.137E-03									
58	140	187.2086	4116.8	-376.7	6.779E-03	4.344E-05	579.8	0.7548	8.200E+01
1.135E-03									
59	142	188.8544	4105.4	-382.8	6.663E-03	4.336E-05	578.2	0.7548	8.102E+01
1.133E-03									
60	144	192.3216	4099.0	-386.1	6.605E-03	4.332E-05	577.1	0.7548	8.027E+01
1.127E-03									

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

VISCOUS FLOW - BOUNDARY LAYER SOLUTION

BODY TRANS PT NO AUGMENT (J) (RUFSMT)	INTEG PT NO (I)	STREAM LENGTH INCH (S)	MOMENTUM THICKNESS MIL (THE)	ENERGY THICKNESS MIL (PHI)	SHAPE FACTOR (HSF)	MOM THICK RE NO (RETH)	ENERGY THICK RE NO (REPH)	HEAT TRANS COEFFICIENT LBM/FT2-SEC (RUCH)	REYNOLDS ANAL FAC (RAF)	INTER-MITTENCY (ADML)	HEAT
1	1	0.0000	1.836	4.224	2.467	0.000E+00	0.000E+00	1.004E-01	0.8415	0.00	
1.000											
2	7	0.8680	6.129	3.081	1.657	2.319E+03	1.165E+03	1.042E+00	1.6019	1.00	
1.262											
3	9	2.6088	12.016	11.853	1.621	4.862E+03	4.796E+03	7.483E-01	1.2896	1.00	
1.247											
4	11	3.9162	137.534	4.779	1.452	4.363E+04	1.516E+03	7.464E-01	2.7416	1.00	
1.154											
5	13	5.0119	146.995	8.842	1.452	4.914E+04	2.956E+03	6.708E-01	2.3591	1.00	
1.159											
6	15	5.9740	124.157	12.173	1.465	4.343E+04	4.258E+03	6.436E-01	2.0956	1.00	
1.167											
7	17	6.8416	106.952	15.101	1.476	3.894E+04	5.499E+03	6.337E-01	1.9263	1.00	
1.174											
8	19	7.6404	93.527	17.947	1.487	3.530E+04	6.774E+03	6.292E-01	1.7976	1.00	
1.181											
9	21	8.3882	82.897	20.810	1.496	3.232E+04	8.113E+03	6.273E-01	1.6937	1.00	
1.188											
10	23	9.0946	74.229	23.722	1.505	2.981E+04	9.527E+03	6.273E-01	1.6059	1.00	
1.194											
11	25	9.7699	67.187	26.722	1.514	2.773E+04	1.103E+04	6.276E-01	1.5313	1.00	
1.200											
12	27	10.4191	61.182	29.954	1.522	2.590E+04	1.268E+04	6.280E-01	1.4643	1.00	
1.205											
13	29	11.1157	55.583	33.776	1.531	2.415E+04	1.467E+04	6.284E-01	1.3985	1.00	
1.211											
14	33	19.4705	19.872	61.033	1.644	1.178E+04	3.619E+04	7.478E-01	0.9719	1.00	
1.272											
15	38	29.2310	19.030	18.103	1.688	1.245E+04	1.184E+04	1.005E+00	1.1929	1.00	
1.282											
16	40	30.2840	18.840	17.394	1.694	1.234E+04	1.139E+04	1.011E+00	1.1996	1.00	
1.282											
17	43	36.5272	18.056	15.885	1.735	1.094E+04	9.629E+03	9.402E-01	1.2251	1.00	
1.278											
18	45	37.3387	18.495	16.457	1.736	1.101E+04	9.796E+03	9.156E-01	1.2258	1.00	
1.276											
19	47	39.8436	19.696	18.144	1.743	1.104E+04	1.017E+04	8.365E-01	1.2296	1.00	
1.269											
20	50	45.7734	24.401	25.903	1.747	1.189E+04	1.262E+04	6.503E-01	1.2274	1.00	
1.246											
21	52	49.0062	27.200	29.157	1.748	1.262E+04	1.352E+04	5.928E-01	1.2365	1.00	
1.237											
22	54	49.5612	27.677	29.706	1.748	1.271E+04	1.365E+04	5.835E-01	1.2384	1.00	
1.235											
23	56	50.7466	28.782	30.979	1.748	1.296E+04	1.395E+04	5.646E-01	1.2423	1.00	
1.231											
24	58	54.0437	32.019	34.786	1.747	1.358E+04	1.475E+04	5.143E-01	1.2526	1.00	
1.221											
25	62	60.6090	39.108	43.649	1.744	1.442E+04	1.609E+04	4.230E-01	1.2729	1.00	
1.198											
26	66	67.1307	46.625	53.302	1.741	1.493E+04	1.707E+04	3.528E-01	1.2896	1.00	
1.178											
27	68	68.4647	47.962	54.889	1.741	1.492E+04	1.707E+04	3.404E-01	1.2939	1.00	
1.174											
28	70	70.3962	50.098	57.442	1.740	1.519E+04	1.742E+04	3.288E-01	1.2970	1.00	
1.170											
29	72	71.7228	51.596	59.190	1.739	1.518E+04	1.742E+04	3.171E-01	1.3013	1.00	
1.166											
30	74	72.6106	52.648	60.409	1.739	1.530E+04	1.756E+04	3.119E-01	1.3030	1.00	
1.164											
31	76	74.9547	55.251	63.155	1.738	1.546E+04	1.767E+04	2.978E-01	1.3086	1.00	
1.159											
32	79	81.3851	62.485	70.932	1.736	1.594E+04	1.810E+04	2.650E-01	1.3217	1.00	
1.147											
33	82	87.7802	69.890	80.116	1.735	1.640E+04	1.880E+04	2.364E-01	1.3292	1.00	
1.136											
34	85	94.1437	76.688	88.857	1.736	1.685E+04	1.953E+04	2.138E-01	1.3339	1.00	
1.127											
35	88	100.4791	83.914	98.213	1.736	1.725E+04	2.019E+04	1.942E-01	1.3383	1.00	
1.119											
36	91	106.7877	91.539	108.176	1.736	1.759E+04	2.079E+04	1.769E-01	1.3424	1.00	
1.110											
37	94	113.0729	99.101	118.306	1.736	1.789E+04	2.136E+04	1.626E-01	1.3457	1.00	
1.102											
38	97	119.1086	106.360	128.184	1.735	1.813E+04	2.185E+04	1.507E-01	1.3485	1.00	
1.095											
39	101	125.5810	114.347	140.232	1.734	1.840E+04	2.257E+04	1.405E-01	1.3493	1.00	
1.088											
40	104	131.8062	122.163	152.142	1.733	1.862E+04	2.318E+04	1.317E-01	1.3502	1.00	
1.081											
41	106	134.9120	126.083	158.110	1.732	1.872E+04	2.347E+04	1.277E-01	1.3507	1.00	
1.078											
42	108	138.0143	129.898	163.987	1.732	1.881E+04	2.375E+04	1.240E-01	1.3510	1.00	
1.075											
43	110	141.1123	133.686	169.802	1.732	1.890E+04	2.401E+04	1.205E-01	1.3515	1.00	
1.072											
44	112	144.2071	137.491	175.637	1.731	1.900E+04	2.427E+04	1.172E-01	1.3519	1.00	
1.069											

MOMENTUM ENERGY INTEGRATION TECHNIQUE (MEIT)

BODY TRANS PT NO AUGMENT (J) (RUFSMT)	INTEG PT NO (I)	STREAM LENGTH INCH (S)	MOMENTUM THICKNESS MIL (THE)	ENERGY THICKNESS MIL (PHI)	SHAPE FACTOR (HSF)	MOM THICK RE NO (RETH)	ENERGY THICK RE NO (REPH)	HEAT TRANS COEFFICIENT LBM/FT2-SEC (RUCH)	REYNOLDS ANAL FAC (RAF)	INTER-MITTENCY (ADML)	HEAT
45 1.067	114	147.2979	141.393	181.614	1.730	1.908E+04	2.451E+04	1.140E-01	1.3524	1.00	
46 1.064	116	150.3855	145.211	187.443	1.730	1.917E+04	2.475E+04	1.111E-01	1.3529	1.00	
47 1.061	118	153.4693	149.013	193.235	1.729	1.926E+04	2.498E+04	1.084E-01	1.3534	1.00	
48 1.059	120	156.5503	152.965	199.273	1.729	1.935E+04	2.520E+04	1.056E-01	1.3538	1.00	
49 1.057	122	159.6284	156.432	204.032	1.729	1.944E+04	2.535E+04	1.032E-01	1.3547	1.00	
50 1.054	124	162.7032	159.971	208.890	1.729	1.953E+04	2.551E+04	1.009E-01	1.3556	1.00	
51 1.052	126	165.7754	163.468	213.666	1.729	1.963E+04	2.565E+04	9.871E-02	1.3565	1.00	
52 1.050	128	168.8342	167.096	218.613	1.729	1.974E+04	2.582E+04	9.669E-02	1.3572	1.00	
53 1.048	130	171.9123	170.721	223.644	1.729	1.981E+04	2.595E+04	9.455E-02	1.3581	1.00	
54 1.046	132	174.9765	174.347	228.633	1.729	1.990E+04	2.609E+04	9.260E-02	1.3590	1.00	
55 1.044	134	178.0383	178.019	233.666	1.729	1.999E+04	2.624E+04	9.073E-02	1.3598	1.00	
56 1.042	136	181.0979	181.567	238.492	1.729	2.008E+04	2.638E+04	8.902E-02	1.3607	1.00	
57 1.041	138	184.1548	185.276	243.566	1.729	2.018E+04	2.652E+04	8.729E-02	1.3615	1.00	
58 1.039	140	187.2086	188.857	248.662	1.728	2.025E+04	2.667E+04	8.572E-02	1.3617	1.00	
59 1.037	142	188.8544	190.833	251.260	1.729	2.019E+04	2.659E+04	8.432E-02	1.3627	1.00	
60 1.037	144	192.3216	194.450	255.529	1.729	2.044E+04	2.687E+04	8.334E-02	1.3637	1.00	

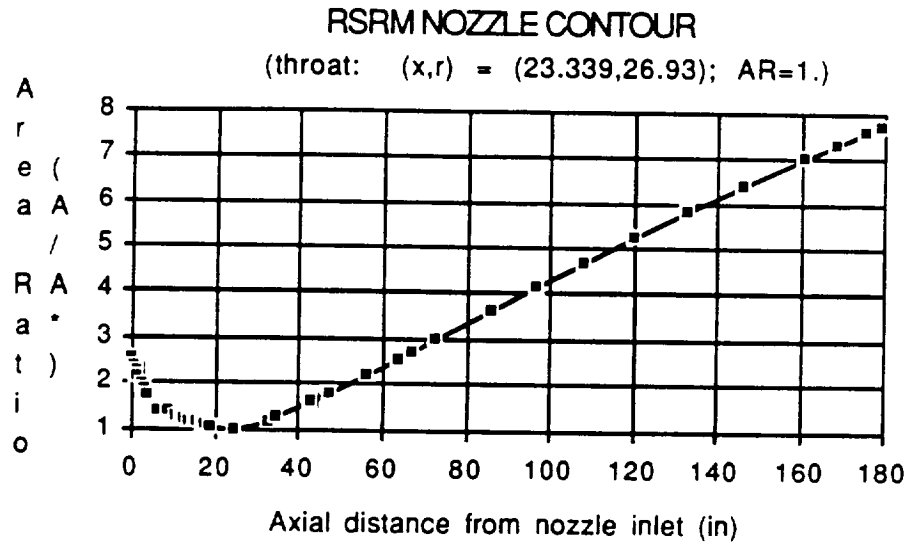

Figure A-5. RSRM Nozzle Contour Coordinates

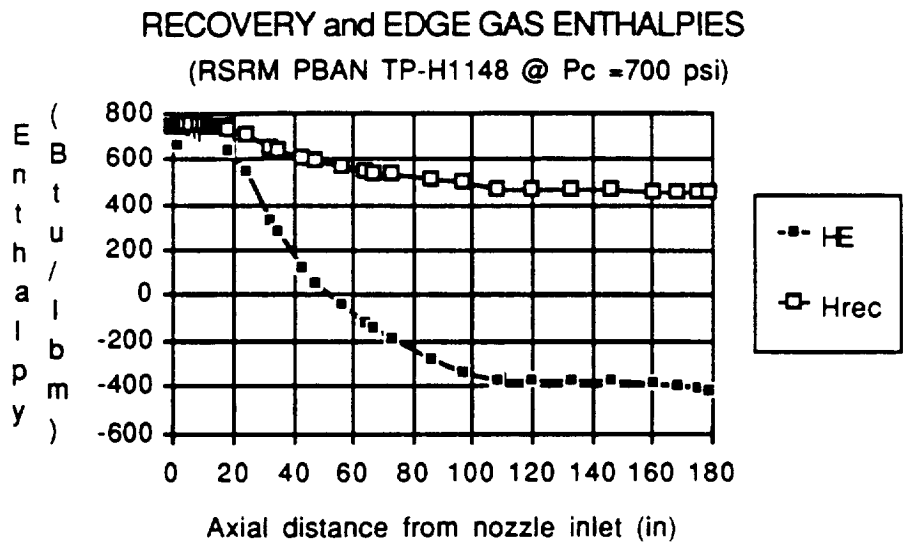

Figure A-6. RSRM Gas Enthalpy Profile

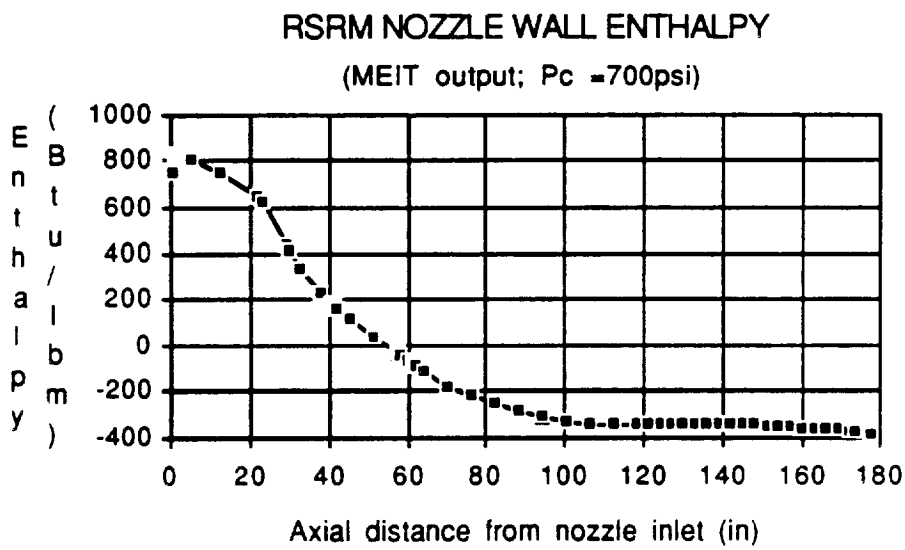

Figure A-7. RSRM Nozzle Wall Enthalpy Profile

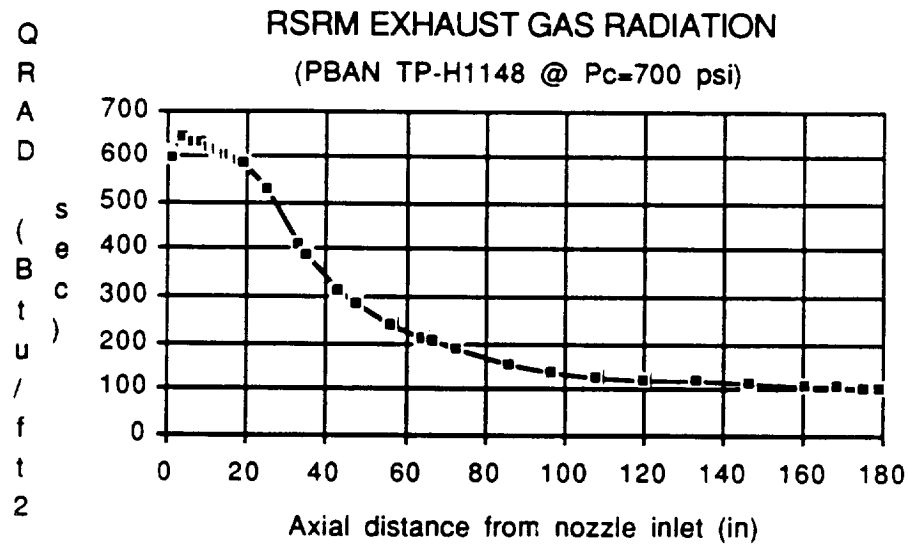

Figure A-8. RSRM Nozzle Gas Radiation Heat Flux

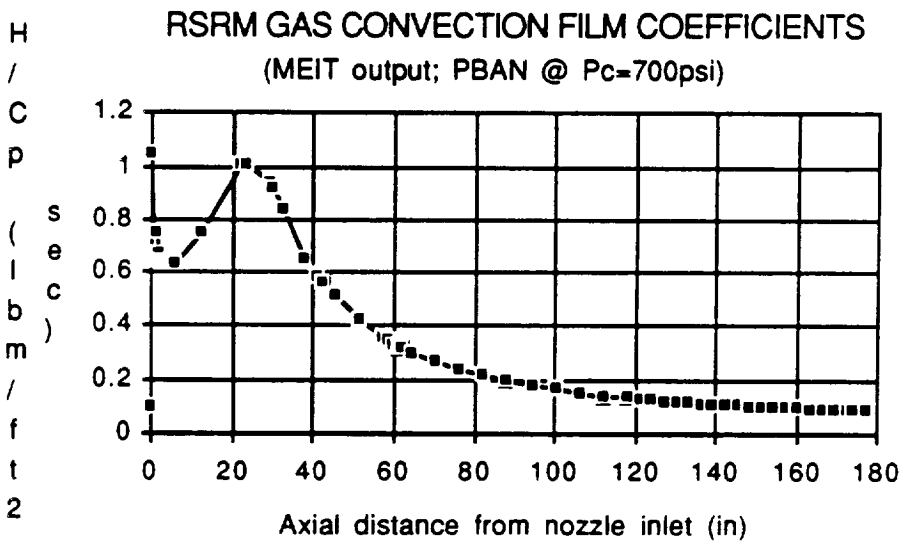

Figure A-9. RSRM Nozzle Gas Convective Film Coefficients

SAMPLE ACE SURFACE THERMOCHEMISTRY INPUT FILE
(RSRM Nozzle Throat Problem)

```
0110200000 3400.0    44.9100                                                ST15
 5
 1 HYDROGEN   1.008     -.03747    -0.137
 6 CARBON     12.011    -.11298    -0.405     -1.000
 7 NITROGEN   14.007    -.08773    -0.017
 8 OXYGEN     16.000    -.24802    -0.441
17 CHLORINE   35.457    -.21104

C.... Include JANNAF card deck here

3000100000            25.80
0000000001 -4000.0    25.80
0000000001 -3500.0    25.80
0000000001 -3000.0    25.80
0000000001 -2500.0    25.80
0000000001 -2000.0    25.80
0000000001 -1500.0    25.80
0000000001 -1000.0    25.80
0000000001 -500.0     25.80
1003000004
 7  9
3.00     2.000     1.00     0.75     0.50     0.250     0.100
1.00     0.750     0.50     0.10     0.050    0.025     0.010     0.005
0.001
8
```

SAMPLE ACE SURFACE THERMOCHEMISTRY OUTPUT FILE
(RSRM Nozzle Throat Problem)

```
25.8000 0.00000 0.000004000.00000.667 1390.595  688.089-1  CHAR     0.000E+00
25.8000 0.00000 0.000003500.00000.667 1057.528  444.380-1  CHAR     0.000E+00
25.8000 0.00000 0.000003000.00000.667  730.529  204.437-1  CHAR     0.000E+00
25.8000 0.00000 0.000002500.00000.667  412.835  -29.350-1  CHAR     0.000E+00
25.8000 0.00000 0.000002000.00000.667  106.824 -255.109-1  CHAR     0.000E+00
25.8000 0.00000 0.000001500.00000.667 -187.082 -472.424-1  CHAR     0.000E+00
25.8000 0.00000 0.000001000.00000.667 -467.615 -680.050-1  CHAR     0.000E+00
25.8000 0.00000 0.00000 500.00000.667 -728.434 -871.758-1  CHAR     0.000E+00
25.8000 3.00000 1.000003445.51770.667 3641.961 2280.181 1  C*       0.000E+00
25.8000 3.00000 0.750003330.42060.667 3307.144 1996.652 1  C*       0.000E+00
25.8000 3.00000 0.500003183.01440.667 2916.952 1676.443 1  C*       0.000E+00
25.8000 3.00000 0.100002779.44820.667 2065.022 1015.200 1  C*       0.000E+00
25.8000 3.00000 0.050002687.72780.667 1909.792  901.109 1  C*       0.000E+00
25.8000 3.00000 0.025002632.17360.667 1821.325  837.142 1  C*       0.000E+00
25.8000 3.00000 0.010002594.32580.667 1763.232  795.573 1  C*       0.000E+00
25.8000 3.00000 0.005002580.76350.667 1742.818  781.052 1  C*       0.000E+00
25.8000 3.00000 0.001002569.52610.667 1726.060  769.163 1  C*       0.000E+00
25.8000 3.00000 0.001002500.00000.667 1631.949  713.580 0  CHAR     0.000E+00
25.8000 3.00000 0.001002000.00000.667 1001.290  317.451 0  CHAR     0.000E+00
25.8000 3.00000 0.001001500.00000.667  379.868  -96.797 0  CHAR     0.000E+00
25.8000 3.00000 0.001001000.00000.667-1016.468-1168.846 0  CHAR     0.000E+00
25.8000 3.00000 0.00100 500.00000.667-1755.770-1760.213 0  CHAR     0.000E+00
25.8000 0.00000 1.000004190.26550.667 4834.653 3842.765 1  C*       0.000E+00
25.8000 0.00000 0.750004064.94190.667 4236.154 3227.483 1  C*       0.000E+00
25.8000 0.00000 0.500003857.50140.667 3347.880 2307.802 1  C*       0.000E+00
25.8000 0.00000 0.100001303.41520.667 -258.113 -431.529 1  C*       0.000E+00
25.8000 0.00000 0.300003531.35120.667 2256.071 1460.022 1  C*       0.000E+00
25.8000 0.00000 0.200003187.64020.667 1473.469  851.431 1  C*       0.000E+00
25.8000 0.00000 0.150002832.81850.667  949.515  460.267 1  C*       0.000E+00
25.8000 0.00000 0.125002418.98940.667  552.908  167.982 1  C*       0.000E+00
25.8000 0.00000 0.112501446.35220.667 -103.010 -306.705 1  C*       0.000E+00
25.8000 0.00000 0.118752152.78310.667  360.414   27.833 1  C*       0.000E+00
25.8000 0.00000 0.115631689.46680.667   66.415 -182.828 1  C*       0.000E+00
25.8000 0.00000 0.050001134.52160.667 -622.342 -750.387 1  C*       0.000E+00
25.8000 0.00000 0.025001064.29770.667 -820.767 -921.597 1  C*       0.000E+00
25.8000 0.00000 0.010001000.27310.667 -986.787-1058.215 1  C*       0.000E+00
25.8000 0.00000 0.00500 944.85750.667-1105.742-1150.609 1  C*       0.000E+00
25.8000 1.00000 1.000003797.50940.667 4187.125 2905.918 1  C*       0.000E+00
25.8000 1.00000 0.750003657.17610.667 3676.229 2443.832 1  C*       0.000E+00
25.8000 1.00000 0.500003457.63990.667 3026.768 1890.529 1  C*       0.000E+00
25.8000 1.00000 0.100002658.14830.667 1363.475  604.619 1  C*       0.000E+00
25.8000 1.00000 0.300003207.91210.667 2355.987 1351.520 1  C*       0.000E+00
25.8000 1.00000 0.200003010.97520.667 1933.271 1026.141 1  C*       0.000E+00
25.8000 1.00000 0.050002075.04740.667  725.933  163.305 1  C*       0.000E+00
25.8000 1.00000 0.075002484.89830.667 1147.157  450.749 1  C*       0.000E+00
25.8000 1.00000 0.025001294.10500.667 -136.242 -431.214 1  C*       0.000E+00
25.8000 1.00000 0.037501343.11780.667  -37.813 -353.639 1  C*       0.000E+00
25.8000 1.00000 0.043751385.33160.667   32.454 -300.542 1  C*       0.000E+00
25.8000 1.00000 0.046881422.14510.667   85.686 -261.717 1  C*       0.000E+00
25.8000 1.00000 0.048441454.97070.667  128.458 -231.379 1  C*       0.000E+00
25.8000 1.00000 0.049221486.90550.667  166.862 -204.732 1  C*       0.000E+00
25.8000 1.00000 0.049612057.67300.667  709.704  152.540 1  C*       0.000E+00
25.8000 1.00000 0.049412048.23720.667  700.923  146.724 1  C*       0.000E+00
25.8000 1.00000 0.049322043.32760.667  696.362  143.705 1  C*       0.000E+00
25.8000 1.00000 0.049272040.81630.667  694.031  142.162 1  C*       0.000E+00
25.8000 1.00000 0.049242039.54580.667  692.852  141.383 1  C*       0.000E+00
25.8000 1.00000 0.010001255.63000.667 -229.805 -507.653 1  C*       0.000E+00
25.8000 1.00000 0.005001245.07980.667 -258.312 -531.331 1  C*       0.000E+00
25.8000 1.00000 0.001001237.16820.667 -280.529 -549.884 1  C*       0.000E+00
25.8000 1.00000 0.001001000.00000.667-1014.278-1139.308 0  CHAR     0.000E+00
25.8000 1.00000 0.00100 500.00000.667-1703.365-1680.050 0  CHAR     0.000E+00
25.8000 0.75000 1.000003873.55870.667 4314.930 3066.623 1  C*       0.000E+00
25.8000 0.75000 0.750003732.12880.667 3774.916 2567.799 1  C*       0.000E+00
25.8000 0.75000 0.500003525.63810.667 3069.783 1958.888 1  C*       0.000E+00
25.8000 0.75000 0.100002595.81630.667 1172.990  492.870 1  C*       0.000E+00
25.8000 0.75000 0.300003257.63010.667 2323.531 1356.261 1  C*       0.000E+00
25.8000 0.75000 0.200003036.74350.667 1845.441  988.429 1  C*       0.000E+00
25.8000 0.75000 0.050001326.88710.667  -99.937 -385.966 1  C*       0.000E+00
25.8000 0.75000 0.075002306.22120.667  859.775  272.822 1  C*       0.000E+00
25.8000 0.75000 0.062501429.37400.667   53.705 -269.786 1  C*       0.000E+00
25.8000 0.75000 0.068752152.56980.667  715.380  174.267 1  C*       0.000E+00
25.8000 0.75000 0.065632005.10660.667  584.747   86.572 1  C*       0.000E+00
25.8000 0.75000 0.025001247.99830.667 -272.241 -526.614 1  C*       0.000E+00
25.8000 0.75000 0.010001216.64660.667 -358.961 -599.840 1  C*       0.000E+00
25.8000 0.75000 0.005001207.29000.667 -386.956 -623.669 1  C*       0.000E+00
25.8000 0.75000 0.001001200.07310.667 -409.189 -642.639 1  C*       0.000E+00
25.8000 0.75000 0.001001000.00000.667-1012.781-1130.030 0  CHAR     0.000E+00
25.8000 0.75000 0.00100 500.00000.667-1685.810-1654.645 0  CHAR     0.000E+00
25.8000 0.50000 1.000003962.38990.667 4465.048 3266.730 1  C*       0.000E+00
25.8000 0.50000 0.750003822.00020.667 3897.844 2727.996 1  C*       0.000E+00
25.8000 0.50000 0.500003610.13060.667 3131.147 2052.822 1  C*       0.000E+00
25.8000 0.50000 0.100002473.31170.667  911.982  337.175 1  C*       0.000E+00
25.8000 0.50000 0.300003322.01830.667 2291.738 1369.311 1  C*       0.000E+00
25.8000 0.50000 0.200003070.67890.667 1741.694  946.018 1  C*       0.000E+00
25.8000 0.50000 0.150002867.87180.667 1399.045  690.238 1  C*       0.000E+00
25.8000 0.50000 0.050001262.98250.667 -261.748 -497.090 1  C*       0.000E+00
25.8000 0.50000 0.075001386.47730.667  -47.806 -325.311 1  C*       0.000E+00
25.8000 0.50000 0.087502228.35930.667  681.623  175.847 1  C*       0.000E+00
25.8000 0.50000 0.081251540.78310.667  117.780 -205.982 1  C*       0.000E+00
25.8000 0.50000 0.084382110.46440.667  581.306  106.935 1  C*       0.000E+00
25.8000 0.50000 0.082812016.43020.667  504.317   54.562 1  C*       0.000E+00
25.8000 0.50000 0.025001202.94380.667 -416.623 -628.911 1  C*       0.000E+00
25.8000 0.50000 0.010001173.62430.667 -505.705 -705.679 1  C*       0.000E+00
25.8000 0.50000 0.005001164.29400.667 -535.622 -731.483 1  C*       0.000E+00
25.8000 0.50000 0.001001156.87880.667 -559.837 -752.352 1  C*       0.000E+00
25.8000 0.50000 0.001001000.00000.667-1010.348-1117.228 0  CHAR     0.000E+00
25.8000 0.50000 0.00100 500.00000.667-1660.631-1619.086 0  CHAR     0.000E+00
25.8000 0.25000 1.000004066.85110.667 4639.028 3519.496 1  C*       0.000E+00
25.8000 0.25000 0.750003931.10230.667 4050.579 2940.045 1  C*       0.000E+00
25.8000 0.25000 0.500003717.55140.667 3219.881 2187.058 1  C*       0.000E+00
```

25.8000	0.25000	0.100002022.43600.667	402.030	14.287	1	C*	0.000E+00
25.8000	0.25000	0.300003408.67140.667	2265.480	1398.289	1	C*	0.000E+00
25.8000	0.25000	0.200003117.62650.667	1618.576	899.322	1	C*	0.000E+00
25.8000	0.25000	0.150002859.34150.667	1204.175	590.422	1	C*	0.000E+00
25.8000	0.25000	0.125002638.99460.667	935.301	393.543	1	C*	0.000E+00
25.8000	0.25000	0.112502457.05470.667	753.631	262.332	1	C*	0.000E+00
25.8000	0.25000	0.050001205.41530.667	-426.237	-611.336	1	C*	0.000E+00
25.8000	0.25000	0.075001280.95540.667	-256.380	-465.711	1	C*	0.000E+00
25.8000	0.25000	0.087501347.89830.667	-148.331	-377.112	1	C*	0.000E+00
25.8000	0.25000	0.093751414.86360.667	-67.050	-313.998	1	C*	0.000E+00
25.8000	0.25000	0.096881493.31860.667	8.822	-258.109	1	C*	0.000E+00
25.8000	0.25000	0.098441715.26890.667	181.155	-137.810	1	C*	0.000E+00
25.8000	0.25000	0.025001149.29490.667	-587.323	-751.511	1	C*	0.000E+00
25.8000	0.25000	0.010001116.81400.667	-689.434	-839.776	1	C*	0.000E+00
25.8000	0.25000	0.005001105.53430.667	-725.496	-870.691	1	C*	0.000E+00
25.8000	0.25000	0.001001096.18500.667	-755.403	-896.199	1	C*	0.000E+00
25.8000	0.25000	0.001001000.00000.667	-1006.476	-1098.754	0	CHAR	0.000E+00
25.8000	0.25000	0.00100 500.00000.667	-1622.013	-1566.137	0	CHAR	0.000E+00
25.8000	0.10000	1.000004138.39500.667	4754.194	3703.631	1	C*	0.000E+00
25.8000	0.10000	0.750004008.03670.667	4158.058	3101.526	1	C*	0.000E+00
25.8000	0.10000	0.500003796.83560.667	3291.175	2297.105	1	C*	0.000E+00
25.8000	0.10000	0.100001362.57520.667	-160.589	-366.919	1	C*	0.000E+00
25.8000	0.10000	0.300003476.65440.667	2256.627	1429.601	1	C*	0.000E+00
25.8000	0.10000	0.200003155.80710.667	1534.170	870.277	1	C*	0.000E+00
25.8000	0.10000	0.150002847.08010.667	1060.393	517.013	1	C*	0.000E+00
25.8000	0.10000	0.125002542.25040.667	731.139	275.374	1	C*	0.000E+00
25.8000	0.10000	0.112502179.46510.667	438.186	63.892	1	C*	0.000E+00
25.8000	0.10000	0.106251466.39360.667	-57.002	-287.154	1	C*	0.000E+00
25.8000	0.10000	0.109381895.18190.667	243.023	-74.230	1	C*	0.000E+00
25.8000	0.10000	0.050001166.09730.667	-537.894	-690.082	1	C*	0.000E+00
25.8000	0.10000	0.025001105.49170.667	-714.896	-844.240	1	C*	0.000E+00
25.8000	0.10000	0.010001064.13060.667	-837.965	-948.951	1	C*	0.000E+00
25.8000	0.10000	0.005001047.62610.667	-885.433	-988.540	1	C*	0.000E+00
25.8000	0.10000	0.001001032.40550.667	-927.815	-1023.439	1	C*	0.000E+00
25.8000	0.10000	0.001001000.30000.667	-1003.420	-1083.504	0	CHAR	0.000E+00
25.8000	0.10000	0.00100 500.00000.667	-1587.539	-1520.140	0	CHAR	0.000E+00

SAMPLE CMA INPUT FILE FOR RSRM THROAT PROBLEM

```
ACE/CMA MODEL - wkbk, vol.2 prob.(MEIT: Qr=525;Hr=730;H/CP=0.750)
MODEL:1-D;3.71"CC/P(0DEG ply);0.25"SI/P(0 DEG);0.50"d6ac;DM-8Ptrace
MTI PROPS. FOR SI/P; CC/P DECOMP. CONSTANTS; NO BACKWALL Q;rc=0.27
A          20.25      0.000        .140E05   3.0       .1540E05  1000.0
B          60.75      32.40        .448E10   3.0       .3680E05   600.0
C          97.40      97.40       0.0000     0.00     0.00        9000.0
   49  2        0.0     430.0       0.10      1.00      10.00       .10    0.40
    1.000    10.00      0.005   -363.00    0.000      0.0      -0.330   536.0
   3.710     3.960
 1 520.0                0.0010      26.930
 1 520.0                0.0020
 1 520.0                0.0030
 1 520.0                0.0040
 1 520.0                0.0100
 1 520.0                0.0100
 1 520.0                0.0100
 1 520.0                0.0100
 1 520.0                0.0100
 1 520.0                0.0500
 1 520.0                0.0900
 1 520.0                0.0900
 1 520.0                0.0900
 1 520.0                0.0900
 1 520.0                0.0900
 1 520.0                0.0900
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25.8000 0.50000 0.087502228.35930.667  681.623  175.847 1  C*        0.000E+00
25.8000 0.50000 0.081251540.78310.667  117.780 -205.982 1  C*        0.000E+00
25.8000 0.50000 0.084382110.46440.667  581.306  106.935 1  C*        0.000E+00
25.8000 0.50000 0.082812016.43020.667  504.317   54.562 1  C*        0.000E+00
25.8000 0.50000 0.025001202.94380.667 -416.623 -628.911 1  C*        0.000E+00
25.8000 0.50000 0.010001173.62430.667 -505.705 -705.679 1  C*        0.000E+00
25.8000 0.50000 0.005001164.29400.667 -535.622 -731.483 1  C*        0.000E+00
25.8000 0.50000 0.001001156.87880.667 -559.837 -752.352 1  C*        0.000E+00
25.8000 0.50000 0.001001000.00000.667-1010.348-1117.228 0  CHAR      0.000E+00
25.8000 0.50000 0.00100 500.00000.667-1660.631-1619.086 0  CHAR      0.000E+00
25.8000 0.25000 1.000004066.85110.667 4639.028 3519.496 1  C*        0.000E+00
25.8000 0.25000 0.750003931.10230.667 4050.579 2940.045 1  C*        0.000E+00
25.8000 0.25000 0.500003717.55140.667 3219.881 2187.058 1  C*        0.000E+00
25.8000 0.25000 0.100002022.43600.667  402.030   14.287 1  C*        0.000E+00
25.8000 0.25000 0.300003408.67140.667 2265.480 1398.289 1  C*        0.000E+00
25.8000 0.25000 0.200003117.62650.667 1618.576  899.322 1  C*        0.000E+00
25.8000 0.25000 0.150002859.34150.667 1204.175  590.422 1  C*        0.000E+00
25.8000 0.25000 0.125002638.99460.667  935.301  393.543 1  C*        0.000E+00
25.8000 0.25000 0.112502457.05470.667  753.631  262.332 1  C*        0.000E+00
25.8000 0.25000 0.050001205.41530.667 -426.237 -611.336 1  C*        0.000E+00
25.8000 0.25000 0.075001280.95540.667 -256.380 -465.711 1  C*        0.000E+00
25.8000 0.25000 0.087501347.89830.667 -148.331 -377.112 1  C*        0.000E+00
25.8000 0.25000 0.093751414.86360.667  -67.050 -313.998 1  C*        0.000E+00
25.8000 0.25000 0.096881493.31860.667    8.822 -258.109 1  C*        0.000E+00
25.8000 0.25000 0.098441715.26890.667  181.155 -137.810 1  C*        0.000E+00
25.8000 0.25000 0.025001149.29490.667 -587.323 -751.511 1  C*        0.000E+00
25.8000 0.25000 0.010001116.81400.667 -689.434 -839.776 1  C*        0.000E+00
25.8000 0.25000 0.005001105.53430.667 -725.496 -870.691 1  C*        0.000E+00
25.8000 0.25000 0.001001096.18500.667 -755.403 -896.199 1  C*        0.000E+00
25.8000 0.25000 0.001001000.00000.667-1006.476-1098.754 0  CHAR      0.000E+00
25.8000 0.25000 0.00100 500.00000.667-1622.013-1566.137 0  CHAR      0.000E+00
25.8000 0.10000 1.000004138.39500.667 4754.194 3703.631 1  C*        0.000E+00
25.8000 0.10000 0.750004008.03670.667 4158.058 3101.526 1  C*        0.000E+00
25.8000 0.10000 0.500003796.83560.667 3291.175 2297.105 1  C*        0.000E+00
25.8000 0.10000 0.100001362.57520.667 -160.589 -366.919 1  C*        0.000E+00
25.8000 0.10000 0.300003476.65440.667 2256.627 1429.601 1  C*        0.000E+00
25.8000 0.10000 0.200003155.80710.667 1534.170  870.277 1  C*        0.000E+00
25.8000 0.10000 0.150002847.08010.667 1060.393  517.013 1  C*        0.000E+00
25.8000 0.10000 0.125002542.25040.667  731.139  275.374 1  C*        0.000E+00
25.8000 0.10000 0.112502179.46510.667  438.186   63.892 1  C*        0.000E+00
25.8000 0.10000 0.106251466.39360.667  -57.002 -287.154 1  C*        0.000E+00
25.8000 0.10000 0.109381895.18190.667  243.023  -74.230 1  C*        0.000E+00
25.8000 0.10000 0.050001166.09730.667 -537.894 -690.082 1  C*        0.000E+00
25.8000 0.10000 0.025001105.49170.667 -714.896 -844.240 1  C*        0.000E+00
25.8000 0.10000 0.010001064.13060.667 -837.965 -948.951 1  C*        0.000E+00
25.8000 0.10000 0.005001047.62610.667 -885.433 -988.540 1  C*        0.000E+00
25.8000 0.10000 0.001001032.40550.667 -927.815-1023.439 1  C*        0.000E+00
25.8000 0.10000 0.001001000.00000.667-1003.420-1083.504 0  CHAR      0.000E+00
25.8000 0.10000 0.00100 500.00000.667-1587.539-1520.140 0  CHAR      0.000E+00
```

SAMPLE CMA OUTPUT FILE FOR RSRM THROAT PROBLEM
(Output Listed for Time = 120 Seconds)

```
1        AEROTHERM CHARRING MATERIAL THERMAL RESPONSE AND ABLATION PROGRAM
                                                                    PAGE  1

ACE/CMA MODEL - wkbk, vol.2 prob.(MEIT: Qr=525;Hr=730;H/CP=0.758)
MODEL:1-D:3.71"CC/P(0DEG ply):0.25"SI/P(0 DEG):0.50"d6ac:DM-8Ptrace
MTI PROPS. FOR SI/P: CC/P DECOMP. CONSTANTS; NO BACKWALL Q:rc=0.27


                  ---REACTION KINETIC EQUATION---

    DRHO/DTIME = GAMMA ( BA*EXP(-EA/T)RHOOA((RHOA-RHORA)/RHOOA)**PSIA )
               + GAMMA ( BB*EXP(-EB/T)RHOOB((RHOB-RHORB)/RHOOB)**PSIB )
             +(1-GAMMA)( BC*EXP(-EC/T)RHOOC((RHOC-RHORC)/RHOOC)**PSIC )

                  ---REACTION KINETIC CONSTANTS---

     REACTION  RHOO      RHOR          B        PSI         E       T REAC
                 (LB/CU FT)        (1/SEC)              (DEG R)    (DEG R)
        A       20.25     0.00  0.1400E+05   3.00  0.1540E+05    1000.
        B       60.75    32.40  0.4480E+10   3.00  0.3680E+05     600.
        C       97.40    97.40  0.0000E+00   0.00  0.0000E+00    9000.
      RESIN VOLUME FRACTION, GAMMA = 0.372(MASS FRACTION = 0.330)

                  ---TIME INCREMENT INFORMATION---

INITIAL TIME (SEC)  0.000                              FINAL TIME (SEC) 430.00

OUTPUT INTERVAL = 0.100 SEC FROM INITIAL TIMEUNTIL   1.000 SEC
OUTPUT INTERVAL = 1.000 SEC FROM  1.000 SEC UNTIL 10.000 SEC
OUTPUT INTERVAL =10.000 SEC FROM 10.000 SEC UNTIL FINAL TIME

MAXIMUM TIME STEP =0.10 SECONDS
1        AEROTHERM CHARRING MATERIAL THERMAL RESPONSE AND ABLATION PROGRAM
                                                                    PAGE  2
                                                                  c=0.27

                        ---NODAL DATA---

NODE   MATL  TEMPERATURE  RELATIVE  THICKNESS  NODAL DEPTH  CONT.RESISTANCE
 NO.    NO. (DEG.RANKINE)   AREA    (INCHES)    (INCHES)   (SQFT-S-DEG/BTU)
  1      1       520.00   0.2693E+02  0.00100   0.000000*     0.0000E+00
  2      1       520.00   0.2693E+02  0.00200   0.002000      0.0000E+00
  3      1       520.00   0.2693E+02  0.00300   0.004500      0.0000E+00
  4      1       520.00   0.2694E+02  0.00400   0.008000      0.0000E+00
  5      1       520.00   0.2694E+02  0.01000   0.015000      0.0000E+00
  6      1       520.00   0.2695E+02  0.01000   0.025000      0.0000E+00
  7      1       520.00   0.2696E+02  0.01000   0.035000      0.0000E+00
  8      1       520.00   0.2697E+02  0.01000   0.045000      0.0000E+00
  9      1       520.00   0.2699E+02  0.01000   0.055000      0.0000E+00
 10      1       520.00   0.2701E+02  0.05000   0.085000      0.0000E+00
 11      1       520.00   0.2708E+02  0.09000   0.155000      0.0000E+00
 12      1       520.00   0.2718E+02  0.09000   0.245000      0.0000E+00
 13      1       520.00   0.2727E+02  0.09000   0.335000      0.0000E+00
 14      1       520.00   0.2736E+02  0.09000   0.425000      0.0000E+00
 15      1       520.00   0.2745E+02  0.09000   0.515000      0.0000E+00
 16      1       520.00   0.2753E+02  0.09000   0.605000      0.0000E+00
 17      1       520.00   0.2762E+02  0.09000   0.695000      0.0000E+00
 18      1       520.00   0.2772E+02  0.09000   0.785000      0.0000E+00
 19      1       520.00   0.2780E+02  0.09000   0.875000      0.0000E+00
 20      1       520.00   0.2790E+02  0.09000   0.965000      0.0000E+00
 21      1       520.00   0.2798E+02  0.09000   1.055000      0.0000E+00
 22      1       520.00   0.2808E+02  0.09000   1.145000      0.0000E+00
 23      1       520.00   0.2817E+02  0.09000   1.235000      0.0000E+00
 24      1       520.00   0.2826E+02  0.09000   1.325000      0.0000E+00
 25      1       520.00   0.2835E+02  0.09000   1.415000      0.0000E+00
 26      1       520.00   0.2843E+02  0.09000   1.505000      0.0000E+00
 27      1       520.00   0.2853E+02  0.09000   1.595000      0.0000E+00
 28      1       520.00   0.2862E+02  0.09000   1.685000      0.0000E+00
 29      1       520.00   0.2871E+02  0.09000   1.775000      0.0000E+00
 30      1       520.00   0.2880E+02  0.09000   1.865000      0.0000E+00
 31      1       520.00   0.2889E+02  0.09000   1.955001      0.0000E+00
 32      1       520.00   0.2898E+02  0.09000   2.045001      0.0000E+00
 33      1       520.00   0.2907E+02  0.09000   2.135000      0.0000E+00
 34      1       520.00   0.2916E+02  0.09000   2.225000      0.0000E+00
 35      1       520.00   0.2924E+02  0.09000   2.315000      0.0000E+00
 36      1       520.00   0.2933E+02  0.09000   2.405000      0.0000E+00
 37      1       520.00   0.2943E+02  0.09000   2.495000      0.0000E+00
 38      1       520.00   0.2952E+02  0.09000   2.585000      0.0000E+00
 39      1       520.00   0.2960E+02  0.09000   2.675000      0.0000E+00
 40      1       520.00   0.2969E+02  0.09000   2.765000      0.0000E+00
 41      1       520.00   0.2979E+02  0.10000   2.860000      0.0000E+00
 42      1       520.00   0.2989E+02  0.10000   2.960000      0.0000E+00
 43      1       520.0u   0.2999E+02  0.10000   3.060000      0.0000E+00
 44      1       520.00   0.3014E+02  0.20000   3.210000      0.0000E+00
 45      1       520.00   0.3034E+02  0.20000   3.410000      0.0000E+00
 46      1       520.00   0.3054E+02  0.20000   3.610000      0.0000E+00
 47      3       520.00   0.3070E+02  0.12500   3.772500      0.0000E+00
 48      3       520.00   0.3083E+02  0.12500   3.897500      0.0000E+00
 49      4       520.00   0.3114E+02  0.50000   4.210000      0.0000E+00
 *INITIAL INTERNAL RADIUS 26.930     AREA PROP.TO RADIUS**1.00
       MINIMUM THICKNESS OF LAST ABLATOR NODE (INCHES) 0.0050
       THERE ARE 10 NODELETS ASSIGNED TO EACH ABLATING NODE
1     AEROTHERM CHARRING MATERIAL THERMAL RESPONSE AND ABLATION PROGRAM
                                                                    PAGE  3
                                                                  c=0.27

       BACK WALL CONVECTION          BACK WALL          RESERVOIR
      COEF BTU/FTSQ-SEC-DEG R       EMISSIVITY        TEMPERATURE
             0.0000                    0.000              0.00

          ---HEAT OF FORMATION OF MATERIAL CONSTITUENTS---
                              (BTU/LB)
```

PLASTIC	CHAR	GAS
-363.00	0.00	0.00

ENTHALPY DATUM TEMPERATURE = 536.000 DEG RANKINE

---MATERIAL THERMAL PROPERTY DATA---

MATERIAL NO. 1 VIRGIN PLASTIC — MATERIAL NO. 2 CHAR — MATERIAL NOS. 3 THROUGH 10 BACK-UP

DECOMPOSING BACK-UP VIRGIN MATERIALS 22,24,26,28,30, CHAR MATERIALS 23,25,27,29,31

MATERIAL NO. 1 DENSITY = 91.300 LB/CU FT

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)	SENSIBLE ENTHALPY (BTU/LB)	EMISSIVITY
530.00	0.2570	0.0001200	-1.82	0.8500
800.00	0.3510	0.0001721	80.26	0.8500
1000.00	0.4210	0.0001761	157.46	0.8500
1160.00	0.4500	0.0001778	227.14	0.8500
1500.00	0.4500	0.0001830	380.14	0.8500
1800.00	0.4660	0.0001830	517.54	0.8500
1980.00	0.4690	0.0001830	601.69	0.8500
2160.00	0.4740	0.0001830	686.56	0.8500
2520.00	0.4820	0.0001830	858.64	0.8500
2700.00	0.4860	0.0001830	945.76	0.8500
3600.00	0.4950	0.0001830	1387.21	0.8500
4500.00	0.4990	0.0001830	1834.51	0.8500
5400.00	0.5000	0.0001830	2284.06	0.8500
6300.00	0.5000	0.0001830	2734.06	0.8500
6750.00	0.5000	0.0001830	2959.06	0.8500

MATERIAL NO. 2 DENSITY = 73.222 LB/CU FT

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)	SENSIBLE ENTHALPY (BTU/LB)	EMISSIVITY
530.00	0.2300	0.0001830	-1.65	0.8500
960.00	0.3200	0.0001700	116.60	0.8500
1460.00	0.3300	0.0001900	279.10	0.8500
1960.00	0.3800	0.0002900	456.60	0.8500
2460.00	0.4500	0.0003800	664.10	0.8500
3460.00	0.5000	0.0005900	1139.10	0.8500
4460.00	0.5200	0.0008300	1649.10	0.8500
5460.00	0.5250	0.0010800	2171.60	0.8500
6460.00	0.5250	0.0013300	2696.60	0.8500

MATERIAL NO. 3 DENSITY = 108.800 LB/CU FT

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)
530.00	0.2600	0.0000940
800.00	0.2750	0.0000943
1000.00	0.2900	0.0000943
1160.00	0.3100	0.0000944
1500.00	0.4720	0.0000944
2000.00	0.4840	0.0000944
3000.00	0.4860	0.0000944
3500.00	0.4960	0.0000944
4000.00	0.4980	0.0000944
5000.00	0.5000	0.0000944

MATERIAL NO. 4 DENSITY = 499.400 LB/CU FT

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)
400.00	0.1070	0.0061100
600.00	0.1100	0.0068100
700.00	0.1150	0.0069400
800.00	0.1200	0.0068800
900.00	0.1250	0.0067800
1000.00	0.1300	0.0066000
1200.00	0.1450	0.0062500
1400.00	0.1600	0.0057600
1600.00	0.1750	0.0052800
2000.00	0.1650	0.0042500
3000.00	0.1650	0.0042500
4000.00	0.1650	0.0042500
5000.00	0.1650	0.0042500
6000.00	0.1650	0.0042500

---RESIN DECOMPOSITION GAS SENSIBLE ENTHALPY---

TEMPERATURE (DEG R)	530.00	800.00	1000.00	1160.00	1500.00
ENTHALPY (BTU/LB)	-1680.00	-1320.00	-1050.00	-830.00	-343.00
TEMPERATURE (DEG R)	1800.00	1980.00	2160.00	2520.00	2700.00
ENTHALPY (BTU/LB)	836.00	351.30	614.80	1140.00	1375.00
TEMPERATURE (DEG R)	3600.00	4500.00	5400.00	6300.00	6750.00
ENTHALPY (BTU/LB)	2655.00	3520.00	4604.00	6554.00	8224.00

---TIME DEPENDENT BOUNDARY CONDITIONS---

TIME (SEC)	PROB OPTN	RECOVERY ENTHALPY (BTU/LB)	RADIATION HEAT RATE (BTU/SQ FT-SECOND)	HEAT COEFF (LB/SQ FT-SECOND)	PRESSURE (ATM)	BLOWING REDUCTION PARAMETER
0.00	1	730.00	525.00	1.0485	25.80000	0.400
10.00	1	730.00	525.00	1.0394	25.80000	0.400
15.00	1	730.00	525.00	1.0303	25.80000	0.400
20.00	1	730.00	525.00	1.0248	25.80000	0.400

25.00	1	730.00	525.00	0.9545	25.80000	0.400
40.00	1	730.00	525.00	0.8083	25.80000	0.400
52.00	1	730.00	525.00	0.7483	25.80000	0.400
60.00	1	730.00	525.00	0.7677	25.80000	0.400
75.00	1	730.00	525.00	0.7980	25.80000	0.400
80.00	1	730.00	525.00	0.7786	25.80000	0.400
90.00	1	730.00	525.00	0.7022	25.80000	0.400
100.00	1	730.00	525.00	0.6294	25.80000	0.400
110.00	1	730.00	525.00	0.5482	25.80000	0.400
115.00	1	730.00	525.00	0.2899	25.80000	0.400
120.00	1	730.00	525.00	0.0503	25.80000	0.400
123.00	1	730.00	525.00	0.0503	25.80000	0.400

TIME (SEC)	PROB OPTN	VIEW FACTOR	RADIATION HEAT RATE (BTU/SQ FT-SECOND)
123.00	3	0.05	0.00
430.00	3	0.05	0.00

CH/CHO = PHI/(EXP(PHI)-1.) WHERE PHI = 2.*BRP*M DOT/CHO. BRP IN TABLE

---SURFACE EQUILIBRIUM DATA---

RATIO OF MASS TO HEAT TRANSFER COEFFICIENTS = 0.715
UNEQUAL DIFFUSION EXPONENT = 0.667
NOMINAL SURFACE VIEW FACTOR = 1.000 (OPTION 1)
FISSURE MODEL NOT USED FOR GAS TERMS
NO RADIUS CORRECTION ON CH
NO CHAR SWELL CORRECTION ON SURFACE RECESSION

P = 25.8000 ATM

TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL
7200.00	1238.56	4500.00	-52.83	1800.00	-1224.09
6300.00	799.88	3600.00	-459.20	900.00	-1569.16
5400.00	367.99	2700.00	-850.36		

M-DOT-GAS/CM = 3.0000 PRESSURE = 25.8000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
900.00	0.0010	7802.62		4669.79	0.0100	4556.33	C*
1800.00	0.0010	9810.21		4737.91	0.0250	4520.25	C*
2700.00	0.0010	3628.15		4837.91	0.0500	4444.11	C*
3600.00	0.0010	4641.37		5003.01	0.1000	4249.26	C*
4500.00	0.0010	4512.65		5729.43	0.5000	2826.45	C*
4625.15	0.0010	4573.60	C*	5994.76	0.7500	1789.28	C*
4645.37	0.0050	4566.37	C*	6201.93	1.0000	451.58	C*

M-DOT-GAS/CM = 0.0000 PRESSURE = 25.8000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
1700.74	0.0050	1107.04	C*	4354.18	0.1250	-181.28	C*
1800.49	0.0100	957.82	C*	5099.07	0.1500	-414.36	C*
1915.74	0.0250	751.45	C*	5737.75	0.2000	-961.08	C*
2042.14	0.0500	503.57	C*	6356.43	0.3000	-2115.77	C*
2346.15	0.1000	65.29	C*	6943.50	0.5000	-4368.80	C*
2603.43	0.1125	-62.35	C*	7316.90	0.7500	-7040.68	C*
3041.04	0.1156	-111.59	C*	7542.48	1.0000	-9621.17	C*
3875.01	0.1187	-135.97	C*				

M-DOT-GAS/CM = 1.0000 PRESSURE = 25.8000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
900.00	0.0010	3597.09		3673.47	0.0493	1505.80	C*
1800.00	0.0010	3873.20		3677.99	0.0493	1505.92	C*
2226.90	0.0010	1602.94	C*	3686.83	0.0494	1506.14	C*
2241.14	0.0050	1564.41	C*	3703.81	0.0496	1506.53	C*
2260.13	0.0100	1516.14	C*	3735.09	0.0500	1507.08	C*
2329.39	0.0250	1369.86	C*	4472.82	0.0750	1407.12	C*
2417.61	0.0375	1245.13	C*	4784.67	0.1000	1315.19	C*
2493.60	0.0437	1182.43	C*	5419.75	0.2000	708.28	C*
2559.86	0.0469	1147.13	C*	5774.24	0.3000	270.49	C*
2618.95	0.0484	1127.08	C*	6223.75	0.5000	-1024.38	C*
2676.43	0.0492	1117.96	C*	6582.92	0.7500	-2549.45	C*
3671.18	0.0492	1505.73	C*	6835.52	1.0000	-4303.92	C*

M-DOT-GAS/CM = 0.7500 PRESSURE = 25.8000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
900.00	0.0010	3071.38		3874.63	0.0688	1095.64	C*
1800.00	0.0010	3136.27		4151.20	0.0750	1074.75	C*
2160.13	0.0010	1423.93	C*	4672.47	0.1000	957.50	C*
2173.12	0.0050	1386.41	C*	5466.14	0.2000	341.16	C*
2189.96	0.0100	1339.67	C*	5863.73	0.3000	-207.57	C*
2246.40	0.0250	1199.85	C*	6346.15	0.5000	-1636.65	C*
2388.40	0.0500	963.62	C*	6717.83	0.7500	-3344.75	C*
2572.87	0.0625	839.76	C*	6972.41	1.0000	-5323.59	C*
3609.19	0.0656	1095.79	C*				

M-DOT-GAS/CM = 0.5000 PRESSURE = 25.0000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
900.00	0.0010	2545.65		3798.84	0.0844	687.06	C*
1800.00	0.0010	2402.84		4011.05	0.0875	677.59	C*
2082.38	0.0010	1250.87	C*	4451.96	0.1000	608.84	C*
2095.73	0.0050	1212.97	C*	5162.17	0.1500	297.26	C*
2112.52	0.0100	1166.29	C*	5527.22	0.2000	-48.53	C*
2165.30	0.0250	1028.82	C*	5979.63	0.3000	-741.25	C*
2273.37	0.0500	803.02	C*	6498.23	0.5000	-2293.11	C*
2495.66	0.0750	572.22	C*	6879.60	0.7500	-4325.45	C*
2773.41	0.0812	514.88	C*	7132.30	1.0000	-6528.71	C*
3629.57	0.0828	688.24	C*				

M-DOT-GAS/CM = 0.2500 PRESSURE = 25.0000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
900.00	0.0010	2019.87		3087.48	0.0984	224.98	C*
1800.00	0.0010	1675.77		3640.38	0.1000	280.46	C*
1973.13	0.0010	1110.69	C*	4422.70	0.1125	212.02	C*
1989.96	0.0050	1061.79	C*	4750.19	0.1250	131.34	C*
2010.27	0.0100	1011.32	C*	5146.81	0.1500	-64.54	C*
2068.73	0.0250	868.04	C*	5611.73	0.2000	-473.80	C*
2169.75	0.0500	644.04	C*	6135.61	0.3000	-1359.83	C*
2305.72	0.0750	424.31	C*	6691.59	0.5000	-3174.15	C*
2426.22	0.0875	310.43	C*	7075.98	0.7500	-5539.85	C*
2546.75	0.0938	250.13	C*	7320.33	1.0000	-7951.74	C*
2687.97	0.0969	216.26	C*				

M-DOT-GAS/CM = 0.1000 PRESSURE = 25.0000 ATM

TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES	TEMP (DEG R)	M-DOT-CHAR/CM	CHEM.PROD (BTU/LB)	SURFACE SPECIES
900.00	0.0010	1704.35		3411.33	0.1094	30.81	C*
1800.00	0.0010	1245.43		3923.04	0.1125	25.61	C*
1858.33	0.0010	1114.56	C*	4576.05	0.1250	-62.04	C*
1885.73	0.0050	1048.40	C*	5124.74	0.1500	-276.66	C*
1915.44	0.0100	974.56	C*	5680.45	0.2000	-755.97	C*
1989.89	0.0250	787.46	C*	6257.98	0.3000	-1792.02	C*
2098.98	0.0500	555.61	C*	6834.30	0.5000	-3846.45	C*
2452.64	0.1000	113.09	C*	7214.47	0.7500	-6402.75	C*
2639.51	0.1063	46.88	C*	7449.11	1.0000	-8922.48	C*

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c=0.27

----OUTPUT----

- - - - - - - - - - - - - - 120.0000 SECONDS - - - - - - - - - - - - - -

TIME STEP	SURF ITER	PROB OPTN	SURFACE RAD (IN)	H WALL (BTU/LB)	H EDGE (BTU/LB)	HEAT COEFF (LB/SQ FT-SEC)	CH/CHO
7894	3	1	28.4981	286.75	730.00	0.0435	0.86525

---ABLATION RATES---

B PRIME	B PRIME G	M DOT CHAR (LB/SQ FT-SEC)	M DOT GAS (LB/SQ FT-SEC)	M CHAR (LB/ORIG SQ FT)	M GAS (LB/ORIG SQ FT)
0.55592	0.39801	0.004914	0.012385	9.846972	2.795194

---RECESSIONS/RECESSION RATES---

(IN) / (IN/SEC)

SURFACE	CHAR (0.27)	PYROLYSIS (0.98)
1.5680959/0.0008053	1.7842326/0.0070896	1.8653069/0.0096762

---SURFACE ENERGY FLUX TERMS---

CURRENT RATES (BTU/SQ FT SURFACE-SEC)
AND INTEGRATED VALUES (BTU/ORIG SQ FT)

	CONVECTED IN	RADIATED IN	RADIATED OUT	CHEMICAL GENERATION	CONDUCTION AWAY
RATE	0.193E+02	0.446E+03	0.306E+03	0.258E+01	0.163E+03
TOTAL	0.440E+05	0.553E+05	0.356E+05	-0.247E+05	0.390E+05

---INTERIOR ENERGY TERMS---

CURRENT RATES (BTU/SQ FT SURFACE-SEC)
AND INTEGRATED VALUES (BTU/ORIG SQ FT)

	PYROL GAS PICK UP	DECOMP ABSORPTION	CONVECTION WITH SOLIDS	STORAGE IN SOLID	LOSS AT REAR FACE
RATE	0.544E+02	0.119E+02	0.124E+02	0.839E+02	0.205E-04
TOTAL	0.112E+05	0.315E+04	0.222E+05	0.237E+04	0.188E-02

NODE	MAT	TEMP (DEG R)	DENSITY (LB/CU FT)	ENTHALPY (BTU/LB)	NODE	MAT	TEMP (DEG R)	DENSITY (LB/CU FT)	ENTHALPY (BTU/LB)
1	0	5228.42	73.342	2048.82	19	1	521.04	91.300	-367.55
2	0	5201.76	73.291	2035.66	20	1	520.35	91.300	-367.76
3	0	5168.35	73.292	2018.19	21	1	520.12	91.300	-367.83
4	0	5121.39	73.294	1993.63	22	1	520.04	91.300	-367.85
5	0	5026.49	73.298	1944.00	23	1	520.02	91.300	-367.86
6	0	4890.25	73.304	1872.74	24	1	520.01	91.300	-367.86
7	0	4752.00	73.312	1800.42	25	1	520.01	91.300	-367.86
8	0	4611.74	73.321	1727.02	26	1	520.01	91.300	-367.86
9	0	4469.35	73.332	1652.49	27	1	520.01	91.300	-367.86
10	0	4004.73	73.381	1414.82	28	1	520.00	91.300	-367.86
11	0	2837.02	73.941	833.71	29	1	520.00	91.300	-367.86
12	0	1537.98	85.045	115.63	30	1	520.00	91.300	-367.86
13	0	940.30	91.225	-227.46	31	1	520.00	91.300	-367.86
14	1	699.13	91.300	-313.41	32	1	520.00	91.300	-367.86
15	1	590.97	91.300	-346.29	33	1	520.00	91.300	-367.86
16	1	546.02	91.300	-359.95	47	3	520.00	108.800	0.00
17	1	529.11	91.300	-365.09	48	3	520.00	108.800	0.00
18	1	523.11	91.300	-366.92	49	4	520.00	499.400	0.00

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CMA Results for RSRM Nozzle Throat Problem

1. Predicted Erosion = 1.466 inches
2. Char Depth = (1.698 - 1.466) = 0.232 inches
3. Bondline Temperature = 60°F (ambient)
4. Nozzle Liner Design Criteria:
   a. Design Thickness = (2 x erosion) + (1.25 x char depth)

      *t, design = 3.222 inches

      t, liner = 3.710 inches

   b. Safety Margin (SM) must be GE 0.0

      SM = (t, liner/t, design) - 1.0

      *SM = 0.151

Introduction to Chapter 8

Model Generation

Because of the rapid increase in graphics capability in state-of-the-art computing systems, geometric generation of analytical models has rapidly grown in popularity. These techniques have evolved from finite element structural analysis codes, but are now utilized for fluid and thermal analyses as well. Even though many thermal analyzers utilize a finite difference solution procedure, geometric model generators, and translators, have been developed to utilize the advanced computer graphics capability. This chapter shows several examples illustrating popular model generation software. A significant advantage of utilization of these codes is the use of graphics post processing of analytical results. The color representations of temperature distributions are valuable communication aids, especially with management. Several simple geometries are given as examples of code utilization, and a set of problems involving complex geometries are shown to illustrate the versatility of these techniques.

CHAPTER 8: MODEL GENERATION

SECTION 1: SINGEN Example

I. Description of Code:

SINGEN is a computer code that was initially developed to create a nodal mesh for the SINDA thermal analyzer code. SINGEN generates the Node, Conductor, Constant, and Array Data Blocks for the SINDA program. It computes the volume of each node and assigns it a value in the Constants Data Block that will be multiplied by the $\rho * C_p$ of the material to form the capacitance of that node. Similarly, it computes an A/x value for each conductor and assigns it a value in the Constants Data Block that will be multiplied by the conductivity of the material to form the conductance of the conductor. Radiation and convection heat transfer boundary conditions, mathematical calculations, FORTRAN code, and other SINDA statements must be input separately.

When creating a nodal mesh within the geometry, it is recommended to create the nodes so that any side of one node will only be conducting to one node. Figure A is the correct way.

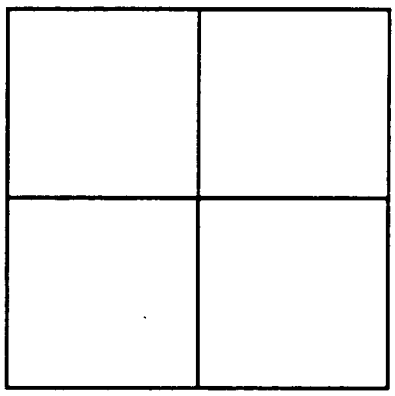


FIGURE A

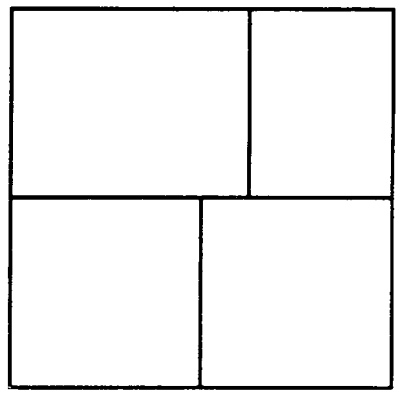


FIGURE B

II. Input

The data required for SINGEN can be input interactively with the computer prompting you for the data, or it can be included in a separate input file. If the model is large, it is generally quicker and easier to use the input file. Generally, four data points are required to generate a 2-dimensional section while eight data points are needed for a 3-dimensional section. These data points are the coordinates at the four or eight corners of the section. The coordinate system must be specified as being 2-D or 3-D and cartesian, cylindrical, or spherical. The size of the mesh is controlled by inputing the number of nodes desired between two opposite sides. A conductor network is also created by specifying which sides of two sections are to be connected.

SINGEN EXAMPLE INPUT

```
8,1,8,1,1
1,1,1,10,8,0.,0.,0.,0.,0.,0.,0
1,1.,1.,0.
2,0.,1.,0.
3,0.,0.,0.
4,1.,0.,0.
5,4.,1.,-8.
6,3.,1.,-8.
7,3.,0.,-8.
8,4.,0.,-8.
0,0,0,0,0,0
2,2,2
1,2,1,10,8,0.,0.,0.,0.,0.,0.,0
1,5.,1.,0.
2,1.,1.,0.
3,1.,0.,0.
4,5.,0.,0.
5,8.,1.,-8.
6,4.,1.,-8.
7,4.,0.,-8.
8,8.,0.,-8.
0,0,0,0,0,0
4,2,2
1,3,1,10,8,0.,0.,0.,0.,0.,0.,0
1,6.,1.,0.
2,5.,1.,0.
3,5.,0.,0.
4,6.,0.,0.
5,9.,1.,-8.
6,8.,1.,-8.
7,8.,0.,-8.
8,9.,0.,-8.
0,0,0,0,0,0
2,2,2
1,4,1,10,8,0.,0.,0.,0.,0.,0.,0
1,1.,5.,0.
2,0.,5.,0.
3,0.,1.,0.
4,1.,1.,0.
5,4.,5.,-8.
6,3.,5.,-8.
7,3.,1.,-8.
8,4.,1.,-8.
0,0,0,0,0,0
2,4,2
1,5,1,10,8,0.,0.,0.,0.,0.,0.,0
1,6.,5.,0.
2,5.,5.,0.
3,5.,1.,0.
4,6.,1.,0.
5,9.,5.,-8.
6,8.,5.,-8.
7,8.,1.,-8.
8,9.,1.,-8.
0,0,0,0,0,0
2,4,2
1,6,1,10,8,0.,0.,0.,0.,0.,0.,0
1,1.,6.,0.
2,0.,6.,0.
3,0.,5.,0.
4,1.,5.,0.
5,4.,6.,-8.
```

```
6,3.,6.,-8.
7,3.,5.,-8.
8,4.,5.,-8.
0,0,0,0,0,0
2,2,2
1,7,1,10,8,0.,0.,0.,0.,0.,0.,0
1,5.,6.,0.
2,1.,6.,0.
3,1.,5.,0.
4,5.,5.,0.
5,8.,6.,-8.
6,4.,6.,-8.
7,4.,5.,-8.
8,8.,5.,-8.
0,0,0,0,0,0
4,2,2
1,8,1,10,8,0.,0.,0.,0.,0.,0.,0
1,6.,6.,0.
2,5.,6.,0.
3,5.,5.,0.
4,6.,5.,0.
5,9.,6.,-8.
6,8.,6.,-8.
7,8.,5.,-8.
8,9.,5.,-8.
0,0,0,0,0,0
2,2,2
1,1,3,1,2,1
1,2,3,1,3,1
1,3,2,1,5,4
1,5,2,1,8,4
1,8,1,1,7,3
1,7,1,1,6,3
1,6,4,1,4,2
1,4,4,1,1,2
1
STEEL
1.0
5
200.0,0.03113
1280.0,0.05235
1380.0,0.1061
1560.0,0.03905
1600.0,0.04188
10
0.0,0.4630E-03
200.0,0.5090E-03
300.0,0.5210E-03
400.0,0.5090E-03
600.0,0.4980E-03
800.0,0.4750E-03
1000.0,0.4510E-03
1200.0,0.4170E-03
1400.0,0.3700E-03
1600.0,0.3590E-03
0
```

III. Output

The two main files created by SINGEN are the SINDA skeleton program and a geometric input file for either a MOVIE.BYU or PATRAN graphics package. Other optional files create a session log file, store the node center coordinates or store the surface area of nodal surfaces.

SINDA Output File

```
BCD 3THERMAL LPCS
BCD 9
END
BCD 3NODE DATA
SIV      1,   70.0,A1    , K1      $
SIV      2,   70.0,A1    , K1      $
SIV      3,   70.0,A1    , K1      $
SIV      4,   70.0,A1    , K1      $
SIV      5,   70.0,A1    , K1      $
SIV      6,   70.0,A1    , K1      $
SIV      7,   70.0,A1    , K1      $
SIV      8,   70.0,A1    , K1      $
SIV      9,   70.0,A1    , K2      $
SIV     10,   70.0,A1    , K2      $
SIV     11,   70.0,A1    , K2      $
SIV     12,   70.0,A1    , K2      $
SIV     13,   70.0,A1    , K2      $
SIV     14,   70.0,A1    , K2      $
SIV     15,   70.0,A1    , K2      $
SIV     16,   70.0,A1    , K2      $
SIV     17,   70.0,A1    , K2      $
SIV     18,   70.0,A1    , K2      $
SIV     19,   70.0,A1    , K2      $
SIV     20,   70.0,A1    , K2      $
SIV     21,   70.0,A1    , K2      $
SIV     22,   70.0,A1    , K2      $
SIV     23,   70.0,A1    , K2      $
SIV     24,   70.0,A1    , K2      $
SIV     25,   70.0,A1    , K1      $
SIV     26,   70.0,A1    , K1      $
SIV     27,   70.0,A1    , K1      $
SIV     28,   70.0,A1    , K1      $
SIV     29,   70.0,A1    , K1      $
SIV     30,   70.0,A1    , K1      $
SIV     31,   70.0,A1    , K1      $
SIV     32,   70.0,A1    , K1      $
SIV     33,   70.0,A1    , K2      $
SIV     34,   70.0,A1    , K2      $
SIV     35,   70.0,A1    , K2      $
SIV     36,   70.0,A1    , K2      $
SIV     37,   70.0,A1    , K2      $
SIV     38,   70.0,A1    , K2      $
SIV     39,   70.0,A1    , K2      $
SIV     40,   70.0,A1    , K2      $
SIV     41,   70.0,A1    , K2      $
SIV     42,   70.0,A1    , K2      $
SIV     43,   70.0,A1    , K2      $
SIV     44,   70.0,A1    , K2      $
SIV     45,   70.0,A1    , K2      $
SIV     46,   70.0,A1    , K2      $
SIV     47,   70.0,A1    , K2      $
SIV     48,   70.0,A1    , K2      $
SIV     49,   70.0,A1    , K2      $
```

```
SIV     50,   70.0,A1    , K2      $
SIV     51,   70.0,A1    , K2      $
SIV     52,   70.0,A1    , K2      $
SIV     53,   70.0,A1    , K2      $
SIV     54,   70.0,A1    , K2      $
SIV     55,   70.0,A1    , K2      $
SIV     56,   70.0,A1    , K2      $
SIV     57,   70.0,A1    , K2      $
SIV     58,   70.0,A1    , K2      $
SIV     59,   70.0,A1    , K2      $
SIV     60,   70.0,A1    , K2      $
SIV     61,   70.0,A1    , K2      $
SIV     62,   70.0,A1    , K2      $
SIV     63,   70.0,A1    , K2      $
SIV     64,   70.0,A1    , K2      $
SIV     65,   70.0,A1    , K1      $
SIV     66,   70.0,A1    , K1      $
SIV     67,   70.0,A1    , K1      $
SIV     68,   70.0,A1    , K1      $
SIV     69,   70.0,A1    , K1      $
SIV     70,   70.0,A1    , K1      $
SIV     71,   70.0,A1    , K1      $
SIV     72,   70.0,A1    , K1      $
SIV     73,   70.0,A1    , K2      $
SIV     74,   70.0,A1    , K2      $
SIV     75,   70.0,A1    , K2      $
SIV     76,   70.0,A1    , K2      $
SIV     77,   70.0,A1    , K2      $
SIV     78,   70.0,A1    , K2      $
SIV     79,   70.0,A1    , K2      $
SIV     80,   70.0,A1    , K2      $
SIV     81,   70.0,A1    , K2      $
SIV     82,   70.0,A1    , K2      $
SIV     83,   70.0,A1    , K2      $
SIV     84,   70.0,A1    , K2      $
SIV     85,   70.0,A1    , K2      $
SIV     86,   70.0,A1    , K2      $
SIV     87,   70.0,A1    , K2      $
SIV     88,   70.0,A1    , K2      $
SIV     89,   70.0,A1    , K1      $
SIV     90,   70.0,A1    , K1      $
SIV     91,   70.0,A1    , K1      $
SIV     92,   70.0,A1    , K1      $
SIV     93,   70.0,A1    , K1      $
SIV     94,   70.0,A1    , K1      $
SIV     95,   70.0,A1    , K1      $
SIV     96,   70.0,A1    , K1      $
END
BCD 3CONDUCTOR DATA
SIV        1,       1,       2, A2     , K100     $
SIV        5,       1,       3, A2     , K100     $
SIV        9,       1,       5, A2     , K101     $
SIV        6,       2,       4, A2     , K100     $
SIV       10,       2,       6, A2     , K101     $
SIV        2,       3,       4, A2     , K100     $
SIV       11,       3,       7, A2     , K101     $
SIV       12,       4,       8, A2     , K101     $
SIV        3,       5,       6, A2     , K100     $
SIV        7,       5,       7, A2     , K100     $
SIV        8,       6,       8, A2     , K100     $
SIV        4,       7,       8, A2     , K100     $
SIV       13,       9,      10, A2     , K102     $
SIV       25,       9,      13, A2     , K103     $
SIV       33,       9,      17, A2     , K104     $
```

```
SIV     14,     10,     11, A2    , K102    $
SIV     26,     10,     14, A2    , K103    $
SIV     34,     10,     18, A2    , K104    $
SIV     15,     11,     12, A2    , K102    $
SIV     27,     11,     15, A2    , K103    $
SIV     35,     11,     19, A2    , K104    $
SIV     28,     12,     16, A2    , K103    $
SIV     36,     12,     20, A2    , K104    $
SIV     16,     13,     14, A2    , K102    $
SIV     37,     13,     21, A2    , K104    $
SIV     17,     14,     15, A2    , K102    $
SIV     38,     14,     22, A2    , K104    $
SIV     18,     15,     16, A2    , K102    $
SIV     39,     15,     23, A2    , K104    $
SIV     40,     16,     24, A2    , K104    $
SIV     19,     17,     18, A2    , K102    $
SIV     29,     17,     21, A2    , K103    $
SIV     20,     18,     19, A2    , K102    $
SIV     30,     18,     22, A2    , K103    $
SIV     21,     19,     20, A2    , K102    $
SIV     31,     19,     23, A2    , K103    $
SIV     32,     20,     24, A2    , K103    $
SIV     22,     21,     22, A2    , K102    $
SIV     23,     22,     23, A2    , K102    $
SIV     24,     23,     24, A2    , K102    $
SIV     41,     25,     26, A2    , K100    $
SIV     45,     25,     27, A2    , K100    $
SIV     49,     25,     29, A2    , K101    $
SIV     46,     26,     28, A2    , K100    $
SIV     50,     26,     30, A2    , K101    $
SIV     42,     27,     28, A2    , K100    $
SIV     51,     27,     31, A2    , K101    $
SIV     52,     28,     32, A2    , K101    $
SIV     43,     29,     30, A2    , K100    $
SIV     47,     29,     31, A2    , K100    $
SIV     48,     30,     32, A2    , K100    $
SIV     44,     31,     32, A2    , K100    $
SIV     53,     33,     34, A2    , K103    $
SIV     61,     33,     35, A2    , K102    $
SIV     73,     33,     41, A2    , K104    $
SIV     62,     34,     36, A2    , K102    $
SIV     74,     34,     42, A2    , K104    $
SIV     54,     35,     36, A2    , K103    $
SIV     63,     35,     37, A2    , K102    $
SIV     75,     35,     43, A2    , K104    $
SIV     64,     36,     38, A2    , K102    $
SIV     76,     36,     44, A2    , K104    $
SIV     55,     37,     38, A2    , K103    $
SIV     65,     37,     39, A2    , K102    $
SIV     77,     37,     45, A2    , K104    $
SIV     66,     38,     40, A2    , K102    $
SIV     78,     38,     46, A2    , K104    $
SIV     56,     39,     40, A2    , K103    $
SIV     79,     39,     47, A2    , K104    $
SIV     80,     40,     48, A2    , K104    $
SIV     57,     41,     42, A2    , K103    $
SIV     67,     41,     43, A2    , K102    $
SIV     68,     42,     44, A2    , K102    $
SIV     58,     43,     44, A2    , K103    $
SIV     69,     43,     45, A2    , K102    $
SIV     70,     44,     46, A2    , K102    $
SIV     59,     45,     46, A2    , K103    $
SIV     71,     45,     47, A2    , K102    $
SIV     72,     46,     48, A2    , K102    $
```

```
SIV      60,    47,    48, A2    , K103    $
SIV      81,    49,    50, A2    , K103    $
SIV      89,    49,    51, A2    , K102    $
SIV     101,    49,    57, A2    , K104    $
SIV      90,    50,    52, A2    , K102    $
SIV     102,    50,    58, A2    , K104    $
SIV      82,    51,    52, A2    , K103    $
SIV      91,    51,    53, A2    , K102    $
SIV     103,    51,    59, A2    , K104    $
SIV      92,    52,    54, A2    , K102    $
SIV     104,    52,    60, A2    , K104    $
SIV      83,    53,    54, A2    , K103    $
SIV      93,    53,    55, A2    , K102    $
SIV     105,    53,    61, A2    , K104    $
SIV      94,    54,    56, A2    , K102    $
SIV     106,    54,    62, A2    , K104    $
SIV      84,    55,    56, A2    , K103    $
SIV     107,    55,    63, A2    , K104    $
SIV     108,    56,    64, A2    , K104    $
SIV      85,    57,    58, A2    , K103    $
SIV      95,    57,    59, A2    , K102    $
SIV      96,    58,    60, A2    , K102    $
SIV      86,    59,    60, A2    , K103    $
SIV      97,    59,    61, A2    , K102    $
SIV      98,    60,    62, A2    , K102    $
SIV      87,    61,    62, A2    , K103    $
SIV      99,    61,    63, A2    , K102    $
SIV     100,    62,    64, A2    , K102    $
SIV      88,    63,    64, A2    , K103    $
SIV     109,    65,    66, A2    , K100    $
SIV     113,    65,    67, A2    , K100    $
SIV     117,    65,    69, A2    , K101    $
SIV     114,    66,    68, A2    , K100    $
SIV     118,    66,    70, A2    , K101    $
SIV     110,    67,    68, A2    , K100    $
SIV     119,    67,    71, A2    , K101    $
SIV     120,    68,    72, A2    , K101    $
SIV     111,    69,    70, A2    , K100    $
SIV     115,    69,    71, A2    , K100    $
SIV     116,    70,    72, A2    , K100    $
SIV     112,    71,    72, A2    , K100    $
SIV     121,    73,    74, A2    , K102    $
SIV     133,    73,    77, A2    , K103    $
SIV     141,    73,    81, A2    , K104    $
SIV     122,    74,    75, A2    , K102    $
SIV     134,    74,    78, A2    , K103    $
SIV     142,    74,    82, A2    , K104    $
SIV     123,    75,    76, A2    , K102    $
SIV     135,    75,    79, A2    , K103    $
SIV     143,    75,    83, A2    , K104    $
SIV     136,    76,    80, A2    , K103    $
SIV     144,    76,    84, A2    , K104    $
SIV     124,    77,    78, A2    , K102    $
SIV     145,    77,    85, A2    , K104    $
SIV     125,    78,    79, A2    , K102    $
SIV     146,    78,    86, A2    , K104    $
SIV     126,    79,    80, A2    , K102    $
SIV     147,    79,    87, A2    , K104    $
SIV     148,    80,    88, A2    , K104    $
SIV     127,    81,    82, A2    , K102    $
SIV     137,    81,    85, A2    , K103    $
SIV     128,    82,    83, A2    , K102    $
SIV     138,    82,    86, A2    , K103    $
SIV     129,    83,    84, A2    , K102    $
```

```
SIV      139,     83,     87, A2    , K103    $
SIV      140,     84,     88, A2    , K103    $
SIV      130,     85,     86, A2    , K102    $
SIV      131,     86,     87, A2    , K102    $
SIV      132,     87,     88, A2    , K102    $
SIV      149,     89,     90, A2    , K100    $
SIV      153,     89,     91, A2    , K100    $
SIV      157,     89,     93, A2    , K101    $
SIV      154,     90,     92, A2    , K100    $
SIV      158,     90,     94, A2    , K101    $
SIV      150,     91,     92, A2    , K100    $
SIV      159,     91,     95, A2    , K101    $
SIV      160,     92,     96, A2    , K101    $
SIV      151,     93,     94, A2    , K100    $
SIV      155,     93,     95, A2    , K100    $
SIV      156,     94,     96, A2    , K100    $
SIV      152,     95,     96, A2    , K100    $
SIV      161,      2,      9, A2    , K105    $
SIV      162,      4,     13, A2    , K105    $
SIV      163,      6,     17, A2    , K105    $
SIV      164,      8,     21, A2    , K105    $
SIV      165,     12,     25, A2    , K105    $
SIV      166,     16,     27, A2    , K105    $
SIV      167,     20,     29, A2    , K105    $
SIV      168,     24,     31, A2    , K105    $
SIV      169,     27,     49, A2    , K106    $
SIV      170,     28,     50, A2    , K106    $
SIV      171,     31,     57, A2    , K106    $
SIV      172,     32,     58, A2    , K106    $
SIV      173,     55,     89, A2    , K106    $
SIV      174,     56,     90, A2    , K106    $
SIV      175,     63,     93, A2    , K106    $
SIV      176,     64,     94, A2    , K106    $
SIV      177,     89,     76, A2    , K105    $
SIV      178,     91,     80, A2    , K105    $
SIV      179,     93,     84, A2    , K105    $
SIV      180,     95,     88, A2    , K105    $
SIV      181,     73,     66, A2    , K105    $
SIV      182,     77,     68, A2    , K105    $
SIV      183,     81,     70, A2    , K105    $
SIV      184,     85,     72, A2    , K105    $
SIV      185,     65,     39, A2    , K106    $
SIV      186,     66,     40, A2    , K106    $
SIV      187,     69,     47, A2    , K106    $
SIV      188,     70,     48, A2    , K106    $
SIV      189,     33,      3, A2    , K106    $
SIV      190,     34,      4, A2    , K106    $
SIV      191,     41,      7, A2    , K106    $
SIV      192,     42,      8, A2    , K106    $
END
BCD 3CONSTANTS DATA

          1, 0.10000E+01 $
          2, 0.20000E+01 $

        100, 0.42720E+01 $
        101, 0.58521E-01 $
        102, 0.21360E+01 $
        103, 0.85440E+01 $
        104, 0.11704E+00 $
        105, 0.28480E+01 $
        106, 0.26667E+01 $
END
BCD 3ARRAY DATA
```

```
      1
     200.0, 0.3113E-01
    1280.0, 0.5235E-01
    1380.0, 0.1061E+00
    1560.0, 0.3905E-01
    1600.0, 0.4188E-01
    END  $ T VS RHO*CP , STEEL
      2
       0.0, 0.4630E-03
     200.0, 0.5090E-03
     300.0, 0.5210E-03
     400.0, 0.5090E-03
     600.0, 0.4980E-03
     800.0, 0.4750E-03
    1000.0, 0.4510E-03
    1200.0, 0.4170E-03
    1400.0, 0.3700E-03
    1600.0, 0.3590E-03
    END  $ T VS K , STEEL
 END
 BCD 3EXECUTION
DIMENSION X(   384)
NDIM=   384
NTH=0
 END
 BCD 3VARIABLES 1
 END
 BCD 3VARIABLES 2
 END
 BCD 3OUTPUT CALLS
     TPRINT
 END
 BCD 3END OF DATA
```

IV. Execution

Before beginning, the following statements must be added to the LOGIN.COM file:

```
$ SINX3:==RUN[044024.SINGEN]SINX3
$ SECTION:==RUN[044024.MOVIEBYU]SECTION
$ COMMAND:==RUN[044024.MOVIEBYU]COMMAND
```

V. Troubleshooting

Most of the errors in SINGEN will result from not following correct format in the input file. Two of the most common mistakes are using a comma where it doesn't belong or using a period instead of a comma. This should be the first thing checked in the event of an error. A problem may also be detected when the geometry is plotted. If this happens, a number was probably typed incorrectly when defining points or mesh.

VI. Example

```
$ SINX3

Output a session log file (Yes/No)
Y
Input the session log filename
MODEL.LOG

  Input:
   0 To enter all dat via the terminal keyboard
   1 To enter geometry, connection, and material
       data via a SINGEN-formatted input file
1

 Enter input filename:
MODEL.INP

 Input:
   1     To generate an output file for a SINDA model
   2     To generate an output file for ASTHMA
   3     To generate an output file for ABAQUS
   4     To generate an output file for SAPIV
1

  Enter SINDA output file name:
MODEL.SIN

 Input:
   0     If no additional output files desired
   1     IF you want to output a MOVIE.BYU file
   2     IF you want to output a PATRAN session file
1

  Enter MOVIE.BYU file name:
MODEL.BYU
```

*At this point, data will start rolling by on the screen. When it stops:

```
 Input initial thermal model temperature:
70

 Output node center coordinates (Yes/No)?
Y

 Enter node center coord output filename
MODEL.CEN

 Output node external surface areas (Yes/No)?
Y

  Enter node surface areas output filename
MODEL.SFA

 Enter starting constant for node statements
1
```

```
 Enter starting constant for conductor statements
100

 Enter minimum conductor ka/x option
<CR>
```

*At this point, data will again start rolling by. The first statement will be "START MESH GENERATION". After all of the data rolls by, it will stop and generate all of the files that were specified by your input. When it is complete, the following statement will appear:

```
* * * JOB FINISHED * * *
```

Then you will be kicked out of the SINX3.EXE file and the prompt will appear.

```
$ SECTION


<MOVIE SYSTEM PROCESSOR>
<FOR CLIPPING AND CAPPING OF SOLIDS>

<READ GEOM FILE>
MODEL.BYU

>> <CR>
```

It will take a couple of minutes here, depending on the size of the BYU file.

```
<WRITE GEOM FILE>
MODEL.GEO

<NUMBER OF DISPLACEMENT FILES>
<CR>

<NUMBER OF SCALAR FUNCTION FILES>
<CR>

<READ GEOM FILE>
<CR>
```

The prompt will appear again. The next section must be done on a Tektronix 4014 or a 4014 emulator. After logging on to the machine, you need to go to the subdirectory that the .GEO file is in. The purpose for this section is to view the geometry that has been created and verify that no mistakes have been make.

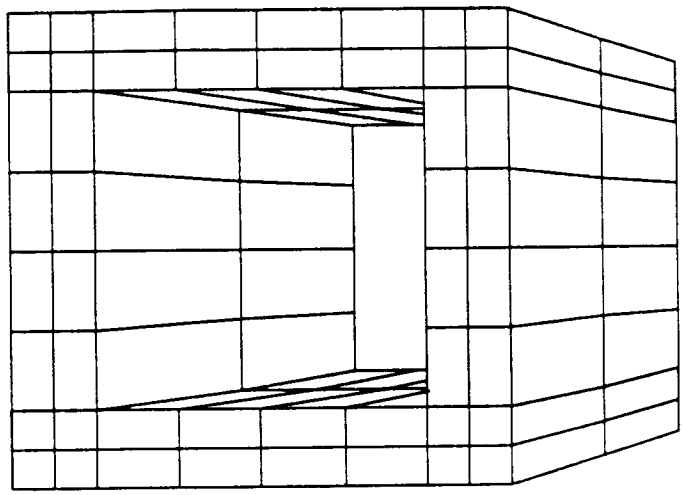
```
$ COMMAND

<MOVIE SYSTEM DISPLAY>
<READ GEOM FILE>
MODEL.GEO

<READ DISP FILE>
<CR>

<READ FUNC FILE>
<CR>
```

```
>>VIEW
```



The image may be rotated about any axis by typing ROTATE. It will prompt for the axis and angle. After those parameters have been input, type VIEW and the new orientation will be shown. Type EXIT to leave the program.

CHAPTER 8. MODEL GENERATION

SECTION 2: PATRAN (Version 2.4) Example

I. Introduction

Patran is a model generator that uses interactive graphics to link engineering design, analysis, and results. It was developed by PDA Engineering. This program provides a preprocessor and post-processor for a variety of analytical codes (e.g., ANSYS, SINDA, NASTRAN, etc). The preprocessor section consist of two parts, first the geometry input where the model is generated using simple geometric shapes. The second part consist of creating a finite element mesh of the geometry. This mesh is used to generate a neutral file which is used (with an appropriate translator) to create an analytical model. The program is located on VAX4 and Silicon Graphics workstations in the Thermal Analysis Branch. Tektronix terminals or emulators (4105, 4129 and 4211 drivers are active) are needed for the VAX version.

The post-processor function of Patran also depends on the analytical code used and its translator. Patran will create contour plots of the results (e.g., temperatures) and includes other general post-processor applications (e.g., time history, temperature distribution along local coordinates).

The Patran to SINDA translator is know as Patsin. Patsin uses the geometry, boundary conditions, and material properties applied to the model in Patran to generate the SINDA input file (see figure 1). The translation generates nodes and conductors, where the node numbers follow the FEM (finite element model) element numbers. The later version of Patsin (version 3.0) will also generate also a neutral file where the the SINDA nodes will match FEM node numbers and the conductors will follow bar element numbers. The next section will show how the translation is made.

The SINDA to Patran translator is known as Sinpat. Sinpat reads the SINDA temperature output file (with the appropriate format) and creates a file that Patran can read, usually in the format *modelnamecase#.els*. Each case is for a different time step or load case.

The following section presents details of both Patran and the translators as well as an example problem

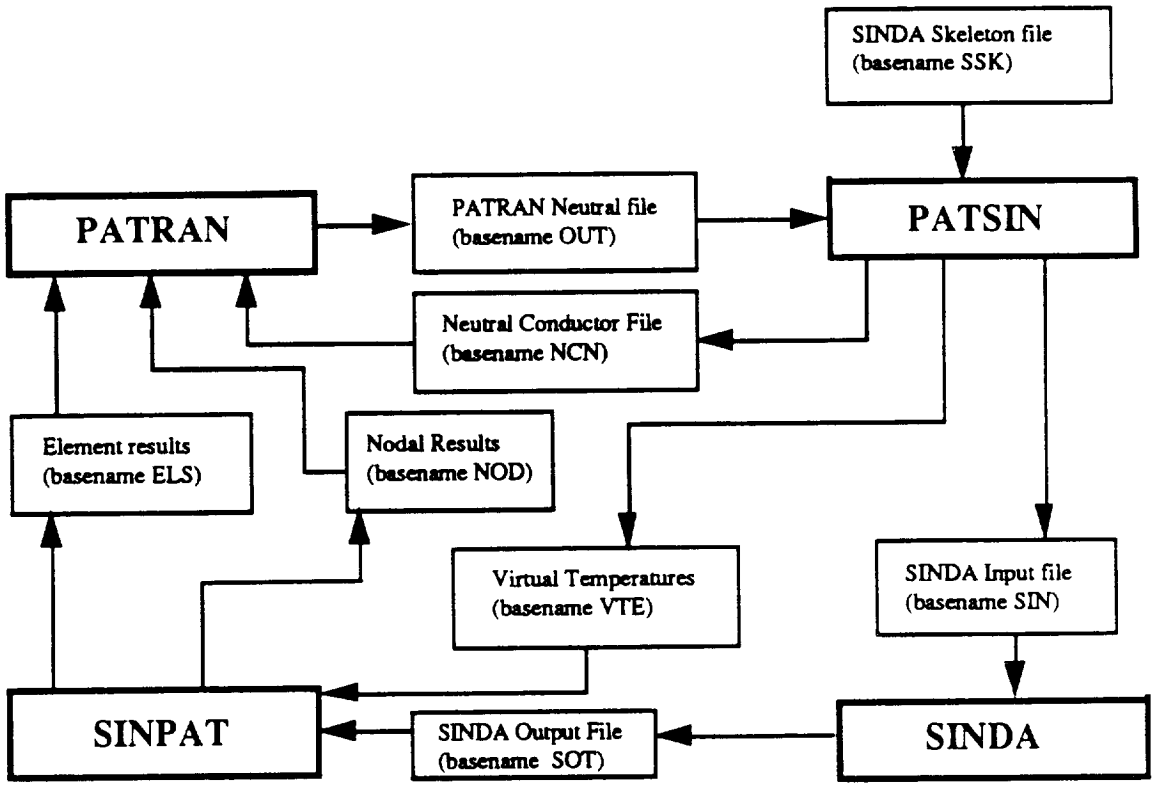


Figure 1

II. Example:

A. Statement of the Problem:

Consider a hardware piece exposed to a fluid at 70 °F on one end and on the other end is kept at a constant wall temperature (-200 °F). The piece is made out of two materials. The heat transfer coefficients between the fluid and the piece is 1.0 BTU/ft hr °F. The conductivity of material one is 1.0 BTU/hr ft °F, and for material two.is 52.1 BTU/hr ft °F.

B. Schematic

Figure 2 presents the schematic of this problem.

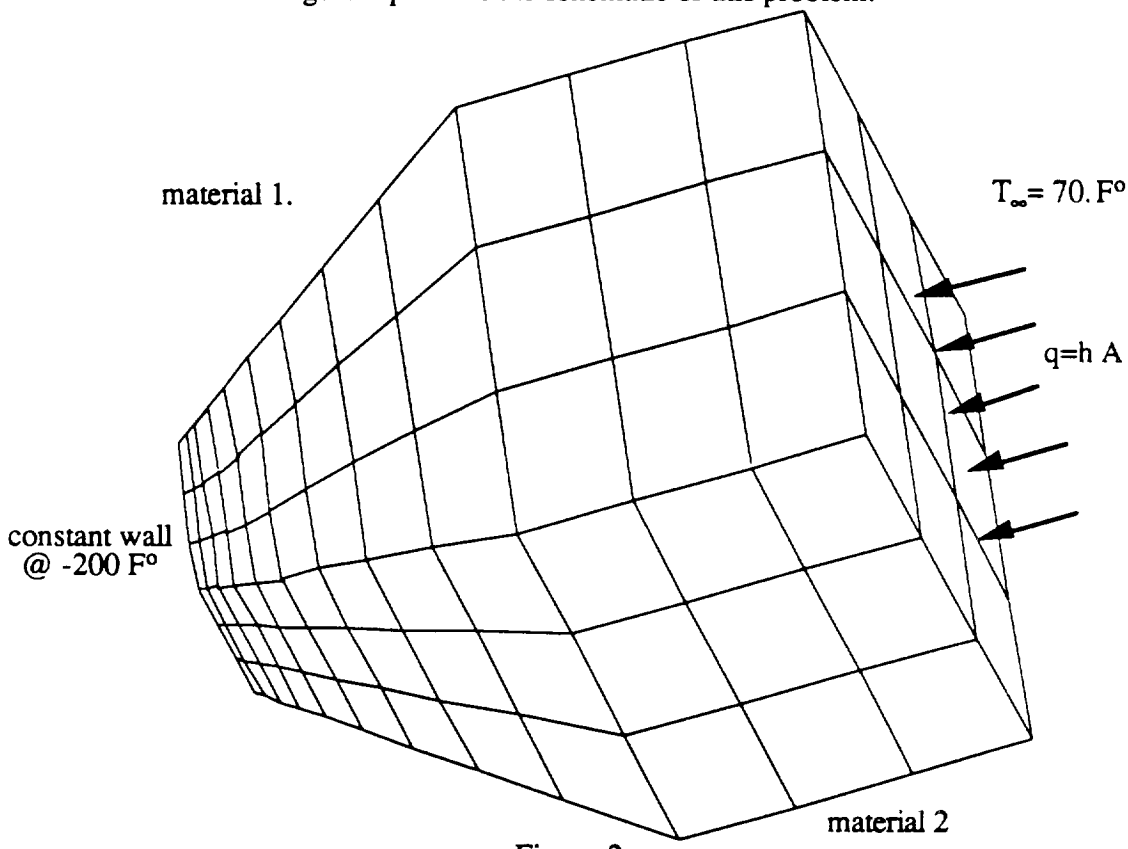


Figure 2.

C. Given

The following data is given to this problem:

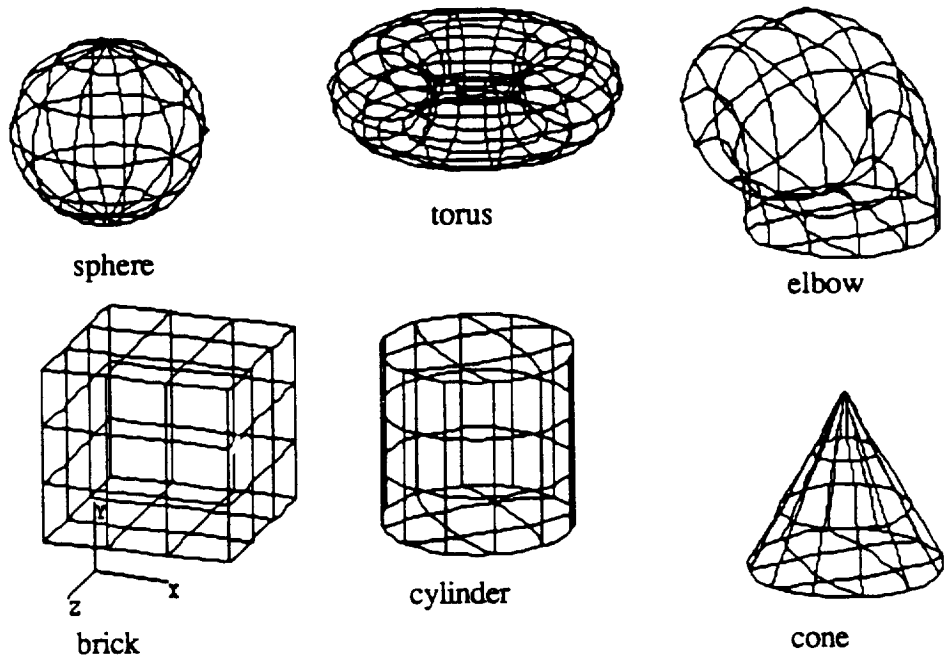
1. The piece dimensions
2. Boundary conditions, Heat transfer coefficient, and wall temperatures
3. Material properties.

D. Find

The steady state temperature distribution in the piece using PATRAN, PATSIN,and SINPAT.

III. PATRAN Model Generator:

Patran will generate a geometry model, create an analysis model, image a model, evaluate results, and create x-y plots. Two types of geometry input can be used to generate the model, one is known as phase 0, the other as phase 1. Phase 0 input consists of primitive geometry or simple geometric shapes. The primitive geometric entries will create (with a single command) a complete 3-D geometry. The available primitives are shown below.



Phase 1 geometry is the geometry that generates the analysis model (phase 2). Grid points, lines (1-D), patches (2-D), and hyperpatches (3-D) are the components of this phase (see figure 3). It can be created in various ways, from phase 0 geometry, by xyz coordinates, or using other phase 1 and phase 2 geometries.

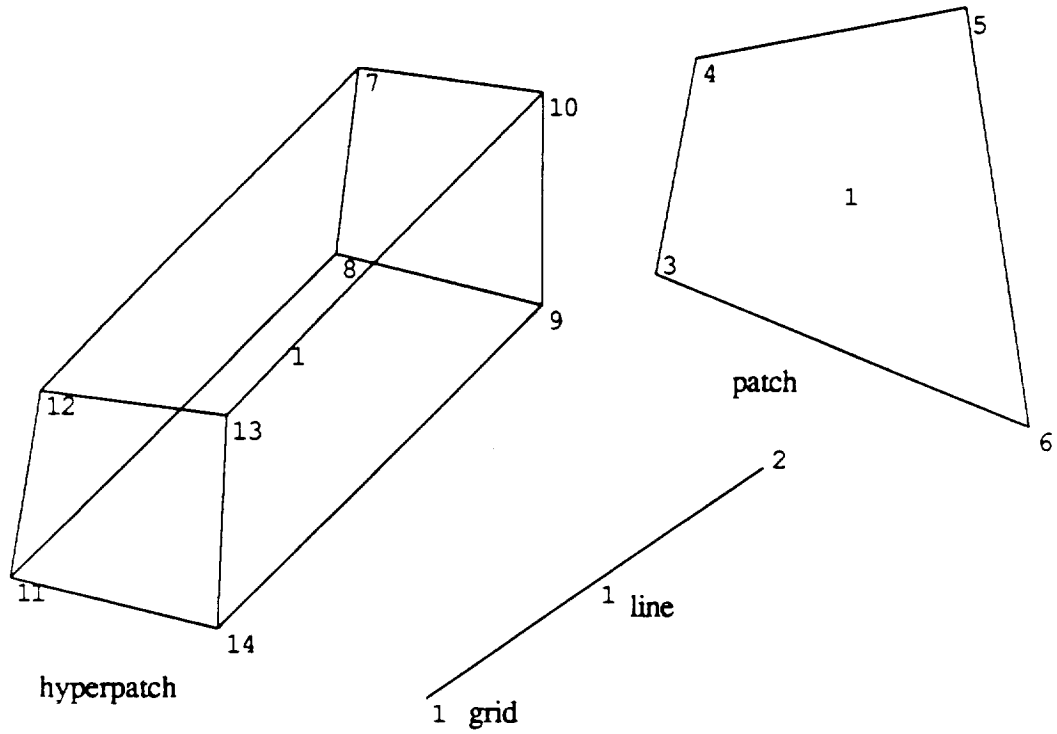


Figure 3

The geometry input method is more powerful than the example presented. The Patran manual (Volume I) presents the details and the options that can be used to generate more complex models.

Phase 2 is the actual model configuration that translates to the analytical code. The phase components are nodes, elements, property data, material data, and boundary conditions. The nodes and elements are derived from the phase 1 geometry using the GFEG and CFEG commands or the new MESH command (on Version 2.4). The property data (e.g., cross sectional area for bar elements) is input using the PFEG command, and the material data using the PMAT command. PATRAN allows input of a variety of boundary conditions, from temperatures to heat sources. These boundary conditions can be applied to the centroid, edges or faces of elements, or to the nodes. The number definition given in the program keeps its identity when translated to the analytical code. PATRAN supports bar, quadralateral, hexagonal, and other more complex elements.

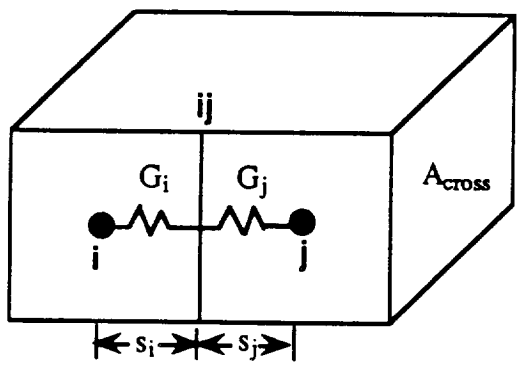
After phase 2 geometry is created, a neutral file is the next step in the procedure. The neutral file is a file in a specific format that PATRAN creates with the data input from the model. This information is used by the translator program to create the analytical model. The neutral file provides the means to transmit data from the PATRAN database to outside programs and to accept data from outside programs into PATRAN's database.

IV. PATSIN

PATSIN is the neutral file translator program from PATRAN to SINDA. The basic function of the program is to convert the FEM model created in PATRAN into a SINDA input file. The program translates the elements to SINDA nodes and creates conductors between them, and also applies the boundary conditions. Node, Source, and Conductor blocks are created by PATSIN (any other blocks are supplied only as skeleton header cards).

To use this program two files are required, the neutral file and the skeleton file. The skeleton file consist of all the data necessary for the program to be able to select the type of model that is generated. Also this file contains the other SINDA blocks required for the model (arrays, constants, etc).

Two computational methods for conductors are available, Centroid of Boundary (COB) and Line of Sight (LOS). COB works by calculating the cross sectional area at the centroid of the element . The heat flow path goes from the centroid of one element to the interface with the adjacent element in a straight line, and then to the centroid of the adjacent element in a straight line.



COB method

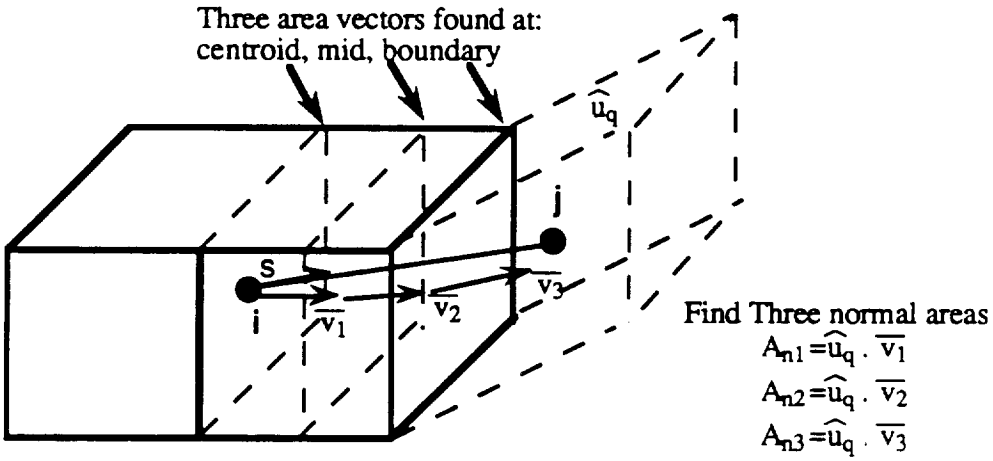
where;

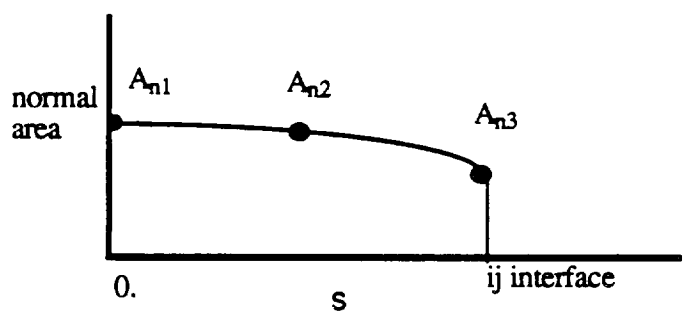
$$G_i = \frac{k\,A_{cross}}{s_i} \qquad G_j = \frac{k\,A_{cross}}{s_j}$$

and the conductor is

$$G_{ij} = \frac{1}{\frac{1}{G_i} + \frac{1}{G_j}}$$

The LOS method uses an integration technique to calculate the conductor G_{ij}. The heat flow path is one straight line from the centroid of the element to the centroid of the adjacent element. If they are not in a straight line, the line is broken into two lines with the boundary crossover point adjusted in order to make the path length a minimum.



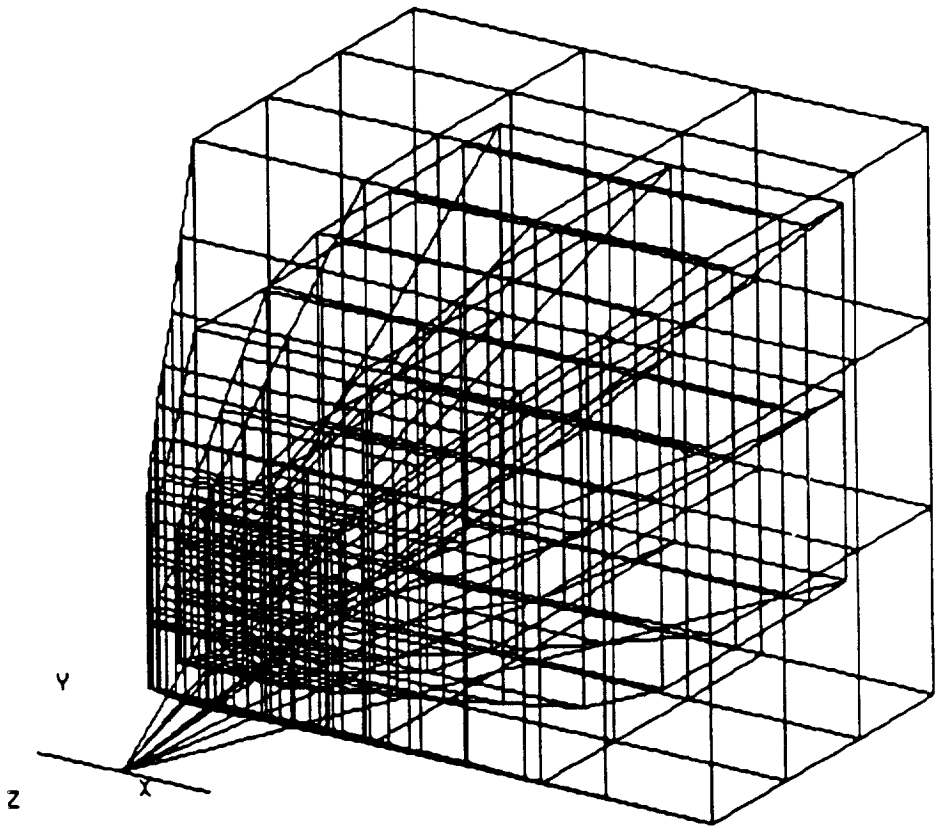


$$\gamma_i = \int_{s=0}^{s=s_3} \frac{ds}{A_n(s)} \qquad G_i = k_i \, \gamma_i$$

The quadratic equation is used to fitted $A_n(s)$.

The LOS method has more accuracy than COB. For cylindrical, spherical and axisymetric element half conductors, COB is forced always used.

Patsin also creates a neutral file with the SINDA nodes represented as FEM elements, and conductors represented as bar elements (see figure 4.).



node-conductor network

Figure 4

Here the neutral file is imposed on the original mesh. It is clear that the SINDA nodes are located at the centroid of the elements. SINDA nodes and conductor numbers are maintained constant, and the boundary conditions are represented as well (convective conductors to the back surface are represented by the lines across the model). This file is a great tool for determining the connectivity of the SINDA model.

The skeleton file contains all the settings that are required by PATSIN to create the SINDA model. Some important entries are; COBLOS selection, material constants, type of SINDA headers (SINDA85/FLUINT model can be created also),and initial temperature. This file has to be created before SINPAT is run, because it is used during the run.

SKELETON FILE EXAMPLE

```
C PATRAN GENERATED NEUTRAL FILE WHOSE TITLE WAS: PATRAN.OUT;6
C
C EXAMPLE OF PATSIN 3.0
C         CREATED ON: 27-AUG-90     AT 14:07:25
C WAS USED BY *** P A T S I N *** VERSION 3.0 TO CREATE THIS
C SINDA INPUT FILE: EXAMPLE.SIN;2
C         CREATED ON: 27-AUG-90     AT 14:23:26
C
C BEGIN TRANSLATION PARAMETERS
C
C SINDA DEFAULT MATERIAL THERMAL PROPERTIES:
C                                          Density = 1.000,        !ANY REAL
C                                     Specific Heat = 1.000,        !ANY REAL
C                                        Cond X dir = 1.000,        !ANY REAL
C                                        Cond Y dir = 1.000,        !ANY REAL
C                                        Cond Z dir = 1.000,        !ANY REAL
C                                             Sigma = 1.000,        !ANY REAL
C
C SINDA ELEMENT CONFIGURATION FLAG ASSIGNMENTS:
C                            3D Bar or Plate or Brick = 1,           !INT 1-255
C                        2D Axisymmetric Bar or Plate = 2,           !INT 1-255
C                              One-Way Fluid Flow Bar = 3,           !INT 1-255
C                              Discrete Conductor Bar = 4,           !INT 1-255
C                              Discrete Convector Bar = 5,           !INT 1-255
C                               Discrete Radiator Bar = 6,           !INT 1-255
C
C SINDA CALCULATION PARAMETERS:
C                                   Approximately Zero = 1.0000E-04,  !ANY REAL
C              CONV & RADI DFEGs Move Node to Surface = NO,           !YES, NO
C  Conductors - Line Of Sight or Centroid Of Boundary = LOS,          !LOS, COB
C
C SINDA OUTPUT SETTINGS:
C                     Default Initial Node Temperature = 70.00,        !ANY REAL
C                               Thermal Node ID Offset = 0,            !ANY INT
C                          Thermal Conductor ID Offset = 0,            !ANY INT
C                                   Data Start Column = 8,             !INT 1-8
C                     Write Out "3 Blank" Conductors > = 0.0000E+00,   !ANY REAL
C   Write Out "3 Blank" DIF Nodes as ARI at Volumes < = 1.0000E-04,    !ANY REAL
C                      Write Flow DATA in SINDA Arrays = NO,           !YES, NO
C                    Write Neutral File of Conduc Bars = YES,          !YES, NO
C                            Data Block Delimiter Type = BCD,          !BCD,HEADER
C                           SINDA-FLUINT Submodel Name = MAIN,         !1-6 CHRS
C                  Arithmetic Operators in SINDA Input = NO,           !YES, NO
C                           Data Traceability Comments = YES,          !YES, NO
C
C END TRANSLATION PARAMETERS
      BCD 3THERMAL LPCS
      BCD 9EXAMPLE OF PATSIN 3.0
      BCD 9
      BCD 2
      END
C
      BCD 3CONSTANTS DATA
          NLOOP,5000
          DRLXCA,0.0005
          BALENG,0.001
          ARLXCA,0.0005
      END
      BCD 3ARRAY DATA
      END
      BCD 3EXECUTION
```

```
F          DIMENSION X(15000)
F          NTH=0
F          NDIM=15000
           SSSOR
       END
       BCD 3VARIABLES 1
       END
       BCD 3VARIABLES 2
       END
       BCD 3OUTPUT CALLS
           TPRNTF
       END
       BCD 3END OF DATA
```

The next step of the procedure is to run PATSIN program. Ask the computer system manager for the commands used to call the program. Patsin presents a menu with three options, where option one is to translate to SINDA.

SINDA INPUT LISTING (FROM PATSIN)

```
      BCD 3THERMAL LPCS
      BCD 9EXAMPLE PATSIN 3.0
      BCD 9
      BCD 2
      END
C PATRAN GENERATED NEUTRAL FILE WHOSE TITLE WAS: PATRAN.OUT;8
C
3.0
C         CREATED ON: 28-AUG-90     AT 09:21:14
C WAS USED BY *** P A T S I N *** VERSION 3.0 TO CREATE THIS
C SINDA INPUT FILE: EX_LOS.SIN;7
C         CREATED ON: 28-AUG-90     AT 09:35:00
C
C BEGIN TRANSLATION PARAMETERS
C
C SINDA DEFAULT MATERIAL THERMAL PROPERTIES:
C                                          Density = 1.000,        !ANY REAL
C                                    Specific Heat = 1.000,        !ANY REAL
C                                       Cond X dir = 1.000,        !ANY REAL
C                                       Cond Y dir = 1.000,        !ANY REAL
C                                       Cond Z dir = 1.000,        !ANY REAL
C                                            Sigma = 1.000,        !ANY REAL
C
C SINDA ELEMENT CONFIGURATION FLAG ASSIGNMENTS:
C                          3D Bar or Plate or Brick = 1,            !INT 1-255
C                      2D Axisymmetric Bar or Plate = 2,            !INT 1-255
C                           One-Way Fluid Flow Bar = 3,            !INT 1-255
C                           Discrete Conductor Bar = 4,            !INT 1-255
C                           Discrete Convector Bar = 5,            !INT 1-255
C                            Discrete Radiator Bar = 6,            !INT 1-255
C
C SINDA CALCULATION PARAMETERS:
C                                Approximately Zero = 1.0000E-04,   !ANY REAL
C              CONV & RADI DFEGs Move Node to Surface = NO,          !YES, NO
C  Conductors - Line Of Sight or Centroid Of Boundary = LOS,         !LOS, COB
C
C SINDA OUTPUT SETTINGS:
C                   Default Initial Node Temperature = 70.00,        !ANY REAL
C                             Thermal Node ID Offset = 0,            !ANY INT
C                        Thermal Conductor ID Offset = 0,            !ANY INT
C                                 Data Start Column = 8,             !INT 1-8
C                   Write Out "3 Blank" Conductors > = 0.0000E+00,   !ANY REAL
C   Write Out "3 Blank" DIF Nodes as ARI at Volumes < = 1.0000E-04,  !ANY REAL
C                    Write Flow DATA in SINDA Arrays = NO,           !YES, NO
C                  Write Neutral File of Conduc Bars = YES,          !YES, NO
C                          Data Block Delimiter Type = BCD,          !BCD,HEADER
C                         SINDA-FLUINT Submodel Name = MAIN,         !1-6 CHRS
C                Arithmetic Operators in SINDA Input = NO,           !YES, NO
C                         Data Traceability Comments = YES,          !YES, NO
C
C END TRANSLATION PARAMETERS
C
      BCD 3NODE DATA
C           Node,    Init Temp,  Density    *  Spec Heat  *   Volume          $   Typ Cfg    Pid  Mid   Cord Typ
User_note...
              -1,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -2,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -3,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -4,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -5,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -6,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -7,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -8,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              -9,   -200.00    ,  8.88889E-08                                 $   BOU   1      1    1 GLOBAL   R
              10,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              11,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              12,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              13,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              14,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              15,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              16,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
              17,    70.000    ,  3.59316E-03                                 $   DIF   1     10    1 GLOBAL   R
```

18,	70.000	,	3.59316E-03	$	DIF	1	10	1	GLOBAL	R
19,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
20,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
21,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
22,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
23,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
24,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
25,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
26,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
27,	70.000	,	1.84028E-03	$	DIF	1	10	1	GLOBAL	R
28,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
29,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
30,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
31,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
32,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
33,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
34,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
35,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
36,	70.000	,	9.79607E-04	$	DIF	1	10	1	GLOBAL	R
37,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
38,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
39,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
40,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
41,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
42,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
43,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
44,	70.000	,	5.43146E-04	$	DIF	1	10	1	GLOBAL	R
45,	70.000	,	5.43147E-04	$	DIF	1	10	1	GLOBAL	R
46,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
47,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
48,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
49,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
50,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
51,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
52,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
53,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
54,	70.000	,	3.13855E-04	$	DIF	1	10	1	GLOBAL	R
55,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
56,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
57,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
58,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
59,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
60,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
61,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
62,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
63,	70.000	,	1.88805E-04	$	DIF	1	10	1	GLOBAL	R
64,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
65,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
66,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
67,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
68,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
69,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
70,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
71,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
72,	70.000	,	1.17932E-04	$	DIF	1	10	1	GLOBAL	R
73,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
74,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
75,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
76,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
77,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
78,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
79,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
80,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
81,	70.000	,	7.62029E-05	$	DIF	1	10	1	GLOBAL	R
82,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
83,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
84,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
85,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
86,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
87,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
88,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
89,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
90,	70.000	,	5.07138E-05	$	DIF	1	10	1	GLOBAL	R
91,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
92,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
93,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
94,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
95,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
96,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
97,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
98,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
99,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
100,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
101,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
102,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
103,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
104,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
105,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
106,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
107,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
108,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
109,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
110,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
111,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
112,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
113,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
114,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
115,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
116,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
117,	70.000	,	806.51	$	DIF	1	91	2	GLOBAL	R
118,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
119,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
120,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
121,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
122,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
123,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
124,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R
125,	-200.00	,	-0.12098	$	ARI	1	1ARI	2	GLOBAL	R

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              126,   -200.00     , -0.12098                                    $   ARI    1     1ARI    2 GLOBAL    R
             -127,    70.000     ,  8.00000E-03                                $   BOU    1     127     1 GLOBAL    R
        END
C
        BCD 3SOURCE DATA
C             NODE,    LoAoV      *    HEAT/LoAoV                              $
        END
C
        BCD 3CONDUCTOR DATA
C CONDUCTOR SYMBOL KEYS: Icond 0, Inode 0, Jnode 0, Gval
C      "_I" - suffix, the Inode part.
C      "_J" - suffix, the Jnode part.
C       "/" - indicates series connection of the two segments on each side into a larger segment or whole conductor.
C "F_RADI" - a Free_RADIation conductor.  Connects between configs 1| 2| 3
C "F_CONV" - a Free_CONVection conductor.  Connects between configs 1| 2| 3
C   "CONT" - a CONTinum segment of a conductor.   Connects between configs 1| 2| 3
C"FL_CONT" - a FLow CONTinum conductor.  Is a config = 3 and connects between configs 1| 2| 3| in restricted ways.
C "C_RADI" - a Contact RADIation conductor.  Connects between configs 1| 2| 3
C "C_CONV" - a Contact_CONVectance (film conductance) segment of a conductor or whole conductor.  Connects configs 1| 2| 3|
C "D_COND" - a Discrete_CONDuctor conductor.  Uses config = 4 to connect configs 1| 2| 3
C "D_CONV" - a Discrete_CONvection conductor.  Uses config = 5 to connect configs 1| 2| 3
C "D_RADI" - a Discrete_RADIation conductor.  Uses config = 6 to connect configs 1| 2| 3
C          Conductor, NodeI, NodeJ, Conductor                                  $
                 1,      1,     2,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                 2,      1,     4,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                 3,      1,    82,   3.3952                                    $     NODE_I/CONT_J/NODE_J
                 4,      2,     3,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                 5,      2,     5,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                 6,      2,    83,   3.7347                                    $     NODE_I/CONT_J/NODE_J
                 7,      3,     6,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                 8,      3,    84,   3.3950                                    $     NODE_I/CONT_J/NODE_J
                 9,      4,     5,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                10,      4,     7,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                11,      4,    85,   3.7347                                    $     NODE_I/CONT_J/NODE_J
                12,      5,     6,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                13,      5,     8,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                14,      5,    86,   4.1497                                    $     NODE_I/CONT_J/NODE_J
                15,      6,     9,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                16,      6,    87,   3.7346                                    $     NODE_I/CONT_J/NODE_J
                17,      7,     8,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                18,      7,    88,   3.3950                                    $     NODE_I/CONT_J/NODE_J
                19,      8,     9,  1.00000E-04                                $     NODE_I/CONT_I/CONT_J/NODE_J
                20,      8,    89,   3.7346                                    $     NODE_I/CONT_J/NODE_J
                21,      9,    90,   3.3951                                    $     NODE_I/CONT_J/NODE_J
                22,     10,    11,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                23,     10,    13,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                24,     10,    19,   1.1834                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                25,     10,    91,   1.0189                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                26,     11,    12,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                27,     11,    14,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                28,     11,    20,   1.3017                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                29,     11,    94,   1.0396                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                30,     12,    15,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                31,     12,    21,   1.1833                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                32,     12,    97,   1.0189                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                33,     13,    14,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                34,     13,    16,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                35,     13,    22,   1.3017                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                36,     13,    92,   1.0396                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                37,     14,    15,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                38,     14,    17,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                39,     14,    23,   1.4463                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                40,     14,    95,   1.0610                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                41,     15,    18,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                42,     15,    24,   1.3017                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                43,     15,    98,   1.0396                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                44,     16,    17,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                45,     16,    25,   1.1834                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                46,     16,    93,   1.0189                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                47,     17,    18,  0.53726                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                48,     17,    26,   1.3017                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                49,     17,    96,   1.0396                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                50,     18,    27,   1.1833                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                51,     18,    99,   1.0189                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                52,     19,    20,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                53,     19,    22,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                54,     19,    28,   1.0976                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                55,     20,    21,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                56,     20,    23,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                57,     20,    29,   1.2073                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                58,     21,    24,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                59,     21,    30,   1.0976                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                60,     22,    23,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                61,     22,    25,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                62,     22,    31,   1.2073                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                63,     23,    24,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                64,     23,    26,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                65,     23,    32,   1.3416                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                66,     24,    27,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                67,     24,    33,   1.2074                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                68,     25,    26,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                69,     25,    34,   1.0977                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                70,     26,    27,  0.40335                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                71,     26,    35,   1.2074                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                72,     27,    36,   1.0976                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                73,     28,    29,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                74,     28,    31,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                75,     28,    37,   1.0596                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                76,     29,    30,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                77,     29,    32,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                78,     29,    38,   1.1655                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                79,     30,    33,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                80,     30,    39,   1.0596                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                81,     31,    32,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                82,     31,    34,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                83,     31,    40,   1.1656                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                84,     32,    33,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
                85,     32,    35,  0.30281                                    $     NODE_I/CONT_I/CONT_J/NODE_J
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 86,   32,   41,   1.2951                    $   NODE_I/CONT_I/CONT_J/NODE_J
 87,   33,   36,  0.30281                    $   NODE_I/CONT_I/CONT_J/NODE_J
 88,   33,   42,   1.1656                    $   NODE_I/CONT_I/CONT_J/NODE_J
 89,   34,   35,  0.30281                    $   NODE_I/CONT_I/CONT_J/NODE_J
 90,   34,   43,   1.0596                    $   NODE_I/CONT_I/CONT_J/NODE_J
 91,   35,   36,  0.30281                    $   NODE_I/CONT_I/CONT_J/NODE_J
 92,   35,   44,   1.1656                    $   NODE_I/CONT_I/CONT_J/NODE_J
 93,   36,   45,   1.0596                    $   NODE_I/CONT_I/CONT_J/NODE_J
 94,   37,   38,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
 95,   37,   40,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
 96,   37,   46,   1.0662                    $   NODE_I/CONT_I/CONT_J/NODE_J
 97,   38,   39,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
 98,   38,   41,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
 99,   38,   47,   1.1727                    $   NODE_I/CONT_I/CONT_J/NODE_J
100,   39,   42,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
101,   39,   48,   1.0661                    $   NODE_I/CONT_I/CONT_J/NODE_J
102,   40,   41,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
103,   40,   43,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
104,   40,   49,   1.1727                    $   NODE_I/CONT_I/CONT_J/NODE_J
105,   41,   42,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
106,   41,   44,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
107,   41,   50,   1.3030                    $   NODE_I/CONT_I/CONT_J/NODE_J
108,   42,   45,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
109,   42,   51,   1.1727                    $   NODE_I/CONT_I/CONT_J/NODE_J
110,   43,   44,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
111,   43,   52,   1.0660                    $   NODE_I/CONT_I/CONT_J/NODE_J
112,   44,   45,  0.22730                    $   NODE_I/CONT_I/CONT_J/NODE_J
113,   44,   53,   1.1727                    $   NODE_I/CONT_I/CONT_J/NODE_J
114,   45,   54,   1.0661                    $   NODE_I/CONT_I/CONT_J/NODE_J
115,   46,   47,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
116,   46,   49,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
117,   46,   55,   1.1176                    $   NODE_I/CONT_I/CONT_J/NODE_J
118,   47,   48,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
119,   47,   50,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
120,   47,   56,   1.2293                    $   NODE_I/CONT_I/CONT_J/NODE_J
121,   48,   51,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
122,   48,   57,   1.1176                    $   NODE_I/CONT_I/CONT_J/NODE_J
123,   49,   50,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
124,   49,   52,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
125,   49,   58,   1.2292                    $   NODE_I/CONT_I/CONT_J/NODE_J
126,   50,   51,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
127,   50,   53,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
128,   50,   59,   1.3660                    $   NODE_I/CONT_I/CONT_J/NODE_J
129,   51,   54,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
130,   51,   60,   1.2295                    $   NODE_I/CONT_I/CONT_J/NODE_J
131,   52,   53,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
132,   52,   61,   1.1176                    $   NODE_I/CONT_I/CONT_J/NODE_J
133,   53,   54,  0.17060                    $   NODE_I/CONT_I/CONT_J/NODE_J
134,   53,   62,   1.2295                    $   NODE_I/CONT_I/CONT_J/NODE_J
135,   54,   63,   1.1176                    $   NODE_I/CONT_I/CONT_J/NODE_J
136,   55,   56,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
137,   55,   58,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
138,   55,   64,   1.2185                    $   NODE_I/CONT_I/CONT_J/NODE_J
139,   56,   57,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
140,   56,   59,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
141,   56,   65,   1.3403                    $   NODE_I/CONT_I/CONT_J/NODE_J
142,   57,   60,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
143,   57,   66,   1.2185                    $   NODE_I/CONT_I/CONT_J/NODE_J
144,   58,   59,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
145,   58,   61,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
146,   58,   67,   1.3404                    $   NODE_I/CONT_I/CONT_J/NODE_J
147,   59,   60,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
148,   59,   62,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
149,   59,   68,   1.4893                    $   NODE_I/CONT_I/CONT_J/NODE_J
150,   60,   63,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
151,   60,   69,   1.3403                    $   NODE_I/CONT_I/CONT_J/NODE_J
152,   61,   62,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
153,   61,   70,   1.2185                    $   NODE_I/CONT_I/CONT_J/NODE_J
154,   62,   63,  0.12802                    $   NODE_I/CONT_I/CONT_J/NODE_J
155,   62,   71,   1.3403                    $   NODE_I/CONT_I/CONT_J/NODE_J
156,   63,   72,   1.2185                    $   NODE_I/CONT_I/CONT_J/NODE_J
157,   64,   65,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
158,   64,   67,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
159,   64,   73,   1.3772                    $   NODE_I/CONT_I/CONT_J/NODE_J
160,   65,   66,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
161,   65,   68,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
162,   65,   74,   1.5150                    $   NODE_I/CONT_I/CONT_J/NODE_J
163,   66,   69,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
164,   66,   75,   1.3772                    $   NODE_I/CONT_I/CONT_J/NODE_J
165,   67,   68,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
166,   67,   70,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
167,   67,   76,   1.5150                    $   NODE_I/CONT_I/CONT_J/NODE_J
168,   68,   69,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
169,   68,   71,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
170,   68,   77,   1.6833                    $   NODE_I/CONT_I/CONT_J/NODE_J
171,   69,   72,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
172,   69,   78,   1.5149                    $   NODE_I/CONT_I/CONT_J/NODE_J
173,   70,   71,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
174,   70,   79,   1.3772                    $   NODE_I/CONT_I/CONT_J/NODE_J
175,   71,   72,  9.60555E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
176,   71,   80,   1.5150                    $   NODE_I/CONT_I/CONT_J/NODE_J
177,   72,   81,   1.3772                    $   NODE_I/CONT_I/CONT_J/NODE_J
178,   73,   74,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
179,   73,   76,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
180,   73,   82,   1.6070                    $   NODE_I/CONT_I/CONT_J/NODE_J
181,   74,   75,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
182,   74,   77,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
183,   74,   83,   1.7676                    $   NODE_I/CONT_I/CONT_J/NODE_J
184,   75,   78,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
185,   75,   84,   1.6069                    $   NODE_I/CONT_I/CONT_J/NODE_J
186,   76,   77,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
187,   76,   79,  7.20595E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
188,   76,   85,   1.7676                    $   NODE_I/CONT_I/CONT_J/NODE_J
189,   77,   78,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
190,   77,   80,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
191,   77,   86,   1.9640                    $   NODE_I/CONT_I/CONT_J/NODE_J
192,   78,   81,  7.20594E-02                $   NODE_I/CONT_I/CONT_J/NODE_J
193,   78,   87,   1.7676                    $   NODE_I/CONT_I/CONT_J/NODE_J
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                194,    79,    80,  7.20594E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                195,    79,    88,   1.6069                        $     NODE_I/CONT_I/CONT_J/NODE_J
                196,    80,    81,  7.20594E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                197,    80,    89,   1.7676                        $     NODE_I/CONT_I/CONT_J/NODE_J
                198,    81,    90,   1.6070                        $     NODE_I/CONT_I/CONT_J/NODE_J
                199,    82,    83,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                200,    82,    85,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                201,    83,    84,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                202,    83,    86,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                203,    84,    87,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                204,    85,    86,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                205,    85,    88,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                206,    86,    87,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                207,    86,    89,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                208,    87,    90,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                209,    88,    89,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                210,    89,    90,  5.40511E-02                    $     NODE_I/CONT_I/CONT_J/NODE_J
                211,    91,    92,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                212,    91,    94,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                213,    91,   100,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                214,    92,    93,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                215,    92,    95,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                216,    92,   101,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                217,    93,    96,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                218,    93,   102,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                219,    94,    95,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                220,    94,    97,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                221,    94,   103,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                222,    95,    96,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                223,    95,    98,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                224,    95,   104,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                225,    96,    99,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                226,    96,   105,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                227,    97,    98,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                228,    97,   106,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                229,    98,    99,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                230,    98,   107,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                231,    99,   108,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                232,   100,   101,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                233,   100,   103,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                234,   100,   109,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                235,   101,   102,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                236,   101,   104,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                237,   101,   110,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                238,   102,   105,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                239,   102,   111,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                240,   103,   104,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                241,   103,   106,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                242,   103,   112,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                243,   104,   105,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                244,   104,   107,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                245,   104,   113,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                246,   105,   108,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                247,   105,   114,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                248,   106,   107,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                249,   106,   115,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                250,   107,   108,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                251,   107,   116,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                252,   108,   117,  0.75000                        $     NODE_I/CONT_I/CONT_J/NODE_J
                253,   109,   110,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                254,   109,   112,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                255,   109,   118,   1.5000                        $     NODE_I/CONT_I/NODE_J
                256,   110,   111,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                257,   110,   113,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                258,   110,   119,   1.5000                        $     NODE_I/CONT_I/NODE_J
                259,   111,   114,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                260,   111,   120,   1.5000                        $     NODE_I/CONT_I/NODE_J
                261,   112,   113,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                262,   112,   115,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                263,   112,   121,   1.5000                        $     NODE_I/CONT_I/NODE_J
                264,   113,   114,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                265,   113,   116,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                266,   113,   122,   1.5000                        $     NODE_I/CONT_I/NODE_J
                267,   114,   117,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                268,   114,   123,   1.5000                        $     NODE_I/CONT_I/NODE_J
                269,   115,   116,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                270,   115,   124,   1.5000                        $     NODE_I/CONT_I/NODE_J
                271,   116,   117,  0.33333                        $     NODE_I/CONT_I/CONT_J/NODE_J
                272,   116,   125,   1.5000                        $     NODE_I/CONT_I/NODE_J
                273,   117,   126,   1.5000                                                          $
NODE_I/CONT_I/NODE_J
                274,   118,   119,  5.00000E-05                    $     NODE_I/CONT_I/CONT_J/NODE_J
                275,   118,   121,  5.00000E-05                    $     NODE_I/CONT_I/CONT_J/NODE_J
                276,   118,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                277,   119,   120,  5.00000E-05                    $     NODE_I/CONT_I7CONT_J7NODE_J
                278,   119,   122,  5.00000E-05                    $     NODE_I/CONT_I/CONT_J/NODE_J
                279,   119,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                280,   120,   123,  5.00000E-05                    $     NODE_I/CONT_I7CONT_J7NODE_J
                281,   120,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                282,   121,   122,  5.00000E-05                    $     NODE_I/CONT_I7CONT_J7NODE_J
                283,   121,   124,  5.00000E-05                    $     NODE_I/CONT_I/CONT_J/NODE_J
                284,   121,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                285,   122,   123,  5.00000E-05                    $     NODE_I/CONT_I7CONT_J7NODE_J
                286,   122,   125,  5.00000E-05                    $     NODE_I/CONT_I/CONT_J/NODE_J
                287,   122,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                288,   123,   126,  5.00000E-05                    $     NODE_I/CONT_I7CONT_J7NODE_J
                289,   123,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                290,   124,   125,  5.00000E-05                    $       NODE_I7CONT_I/CONT_J/NODE_J
                291,   124,   127,   1.1400                        $     NODE_I7F_CONV_I/NODE_J
                292,   125,   126,  5.00000E-05                    $     NODE_I/CONT_I7CONT_J7NODE_J
                293,   125,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
                294,   126,   127,   1.1400                        $     NODE_I/F_CONV_I/NODE_J
        END
C
        BCD 3CONSTANTS DATA
            NLOOP,5000
            DRLXCA,0.0005
```

```
            BALENG,0.001
            ARLXCA,0.0005
        END
        BCD 3ARRAY DATA
        END
        BCD 3EXECUTION
F           DIMENSION X(15000)
F           NTH=0
F           NDIM=15000
            SSSOR
        END
        BCD 3VARIABLES 1
        END
        BCD 3VARIABLES 2
        END
        BCD 3OUTPUT CALLS
            TPRNTF
        END
        BCD 3END OF DATA
```

After the input model is created and modified with the remaining input (arrays, constants, etc), the model is submitted to SINDA.

V. SINPAT

SINPAT is the translator program from SINDA to PATRAN. It works by reading the SINDA output file and creating two groups of files. The first group creates the element results file (*modelname#.els*). This file contains the node temperature and the node number, in one file per time step selected. The other group of files are used with conjunction of the original neutral file and calculates the FEM node temperatures from the SINDA results. The use of this file is shared with finite element codes. Patran can read both files.

For SINPAT be able to work a modification of the output file is needed. This modification consists of adding a line with "SINPAT_TIME = (time step number) " under the " TIME = " line. The following example, illustrates this change.

SINDA OUTPUT EXAMPLE FILE

```
TRW SYSTEMS IMPROVED NUMERICAL DIFFERENCING ANALYZER   - - - SINDA/SINFLO - - -  DEC VAX-11  (SPERRY VERSION 85)      PAGE     1

   EXAMPLE

********
TIME= 0.00000E+00 DTIMEU= 0.00000E+00 CSGMIN(     0)= 0.00000E+00 TEMPCC(     0)= 0.00000E+00 REDICC(     0)= 0.00000E+00
SINPAT_TIME = 0.00000E+00

T     1= -200.00  T     2= -200.00  T     3= -200.00  T     4= -200.00  T     5= -200.00  T     6= -200.00  T     7= -200.00
T     8= -200.00  T     9= -200.00  T    10=   70.00  T    11=   70.00  T    12=   70.00  T    13=   70.00  T    14=   70.00
T    15=   70.00  T    16=   70.00  T    17=   70.00  T    18=   70.00  T    19=   70.00  T    20=   70.00  T    21=   70.00
T    22=   70.00  T    23=   70.00  T    24=   70.00  T    25=   70.00  T    26=   70.00  T    27=   70.00  T    28=   70.00
T    29=   70.00  T    30=   70.00  T    31=   70.00  T    32=   70.00  T    33=   70.00  T    34=   70.00  T    35=   70.00
T    36=   70.00  T    37=   70.00  T    38=   70.00  T    39=   70.00  T    40=   70.00  T    41=   70.00  T    42=   70.00
T    43=   70.00  T    44=   70.00  T    45=   70.00  T    46=   70.00  T    47=   70.00  T    48=   70.00  T    49=   70.00
T    50=   70.00  T    51=   70.00  T    52=   70.00  T    53=   70.00  T    54=   70.00  T    55=   70.00  T    56=   70.00
T    57=   70.00  T    58=   70.00  T    59=   70.00  T    60=   70.00  T    61=   70.00  T    62=   70.00  T    63=   70.00
T    64=   70.00  T    65=   70.00  T    66=   70.00  T    67=   70.00  T    68=   70.00  T    69=   70.00  T    70=   70.00
T    71=   70.00  T    72=   70.00  T    73=   70.00  T    74=   70.00  T    75=   70.00  T    76=   70.00  T    77=   70.00
T    78=   70.00  T    79=   70.00  T    80=   70.00  T    81=   70.00  T    82=   70.00  T    83=   70.00  T    84=   70.00
T    85=   70.00  T    86=   70.00  T    87=   70.00  T    88=   70.00  T    89=   70.00  T    90=   70.00  T    91=   70.00
T    92=   70.00  T    93=   70.00  T    94=   70.00  T    95=   70.00  T    96=   70.00  T    97=   70.00  T    98=   70.00
T    99=   70.00  T   100=   70.00  T   101=   70.00  T   102=   70.00  T   103=   70.00  T   104=   70.00  T   105=   70.00
T   106=   70.00  T   107=   70.00  T   108=   70.00  T   109=   70.00  T   110=   70.00  T   111=   70.00  T   112=   70.00
T   113=   70.00  T   114=   70.00  T   115=   70.00  T   116=   70.00  T   117=   70.00  T   118= -200.00  T   119= -200.00
T   120= -200.00  T   121= -200.00  T   122= -200.00  T   123= -200.00  T   124= -200.00  T   125= -200.00  T   126= -200.00
T   127=   70.00
BNGERL IS LESS THAN BALENG.  MAXIMUM BNGERL WAS  0.97656E-03 AT NODE   113.

********
TIME= 0.00000E+00 DTIMEU= 0.00000E+00 CSGMIN(     0)= 0.00000E+00 TEMPCC(     0)= 0.00000E+00 REDICC(    15)= 6.86646E-05
SINPAT_TIME = 1.00000E+00

T     1= -200.00  T     2= -200.00  T     3= -200.00  T     4= -200.00  T     5= -200.00  T     6= -200.00  T     7= -200.00
T     8= -200.00  T     9= -200.00  T    10=   57.97  T    11=   57.45  T    12=   57.97  T    13=   57.45  T    14=   56.85
T    15=   57.45  T    16=   57.97  T    17=   57.45  T    18=   57.97  T    19=   26.52  T    20=   26.31  T    21=   26.52
T    22=   26.31  T    23=   26.05  T    24=   26.31  T    25=   26.52  T    26=   26.31  T    27=   26.52  T    28=   -7.18
T    29=   -7.28  T    30=   -7.18  T    31=   -7.28  T    32=   -7.39  T    33=   -7.28  T    34=   -7.18  T    35=   -7.27
T    36=   -7.18  T    37=  -41.99  T    38=  -42.04  T    39=  -41.99  T    40=  -42.04  T    41=  -42.09  T    42=  -42.04
T    43=  -41.99  T    44=  -42.03  T    45=  -41.99  T    46=  -76.54  T    47=  -76.56  T    48=  -76.54  T    49=  -76.56
T    50=  -76.59  T    51=  -76.56  T    52=  -76.54  T    53=  -76.56  T    54=  -76.54  T    55= -109.47  T    56= -109.48
T    57= -109.47  T    58= -109.48  T    59= -109.50  T    60= -109.48  T    61= -109.47  T    62= -109.48  T    63= -109.47
T    64= -139.67  T    65= -139.67  T    66= -139.66  T    67= -139.67  T    68= -139.68  T    69= -139.67  T    70= -139.66
T    71= -139.67  T    72= -139.66  T    73= -166.39  T    74= -166.39  T    75= -166.39  T    76= -166.39  T    77= -166.39
T    78= -166.39  T    79= -166.39  T    80= -166.39  T    81= -166.39  T    82= -189.30  T    83= -189.30  T    84= -189.30
```

T	85-	-189.30	T	86-	-189.30	T	87-	-189.30	T	88-	-189.30	T	89-	-189.30	T	90-	-189.30	T	91-	69.70
T	92-	69.70	T	93-	69.70	T	94-	69.70	T	95-	69.70	T	96-	69.70	T	97-	69.70	T	98-	69.70
T	99-	69.70	T	100-	69.71	T	101-	69.71	T	102-	69.71	T	103-	69.71	T	104-	69.71	T	105-	69.71
T	106-	69.71	T	107-	69.71	T	108-	69.71	T	109-	69.72	T	110-	69.72	T	111-	69.72	T	112-	69.72
T	113-	69.72	T	114-	69.72	T	115-	69.72	T	116-	69.72	T	117-	69.72	T	118-	69.72	T	119-	69.72
T	120-	69.72	T	121-	69.72	T	122-	69.72	T	123-	69.72	T	124-	69.72	T	125-	69.72	T	126-	69.72
T	127-	70.00																		

END OF DATA

The contour plot is shown in figure 5. This is created in PATRAN with the result option, reading the element result file (.els file) created by SINPAT. Appendix A. presents examples of more complex models used by ED64, the Thermal Analysis Branch.

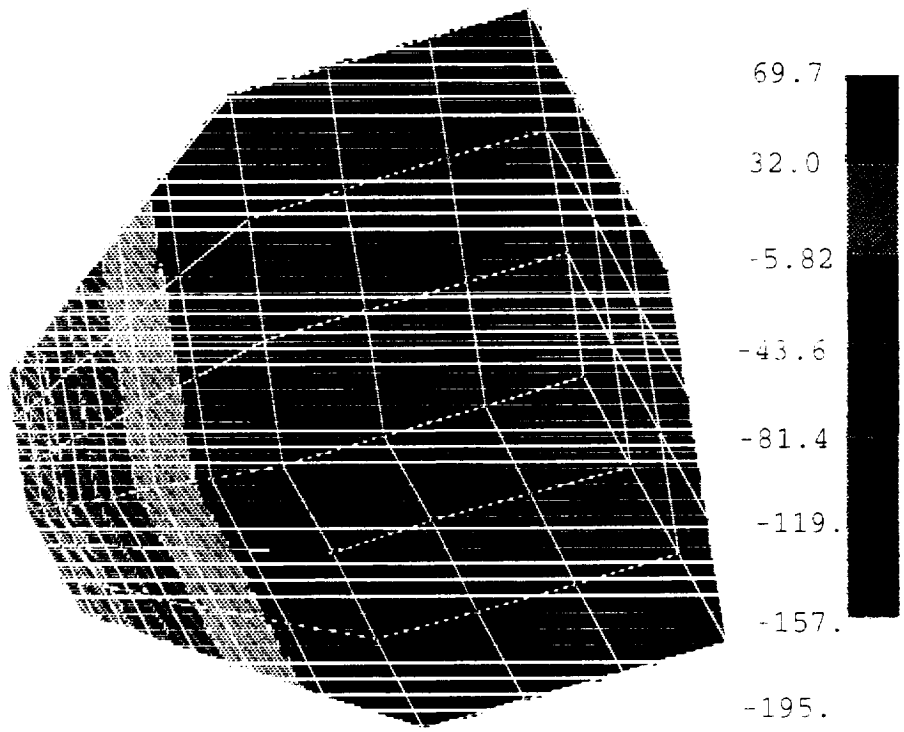

Figure 5

VI. PPLOT

PPlot is a general purpose program for creating x-y plots. The program can plot virtually any data from the database, e.g., results, xyz coordinates, local coordinates, etc. PPlot is available from the system and through PATRAN. Time history plots are available in PATRAN when analytical results are post-processed. The advantage of this application is that data can be input straight from the results file, it can be used without leaving PATRAN, and the local temperature distribution can be observed. The program is available in the results option on the PATRAN main menu, and at the x-y plot option. Figure 6 presents an example of this application where temperature is shown versus distance.

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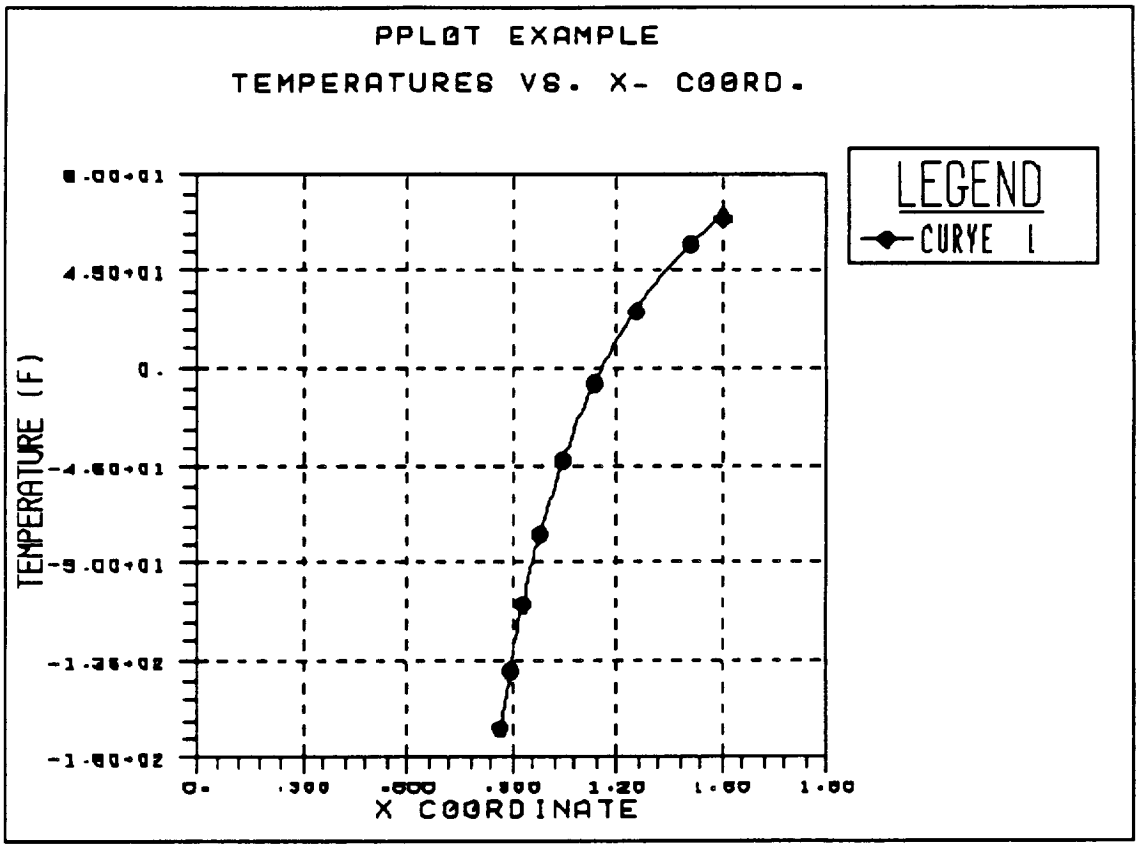

Figure 6

VII. References

PATRAN Plus User Manual Vol I.
PATRAN Plus User Manual Vol II.
PAT/SINDA, Application Interface, Release 3.0

VIII. Appendix

The following plots represent some of the model that has been created by PATRAN, SINPAT and PATSIN.

A. SSME Nozzle to Main Combustion Chamber Joint (G15)

Figure 1 is a color contour plot of the temperature distribution of the G15 Steady State thermal model generated by Patsin and executed on Sinda code.

B. SSME High Pressure Oxygen Turbopump Ball Bearing

Figure 2 is a color contour plot of the steady state temperatures within a ball bearing. The contours were adjusted to plot any temperatures above 250 °R as red to highlight the "hot spots" where the frictional heat is generated. The surfaces are cooled by heat transfer to the flowing coolant. The temperatures were calculated using the SINDA code.

C. RSRM Case Fieldjoint Insulation

Figure 3 presents the temperature isothermal contour plot from the Sinda model of the fieldjoint insulation flow analysis. The Sinda model was constructed with various insulation size flaws in the joint area.

D. External Tank Ice Formation Model

Figure 4 shows the result of temperatures of the Sinda ET ICE model . This model predicts the ice and frost formation of the ET before launch.

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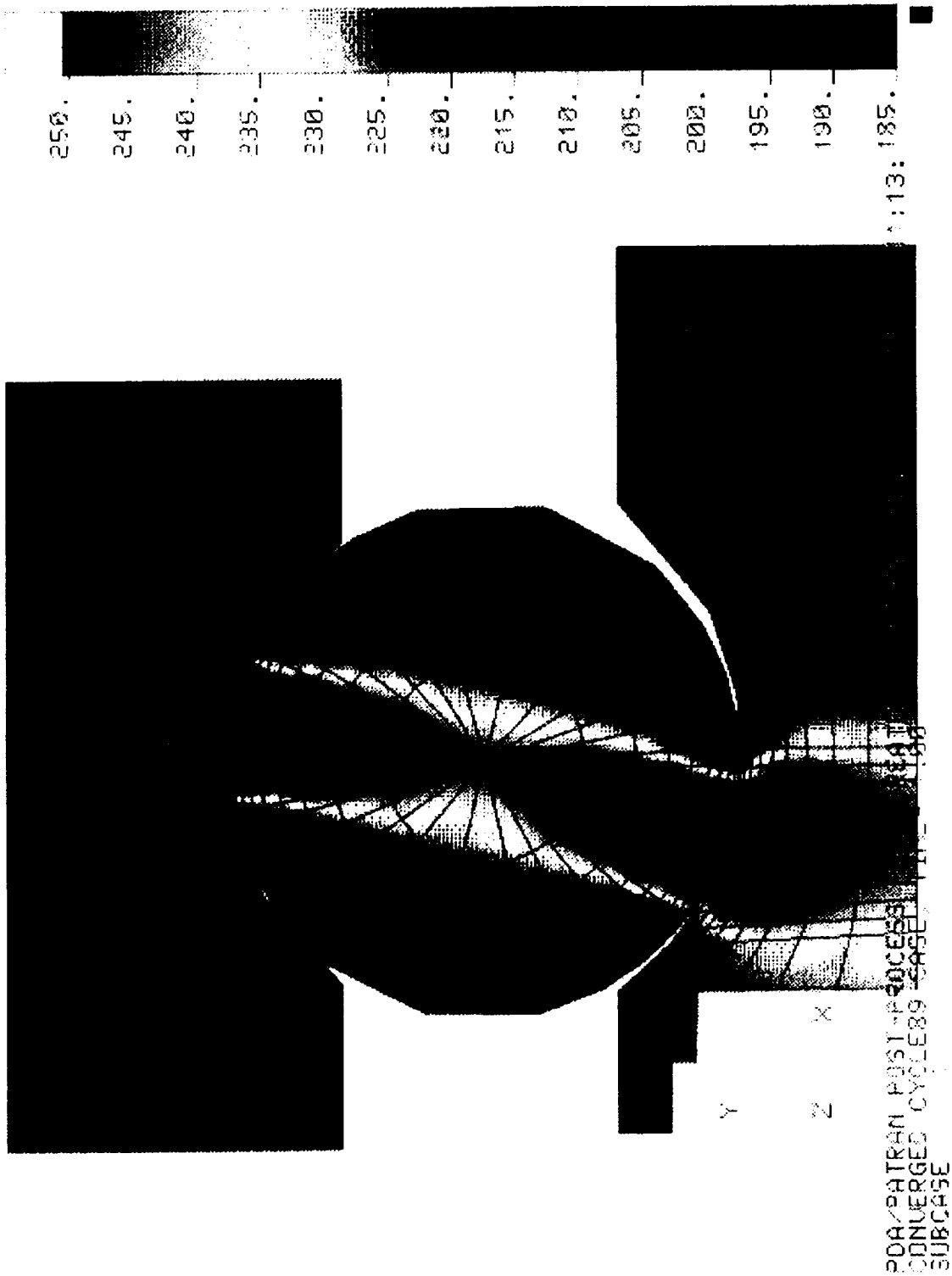

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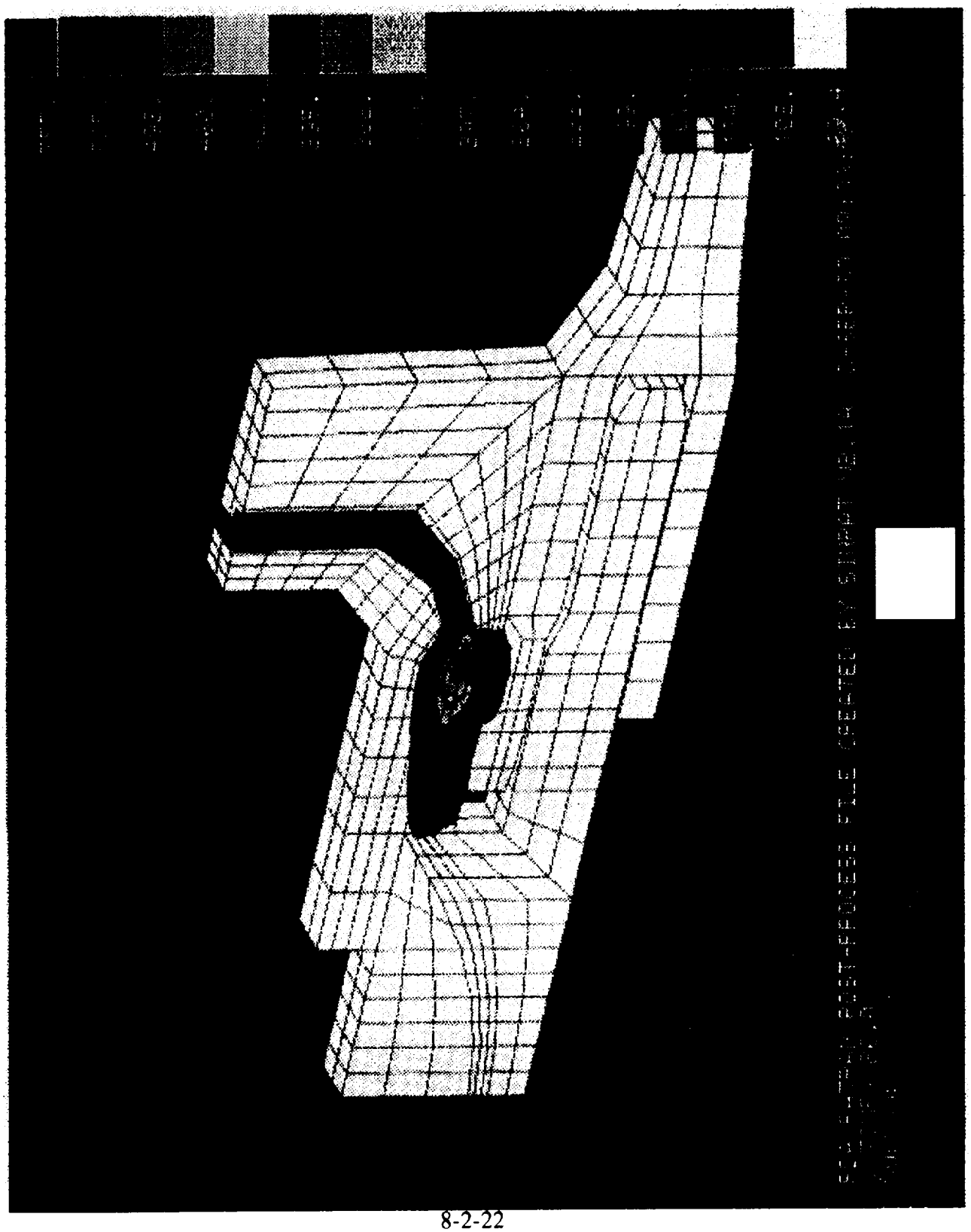

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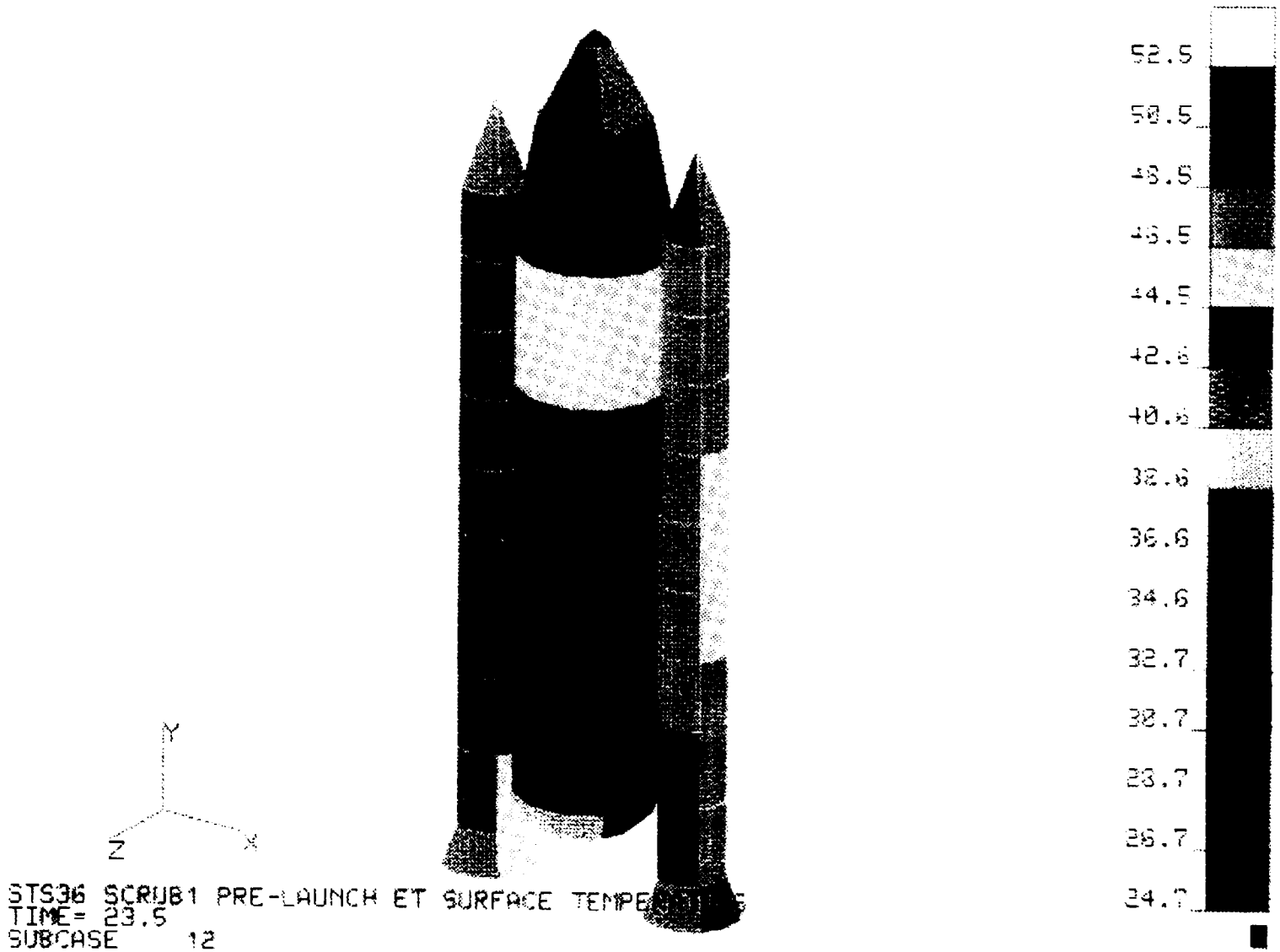

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SECTION 3: FEM-SINDA Example

I. INTRODUCTION:

The input to SINDA generally requires tedious hand calculations of nodal capacitances and conductances. For this reason, Martin Marietta Missile Systems developed a finite element - finite difference hybrid thermal analysis code known as FEM/SINDA. This is used to translate finite element models, developed in PATRAN or SUPERTAB, into SINDA or MITAS finite difference network model.

A FEM/SINDA input deck may be generated from a PATRAN neutral file using the PATRAN-to-FEM/SINDA translator (see Figure 1). FEM/SINDA can then generate a SINDA input deck for subsequent finite difference analyses. This deck may be automatically combined with a SINDA deck (SFILE) that has, for example, arrays defined for temperature varying thermal properties and time or temperature varying boundary conditions. The SINDA model can be run as usual to produce temperatures at the finite element nodes. This will insure, for example, that the temperature field is determined at the nodes of a coupled stress model. In comparison, a centroidal method would require the interpolation/extrapolation of the centroidal temperatures to determine the nodal temperatures and there is always the possibility of misinterpolation and/or error.

FEM/SINDA is also integrated with TRASYS. FEM/SINDA may be used to generate the necessary input deck, to TRASYS, for view factor and orbital heat flux calculations. A subsequent TRASYS run will return SINDA radiation conductors. These radiation conductors will reflect the view factors between the various radiating elements, selected in PATRAN. Moreover, the radiation conductors lie between finite element nodes and can be combined with the SINDA deck of thermal conductors, for a system analysis involving conduction, convection and radiation. The output from FEM/SINDA can be brought back to PATRAN, for post-processing.

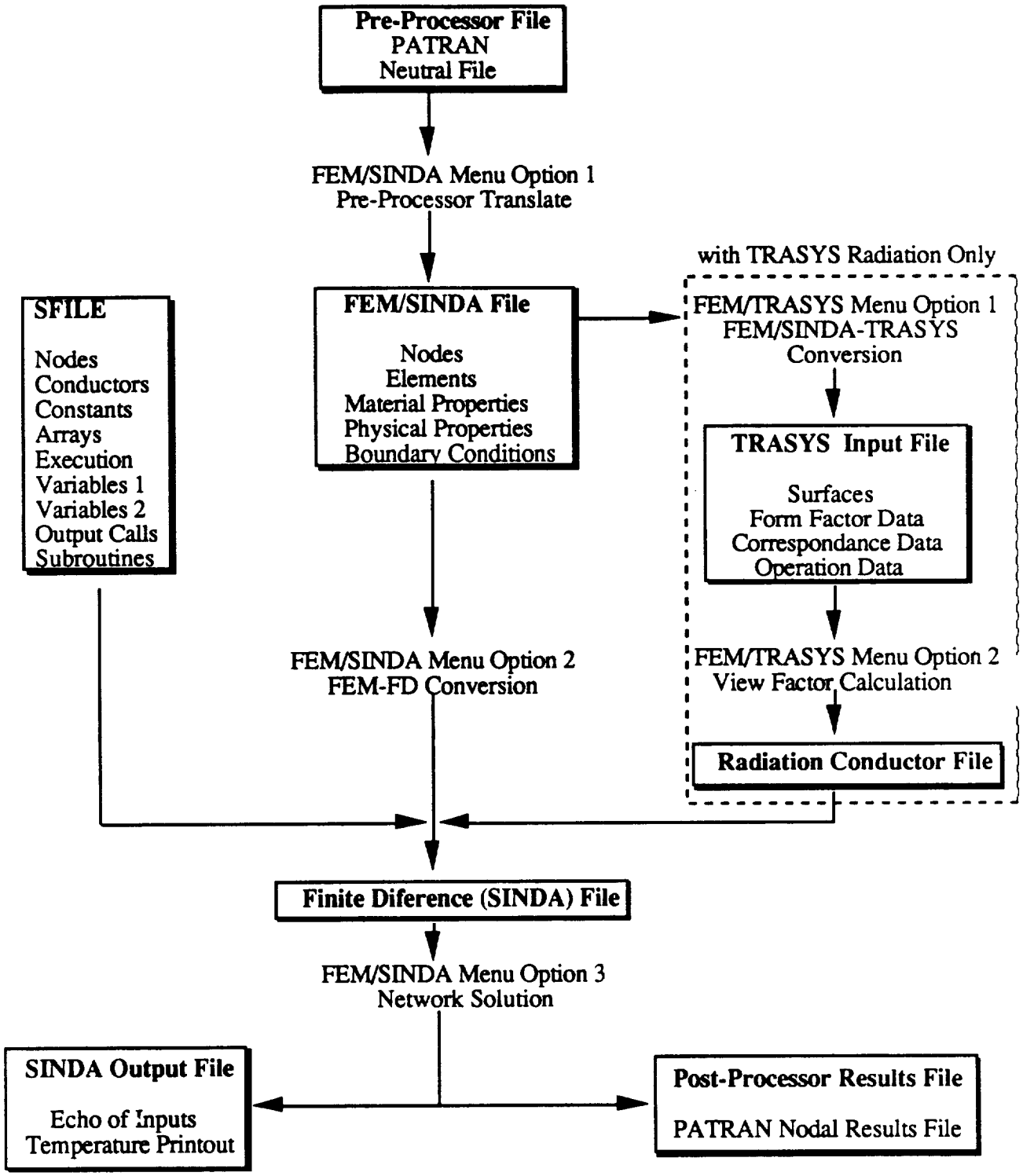

Figure 1: FEM/SINDA File Structure

II. Example:

A. Statement of the Problem:

Consider the piece of hardware shown in figure 2. The component is exposed to a gas, at 70 °F, at one end and at the opposing end is kept at a constant wall temperature of 200 °F. The piece is made of two materials. The heat transfer coefficient between the gas and the exposed wall piece is 1.0 BTU/ft^2- hr °F. The thermal conductivity of material-one is 1.0 BTU/hr ft °F and that of material two is 52.1 BTU/hr ft °F.

B. Schematic:

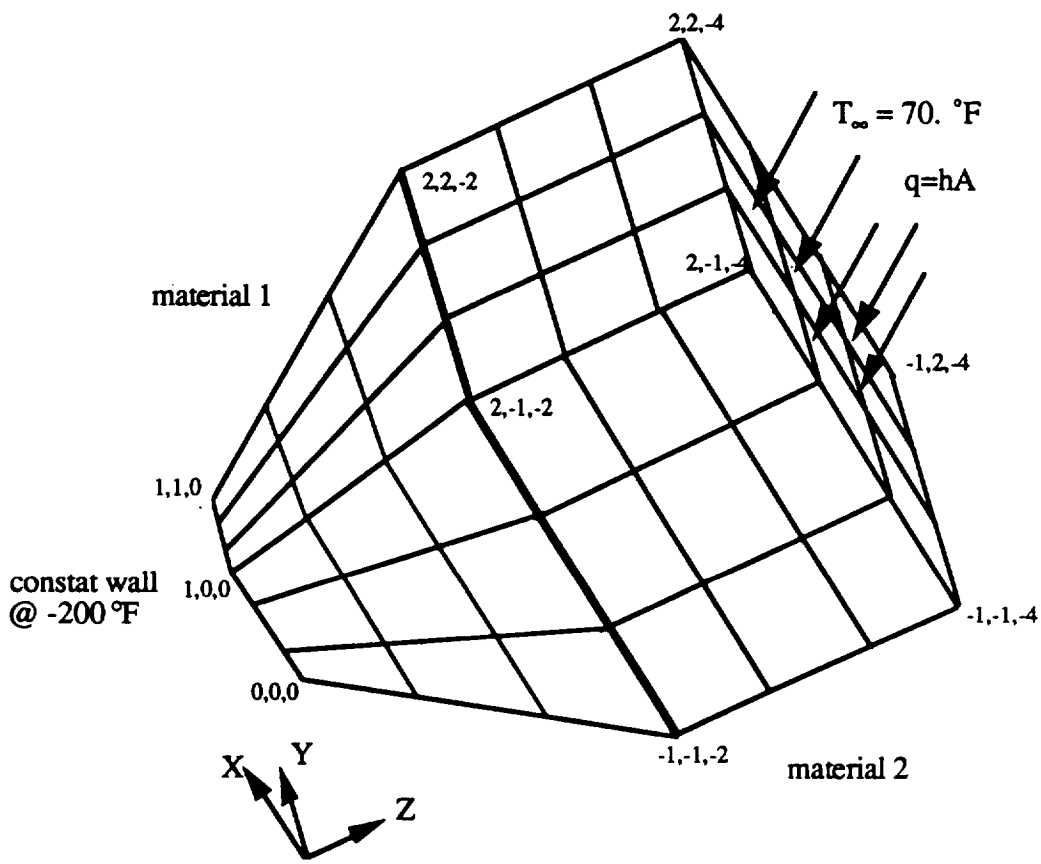

Figure 2: Schematic of the Problem

C. Given:

The following data is given for this problem:

1. Physical dimensions of the component
2. Boundary conditions, heat transfer coefficient and left hand wall temperature.
3. Material thermal conductivities.

D. Find

The steady state temperature distribution in the component, using PATRAN and FEM/SINDA to generate the SINDA model.

III. FEM Input Deck

Input to FEM/SINDA consists of two separate files. One file contains the finite element data. This file is separated into two basic sections. The first section is the Control Data and the second section is the Bulk Data. The Bulk Data contains all data necessary to define the geometry and boundary conditions, while the Control Data defines the problem title, output requests, etc.

The FEM/SINDA deck can be generated in one of two ways. For very simple models, it is convenient to manually enter the data using a standard text editor. For most problems, however, the most efficient and accurate way to create the FEM/SINDA input is with a pre-processor, such as PATRAN.

The second input file required by FEM/SINDA is a SINDA-formatted file which is refered to as SFILE. The SFILE is a stripped down SINDA input deck. At the very least, the SFILE contains constants (such as convergence criteria, etc.) and specifies the solution type (i.e. transient or steady state). For more complicated analyses, the SFILE gives the user complete access to all the capabilities of SINDA including properties and boundary conditions that vary with time or temperature, user written subroutines, etc.

IV. PATRAN Interface:

The PATRAN phase 1 geometry presented in the previous section was used, here. However, to perform the actual translation of the model, it was necessary to regenerate the phase 2 of the PATRAN model so that the data is correctly represented in the neutral file. The following are examples of line commands used for defining different sections of the phase 2 of the PATRAN model:

A. Nodes:

Nodes are created using the standard GFEG command.

Example: > GFEG,H1,,2/4/2

The above command generates two nodes in the C1 direction, four nodes in the C2 direction, and two nodes in the C3 direction of hyperpatch number-1, using the default node type.

B. Elements:

Elements are generated using the standard CFEG command.

Example: > CFEG,P1,QUAD,,1

This command generates quad elements on patch 1 and assigns physical property number-1 to them.

C: Physical Properties:

Physical properties relate materials (for solid elements) or materials and thicknesses (for shell elements) to elements. Physical properties are entered using the PROP command.

Example:
```
> PROP,1,ADD
enter element type and configuration (i.e. HEX)
> QUAD
enter property data
> 1,0.125
```

This command adds physical property-1 to the tables. PATRAN prompts for the type of element and the property data. For solid elements (HEX, WEDGE, TETRA) only the material ID is entered for property data. Shell elements (QUAD, TRIA) require material ID and thickness, for property data.

D: Material Properties:

Material properties are entered using the PMAT command.

Example:
```
> PMAT,1,TIS,100.,.1,.2
> PMAT,2,TAN,50.,100.,150.,.1,.2,4
```

The first command creates material number-1, which has a thermal conductivity of 100., a specific heat of 0.1, and a density of 0.2. If conductivity or specific heat are negative, FEM/SINDA will assume that an array of the same number will be referenced, as a function of temperature, for that property. For example, if the conductivity was entered as -100, FEM/SINDA will cause that conductivity to be interpolated from array 100. The second example creates orthotropic material -2 (using the thermal anisotropic - TAN option) in which Kx, Ky, and Kz are 50., 100., and 150., respectively, and Cp = 0.1, density = 0.2, and orientation is defined by coordinate frame 4. The units for all the above variables must be consistant with those used to build the geometry.

E. Boundary Temperatures:

Boundary temperatures are entered using the standard DFEG command.

Example:
```
> DFEG,P1,TEMP,85.,,ED4
> DFEG,P1,TEMP,/3,,ED4
```

The first command imposes boundary temperatures to the nodes on edge 4 of patch 1. The second command sets up an interpolation from array-3, as a function of time for the temperature. The The user must input array 3 in the BCD 3 ARRAY DATA section of the SFILE.

F: Nodal Heat Sources:

Nodal heat sources are entered using the standard DFEG command.

Example: > DFEG,P1,NSRC,10.8,,ED2
> DFEG,P1,NSRC,/2,,ED1

The first command imposes nodal heat sources of 10.8 to nodes on edge 2 of patch 1. The second command sets up interpolation of heat source versus time from array-2.

G: Heat Fluxes:

Heat fluxes are entered using the standard DFEG command.

Example: > DFEG,P1,HEAT,4.5,,ED2
> DFEG,H1,HEAT,/4,,FA4

The first command imposes a per-unit-area heat flux of 4.5 to the edge of patch 1. The second example applies a per-unit-area heat flux which is interpolated from array 4 to face 4 of hyperpatch 1. The user must input array-4 in the BCD 3ARRAY DATA section of the SFILE.

H: Convection:

Convection is entered using the standard DFEG command.

Example: > DFEG,P1,CONV,0.7,1000,ED1
> DFEG,H2,CONV,3.0/1,5000,FA3

The first first command provides for convection, with a per-unit-area coefficient of 0.7, to the edge-1 of patch-1. The edge convects to fluid node 1000. The fourth field in the second example indicates that convection coefficients will be interpolated from array-3, as a function of average temperature. Other configuration numbers are as follows:

0 or blank	H is constant
1	H evaluated versus (Tsurf+Tfluid)/2
2	H evaluated versus time.
3	H evaluated versus ABS(Tsurf-Tfluid)

I: Radiation:

The PATRAN interface supports both types of radiation. Simple face radiation is entered using the standard DFEG command.

Example: > DFEG,H1,RADI,0.,2,FA4

The command applies simple face radiation to face-4 of hyperpatch-1, as part of radiation surface set #2. The 0. in the data field indicates that simple radiation is desired.
To produce FRADT cards (TRASYS radiation), an emissivity greater than 0 must be specified.

Example: > DFEG,H3,RADI,0.8/0,4,FA2

The command applies TRASYS radiation to face-2 of hyperpatch-3 with an emissivity of 0.8. The /0 will cause 'NO' to be written in field 6 on the FRADT card, indicating that this face cannot see any other faces of the same radiation set. The user must enter /1 to cause 'YES' to be entered in field 6.

Appropriate sets of commands from the aforementioned list of examples were used to generate nodes and to define the boundary conditions for the problem at hand. A PATRAN neutral file was generated. Option-1 of the FEM/SINDA interfaces menu was used to read the PATRAN neutral file and to generate the FEM input deck. Listings of the FEM input deck and the SFILE are as follows:

LISTING OF THE FEM INPUT DECK

```
TITLE=FEM/SINDA EXAMPLE
OUTPUT=PATRAN,PLOT
ITEMP=70
RTEMP=-460.
SOLVER=sinda
SFILE=STANDARD_sinda
MINCOND=1.0E-16
BEGIN BULK

$
$ Section 1 -- Coordinate Systems
$
$
$ Section 2 -- Nodes
NODE          1       0-1.00000-1.00000-2.00000
NODE          2       0 0.00000-1.00000-2.00000
NODE          3       0 1.00000-1.00000-2.00000
NODE          4       0 2.00000-1.00000-2.00000
NODE          5       0-1.00000 0.00000-2.00000
NODE          6       0 0.00000 0.00000-2.00000
NODE          7       0 1.00000 0.00000-2.00000
NODE          8       0 2.00000 0.00000-2.00000
NODE          9       0-1.00000 1.00000-2.00000
NODE         10       0 0.00000 1.00000-2.00000
NODE         11       0 1.00000 1.00000-2.00000
NODE         12       0 2.00000 1.00000-2.00000
NODE         13       0-1.00000 2.00000-2.00000
NODE         14       0 0.00000 2.00000-2.00000
NODE         15       0 1.00000 2.00000-2.00000
NODE         16       0 2.00000 2.00000-2.00000
NODE         17       0-0.66667-0.66667-1.33333
NODE         18       0 0.11111-0.66667-1.33333
NODE         19       0 0.88889-0.66667-1.33333
NODE         20       0 1.66667-0.66667-1.33333
NODE         21       0-0.66667 0.11111-1.33333
NODE         22       0 0.11111 0.11111-1.33333
NODE         23       0 0.88889 0.11111-1.33333
NODE         24       0 1.66667 0.11111-1.33333
NODE         25       0-0.66667 0.88889-1.33333
NODE         26       0 0.11111 0.88889-1.33333
NODE         27       0 0.88889 0.88889-1.33333
NODE         28       0 1.66667 0.88889-1.33333
NODE         29       0-0.66667 1.66667-1.33333
NODE         30       0 0.11111 1.66667-1.33333
NODE         31       0 0.88889 1.66667-1.33333
NODE         32       0 1.66667 1.66667-1.33333
NODE         33       0-0.33333-0.33333-0.66667
NODE         34       0 0.22222-0.33333-0.66667
NODE         35       0 0.77778-0.33333-0.66667
NODE         36       0 1.33333-0.33333-0.66667
NODE         37       0-0.33333 0.22222-0.66667
NODE         38       0 0.22222 0.22222-0.66667
NODE         39       0 0.77778 0.22222-0.66667
NODE         40       0 1.33333 0.22222-0.66667
NODE         41       0-0.33333 0.77778-0.66667
NODE         42       0 0.22222 0.77778-0.66667
NODE         43       0 0.77778 0.77778-0.66667
NODE         44       0 1.33333 0.77778-0.66667
NODE         45       0-0.33333 1.33333-0.66667
NODE         46       0 0.22222 1.33333-0.66667
NODE         47       0 0.77778 1.33333-0.66667
NODE         48       0 1.33333 1.33333-0.66667
```

NODE	49	0	0.00000	0.00000	0.00000
NODE	50	0	0.33333	0.00000	0.00000
NODE	51	0	0.66667	0.00000	0.00000
NODE	52	0	1.00000	0.00000	0.00000
NODE	53	0	0.00000	0.33333	0.00000
NODE	54	0	0.33333	0.33333	0.00000
NODE	55	0	0.66667	0.33333	0.00000
NODE	56	0	1.00000	0.33333	0.00000
NODE	57	0	0.00000	0.66667	0.00000
NODE	58	0	0.33333	0.66667	0.00000
NODE	59	0	0.66667	0.66667	0.00000
NODE	60	0	1.00000	0.66667	0.00000
NODE	61	0	0.00000	1.00000	0.00000
NODE	62	0	0.33333	1.00000	0.00000
NODE	63	0	0.66667	1.00000	0.00000
NODE	64	0	1.00000	1.00000	0.00000
NODE	81	0	-1.00000	-1.00000	-2.66667
NODE	82	0	-1.00000	0.00000	-2.66667
NODE	83	0	-1.00000	1.00000	-2.66667
NODE	84	0	-1.00000	2.00000	-2.66667
NODE	85	0	0.00000	-1.00000	-2.66667
NODE	86	0	0.00000	0.00000	-2.66667
NODE	87	0	0.00000	1.00000	-2.66667
NODE	88	0	0.00000	2.00000	-2.66667
NODE	89	0	1.00000	-1.00000	-2.66667
NODE	90	0	1.00000	0.00000	-2.66667
NODE	91	0	1.00000	1.00000	-2.66667
NODE	92	0	1.00000	2.00000	-2.66667
NODE	93	0	2.00000	-1.00000	-2.66667
NODE	94	0	2.00000	0.00000	-2.66667
NODE	95	0	2.00000	1.00000	-2.66667
NODE	96	0	2.00000	2.00000	-2.66667
NODE	97	0	-1.00000	-1.00000	-3.33333
NODE	98	0	-1.00000	0.00000	-3.33333
NODE	99	0	-1.00000	1.00000	-3.33333
NODE	100	0	-1.00000	2.00000	-3.33333
NODE	101	0	0.00000	-1.00000	-3.33333
NODE	102	0	0.00000	0.00000	-3.33333
NODE	103	0	0.00000	1.00000	-3.33333
NODE	104	0	0.00000	2.00000	-3.33333
NODE	105	0	1.00000	-1.00000	-3.33333
NODE	106	0	1.00000	0.00000	-3.33333
NODE	107	0	1.00000	1.00000	-3.33333
NODE	108	0	1.00000	2.00000	-3.33333
NODE	109	0	2.00000	-1.00000	-3.33333
NODE	110	0	2.00000	0.00000	-3.33333
NODE	111	0	2.00000	1.00000	-3.33333
NODE	112	0	2.00000	2.00000	-3.33333
NODE	113	0	-1.00000	-1.00000	-4.00000
NODE	114	0	-1.00000	0.00000	-4.00000
NODE	115	0	-1.00000	1.00000	-4.00000
NODE	116	0	-1.00000	2.00000	-4.00000
NODE	117	0	0.00000	-1.00000	-4.00000
NODE	118	0	0.00000	0.00000	-4.00000
NODE	119	0	0.00000	1.00000	-4.00000
NODE	120	0	0.00000	2.00000	-4.00000
NODE	121	0	1.00000	-1.00000	-4.00000
NODE	122	0	1.00000	0.00000	-4.00000
NODE	123	0	1.00000	1.00000	-4.00000
NODE	124	0	1.00000	2.00000	-4.00000
NODE	125	0	2.00000	-1.00000	-4.00000
NODE	126	0	2.00000	0.00000	-4.00000
NODE	127	0	2.00000	1.00000	-4.00000
NODE	128	0	2.00000	2.00000	-4.00000

```
FNODE       1000
$
$
$ Section 4 -- Material Properties
$
$mati*                mid        k              rho              cp
$
$mato*                mid        kx             ky               kz          +m
$+m                   rho        cp            cid
$
MATI*                   1 0.100000000E+01 0.200000003E+00 0.100000001E+00
MATI*                   2 0.520999985E+02 0.200000003E+00 0.100000001E+00
$
$
$ Section 5 -- Physical Properties
$
PSOLID*                 1                1
PSOLID*                 2                2
$
$
$ Section 6 -- Elements
$
BRICK          1        1        1        2        6        5       17       18+
+             22       21
BRICK          2        1        2        3        7        6       18       19+
+             23       22
BRICK          3        1        3        4        8        7       19       20+
+             24       23
BRICK          4        1        5        6       10        9       21       22+
+             26       25
BRICK          5        1        6        7       11       10       22       23+
+             27       26
BRICK          6        1        7        8       12       11       23       24+
+             28       27
BRICK          7        1        9       10       14       13       25       26+
+             30       29
BRICK          8        1       10       11       15       14       26       27+
+             31       30
BRICK          9        1       11       12       16       15       27       28+
+             32       31
BRICK         10        1       17       18       22       21       33       34+
+             38       37
BRICK         11        1       18       19       23       22       34       35+
+             39       38
BRICK         12        1       19       20       24       23       35       36+
+             40       39
BRICK         13        1       21       22       26       25       37       38+
+             42       41
BRICK         14        1       22       23       27       26       38       39+
+             43       42
BRICK         15        1       23       24       28       27       39       40+
+             44       43
BRICK         16        1       25       26       30       29       41       42+
+             46       45
BRICK         17        1       26       27       31       30       42       43+
+             47       46
BRICK         18        1       27       28       32       31       43       44+
+             48       47
BRICK         19        1       33       34       38       37       49       50+
+             54       53
BRICK         20        1       34       35       39       38       50       51+
+             55       54
BRICK         21        1       35       36       40       39       51       52+
+             56       55
```

```
BRICK      22      1      37      38      42      41      53      54+
+          58     57
BRICK      23      1      38      39      43      42      54      55+
+          59     58
BRICK      24      1      39      40      44      43      55      56+
+          60     59
BRICK      25      1      41      42      46      45      57      58+
+          62     61
BRICK      26      1      42      43      47      46      58      59+
+          63     62
BRICK      27      1      43      44      48      47      59      60+
+          64     63
BRICK      28      2       1       5       6       2      81      82+
+          86     85
BRICK      29      2       5       9      10       6      82      83+
+          87     86
BRICK      30      2       9      13      14      10      83      84+
+          88     87
BRICK      31      2       2       6       7       3      85      86+
+          90     89
BRICK      32      2       6      10      11       7      86      87+
+          91     90
BRICK      33      2      10      14      15      11      87      88+
+          92     91
BRICK      34      2       3       7       8       4      89      90+
+          94     93
BRICK      35      2       7      11      12       8      90      91+
+          95     94
BRICK      36      2      11      15      16      12      91      92+
+          96     95
BRICK      37      2      81      82      86      85      97      98+
+         102    101
BRICK      38      2      82      83      87      86      98      99+
+         103    102
BRICK      39      2      83      84      88      87      99     100+
+         104    103
BRICK      40      2      85      86      90      89     101     102+
+         106    105
BRICK      41      2      86      87      91      90     102     103+
+         107    106
BRICK      42      2      87      88      92      91     103     104+
+         108    107
BRICK      43      2      89      90      94      93     105     106+
+         110    109
BRICK      44      2      90      91      95      94     106     107+
+         111    110
BRICK      45      2      91      92      96      95     107     108+
+         112    111
BRICK      46      2      97      98     102     101     113     114+
+         118    117
BRICK      47      2      98      99     103     102     114     115+
+         119    118
BRICK      48      2      99     100     104     103     115     116+
+         120    119
BRICK      49      2     101     102     106     105     117     118+
+         122    121
BRICK      50      2     102     103     107     106     118     119+
+         123    122
BRICK      51      2     103     104     108     107     119     120+
+         124    123
BRICK      52      2     105     106     110     109     121     122+
+         126    125
BRICK      53      2     106     107     111     110     122     123+
+         127    126
```

```
BRICK          54        2      107      108      112      111      123      124+
+             128      127
$
$
$ Section 7 -- Boundary Conditions
$
$ Loads
$
$
$
$
$ Convection
$
$
FCNVECT ,       46,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       47,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       48,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       49,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       50,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       51,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       52,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       53,        2, 0.100000000E+01,     1000,        0
FCNVECT ,       54,        2, 0.100000000E+01,     1000,        0
$
$ Radiation
$
$
$
$
$ Restraints
TEMP*                  49  -0.2000000E+03
TEMP*                  50  -0.2000000E+03
TEMP*                  51  -0.2000000E+03
TEMP*                  52  -0.2000000E+03
TEMP*                  53  -0.2000000E+03
TEMP*                  54  -0.2000000E+03
TEMP*                  55  -0.2000000E+03
TEMP*                  56  -0.2000000E+03
TEMP*                  57  -0.2000000E+03
TEMP*                  58  -0.2000000E+03
TEMP*                  59  -0.2000000E+03
TEMP*                  60  -0.2000000E+03
TEMP*                  61  -0.2000000E+03
TEMP*                  62  -0.2000000E+03
TEMP*                  63  -0.2000000E+03
TEMP*                  64  -0.2000000E+03
```

LISTING OF THE SFILE

```
HEADER CONTROL DATA,GLOBAL
C-----------------------------------------------------------------------------
C  Data from SFILE:
     TIMEO  = 0.          $ STARTING TIME
     TIMEND = 0.          $ STOP TIME
     NLOOPS = 2000        $ MAX RELAXATION ITERATIONS
     SIGMA  = 3.303E-15 $ STEPHAN-BOLTZMAN CONSTANT (ASSUMING IN,BTU,R,SEC)
     ABSZRO = -460.       $ ABSOLUTE ZERO (F)
C-----------------------------------------------------------------------------
HEADER CONTROL DATA,FEMSINDA
C-----------------------------------------------------------------------------
C  Data from SFILE:
     ARLXCA = 0.01        $ MAX ARITHMETIC TEMP CHANGE PER ITERATION
     DRLXCA = 0.01        $ MAX DIFFUSION TEMP CHANGE PER ITERATION
     EBALSA = 0.01        $ ENERGY BALANCE
     DTIMEH = 1.0E+30     $ MAXIMUM ALLOWABLE TIME STEP
     OUTPUT = 0.0         $ PRINT INTERVAL
C-----------------------------------------------------------------------------
HEADER OPERATION DATA
BUILD SINDA85, FEMSINDA
C-----------------------------------------------------------------------------
C  Data from SFILE:
      CALL STDSTL
C      CALL FWDBCK
END OF DATA
```

V. FEM/SINDA File

Option-2 of the FEM/SINDA interface menu was used to generate the SINDA input deck. Using this option, the program prompts the user for the names of the FEM input file and the SINDA outout file. The following is a listing of the SINDA file generated by FEM/SINDA.

LISTING OF THE FEM/SINDA DECK

```
HEADER OPTIONS DATA
TITLE  FEM/SINDA EXAMPLE
      MODEL = SINDA85
HEADER NODE DATA,FEMSINDA
                 1,          70.00000,          3.100154947E-03
                 2,          70.00000,          6.200309894E-03
                 3,          70.00000,          6.200309894E-03
                 4,          70.00000,          3.100154947E-03
                 5,          70.00000,          6.200309894E-03
                 6,          70.00000,          1.240061979E-02
                 7,          70.00000,          1.240061979E-02
                 8,          70.00000,          6.200309894E-03
                 9,          70.00000,          6.200309894E-03
                10,          70.00000,          1.240061979E-02
                11,          70.00000,          1.240061979E-02
                12,          70.00000,          6.200309894E-03
                13,          70.00000,          3.100154947E-03
                14,          70.00000,          6.200309894E-03
                15,          70.00000,          6.200309894E-03
                16,          70.00000,          3.100154947E-03
                17,          70.00000,          2.043897136E-03
                18,          70.00000,          4.087797976E-03
                19,          70.00000,          4.087797976E-03
                20,          70.00000,          2.043897136E-03
                21,          70.00000,          4.087797976E-03
                22,          70.00000,          8.175603359E-03
                23,          70.00000,          8.175603359E-03
                24,          70.00000,          4.087797976E-03
                25,          70.00000,          4.087797976E-03
                26,          70.00000,          8.175603359E-03
                27,          70.00000,          8.175603359E-03
                28,          70.00000,          4.087797976E-03
                29,          70.00000,          2.043897136E-03
                30,          70.00000,          4.087797976E-03
                31,          70.00000,          4.087797976E-03
                32,          70.00000,          2.043897136E-03
                33,          70.00000,          1.056223037E-03
                34,          70.00000,          2.112460890E-03
                35,          70.00000,          2.112460890E-03
                36,          70.00000,          1.056223037E-03
                37,          70.00000,          2.112460890E-03
                38,          70.00000,          4.224951409E-03
                39,          70.00000,          4.224951409E-03
                40,          70.00000,          2.112460890E-03
                41,          70.00000,          2.112460890E-03
                42,          70.00000,          4.224951409E-03
                43,          70.00000,          4.224951409E-03
                44,          70.00000,          2.112460890E-03
                45,          70.00000,          1.056223037E-03
                46,          70.00000,          2.112460890E-03
                47,          70.00000,          2.112460890E-03
                48,          70.00000,          1.056223037E-03
               -49,        -200.0000,         -1.000000000E+00
               -50,        -200.0000,         -1.000000000E+00
               -51,        -200.0000,         -1.000000000E+00
               -52,        -200.0000,         -1.000000000E+00
               -53,        -200.0000,         -1.000000000E+00
               -54,        -200.0000,         -1.000000000E+00
               -55,        -200.0000,         -1.000000000E+00
               -56,        -200.0000,         -1.000000000E+00
               -57,        -200.0000,         -1.000000000E+00
```

```
-58,        -200.0000,        -1.000000000E+00
-59,        -200.0000,        -1.000000000E+00
-60,        -200.0000,        -1.000000000E+00
-61,        -200.0000,        -1.000000000E+00
-62,        -200.0000,        -1.000000000E+00
-63,        -200.0000,        -1.000000000E+00
-64,        -200.0000,        -1.000000000E+00
 81,         70.00000,         3.333325083E-03
 82,         70.00000,         6.666650167E-03
 83,         70.00000,         6.666650167E-03
 84,         70.00000,         3.333325083E-03
 85,         70.00000,         6.666650167E-03
 86,         70.00000,         1.333330033E-02
 87,         70.00000,         1.333330033E-02
 88,         70.00000,         6.666650167E-03
 89,         70.00000,         6.666650167E-03
 90,         70.00000,         1.333330033E-02
 91,         70.00000,         1.333330033E-02
 92,         70.00000,         6.666650167E-03
 93,         70.00000,         3.333325083E-03
 94,         70.00000,         6.666650167E-03
 95,         70.00000,         6.666650167E-03
 96,         70.00000,         3.333325083E-03
 97,         70.00000,         3.333325083E-03
 98,         70.00000,         6.666650167E-03
 99,         70.00000,         6.666650167E-03
100,         70.00000,         3.333325083E-03
101,         70.00000,         6.666650167E-03
102,         70.00000,         1.333330033E-02
103,         70.00000,         1.333330033E-02
104,         70.00000,         6.666650167E-03
105,         70.00000,         6.666650167E-03
106,         70.00000,         1.333330033E-02
107,         70.00000,         1.333330033E-02
108,         70.00000,         6.666650167E-03
109,         70.00000,         3.333325083E-03
110,         70.00000,         6.666650167E-03
111,         70.00000,         6.666650167E-03
112,         70.00000,         3.333325083E-03
113,         70.00000,         1.666675042E-03
114,         70.00000,         3.333350083E-03
115,         70.00000,         3.333350083E-03
116,         70.00000,         1.666675042E-03
117,         70.00000,         3.333350083E-03
118,         70.00000,         6.666700167E-03
119,         70.00000,         6.666700167E-03
120,         70.00000,         3.333350083E-03
121,         70.00000,         3.333350083E-03
122,         70.00000,         6.666700167E-03
123,         70.00000,         6.666700167E-03
124,         70.00000,         3.333350083E-03
125,         70.00000,         1.666675042E-03
126,         70.00000,         3.333350083E-03
127,         70.00000,         3.333350083E-03
128,         70.00000,         1.666675042E-03
-1000,       70.00000,        -1.000000000E+00
HEADER CONDUCTOR DATA,FEMSINDA
C
C ... Conductors ...
C
  1,     1,     2,  1.00000E+00  *  5.896942713E+00
  2,     1,     5,  1.00000E+00  *  5.896942713E+00
  3,     1,     6,  1.00000E+00  * -3.483145727E-01
  4,     1,    17,  1.00000E+00  *  1.820986574E-01
```

5,	1,	18,	1.00000E+00	*	-1.928936343E-02
6,	1,	21,	1.00000E+00	*	-1.928936343E-02
7,	1,	81,	5.21000E+01	*	2.499987500E-01
8,	1,	82,	5.21000E+01	*	6.249968750E-02
9,	1,	85,	5.21000E+01	*	6.249968750E-02
10,	2,	3,	1.00000E+00	*	5.884597343E+00
11,	2,	5,	1.00000E+00	*	-3.826072956E-01
12,	2,	6,	1.00000E+00	*	1.177536737E+01
13,	2,	7,	1.00000E+00	*	-3.678614297E-01
14,	2,	17,	1.00000E+00	*	1.288567477E-01
15,	2,	18,	1.00000E+00	*	3.827153704E-01
16,	2,	19,	1.00000E+00	*	5.169734954E-02
17,	2,	22,	1.00000E+00	*	-4.475141204E-02
18,	2,	81,	5.21000E+01	*	6.249968750E-02
19,	2,	85,	5.21000E+01	*	4.999975000E-01
20,	2,	86,	5.21000E+01	*	1.249993750E-01
21,	2,	89,	5.21000E+01	*	6.249968750E-02
22,	3,	4,	1.00000E+00	*	5.896942713E+00
23,	3,	6,	1.00000E+00	*	-3.678614297E-01
24,	3,	7,	1.00000E+00	*	1.177536737E+01
25,	3,	8,	1.00000E+00	*	-3.826072956E-01
26,	3,	18,	1.00000E+00	*	5.169734954E-02
27,	3,	19,	1.00000E+00	*	3.827153704E-01
28,	3,	20,	1.00000E+00	*	1.288567477E-01
29,	3,	23,	1.00000E+00	*	-4.475141204E-02
30,	3,	85,	5.21000E+01	*	6.249968750E-02
31,	3,	89,	5.21000E+01	*	4.999975000E-01
32,	3,	90,	5.21000E+01	*	1.249993750E-01
33,	3,	93,	5.21000E+01	*	6.249968750E-02
34,	4,	7,	1.00000E+00	*	-3.483145727E-01
35,	4,	8,	1.00000E+00	*	5.896942713E+00
36,	4,	19,	1.00000E+00	*	-1.928936343E-02
37,	4,	20,	1.00000E+00	*	1.820986574E-01
38,	4,	24,	1.00000E+00	*	-1.928936343E-02
39,	4,	89,	5.21000E+01	*	6.249968750E-02
40,	4,	93,	5.21000E+01	*	2.499987500E-01
41,	4,	94,	5.21000E+01	*	6.249968750E-02
42,	5,	6,	1.00000E+00	*	1.177536737E+01
43,	5,	9,	1.00000E+00	*	5.884597343E+00
44,	5,	10,	1.00000E+00	*	-3.678614297E-01
45,	5,	17,	1.00000E+00	*	1.288567477E-01
46,	5,	21,	1.00000E+00	*	3.827153704E-01
47,	5,	22,	1.00000E+00	*	-4.475141204E-02
48,	5,	25,	1.00000E+00	*	5.169734954E-02
49,	5,	81,	5.21000E+01	*	6.249968750E-02
50,	5,	82,	5.21000E+01	*	4.999975000E-01
51,	5,	83,	5.21000E+01	*	6.249968750E-02
52,	5,	86,	5.21000E+01	*	1.249993750E-01
53,	6,	7,	1.00000E+00	*	1.175067663E+01
54,	6,	9,	1.00000E+00	*	-3.678614297E-01
55,	6,	10,	1.00000E+00	*	1.175067663E+01
56,	6,	11,	1.00000E+00	*	-3.702619252E-01
57,	6,	18,	1.00000E+00	*	2.515408102E-01
58,	6,	21,	1.00000E+00	*	2.515408102E-01
59,	6,	22,	1.00000E+00	*	8.024668519E-01
60,	6,	23,	1.00000E+00	*	9.722201389E-02
61,	6,	26,	1.00000E+00	*	9.722201389E-02
62,	6,	82,	5.21000E+01	*	1.249993750E-01
63,	6,	85,	5.21000E+01	*	1.249993750E-01
64,	6,	86,	5.21000E+01	*	9.999950000E-01
65,	6,	87,	5.21000E+01	*	1.249993750E-01
66,	6,	90,	5.21000E+01	*	1.249993750E-01
67,	7,	8,	1.00000E+00	*	1.177536737E+01
68,	7,	10,	1.00000E+00	*	-3.702619252E-01

69,	7,	11,	1.00000E+00	*	1.175067663E+01
70,	7,	12,	1.00000E+00	*	-3.678614297E-01
71,	7,	19,	1.00000E+00	*	2.515408102E-01
72,	7,	22,	1.00000E+00	*	9.722201389E-02
73,	7,	23,	1.00000E+00	*	8.024668519E-01
74,	7,	24,	1.00000E+00	*	2.515408102E-01
75,	7,	27,	1.00000E+00	*	9.722201389E-02
76,	7,	86,	5.21000E+01	*	1.249993750E-01
77,	7,	89,	5.21000E+01	*	1.249993750E-01
78,	7,	90,	5.21000E+01	*	9.999950000E-01
79,	7,	91,	5.21000E+01	*	1.249993750E-01
80,	7,	94,	5.21000E+01	*	1.249993750E-01
81,	8,	11,	1.00000E+00	*	-3.678614297E-01
82,	8,	12,	1.00000E+00	*	5.884597343E+00
83,	8,	20,	1.00000E+00	*	1.288567477E-01
84,	8,	23,	1.00000E+00	*	-4.475141204E-02
85,	8,	24,	1.00000E+00	*	3.827153704E-01
86,	8,	28,	1.00000E+00	*	5.169734954E-02
87,	8,	90,	5.21000E+01	*	1.249993750E-01
88,	8,	93,	5.21000E+01	*	6.249968750E-02
89,	8,	94,	5.21000E+01	*	4.999975000E-01
90,	8,	95,	5.21000E+01	*	6.249968750E-02
91,	9,	10,	1.00000E+00	*	1.177536737E+01
92,	9,	13,	1.00000E+00	*	5.896942713E+00
93,	9,	14,	1.00000E+00	*	-3.826072956E-01
94,	9,	21,	1.00000E+00	*	5.169734954E-02
95,	9,	25,	1.00000E+00	*	3.827153704E-01
96,	9,	26,	1.00000E+00	*	-4.475141204E-02
97,	9,	29,	1.00000E+00	*	1.288567477E-01
98,	9,	82,	5.21000E+01	*	6.249968750E-02
99,	9,	83,	5.21000E+01	*	4.999975000E-01
100,	9,	84,	5.21000E+01	*	6.249968750E-02
101,	9,	87,	5.21000E+01	*	1.249993750E-01
102,	10,	11,	1.00000E+00	*	1.175067663E+01
103,	10,	13,	1.00000E+00	*	-3.483145727E-01
104,	10,	14,	1.00000E+00	*	1.177536737E+01
105,	10,	15,	1.00000E+00	*	-3.678614297E-01
106,	10,	22,	1.00000E+00	*	9.722201389E-02
107,	10,	25,	1.00000E+00	*	2.515408102E-01
108,	10,	26,	1.00000E+00	*	8.024668519E-01
109,	10,	27,	1.00000E+00	*	9.722201389E-02
110,	10,	30,	1.00000E+00	*	2.515408102E-01
111,	10,	83,	5.21000E+01	*	1.249993750E-01
112,	10,	86,	5.21000E+01	*	1.249993750E-01
113,	10,	87,	5.21000E+01	*	9.999950000E-01
114,	10,	88,	5.21000E+01	*	1.249993750E-01
115,	10,	91,	5.21000E+01	*	1.249993750E-01
116,	11,	12,	1.00000E+00	*	1.177536737E+01
117,	11,	14,	1.00000E+00	*	-3.678614297E-01
118,	11,	15,	1.00000E+00	*	1.177536737E+01
119,	11,	16,	1.00000E+00	*	-3.483145727E-01
120,	11,	23,	1.00000E+00	*	9.722201389E-02
121,	11,	26,	1.00000E+00	*	9.722201389E-02
122,	11,	27,	1.00000E+00	*	8.024668519E-01
123,	11,	28,	1.00000E+00	*	2.515408102E-01
124,	11,	31,	1.00000E+00	*	2.515408102E-01
125,	11,	87,	5.21000E+01	*	1.249993750E-01
126,	11,	90,	5.21000E+01	*	1.249993750E-01
127,	11,	91,	5.21000E+01	*	9.999950000E-01
128,	11,	92,	5.21000E+01	*	1.249993750E-01
129,	11,	95,	5.21000E+01	*	1.249993750E-01
130,	12,	15,	1.00000E+00	*	-3.826072956E-01
131,	12,	16,	1.00000E+00	*	5.896942713E+00
132,	12,	24,	1.00000E+00	*	5.169734954E-02

133,	12,	27,	1.00000E+00	*	-4.475141204E-02
134,	12,	28,	1.00000E+00	*	3.827153704E-01
135,	12,	32,	1.00000E+00	*	1.288567477E-01
136,	12,	91,	5.21000E+01	*	1.249993750E-01
137,	12,	94,	5.21000E+01	*	6.249968750E-02
138,	12,	95,	5.21000E+01	*	4.999975000E-01
139,	12,	96,	5.21000E+01	*	6.249968750E-02
140,	13,	14,	1.00000E+00	*	5.896942713E+00
141,	13,	25,	1.00000E+00	*	-1.928936343E-02
142,	13,	29,	1.00000E+00	*	1.820986574E-01
143,	13,	30,	1.00000E+00	*	-1.928936343E-02
144,	13,	83,	5.21000E+01	*	6.249968750E-02
145,	13,	84,	5.21000E+01	*	2.499987500E-01
146,	13,	88,	5.21000E+01	*	6.249968750E-02
147,	14,	15,	1.00000E+00	*	5.884597343E+00
148,	14,	26,	1.00000E+00	*	-4.475141204E-02
149,	14,	29,	1.00000E+00	*	1.288567477E-01
150,	14,	30,	1.00000E+00	*	3.827153704E-01
151,	14,	31,	1.00000E+00	*	5.169734954E-02
152,	14,	84,	5.21000E+01	*	6.249968750E-02
153,	14,	87,	5.21000E+01	*	1.249993750E-01
154,	14,	88,	5.21000E+01	*	4.999975000E-01
155,	14,	92,	5.21000E+01	*	6.249968750E-02
156,	15,	16,	1.00000E+00	*	5.896942713E+00
157,	15,	27,	1.00000E+00	*	-4.475141204E-02
158,	15,	30,	1.00000E+00	*	5.169734954E-02
159,	15,	31,	1.00000E+00	*	3.827153704E-01
160,	15,	32,	1.00000E+00	*	1.288567477E-01
161,	15,	88,	5.21000E+01	*	6.249968750E-02
162,	15,	91,	5.21000E+01	*	1.249993750E-01
163,	15,	92,	5.21000E+01	*	4.999975000E-01
164,	15,	96,	5.21000E+01	*	6.249968750E-02
165,	16,	28,	1.00000E+00	*	-1.928936343E-02
166,	16,	31,	1.00000E+00	*	-1.928936343E-02
167,	16,	32,	1.00000E+00	*	1.820986574E-01
168,	16,	92,	5.21000E+01	*	6.249968750E-02
169,	16,	95,	5.21000E+01	*	6.249968750E-02
170,	16,	96,	5.21000E+01	*	2.499987500E-01
171,	17,	18,	1.00000E+00	*	2.716037500E-01
172,	17,	21,	1.00000E+00	*	2.716037500E-01
173,	17,	22,	1.00000E+00	*	7.870268355E-02
174,	17,	33,	1.00000E+00	*	9.567861110E-02
175,	17,	34,	1.00000E+00	*	-2.237715278E-02
176,	17,	37,	1.00000E+00	*	-2.237715278E-02
177,	18,	19,	1.00000E+00	*	2.469125463E-01
178,	18,	21,	1.00000E+00	*	4.628609447E-03
179,	18,	22,	1.00000E+00	*	5.061697222E-01
180,	18,	23,	1.00000E+00	*	3.549318122E-02
181,	18,	33,	1.00000E+00	*	8.873618057E-02
182,	18,	34,	1.00000E+00	*	2.098780556E-01
183,	18,	35,	1.00000E+00	*	3.009242362E-02
184,	18,	38,	1.00000E+00	*	-5.092735419E-02
185,	19,	20,	1.00000E+00	*	2.716037500E-01
186,	19,	22,	1.00000E+00	*	3.549318122E-02
187,	19,	23,	1.00000E+00	*	5.061697222E-01
188,	19,	24,	1.00000E+00	*	4.628609447E-03
189,	19,	34,	1.00000E+00	*	3.009242362E-02
190,	19,	35,	1.00000E+00	*	2.098780556E-01
191,	19,	36,	1.00000E+00	*	8.873618057E-02
192,	19,	39,	1.00000E+00	*	-5.092735419E-02
193,	20,	23,	1.00000E+00	*	7.870268355E-02
194,	20,	24,	1.00000E+00	*	2.716037500E-01
195,	20,	35,	1.00000E+00	*	-2.237715278E-02
196,	20,	36,	1.00000E+00	*	9.567861110E-02

197,	20,	40,	1.00000E+00	*	-2.237715278E-02
198,	21,	22,	1.00000E+00	*	5.061697222E-01
199,	21,	25,	1.00000E+00	*	2.469125463E-01
200,	21,	26,	1.00000E+00	*	3.549318122E-02
201,	21,	33,	1.00000E+00	*	8.873618057E-02
202,	21,	37,	1.00000E+00	*	2.098780556E-01
203,	21,	38,	1.00000E+00	*	-5.092735419E-02
204,	21,	41,	1.00000E+00	*	3.009242362E-02
205,	22,	23,	1.00000E+00	*	4.567881482E-01
206,	22,	25,	1.00000E+00	*	3.549318122E-02
207,	22,	26,	1.00000E+00	*	4.567881482E-01
208,	22,	27,	1.00000E+00	*	2.932059688E-02
209,	22,	34,	1.00000E+00	*	1.713001459E-01
210,	22,	37,	1.00000E+00	*	1.713001459E-01
211,	22,	38,	1.00000E+00	*	4.567961112E-01
212,	22,	39,	1.00000E+00	*	5.401263196E-02
213,	22,	42,	1.00000E+00	*	5.401263196E-02
214,	23,	24,	1.00000E+00	*	5.061697222E-01
215,	23,	26,	1.00000E+00	*	2.932059688E-02
216,	23,	27,	1.00000E+00	*	4.567881482E-01
217,	23,	28,	1.00000E+00	*	3.549318122E-02
218,	23,	35,	1.00000E+00	*	1.713001459E-01
219,	23,	38,	1.00000E+00	*	5.401263196E-02
220,	23,	39,	1.00000E+00	*	4.567961112E-01
221,	23,	40,	1.00000E+00	*	1.713001459E-01
222,	23,	43,	1.00000E+00	*	5.401263196E-02
223,	24,	27,	1.00000E+00	*	3.549318122E-02
224,	24,	28,	1.00000E+00	*	2.469125463E-01
225,	24,	36,	1.00000E+00	*	8.873618057E-02
226,	24,	39,	1.00000E+00	*	-5.092735419E-02
227,	24,	40,	1.00000E+00	*	2.098780556E-01
228,	24,	44,	1.00000E+00	*	3.009242362E-02
229,	25,	26,	1.00000E+00	*	5.061697222E-01
230,	25,	29,	1.00000E+00	*	2.716037500E-01
231,	25,	30,	1.00000E+00	*	4.628609447E-03
232,	25,	37,	1.00000E+00	*	3.009242362E-02
233,	25,	41,	1.00000E+00	*	2.098780556E-01
234,	25,	42,	1.00000E+00	*	-5.092735419E-02
235,	25,	45,	1.00000E+00	*	8.873618057E-02
236,	26,	27,	1.00000E+00	*	4.567881482E-01
237,	26,	29,	1.00000E+00	*	7.870268355E-02
238,	26,	30,	1.00000E+00	*	5.061697222E-01
239,	26,	31,	1.00000E+00	*	3.549318122E-02
240,	26,	38,	1.00000E+00	*	5.401263196E-02
241,	26,	41,	1.00000E+00	*	1.713001459E-01
242,	26,	42,	1.00000E+00	*	4.567961112E-01
243,	26,	43,	1.00000E+00	*	5.401263196E-02
244,	26,	46,	1.00000E+00	*	1.713001459E-01
245,	27,	28,	1.00000E+00	*	5.061697222E-01
246,	27,	30,	1.00000E+00	*	3.549318122E-02
247,	27,	31,	1.00000E+00	*	5.061697222E-01
248,	27,	32,	1.00000E+00	*	7.870268355E-02
249,	27,	39,	1.00000E+00	*	5.401263196E-02
250,	27,	42,	1.00000E+00	*	5.401263196E-02
251,	27,	43,	1.00000E+00	*	4.567961112E-01
252,	27,	44,	1.00000E+00	*	1.713001459E-01
253,	27,	47,	1.00000E+00	*	1.713001459E-01
254,	28,	31,	1.00000E+00	*	4.628609447E-03
255,	28,	32,	1.00000E+00	*	2.716037500E-01
256,	28,	40,	1.00000E+00	*	3.009242362E-02
257,	28,	43,	1.00000E+00	*	-5.092735419E-02
258,	28,	44,	1.00000E+00	*	2.098780556E-01
259,	28,	48,	1.00000E+00	*	8.873618057E-02
260,	29,	30,	1.00000E+00	*	2.716037500E-01

261,	29,	41,	1.00000E+00	*	-2.237715278E-02
262,	29,	45,	1.00000E+00	*	9.567861110E-02
263,	29,	46,	1.00000E+00	*	-2.237715278E-02
264,	30,	31,	1.00000E+00	*	2.469125463E-01
265,	30,	42,	1.00000E+00	*	-5.092735419E-02
266,	30,	45,	1.00000E+00	*	8.873618057E-02
267,	30,	46,	1.00000E+00	*	2.098780556E-01
268,	30,	47,	1.00000E+00	*	3.009242362E-02
269,	31,	32,	1.00000E+00	*	2.716037500E-01
270,	31,	43,	1.00000E+00	*	-5.092735419E-02
271,	31,	46,	1.00000E+00	*	3.009242362E-02
272,	31,	47,	1.00000E+00	*	2.098780556E-01
273,	31,	48,	1.00000E+00	*	8.873618057E-02
274,	32,	44,	1.00000E+00	*	-2.237715278E-02
275,	32,	47,	1.00000E+00	*	-2.237715278E-02
276,	32,	48,	1.00000E+00	*	9.567861110E-02
277,	33,	34,	1.00000E+00	*	2.716059722E-01
278,	33,	37,	1.00000E+00	*	2.716059722E-01
279,	33,	38,	1.00000E+00	*	1.157419375E-01
280,	33,	49,	1.00000E+00	*	3.394976853E-02
281,	33,	50,	1.00000E+00	*	-1.928964121E-02
282,	33,	53,	1.00000E+00	*	-1.928964121E-02
283,	34,	35,	1.00000E+00	*	2.469089908E-01
284,	34,	37,	1.00000E+00	*	4.166697452E-02
285,	34,	38,	1.00000E+00	*	5.061787223E-01
286,	34,	39,	1.00000E+00	*	7.253060186E-02
287,	34,	49,	1.00000E+00	*	5.478258103E-02
288,	34,	50,	1.00000E+00	*	8.641870371E-02
289,	34,	51,	1.00000E+00	*	1.465899768E-02
290,	34,	54,	1.00000E+00	*	-4.475111574E-02
291,	35,	36,	1.00000E+00	*	2.716059722E-01
292,	35,	38,	1.00000E+00	*	7.253060186E-02
293,	35,	39,	1.00000E+00	*	5.061787223E-01
294,	35,	40,	1.00000E+00	*	4.166697452E-02
295,	35,	50,	1.00000E+00	*	1.465899768E-02
296,	35,	51,	1.00000E+00	*	8.641870371E-02
297,	35,	52,	1.00000E+00	*	5.478258103E-02
298,	35,	55,	1.00000E+00	*	-4.475111574E-02
299,	36,	39,	1.00000E+00	*	1.157419375E-01
300,	36,	40,	1.00000E+00	*	2.716059722E-01
301,	36,	51,	1.00000E+00	*	-1.928964121E-02
302,	36,	52,	1.00000E+00	*	3.394976853E-02
303,	36,	56,	1.00000E+00	*	-1.928964121E-02
304,	37,	38,	1.00000E+00	*	5.061787223E-01
305,	37,	41,	1.00000E+00	*	2.469089908E-01
306,	37,	42,	1.00000E+00	*	7.253060186E-02
307,	37,	49,	1.00000E+00	*	5.478258103E-02
308,	37,	53,	1.00000E+00	*	8.641870371E-02
309,	37,	54,	1.00000E+00	*	-4.475111574E-02
310,	37,	57,	1.00000E+00	*	1.465899768E-02
311,	38,	39,	1.00000E+00	*	4.567851482E-01
312,	38,	41,	1.00000E+00	*	7.253060186E-02
313,	38,	42,	1.00000E+00	*	4.567851482E-01
314,	38,	43,	1.00000E+00	*	6.635669213E-02
315,	38,	50,	1.00000E+00	*	1.033949954E-01
316,	38,	53,	1.00000E+00	*	1.033949954E-01
317,	38,	54,	1.00000E+00	*	2.098757407E-01
318,	38,	55,	1.00000E+00	*	2.314699537E-02
319,	38,	58,	1.00000E+00	*	2.314699537E-02
320,	39,	40,	1.00000E+00	*	5.061787223E-01
321,	39,	42,	1.00000E+00	*	6.635669213E-02
322,	39,	43,	1.00000E+00	*	4.567851482E-01
323,	39,	44,	1.00000E+00	*	7.253060186E-02
324,	39,	51,	1.00000E+00	*	1.033949954E-01

325,	39,	54,	1.00000E+00	*	2.314699537E-02
326,	39,	55,	1.00000E+00	*	2.098757407E-01
327,	39,	56,	1.00000E+00	*	1.033949954E-01
328,	39,	59,	1.00000E+00	*	2.314699537E-02
329,	40,	43,	1.00000E+00	*	7.253060186E-02
330,	40,	44,	1.00000E+00	*	2.469089908E-01
331,	40,	52,	1.00000E+00	*	5.478258103E-02
332,	40,	55,	1.00000E+00	*	-4.475111574E-02
333,	40,	56,	1.00000E+00	*	8.641870371E-02
334,	40,	60,	1.00000E+00	*	1.465899768E-02
335,	41,	42,	1.00000E+00	*	5.061787223E-01
336,	41,	45,	1.00000E+00	*	2.716059722E-01
337,	41,	46,	1.00000E+00	*	4.166697452E-02
338,	41,	53,	1.00000E+00	*	1.465899768E-02
339,	41,	57,	1.00000E+00	*	8.641870371E-02
340,	41,	58,	1.00000E+00	*	-4.475111574E-02
341,	41,	61,	1.00000E+00	*	5.478258103E-02
342,	42,	43,	1.00000E+00	*	4.567851482E-01
343,	42,	45,	1.00000E+00	*	1.157419375E-01
344,	42,	46,	1.00000E+00	*	5.061787223E-01
345,	42,	47,	1.00000E+00	*	7.253060186E-02
346,	42,	54,	1.00000E+00	*	2.314699537E-02
347,	42,	57,	1.00000E+00	*	1.033949954E-01
348,	42,	58,	1.00000E+00	*	2.098757407E-01
349,	42,	59,	1.00000E+00	*	2.314699537E-02
350,	42,	62,	1.00000E+00	*	1.033949954E-01
351,	43,	44,	1.00000E+00	*	5.061787223E-01
352,	43,	46,	1.00000E+00	*	7.253060186E-02
353,	43,	47,	1.00000E+00	*	5.061787223E-01
354,	43,	48,	1.00000E+00	*	1.157419375E-01
355,	43,	55,	1.00000E+00	*	2.314699537E-02
356,	43,	58,	1.00000E+00	*	2.314699537E-02
357,	43,	59,	1.00000E+00	*	2.098757407E-01
358,	43,	60,	1.00000E+00	*	1.033949954E-01
359,	43,	63,	1.00000E+00	*	1.033949954E-01
360,	44,	47,	1.00000E+00	*	4.166697452E-02
361,	44,	48,	1.00000E+00	*	2.716059722E-01
362,	44,	56,	1.00000E+00	*	1.465899768E-02
363,	44,	59,	1.00000E+00	*	-4.475111574E-02
364,	44,	60,	1.00000E+00	*	8.641870371E-02
365,	44,	64,	1.00000E+00	*	5.478258103E-02
366,	45,	46,	1.00000E+00	*	2.716059722E-01
367,	45,	57,	1.00000E+00	*	-1.928964121E-02
368,	45,	61,	1.00000E+00	*	3.394976853E-02
369,	45,	62,	1.00000E+00	*	-1.928964121E-02
370,	46,	47,	1.00000E+00	*	2.469089908E-01
371,	46,	58,	1.00000E+00	*	-4.475111574E-02
372,	46,	61,	1.00000E+00	*	5.478258103E-02
373,	46,	62,	1.00000E+00	*	8.641870371E-02
374,	46,	63,	1.00000E+00	*	1.465899768E-02
375,	47,	48,	1.00000E+00	*	2.716059722E-01
376,	47,	59,	1.00000E+00	*	-4.475111574E-02
377,	47,	62,	1.00000E+00	*	1.465899768E-02
378,	47,	63,	1.00000E+00	*	8.641870371E-02
379,	47,	64,	1.00000E+00	*	5.478258103E-02
380,	48,	60,	1.00000E+00	*	-1.928964121E-02
381,	48,	63,	1.00000E+00	*	-1.928964121E-02
382,	48,	64,	1.00000E+00	*	3.394976853E-02
383,	49,	50,	1.00000E+00	*	1.450614352E-01
384,	49,	53,	1.00000E+00	*	1.450614352E-01
385,	49,	54,	1.00000E+00	*	1.108539159E-01
386,	50,	51,	1.00000E+00	*	1.327126389E-01
387,	50,	53,	1.00000E+00	*	6.558755786E-02
388,	50,	54,	1.00000E+00	*	2.716088889E-01

389,	50,	55,	1.00000E+00	*	8.307606098E-02
390,	51,	52,	1.00000E+00	*	1.450614352E-01
391,	51,	54,	1.00000E+00	*	8.307606098E-02
392,	51,	55,	1.00000E+00	*	2.716088889E-01
393,	51,	56,	1.00000E+00	*	6.558755786E-02
394,	52,	55,	1.00000E+00	*	1.108539159E-01
395,	52,	56,	1.00000E+00	*	1.450614352E-01
396,	53,	54,	1.00000E+00	*	2.716088889E-01
397,	53,	57,	1.00000E+00	*	1.327126389E-01
398,	53,	58,	1.00000E+00	*	8.307606098E-02
399,	54,	55,	1.00000E+00	*	2.469109260E-01
400,	54,	57,	1.00000E+00	*	8.307606098E-02
401,	54,	58,	1.00000E+00	*	2.469109260E-01
402,	54,	59,	1.00000E+00	*	7.793126159E-02
403,	55,	56,	1.00000E+00	*	2.716088889E-01
404,	55,	58,	1.00000E+00	*	7.793126159E-02
405,	55,	59,	1.00000E+00	*	2.469109260E-01
406,	55,	60,	1.00000E+00	*	8.307606098E-02
407,	56,	59,	1.00000E+00	*	8.307606098E-02
408,	56,	60,	1.00000E+00	*	1.327126389E-01
409,	57,	58,	1.00000E+00	*	2.716088889E-01
410,	57,	61,	1.00000E+00	*	1.450614352E-01
411,	57,	62,	1.00000E+00	*	6.558755786E-02
412,	58,	59,	1.00000E+00	*	2.469109260E-01
413,	58,	61,	1.00000E+00	*	1.108539159E-01
414,	58,	62,	1.00000E+00	*	2.716088889E-01
415,	58,	63,	1.00000E+00	*	8.307606098E-02
416,	59,	60,	1.00000E+00	*	2.716088889E-01
417,	59,	62,	1.00000E+00	*	8.307606098E-02
418,	59,	63,	1.00000E+00	*	2.716088889E-01
419,	59,	64,	1.00000E+00	*	1.108539159E-01
420,	60,	63,	1.00000E+00	*	6.558755786E-02
421,	60,	64,	1.00000E+00	*	1.450614352E-01
422,	61,	62,	1.00000E+00	*	1.450614352E-01
423,	62,	63,	1.00000E+00	*	1.327126389E-01
424,	63,	64,	1.00000E+00	*	1.450614352E-01
425,	81,	82,	5.21000E+01	*	2.222216667E-01
426,	81,	85,	5.21000E+01	*	2.222216667E-01
427,	81,	86,	5.21000E+01	*	-1.388947917E-02
428,	81,	97,	5.21000E+01	*	2.500025000E-01
429,	81,	98,	5.21000E+01	*	6.250062501E-02
430,	81,	101,	5.21000E+01	*	6.250062501E-02
431,	82,	83,	5.21000E+01	*	2.222216667E-01
432,	82,	85,	5.21000E+01	*	-1.388947917E-02
433,	82,	86,	5.21000E+01	*	4.444433333E-01
434,	82,	87,	5.21000E+01	*	-1.388947917E-02
435,	82,	97,	5.21000E+01	*	6.250062501E-02
436,	82,	98,	5.21000E+01	*	5.000050001E-01
437,	82,	99,	5.21000E+01	*	6.250062501E-02
438,	82,	102,	5.21000E+01	*	1.250012500E-01
439,	83,	84,	5.21000E+01	*	2.222216667E-01
440,	83,	86,	5.21000E+01	*	-1.388947917E-02
441,	83,	87,	5.21000E+01	*	4.444433333E-01
442,	83,	88,	5.21000E+01	*	-1.388947917E-02
443,	83,	98,	5.21000E+01	*	6.250062501E-02
444,	83,	99,	5.21000E+01	*	5.000050001E-01
445,	83,	100,	5.21000E+01	*	6.250062501E-02
446,	83,	103,	5.21000E+01	*	1.250012500E-01
447,	84,	87,	5.21000E+01	*	-1.388947917E-02
448,	84,	88,	5.21000E+01	*	2.222216667E-01
449,	84,	99,	5.21000E+01	*	6.250062501E-02
450,	84,	100,	5.21000E+01	*	2.500025000E-01
451,	84,	104,	5.21000E+01	*	6.250062501E-02
452,	85,	86,	5.21000E+01	*	4.444433333E-01

453,	85,	89,	5.21000E+01	*	2.222216667E-01
454,	85,	90,	5.21000E+01	*	-1.388947917E-02
455,	85,	97,	5.21000E+01	*	6.250062501E-02
456,	85,	101,	5.21000E+01	*	5.000050001E-01
457,	85,	102,	5.21000E+01	*	1.250012500E-01
458,	85,	105,	5.21000E+01	*	6.250062501E-02
459,	86,	87,	5.21000E+01	*	4.444433333E-01
460,	86,	89,	5.21000E+01	*	-1.388947917E-02
461,	86,	90,	5.21000E+01	*	4.444433333E-01
462,	86,	91,	5.21000E+01	*	-1.388947917E-02
463,	86,	98,	5.21000E+01	*	1.250012500E-01
464,	86,	101,	5.21000E+01	*	1.250012500E-01
465,	86,	102,	5.21000E+01	*	1.000010000E+00
466,	86,	103,	5.21000E+01	*	1.250012500E-01
467,	86,	106,	5.21000E+01	*	1.250012500E-01
468,	87,	88,	5.21000E+01	*	4.444433333E-01
469,	87,	90,	5.21000E+01	*	-1.388947917E-02
470,	87,	91,	5.21000E+01	*	4.444433333E-01
471,	87,	92,	5.21000E+01	*	-1.388947917E-02
472,	87,	99,	5.21000E+01	*	1.250012500E-01
473,	87,	102,	5.21000E+01	*	1.250012500E-01
474,	87,	103,	5.21000E+01	*	1.000010000E+00
475,	87,	104,	5.21000E+01	*	1.250012500E-01
476,	87,	107,	5.21000E+01	*	1.250012500E-01
477,	88,	91,	5.21000E+01	*	-1.388947917E-02
478,	88,	92,	5.21000E+01	*	2.222216667E-01
479,	88,	100,	5.21000E+01	*	6.250062501E-02
480,	88,	103,	5.21000E+01	*	1.250012500E-01
481,	88,	104,	5.21000E+01	*	5.000050001E-01
482,	88,	108,	5.21000E+01	*	6.250062501E-02
483,	89,	90,	5.21000E+01	*	4.444433333E-01
484,	89,	93,	5.21000E+01	*	2.222216667E-01
485,	89,	94,	5.21000E+01	*	-1.388947917E-02
486,	89,	101,	5.21000E+01	*	6.250062501E-02
487,	89,	105,	5.21000E+01	*	5.000050001E-01
488,	89,	106,	5.21000E+01	*	1.250012500E-01
489,	89,	109,	5.21000E+01	*	6.250062501E-02
490,	90,	91,	5.21000E+01	*	4.444433333E-01
491,	90,	93,	5.21000E+01	*	-1.388947917E-02
492,	90,	94,	5.21000E+01	*	4.444433333E-01
493,	90,	95,	5.21000E+01	*	-1.388947917E-02
494,	90,	102,	5.21000E+01	*	1.250012500E-01
495,	90,	105,	5.21000E+01	*	1.250012500E-01
496,	90,	106,	5.21000E+01	*	1.000010000E+00
497,	90,	107,	5.21000E+01	*	1.250012500E-01
498,	90,	110,	5.21000E+01	*	1.250012500E-01
499,	91,	92,	5.21000E+01	*	4.444433333E-01
500,	91,	94,	5.21000E+01	*	-1.388947917E-02
501,	91,	95,	5.21000E+01	*	4.444433333E-01
502,	91,	96,	5.21000E+01	*	-1.388947917E-02
503,	91,	103,	5.21000E+01	*	1.250012500E-01
504,	91,	106,	5.21000E+01	*	1.250012500E-01
505,	91,	107,	5.21000E+01	*	1.000010000E+00
506,	91,	108,	5.21000E+01	*	1.250012500E-01
507,	91,	111,	5.21000E+01	*	1.250012500E-01
508,	92,	95,	5.21000E+01	*	-1.388947917E-02
509,	92,	96,	5.21000E+01	*	2.222216667E-01
510,	92,	104,	5.21000E+01	*	6.250062501E-02
511,	92,	107,	5.21000E+01	*	1.250012500E-01
512,	92,	108,	5.21000E+01	*	5.000050001E-01
513,	92,	112,	5.21000E+01	*	6.250062501E-02
514,	93,	94,	5.21000E+01	*	2.222216667E-01
515,	93,	105,	5.21000E+01	*	6.250062501E-02
516,	93,	109,	5.21000E+01	*	2.500025000E-01

517,	93,	110,	5.21000E+01	*	6.250062501E-02
518,	94,	95,	5.21000E+01	*	2.222216667E-01
519,	94,	106,	5.21000E+01	*	1.250012500E-01
520,	94,	109,	5.21000E+01	*	6.250062501E-02
521,	94,	110,	5.21000E+01	*	5.000050001E-01
522,	94,	111,	5.21000E+01	*	6.250062501E-02
523,	95,	96,	5.21000E+01	*	2.222216667E-01
524,	95,	107,	5.21000E+01	*	1.250012500E-01
525,	95,	110,	5.21000E+01	*	6.250062501E-02
526,	95,	111,	5.21000E+01	*	5.000050001E-01
527,	95,	112,	5.21000E+01	*	6.250062501E-02
528,	96,	108,	5.21000E+01	*	6.250062501E-02
529,	96,	111,	5.21000E+01	*	6.250062501E-02
530,	96,	112,	5.21000E+01	*	2.500025000E-01
531,	97,	98,	5.21000E+01	*	2.222216667E-01
532,	97,	101,	5.21000E+01	*	2.222216667E-01
533,	97,	102,	5.21000E+01	*	-1.388947917E-02
534,	97,	113,	5.21000E+01	*	2.499987500E-01
535,	97,	114,	5.21000E+01	*	6.249968750E-02
536,	97,	117,	5.21000E+01	*	6.249968750E-02
537,	98,	99,	5.21000E+01	*	2.222216667E-01
538,	98,	101,	5.21000E+01	*	-1.388947917E-02
539,	98,	102,	5.21000E+01	*	4.444433333E-01
540,	98,	103,	5.21000E+01	*	-1.388947917E-02
541,	98,	113,	5.21000E+01	*	6.249968750E-02
542,	98,	114,	5.21000E+01	*	4.999975000E-01
543,	98,	115,	5.21000E+01	*	6.249968750E-02
544,	98,	118,	5.21000E+01	*	1.249993750E-01
545,	99,	100,	5.21000E+01	*	2.222216667E-01
546,	99,	102,	5.21000E+01	*	-1.388947917E-02
547,	99,	103,	5.21000E+01	*	4.444433333E-01
548,	99,	104,	5.21000E+01	*	-1.388947917E-02
549,	99,	114,	5.21000E+01	*	6.249968750E-02
550,	99,	115,	5.21000E+01	*	4.999975000E-01
551,	99,	116,	5.21000E+01	*	6.249968750E-02
552,	99,	119,	5.21000E+01	*	1.249993750E-01
553,	100,	103,	5.21000E+01	*	-1.388947917E-02
554,	100,	104,	5.21000E+01	*	2.222216667E-01
555,	100,	115,	5.21000E+01	*	6.249968750E-02
556,	100,	116,	5.21000E+01	*	2.499987500E-01
557,	100,	120,	5.21000E+01	*	6.249968750E-02
558,	101,	102,	5.21000E+01	*	4.444433333E-01
559,	101,	105,	5.21000E+01	*	2.222216667E-01
560,	101,	106,	5.21000E+01	*	-1.388947917E-02
561,	101,	113,	5.21000E+01	*	6.249968750E-02
562,	101,	117,	5.21000E+01	*	4.999975000E-01
563,	101,	118,	5.21000E+01	*	1.249993750E-01
564,	101,	121,	5.21000E+01	*	6.249968750E-02
565,	102,	103,	5.21000E+01	*	4.444433333E-01
566,	102,	105,	5.21000E+01	*	-1.388947917E-02
567,	102,	106,	5.21000E+01	*	4.444433333E-01
568,	102,	107,	5.21000E+01	*	-1.388947917E-02
569,	102,	114,	5.21000E+01	*	1.249993750E-01
570,	102,	117,	5.21000E+01	*	1.249993750E-01
571,	102,	118,	5.21000E+01	*	9.999950000E-01
572,	102,	119,	5.21000E+01	*	1.249993750E-01
573,	102,	122,	5.21000E+01	*	1.249993750E-01
574,	103,	104,	5.21000E+01	*	4.444433333E-01
575,	103,	106,	5.21000E+01	*	-1.388947917E-02
576,	103,	107,	5.21000E+01	*	4.444433333E-01
577,	103,	108,	5.21000E+01	*	-1.388947917E-02
578,	103,	115,	5.21000E+01	*	1.249993750E-01
579,	103,	118,	5.21000E+01	*	1.249993750E-01
580,	103,	119,	5.21000E+01	*	9.999950000E-01

581,	103,	120,	5.21000E+01	*	1.249993750E-01
582,	103,	123,	5.21000E+01	*	1.249993750E-01
583,	104,	107,	5.21000E+01	*	-1.388947917E-02
584,	104,	108,	5.21000E+01	*	2.222216667E-01
585,	104,	116,	5.21000E+01	*	6.249968750E-02
586,	104,	119,	5.21000E+01	*	1.249993750E-01
587,	104,	120,	5.21000E+01	*	4.999975000E-01
588,	104,	124,	5.21000E+01	*	6.249968750E-02
589,	105,	106,	5.21000E+01	*	4.444433333E-01
590,	105,	109,	5.21000E+01	*	2.222216667E-01
591,	105,	110,	5.21000E+01	*	-1.388947917E-02
592,	105,	117,	5.21000E+01	*	6.249968750E-02
593,	105,	121,	5.21000E+01	*	4.999975000E-01
594,	105,	122,	5.21000E+01	*	1.249993750E-01
595,	105,	125,	5.21000E+01	*	6.249968750E-02
596,	106,	107,	5.21000E+01	*	4.444433333E-01
597,	106,	109,	5.21000E+01	*	-1.388947917E-02
598,	106,	110,	5.21000E+01	*	4.444433333E-01
599,	106,	111,	5.21000E+01	*	-1.388947917E-02
600,	106,	118,	5.21000E+01	*	1.249993750E-01
601,	106,	121,	5.21000E+01	*	1.249993750E-01
602,	106,	122,	5.21000E+01	*	9.999950000E-01
603,	106,	123,	5.21000E+01	*	1.249993750E-01
604,	106,	126,	5.21000E+01	*	1.249993750E-01
605,	107,	108,	5.21000E+01	*	4.444433333E-01
606,	107,	110,	5.21000E+01	*	-1.388947917E-02
607,	107,	111,	5.21000E+01	*	4.444433333E-01
608,	107,	112,	5.21000E+01	*	-1.388947917E-02
609,	107,	119,	5.21000E+01	*	1.249993750E-01
610,	107,	122,	5.21000E+01	*	1.249993750E-01
611,	107,	123,	5.21000E+01	*	9.999950000E-01
612,	107,	124,	5.21000E+01	*	1.249993750E-01
613,	107,	127,	5.21000E+01	*	1.249993750E-01
614,	108,	111,	5.21000E+01	*	-1.388947917E-02
615,	108,	112,	5.21000E+01	*	2.222216667E-01
616,	108,	120,	5.21000E+01	*	6.249968750E-02
617,	108,	123,	5.21000E+01	*	1.249993750E-01
618,	108,	124,	5.21000E+01	*	4.999975000E-01
619,	108,	128,	5.21000E+01	*	6.249968750E-02
620,	109,	110,	5.21000E+01	*	2.222216667E-01
621,	109,	121,	5.21000E+01	*	6.249968750E-02
622,	109,	125,	5.21000E+01	*	2.499987500E-01
623,	109,	126,	5.21000E+01	*	6.249968750E-02
624,	110,	111,	5.21000E+01	*	2.222216667E-01
625,	110,	122,	5.21000E+01	*	1.249993750E-01
626,	110,	125,	5.21000E+01	*	6.249968750E-02
627,	110,	126,	5.21000E+01	*	4.999975000E-01
628,	110,	127,	5.21000E+01	*	6.249968750E-02
629,	111,	112,	5.21000E+01	*	2.222216667E-01
630,	111,	123,	5.21000E+01	*	1.249993750E-01
631,	111,	126,	5.21000E+01	*	6.249968750E-02
632,	111,	127,	5.21000E+01	*	4.999975000E-01
633,	111,	128,	5.21000E+01	*	6.249968750E-02
634,	112,	124,	5.21000E+01	*	6.249968750E-02
635,	112,	127,	5.21000E+01	*	6.249968750E-02
636,	112,	128,	5.21000E+01	*	2.499987500E-01
637,	113,	114,	5.21000E+01	*	1.111116667E-01
638,	113,	117,	5.21000E+01	*	1.111116667E-01
639,	113,	118,	5.21000E+01	*	-6.943854168E-03
640,	114,	115,	5.21000E+01	*	1.111116667E-01
641,	114,	117,	5.21000E+01	*	-6.943854168E-03
642,	114,	118,	5.21000E+01	*	2.222233333E-01
643,	114,	119,	5.21000E+01	*	-6.943854168E-03
644,	115,	116,	5.21000E+01	*	1.111116667E-01

```
                645,      115,      118,  5.21000E+01  * -6.943854168E-03
                646,      115,      119,  5.21000E+01  *  2.222233333E-01
                647,      115,      120,  5.21000E+01  * -6.943854168E-03
                648,      116,      119,  5.21000E+01  * -6.943854168E-03
                649,      116,      120,  5.21000E+01  *  1.111116667E-01
                650,      117,      118,  5.21000E+01  *  2.222233333E-01
                651,      117,      121,  5.21000E+01  *  1.111116667E-01
                652,      117,      122,  5.21000E+01  * -6.943854168E-03
                653,      118,      119,  5.21000E+01  *  2.222233333E-01
                654,      118,      121,  5.21000E+01  * -6.943854168E-03
                655,      118,      122,  5.21000E+01  *  2.222233333E-01
                656,      118,      123,  5.21000E+01  * -6.943854168E-03
                657,      119,      120,  5.21000E+01  *  2.222233333E-01
                658,      119,      122,  5.21000E+01  * -6.943854168E-03
                659,      119,      123,  5.21000E+01  *  2.222233333E-01
                660,      119,      124,  5.21000E+01  * -6.943854168E-03
                661,      120,      123,  5.21000E+01  * -6.943854168E-03
                662,      120,      124,  5.21000E+01  *  1.111116667E-01
                663,      121,      122,  5.21000E+01  *  2.222233333E-01
                664,      121,      125,  5.21000E+01  *  1.111116667E-01
                665,      121,      126,  5.21000E+01  * -6.943854168E-03
                666,      122,      123,  5.21000E+01  *  2.222233333E-01
                667,      122,      125,  5.21000E+01  * -6.943854168E-03
                668,      122,      126,  5.21000E+01  *  2.222233333E-01
                669,      122,      127,  5.21000E+01  * -6.943854168E-03
                670,      123,      124,  5.21000E+01  *  2.222233333E-01
                671,      123,      126,  5.21000E+01  * -6.943854168E-03
                672,      123,      127,  5.21000E+01  *  2.222233333E-01
                673,      123,      128,  5.21000E+01  * -6.943854168E-03
                674,      124,      127,  5.21000E+01  * -6.943854168E-03
                675,      124,      128,  5.21000E+01  *  1.111116667E-01
                676,      125,      126,  5.21000E+01  *  1.111116667E-01
                677,      126,      127,  5.21000E+01  *  1.111116667E-01
                678,      127,      128,  5.21000E+01  *  1.111116667E-01
C
C ... Convection conductors ...
C
                679,      113,     1000,  1.00000E+00  *  2.500000000E-01
                680,      114,     1000,  1.00000E+00  *  5.000000000E-01
                681,      115,     1000,  1.00000E+00  *  5.000000000E-01
                682,      116,     1000,  1.00000E+00  *  2.500000000E-01
                683,      117,     1000,  1.00000E+00  *  5.000000000E-01
                684,      118,     1000,  1.00000E+00  *  1.000000000E+00
                685,      119,     1000,  1.00000E+00  *  1.000000000E+00
                686,      120,     1000,  1.00000E+00  *  5.000000000E-01
                687,      121,     1000,  1.00000E+00  *  5.000000000E-01
                688,      122,     1000,  1.00000E+00  *  1.000000000E+00
                689,      123,     1000,  1.00000E+00  *  1.000000000E+00
                690,      124,     1000,  1.00000E+00  *  5.000000000E-01
                691,      125,     1000,  1.00000E+00  *  2.500000000E-01
                692,      126,     1000,  1.00000E+00  *  5.000000000E-01
                693,      127,     1000,  1.00000E+00  *  5.000000000E-01
                694,      128,     1000,  1.00000E+00  *  2.500000000E-01
HEADER CONTROL DATA,GLOBAL
C-----------------------------------------------------------------------------
C  Data from SFILE:
     TIMEO  = 0.          $ STARTING TIME
     TIMEND = 0.          $ STOP TIME
     NLOOPS = 2000        $ MAX RELAXATION ITERATIONS
     SIGMA  = 3.303E-15 $ STEPHAN-BOLTZMAN CONSTANT (ASSUMING IN,BTU,R,SEC)
     ABSZRO = -460.       $ ABSOLUTE ZERO (F)
C-----------------------------------------------------------------------------
HEADER CONTROL DATA,FEMSINDA
C-----------------------------------------------------------------------------
```

```
C  Data from SFILE:
     ARLXCA = 0.01       $ MAX ARITHMETIC TEMP CHANGE PER ITERATION
     DRLXCA = 0.01       $ MAX DIFFUSION TEMP CHANGE PER ITERATION
     EBALSA = 0.01       $ ENERGY BALANCE
     DTIMEH = 1.0E+30    $ MAXIMUM ALLOWABLE TIME STEP
     OUTPUT = 0.0        $ PRINT INTERVAL
C-----------------------------------------------------------------------------
HEADER ARRAY DATA,FEMSINDA
HEADER OPERATION DATA
BUILD SINDA85, FEMSINDA
C-----------------------------------------------------------------------------
C  Data from SFILE:
      CALL STDSTL
C      CALL FWDBCK
C-----------------------------------------------------------------------------
HEADER VARIABLES1,FEMSINDA
      CALL FSGVTEMP('FEMSINDA')
HEADER OUTPUT CALLS,FEMSINDA
F     CALL TPRINT('FEMSINDA')
F     CALL NROUT(
F    &'FEM/SINDA EXAMPLE                                  ')
END OF DATA
```

As noted in the OUTPUT CALLS block, there is a call to NROUT subroutine, as well as TPRINT. NROUT creates a nodal result output file that is compatible with PATRAN. This file can be read by PATRAN for post processing of the results. Figure 3 shows the PATRAN color contour plot of the steady state temperatures for this problem. A listing of the SINDA nodal temperature results is also included on the following pages.

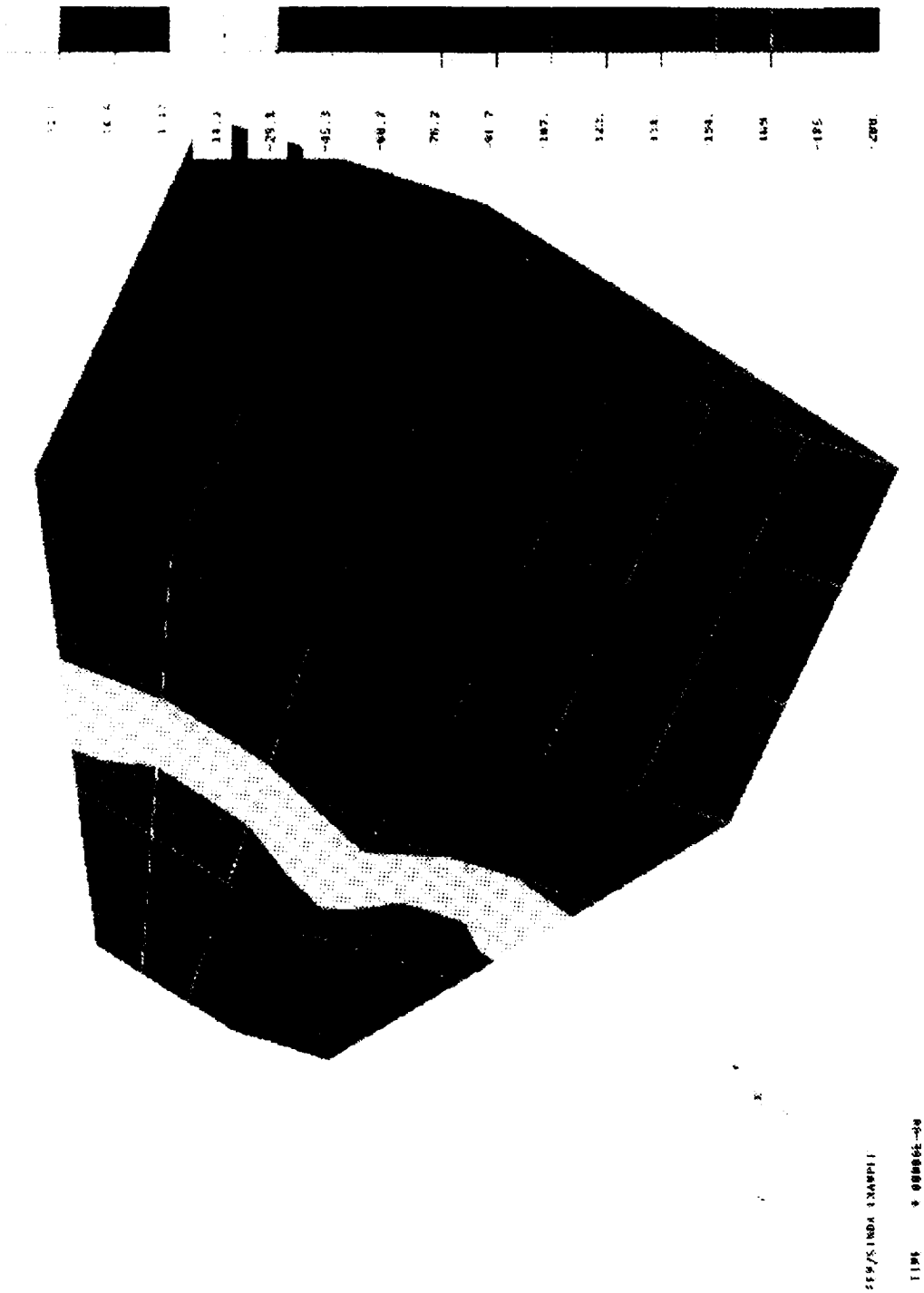

Figure 3. PATRAN color contour plot of steady state temperature results.

ORIGINAL PAGE
COLOR PHOTOGRAPH

LISTING OF THE SINDA OUTPUT

```
                                  N A S A / M A R T I N   M A R I E T T A
                  S Y S T E M S   I M P R O V E D   N U M E R I C A L   D I F F E R E N C I N G
                                  T H E R M A L   A N A L Y Z E R   1 9 8 5
                                  W I T H   F L U I D   I N T E G R A T O R

      SSSSSSSSS
     SSSSSSSSSSS
     SSS      SS
     SSS
      SSSSSSSSS
            SSS    IIIIIIIIIII
     SS     SSS    IIIIIIIIIII
     SSSSSSSSSSS       III
      SSSSSSSSS        III
                       III
                       III        NNN     NNN
                       III        NNNN    NNN
                  IIIIIIIIIII    NNNNN   NNN
                  IIIIIIIIIII    NNNNNN  NNN
                                 NNN NNN NNN
                                 NNN  NNNNNN    DDDDDDDDD
                                 NNN   NNNNN    DDDDDDDDDD
                                 NNN    NNNN    DDD     DDD
                                 NNN     NNN    DDD     DDD
                                                DDD     DDD
                                                DDD     DDD      AAAAAAA
                                                DDD     DDD     AAAAAAAAA
                                                DDDDDDDDDD     AAA     AAA
                                                DDDDDDDDD      AAA     AAA
                                                               AAAAAAAAAAA
                                                               AAA     AAA
                                                               AAA     AAA        ##
                                                               AAA     AAA        ##
        W I T H   S P E C I A L   G U E S T   S T A R          AAA     AAA        #     ########
                                                                                        #########
        FFFFFFF  LL      UU    UU  IIIIII  NN   NN  TTTTTTT                            ###     ###
       FF       LL      UU    UU    II    NNN  NN     TT                              ###     ###
      FFFFF    LL      UU    UU    II    NN N NN     TT                               #########
     FF       LL      UU    UU    II    NN  NNN     TT                               ###     ###    55555555555
    FF       LLLLLLL   UUUUUU  IIIIII  NN   NN     TT                                ###     ###    55555555555
                                                                                       ###########    555
                                                                                        #########     555
     P R O C E S S O R   E X E C U T I O N                                                            5555555555
     VERSION.MODIFICATION ... P2.3                                                                         555
     MODIFICATION DATE ...... 040190                                                                       555
                                                                                                     55555555555
                                                                                                     5555555555
```

1

```
                    SYSTEMS IMPROVED NUMERICAL DIFFERENCING ANALYZER '85 (SINDA '85)          PAGE     1

MODEL - SINDA85                                FEM/SINDA EXAMPLE


 BUILDING MODEL SINDA85  WITH SUBMODEL(S) -
        FEMSINDA.

 SUBMODEL NAME - FEMSINDA

  ARLXCA -  1.000000E-02 ARLXCC -   1.01000       ATMPCA -  1.000000E+30   ATMPCC -  0.000000E+00   BACKUP -  0.000000E+00
  CSGFAC -  0.000000E+00 CSGMAX -  0.000000E+00   CSGMIN -  0.000000E+00   DRLXCA -  1.000000E-02   DRLXCC -   1.01000
  DTIMEH -  1.000000E+30 DTIMEI -  0.000000E+00   DTIMEL -  0.000000E+00   DTIMEU -  0.000000E+00   DTMPCA -  1.000000E+30
  DTMPCC -  0.000000E+00 EBALNA -  0.000000E+00   EBALNC -  0.000000E+00   EBALSA -  1.000000E-02   EBALSC -  1.000000E+30
  ESUMIS -  0.000000E+00 ESUMOS -  0.000000E+00   EXTLIM -   50.0000       ITHOLD -         10      NARLXN -          0
  NATMPN -          0    NCGMAN -          0      NCSGMN -          0      NDRLXN -          0      NDTMPN -          0
  NEBALN -          0    NLOOPT -          0      ITEROT -          0      ITERXT -          3      OPEITR -          0
  OUTPUT -  0.000000E+00

 GLOBAL CONTROL CONSTANTS

  ABSZRO -  -460.000     SIGMA  -  3.303000E-15   TIMEM  -  0.000000E+00   TIMEN  -  0.000000E+00   TIMEND -  0.000000E+00
  TIMEO  -  0.000000E+00
```

1

```
                    SYSTEMS IMPROVED NUMERICAL DIFFERENCING ANALYZER '85 (SINDA '85)          PAGE     2

MODEL - SINDA85                                FEM/SINDA EXAMPLE
  STDSTL

 SUBMODEL NAME - FEMSINDA

                                  CALCULATED                                ALLOWED
       MAX DIFF DELTA T PER ITER  DRLXCC(          0)-  1.01000      VS. DRLXCA- 1.000000E-02
       MAX ARITH DELTA T PER ITER ARLXCC(          0)-  1.01000      VS. ARLXCA- 1.000000E-02
       MAX SYSTEM ENERGY BALANCE  EBALSC             - 1.000000E+30  VS. EBALSA * ESUMIS        - 0.000000E+00
                                                                       EBALSA- 1.000000E-02
       ENERGY INTO AND OUT OF SYS ESUMIS             - 0.000000E+00     ESUMOS- 0.000000E+00
       MAX NODAL ENERGY BALANCE   EBALNC(          0)- 0.000000E+00  VS. EBALNA- 0.000000E+00
       NUMBER OF ITERATIONS       LOOPCT             -        0      VS. NLOOPS-    2000
       PROBLEM TIME               TIMEN              - 0.000000E+00  VS. TIMEND- 0.000000E+00

                                DIFFUSION NODES IN INPUT NODE NUMBER ORDER
```

```
T     1=  80.000     T     2=  80.000     T     3=  80.000     T     4=  80.000     T     5=  80.000     T     6=  80.000
T     7=  80.000     T     8=  80.000     T     9=  80.000     T    10=  80.000     T    11=  80.000     T    12=  80.000
T    13=  80.000     T    14=  80.000     T    15=  80.000     T    16=  80.000     T    17=  80.000     T    18=  80.000
T    19=  80.000     T    20=  80.000     T    21=  80.000     T    22=  80.000     T    23=  80.000     T    24=  80.000
T    25=  80.000     T    26=  80.000     T    27=  80.000     T    28=  80.000     T    29=  80.000     T    30=  80.000
T    31=  80.000     T    32=  80.000     T    33=  80.000     T    34=  80.000     T    35=  80.000     T    36=  80.000
T    37=  80.000     T    38=  80.000     T    39=  80.000     T    40=  80.000     T    41=  80.000     T    42=  80.000
T    43=  80.000     T    44=  80.000     T    45=  80.000     T    46=  80.000     T    47=  80.000     T    48=  80.000
T    81=  80.000     T    82=  80.000     T    83=  80.000     T    84=  80.000     T    85=  80.000     T    86=  80.000
T    87=  80.000     T    88=  80.000     T    89=  80.000     T    90=  80.000     T    91=  80.000     T    92=  80.000
T    93=  80.000     T    94=  80.000     T    95=  80.000     T    96=  80.000     T    97=  80.000     T    98=  80.000
T    99=  80.000     T   100=  80.000     T   101=  80.000     T   102=  80.000     T   103=  80.000     T   104=  80.000
T   105=  80.000     T   106=  80.000     T   107=  80.000     T   108=  80.000     T   109=  80.000     T   110=  80.000
T   111=  80.000     T   112=  80.000     T   113=  80.000     T   114=  80.000     T   115=  80.000     T   116=  80.000
T   117=  80.000     T   118=  80.000     T   119=  80.000     T   120=  80.000     T   121=  80.000     T   122=  80.000
T   123=  80.000     T   124=  80.000     T   125=  80.000     T   126=  80.000     T   127=  80.000     T   128=  80.000
                                   ARITHMETIC NODES IN INPUT NODE NUMBER ORDER
                                                  ++NONE++
                                   HEATER NODES IN INPUT NODE NUMBER ORDER
T    49= -200.00     T    50= -200.00     T    51= -200.00     T    52= -200.00     T    53= -200.00     T    54= -200.00
T    55= -200.00     T    56= -200.00     T    57= -200.00     T    58= -200.00     T    59= -200.00     T    60= -200.00
T    61= -200.00     T    62= -200.00     T    63= -200.00     T    64= -200.00     T  1000=  70.000
                                   BOUNDARY NODES IN INPUT NODE NUMBER ORDER
                                                  ++NONE++
1
                        SYSTEMS IMPROVED NUMERICAL DIFFERENCING ANALYZER '85 (SINDA '85)              PAGE     3

MODEL - SINDA85                                FEM/SINDA EXAMPLE
  STDSTL


 SUBMODEL NAME - FEMSINDA


                                   CALCULATED                                ALLOWED
        MAX DIFF DELTA T PER ITER  DRLXCC(FEMSINDA     4)=-1.953125E-03 VS. DRLXCA= 1.000000E-02
        MAX ARITH DELTA T PER ITER ARLXCC'             0)= 0.000000E+00 VS. ARLXCA= 1.000000E-02
        MAX SYSTEM ENERGY BALANCE  EBALSC                = -3.33139     VS. EBALSA * ESUMIS       =  3.41090
                                                                           EBALSA= 1.000000E-02
        ENERGY INTO AND OUT OF SYS ESUMIS                =  341.090         ESUMOS=  344.455
        MAX NODAL ENERGY BALANCE   EBALNC(FEMSINDA    90)=-0.132813     VS. EBALNA= 0.000000E+00
        NUMBER OF ITERATIONS       LOOPCT                =     445      VS. NLOOPS=    2000
        PROBLEM TIME               TIMEN                 = 0.000000E+00 VS. TIMEND= 0.000000E+00

                                   DIFFUSION NODES IN INPUT NODE NUMBER ORDER
T     1=  30.962     T     2=  30.754     T     3=  30.753     T     4=  30.961     T     5=  30.753     T     6=  30.450
T     7=  30.450     T     8=  30.752     T     9=  30.752     T    10=  30.449     T    11=  30.449     T    12=  30.751
T    13=  30.960     T    14=  30.751     T    15=  30.751     T    16=  30.958     T    17=  10.810     T    18=  1.4784
T    19=  1.4780     T    20=  10.808     T    21=  1.4783     T    22= -11.929     T    23= -11.929     T    24=  1.4771
T    25=  1.4776     T    26= -11.929     T    27= -11.930     T    28=  1.4763     T    29=  10.808     T    30=  1.4768
T    31=  1.4763     T    32=  10.807     T    33= -42.965     T    34= -60.541     T    35= -60.541     T    36= -42.966
T    37= -60.541     T    38= -79.362     T    39= -79.362     T    40= -60.541     T    41= -60.541     T    42= -79.362
T    43= -79.362     T    44= -60.542     T    45= -42.966     T    46= -60.542     T    47= -60.542     T    48= -42.967
T    81=  31.229     T    82=  31.159     T    83=  31.158     T    84=  31.227     T    85=  31.159     T    86=  31.076
T    87=  31.075     T    88=  31.157     T    89=  31.159     T    90=  31.076     T    91=  31.075     T    92=  31.157
T    93=  31.228     T    94=  31.158     T    95=  31.157     T    96=  31.226     T    97=  31.649     T    98=  31.625
T    99=  31.624     T   100=  31.647     T   101=  31.626     T   102=  31.600     T   103=  31.599     T   104=  31.623
T   105=  31.625     T   106=  31.600     T   107=  31.599     T   108=  31.623     T   109=  31.647     T   110=  31.624
T   111=  31.623     T   112=  31.645     T   113=  32.119     T   114=  32.106     T   115=  32.106     T   116=  32.117
T   117=  32.107     T   118=  32.093     T   119=  32.093     T   120=  32.105     T   121=  32.106     T   122=  32.093
T   123=  32.092     T   124=  32.104     T   125=  32.118     T   126=  32.105     T   127=  32.104     T   128=  32.116
                                   ARITHMETIC NODES IN INPUT NODE NUMBER ORDER
                                                  ++NONE++
                                   HEATER NODES IN INPUT NODE NUMBER ORDER
T    49= -200.00     T    50= -200.00     T    51= -200.00     T    52= -200.00     T    53= -200.00     T    54= -200.00
T    55= -200.00     T    56= -200.00     T    57= -200.00     T    58= -200.00     T    59= -200.00     T    60= -200.00
T    61= -200.00     T    62= -200.00     T    63= -200.00     T    64= -200.00     T  1000=  70.000
                                   BOUNDARY NODES IN INPUT NODE NUMBER ORDER
                                                  ++NONE++
```

VI. References:

FEM/SINDA User's Manual, Version 2.0, June 1989.

VII. Appendix

The following are some applications for which PATRAN and FEM/SINDA were used to generate detailed SINDA models.

A. AMCC Handling Fixture:

To investigate a potential thermal problem associated with retaining the alternate combustion chamber (AMCC) casting, a detailed SINDA model was developed. The model represented a 1/16 pie section of the AMCC handling fixture. Figure 4 is PATRAN color contour plot of the steady state temperature results for this model.

B. 70 Pound Test Motor Field Joint:

PATRAN and FEM/SINDA were utilized to generate a 2-D model of the 70 pound test motor (SRM D MSFC 3-2) field joint, with a simulated flaw in the insulation seal. This model is used to predict the gas cavity and the wall temperatures near the O-ring seals. A snap shot of the temperature profile of this model, (5. seconds after ignition), is shown in Figure 5.

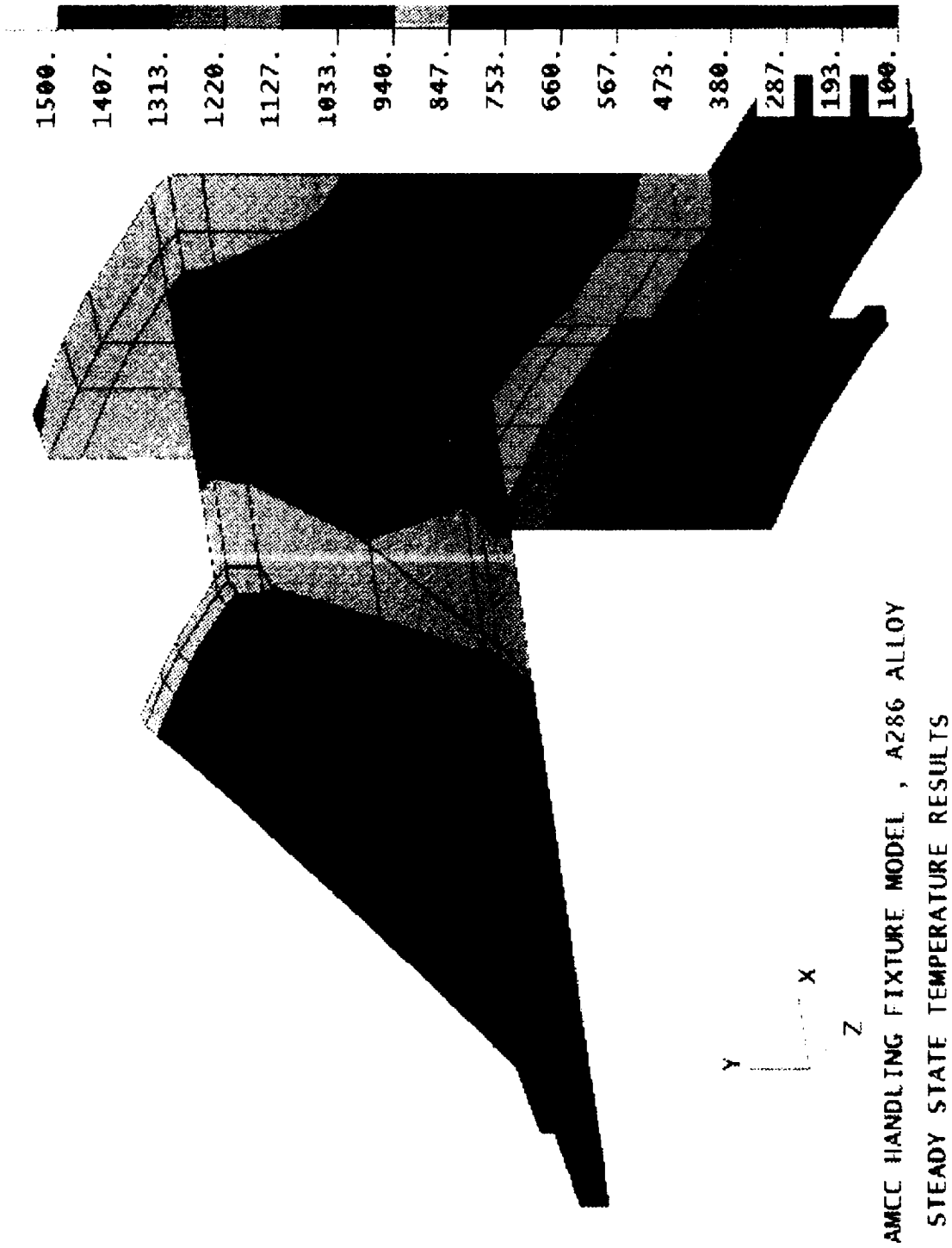

Figure 4: PATRAN color contour plot of AMCC handling fixture.

ORIGINAL PAGE
COLOR PHOTOGRAPH

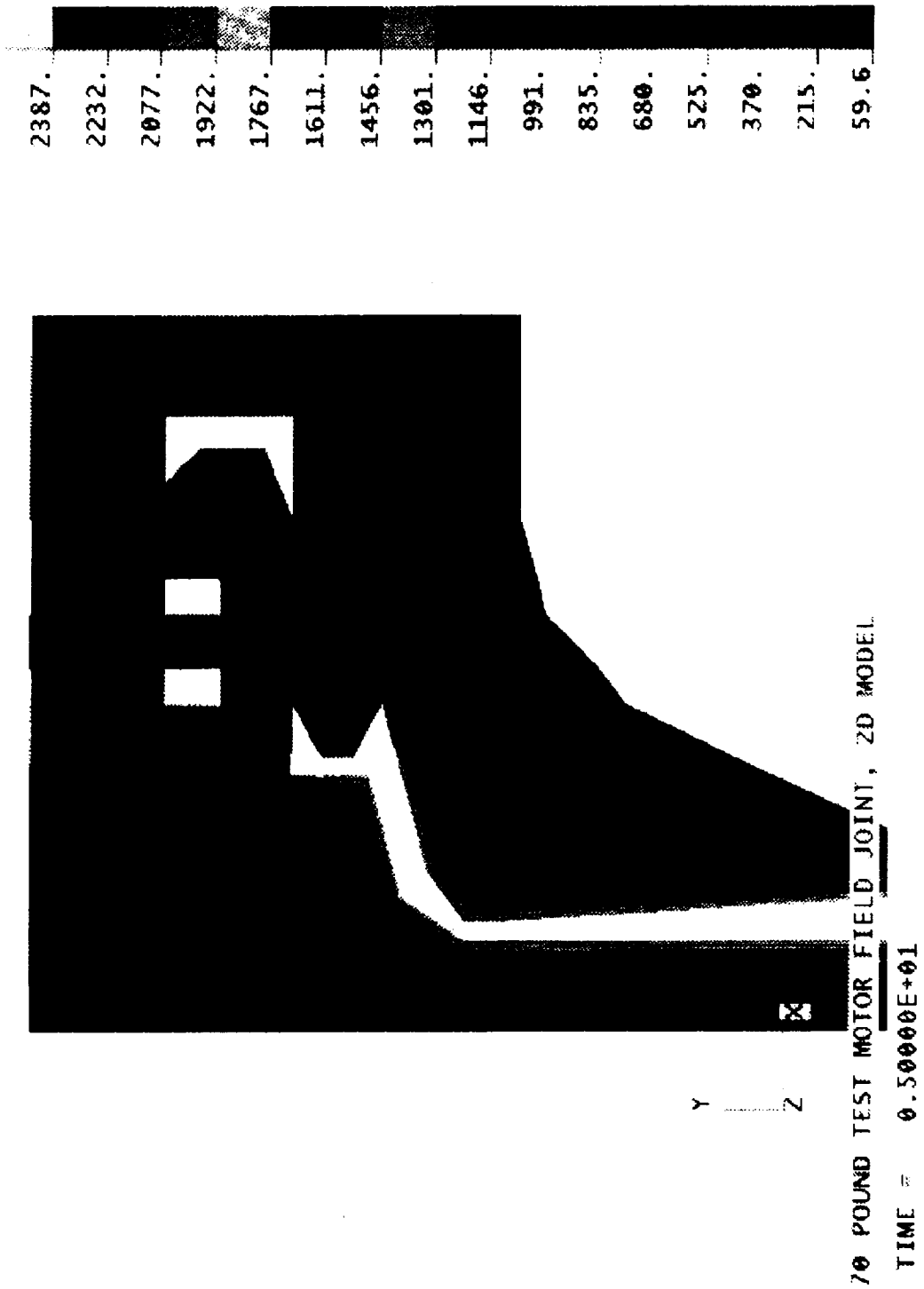

Figure 5: PATRAN color contour plot of 70 pound test motor 2-D model.

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APPENDIX A: RUN PROCEDURES

A. Resources

The computing resources available are MacIntosh Desktop computers, IBM PC computers, a VAX 11/785, an IBM 3084-QX Front End Processor and a CRAY X-MP/416 High Speed Vector Processor. The mainframes may be accessed from all PCs and MacIntoshes. The following information is intended to briefly describe the steps necessary to run SINDA and TRASYS on these computers. For the MacIntosh and the PCs it is assumed that the software is already loded on the computer.

A.1 Mac SINDA on the MacIntosh

Running SINDA on the MacIntosh is permormed mostly using the SindaShell Menu. Preprocessing, compiling, linking and running the program are all steps that can be executed from the menu. The following steps will execute the MODEL.SIN input deck using the SindaShell Menu.

Step 1. Double click on the SindaShell to display the SINDA Control Panel.

Step 2. Single click on the Preprocessor button and then proceed to open the SINDA Model called MODEL.SIN in this case.

Step 3. Single click on the Compiler button and then proceed to open tape3.for in the SINDAWORKS folder. In the next menu choose the M,P,V,B,Q,H, and U for Mac II and then single click on the Compiler button. TAPE3.APL will be created. Close the window which has the compiler options.

Step 4. Single click on the Link button and then proceed to open the file, A LINK SCRIPT FOR MAC II. This will create a SINDARUN file. Close the window that has the link information.

Step 5. Single click on the Run Model button. This will execute the SINDARUN application program.

Step 6. Single click on the Editor button and select the MODEL.OUT file to look at results.

The SindaShell is configured to run models out of the SINDA:SINDAWORKS folder.

A.2 PC-SINDA on the IBM PC

For the majority of PCs the software for executing PC-SINDA is in the SINDA subdirectory. To run a model named MODEL.SIN in the SINDA subdirectory, the following commands are used.

```
C:\SINDA>PC-SINDA

Input File    [TAPE5]      : MODEL.SIN
Output File   [TAPE6]      : <CR>
```

```
Screen Writes      [Y]        : N

C:\SINDA>F77L TAPE3
C:\SINDA>LINK TAPE3,SINDA,NUL,SL1+SL2
C:\SINDA>SINDA
```

Output will reside in TAPE6 unless an output file is specified.

A.3 SINDA on the VAX

SINDA models may be run in batch or interactive on the VAX. A model called MODEL.SIN is run in batch using the following command.

```
$ @ZFB0:[041001.SINDA]BATCHSIN MODEL
```

MODEL.SIN is run interactive using the following command

```
$ @ZFB0:[041001.SINDA]RUNSIN MODEL
```

It is recommended that the interactive commands only be used for preprocessing of models only since running interactive impacts the time to run batch jobs.

A.4 SINDA on the IBM

SINDA on the IBM mainframe may be executed with a menu or with a few lines of JCL inserted at the beginning of the model. The menu can be displayed by copying and executing the dataset ASDW197.CLIST(SINDIBM). The following is an example of how to run the model HBKG197.SINDA.DATA(MODEL) with the use of the menu. The menus are called up from the TSO command environment (=6) by typeing the member name of the CLIST.

```
 ------------------- GASKI SINDA IBM PANEL ----------------------------
COMMAND  ===>                                      USERID ===> HBKG197

 ----------------------------------------------------------------------
ACCOUNT     ===> 6ED123456789    USERNAME  ===> HBKG197
    TIME        ===> 100
 GASKI SINDA MODEL:                 USER SPECIAL LIBRARY:
    USERID      ===> HBKG197          USERID     ===>
    FILENAME    ===> SINDA            FILENAME   ===>
    TYPE        ===> DATA             TYPE       ===>
    MEMBER      ===> MODEL
 GASKI OPTIONS (Y or blank)        OUTPUT DATASET NAMES:
    SAVINP      ===>                  USERID     ===> HBKG197
    TDUMP       ===>                  FILENAME   ===> SINDA
    RSO         ===>                  TYPE       ===> MODEL
                                   INPUT DATASET NAMES:
    LODTMP      ===>                  USERID     ===>
    TMERG       ===>                  FILENAME   ===>
    RSI         ===>                  TYPE       ===>
 DOUBLE SPACE   ===>                (default space TRK 40,20)
       ***PREALLOCATED USER FORTRAN FILES***
```

```
USER FORTRAN UNIT SELECTIONS ( Y or blank )
 FT21  ===>            FT22  ===>            FT23  ===>
```

The following rules apply to using the IBM SINDA panel

1. Time may be entered in hours:minutes:seconds format or in seconds, here it is entered as 100 seconds.

2. The output dataset must be calaloged.

A.5 SINDA on the CRAY

To run SINDA on the CRAY either a menu or JCL can be used. The menu is contained in the dataset ASDW197.CLIST(GSINDA87) and it may be copied and executed.

```
 ------------------- GASKI SINDA UNICOS CRAY PANEL ---------------------
COMMAND  ===>                                      USERID ===> HBKG197

 ----------------------------------------------------------------------
USER ===> hbkg197  PASS WD ===> hbkg197        CSS  ===> CSS3
   MFL  ===> 1.5MW    ACCOUNT ===> 6ED123456789   TIME ===> 0:30:0
 GASKI SINDA MODEL:                USERNAME ===> hbkg197
   USERID  ===> HBKG197            SPACE:   TRK/CYL  ===> TRK
   LIB     ===> SINDA                 PRI  ===> 40      SEC  ===> 20
   TYPE    ===> DATA                  DIR  ===> 10
   MEMBER  ===> CHAN
 OTHER INPUT DATASETS:          OUTPUT DATASET--------CATALOG  ===>
   USERID  ===>                     USERID  ===> HBKG197
   LIB     ===>                     LIB     ===> SINDA
   TYPE    ===>                     TYPE    ===> OUT
   TMERG   ===>                     TDUMP   ===>            SEQ ===>
                                    OUTPUT  ===> CHAN       SEQ ===>
 **LODTMP  ===>                   **SAVINP  ===>
 FT23 ===>            DF ===> CB     FT21 ===>              DF ===> CB
 FT24 ===>            DF ===> CB     FT22 ===>              DF ===> CB
       Compiled Processor Listing------------- (Y or blank)  ===>
```

The following rules apply to using the CRAY SINDA panel

1. Time may be entered in hours:minutes:seconds format or in seconds, here it is entered as 0 hours, 30 minutes and 0 seconds (0:30:0).

2. The output dataset must be calaloged.

A.6 TRASYS on the VAX

TRASYS may be executed on the VAX using the following command to run MODEL.INP.

```
$ @ZFB0:[041001.TRA385]BATCHTRA MODEL
```

To obtain a node plot the following command is used

```
$ RUN ZFB0:[041001.TRA385]TRASPLOT MODEL.PLT
```

A.7 TRASYS on the CRAY

The menu for running TRASYS on the CRAY may be copied from ABAV234.CLIST(TRASYSJ)

```
 -------------- TRASYS VERSION P22   CRAY PANEL --------------------
COMMAND  ===>                                    USERID ===> HBKG197

  MFL  ===> 1.5MW      ACCOUNT  ===> 6ED123456789  CSS ===> CSS3
  TIME ===> 0:30:0     USERNAME ===> hbkg197       PASS ==> hbkg197
 INPUT PDS:                     OUTPUT PDS                 Is dataset
   USERID   ===> HBKG197          USERID ===> HBKG197      (Y or blank)
   LIB      ===> TRASYS           LIB    ===> TRASYS
   TYPE**   ===> DATA             TYPE** ===> OUT          CAT ===> Y
   MODEL    ===> NOTEBK
   PP MOD   ===>
   P  MOD   ===>
 RESTART INPUT DATASET:         RESTART OUTPUT DATASET:
   USERID   ===>                  USERID   ===>
   LIB      ===>                  LIB      ===>
   TYPE     ===>                  TYPE     ===>            CAT ===>




 OUTPUT:     SPACE=( ===> TRK ,( ===> 40  , ===> 20  , ===> 10  )
```

The following rules apply when using the TRASYSJ panel;

1. Username and Password must be entered in lower case.
2. Time may be input in hours:minutes:seconds format or in seconds
3. If the output dataset is cataloged type Y in the CAT field.

Currently TRASYS does not run on the IBM Mainframe.

APPROVAL

THERMAL ANALYSIS WORKBOOK

Edited by James W. Owen

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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