REPORT FOR NASA-JSC CONTRACT
NAS9-7644

FINAL REPORT

EXTRAVEHICULAR MOBILITY UNIT
THERMAL SIMULATOR

REPORT NO. T155-03

31 JULY 1973

SUBMITTED BY

VOUGHT SYSTEM DIVISION
LTV AEROSPACE CORPORATION
P. O. BOX 5907 - Dallas, Texas - 75222

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER - HOUSTON, TEXAS

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1.0 SUMMARY

This report presents the analytical methods, thermal model, and user's instructions for the Extravehicular Mobility Unit (EMU) routine. This digital computer program was developed for detailed thermal performance predictions of the Extravehicular Mobility Unit on the NASA-MSC Univac 1108 computer system. It accounts for conductive, convective, and radiant heat transfer as well as single and two-phase fluid flow and flow controls.

The program has the operational flexibility to: (1) accept card or magnetic tape data input for the thermal model describing the EMU structure, fluid systems, astronaut, and component performance, (2) accept card and/or magnetic tape input of internally generated heat and heat influx from the space environment, (3) output tabular and/or plotted histories of temperature, flow rates, and other parameters describing system operating modes, (4) allow stopping and restarting during a mission simulation, and (5) permit a steady state analysis.

The analytical methods used in the computer routine are based on finite difference approximations to differential heat and mass balance equations which accounts for temperature or time dependent thermo-physical properties. These generalized methods are applied within the routine to the majority of nodes which describe the structure and fluid systems. Additional specialized methods are written into the routine to characterize: (1) the ventilation gas and oxygen purge systems, (2) transport water and sublimator feedwater systems, (3) oxygen regulators, (4) oxygen bottle blowdown, (5) the lithium hydroxide canister, (6) the sublimator, (7) the water separator, (8) the helmet visors, (9) crewman, (10) variation of system flowrates resulting from pump flowrate/pressure drop characteristics.

The EMU routine utilizes an integrated thermal model of the EMU structure and flow systems which was assembled from Hamilton Standard drawings and component data.

The user's manual and supporting appendices provide a complete routine description including instructions for problem submission in compliance with current NASA-MSC Computation and Analysis Division procedures. Methods are provided for estimating run time, amount of paper output, and core storage space requirements. A detailed description of data card preparation, examples of program output, and run failure analysis are given.

2.0 INTRODUCTION

This report describes the EMU digital simulator (routine) and the Baseline Thermal Model developed by the LTV Aerospace Corporation. The thermal model was created from hardware manufacturer's drawings (Hamilton Standard), procurement specifications, and design verification test results.

The routine simulates the suited crewman using the Portable Life Support System (PLSS) or Oxygen Purge System (OPS) in a vacuum environment. The thermal model uses the -7 PLSS and -4 Remote Control Unit as the baseline input data. More detailed information on the thermal model is presented in Section 4.0. The routine simulates the crewman in the suited, partially suited and shirtsleeves modes. In the suited or partially suited mode, the crewman may be simulated using the PLSS, OPS or the Lunar Module Suit Gas Loop.

The routine and thermal model have been correlated against the EMU Manned Lunar Qualification Tests of 1969, Part III Unmanned Investigative Space Suit Tests of 1969, Apollo 12 flight data, Buddy Secondary Life Support System (BSLSS) Design Verification Test and Apollo 15 EMU Manned Qualification Test of 1971.

3.0 ANALYTICAL METHODS

Sections 3.1 through 3.4 describe generalized heat balance and flow system calculation methods used in this computer routine which may be applied to other thermal simulation models. Sections 3.5 through 3.8 describe specialized analytical characterizations which have been created for the Extravehicular Mobility Unit (EMU) program formulation.

Differential equations which describe conductive, convective, and radiative heat transfer, and internally generated heat as well, are solved by the familiar explicit finite difference approximation technique (Reference 1). In this technique the subject of the analysis is divided into lumps which are considered to be isothermal for evaluation of thermal properties and heat capacitance effects, and which are considered to have temperatures located at their geometric centers (nodes or lumps) for conduction effects.

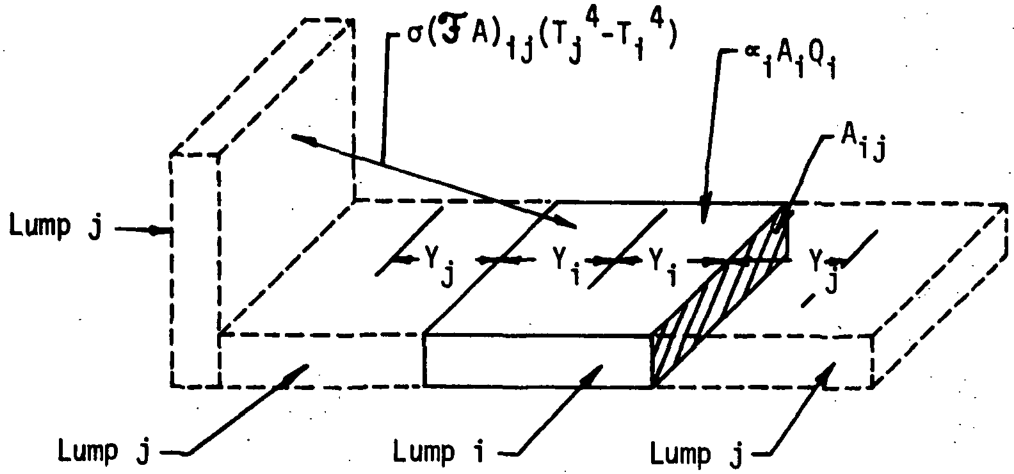
3.1 Thermal Analysis

In the computer routine, lumps are classified as: (1) structure lumps; (2) tube lumps; and (3) fluid lumps. In general, structure lumps are lumps which are not in contact with any flowing fluid. Tube lumps are lumps which are in contact with a flowing fluid, as well as structure lumps and other tube lumps. Fluid lumps are flowing or stagnant liquid or gas lumps which experience convective heat transfer interchange with tube lumps. These three classifications, which are discussed below, govern much of the computer routine input data format discussed in Section 5.7. Each lump must be numbered, and the lump numbers in each classification start at 1 and go consecutively through the maximum number for that classification.

As will be seen later, nodes requiring special analysis do not necessarily follow the classifications described above. In most instances where the classifications break down, the node is made a structure node which requires less interrelated input data.

The finite-difference equations used for each lump classification are described below.

3.1.1 Structure Lumps (illustrated by the sketch below)



$$w_i c_i \frac{T_i' - T_i}{\Delta\tau} = \sum_j U_{ij}(T_j - T_i) + \alpha_i A_i Q_i + \sum_j \sigma \mathcal{F}_{i-j} A_i (T_j^4 - T_i^4) \quad (1)$$

Heat Stored *Net Heat Flux*

Equation (1) may be rewritten in the form:

$$T_i' = T_i + \frac{\Delta\tau}{w_i c_i}\left[\sum_j U_{ij}(T_j - T_i) + (\alpha A)_i Q_i + \sum_j \sigma(\mathcal{F}A)_{ij}(T_j^4 - T_i^4)\right] \quad (2)$$

Equation (2) is the basic form of the structure lump heat balance equation.

where:

i = lump number (data input)

T_i = temperature of lump i at time τ, °R (Routine input and output are in °F)

T_i' = temperature of lump i at time $\tau + \Delta\tau$, °R

$\Delta\tau$ = time increment of next step in calculation as determined by convergence criteria within the routine (see Section 3.2.1) hrs

w_i = weight of lump i, (input data - lbs)

c_i = specific heat of lump i. This quantity is entered as a table of specific heat (BTU/lb-°F) versus temperature in °F.

U_{ij} = the conductance between structure lump i and adjacent structure lumps, j, BTU/hr-°F

$$U_{ij} = \frac{1}{\frac{R_i}{k_i} + \frac{R_j}{k_j}} \qquad (3)$$

This form of U_{ij} permits an accounting of temperature dependent dissimilar materials in adjacent nodes.

R_i = that portion of the conduction resistance from lump i to j which is attributed to i, $\frac{Y_i}{K_i A_{ij}}$ (input as R_1,hr-°F/BTU)

R_j = that portion of the resistance from lump i to j which is attributed to j, = $\frac{Y_j}{K_j A_{ij}}$ (input as R_2,hr-°F/BTU)

where: Y_i = is that portion of the conduction path length between node i and j which lies in lump i

Y_j = is that portion of the conduction path length between node i and j which lies in lump j

A_{ij} = is the effective conduction area between lumps i and j

K_i = is the thermal conductivity of lump i

K_j = is the thermal conductivity of lump j

k_i = thermal conductivity of lump i at the present temperature (time τ) normalized by the thermal conductivity at which R_i was evaluated, i.e., K_i/K_{R_i}. This quantity is entered as a table of normalized conductivity versus temperature in °F for each lump, dimensionless

k_j = thermal conductivity of lump j at the present temperature (time τ) normalized by the thermal conductivity at which R_j was evaluated, i.e., K_j/K_{R_j}, dimensionless

In the case of constant thermal conductivity, the entire resistance may be calcuated as R_i, and R_j is entered as 0.0. This is desirable since it saves data space in the computer core.

T_j = temperature of adjacent lumps at time τ (lump numbers, j, which are connected to lump i are data input), °R

$(\alpha A)_i$ = incident heat application area for lump i, (data input sq. in.). This quantity can be entered as absorptance (α_i) times area (A_i) or as area alone depending on how Q_i is entered. BTU/hr

Q_i = incident heat on lump i, BTU/ft^2-hr. This quantity is entered as a table versus time in hours. Obviously absorbed heat (α Q) could be entered here in which case α A would be entered as area only.

σ = Stefan-Boltzmann constant, 0.173×10^{-8} BTU/hr-ft^2(°R)^4

$(\mathcal{F} A)_{ij}$ = Gray-body configuration factor (a function of surface emittances, areas, and geometry) from lump i to lump j, sq. ft. (data input - sq. in.)

The routine calculates the energy entering a structure lump for each connection to that lump prescribed in the data. The calculated energy is summed algebratically and stored in the TSQRAT array until the structure temperatures are updated.

3.1.2 Tube Lumps

The development of the equations for tube lumps departs in subtle but significant ways from the explicit finite difference method of the structure equations. Tube lump temperatures are calculated using a hybrid implicit-explicit numerical differencing technique (Reference 2). The advantage of the hybrid finite difference equations is that they are numerically stable for relatively large time increments. The hybrid form of the tube temperature equation is written as follows:

$$\dot{Q}_{STORED} = \dot{Q}_{CONV} + \dot{Q}_{COND} + \dot{Q}_{RAD} + \dot{Q}_{ABSORBED}$$

$$\frac{wc_i}{\Delta\tau}(T_i'-T_i) = h_f A_f (T_f'-T_i') + \sum_j (UA)_{ij}(T_j-T_i) + \sum_j \sigma(\mathcal{F}A)_{ij}(T_j^4-T_i^4) + \dot{Q} \qquad (4)$$

where: h_f = convective heat transfer coefficient, BTU/(hr-ft^2-°F)

A_f = area for convective heat transfer, ft^2 (data input - in^2)

T_f = updated temperature of fluid lump associated with tube lump i, °R

T_j = tube or structure lump j to which tube lump i is connected

The input data for tube lumps includes all of the data input required for structure lumps plus the lump number of the enclosed fluid lump and the convective heat transfer area, A_f. Data required for computing the heat transfer coefficient is given with the enclosed fluid lump input data. Heat transfer coefficient computation is discussed in Section 3.3.

To solve for T_i' explicitly, it is necessary to have the updated fluid temperature, T_f'.

$$T_i' = \frac{\frac{(wc)_i}{\Delta\tau} T_i + h_f A_f' + \sum_j (UA)_{ij}(T_j - T_i) + \sum_j \sigma(\mathcal{F}A)_{ij}(T_j^4 - T_i^4) + (\alpha A)_i Q_i}{\frac{(wc)_i}{\Delta\tau} + h_f A_f} \tag{5}$$

Therefore, the fluid temperatures must be known or calculated at each time increment ($\Delta\tau$) prior to the tube lump calculation.

3.1.3 Fluid Lumps

Fluid lump temperatures are calculated using the hybrid finite difference based on the following energy balance.

$$\dot{Q}_{STORED} = \dot{Q}_{\substack{MASS\\FLUX}} + \dot{Q}_{CONV}$$

$$\frac{(wc)_f}{\Delta\tau}(T_f' - T_f) = \dot{w}c_p(T_{fu}' - T_f') + \sum_t (hA)_t (T_t' - T_f') \tag{6}$$

Solving for T_f' and substituting equation (5) for T_t' :

$$T_f' = \frac{\frac{(wc)_f}{\Delta\tau} T_f + \dot{W}C_p T_{fu}' + \sum_t (hA)_t \left(\frac{\frac{(wc)}{\Delta\tau}_t T_t + \sum_j (UA)_j (T_j - T_t)}{\frac{wc}{\Delta\tau}_t + (hA)_t} \right)}{\frac{(wc)_f}{\Delta\tau} + \dot{W}C_p + \sum_t \frac{(hA)_t \frac{(wc)_t}{\Delta\tau}}{\frac{(wc)}{\Delta\tau}_t + (hA)_t}} \tag{7}$$

Inspection of equation (7) reveals the requirement for the updated upstream fluid temperature, T_{fu}' , while the other temperatures are known from the previous time increment. Each separate system has a system starting point from which the temperature calculations proceed in the direction of the flow each iteration. Therefore T_{fu}' is established initially at the system starting point in a closed loop system and then calculated on subsequent iterations. In an open system the T_{fu}' must be known as a function of time at the origination of flow.

3.2 Convergence and Accuracy Criteria

The heat transfer equations used in the computer routine described herein are based on explicit and implicit-explicit hybrid methods of finite difference solution. With the first method, the future temperature of any structure lump is evaluated from the present temperature of surrounding lumps and the thermal environment. The validity of this type of solution depends on satisfying criteria for stability, oscillation, and truncation error minimization. The hybrid method was employed to remove the heat transfer coefficient from the stability criteria for the tube lump analysis.

3.2.1 Stability

The term stability usually refers to errors in equation solution that progressively increase or accumulate as the calculations proceed. Clark (Reference 3) concludes that any explicit forward difference equation will yield stable results for the future temperatures of any lump if the coefficients of the present lump temperature are at least zero or have the same sign as the other coefficients of known temperatures. This stability criterion defines the size of the time step to be used with the basic equations. The equations used in the computer routine are rearranged below to show the development of the stability requirement for structure lumps. It should be noted that failure to meet this stability criteria means only that the solution may be unstable and not that it is. For structure lumps, Equation (2) may be written as:

$$T_i' = \frac{\Delta\tau}{w_i c_i}\left[\sum_j U_{ij}T_j + (\alpha A)_i Q_i + \sum_j \sigma(\mathcal{F}A)_{ij}(T_i^2+T_j^2)(T_i+T_j)T_j\right]$$

$$+ \; T_i\left[1 - \frac{\Delta\tau}{w_i c_i}\left(\sum_j U_{ij} + \sum_j \sigma(\mathcal{F}A)_{ij}(T_i^2+T_j^2)(T_i+T_j)\right)\right] \qquad (8)$$

According to Reference (4) the linearized radiation can cause oscillations when the radiative coupling is dominant and suggests replacing

$$\sum \sigma(\mathcal{F}A)_{ij}(T_i^2+T_j^2)(T_i+T_j) \quad \text{with} \quad 4\,\sigma \sum (\mathcal{F}A)_{ij}T_i^3$$

in the stability criterion equation. For the coefficient of T_i to be positive,

$$\Delta\tau \leq \frac{w_i c_i}{\sum_j U_{ij} + 4\,\sigma\, T_i^3 \;\; \sum (\mathcal{F}A)_{ij}} \qquad (9)$$

An identical stability equation exists for the tube lump Equation (5). The hybrid technique as written for the fluid lump temperature (Equation 7) is inherently stable according to Clark's criterion.

3.2.2 Oscillation

Even though a solution is stable, it may oscillate around a correct mean value. An oscillatory condition is dependent on the problem boundary conditions and the node spacing. In cases where oscillation occurs, this undesirable condition may be damped or eliminated by use of a $\Delta\tau$ smaller than the limiting value specified by equation (13). This is accommodated by the input of TINCMN described in Section 3.2.4.

3.2.3 Truncation Error

The truncation error in the routine solution results from replacing derivatives with finite differences. In order to provide a measure of the accumulated truncation error, results for smaller time and space increments (subject to stability and oscillation criteria) should be compared. Chu (Reference 5) recommends halving the space increment and quartering the time increment to obtain an estimate of the error in a numerical result. In general, an investigation of truncation error must be made by changing lump sizes for each type of problem to determine the maximum size of isothermal lumps that can be used for a valid solution.

The truncation error has been shown to be of the form A + B (Ref. 3) where A is proportional to the time increment and B is proportional to the square of the lump linear dimension. LTV experience indicates that time truncation error (A) is relatively small (≈ 3 percent) if the time increment satisfies the stability criteria. The spatial truncation error (B) can be evaluated at steady state.

3.2.4 Steady State Nodes

In a large complex thermal model such as the one to which this routine is applied, it is generally desirable to decrease computation time by having the temperature calculations advance at a larger time increment, $\Delta\tau$, than the calculated maximum time increment, $\Delta\tau_{max}$ (equation 9), for some individual lumps. For this reason the routine was setup so that the computing interval, TINCMN, is supplied by the user on Parameter Card 2, Section 5.7.1. In order to prevent oscillation in those lumps having a $\Delta\tau_{max}$ less than TINCMN, the routine tests TINCMN against the $\Delta\tau_{max}$ for each lump, and in cases where $\Delta\tau_{max}$ is smaller, the heat balance equation is modified so that the individual values of $\Delta\tau_{max}$ are applied to compute T' for these particular lumps. This is illustrated below for a structure lump with no radiation or incident heat flux. The operation is commonly referred to as "overriding" these particular lumps.

$$T_i' = T_i + \frac{\Delta\tau}{w_i c_i} \sum U_{ij}(T_j - T_i) \qquad (10)$$

$$\Delta\tau_{max} = \frac{w_i c_i}{\sum U_{ij}} \qquad (11)$$

Substitute (11) into (10) and

$$T_i' = T_i + \frac{\sum U_{ij}(T_j - T_i)}{\sum U_{ij}} = T_i + \frac{\sum U_{ij} T_j}{\sum U_{ij}} - T_i$$

$$T_i' = \frac{\sum U_{ij} T_i}{\sum U_{ij}} \quad \text{or} \quad \sum U_{ij}(T_j - T_i') = 0 \tag{12}$$

Thus, T_i' is the temperature which would yield an equilibrium heat balance with lump i and surrounding temperatures of T_j. While this feature allows greater run speed and prevents "overridden" lump oscillation, care should be exercised to prevent large errors which can result from "overriding" two adjacent lumps.

3.3 Fluid Heat Transfer Coefficient

Commonly used equations for determining both laminar and turbulent fluid heat transfer coefficients were programmed into the computer routine. An option was also included to permit the program user to input heat transfer coefficient as a function of flow rate in a table (Card 2, Fluid Data Cards). This option is useful for characterizing convective heat transfer in fluid system components when applicable performance data is available.

The use of theoretical solutions based on the assumption of constant fluid properties may introduce errors for fluids where viscosity is a strong function of temperature. The EMU uses two fluids; oxygen and water, the latter has a significant viscosity variation with temperature. This variation is accounted for through curve data input (Section 5.7.16).

3.3.1 Laminar Flow

Both the thermal entry length and the fully developed flow regimes must be considered to properly evaluate a laminar flow heat transfer coefficient. The thermal entry length region is usually considered to include those values of $(1/\text{Re Pr})(L/D_h)$ below .050.

Results are shown in Figure 3-1 for theoretical local and mean Nusselt Numbers obtained by the Graetz solution for circular tubes with uniform surface temperature (Reference 6). The solutions exhibit an asymptotic approach to a

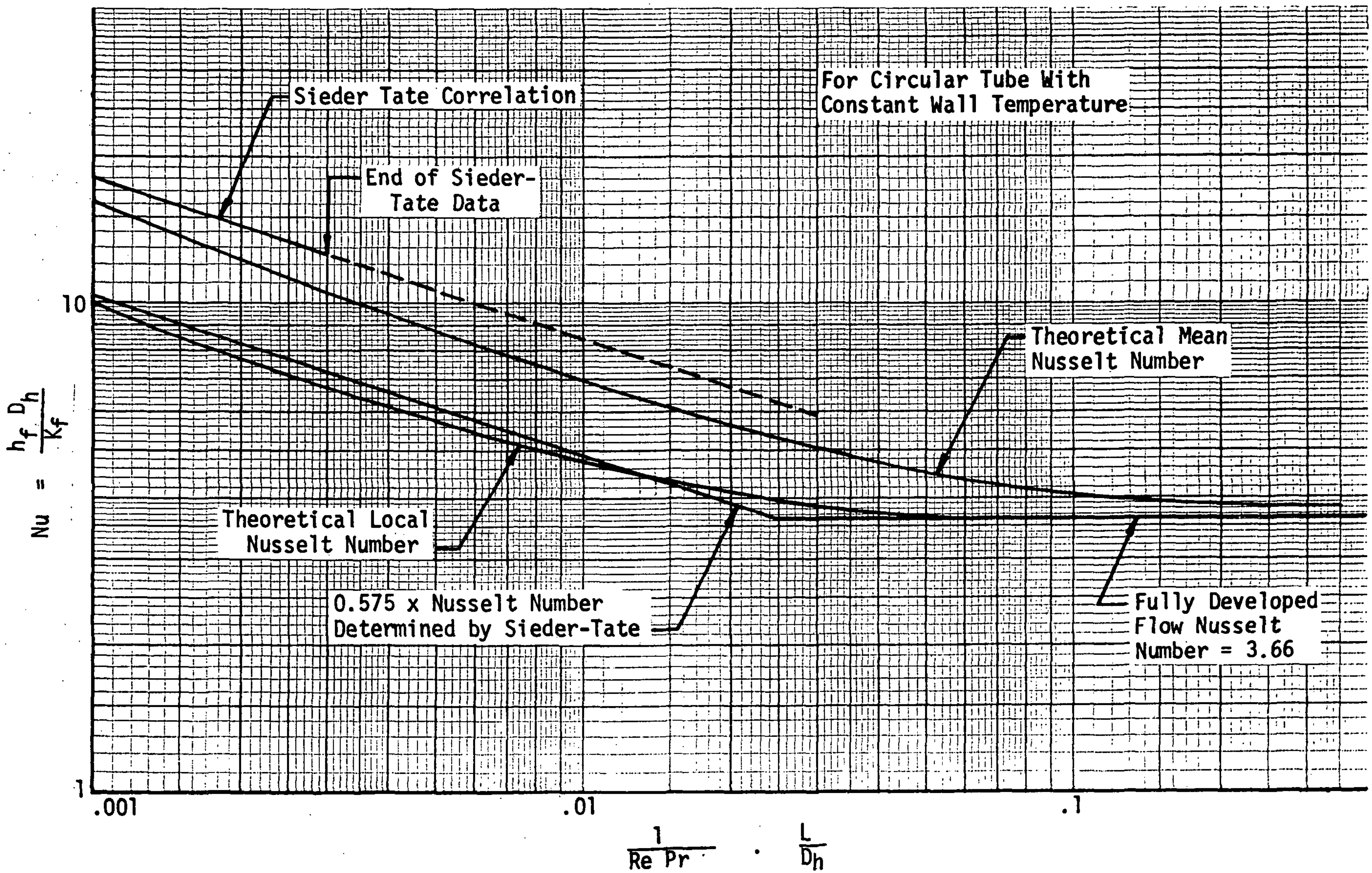


FIGURE 3-1 LAMINAR FLOW NUSSELT NUMBERS

fully developed flow Nusselt Number of 3.66. A plot of the Sieder-Tate equation (Reference 7) which represents an experimental correlation of test data for $(1/RePr)(L/D_h)$ of 0.003 and below is also shown in Figure 3-1. The entry length heat transfer coefficient equation programmed in the computer routine is the Sieder-Tate correlation modified by a factor of 0.575. This equation is shown to provide an adequate fit for the theoretical local heat transfer coefficients which are needed for the individual lumps in the computer routine.

$$h_f = (1.86)(.575)\ K_f/D_h \left[\frac{Re\ Pr}{L/D_h}\right]^{1/3} \tag{13}$$

where:

h_f = convective heat transfer coefficient, BTU/hr-ft^2-°F
K_f = fluid thermal conductivity, BTU/hr-ft-°F
L = length from tube entrance, ft
D_h = tube hydraulic diameter = 4 CSA/WP, ft
CSA = cross sectional area of tube, ft^2 (data input - in^2)
WP = wetted perimeter of tube, ft (data input - in)
Re = Reynolds number, dimensionless
Pr = Prandtl number, dimensionless

The values calculated with Equation (13) are compared with the values calculated by the fully developed flow heat transfer equation:

$$h_f = 3.66\ K_f/D_h \tag{14}$$

and the higher value is used in the heat balance equation.

In this routine it is also possible to have stagnant fluid in flow systems. When this occurs equation (14) is used to determine the heat transfer coefficient to the fluid.

3.3.2 Turbulent Flow

The correlation of equation (15), recommended in Reference 8, is used to determine heat transfer coefficients at Reynolds numbers greater than 2000.

$$h_f = .023\ \frac{K_f}{D_h}\ (Re)^{.8}\ (Pr)^{1/3} \tag{15}$$

In turbulent flow the undeveloped region of heat transfer is short ($\approx$ 4 diameters) such that for most cases it will constitute only a small portion of the total internal heat transfer region.

3.4 Fluid Pressure Loss

The flow system pressure loss is calculated by the Fanning equation with a dynamic head loss factor ($\mathbf{K}$) added. The pressure loss for each fluid lump is calculated by:

$$\Delta P = 4\, f\frac{FLL}{D_h}\,\frac{\rho V^2}{2} + \mathbf{K}\,\frac{\rho V^2}{2} = \frac{\dot{w}^2}{2\rho CSA^2}\left[\frac{f(WP)FLL}{CSA} + \mathbf{K}\right] \quad (22)$$

where

- f = friction factor 16/Re for Reynolds Numbers less than 2000 and is read from input data for Reynolds Numbers greater than 2000 (NFFC, Fluid Data Card 2). The laminar flow friction factor may also be multiplied by FRE, Fluid Data Card 2 to account for non-circular pipe flow.
- FLL = fluid lump length (not necessarily equal to tube lump length)
- $\mathbf{K}$ = number of fluid dynamic head losses
- $\dot{w}$ = tube fluid flow rate, lb/hr
- WP = wetted perimeter, ft (data input - in)
- CSA = fluid cross section area, ft^2 (data input - in^2)
- D_h = tube hydraulic diameter - 4 CSA/WP, ft
- ρ = fluid density, lb/ft^3
- v = fluid velocity, ft/hr

The fluid lump type cards provide for inputs of ($\mathbf{K}$) which can be different for each fluid lump type. The term is used to account for pressure losses in tube entrance regions, bends, contractions, and expansions. Entrance pressure losses for varying duct geometries (Reference 9) may also be specified by ($\mathbf{K}$).

3.5 Flow System Characterization

There are five flow systems in the PLSS and OPS (Figures 3-2, 3-3, and 3-4) and all are simulated in this work. The purpose of the ventilation gas system (Figure 3-2) is to supply life sustaining oxygen to the crewman at a comfortable humidity and temperature. This system is a multi-component

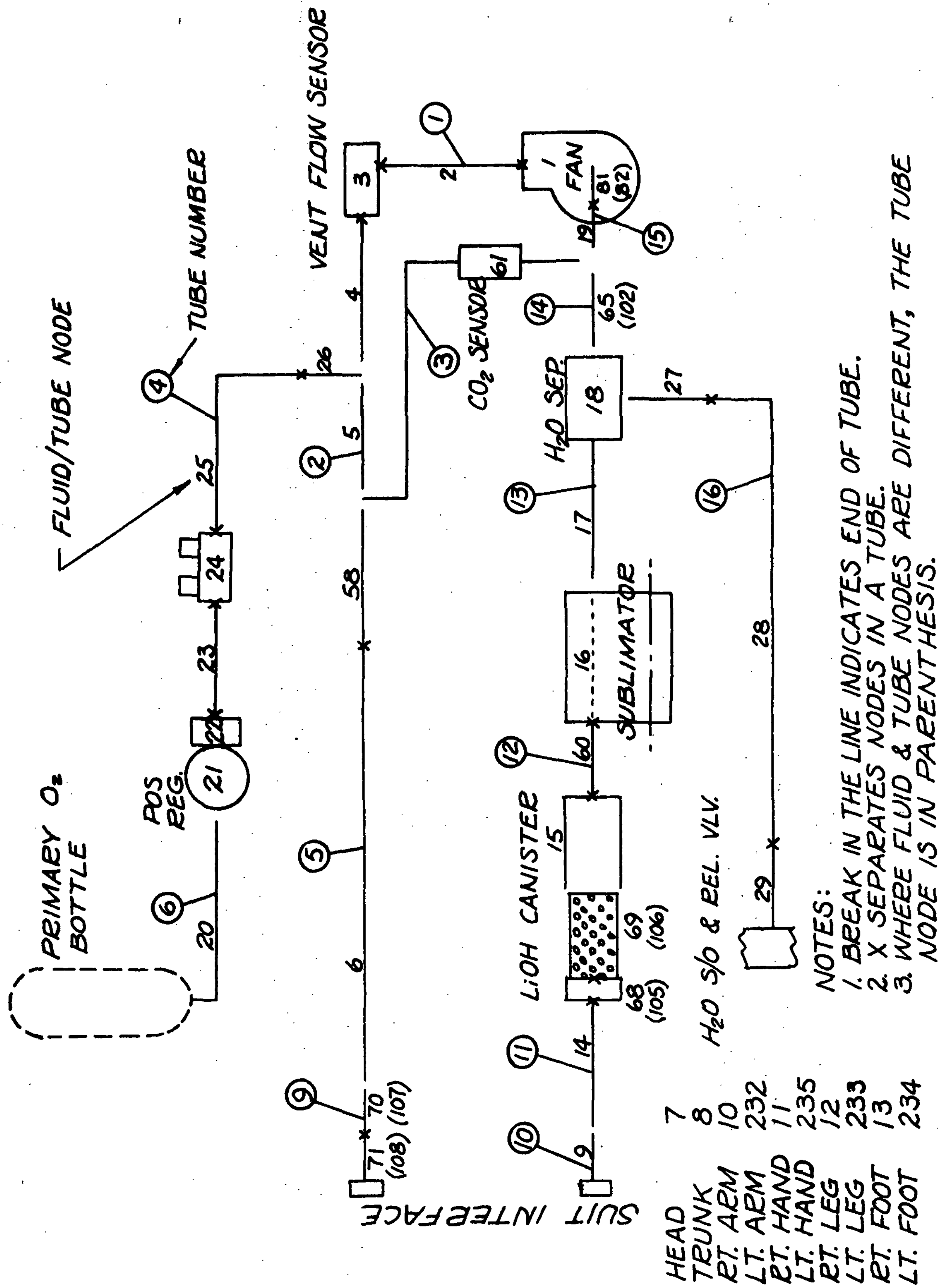


FIGURE 3-2 VENTILATION GAS SYSTEM SCHEMATIC

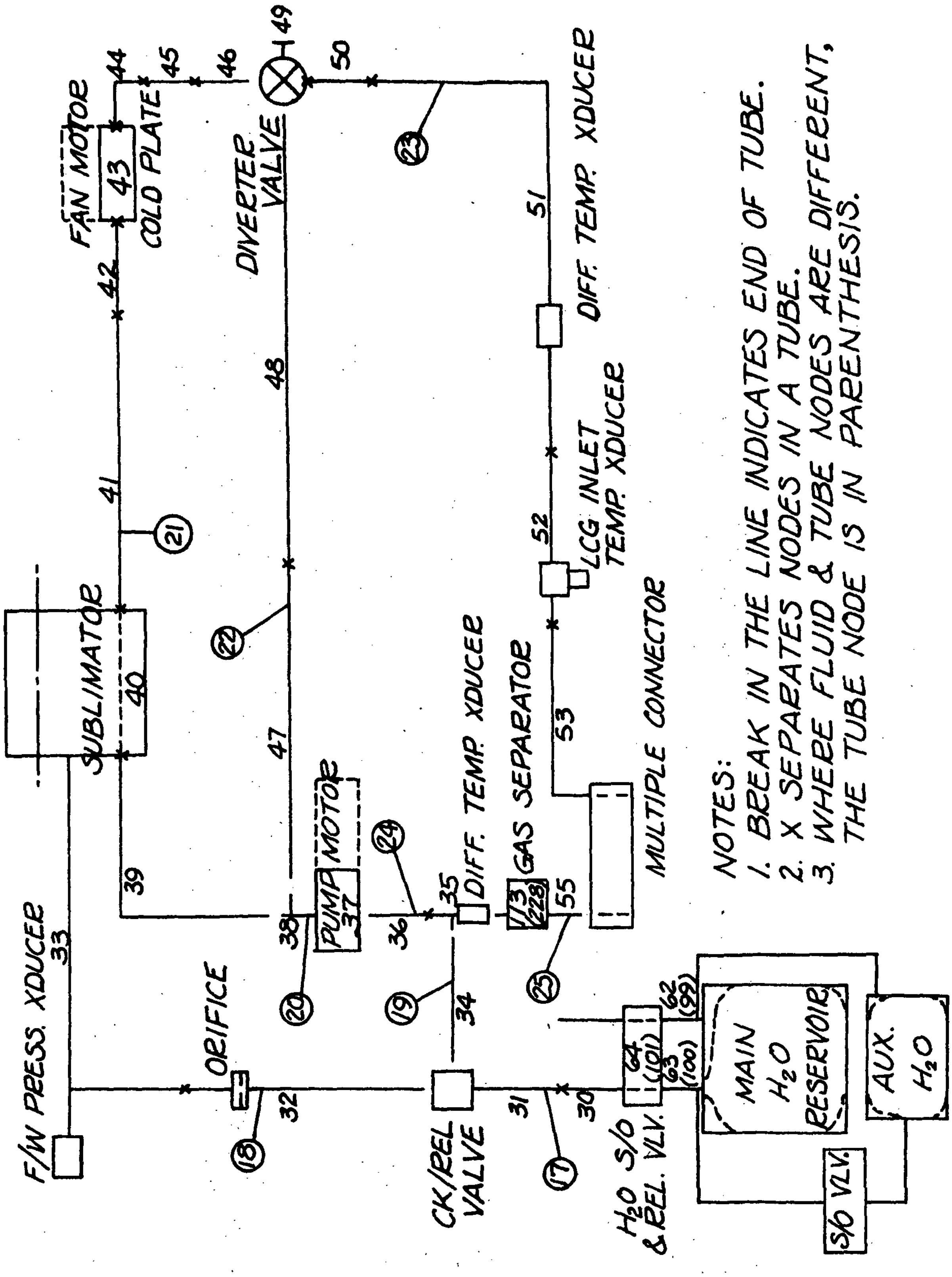


FIGURE 3-3 TRANSPORT WATER SYSTEM SCHEMATIC

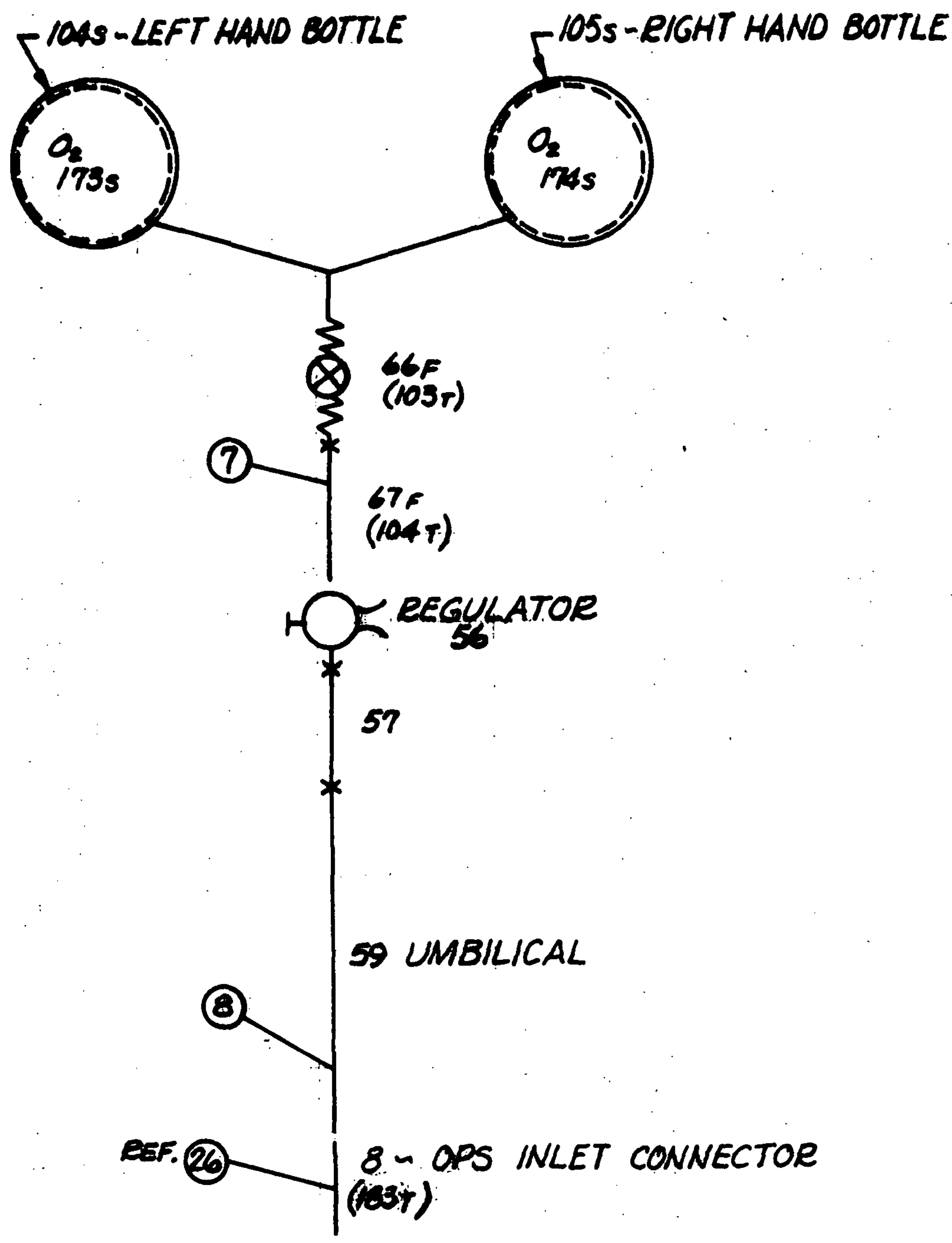


FIGURE 3-4 OXYGEN PURGE SYSTEM SCHEMATIC

fluid system composed of oxygen, water vapor, and carbon dioxide. The latter two are controlled to acceptable levels by components in the loop. The water vapor is condensed in the sublimator and removed in the water separator while the LiOH canister removes the CO_2. The gas leaving the sublimator is assumed to be saturated. When the total heat load on the sublimator is less than the maximum sublimator heat load input by the curve data (Section 5.7.16). Another assumption made on the system is that the removal rate of CO_2 in the canister is equal to the crewman's production rate of CO_2. System oxygen pressure is input as a function of time for the gas at the fan exit port. The total system flowrate is approximately 7 pounds of O_2 per hour. The water vapor flowrate is relatively high between the suit exit and the sublimator when the crewman is working at a high metabolic rate. Tubes 11 and 12 (Figure 3-2) are checked to determine if condensation can occur. If a tube node in tubes 11 or 12 is cool enough, water vapor is removed from the stream, however, no provisions are made for reevaporation. The rate of condensation and the total amount condensed is output per tube.

The primary oxygen system (Figure 3-2) is an open system used to replenish the oxygen lost from the ventilation gas system due to suit leakage and oxygen consumption. CO_2 removed in the LiOH canister would slowly reduce the total gas flow if not replaced. The primary oxygen system has a regulator to control the gas expansion from the oxygen bottle and the simulation assumes no variation in regulator outlet pressure as the upstream pressure of the regulator is reduced.

The transport water system (Figure 3-3) is designed to provide heat removal from the crewman. Since the work rate of the crewman varies over a fairly wide range, a bypass line is used to vary the inlet water temperature to the liquid cooling garment. By manual operation the crewman selects one of three discrete cooling positions on a bypass valve for individual comfort. Flow through the sublimator is never zero but in the minimum cooling position the flow is less than 1% of the total flow. Flow passing through the sublimator cools the fan motor before being mixed with the bypassed flow.

The sublimator feedwater system (Figure 3-3) carries water from the water reservoir to the porous plate in the sublimator. This system is pressurized by the ventilation gas system at the water separator.

The oxygen purge system (Figure 3-4) is used to purge the suit in case of dangerous CO_2 buildup or may be used as a reserve oxygen supply. The system flowrate is determined from user input as a function of time.

3.6 Crewman Characterization

The EMU simulator has incorporated the 41-node metabolic man simulation developed by the National Aeronautics and Space Administration (NASA)-Manned Spacecraft Center (MSC) (Reference 10). Program logic change was necessary to interface the 41-node man with the simulator but the basic relationships representing the thermal regulatory processes are unchanged. The principle area of significant change is at the man's skin/environment interface. NASA's simulation of the undergarment, and the Liquid Cooled Garment (LCG) (Section 3.7.8) were modified from the original steady state analysis to a transient calculation of temperatures.

All forty-one man temperatures, temperature averages for skin and muscle plus twelve other variables to determine the man's relationship to his environment are output at each print interval.

3.7 Component Characterization

3.7.1 Fan

The ventilation gas is circulated by a fan. The system pressure drop is calculated by summing all the individual pressure drops of components and connecting lines around the closed loop containing the fan. System pressure varies from about 3.8 psia when the PLSS is operating in a vacuum to approximately 8.8 psia when the PLSS is operating in the pressurized Lunar Module cabin. The user selects a system pressure which is compatible with the environment to be analyzed and the simulator iterates on the oxygen flowrate and system pressure (see Figure 3-5) drop until acceptable convergence is obtained. Heating of the gas as it passes through the fan has been correlated with test data in the form of a convective heat transfer coefficient to obtain the proper gas temperature rise. The fan motor is modelled as a structure lump with an internal heat generation having connections to the volute housing and a transport water cooling tube.

3.7.2 Lithium Hydroxide Canister

The lithium hydroxide (LiOH) canister is the first component the ventilation gas passes through upon returning from the crewman's suit to the

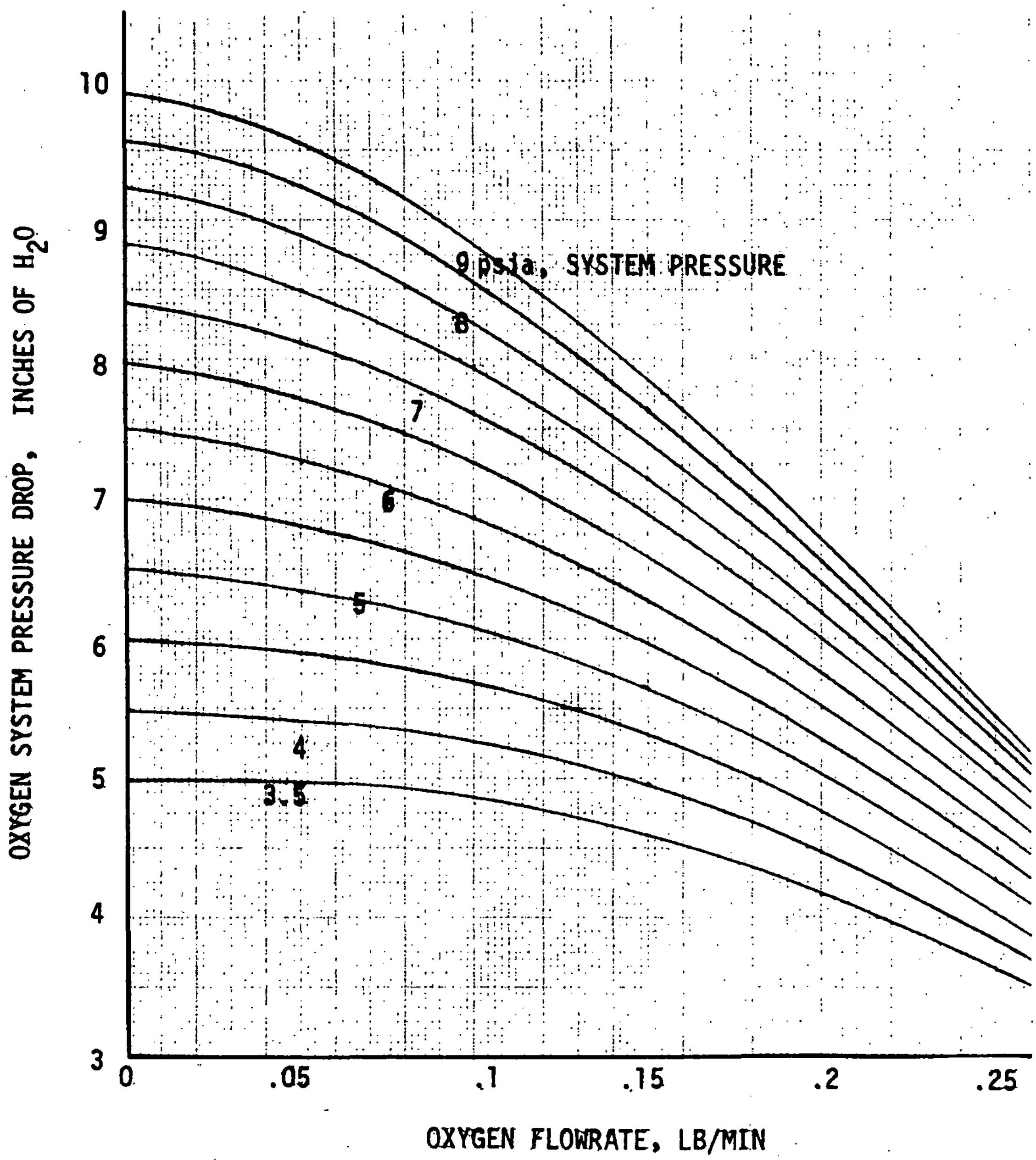


FIGURE 3-5 OXYGEN FAN FLOWRATE

PLSS. In the suit the gas stream picks up exhaled carbon dioxide, water vapor, and odorous gas traces. Carbon dioxide (CO_2) reacts with the LiOH in the following exothermic reaction.

$$2LiOH + CO_2 \longrightarrow Li_2CO_3 + H_2O + \text{heat}$$

The process occurring in the canister is dependent on a number of variables which affect the chemical reaction; however, for the majority of the extra-vehicular activities the LiOH canister design is such that the chemical reaction may be assumed to occur as written above. The simulator analysis assumes the canister removes all CO_2 as it is generated. The canister contains activated charcoal to eliminate pungent odors.

To calculate the heat generated in the LiOH bed, the generation rate of CO_2 is required. The CO_2 generation rate is dependent upon the respiratory quotient (RQ). The simulator uses RQ = .82 which results in the following equation:

$$\dot{Q}_{canister} = .162 \text{ RM}$$

where $\dot{Q}_{canister}$ = the heat generation rate in the canister, BTU/hr

RM = the crewman metabolic rate, BTU/hr

The water vapor added to the gas stream due to the chemical reaction is

$$\dot{W}_{H_2O} = \frac{M_{H_2O}}{M_{CO_2}} \dot{W}_{CO_2}$$

where $\dot{W}_{H_2O}$ = the water vapor generation rate, LB/hr

M_{H_2O} = molecular weight of water, 18

M_{CO_2} = molecular weight of carbon dioxide, 44

$\dot{W}_{CO_2}$ = .000189 RM = the mass rate of CO_2 added to the reaction, LB/hr

The pressure drop of the gas through the LiOH canister is calculated by the equation:

$$\Delta P = C_2 \frac{T_{in}}{P_{in}} (\dot{W})^{N_2}$$

where ΔP = the pressure drop of the gas through the canister, psi

T_{in} = the gas temperature into the canister, ^{O}R

P_{in} = the gas pressure into the canister, psia

$\dot{W}$ = the gas flowrate, LB/hr

Suggested values for C_2 = 4.58E-6 and N_2 = 2.044 (See Section 5.7, Card 6)

3.7.3 Sublimator

The sublimator cools the ventilation gas and transport water loops by dissipating heat with an expendable water supply. Simulation of the sublimator includes start-up transient, maximum cooling capability, effectiveness (temperature out for both loops), effect of humidity and condensation in the gas side, pressure drop of both loops, and the shut-down transient.

An initial specific humidity out of the sublimator on the gas side is input for the first iteration. Subsequent specific humidity values are dependent on the water introduced into the system and the maximum cooling cooling capacity (input data) of the sublimator. If the sublimator has the capacity to cool both the transport water and ventilation gas streams plus absorb the heat from the PLSS structure, the gas leaving the sublimator will be saturated. Since the ventilation gas flowrate is relatively constant, the simulation of the outlet gas temperature reduces to a function of inlet temperature and inlet dew point temperature. Figure 3-6, 3-7, and 3-8 present component data on the sublimator taken from Reference (11), Memorandum NA-SS-3326 and used to generate Figure 3-9. Analytical expressions were derived for the data represented in Figure 3-9 and are formulated in subroutine SUBLIM.

The sublimator water outlet temperature is determined by interpolating on a bivariant curve with the sublimator water flowrate and inlet temperature. The curve data were generated from Figures 3-10 and 3-11 (reproduced from NA-SS-3326). The data were extrapolated such that an inlet temperature

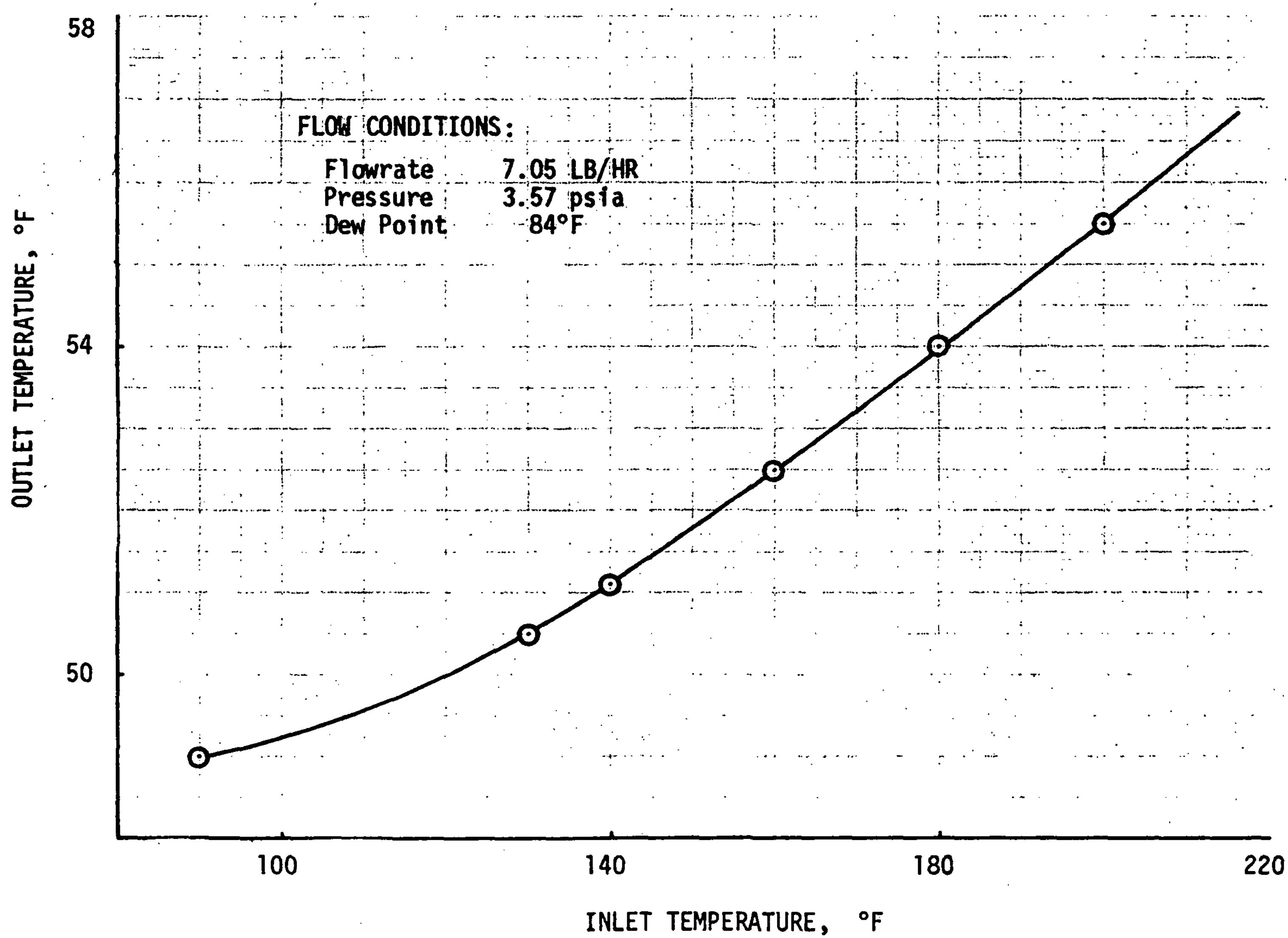


FIGURE 3-6 EFFECT OF OXYGEN INLET TEMPERATURE ON SUBLIMATOR OXYGEN OUTLET TEMPERATURE

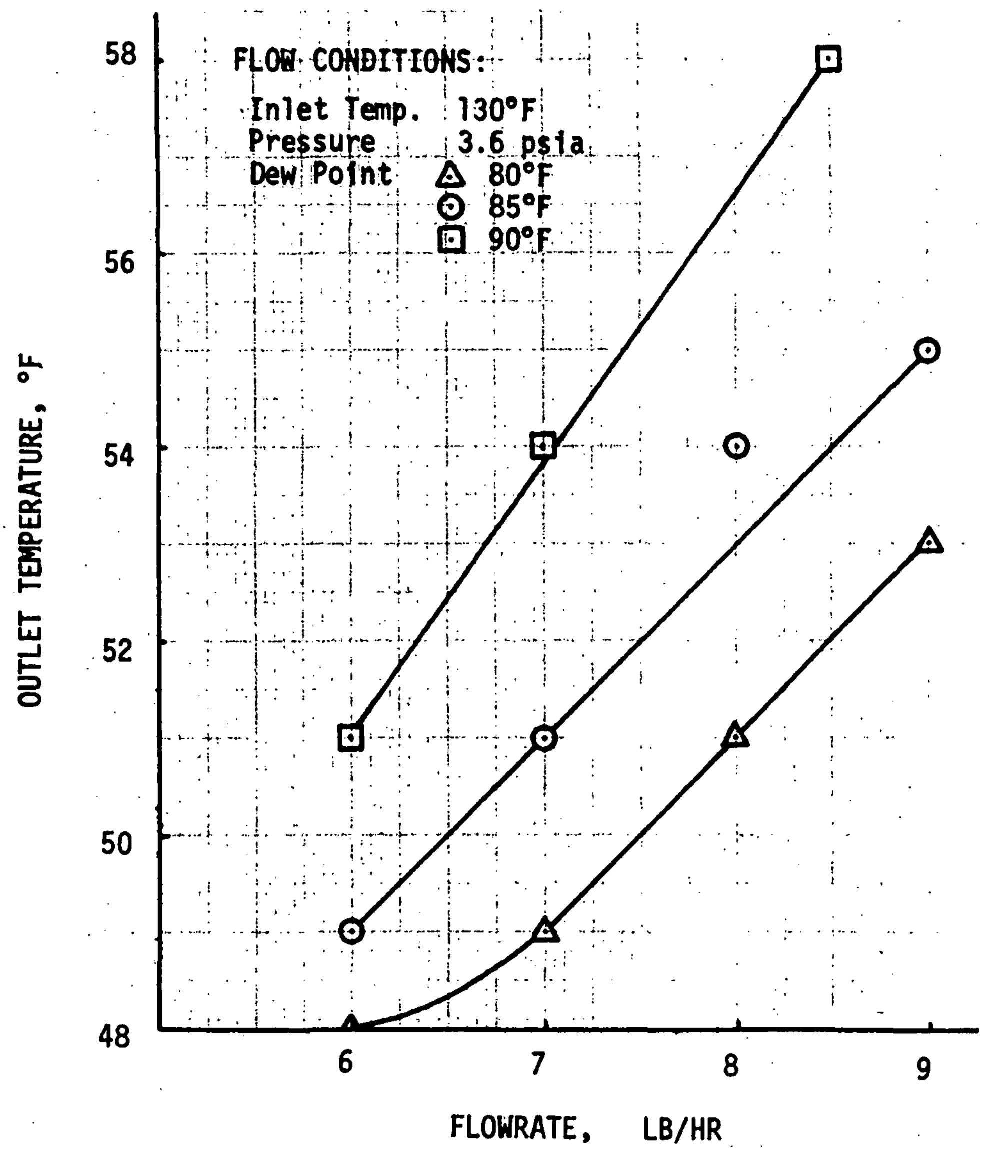


FIGURE 3-7 EFFECT OF OXYGEN FLOWRATE ON SUBLIMATOR OXYGEN OUTLET TEMPERATURE

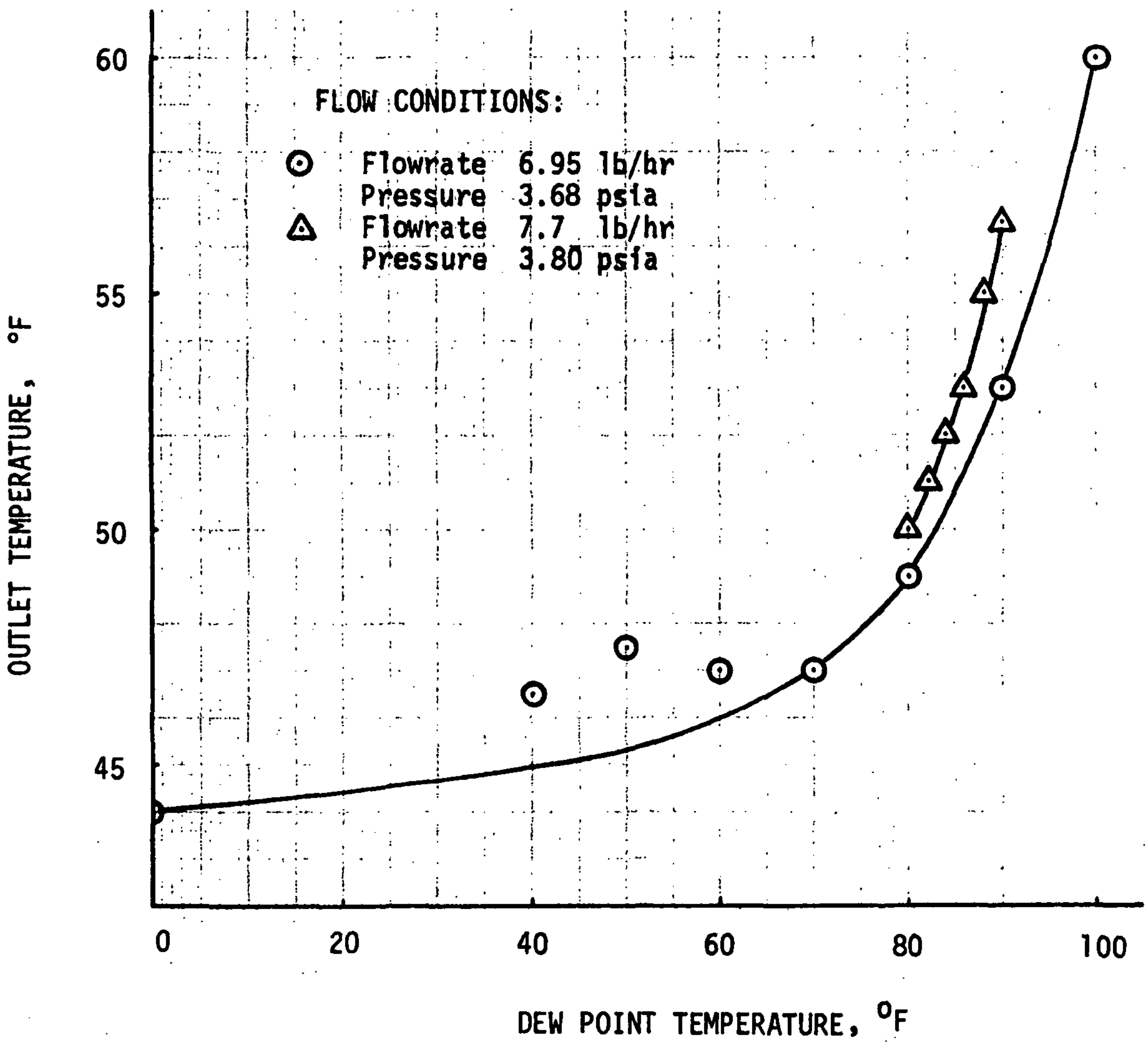


FIGURE 3-8 EFFECT OF OXYGEN INLET DEW POINT TEMPERATURES ON SUBLIMATOR OXYGEN OUTLET TEMPERATURE

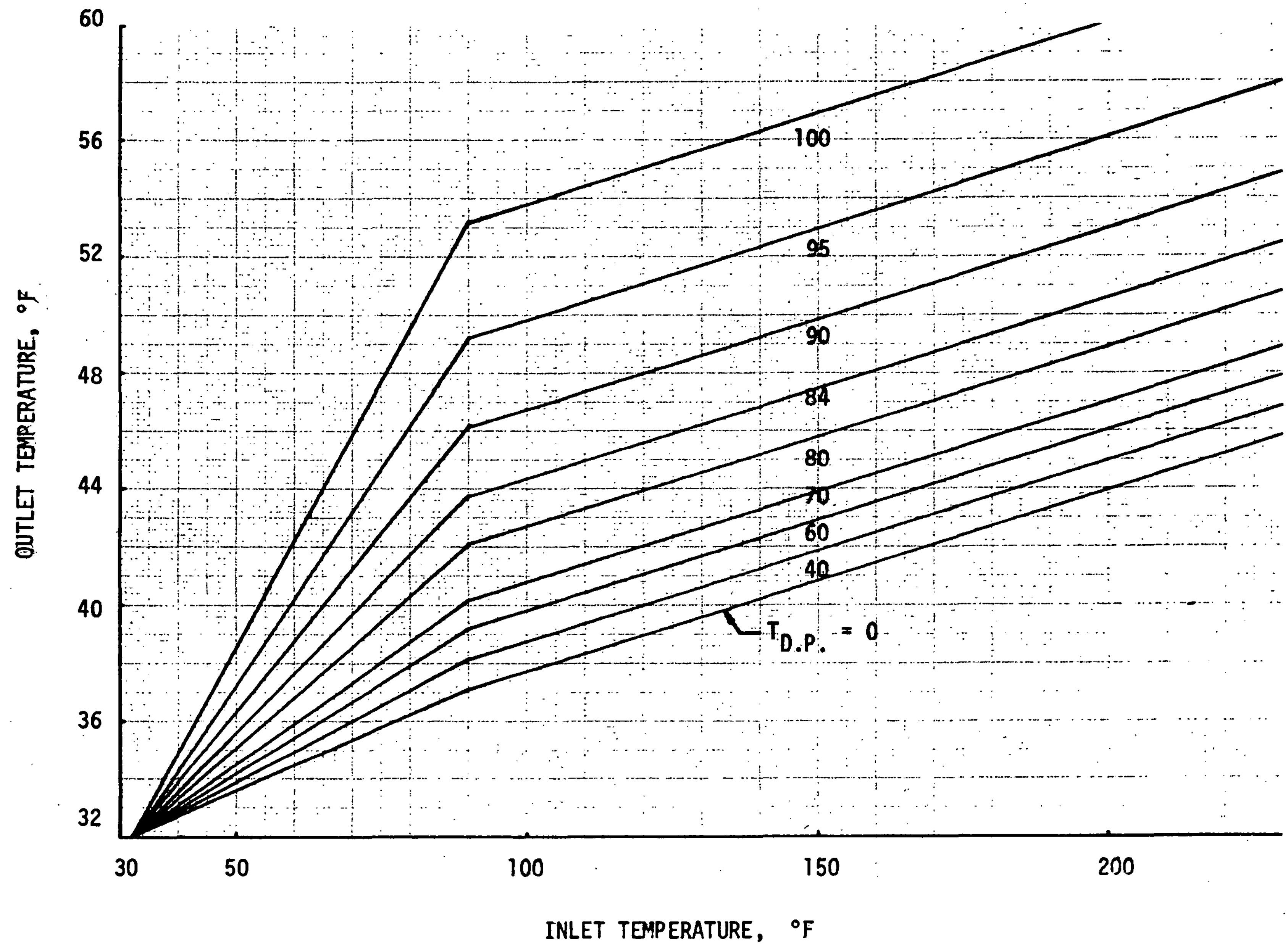


FIGURE 3-9 SUBLIMATOR OUTLET TEMPERATURE - OXYGEN

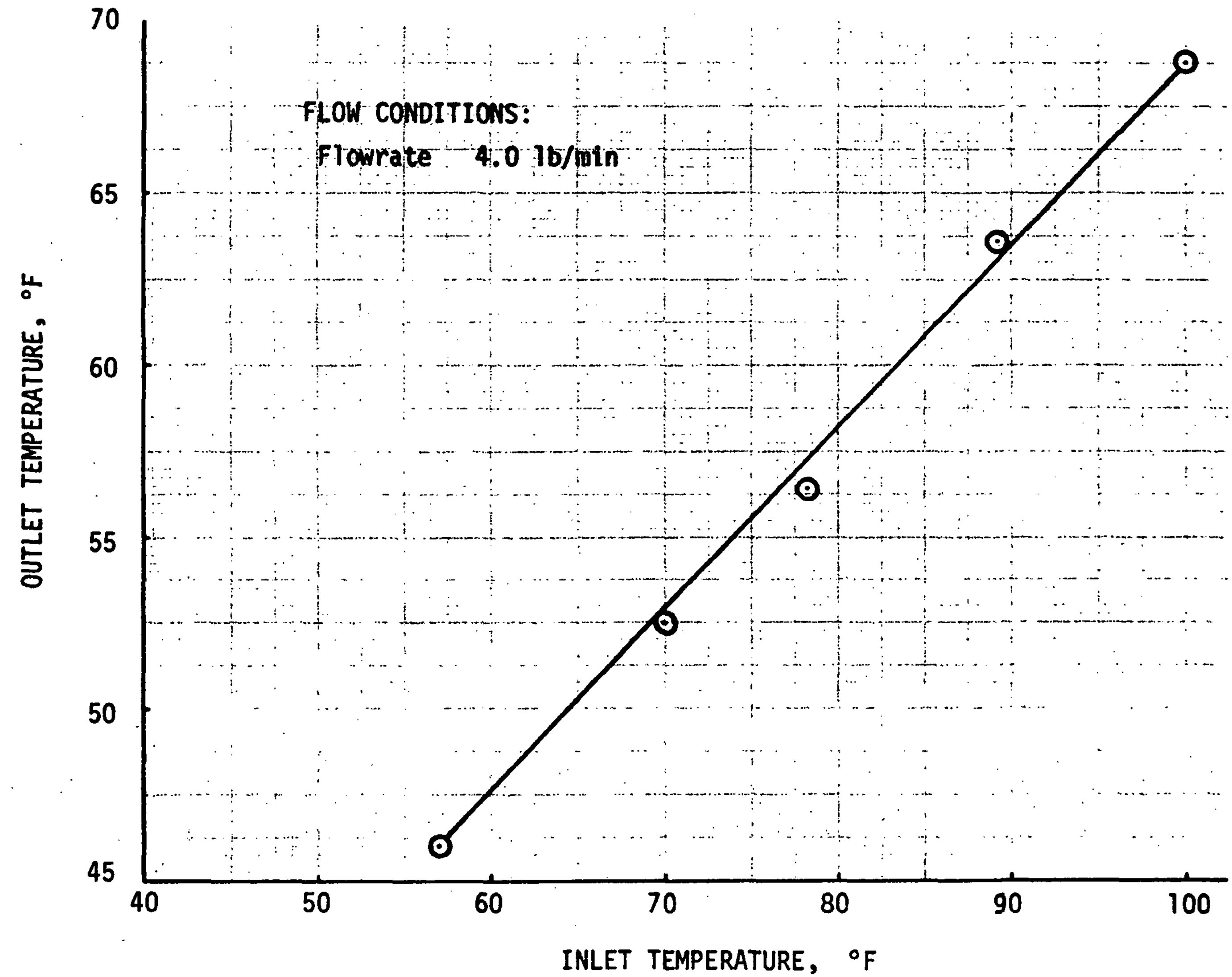


FIGURE 3-10 EFFECT OF WATER INLET TEMPERATURE ON SUBLIMATOR WATER OUTLET TEMPERATURE

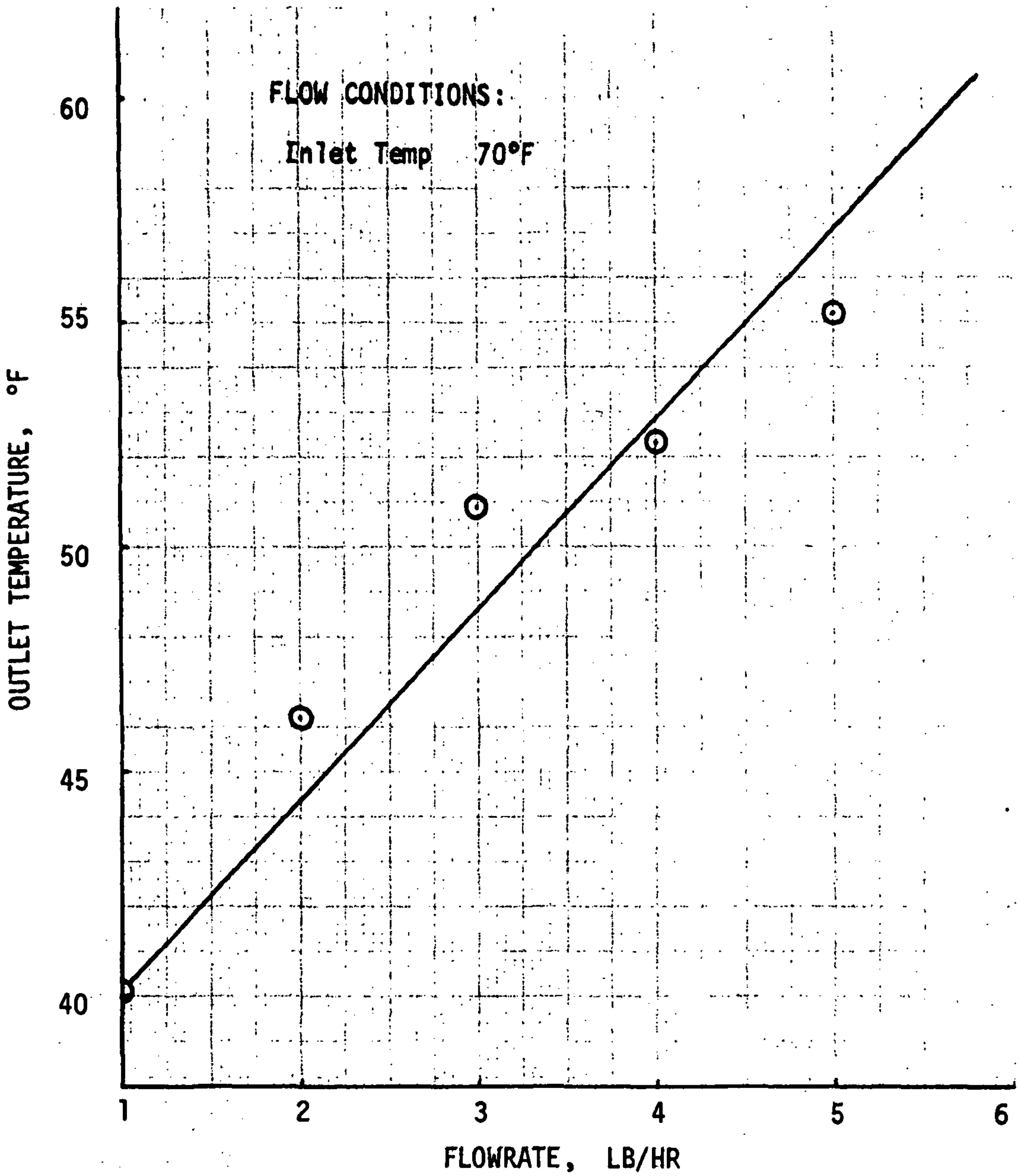


FIGURE 3-11 EFFECT OF WATER FLOWRATE ON SUBLIMATOR WATER OUTLET TEMPERATURE

of 32°F would give an outlet of 32°F for any flowrate and that zero flowrate would give an outlet temperature of 32°F.

The maximum capacity or cooling rate of the sublimator is simulated by allowing the core temperature to rise above 32°F. Using the outlet temperatures of the two loops and all other connection data, the net heat into the sublimator is calculated and compared to the maximum cooling rate input in the curve data. If the cooling rate is less than the net heat gained, this difference is used to calculate a new sublimator core temperature to be used on the following iteration.

As stated previously the pressure drop through the sublimator is calculated for both loops and used to calculate a system pressure drop in the respective loops. To provide for as much latitude as possible with components, the user is allowed to supply the constants in the equations for pressure drop thus making new component data easy to incorporate. For the gas side, the equation is:

$$\Delta P = C_1 \frac{T_{in}}{P_{in}} (\dot{W})^{N_1}$$

where: ΔP = the pressure drop of the gas through the sublimator, psi

T_{in} = temperature of gas into the sublimator, °R

P_{in} = total pressure of gas into the sublimator, psia

$\dot{W}$ = the gas flowrates, LB/hr

Suggested values for C_1 = 1.28E-5 and N_1 = 1.55

For the water side, the equation is

$$\Delta P = C_2 (\dot{W})^{N_2}$$

where: ΔP = the pressure drop of the water through the sublimator, psi

$\dot{W}$ = the water flowrate, LB/hr

Suggested values for C_2 = 1.583E-6 and N_2 = 8.2023

Sublimator performance is independent of feedwater pressure in the simulator, therefore the program does not stop with the emptying of the water reservoir. However, continuous monitoring of the feedwater reservoir quantity is maintained throughout the mission and if the available water quantity becomes zero, automatic sublimator dryout commences. The automatic dryout profile is shown in Figure 3-12, and occurs if the primary and auxiliary water reservoirs are depleted or if the primary supply is depleted and the auxiliary water shut-off valve is closed. The auxiliary supply is not used until the primary reservoir registers empty. If the auxiliary water shut-off valve is opened during a dryout transient, the sublimator enters a recovery transient (Figure 3-12) and will eventually attain the input value. The user must enter his own dryout transient when he wishes to terminate the mission prior to exhausting the available water.

3.7.4 Water Separator

The water separator is located in the ventilation gas loop downstream of the sublimator. Entrained water droplets condensed in the sublimator are removed from the gas flow by the water separator. Water picked up by the separator flows to the backside of the bladder in the water reservoir. This process is simulated as well as the pressure drop of the gas through the water separator. The pressure drop is calculated by the following equation.

$$\Delta P = C_3 \frac{T_{in}}{P_{in}} (\dot{W})^{N_3}$$

where: ΔP = the pressure drop of the gas through the water separator, psi

T_{in} = the gas temperature into the separator, $^{\circ}R$

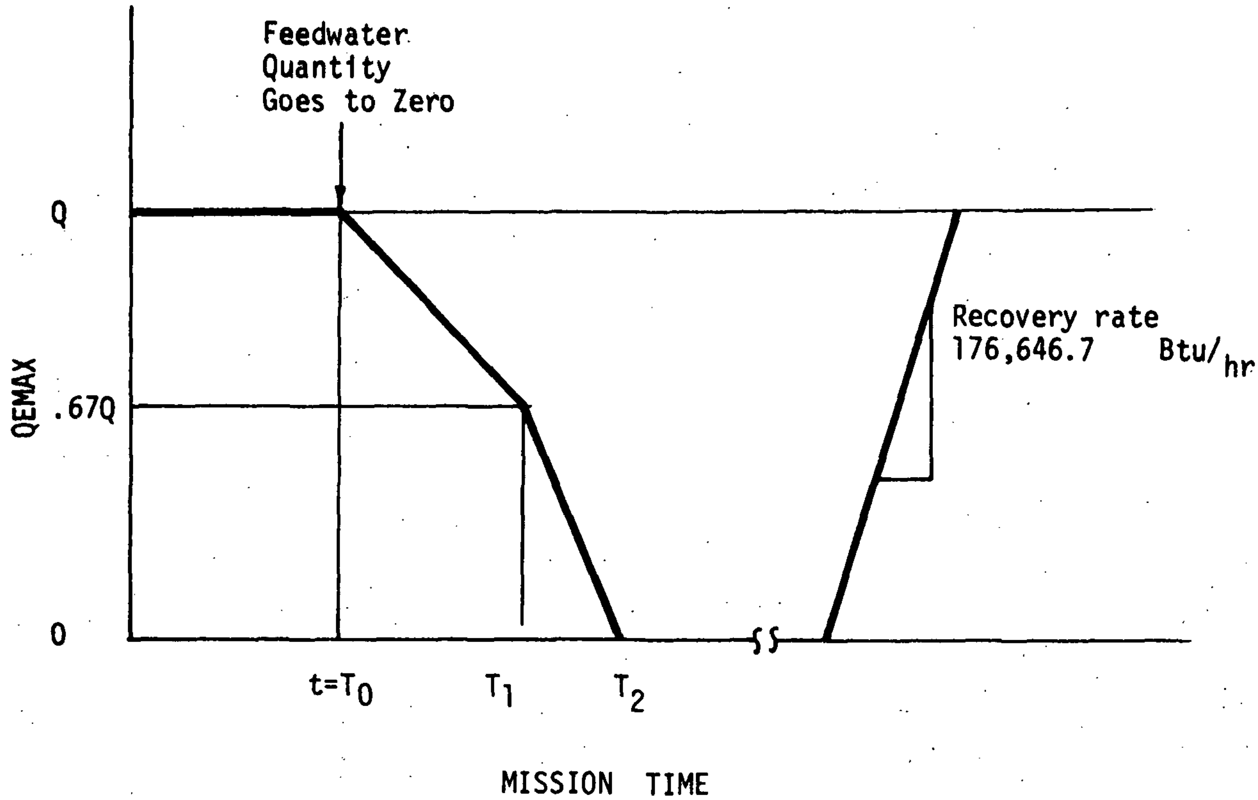
P_{in} = the gas pressure into the separator, psia

Suggested values for C_3 = 7.317E-6 and N_3 = 2.142

3.7.5 Suit

The crewman's space suit is composed of the pressure garment assembly (PGA) and the integrated thermal/meteoroid garment (ITMG). The flow-splits in the PGA for the suited modes were furnished in the subroutines of the 41-node metabolic man program (NASA) and were used without change. Likewise, the convection and radiation heat transfer between the suit wall and crewman's undergarment are calculated as in the NASA program with provisions added to handle multi-node suit areas around a single skin compartment.

The PGA may be assumed to have leakage by inputting a curve of leakage rate versus time. Gas leakage leaves the PGA and the gas loop at the outlet gas connector at a humidity which is the average of the inlet and



QEMAX - Sublimator Maximum Load Capability (Btu/hr)

To - Time at which Primary Feedwater quantity goes to zero and auxiliary feedwater shut-off valve closed

or

primary and auxiliary feedwater depleted.

T_1 - Time at which QEMAX has reached two thirds of value at T_0

T_2 - Time at which dryout is complete

Q - MAXIMUM LOAD INPUT BY THE USER

FIGURE 3-12 SUBLIMATOR DRYOUT/RECOVERY TRANSIENT outlet humidities of the suit gas. Pressure drop through the suit is calculated using the following equation:

$$\Delta P = C_7 \quad \frac{T_{in}}{P_{in}} \quad (\dot{W})^{N_7}$$

where ΔP = the pressure drop through the suit, psi

T_{in} = gas temperature into the suit, ^oR

P_{in} = gas system pressure into the suit, psia

$\dot{W}$ = gas flowrate, LB/hr

Suggested values for C_7 = 1.062E-5 and N_7 = 1.862

3.7.6 Pump

The transport water system pump is located immediately upstream of the tee which directs flow to the sublimator or sublimator bypass line. The system pressure drop is calculated using the line containing the sublimator (since the flow is never zero in this line) and used in the following equation to find the total flow for the next iteration.

$$\dot{W} = C_6 \, \Delta P^{\;N_6}$$

where: $\dot{W}$ = the total water flow, LB/hr

ΔP = transport water system pressure drop, psi

Suggested values for C_6 = 656. and N_6 = -.686

3.7.7 Transport Water Diverter Valve

The diverter valve is a three-position, manually-operated valve by which the crewman controls the LCG inlet temperature. The three positions have been named according to the cooling capacity as maximum, intermediate and minimum.

In the maximum cooling position, the diverter valve closes the sublimator bypass and forces total transport water flow through the sublimator. If the crewman selects the intermediate cooling position of the valve, 87.5 percent of the total flow is bypassed around the sublimator. In the minimum cooling position , the valve bypasses 96.5 percent of the total flow. The above percentages are based on the nominal steady-state flowrates called for in Hamilton Standard's specification SVHS3133, Section 3.5.2.2.

The valve position is input as a Type 34 curve, position code versus time. The following codes determine valve position: 1, maximum cooling; 2, intermediate cooling; 3, minimum cooling. One additional code is available to the user; 4, automatic positioning of the diverter valve as a function of the crewman's internal heat storage. Figure 3-13 shows the comfort band of the average crewman as a function of the metabolic rate. If the crewman's heat storage rises above the comfort band, the valve position is moved one position to provide increased cooling. The valve may be moved to provide further cooling after 3 minutes has elapsed from time of the last position change if the diverter valve is not already set to maximum cooling. The three minute delay between position changes simulates crewman and system response time. If the crewman's internal heat storage falls below the comfort band, the diverter valve position is changed to reduce the cooling at three minute intervals until minimum cooling is reached or the crewman's internal heat storage is in the comfort band. When using the automatic positioning option, it is necessary to initialize the valve in one of the other three positions before going to automatic.

3.7.8 Liquid Cooling Garment

At high metabolic rates the convective and evaporative heat transfer cannot maintain an acceptable crewman heat storage level; therefore, a liquid cooling garment (LCG) is worn during extravehicular activity. The LCG is constructed of one layer each of chiffon and Spandex with Tygon tubing sandwiched between the two layers. Water, chilled by the PLSS sublimator, flows through the LCG tubing which covers the crewman's legs, torso, and arms. Figure 3-14 shows the parallel flow paths of the LCG distribution system and includes the fluid and tube lump numbers used in the LCG thermal model. The model shown in Figure 3-14 is a departure from the steady state method used by NASA in their 41-node man characterization. The total UA (conductance) between the crewman and LCG was maintained the same for both simulations at 43.5 BTU/hr. Figure 3-15 shows the details of the thermal model bounded by

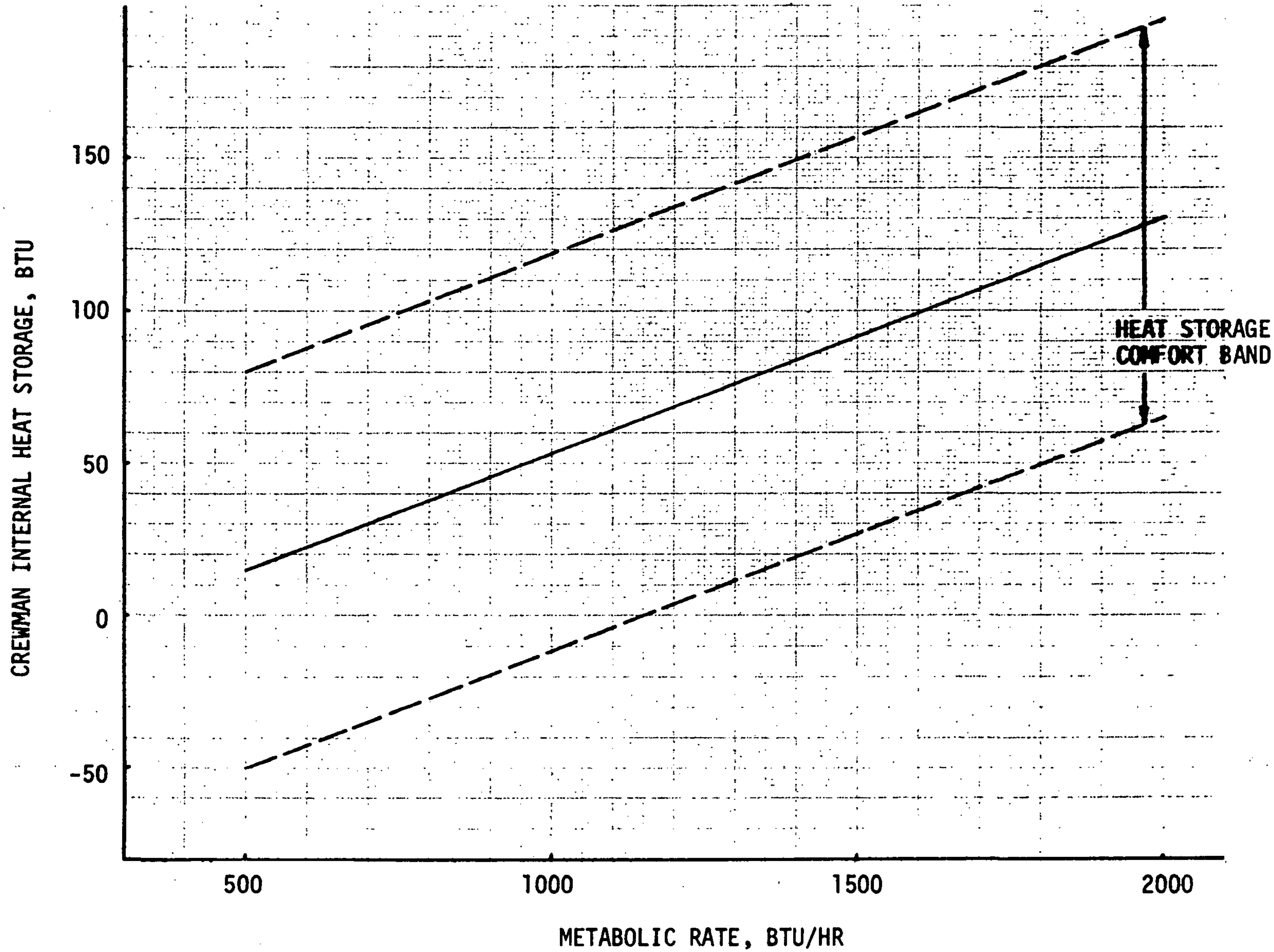


FIGURE 3-13 CREWMAN HEAT STORAGE COMFORT BAND

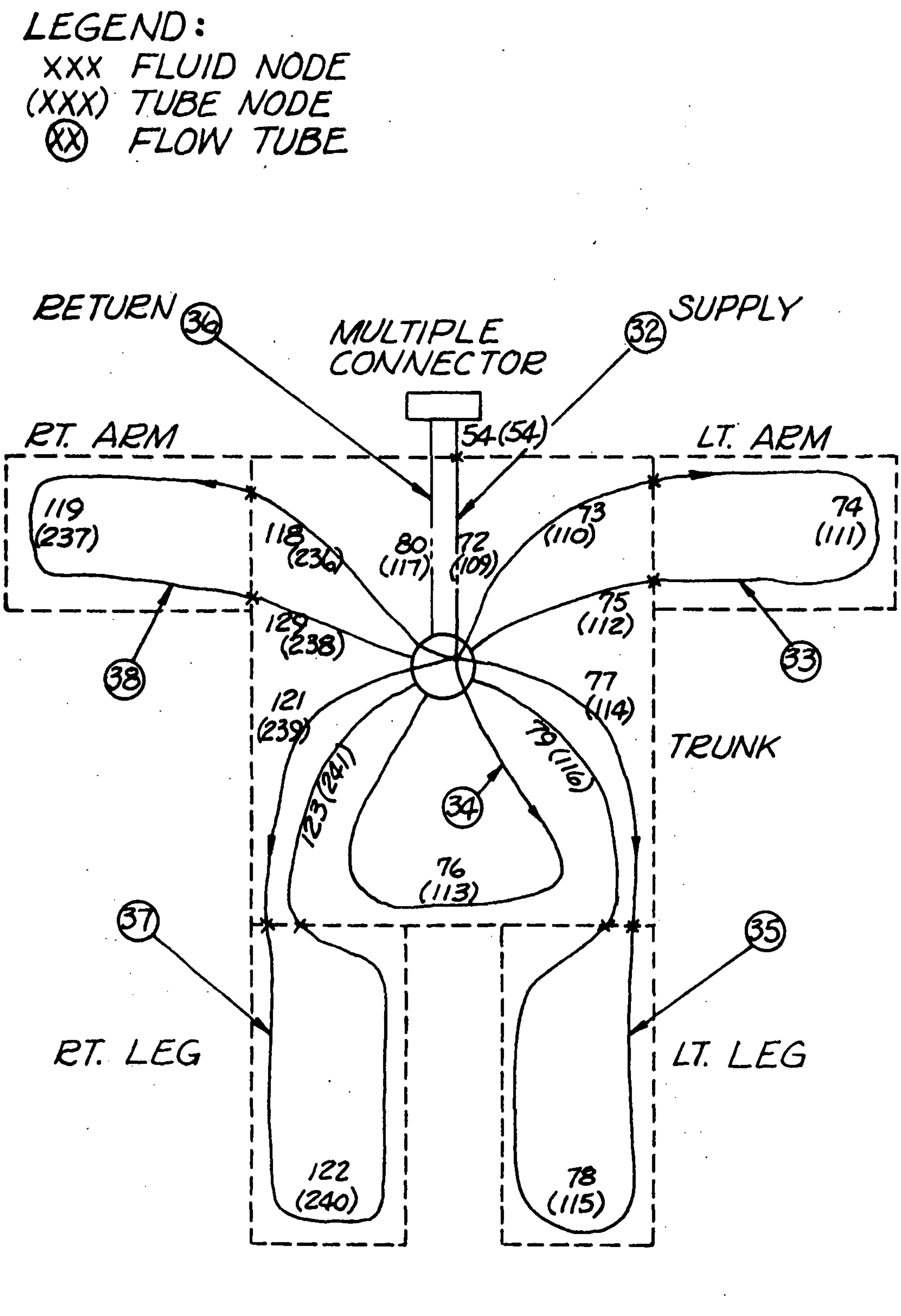


FIGURE 3-14 LIQUID COOLING GARMENT FLOW SCHEMATIC

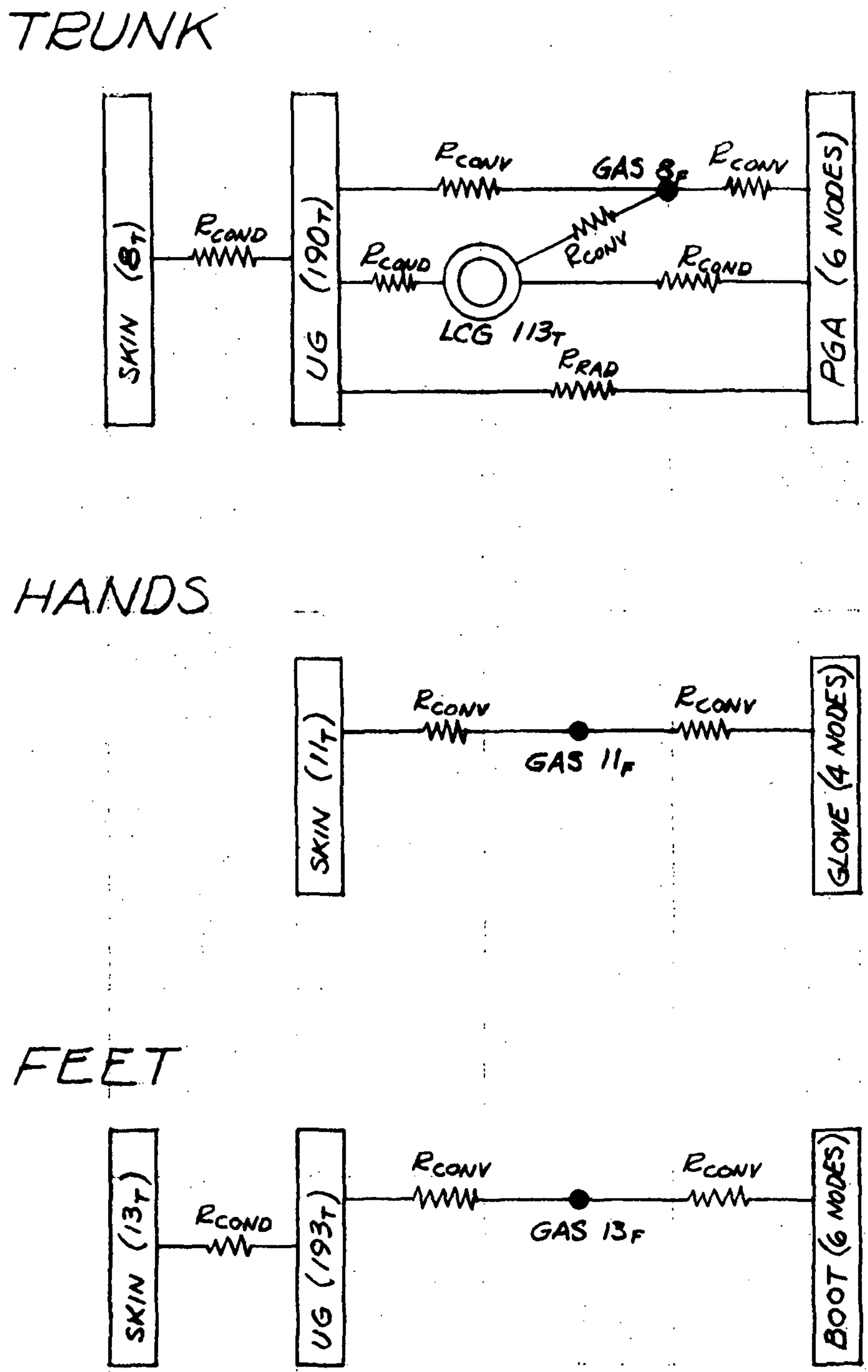


FIGURE 3-15 LIQUID COOLING GARMENT MODEL

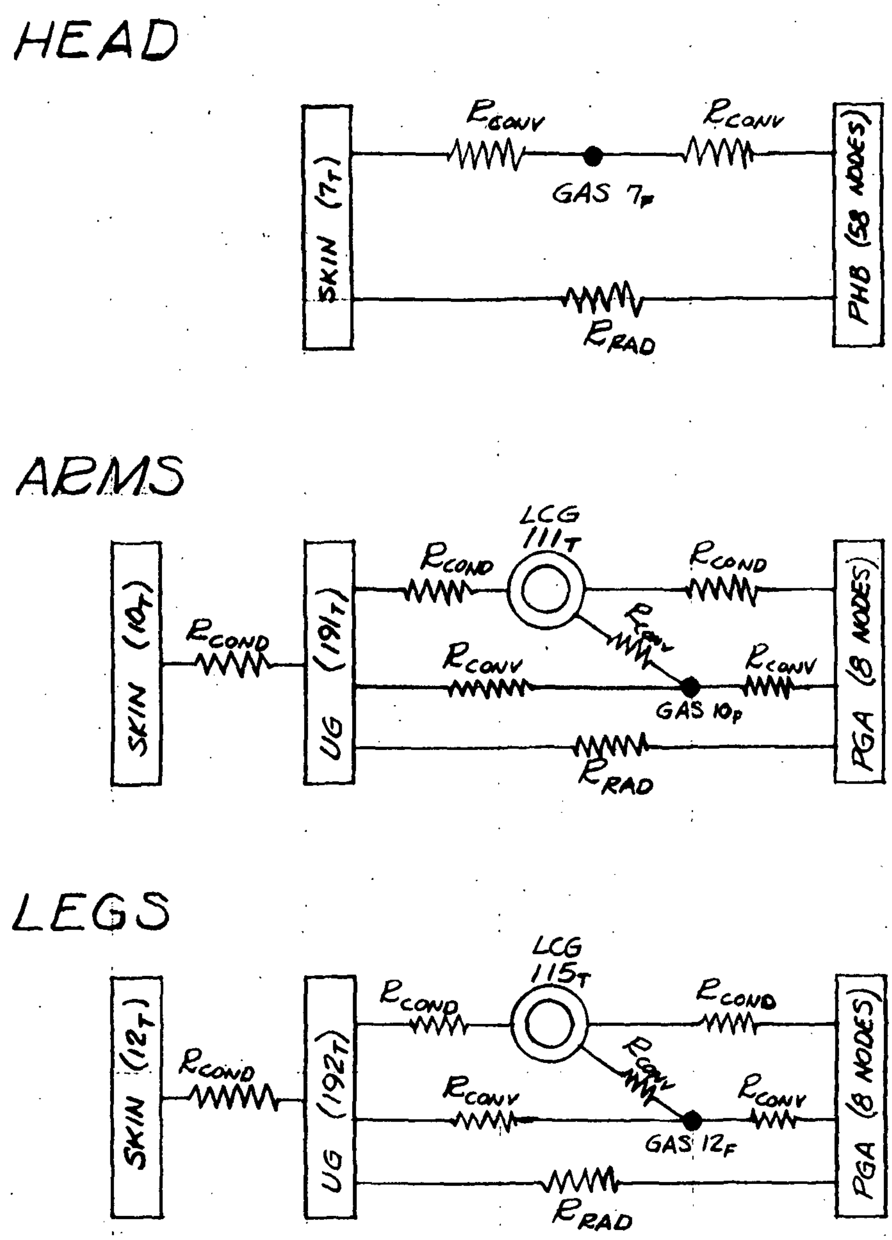


FIGURE 3-15 (CONT'D) LIQUID COOLING GARMENT MODEL

the crewman's skin and the pressure garment assembly. The reciprocal of R_{cond} summed for the trunk, arms, and legs from the skin nodes to the LCG tube nodes will give the total LCG conductance.

3.7.9 Oxygen Regulator

The EMU has two oxygen regulators in which the oxygen is expanded to a lower pressure. The expansion process cools the gas which in turn cools the regulator. The temperature and pressure into the regulator are known and used to interpolate on a curve to find the enthalpy of the gas entering the regulator. An isoenthalpic expansion is assumed as the gas enters the regulator. The user inputs the heat transfer coefficient between the expanded gas and the regulator .

3.7.10 Oxygen Purge System (OPS) Heater

The heater, heater controller, and battery were deleted in OPS's assembled for Apollo 14 and subsequent flights. Logic to analyze the heater was retained but the data tape was modified to reflect the deletion. The following paragraph documents the heater as originally used.

The OPS heater is located upstream of the OPS oxygen regulator and preheats the oxygen before it is expanded in the regulator. Downstream of the regulator is a fluid sensor which determines when the heater is on. The user inputs the heat transfer coefficient between the gas and heater element and the heater power. Two sensor set point temperatures (TSEN1, TSEN2) are input. If the sensor temperature is below TSEN1 and increasing, heater power will be maintained at a constant value (user input) until the TSEN2 valve is exceeded. If the sensor temperature is above TSEN2 and decreasing, the heater remains off until the sensor temperature drops below TSEN1. The heater may be on or off if the sensor temperature is within the TSEN1 to TSEN2 band as explained above.

3.8 Consumables Characterization

The EMU simulator considers the depletion and/or conversion of the following expendables; lithium hydroxide, oxygen, and water. The user inputs initial values for each of the expendables and the simulator subtracts the quantity used and outputs the quantity remaining.

The lithium hydroxide combines with CO_2 in the gas stream and forms lithium carbonate and water vapor. The weight of the lithium carbonate is increasing as the lithium hydroxide is depleted. The user is required to input the fluid lump number of the canister cartridge used in the model. This is needed in determining the cartridge tube lump number which has a variable thermal capacitance. Lithium carbonate is heavier and has a larger specific heat than lithium hydroxide thus increasing the thermal capacitance of the cartridge.

Oxygen quantity in the three oxygen bottles is indicated by the number of pounds remaining and the bottle pressure. The oxygen and oxygen bottle are entered as structure lumps with the heat transfer coefficient, initial pressure, and volume input. Bottle pressure is updated each iteration to account for temperature and/or mass changes. Mass of the oxygen initially in the primary oxygen bottle is input as the product of the mass times the specific heat as described on the structure type data card for the oxygen. The input for the OPS oxygen is similar. In the baseline thermal model, the initial mass of the oxygen is split equally between the two OPS bottles. An average temperature out of the OPS bottles is used since the OPS bottles blowdown simultaneously.

The PLSS has two water reservoirs. An auxiliary water reservoir was added beginning with the Apollo 15 mission. Although the auxiliary reservoir has a separate shut-off valve, it is connected to the feedwater supply system through the primary reservoir shut-off valve. This arrangement allows the primary shut-off valve to control the flow from both reservoirs. The water reservoirs and the water quantities are modeled as structure lumps. The thermal mass of the water structure lump is varied as water flows out of the bladder to the sublimator and as condensed water vapor collected by the water separator flows to the backside of the bladder.

3.9 Oxygen Bottle Blowdown Characterization

The EMU has three oxygen bottles. The primary oxygen supply in the PLSS and two bottles which comprise an emergency or purge supply in the OPS. The flowrate from each bottle is known as a function of time. Flow from the primary oxygen bottle is determined from crewman consumption and suit leakage. The OPS oxygen flowrate is determined by a purge relief valve placed in the right hand side, oxygen, suit outlet connector.

The increase in stored energy of the gas is, semantically:

$$\begin{bmatrix}\text{Increase in}\\ \text{Stored Energy}\\ \text{of Gas in Bottle}\end{bmatrix} = \begin{bmatrix}\text{Energy Added to}\\ \text{Gas From Bottle}\end{bmatrix} - \begin{bmatrix}\text{Energy of Gas}\\ \text{Leaving Bottle}\end{bmatrix}$$

Using the above equation the temperature of the gas is calculated. This temperature and the last bottle pressure value is used to interpolate on a compressibility factor curve. The gas temperature and mass remain constant while the pressure and compressibility factor are interated until the pressure on successive iterations is within DPTOL.

The heat transfer coefficient inside each oxygen bottle is input and is constant for a mission.

3.10 Heat Leak Calculation

The EMU simulator has the capability of calculating the heat flux between any two nodes. Data input format (see Section 5.7.6) permits the user to group pairs of nodes to create the desired control volume. Figure 3-16 presents a typical heat leak model to calculate the heat transferred across the boundary of a control volume. The input data would be set up with one group consisting of five heat leak paths. Semantically, the analysis per heat leak path is:

$$\begin{bmatrix}\text{Energy Entering}\\ \text{The}\\ \text{Control Volume}\end{bmatrix} = \begin{bmatrix}\text{Energy Conducted}\\ \text{To Node j}\\ \text{From Node K}\end{bmatrix} + \begin{bmatrix}\text{Energy Radiated}\\ \text{To Node j}\\ \text{From Node k}\end{bmatrix} - \begin{bmatrix}\text{Energy Stored}\\ \text{By Node j}\end{bmatrix}$$

Notice that the heat leak into the control volume (or from node k to node j) is assumed positive.

In the EMU simulator, heat leak groups for the Lunar Extravehicular Visor Assembly (LEVA), Pressure Garment Assembly (PGA), and several other components of interest are set up. There is no program limit on the number of groups or the number of heat leak paths (node pairings) per group. One restriction is made; and it requires the first group to be the LEVA heat leak group. This requirement arises because the LEVA visor material transmits solar wavelength energy through "node j". The energy entering the LEVA through the visors is automatically added to the first heat leak group. There are other unique features associated with the visor analysis as explained in Section 3.12.

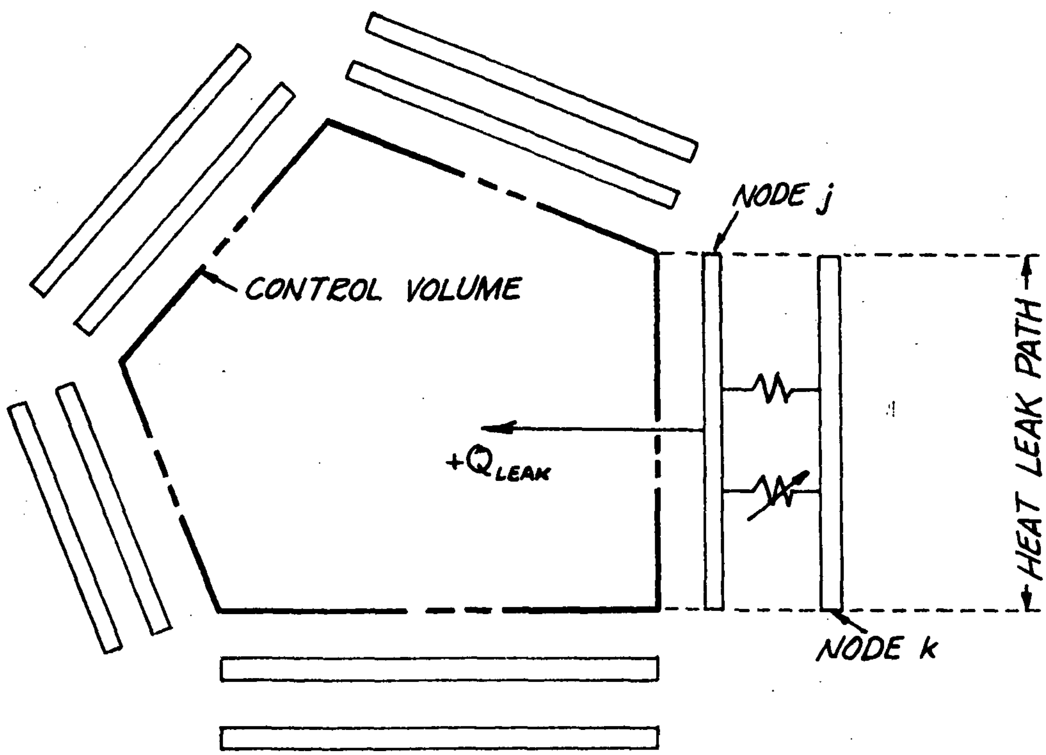


FIGURE 3-16 TYPICAL HEAT LEAK MODEL

To identify a heat leak path the user enters the two nodes (j and k) and a connection number for conduction and radiation between nodes j and k. The connection number is determined from node j lump card (tube or structure) by counting, from left to right, the "to" lumps to node k. It is necessary that the user know which node j to node k connection is the conduction connection and which is radiation to properly assign the connection numbers in the heat leak data. A check of the type data for node j will aid the user in establishing the kind of connection made to node j. Notice, when node j is connected to node k by conduction and radiation, node k will appear twice as a "to" lump on the node j lump card. Therefore, the connection numbers for a node pair in the heat leak data cannot be equal.

3.11 Heat Storage Calculation

The EMU simulator has the capability of calculating the energy stored by a node from initial condition (i.e., initial temperature on lump card) to some later time. Net heat stored by a node at time, τ, is calculated by the following equation

$$Q_{stored,j} = WC_{j,\ at\ \tau}\ (T_{j,\ at\ \tau} - T_{j,\ at\ \tau=\tau_i})$$

If the computer run is interrupted and restarted, the initial temperature used in the above equation is identical to the temperature input on the tube or structure lump card. The WC product is the current value including any adjustments prescribed by the Time-Variant Mass Data and/or the specific heat curve data. The user inputs the node number and the applicable identifying code (see Section 5.7.7) of the nodes for which heat storage calculations are desired. A single value of heat storage will be output when several nodes are grouped together. There is no program limit on the number of groups or the number of nodes per group that may be input.

3.12 LEVA Visor Analysis

The crewman's face is protected by two retractable visors and a pressure bubble. The retractable visors have special coatings which transmit radiation in the visible spectrum and block infrared radiation. A visor analysis is required to calculate the fraction of external incident energy absorbed by each visor and the crewman's face. The analysis is complicated by the fact that the visors may be positioned in three unique configurations (see Figure 3-17); both visors down, sun visor up, and both sun visor and impact visor up.

The fraction of incident energy absorbed by a visor surface can be determined from coating properties and has been done by A. J. Chapman as recorded in informal documentation received October 1966. Chapman numbers the surfaces 1 to seven with one being the crewman's face and seven, the outer surface of the sun visor (Figure 3-17). This same convention is followed below as well as Chapman's notation of the energy fraction. $F_i^{(k)}$ refers to the fraction of the external incident radiation on the ith surface for the kth visor configuration. To shorten the equations we define R_{ij} as the fraction, $1/(1-\rho_i\rho_j)$, where ρ is the solar reflectivity and i and j are visor surfaces.

Each node on the visor and helmet surfaces is assigned a position number; one to the total number of nodes on the visor and helmet surfaces. In addition to a position number, the user inputs a position type (see Section 5.7.8) to associate the correct surface properties with the visor, helmet, and face nodes. The visor analysis is a two band spectral distribution analysis with the separation point between solar and infrared radiation established by the flux data input from the Environmental Heat Flux Routine (Reference 12).

With both visors retracted - n = 1

$$F_1^{(1)} = \tau_{23}\, R_{12};\ F_2^{(1)} = \rho_1\, F_1^{(1)}\ ;\ \ F_3^{(1)} = 1.$$

Transmissivity, τ_{23}, is the solar transmissivity of the pressure bubble and, in Chapman's development of the $F_i^{(n)}$, the assumption was made that $\tau_{ij} = \tau_{ji}$.

With the impact visor down and sun visor up - n = 2

$$F_1^{(2)} = F_1^{(1)}\ F_3^{(2)}$$

$$F_2^{(2)} = F_2^{(1)}\ F_3^{(2)}$$

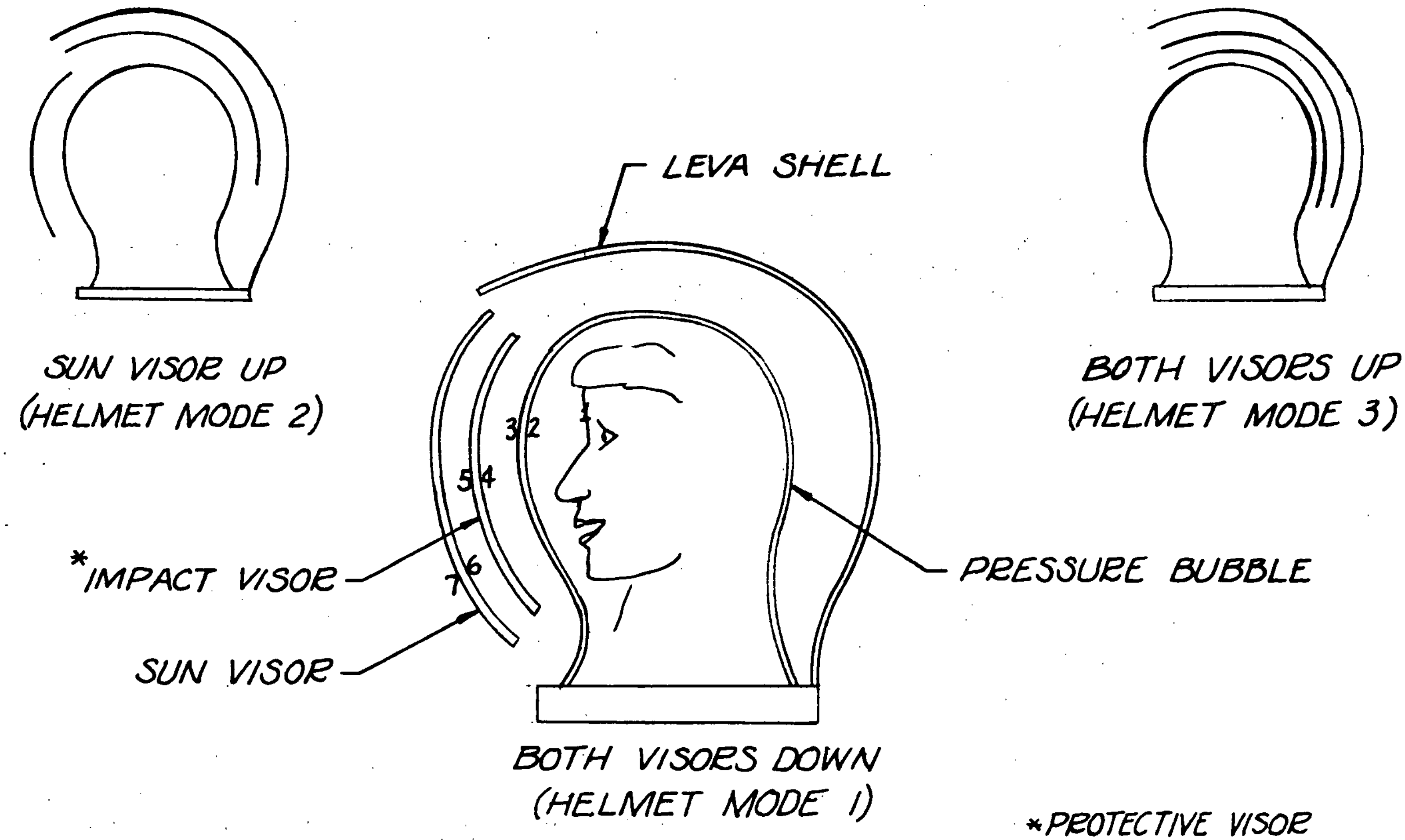


FIGURE 3-17 LUNAR EXTRAVEHICULAR VISOR ASSEMBLY (LEVA)

$$F_3^{(2)} = \frac{\tau_{45} \quad R_{34}}{1-\rho_4\tau_{23}R_{34}F_2^{(1)}}$$

$$F_4^{(2)} = \rho_3 \, \tau_{45} \, R_{34} \; + \; \tau_{23} \, R_{34} \, F_2^{(1)} \, F_3^{(2)}$$

$$F_5^{(2)} = 1.$$

With sun visor down - n = 3

$$F_1^{(3)} = F_1^{(2)} \, F_5^{(3)}$$

$$F_2^{(3)} = F_2^{(2)} \, F_5^{(3)}$$

$$F_3^{(3)} = F_3^{(2)} \, F_5^{(3)}$$

$$F_4^{(3)} = F_4^{(2)} \, F_5^{(3)}$$

$$F_5^{(3)} = \frac{\tau_{67} \quad R_{56}}{1-\rho_6\tau_{45}R_{56}F_4^{(2)}}$$

$$F_6^{(3)} = \rho_5 \, \tau_{67} \, R_{56} \; + \; \tau_{45} \, R_{56} \, F_4^{(2)} \, F_5^{(3)}$$

$$F_7^{(3)} = 1.$$

3.13 Local Temperature Perturbation (LTP) Calculation

The simulator has the capability of calculating the effect of a perturbed suit condition on the crewman. By perturbed suit condition is meant the local compression of the suit against the crewman due to sitting, kneeling, gripping with the gloves, etc. The purpose of the capability is to determine crewman comfort (skin temperature below threshhold of pain) when engaged in any activity which involves "shorting" the suit multilayer insulation. Section 5.7.5 details the input data for local temperature perturbation calculations. It is important to remember when preparing data for the LTP model that this model is completely independent of the basic EMU model and has no feedback to it. Notice should be made that LTP model lump numbers are described in the regular data and that Section 5.7.5 provides additional information which identifies certain lump numbers as LTP lump numbers. All LTP model fluid (gas) lumps must be input in tube 43 which satisfies the data input requirement for a flow tube but the order of fluid lumps in tube 43 is arbitrary.

3.14 Thermal Model Data Options

The simulator has several unique data options which are required to describe the thermal model or provide the user flexibility desired.

3.14.1 Suit, Gloves, and EV Boots Node Identification

This option is required to simulate the suit donning and doffing procedures by the crewman in the Lunar Module (LM). Table 3-1 defines the EMU configuration modes the user may select to include in the mission analysis. Each category of nodes is identified either directly or by the process of elimination. The pressure bubble nodes are identified through Helmet and Visor Data and with the suit, gloves and boots identified all other nodes are considered to be in the remaining category of Portable Life Support System (PLSS), Oxygen Purge System (OPS) and Remote Control Unit (RCU). All node connections are made in the baseline thermal model necessary to analyze EMU Configuration Mode 1. When other modes are specified the simulator stops analyzing components designated as "off" and no temperature update of nodes identified with "off" components occurs until a mode is again selected in which those components are designated as "on".

3.14.2 Configuration-Associated Node Identification

This option is similar to the one discussed above but requires more input data to establish the same configuration. The user may view this option as an override of the configurations specified by Table 3-1. As an example of how this option may be used, consider Mode 8 which specifies analysis of the crewman in his shirtsleeves only. To obtain the effect of an enclosure such as the LM cabin walls on a shirtsleeves crewman, structure nodes representing the wall can be input in the regular data and then associated with Configuration Mode 8.

3.14.3 Heat Flux Curve Assignment

The simulator uses the Environmental Heat Flux Routine (EHFR) described in Reference 12 as a source of input flux data representing various lunar surface topology. The EHFR has geometric heat flux models of the EMU and the Lunar Roving Vehicle (LRV) which are consistent with the surface areas

TABLE 3-1 EMU CONFIGURATION MODES

MODES	PLSS OPS & RCU	ITMG SUIT	GLOVES	EV BOOTS	PRESSURE BUBBLE	TYPE ACTIVITY	NOTES
± 1	ON	ON	ON	ON	ON	EV	LEVA ON + PGA FLOW DIV. VLV.,HOR.(IV) - PGA FLOW DIV. VLV.,VERT.(EV)
± 2	ON	ON	ON	ON	ON	IV	LEVA MAY BE ON OR OFF + OR - INDICATES PGA FLOW SPLIT
± 3	ON	ON	OFF	ON	ON	IV	+ OR - INDICATES PGA FLOW SPLIT, PGA AND EV GLOVES REMOVED TOGETHER
4	ON	ON	OFF	ON	OFF	IV	ON ARS* AND -192 PACKAGE **
5	OFF	ON	OFF	ON	OFF	IV	ON ARS AND -192 PACKAGE
6	OFF	ON	OFF	OFF	OFF	IV	ON ARS AND -192 PACKAGE
± 7	OFF	ON	ON	OFF	ON	IV	
8	OFF	OFF	OFF	OFF	OFF	IV	PGA OFF - SHIRTSLEEVES

* Atmospheric Revitalization System (LM)
** LCG Water Cooling Component (LM)

of the simulator baseline thermal model. Section 5.7.1, Cards 4 and 5 give instructions on the manipulation of the EHFR generated flux data actually creating heat flux curves. Although the curves have been created and are available, heat flux curve assignment data is required to apply the flux to a particular thermal model node. The EHFR outputs a contact temperature which represents the lunar surface temperature and this temperature is prescribed to a baseline thermal model node which is in contact with the extravehicular boot soles. All EHFR input data is assigned through the data described in Section 5.7.11.

3.14.4 Prescribed Wall Temperature Data

The simulator has two types of prescribed wall temperatures excluding the contact temperature discussed in Section 3.14.3. These prescribed temperatures are designated as type numbers 10 and 11 in Sections 5.7.12 and 5.7.16. Type 10 is used to create a "deep space" node held constant at -459.69°F or other prescribed temperatures where the entire curve can be put on the data tape. Type 11 is used to input LRV prescribed temperatures either the complete curve or segments of a large curve contained on an independent input tape. Variable NPRTCD on Card 2 (Section 5.7.1) designates how the LRV temperatures will be input. The simulator will interrogate NPRTCD and, if 1, will read additional LRV temperature data when the largest time of the segment of the curve in the computer is less than mission time.

3.14.5 Time Variant Node Data

Time variant data allows the user to vary with time the mass of a node and/or the connection between two nodes. This data is a multiplying factor applied after variations in specific heat and thermal conductivity have been taken into account. The time variant mass data is straight forward with the user identifying the node and the controlling curve number. If a connection between two nodes is to be varied, the user must identify the "from" node and specify a connection number. The connection number for a node varies from 1 to the number of "to" nodes listed in the tube and structure lump cards for the node. This option applies to both conduction and radiation connections for tube and structure nodes.

3.14.6 Special Tube/Fluid Connection Data

This option is required to transiently analyze the Liquid Cooled Garment (LCG) and may not be used as a general capability for placing two fluids in contact with a single tube node. A fluid node can be enclosed by several tube nodes by inputting that fluid node on Card 34, however occasions arise when two fluids wet a single tube node. In the model of the LCG, water flows in the tygon tubing and suit oxygen flows over the outside of the tygon tubing. If the tubing nodes were modeled as two radial nodes connected by a large conduction, experience has taught that the situation would result in instability. Data input for this option identifies a second fluid and film heat transfer coefficient with a LCG tube node.

4.0 BASELINE THERMAL MODEL

A baseline thermal model was created in conjunction with the EMU simulator and contains the following items:

1. ITMG - Integrated Thermal/Meteoroid Garment (A7LB)
2. PGA - Pressure Garment Assembly
3. LCG - Liquid Cooling Garment
4. Boots - Lunar EVA Configuration
5. Gloves - Extravehicular Configuration
6. LEVA - Lunar Extravehicular Visor Assembly
7. PLSS - Portable Life Support System (-7)
8. OPS - Oxygen Purge System
9. RCU - Remote Control Unit (-4)
10. CREWMAN - 41 Node Man (Ref. 10)
11. LRV - Lunar Roving Vehicle
12. BSLSS - Buddy Secondary Life Support System

The model is composed of the three types of nodes described in Section 3.1. The number of flow tubes in the simulator is 43 for NBSY = 0 and 45 for NBSY = 1 or 2 as input in column 72 on Card 2 of Section 5.7.1. The simulator is programmed to expect the number of tubes indicated above and program modifications are required to change the tube arrangement. Although the user is limited in the extent to which he can change the basic thermal model, important options are open as to the fineness of the model breakdown and the amount and type of data output.

The ITMG, PGA, Boots, and Gloves were broken up into 96 surface nodes and 5 nodes through the thickness. Figure 4-1 and 4-2 show the surface nodes as numbered in the baseline thermal model and a typical cross-section of the suit. Table 4-1 presents the complete suit node numbering with the "EXTERIOR ITMG NODE" column corresponding to the nodes on Figure 4-1. The multilayer insulation has the same fineness of nodal breakdown as the exterior suit surface, but the three interior node layers have fewer nodes as indicated by the brackets in Table 4-1 connecting two or more insulation nodes to an "INTERIOR ITMG NODE". Figure 4-1 presents a surface area lumping of a more detailed geometric suit model found in Reference 12. Conductance values for the

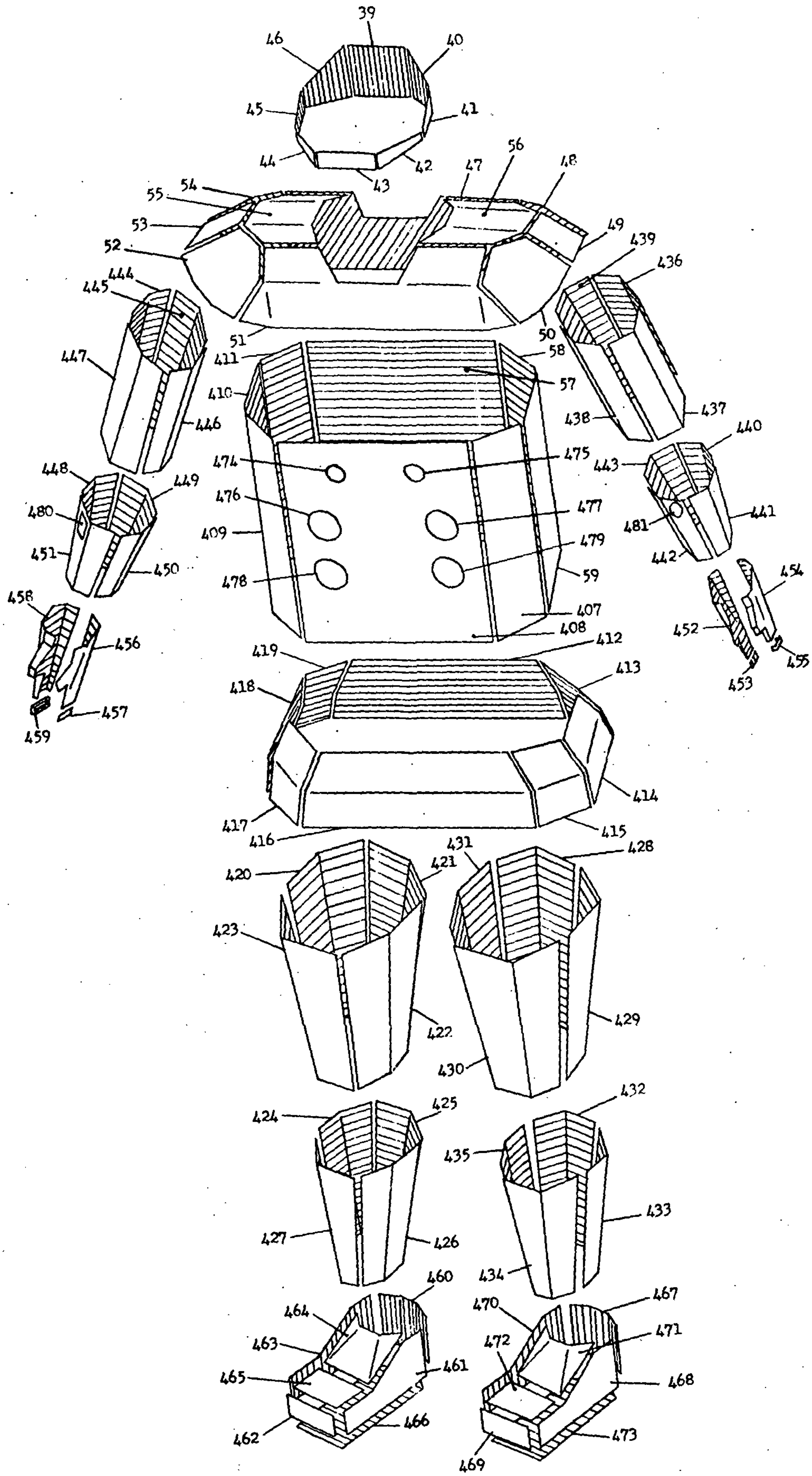


FIGURE 4-1 SUIT, BOOTS, AND GLOVES BASELINE THERMAL MODEL

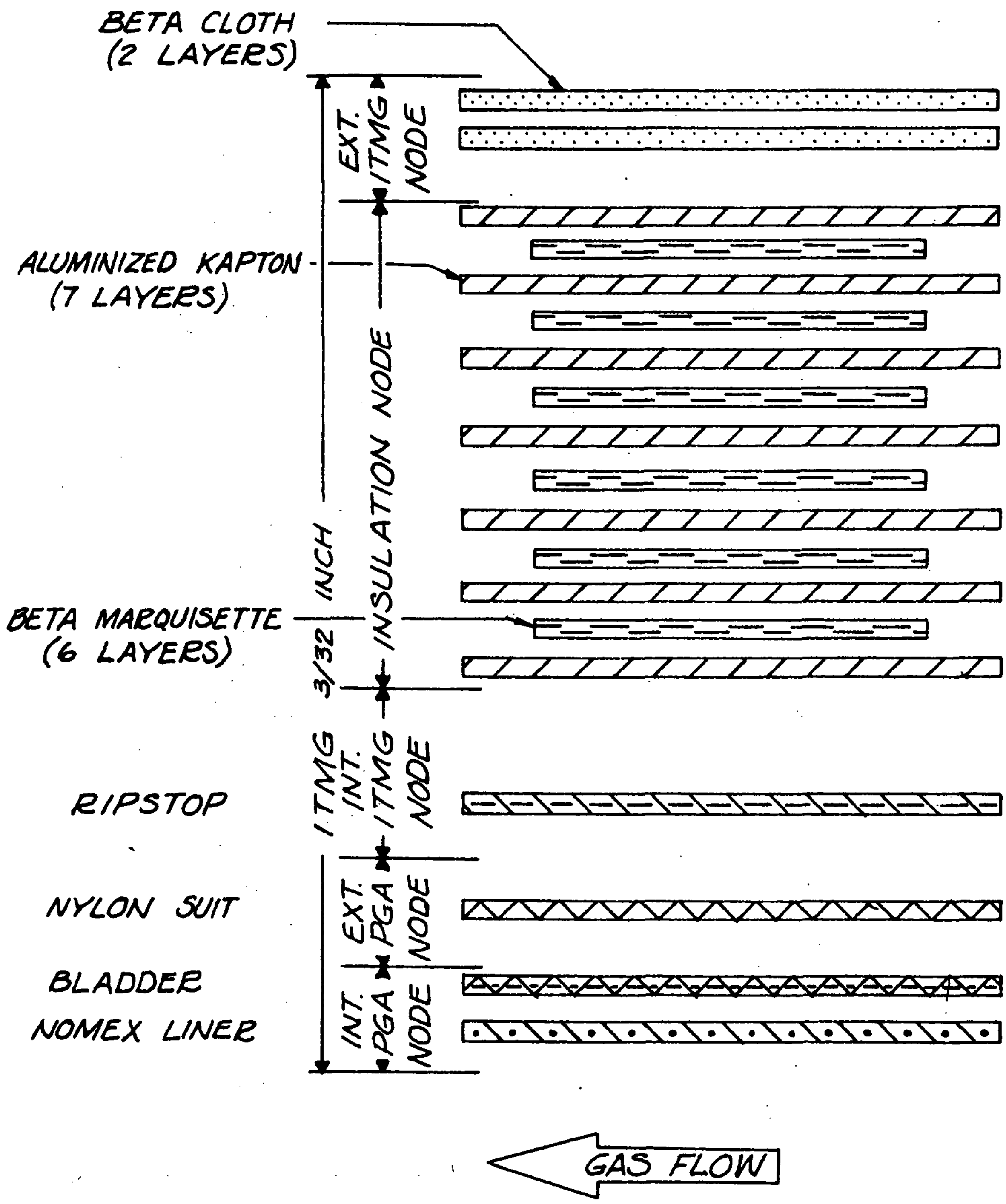


FIGURE 4-2 TYPICAL SUIT CROSS-SECTION

TABLE 4-1

NODAL NUMBERING THROUGH SPACE SUIT

EXTERIOR ITGM NODE	INSULATION NODE	INTERIOR ITMG NODE	EXPERIOR PGA NODE	INTERIOR PGA NODE
39 40 41	60 61 62	81	217	62
42 43 44 45	62 63 64 65 66	82	218	63
46	66 67	81	217	62
47 48	68 69	83	219	64
59	69 70	89	225	70
50	70 71	91	227	72
51 52	71 72 73	84	220	65
53	73 74	92	228	73
54	74 75	90	226	71
55 56	75 76 77	83	219	64
	76 77	84	220	65
57 58 59	78 79 80	86	222	67
407 408 409 410	80 482 483 484 485	85	221	66
411	485 486	86	222	67
412 413 414	487 488 489	88	224	69
415 416 417 418	489 490 491 492 493	87	223	68
	493	88	224	69

TABLE 4-1(CONTINUED)

EXTERIOR ITMG NODE	INSULATION NODE	INTERIOR ITMG NODE	EXTERIOR PGA NODE	INTERIOR PGA NODE
419	494	88	224	69
420	495	549	561	169
421	496			
422	497	100	236	167
423	498			
424	499	553	565	173
425	500			
426	501	551	563	171
427	502			
428	503	550	562	170
429	504			
430	505	101	237	168
431	506			
432	507	554	566	174
433	508			
434	509	552	564	172
435	510			
436	511	89	225	70
437	512	91	227	72
438	513			
439	514	89	225	70
440	515	94	230	75
441	516	96	232	77
442	517			
443	518	94	230	75
444	519	90	226	71
445	520			
446	521	92	228	73
447	522			
448	523	93	229	74
449	524			
450	525	95	231	76
451	526			
452	527	99	235	81
453	528			
454	529	98	234	80
455	530			
456	531	97	233	79
457	532			
458	533	624	625	78
459	534			
460	535	557	569	177
461	536			
462	537			
463	538	555	567	175
464	539			
465	540			
466	541	559	571	179
467	542	558	570	178

TABLE 4-1(CONTINUED)

EXTERIOR ITMG NODE	INSULATION NODE	INTERIOR ITMG NODE	EXTERIOR PGA NODE	INTERIOR PGA NODE
468	543			
469	544			
470	545	556	568	176
471	546			
472	547			
473	548	560	572	180
BIB DATA, IF BIB IS WORN			474	181
			475	182
			476	183
			477	184
			478	185
			479	186
480	573	574	575	187
481	576	577	578	188

multilayer buildup were generated by the Lockheed Electronics Corporation under the direction of the Crew Systems Division - Manned Spacecraft Center and edited into the baseline thermal model data tape. These conductances were based on data obtained from manned and unmanned suit tests conducted by NASA at the Manned Spacecraft Center.

The LCG is modeled with 13 nodes as depicted in Figure 3-14. Nine of the 13 nodes are in contact with the trunk due to the fact that the distribution points of the flow system are located about the waist. This nodal arrangement attempts to model the torso heating of the water before and after it flows over the extremities. The total conductance between the LCG water and the skin over the entire skin area of contact is 43.5 BTU/hr-°F. Individual skin node conductances are obtained as a ratio of the individual skin areas to the total contact area and proportioning the total conductance according to the various ratios.

The LEVA thermal model consists of the sun visor, protective visor, pressure bubble, and LEVA shell as presented in Figures 4-3 through 4-7. Tables 4-2 and 4-3 are to be used in conjunction with Figures 4-3 and 4-4 respectively in interpreting the thermal model data. The simulator allows the user to specify visor configuration changes throughout the mission. The three helmet modes illustrated in Figure 3-17 require connections between nodes peculiar to an individual helmet mode, therefore for the sun visor (SV) and protective visor (PV) there is a set of nodes for each helmet mode. When the helmet is in MODE 1, only the nodes corresponding to this mode for the SV and the PV are analyzed; however the other nodes are updated each iteration. A change to a different helmet mode changes the set of nodes being analyzed and the initial temperatures for the new modes are the last temperatures calculated for MODE 1 because of the continuous iteration update. A similar discussion applies when the helmet mode is begun in MODE 2 or MODE 3.

The LEVA shell is divided into two layers thus the node numbering in Figures 4-5 and 4-6. The exterior layer of the LEVA shell thermal model is the beta cloth cover while the interior layer includes the multilayer insulation and the polycarbonate inner shell. There is a single set of nodes for the LEVA shell layers. The surface area nodal breakdown is a modified version of that found in Reference 13. Nodes near the side of the helmet were increased

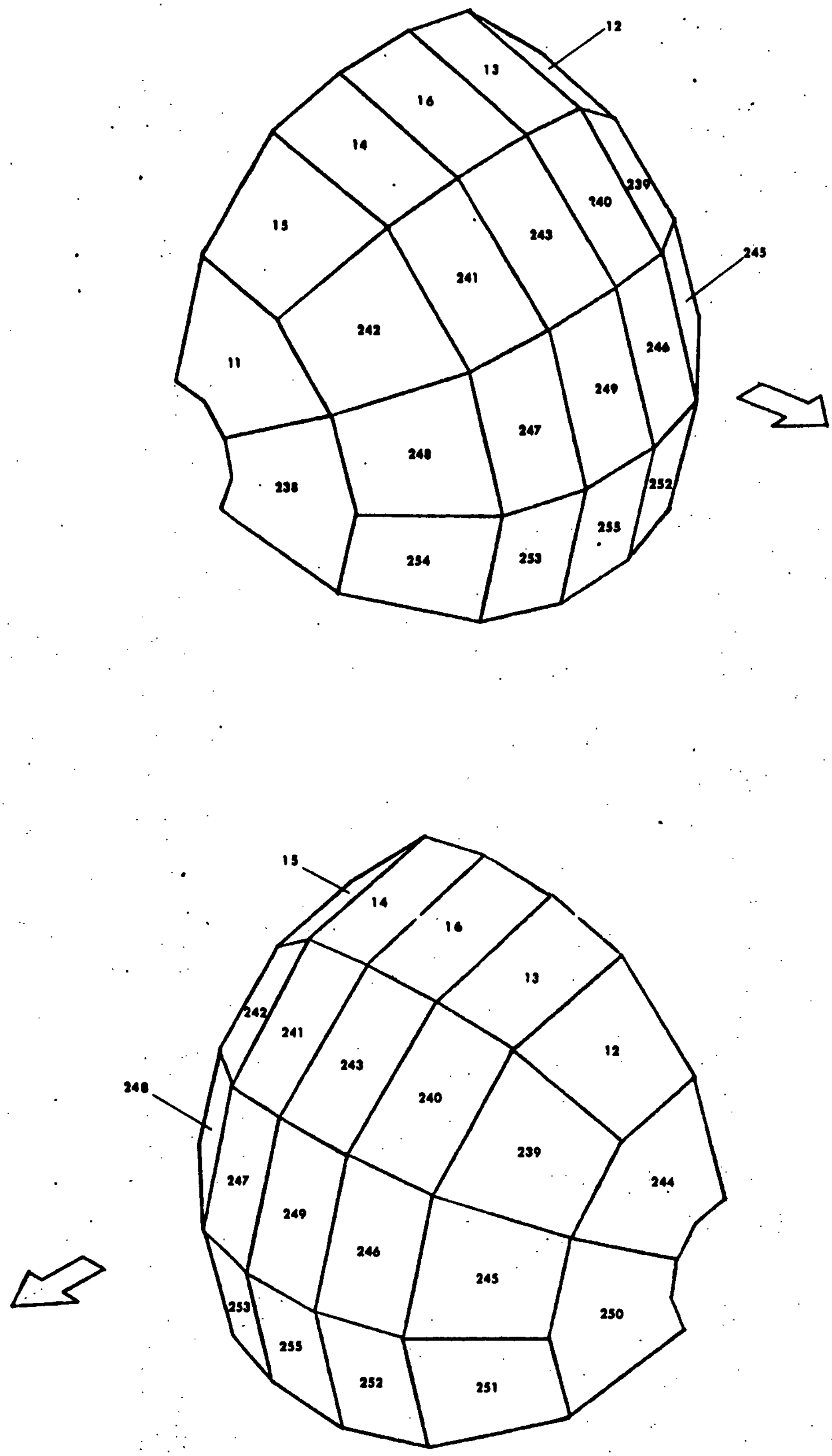


FIGURE 4-3 SUN VISOR THERMAL MODEL

TABLE 4-2

SUN VISOR NODE CORRESPONDENCE FOR HELMET MODES

MODE 1 (SUN VISOR DOWN)	MODE 2 (SUN VISOR ONLY UP)	MODE 3 (BOTH VISORS UP)
11	181	193
12	182	194
133	183	195
14	184	196
15	185	197
16	186	198
238	256	274
239	257	275
240	258	276
241	259	277
242	260	278
243	261	279
244	262	280
245	263	281
246	264	282
247	265	283
248	266	284
249	267	285
250	268	286
251	269	287
252	270	288
253	271	289
254	272	290
255	273	291

All nodes are structure nodes.

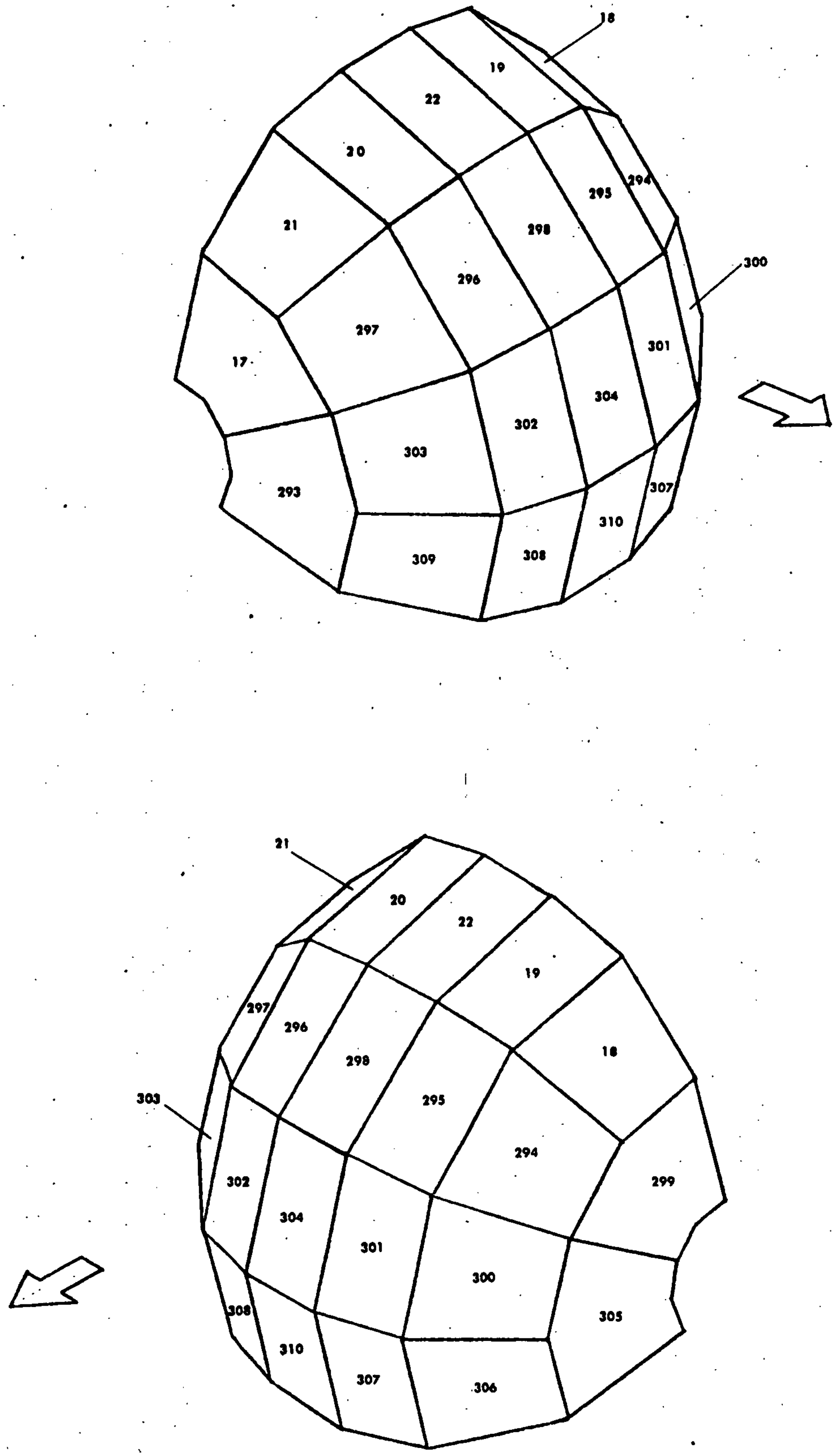


FIGURE 4-4 PROTECTIVE VISOR THERMAL MODEL

TABLE 4-3

PROTECTIVE VISOR NODE CORRESPONDENCE FOR HELMET MODES

MODE 1 (SUN VISOR DOWN)	MODE 2 (SUN VISOR ONLY UP)	MODE 3 (BOTH VISORS UP)
17	187	199
18	188	200
19	189	201
20	190	202
21	191	203
22	192	204
293	311	329
294	312	330
295	313	331
296	314	332
297	315	333
298	316	334
299	317	335
300	318	336
301	319	337
302	320	338
303	321	339
304	322	340
305	323	341
306	324	342
307	325	343
308	326	344
309	327	345
310	328	346

All nodes are structure nodes.

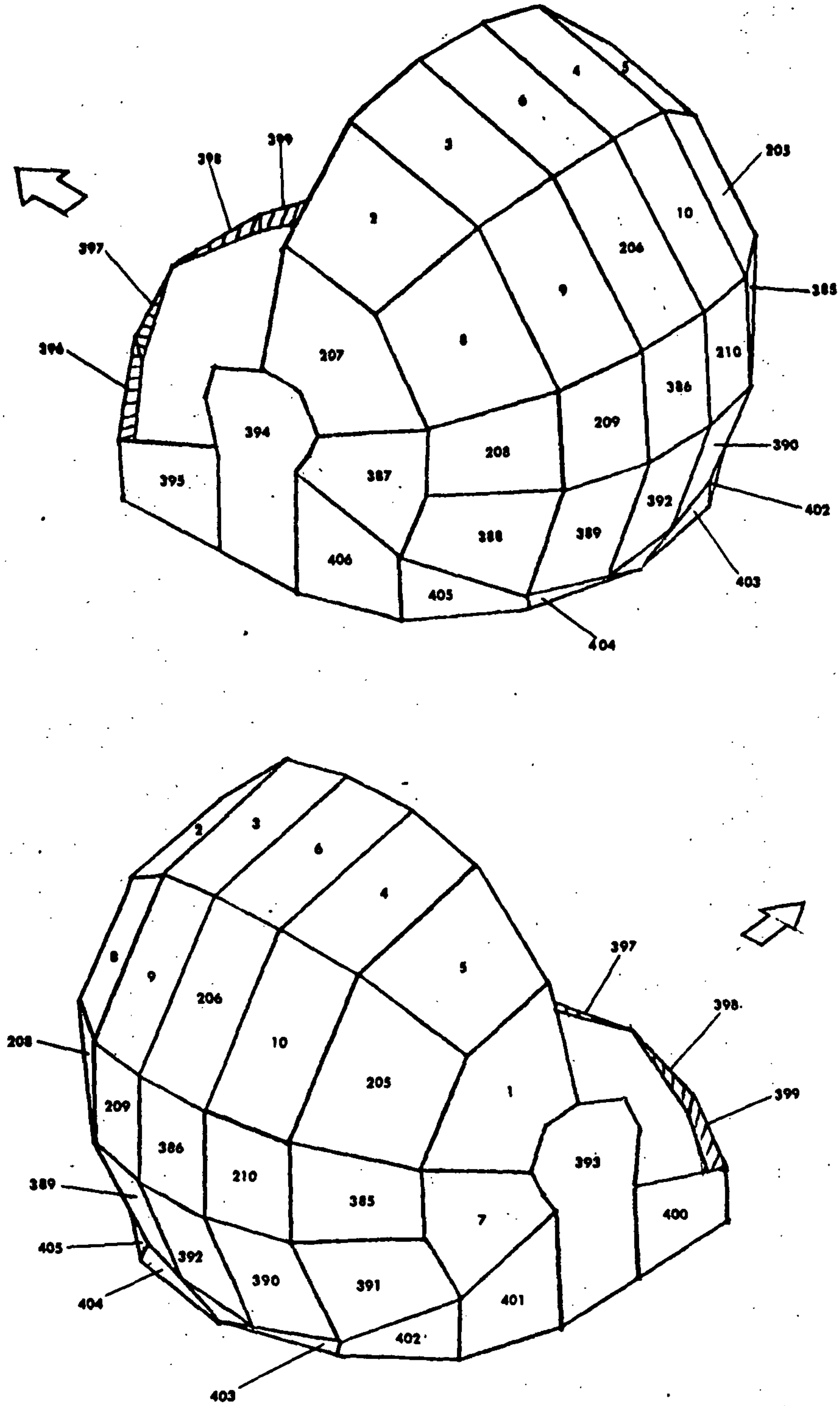


FIGURE 4-5 LEVA EXTERIOR THERMAL MODEL

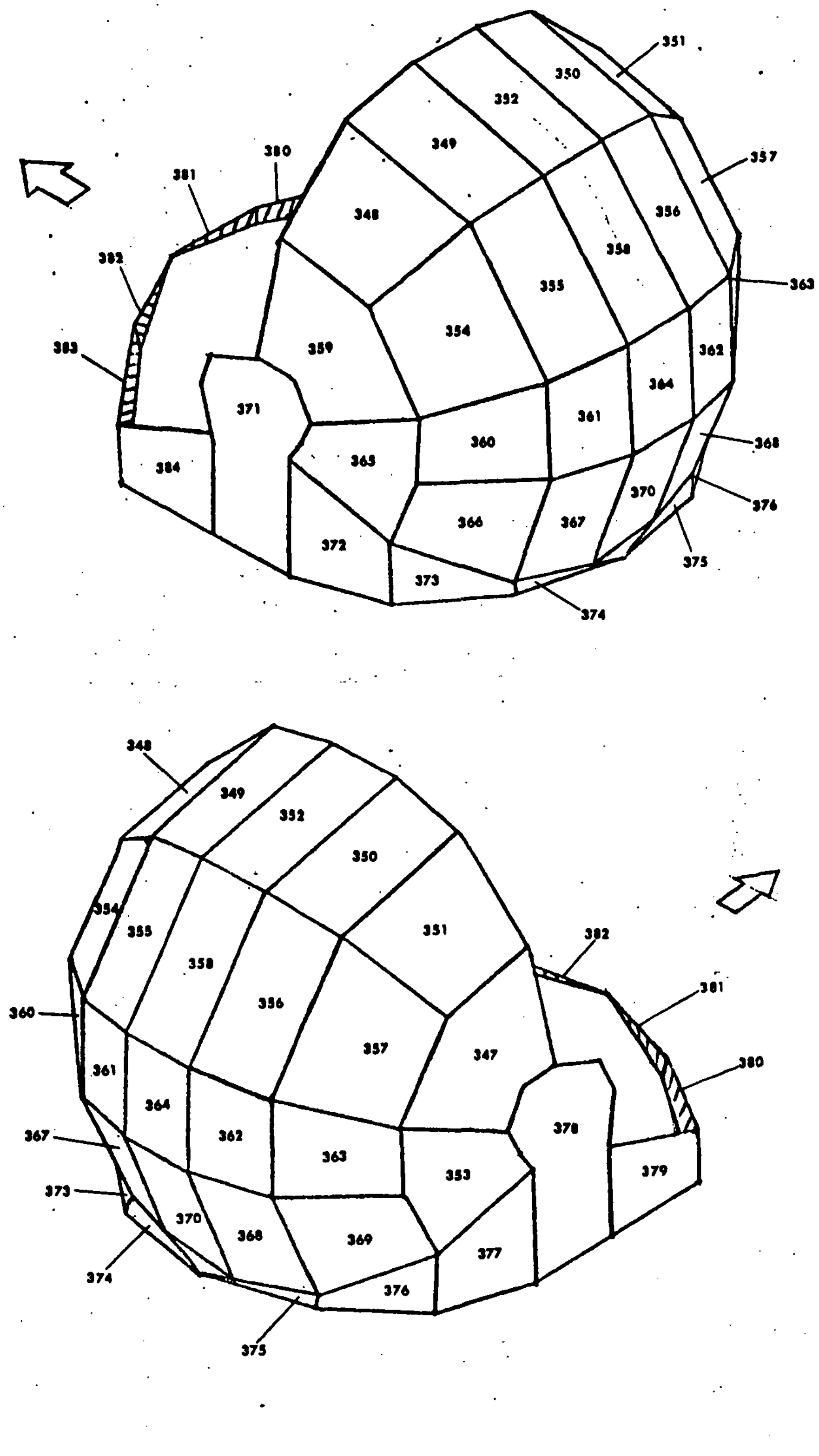


FIGURE 4-6 LEVA INTERIOR THERMAL MODEL

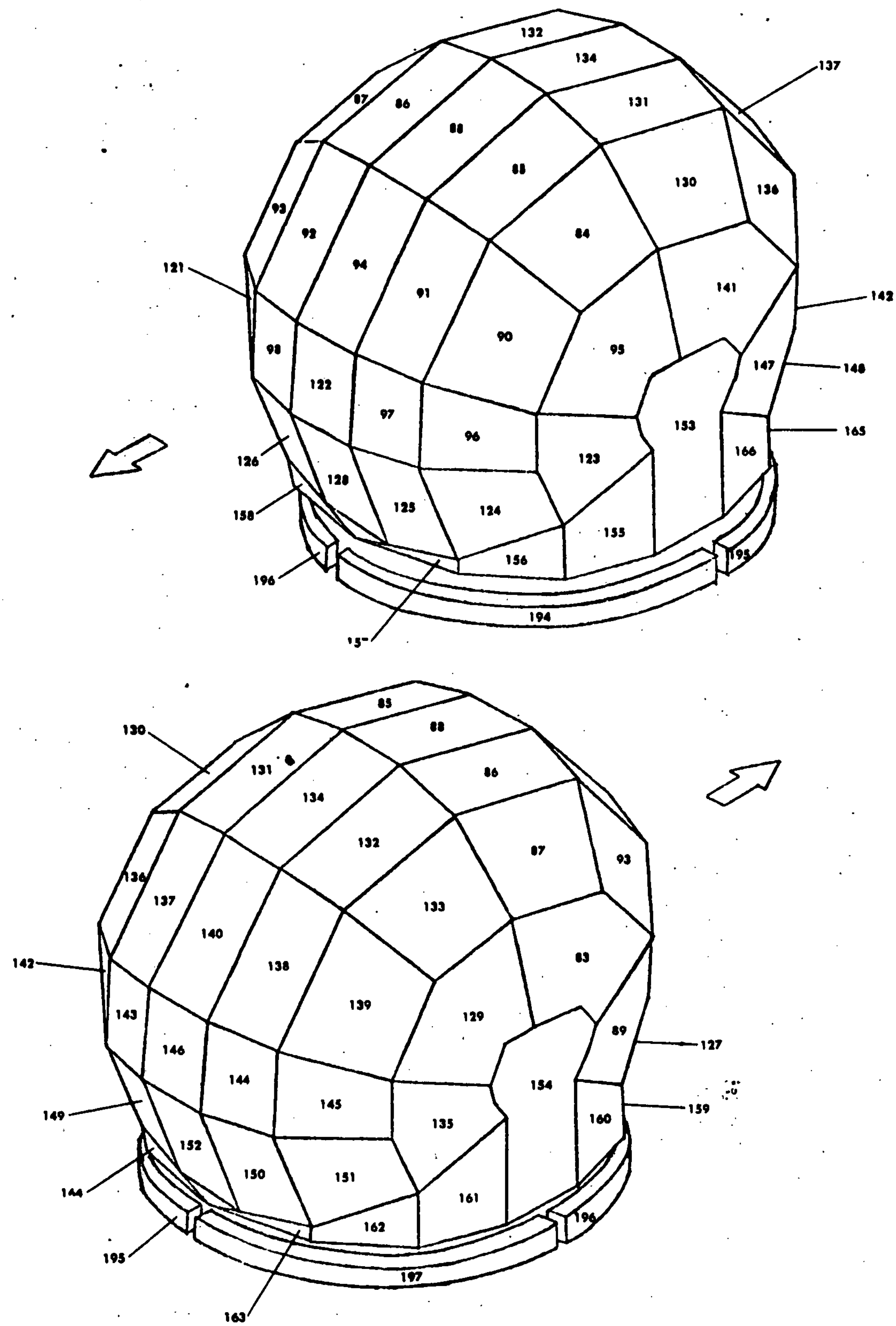


FIGURE 4-7 PRESSURE BUBBLE HELMET THERMAL MODEL

in area and an additional row of node areas were created along the vertical centerline maintaining a constant number of nodes.

The pressure bubble is modeled as tube nodes because the inside of the bubble is in contact with the suit oxygen flow. A single set of nodes is used for all three visor configurations and the nodes are analyzed continuously as are the LEVA shell nodes. Two types of connections from the pressure bubble tube nodes must be made a function of the helmet mode. The first is the pressure bubble connection to space when both visors are up and the second is the connection to the interior layer of the LEVA shell when both visors are down. Since both the pressure bubble, the space node, and the LEVA nodes are analyzed continuously, some method of making and breaking the connections described above is required. The simulator has such a capability called Time Variant Connections (Section 3.14.5) and it is used to coordinate pressure bubble connections with the visor connections which are determined by the set of visor nodes analyzed. No intermediate positions of the visors are allowed; a visor is either all the way up or all the way down. The LEVA has three sun shades which may be varied by the crewman through an infinite number of positions. These sun shades are not modeled in the baseline thermal model.

The PLSS, OPS, and RCU were modeled using the information from Reference 13 and the manufacturer's hardware drawings. The flow systems were broken up into fluid and tube nodes as shown in Figures 3-2, 3-3, and 3-4. As a general rule, the system piping was broken at rubber splice joints and components. The fluid type data for the components was input so the regular pressure drop calculation would yield a zero delta P. Figures 4-8, 4-9, and 4-10 show the break-up of the PLSS, OPS and RCU structure. Note the seven layers of multilayer insulation are modeled as two nodes through the thickness for the PLSS and OPS thermal covers. Multilayer insulation conductances used in the baseline thermal model were obtained from correlations of unmanned space suit test conducted at NASA and LTV Aerospace.

Five umbilicals attach to the space suit and are modeled in the EMU simulator. Each umbilical is four-sided along the full length in regard to the calculation of heat flux. Table 4-4 and Figure 4-11 describe the umbilicals as modeled in the baseline thermal model. Note that each umbilical has three

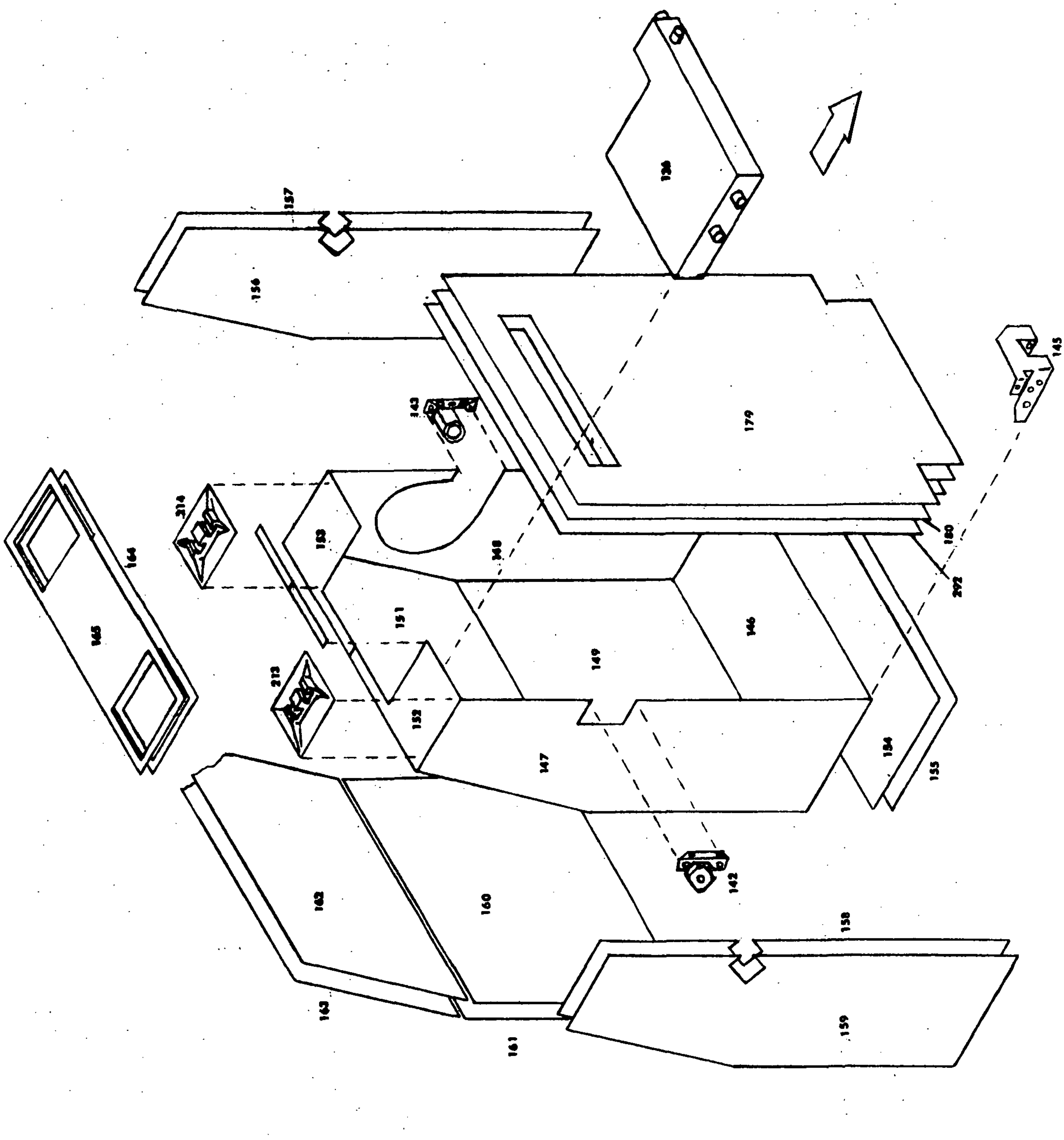


FIGURE 4-8 PLSS HARDCOVER NODAL BREAKDOWN

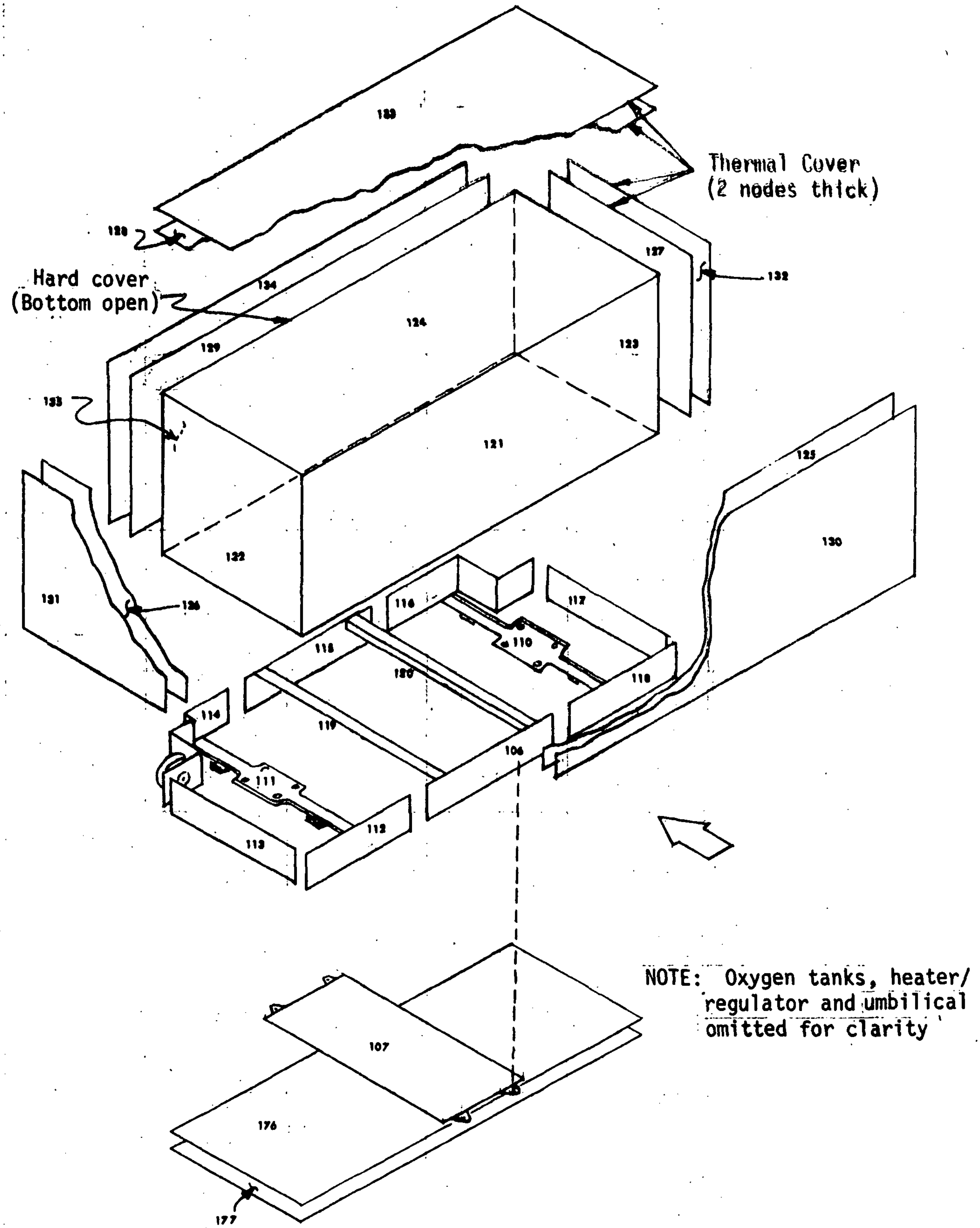


FIGURE 4-9 OPS HARDCOVER NODAL BREAKDOWN

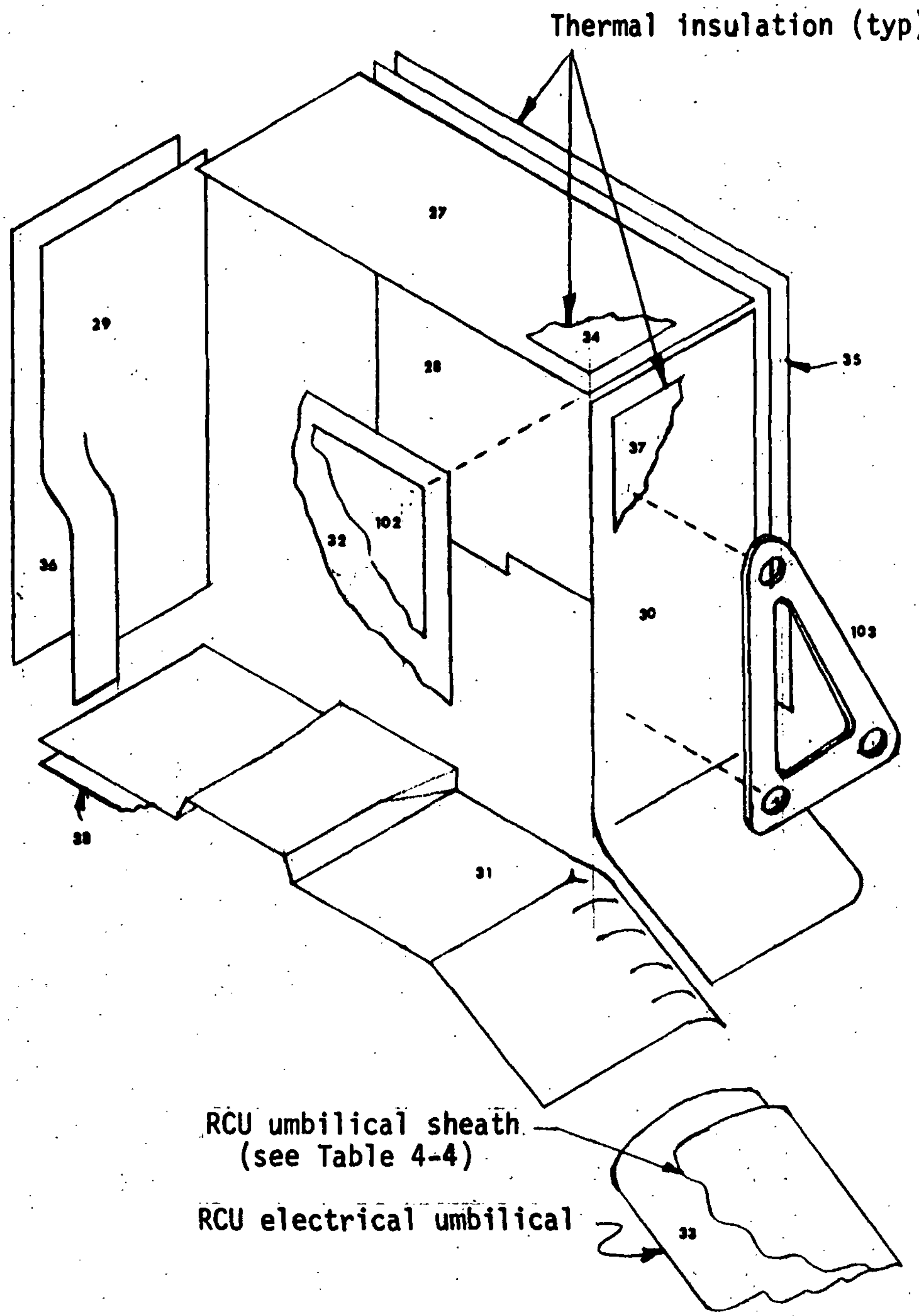


FIGURE 4-10 RCU SHELL NODAL BREAKDOWN

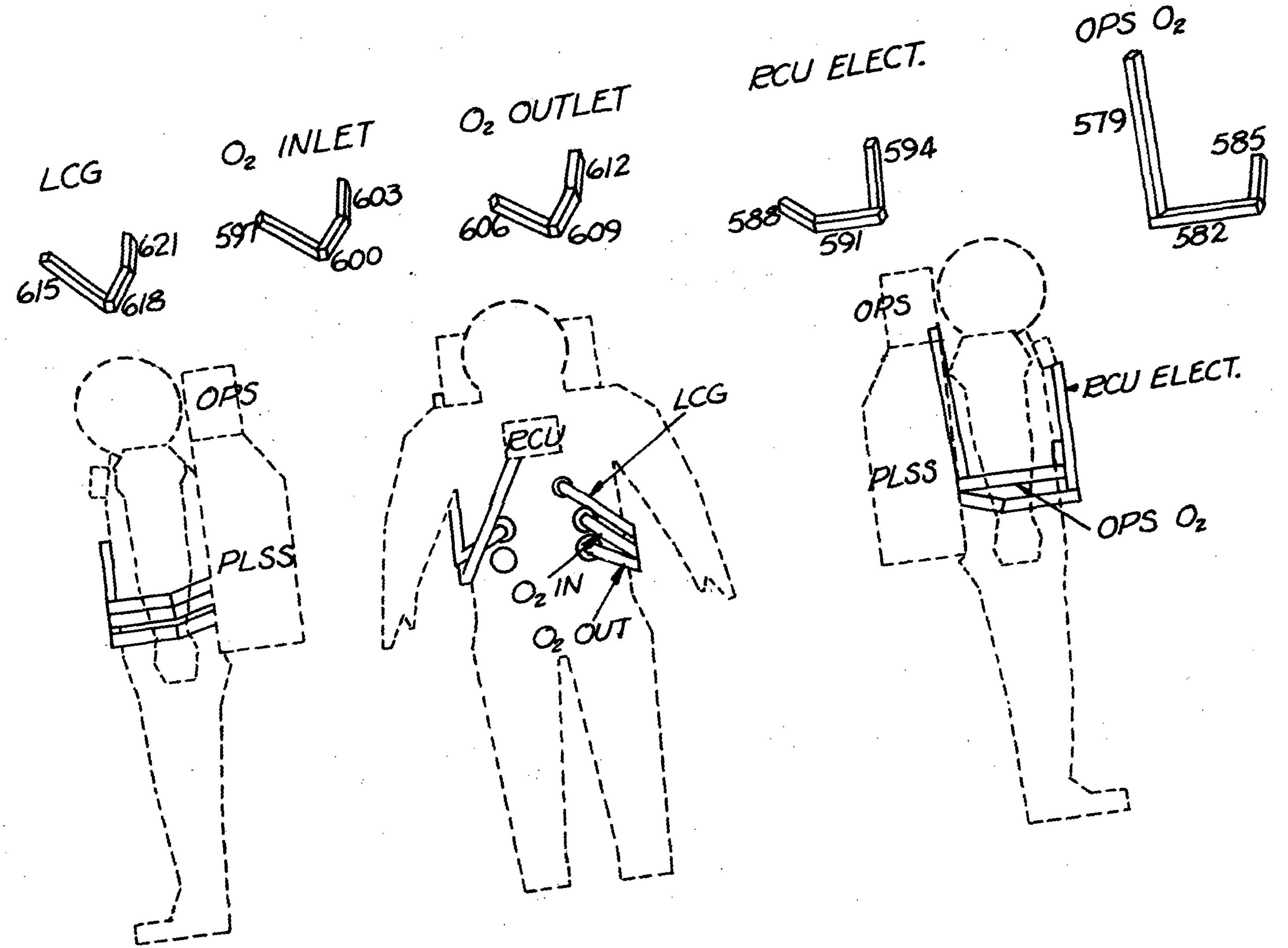


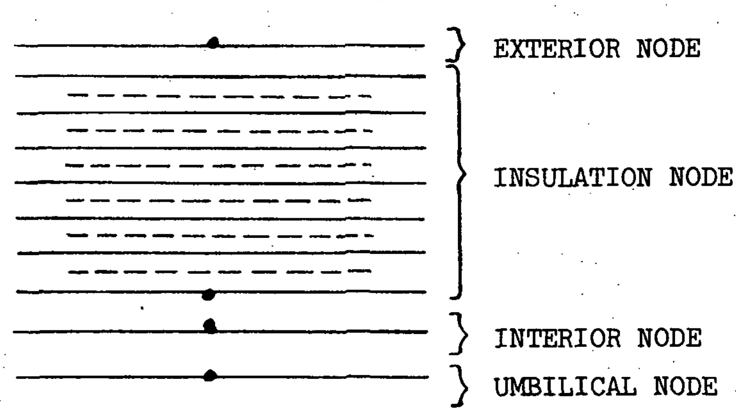
FIGURE 4-11 EMU UMBILICAL THERMAL MODEL

TABLE 4-4

UMBILICAL NODE CORRESPONDENCE

EXTERIOR NODE	INSULATION NODE	INTERIOR NODE	UMBILICAL NODE
579	580	581	59T
582	583	584	
585	586	587	
588	589	590	33S
591	592	593	
594	595	596	
597	598	599	6T
600	601	602	
603	604	605	
606	607	608	14T
609	610	611	
612	613	614	
615	616	617	53T, 55T*
618	619	620	
621	622	623	

* INLET AND OUTLET LCG TUBES FORM LCG UMBILICAL



surface nodes and two insulation nodes beneath the exterior node.

With the advent of longer and more adventurous EVA's, the BLSS was added to the EMU equipment as an emergency/rescue item. If a crewman experienced a PLSS failure, he can activate his OPS and use the BLSS umbilical to connect to his "buddy's" PLSS effecting the rescue. The water-charged BSLSS umbilical is stored in an insulated bag and carried on the back of a crewman's PLSS on walking EVA's. On EVAs using the LRV the BSLSS bag is strapped to the back of the right-hand seat of the LRV. There are two sets of nodes for the umbilical sheath (insulation cover) exterior. The "stowed" set of exterior nodes (Table 4-5) have connections to the umbilical bag and each other as shown in Figure 4-12. When the umbilical is deployed, the deployed set of nodes have temperatures corresponding to the last temperatures calculated for stowed nodes. Connections to the deployed nodes, which are zero until the deployed umbilical is to be simulated, are determined by the time variant connection data. Appendix A provides additional descriptive information on the fluid, tube, and structure nodes discussed in this section.

The LRV is modeled with 59 structure nodes as shown in Figures 4-13 through 4-18. All LRV nodes are prescribed temperature nodes and are not analyzed transiently. The purpose of the LRV in the EMU simulation is to simulate the heat flux environment on the crewman as affected by the LRV emitting, reflecting and blocking energy. The Boeing Company, under direction of the NASA - Structure and Mechanics Division developed a computer program to perform a thermal analysis of the LRV throughout the EVA and output temperatures on magnetic tape. Temperatures corresponding to the models shown in Figures 4-13 through 4-18 were used to create the LRV prescribed temperature curves.

TABLE 4-5

BSLSS UMBILICAL NODAL CORRESPONDENCE

SHEATH EXTERIOR NODE (STOWED)	SHEATH EXTERIOR NODE (DEPLOYED)	SHEATH INTERIOR NODE	UMBILICAL NODE (SUPPLY)	(RETURN)
638	668	653	198	213
639	669	654	199	214
640	670	655	200	215
641	671	656	201	216
642	672	657	202	217
643	673	658	203	218
644	674	659	204	219
645	675	660	205	220
646	676	661	206	221
647	677	662	207	222
648	678	663	208	223
649	679	664	209	224
650	680	665	210	225
651	681	666	211	226
652	682	667	212	227

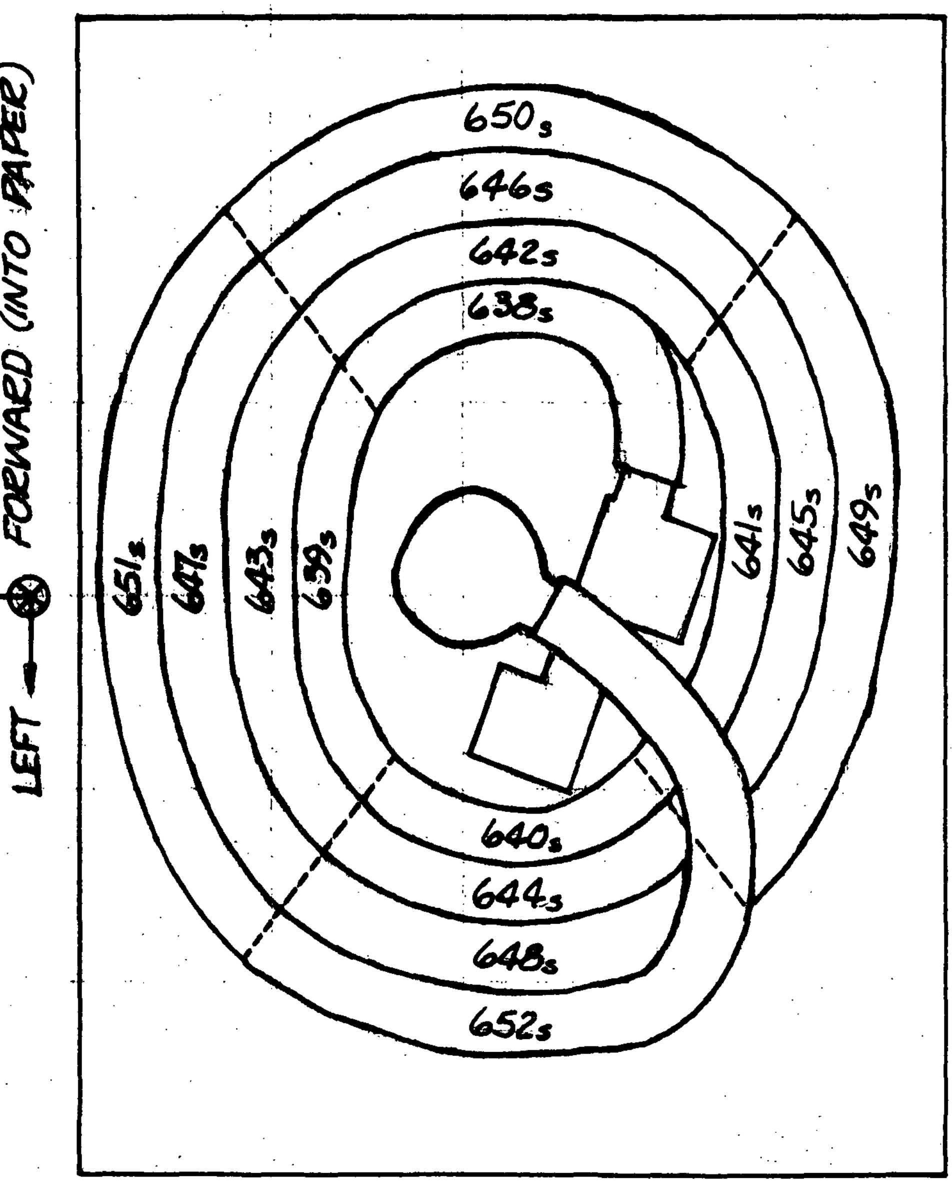


FIGURE 4-12 BSLSS UMBILICAL THERMAL MODEL

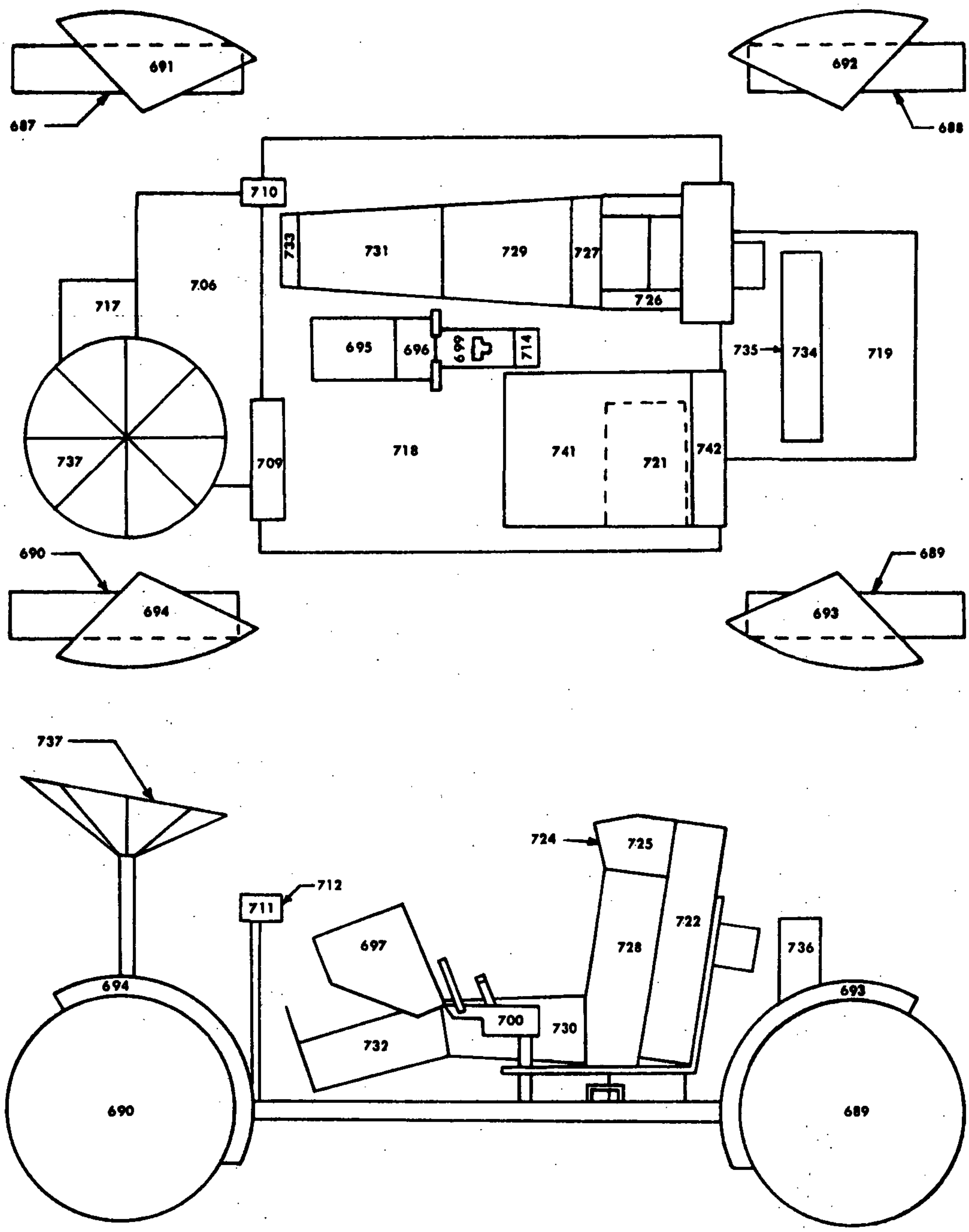


FIGURE 4-13 LRV THERMAL MODEL

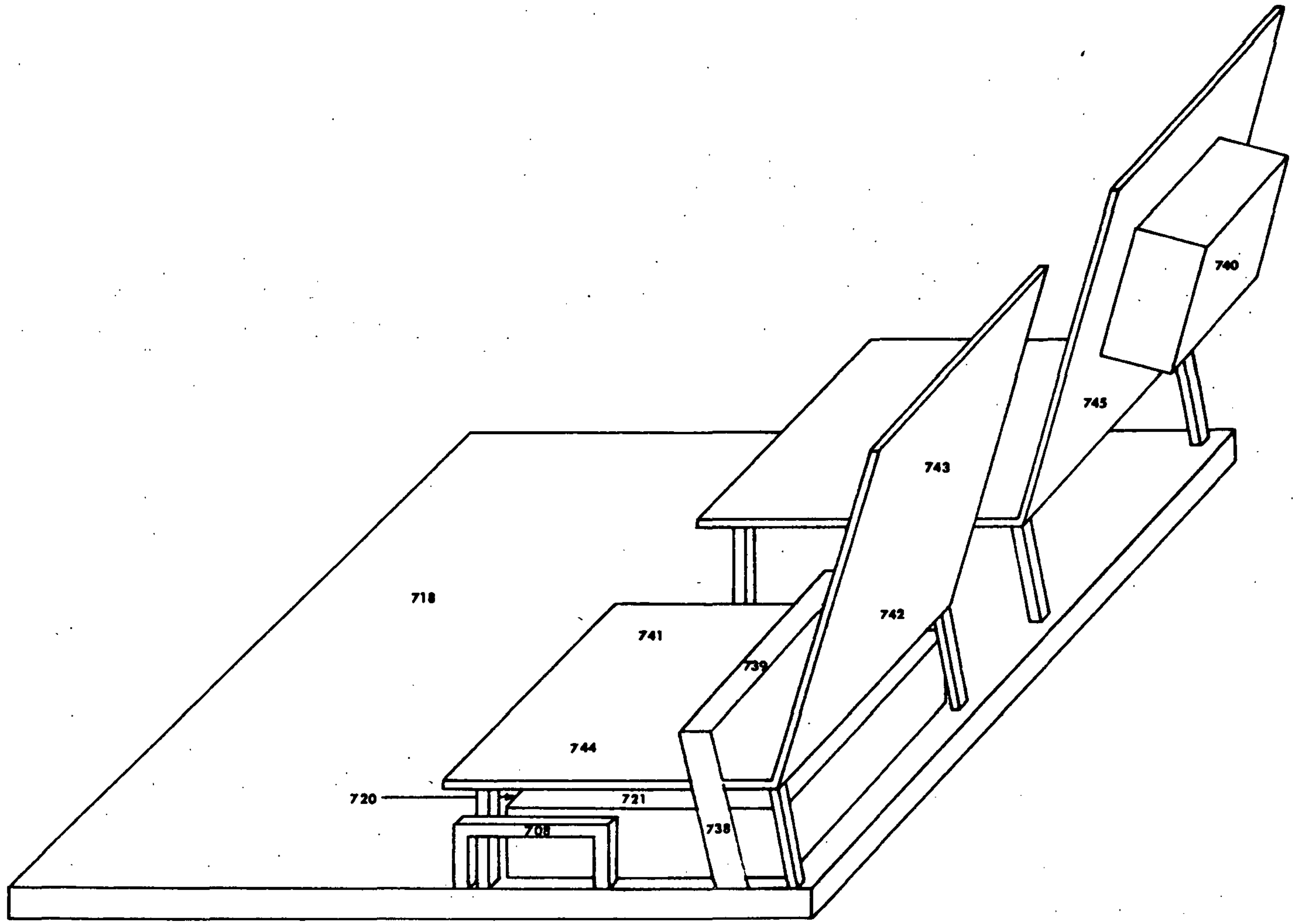


FIGURE 4-14 LRV CENTER MODULE THERMAL MODEL

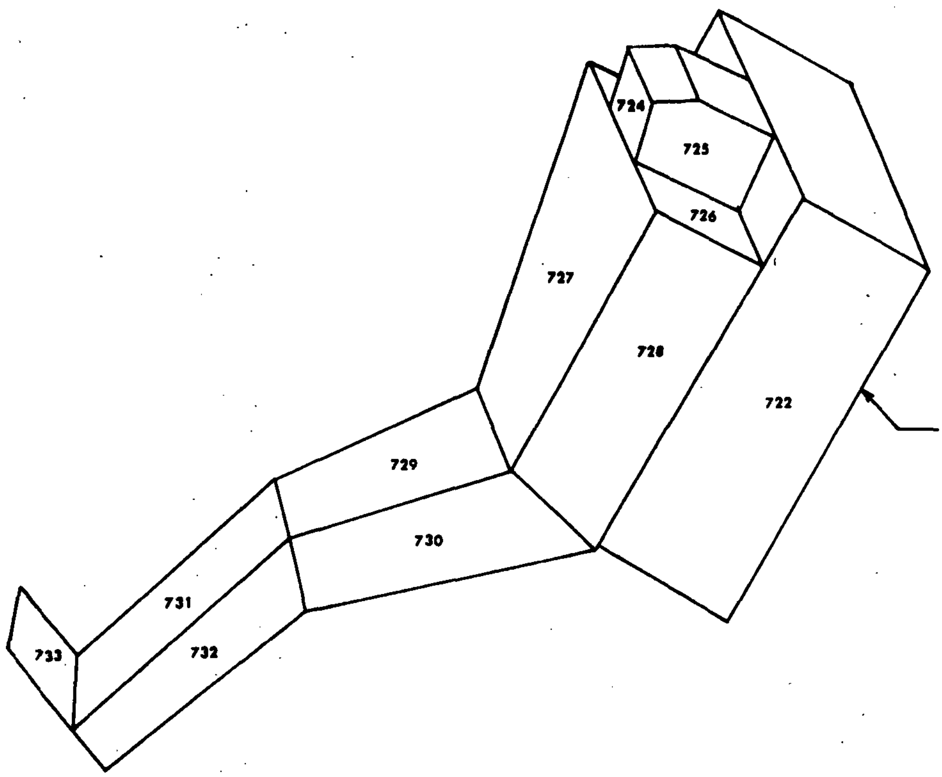


FIGURE 4-15 LRV SECOND CREWMAN THERMAL MODEL

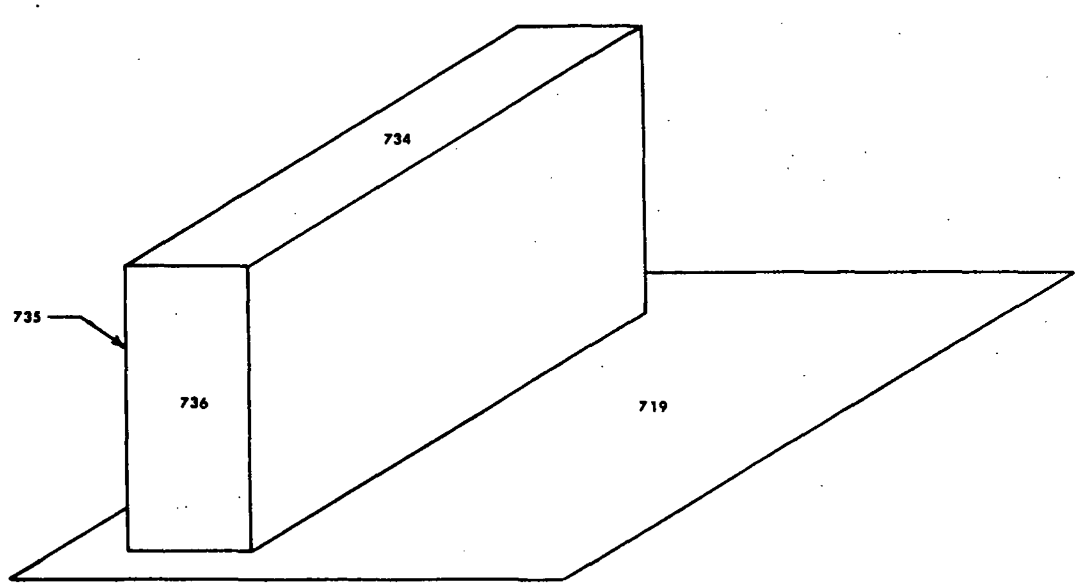


FIGURE 4-16 LRV AFT STORAGE BAY THERMAL MODEL

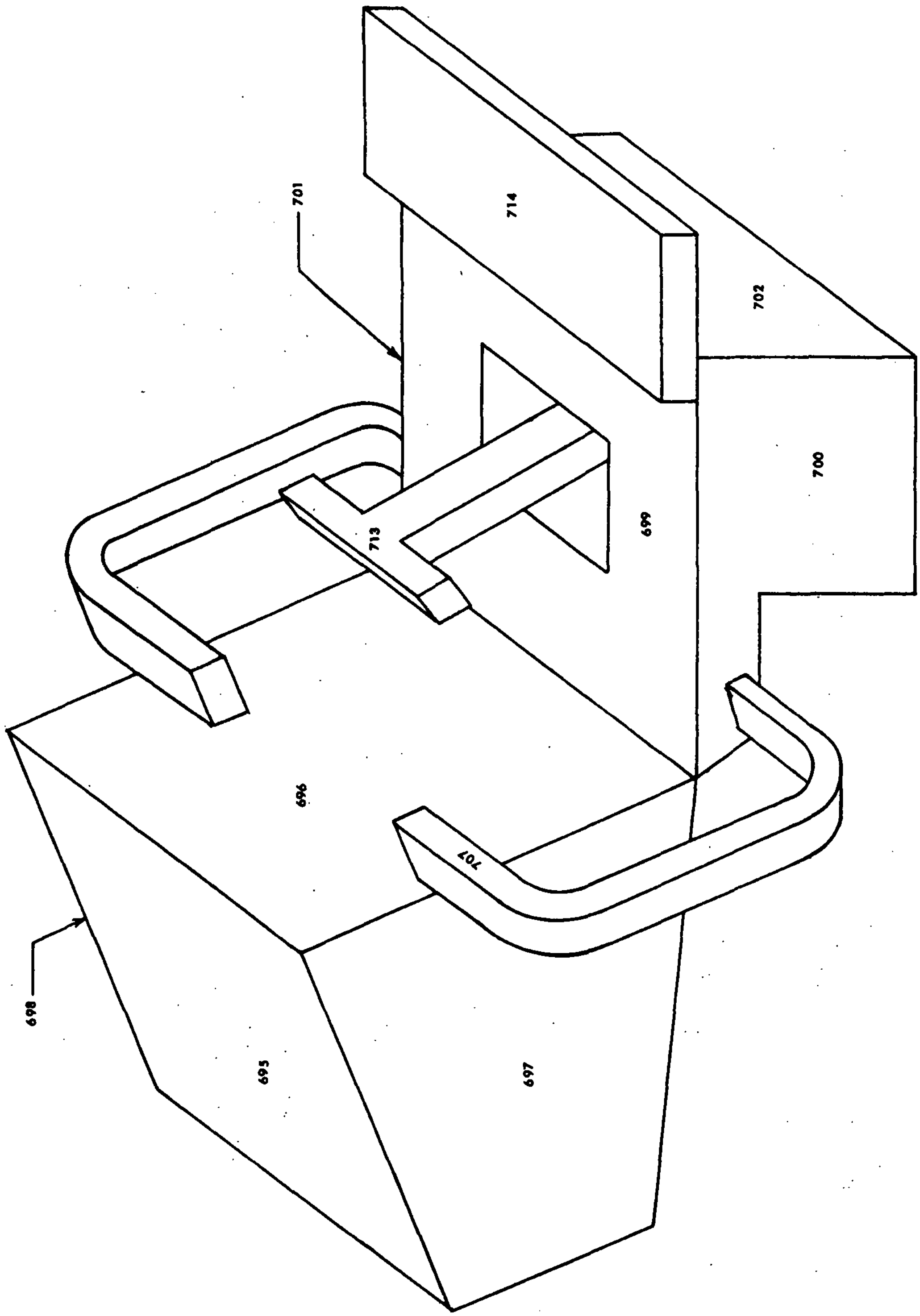


FIGURE 4-17 LRV CONTROL CONSOLE THERMAL MODEL

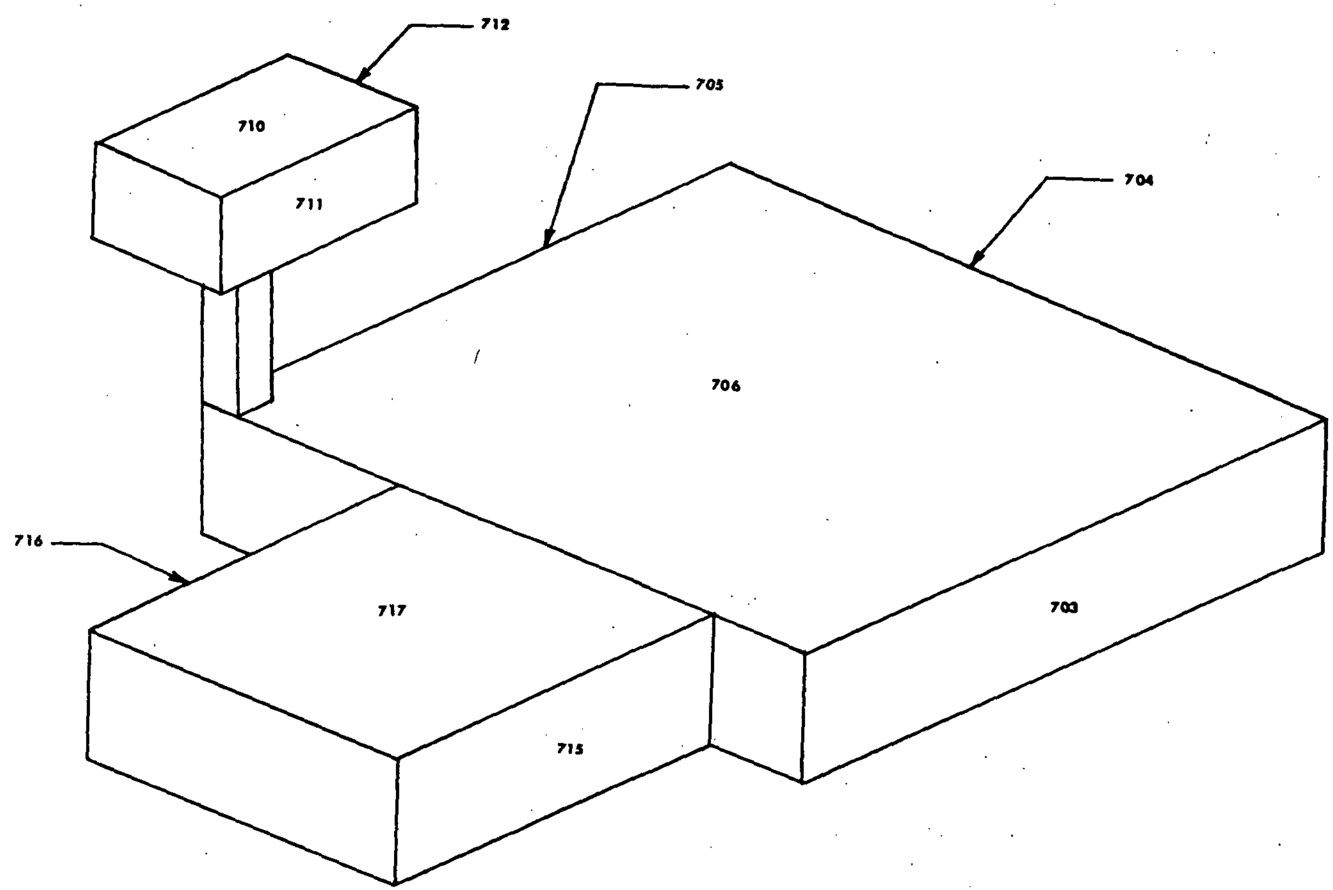


FIGURE 4-18 LRV FORWARD ELECTRONICS BAY THERMAL MODEL

5.0 USER'S MANUAL

5.1 Program Description

This computer routine was written in Fortran V for the UNIVAC 1108 computer which has a core storage capacity of 65,536 words (with 53,248 words of memory available to the user) and a maximum of eight magnetic tape drives accessible. These tape units are used to maximum advantage for eliminating handling of large volumes of data cards and for providing the user with a flexibility to make data changes, interrupt the program for inspection of results and/or continuation of the analysis at a later time. There are options permitting the use of thirteen separate tape units, however, some of the options are mutually exclusive, so that no more than eight units are required at any given time.

A flow schematic of the routine is given in Figure 5-1. The program makes use of the overlay feature of Fortran V to provide for a large data block by minimizing the amount of core storage required for the program during data execution. This is accomplished by having subroutines SUB1, SUB2, SUB3, SUB4, SUB5, SUB6, and SUB7 share the same core storage location.

The first six main subroutines (SUB1 through SUB6) read, process and store data in a packed data block, and the seventh subroutine (SUB7) performs the analysis. The operations performed by each subroutine are outlined briefly in the following paragraphs.

<u>MAIN</u> calls the seven main subroutines (SUB1 through SUB7)

<u>SUB1</u>

1. Calls subroutine SUBX to read the first two data cards and stores all of the first for a heading to be printed at the top of every page of output; stores the parameters of the second card.

2. Tests the restart code. If it is zero, the data processing will be continued by SUB1 as described in the following paragraphs. If it is one or two, this indicates that all data is from the dump of a previous problem. In the case where the restart code is one, SUB1 reads data from Unit J; when the restart code is two, data is read from Unit J for the man with an active PLSS and from Unit K for the man with a failed PLSS to continue a mission with the BSLSS employed. In both cases where the restart

FIGURE 5-1 EMU PROGRAM SCHEMATIC

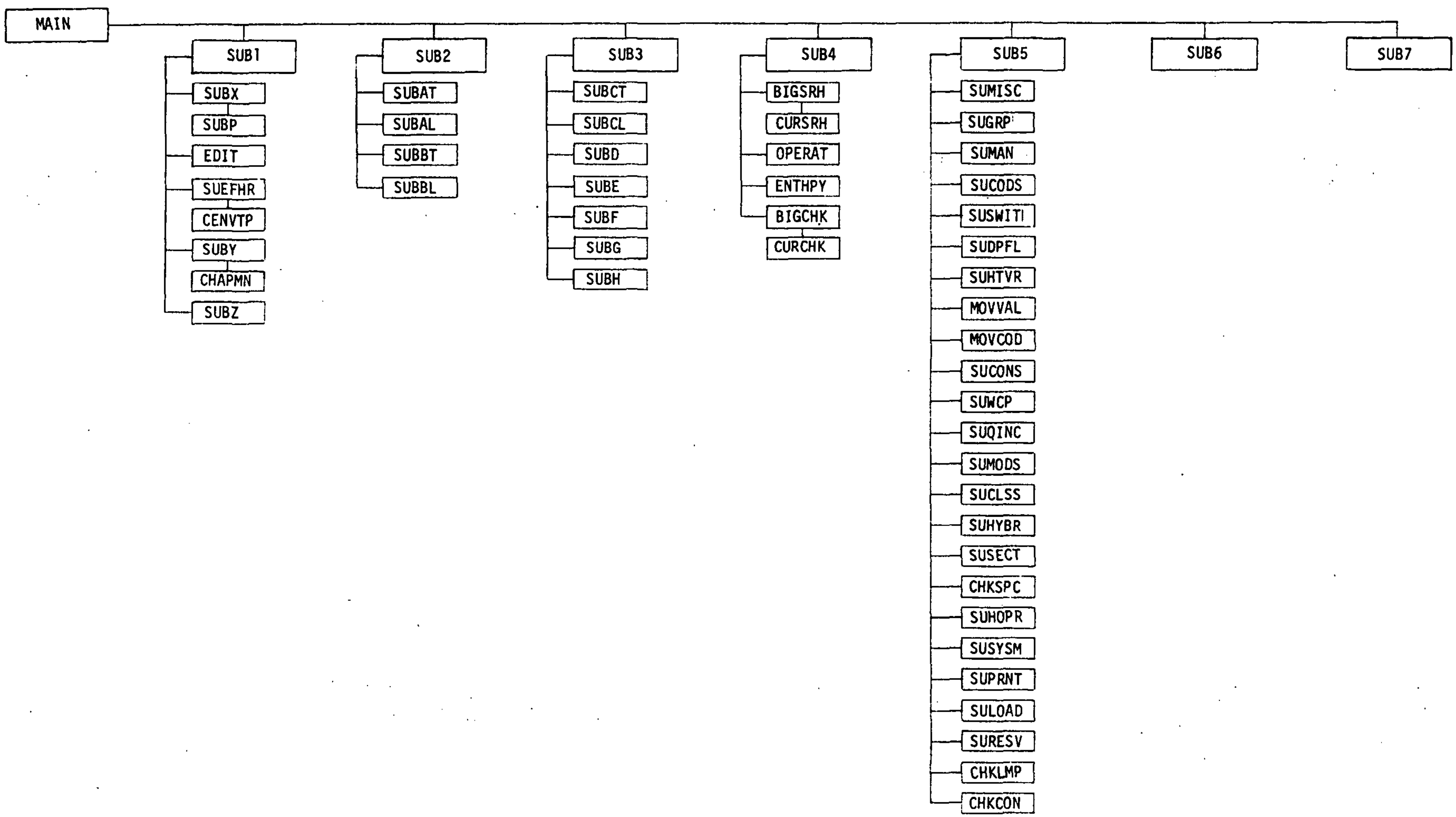
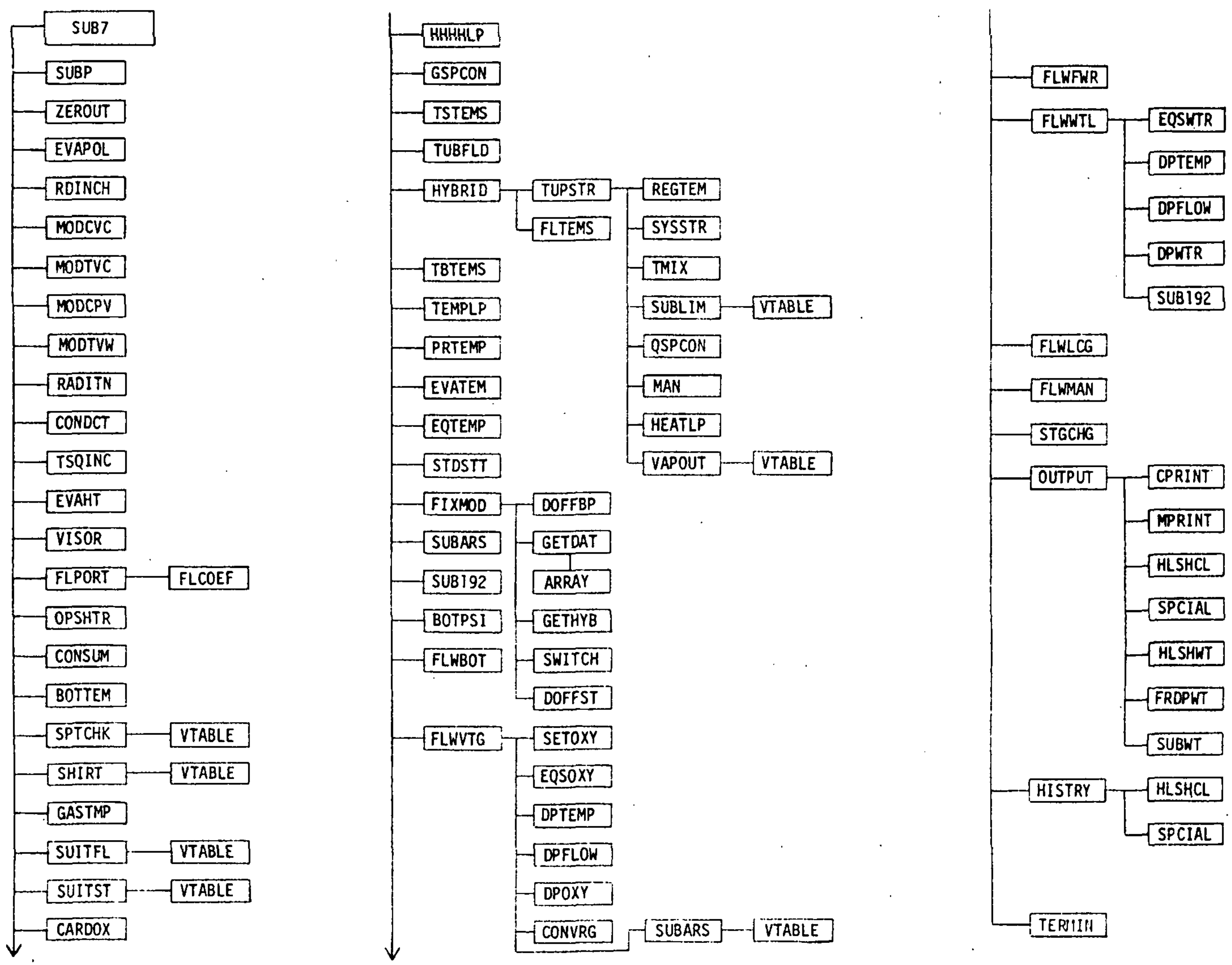


FIGURE 5-1 (CONT'D) EMU PROGRAM SCHEMATIC



code is not zero, execution is transferred through MAIN to SUB6.

3. Calls subroutine EDIT if required to make changes to the data tape.

4. Calls subroutine SUEHFR which reads and stores the parameters of the third data card, which calls subroutine CENVTP if required to create absorbed heat flux, prescribed temperature and radiant interchange mode curves on tape Unit E using data on tape Unit D and parameter cards 4 and 5.

5. Calls subroutine SUBY to read, check and store the parameters on cards 6 through 20, which calls subroutine CHAPMAN to calculate the fraction of the incident solar absorbed by the visors.

6. Calls subroutine SUBZ to read and store the parameters on cards 21 through 26.

7. Writes amount of data space used by parameter card data.

8. Returns to MAIN which calls subroutine SUB2.

<u>SUB2</u>

1. Calls subroutine SUBAT to read, check and store the fluid type data.

2. Writes amount of data space used thus far.

3. Calls subroutine SUBAL to read, check and store the fluid lump data.

4. Writes amount of data space used thus far.

5. Calls subroutine SUBBT to read, check and store the tube type data.

6. Writes amount of data space used thus far.

7. Calls subroutine SUBBL to read, check and store the tube lump data.

8. Writes amount of data space used thus far.

9. Returns to MAIN which calls SUB3.

<u>SUB3</u>

1. Calls subroutine SUBCT to read, check and store the structure type data.

2. Writes amount of data space used thus far.

3. Calls subroutine SUBCL to read, check and store the structure lump data.

4. Writes amount of data space used thus far.

5. Calls subroutine SUBD to read, check and store local temperature perturbation data, heat leak data, and heat storage data.

6. Writes amount of data space used thus far.

7. Calls subroutine SUBE to read, check and store helmet and visor data, lump identification data, and configuration-associated node identification data.

8. Writes amount of data space used thus far.

9. Calls subroutine SUBF to read, check and store heat flux curve assignment data and prescribed wall temperature data.

10. Writes amount of data space used thus far.

11. Calls subroutine SUBG to read, check and store time variant mass data and time variant connection data.

12. Writes amount of data space used thus far.

13. Calls subroutine SUBH to read, check and store special tube/fluid connection data.

14. Writes amount of data space used thus far.

15. Returns to MAIN which calls subroutine SUB4.

<u>SUB4</u>

1. Reads, checks and stores all the curve data.

2. Calls subroutine BIGSRH to setup curve type number information, BIGSRH calls subroutine CURSRH to see if a curve is needed.

3. Calls subroutine OPERAT to alter code curves by a $\pm$ .5 and converts temperature curves from degrees Fahrenheit to degrees Rankine.

4. Checks for specific heat curve and calls subroutine ENTHPY to generate an enthalphy curve and a reverse enthalpy curve.

5. Calls subroutine BIGCHK to setup calls to CURCHK for curve types. BIGCHK calls subroutine CURCHK to see if necessary curves have been supplied.

6. Writes amount of data space used thus far.

7. Returns to MAIN which calls SUB5.

<u>SUB5</u>

1. Calls subroutine SUMISC to define some constant values.

2. Calls subroutine SUGRP to setup arrays for the last fluid lump in each tube, for fluid lumps down a tube for each tube, and for tube lump numbers which enclose the fluid lumps down each tube.

3. Calls subroutine SUMAN to setup the 43 man nodes temperatures, checks and stores enclosed fluid lumps for the man's ten skin and undergarment tube lumps.

4. Calls subroutine SUCODS to set codes for special fluid, tube and structure lumps which are not to have temperature calculations.

5. Calls subroutine SUSWIT to set logical codes.

6. Calls subroutine SUDPFL to setup data for pressure drop analysis.

7. Calls subroutine SUHTVR to setup data for helmet and visor analysis.

8. Calls subroutine MOVVAL to interpolate specific heat, conductivity and time variant mass curves for initial conditions.

9. Writes amount of data space used thus far.

10. Calls subroutine MOVCOD to move code arrays to configuration data block.

11. Calls subroutine SUCONS to setup data for radiation and conduction connections between tubes and structure lumps.

12. Calls subroutine SUWCP to setup data for weight-specific heat of tube and structure lumps.

13. Calls subroutine SUQINC to setup data for lumps with incident heat curves.

14. Calls subroutine SUMODS to setup codes for classes of lumps to be analyzed for each EMU configuration mode.

15. Calls subroutine SUCLSS to store lumps by classes for EMU configuration modes. SUCLSS writes amount of data space used thus far.

16. Calls subroutine SUHYBR to setup codes for the order of hybrid calculations for each EMU configuration mode.

17. Calls subroutine SUSECT to store fluid lumps to be analyzed for each EMU configuration mode.

18. Calls subroutine CHKSPC to check special connection fluid and tube lumps.

19. Writes amount of data space used thus far.

20. Calls subroutine SUHOPR to setup data space for various types of analysis for a particular EMU configuration mode.

21. Calls subroutine SUSYSM to setup initial constants and set diverter valve conditions.

22. Calls subroutine SUPRNT to setup temperature print array.

23. Calls subroutine SULOAD to zero arrays for initial conditions.

24. Calls subroutine SURESV to setup some arrays for use during iteration loop.

25. Calls subroutine CHKLMP to check lumps in certain tubes as defined under restrictions.

26. Calls subroutine CHKCON to check lumps which cannot have connections.

27. Writes amount of data space used thus far.

28. Returns to MAIN which calls SUB6.

<u>SUB6</u>

1. Stores initial temperatures for the forty-three nodes of the man.

2. Stores area for heat transfer and its reciprocal for the undergarment tube lumps.

3. Test the plot code. If it is not zero, the title and item count are written on the first record of tape Unit I.

4. Test the code for a restart from a previous plot tape. If it is not zero, temperatures are read from tape unit H for the time input as TMPTIM.

5. Returns to MAIN which calls SUB7.

<u>SUB7</u>

1. Test the restart code (ISTART). If it is zero, execution is transferred to FIXMOD; otherwise execution is continued as follows:

2. Test the LRV prescribed temperature code (NPRTCD). If it is not zero, then LRV prescribed temperature curves (Type 11) read from tape Unit L.

3. Test the heat flux and prescribed temperature code (NENVTP). If it is not zero, then absorbed heat curves are read from Unit E.

4. Calls subroutine ZEROUT to zero arrays for conductance summation, temperature change and heating rates for fluid, tube and structure lumps.

5. Calls the following subroutines as needed:

(a) EVAPOL which interpolates and stores values for absorbed heat flux (Type 19), prescribed temperature (Type 20) and the generated radiant interchange mode curves.

(b) RDINCH which reads radiation connections from UNIT G.

(c) MODCVC which calculates connection value for lumps with conductivity variant connections.

(d) MODTVC which calculates connection value for lumps with time variant connections.

(e) MODCPV which calculates weight-specific heat for lumps with variant specific heat.

(f) MODTVW which calculates weight-specific heat for lumps with time variant mass.

(g) RADITN which calculates and stores heat rate for lumps with radiation connections.

(h) CONDCT which calculates and stores heat rate for lumps with conduction connections.

(i) TSQINC which adds heat rate for lumps with incident heat curves (Type 9)

(j) EVAHT which adds heat rate for absorbed heat fluxes.

(k) VISOR which calculates the amount of heat absorbed by each helmet and visor lump.

6. Calls subroutine FLPORT which calls subroutine FLCOEF to calculate heat transfer coefficient for fluid lumps.

7. Calls the following subroutines as needed:

(a) OPSHTR which determines whether the oxygen purge system heater is on or off and adds the heat to appropriate lump it if is on.

(b) CONSUM which performs calculations for the LiOH canister and water reservoirs.

(c) BOTTEM which calculates temperature for oxygen purge system and primary oxygen bottles.

(d) SPTCHK which performs spot check for condensation in tubes 11 and 12 and determines condensation in the sublimator. If condensation exists, heat is added to the appropriate lump. It also calculates water vapor into and out of suit.

(e) SHIRT which calculates variables needed when the man is in a shirtsleeve mode.

(f) GASTMP which calculates gas temperature for man fluid lumps.

(g) SUITFL which calculates variables for suit with flowing gas.

(h) SUITST which calculates variables for suit with stagnant gas.

(i) CARDOX which calculates the partial pressure of carbon dioxide in the helmet.

(j) HHHHLP which calculates the heat transfer coefficient and conductance summation for local temperature perturbation tube lumps.

(k) GSPCON which calculates the heat transfer coefficient, conductance and heat rate for special connection of a fluid lump to a tube lump.

(l) TSTEMPS which calculates temperature for structure lumps being analyzed.

(m) TUBFLD which calculates conductance and heat rates for tube and fluid lumps being analyzed.

8. Calls subroutine HYBRID which determines fluid lump temperatures and lumps requiring special calculation using the following subroutines:

(a) TUPSTR which determines the upstream temperature for the lumps using the following subroutines:

(1) REGTEM which calculates the upstream temperature for the oxygen purge system and primary oxygen system regulators.

(2) SYSSTR which calculates first temperature in the system.

(3) TMIX which calculates a temperature when two or more fluids are mixed together.

(4) SUBLIM which determines oxygen and water temperatures out of the sublimator.

(5) QSPCON which calculates heat rate for fluid lumps with special connections.

(6) MAN which calculates the man temperatures.

(7) HEATLP which calculates heat rate for local perturbation tube lumps.

(8) VAPOUT which calculates water vapor added to the gas by the man, and specific humidity out of the suit.

(b) FLTEMS which calculates temperatures of fluid lump being analyzed.

9. Calls the following subroutines as needed:

(a) TBTEMS which calculates temperatures of tube lumps being analyzed.

(b) TEMPLP which calculates temperatures for local perturbation fluid and tube lumps.

(c) PRTEMP which interpolates prescribed wall temperature curves type 10 and sets temperatures of appropriate lumps.

(d) PRTLRV which interpolates LRV prescribed temperature curves type 11 and set temperatures of appropriate lumps.

(e) EVATEM which sets the temperature of lumps with prescribed temperature curves, type 20.

(f) EQTEMP which sets temperatures of unanalyzed helmet and visor lumps to temperature of analyzed lumps.

(g) STDSST which checks man's sweat or shiver rate for stabilization and temperature difference against steady state criterion.

10. FIXMOD which set variables for this iteration depending on the helmet and EMU configuration modes. It calls subroutines GETDAT and GETHYB to store lumps to be analyzed in this iteration, DOFFBP to doff the backpack, DOFFST to doff the suit and SWITCH which determines logical variables which are used by SUB7 to determine which subroutines will be called.

11. Calls the following subroutines as needed:

(a) SUBARS which sets inlet temperature, flowrate and pressure into the suit when the ARS is activated .

(b) SUB192 which sets inlet temperature and flowrate into the LCG when the 192 package is activated.

(c) BOTPSI which determines pressure of the oxygen purge system and primary oxygen system bottles.

(d) FLWBOT which sets flowrate in oxygen purge system tubes 7 and 8 and primary oxygen system tubes 4 and 6.

(e) FLWVTG which sets flowrate in oxygen tubes 1 and 9. FLWVTG calls SETOXY to set flowrate in tube 16, EQSOXY which sets flowrate in oxygen tubes 2,3,5,11,12,13,14 and 15, DPTEMP, DPFLOW and DPOXY which calculate pressure drop in the tubes mentioned above.

(f) FLWFWR which calculates amount of feedwater out of reservior, sets flowrate in water tubes 17, 18 and 19 and calculates sublimator feedwater dryout.

(g) FLWWTL which calculates flowrate in tube 20 and sets diverter valve position. FLWWTL calls EQSWTR which sets flow in water tubes 21 through 25, 32, 44 and 45, DPTEMP, DPFLOW and DPWTR which calculate pressure drop in the tubes mentioned above.

(h) FLWLCG which sets flowrate in the LCG (tubes 33 through 38).

(i) FLWMAN which sets flowrate in the man oxygen tubes 10, 26 through 31 and 39 through 42.

(j) STGCHG which calculates water vapor of suit gas nodes when the suit has no flow.

12. Calls the following when it is time to print.

(a) OUTPUT which writes headings.

(b) CPRINT which writes consumable data.

(c) MPRINT which writes man temperatures and man associated quantities.

(d) HLSHCL which calculates heat leak and heat storage.

(e) SPCIAL which calculates solar energy transmitted through the visors and added to the first heat leak group.

(f) HLSHWT which writes heat leak and heat storage data.

(g) FRDPWT which writes flowrates and pressure drops.

(h) SUBWT which converts a block of temperatures from Rankine to Fahrenheit, writes the temperatures, and converts them back to Rankine.

(i) HISTRY which writes history tape on Unit K.

(j) TERMIN which writes a message when the run is terminated.

13. Test the computer time usage and ends the run if requested time is exceeded.

14. Writes the entire data block and the variable block on tape Unit I, if the run is ended before completion or if the dump option is used, so that the problem can be restarted at a later time.

Miscellaneous

(1) Function BIPOL - does table look-up and straight line interpolation on bi-variant curves.

(2) Function Pol - does table look-up and straight line interpolation.

(3) Subroutine SPCTIM - checks data space required against data space available and writes amount of data used.

(4) Subroutine SUBP - starts a new page of output and writes parameter card one as a heading.

5.2 List of System Subroutines Used

The following is a list of the Univac 1108, Fortran V, system subroutines which are used with the EMU routine.

*1. ALOG	12. NEXP2$	23. NRWND$
*2. CBRT	13. NFINP$	24. NSTOP$
*3. CLOCK	14. NFMT$	25. NTAB$
4. DEPTH	15. NFOUT$	*26. NTRAN
*5. EXP	16. NFTV$	*27. SQRT
6. FPACK$	17. NIER$	28. THRU$
7. MAUTO$	18. NININ$	29. TINTL$
8. NBDCV$	19. NINPT$	30. TLABL$
9. NBUFF$	20. NIOIN$	31. TSCRH$
10. NCNVT$	21. NOTIN$	32. TSWAP$
11. NERR$	22. NOUT$	

* These subroutines are necessary regardless of the system on which the program is run.

5.3 MSC Run Submission Requirements

For operation on the MSC Univac systems (Fortran V), using the overlay provisions, the program is stored on tape and the data deck with appropriate control cards submitted.

The EMU deck set up is as follows:

```
* 7
  8Z_RUN

* 7
  8N_MSG

  7
  8_ASG_A=AXXXXX (Input Program Tape Number)

  7
  8_ASG_B=AXXXXX (Input Old Data Tape Number) or

  7
  8S_ASG_B=DATA (Output New Data Tape)

  7
  8_ASG_C=AXXXXX (Input Old Data Tape Number)

  7
  8_ASG_D=AXXXXX (Input EHFR Output Tape Number)

  7
  8_ASG_E=AXXXXX (Input Heat Flux & Prescribed Temperature Tape Number ) or

  7
  8S_ASG_E=FLUX (Output Heat Flux and Prescribed Temperature Tape)

  7
  8_ASG_G=AXXXXX (Input Radiant Interchange Data Tape Number)

  7
  8_ASG_H=AXXXXX (Input NEWTMP Tape Number)

  7
  8S_ASG_I=DUMP (Output Data Dump and/or Plot Tape)

  7
  8_ASG_J=AXXXXX (Input Restart Tape Number)

  7
  8_ASG_L=AXXXXX (Input LRV Prescribed Temperature Tape Number)

  7
  8_XQT_CUR

  __TRW_A
```

```
_ _IN_A

_ _TRI_A

7
8_XQT_PROG

DATA (See Section 5.7)

7
8_EOF
```

* See CAD Procedures Manual - MSC EXEC II Part 19 Page 19.30.110

Description of Tape Units Used:

A - is the tape on which the program is stored and is always an input tape. (A is logical unit 1)

B - may be an input tape, an output tape, or not used at all; depending on the value of INDATA. If INDATA = 0, B is not used at all. If INDATA = 1 or 2, B is an output tape on which the new data is stored. If INDATA = 3, B is an input tape on which data has been stored prior to this run. (B is logical unit 2)

C - is an input tape necessary only if INDATA = 2. The data to be edited was stored on this tape in an earlier run. (C is logical unit 3)

D - is an input tape necessary only if NENVTP = 2. This tape is an EHFR output tape. (D is logical unit 4)

E - may be an input tape, an output tape or not used at all, depending on the value of NENVTP. If NENVTP = 0, E is not used at all. If NENVTP = 1, E is an input tape which was created on an earlier run. If NENVTP = 2, E is an output tape on which created heat flux and prescribed temperature curves are written (E is logical unit 7)

G - is an input tape necessary only if NRIC = 1. This tape has script FA connections for radiant interchange and radiation to space of external suit nodes. (G is logical unit 9)

H - is an input tape necessary only if NEWTMP = 1. This tape was the I tape from a previous problem with IPLOTN = 1. (H is logical unit 10)

I - is an output tape necessary only if IDUMP = 1 and/or IPLOTN = 1. This tape need not be generated unless the problem is to be restarted and/or plots of the mission are to be made. (I is logical unit 11)

J - is an input tape necessary only if ISTART = 1 or 2. This tape was the I tape from a previous run with IDUMP = 1. (J is logical unit 12)

L - is an input tape necessary only if NPRTCD = 1. This tape is used to supply LRV prescribed temperature curves. Every type 11** curve must start on the data tape. (L is logical unit 14)

** See Section 5.7 curve Data Cards

The EMU deck set-up for a restart with BSLSS employed (assuming the man #1 has an operating PLSS and man #2 has a failed PLSS) is as follows:

```
7
8Z_RUN

7
8N_MSG

7
8_ASG_A=AXXXXX (Input Program Tape Number)

7
8_ASG_G=AXXXXX (Input Radiant Interchange Data Tape Number)

7
8_ASG_E=AXXXXX (Input Flux Tape Number For Man #1)

7
8_ASG_S=AXXXXX (Input Flux Tape Number For Man #2)

7
8_ASG_J=AXXXXX (Input Restart Tape Number For Man #1)

7
8_ASG_K=AXXXXX (Input Restart Tape Number For Man #2)

7
8S_ASG_I=DUMP1  (Output Data Dump and/or Plot Tape For Man #1)

7
8S_ASG_R=DUMP2  (Output Data Dump and/or Plot Tape For Man #2)

7
8_XQT_CUR

_ _ TRW_A

_ _ IN_A

_ _ TRI_A

7
8_XQT_PROG
```

DATA (See Section 5.7)
7
8_EOF

Description of Tape Units Used On BSLSS Restart

A - is the tape on which the program is stored and is always an input tape. (A is logical unit 1)

E - is an input tape with heat flux and prescribed temperatures generated from a previous EMU man #1 problem. (E is logical unit 7)

G - is an input tape necessary only if NRIC = 1. This tape has script FA connections for radiant interchange and radiation to space of external suit nodes. (G is logical unit 9)

I - is an output tape necessary only if IDUMP = 1 and/or IPLOTN = 1. This tape will contain man #1 data dump and plot information. (I is logical unit 11)

J - is an input data dump tape generated from a previous EMU man #1 problem with IDUMP = 1. (J is logical unit 12)

K - is an input data dump tape generated from a previous EMU man #2 problem with IDUMP = 1. (K is logical unit 13)

R - is an output tape necessary only if IDUMP = 1 and/or IPLOTN = 1. This tape will contain man #2 data dump and plot information (R is logical unit 21)

S - is an input tape with heat flux and prescribed temperatures generated from a previous EMU man #2 problem. (S is logical unit 22)

The only cards necessary for a run if the data is supplied on cards (i.e., INDATA = 0) are those marked by an asterisk. Depending on the options chosen, other input tapes may be incorporated and various output tapes may be generated.

The other "$^{7}_{8}$ ASG" or "$^{7}_{8}$ S_ASG" cards are required when the various options are exercised. Any required input tape must be signified by a "$^{7}_{8}$ ASG" card. Any required output tape must be signified by a "$^{7}_{8}$ S_ASG" card. The proper unit must be designated on this card (e.g., a restart tape is always input on unit J, a plot tape is always output on unit I, etc.). It is imperative that the proper unit be specified.

If a tape is an input tape, the number of the tape should be punched immediately following the equal sign without skipping any spaces between the equal sign and the tape number. If a tape is an output tape, the same rule applies except the number is replaced by a symbolic name. This symbolic name should also appear on the run request card under the heading "FILE NAME" for the corresponding output tape.

All input and output tapes must be so designated on the run request card (MSC FORM 588). If the output tapes are to be saved, separate tape reel labels (MSC FORM 874) should be submitted with the run for each tape. The appropriate information for each tape should be supplied on these forms. A method for estimating run time and program output required on these forms is provided in the following section.

5.4 Run Time and Output Estimation

Run time for the EMU may be estimated for the Univac 1108 using the following equation:

$$\mathrm{RTIME} = \mathrm{AI} + \left(\frac{\mathrm{FL} + \mathrm{TL} + \mathrm{SL}}{40800}\right)\left(\frac{\mathrm{TAU} - \mathrm{TIME}}{\mathrm{TINCMN}}\right)$$

where:

RTIME	=	requested computer time in minutes
FL	=	number of fluid lumps
TL	=	number of tube lumps
SL	=	number of structure lumps
TAU	=	mission completion time, hours
TIME	=	mission start time, hours
TINCMN	=	input time interval, hours
AI	=	0, if the run is a restart
	=	3, if the run is not a restart

This expression is not valid when the print interval is less than 0.1 hours. This expression is also an approximation because the amount of time spent in determining flow rates is dependent on the severity of the transient being run and cannot be readily estimated in advance.

Output from EMU may be estimated using the following equation:

$$NPO = 18 + 3 \frac{TAU - TIME}{DELTAU} + 23\,AI + 70\,BI$$

where:

NPO	=	number of pages of output
TAU	=	mission completion time
TIME	=	mission start time
DELTAU	=	print interval
AI	=	0, if the run is restart
	=	1, if the run is not a restart
BI	=	0, if the data tape is not edited
	=	1, if the data tape is edited

5.5 Restrictions

Programming, analytical, and core storage space restrictions applicable to the EMU are outlined in the following paragraphs.

5.5.1 Programming

Some of the programming restrictions are described in other parts of the report and are listed here to emphasize their importance.

A. A fluid lump may be enclosed by more than one tube lump, but it <u>must</u> be enclosed by at least one.

B. When setting up the fluid lump data, care must be exercised to insure that upstream lumps are set up properly. Data should be listed so that it is possible to go from the last lump in the tube to the first lump in that tube simply by following the upstream lump numbers. All fluid lumps in the tube should be covered in this search.

C. When conduction data is set-up, the second conductance value may be zero, but the first should never be in order to save core storage space.

D. Tubes 26, 27, 28, 29, 30, 31, 39, 40, 41 and 42 contain the vent gas flow over the trunk, right arm, right leg, head, right hand, right foot, left arm, left leg, left hand and left foot respectively and must contain one and only one fluid lump. Each preceding fluid lump must be enclosed by at least two tube lumps one of which must be the corresponding skin tube lump number. Additional tube lumps, enclosing the suit fluid lumps and representing the inside suit wall, are required by the program.

E. Tubes 9, 11, 12, 13, 15, 24, 32 must contain at least two fluid lumps.

F. The sublimator oxygen fluid lump, sublimator water fluid lump, first fluid lump in tube 9, and the first fluid lump in tube 32 must be surrounded by only one tube lump.

G. The last fluid lump in tubes 11 and 12 must be respectively the lithium hydroxide canister lump and the sublimator oxygen lump.

H. The sublimator water fluid lump must be in tube 21, but not the first lump or last lump of that tube.

I. The structure lump of oxygen in the OPS bottle on left side and right side, the structure lump of oxygen in the primary oxygen bottle, and the tube lump surrounding the first lump in tubes 9 and 32 must not have any connections.

J. In the special tube/fluid connection data the fluid lump must be a lump surrounding the man and the tube lump must be a man skin lump or a lump in tubes 32 through 38.

K. If a lump has a prescribed temperature, the temperature is prescribed for the entire problem according to the curve data input.

L. A BSLSS Man No. 1 run must always have at least one local temperature perturbation calculation.

5.5.2 Analytical

In addition to the analytical restrictions for any finite difference approximation to differential equations, the user of the EMU should also be aware of the following:

A. The EMU has special equations or curves for computing the pressure drop of various components. In order to compute a pressure drop of zero for the fluid lump which represents the component, a wetted perimeter of zero must be specified for the fluid lump. However, the specifying of a wetted perimeter of zero causes the calculation of a zero heat transfer coefficient for the fluid lump. Therefore, if a heat transfer coefficient other than zero is needed, it must be specified on a curve as a function of flow rate.

B. The EMU automatically determines for the lumps on the visors the amount of incident solar and incident infrared radiation absorbed as a function of visor positon. The visor node connections are made and broken automatically according to visor position. The pressure bubble lumps connected to the LEVA shell lumps must be done manually by use of lumps with time variant properties. The time variant curve must be consistent with the helmet mode curve which is a function of mission time.

5.5.3 Core Storage Space

The computer program requires approximately 8000 core locations. In addition, a blank common block of 40,980 is allocated for storing input and calculated data. The largest part of the common block is assigned to an array called DATA. Basically the size of this array is determined by the size of core and the size of the SUB7 link. For operation on the Univac 1108 the dimensioned size of DATA is 40,000 locations. The DATA array is divided into three sections: transient, permanent and temporary. The transient section has two blocks, iteration and configuration, which share the 14,000 locations available. Only one block is stored in core at a time, while the other is stored on a drum. The iteration block occupies core all the time except when an EMU configuration change takes place and the configuration block is in core to make necessary changes to the permanent section. The permanent and temporary sections have variable length which cannot exceed 26,000 locations. These storage values are allocated as shown in the following paragraph.

A. The equations for determining the amount of core space in the DATA block that a thermal model will require are:

(1) Transient Section - Iteration Block

Storage required = 200 + 14 NIHEVA + 14 NPTEVA +
14 NTFL + 2 NTML + 3 NGRHL + 3 NGRSH
+ 3 NPHHL + 2 NNDSH + 10 NHVPOS +
2 NNEVAH + 2 NCR1 + 4 NCR2 + 2 NP1
+ NP2 + NP3 + NP2 * NP3

(2) Transient Section - Configuration Block

Storage required = 200 + 3 NTFL + 6 NTML + 6 NSL +
3 NUMCON + NLMPEM

(3) Permanent and Temporary Section

Storage required = 300 + 6 NFLT + 13 NTFL + 10 NMLT +
14 NTML + 7 NT + 13 NSL + 10 NLOCPT
+ 2 NNEVAT + 2 NPRTEM + 4 NUMTVW +
4 NUMTVC + 6 NSPCON + 3 NHV123 +
5 NUMCON + 7 NUMCVC + 4 NUMCPV +
4 NUMQIN + 2 NLMPID + 2 NLMPEM +
2 NPTLRV + NRFST + NRFTT

B. Identification of Symbols Used in Above Equations:

NCR1	-	Number of curves other than bivariant curves
NCR2	-	Number of bivariant curves
NFLT	-	Number of fluid lump types
NGRHL	-	Number of groups of nodes for heat leak calculations
NGRSH	-	Number of groups of nodes for heat storage calculations
NHVPOS	-	Number of positions on helmet and visor
NHV123	-	Number of type 1, 2, and 3 positions on helmet and visor
NIHEVA	-	Number of heat flux curves
NLMPEN	-	Number of structure lumps associated with an EMU configuration
NLMPID	-	Number of structure lump identified as suit, glove, and boot node

NLOCPT	-	Number of local temperature perturbation nodes
NMLT	-	Number of tube lump types
NNDSH	-	Total number of nodes for heat storage calculations
NNEVAH	-	Number of nodes with heat flux curve assignments
NNEVAT	-	Number of nodes with prescribed temperature curve assignments
NPHHL	-	Total number of paths for heat leak calculations
NPRTEM	-	Number of prescribed temperature curves
NPTEVA	-	Number of prescribed temperature curves generated from EHFR input
NPTLRV	-	Number of LRV prescribed temperature curves
NP1	-	Total number of points on all curves other than fluid specific heat and bivariant curves
NP2	-	Total number of points on fluid specific heat curves
NP3	-	Total number of dependent variables on bivariant curves
NRFST	-	Number of resistors and FAs in structure type data
NRFTT	-	Number of resistors and FAs in tube type data
NSL	-	Number of structure lumps
NSPCON	-	Number of special tube/fluid connections
NT	-	Number of structure lump types
NTFL	-	Number of fluid lumps
NTML	-	Number of tube lumps
NUMCON	-	Number of connections
NUMCPC	-	Number of nodes with variable specific heat
NUMCVC	-	Number of nodes with variable conductivity connections
NUMQIN	-	Number of nodes with incident heat applied
NUMTVC	-	Number of nodes with time variant connections
NUMTVW	-	Number of nodes with time variant mass

5.6 Program Options

5.6.1 Plot Tape

A "1" punch in column 68 of parameter card 2 will cause the generation of a plot tape. This tape will have all of the fluid, tube, and structure lump temperatures, plus other items indicated below, recorded on it under control of the plot interval given on Card 2. The plot tape is generated on tape UNIT I. Set-up cards are required when the program is submitted to cause the tape to be mounted as discussed in Section 5.3. Also, the computer request card must indicate that there is to be an output tape on UNIT I.

The format of the plot tape is:

Record No. 1

Title (from title card, 12A6), 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 2, 2, 2, 7, 8, 43, number of groups of heat leak calculations, number of groups of heat storage calculations, number of flowrates, number of pressure drops, number of fluid temperatures, number of tube temperatures, number of structure temperatures.

Record No. 2

Time, LCG delta temperature, crewman stored heat, partial pressure of CO_2 in helmet, dewpoint temperature in helmet, suit inlet specific humidity, suit outlet specific humidity, pressure in OPS bottles, pressure in primary bottle, condensation rate in tube 11, condensation rate in tube 12, sublimator heat load, crewman sensible heat loss, crewman evaporation heat loss, crewman latent heat loss, crewman storage rate, crewman shiver rate, crewman metabolic rate, oxygen in OPS bottles, oxygen in primary bottle, total condensation in tube 11, total condensation in tube 12, usable water in reservoir, unusable water in reservoir, lithium hydroxide in canister, unremoved sweat on crewman, crewman temperatures, flowrates, pressure drops, fluid lump temperatures, tube lump temperatures, and structure lump temperatures.

Record No. 3

Time, etc.

The last record has a negative time to indicate end of output. This record need not be included in the plot since the values printed out are identical to those on the previous record.

5.6.2 LRV Prescribed Temperature Curves on Tape

LRV prescribed temperature curves may be read from tape by putting a "1" punch in column 66 of Card 2. Also, the tape unit L must be designated on the computer request card, and the proper set-up cards must be included. (Section 5.3.1) An auxiliary routine must be used to "block" the prescribed temperatures on the tape prior to its use as an input tape.

Restrictions on the option are:

(1) All LRV prescribed temperature curves must be read from tape.

(2) The initial block of curve data must be input on cards or data tape in the usual manner (Section 5.7.16)

(3) Each curve on tape must have the same number of points per block of curve data as were input on cards initially.

(4) Each curve must have the same number of points per block and therefore the same total number of points.

(5) The order of the curves on the tape must be the same as curves in the data deck.

The data is read from a binary tape which has the following format:

Record No. 1

First Read Time, 9A6

Record No. 2

Number of points on Curve No. 1 (Integer), Curve 1 independent variables, Curve 1 dependent variables, Number of points on Curve 2, Curve 2 independent variables, Curve 2 dependent variables, etc. for all curves.

Record No. 3

Second Read Time, 9A6

Record No. 4

Same as Record No. 2

Record No. 5

Same as Record No. 1 but for the third read time.

Etc. until all blocks of data are on tape.

The amount of the data which can be read in from tape is unlimited since successive tapes can be mounted and read. The amount of data which can be read in a given block is dependent upon the data space available in the computer. It is possible to restart a problem which reads prescribed temperature curve data from tape. Although the tape rewinds on a program restart, the program searches for the proper program time before reading.

5.6.3 Restart

Requested Dump for Restarting

Any problem can be dumped and restarted at a later time. This is achieved by punching a "1" in column 70 on parameter card 2. This option is useful in data checkout in that a problem can be submitted for a short transient time, and, after examination of the results, restarted for a longer transient time. The computer request card must specify that the output tape is expected, and the proper set-up card must be included in the deck.

Automatic Dump for Restarting

If a problem does not attain the specified mission transient time within the requested computer time, the problem is dumped and may be restarted later. This occurs whether there is a "1" in column 70 on parameter card 2 or not. The computer request card must specify that an output tape is expected or the dump will be lost; a save tape label must also be provided.

Restart Procedure

The procedure for restarting a problem which has been dumped is:

(1) Fill out the computer request card as in an initial run, except specify the previously dumped tape as an input tape on UNIT J.

(2) If on the initial run, an EHFR tape was input on UNIT D, the output tape created on UNIT E is specified as an input tape on restart. An EHFR tape cannot be used directly on restart.

(3) Submit only the first two of the data cards (that is, parameter cards 1 and 2) with a"1" punch in column 60 on Card 2 to indicate that data is to be read from a restart tape.

(4) See Section 5.3.2 for restarting with BSLSS option.

5.6.4 EDIT

The large number of data cards required for problems run on this routine presents three problems: (1) increased probability of operator and/or card reader error, (2) increased probability of a card reader jam, and (3) significant extra time required to read in data from the card reader when problem (2) occurs. For these reasons a routine was developed (Reference 14) for reading input data from tape with the capability for modifying the data on read-in.

The EDIT routine is called by parameter INDATA input on columns 61 and 62 on parameter card 2. Possible inputs are:

(1) INDATA = 0, All data is supplied on cards.

(2) INDATA = 1, All data is supplied on cards and the card images are written on tape on UNIT B. (Should be specified as an output tape on job card).

(3) INDATA = 2, Use data input on tape on UNIT C with desired changes on cards to write a new data tape on UNIT B. (C is input tape and B is output tape)

(4) INDATA = 3, Use the data read in from UNIT B without change. Parameter cards 1 and 2 are read in from cards. (B is input tape)

If INDATA <0 , the card images are punched as they are written on UNIT B.

When INDATA = 2, deck set-up consists of parameter cards 1 and 2, *the EDIT control cards (described below), and the new data cards (with the* same format as the cards being replaced).

The EDIT control cards, used only when INDATA has a value of $\pm$ 2 are:

COLUMN	FORMAT	NAME	DESCRIPTION
1	A1	ID	* in column 1 identifies the card as an EDIT control card

COLUMN	FORMAT	NAME	DESCRIPTION
6-15	I10	K3	Card number of first card to be removed if K3 is positive and K4 > 0. If K3 is negative, K3 is the card number of the card for which a merge correction will be performed. If K4 is blank or zero, cards change cards between this card and the next EDIT Control card will be added immediately following card K3.
16-25	I10	K4	Card number of last card to be removed prior to inserting the change cards in the data. If K3 is negative, K4 is ignored.

The UNIT C tape is not altered in any way should there be errors in the edit deck which cause fatal errors in the LTV program. It is the responsibility of the user to maintain extra copies of the data tape and/or an up-to-date card deck.

5.6.5 Imposed Node Temperature History

It is possible to impose a temperature history on structure nodes for the duration of the problem. The temperature history is called a prescribed wall temperature and data preparation is given in Section 5.7.12.

5.6.6 Heat Flux and Prescribed Temperature Data From EHFR

The Environmental Heat Flux Routine (EHFR) outputs on a tape, incident heat in two wavelength bands (solar and infrared) for each helmet and visor node of its geometrical model of the EMU. Absorbed heat for each remaining node and a contact temperature is also output on the tape. This tape is used as input to the EMU simulator on tape UNIT D when NENVTP = 2. This parameter is specified in column 30 of parameter card 3. When NENVTP = 2, the EMU simulator reads data from UNIT D and creates on UNIT E curves of absorbed heat, incident solar heat, incident infrared heat, and contact temperature as specified on parameter cards 4 and 5. The incident solar and incident infrared heat curves are assigned in the Helmet and Visor Data (Section 5.7.8) while the absorbed heat and contact temperature curves are assigned in the Curve Assignment Data (Section 5.7.11). The tape created on UNIT E on one run can be used on other runs as an input tape by specifying NENVTP = 1. The user can, by specifying NENVTP = 0, input curves requested on parameter card 3 in the Curve Data (Section 5.7.16) as type 19 and type 20 curves. Parameter cards 4 and 5 must be omitted and tapes are not specified for UNIT D and UNIT E. If NENVTP = 0 and NRIC = 1, the user must supply a type 21 (radiant interchange mode) curve. This curve determines the set of radiant interchange connection values to be used from UNIT G as a function of time. The connection values should correspond to the variation in EHFR heat flux which is a function of the EMU geometric configuration.

To restart a run which uses an EHFR tape as input on UNIT D, a tape must have been created on UNIT E and saved for restart. The tape generated on UNIT E becomes an input tape read from the same unit. UNIT D cannot be used on restart. (Section 5.6.3)

5.7 DATA CARD PREPARATION FOR EMU

5.7.1 PARAMETER CARDS

Columns	Format	Title	Description
Card 1			
1-72	12A6	TITLE	Any 72 alphanumeric characters to be used for page heading
Card 2			
1-10	F10.5	TIME	Mission start time (hrs)
11-15	F5.5	TINCMN	Minimum time increment (hrs)
16-20	F5.5	PLTINC	Plot interval (hrs)
21-25	F5.5	DELTAU	Print interval (hrs)
26-35	F10.5	TAU	Mission completion time (hrs)
36-40	F5.0	SSTEST	Steady state tolerance (°F)
41-45	F5.0	RTIME	Computer time requested (minutes)
46-50	F5.0	TMPTIM	Time of initial temperatures from history tape (UNIT H)
51-55	F5.0	DPTOL	Pressure drop tolerance (.01)
56			Blank
57-58	I2	NSTEAD	= 0, Not steady state ≠ 0, Steady state run
59-60	I2	ISTART	= 0, New data follows = 1, Read data from restart tape to continue mission = 2, Read data from two restart tapes to continue mission with BSLSS employed
61-62	I2	INDATA	= 0, All data supplied on cards = 1, Write card images on UNIT B = 2, Use cards from C to update B = 3, Use B without edit =-2, Punch data
63-64	I2	NEWTMP	= 0, Use current temperature tables = 1, Read initial temperatures from Unit H

Columns	Format	Title	Description
Card 2 (Continued)			
65-66	I2	NPRTCD	= 0, Use current LRV prescribed temperature tables = 1, LRV prescribed temperature tables supplied by unit L
67-68	I2	IPLOTN	= 0, No temperature history = 1, Write temperature history on Unit I
69-70	I2	IDUMP	= 0, No dump tape to be written = 1, Dump data on UNIT I when either TAU or RTIME is exceeded
71-72	I2	NBSY	= 0, Normal EMU run = 1, Initial EMU run with BSLSS for man with active PLSS = 2, Initial EMU run with BSLSS for man with failed PLSS
Card 3			
1-5	I5	NTFL	Total number of fluid lumps
6-10	I5	NTML	Total number of tube lumps
11-15	I5	NSL	Total number of structure lumps
16-20	I5	NIHEVA	Number of heat flux curves to be created from EHFR output or supplied in curve data. If none, enter zero
21-25	I5	NPTEVA	Number of prescribed temperatures history curves to be created from EHFR output or supplied in curve data. If none enter zero
26-30	I5	NENVTP	Code for heat flux curves, type 19, and prescribed temperature curves, type 20, = 0, Curves supplied in curve data = 1, Heat flux and prescribed temperature curves read from UNIT E, = 2, Heat flux and prescribed temperature curves created on UNIT E from EHFR output on UNIT D
31-35	I5	NRIC	= 0, No radiant interchange tape = 1, Read radiant interchange tape on UNIT G

Columns	Format	Title	Description
Card 4			
1-5	I5	NUM	Curve number assigned to this group of combined heat fluxes (or temperature histories)
6-10	I5	NF	Number of heat fluxes (or temperature histories) from EHFR composing this group
Card 5			
1-5	I5	NF1	First facet number corresponding to the heat flux (or temperature history) included in this group
6-10	F5.0	FRAC1	Fraction of heat flux (or temperature history) of first facet included in this group
11-15	I5	NF2	Second facet number corresponding to the heat flux (or temperature history) included in this group
16-20	F5.0	FRAC2	Fraction of heat flux (or temperature history) of second facet included in this group
21-25	I5	NF3	Third facet number corresponding to the heat flux (or temperature history) included in this group
26-30	F5.0	FRAC3	etc.

Alternate the facet number and fraction in the proper format through column 70. Then, repeat Card 5 until NF facet numbers and the appropriate fraction have been supplied. Repeat Card 4 followed by Card 5 for the heat flux curves NIHEVA times followed by Cards 4 and 5 for prescribed temperature history curves as required. If NENVTP = 0, omit Cards 4 and 5.

Columns	Format	Title	Description
Card 6			
1-10	E10.5	C1	Suit $\Delta P(psi) = C1 * \frac{T_{in}}{P_{in}} (\dot{W}_o)^{END1}$
11-20	E10.5	END1	
21-30	E10.5	C2	Canister $\Delta P(psi) = C2 * \frac{T_{in}}{P_{in}} (\dot{W}_o)^{END2}$
31-40	E10.5	END2	
41-50	E10.5	C3	Sublimator oxygen $\Delta P(psi) =$ $C3 * \frac{T_{in}}{P_{in}} (\dot{W}_o)^{END3}$
51-60	E10.5	END3	

Columns	Format	Title	Description
Card 7			
1-10	E10.5	C4	Water separator, $\Delta P(psi) =$
11-20	E10.5	END4	$C4 * \frac{T_{in}}{P_{in}} (\dot{W}_o)^{END4}$
21-30	E10.5	C5	Sublimator water, $\Delta P(psi) =$
31-40	E10.5	END5	$C5 * (\dot{W}_w)^{END5}$
41-50	E10.5	CW1	Flowrate of water pump (lbs/hr) =
51-60	E10.5	CW2	$CW1 * (\Delta P_{SYS})^{CW2}$
Card 8			
1-5	I5	LMPCAN	Canister fluid lump number
6-10	I5	LMPSBO	Sublimator oxygen fluid lump number
11-15	I5	LMPWSP	Water separator fluid lump number
16-20	I5	LMPSBW	Sublimator water fluid lump number
21-25	I5	LMPWRS	Lump number of water in water reservoir (structure)
26-30	I5	LMPWAX	Lump number of water in auxiliary water reservoir (structure)
Card 9			
1-5	I5	LMPHTR	OPS heater tube lump number
6-10	I5	LSNHTR	OPS heater fluid sensor lump number
11-20	F10.5	TSEN1	OPS "heater-on" temperature, °F
21-30	F10.5	TSEN2	OPS "heater-off" temperature, °F
31-40	F10.5	QHTR	Heater dissipation rate, Btu/hr
Card 10			
1-5	I5	LIØPS1	Lump number of oxygen in OPS bottle on left side (structure)
6-10	I5	LØØPS1	Lump number of shell of OPS bottle on left side (structure)
11-20	F10.5	HAØPS1	HA for left hand side OPS bottle, BTU/hr-°F
21-30	F10.5	PGØPS1	Initial pressure in left hand side OPS bottle, psi

<u>Card 11</u>

Same as <u>Card 10</u> except for right hand side OPS bottle.

Columns	Format	Title	Description
Card 12			
Same as Card 10 except for Primary oxygen bottle.			
Card 13			
1-10	F10.5	VØLØPS	OPS bottle volume, in^3
11-20	F10.5	VØLPRI	Primary oxygen bottle volume, in^3
21-30	F10.5	PSISUB	Initial specific humidity out of sublimator
31-40	F10.5	DPDIV	Diverter valve pressure drop, psi
Card 14			
1-10	F10.5	WTRUSE	Usable water in main reservoir, lb
11-20	F10.5	WTRSTR	Unusable water in main reservoir, lb
21-30	F10.5	WRAXUS	Usable water in auxiliary reservoir, lb
31-40	F10.5	WRAXST	Unusable water in auxiliary reservoir, lb
41-50	F10.5	VOLHMT	Net helmet volume, in^3
51-60	F10.5	CO2WGT	Initial weight of CO_2 in helmet, lb
Card 15			
1-5	I5	L1	Trunk skin tube lump number
6-10	I5	L2	Right arm skin tube lump number
11-15	I5	L3	Left arm skin tube lump number
16-20	I5	L4	Right leg skin tube lump number
21-25	I5	L5	Left leg skin tube lump number
26-30	I5	L6	Head skin tube lump number
31-35	I5	L7	Right hand skin tube lump number
36-40	I5	L8	Left hand skin tube lump number
41-45	I5	L9	Right foot skin tube lump number
46-50	I5	L10	Left foot skin tube lump number

Columns	Format	Title	Description
Card 16			
1-5	I5	L11	Trunk undergarment tube lump number
6-10	I5	L12	Right arm undergarment tube lump number
11-15	I5	L13	Left arm undergarment tube lump number
16-20	I5	L14	Right leg undergarment tube lump number
21-25	I5	L15	Left leg undergarment tube lump number
26-30	I5	L16	Head undergarment tube lump number
31-35	I5	L17	Right hand undergarment tube lump number
36-40	I5	L18	Left hand undergarment tube lump number
41-45	I5	L19	Right foot undergarment tube lump number
46-50	I5	L20	Left foot undergarment tube lump number
Card 17			
1-10	F10.5	WGLIØH	Weight of LiOH in canister, lb
11-20	F10.5	WGLICØ	Initial weight of Li_2CO_3 in canister, lb
21-30	F10.5	WGSHEL	Weight of LiOH cartridge shell, lb
31-40	F10.5	CPLIØH	Specific heat of LiOH, Btu/lb °F
41-50	F10.5	CPLICØ	Specific heat of Li_2CO_3, Btu/lb °F
51-60	F10.5	CPSHEL	Specific heat of LiOH cartridge shell, Btu/lb °F
Card 18			
1-10	F10.5	RF1	Solar reflectivity of astronaut's face
11-20	F10.5	RF2	Solar reflectivity of inside of pressure bubble
21-30	F10.5	RF3	Solar reflectivity of outside of pressure bubble
31-40	F10.5	RF4	Solar reflectivity of inside of impact visor

Columns	Format	Title	Description
Card 18 (Continued)			
41-50	F10.5	RF5	Solar reflectivity of outside of impact visor
51-60	F10.5	RF6	Solar reflectivity of inside of sun visor
61-70	F10.5	RF7	Solar reflectivity of outside of sun visor
Card 19			
1-10	F10.5	RFT	Solar reflectivity of helmet top
11-20	F10.5	T23	Solar transmissivity of pressure bubble
21-30	F10.5	T45	Solar transmissivity of impact visor
31-40	F10.5	T67	Solar transmissivity of sun visor
Card 20			
1-10	F10.5	EM1	Infrared emittance of outer surface of sun visor
11-20	F10.5	EM2	Infrared emittance of outer surface of impact visor
21-30	F10.5	EM3	Infrared emittance of outer surface of helmet top
31-40	F10.5	EM4	Infrared emittance of outer surface of pressure bubble
41-50	F10.5	EM5	Infrared emittance of man's face
Card 21			
1-5	I5	NOXDEN	Oxygen density curve number
6-10	I5	NOXCON	Oxygen conductivity curve number
11-15	I5	NOXSPH	Oxygen specific heat curve number
16-20	I5	NOXVIS	Oxygen viscosity curve number
21-25	I5	NOXFFR	Oxygen friction factor curve number

Columns	Format	Title	Description
Card 22			
1-5	I5	NWRDEN	Water density curve number
6-10	I5	NWRCON	Water conductivity curve number
11-15	I5	NWRSPH	Water specific heat curve number
16-20	I5	NWRVIS	Water viscosity curve number
21-25	I5	NWRFFR	Water friction factor curve number
Card 23			
1-5	I5	NTCAB	Cabin gas temperature curve number
6-10	I5	NTDEWC	Cabin gas dew point temperature curve number
11-15	I5	NOXYDP	Suit inlet dew point temperature curve number
16-20	I5	NOXYIT	Suit inlet temperature curve number
21-25	I5	NWTRIT	LCG inlet temperature curve number

All curves on this card are type 12.

Columns	Format	Title	Description
Card 24			
1-5	I5	NZFACT	Compressibility factor curve number, Z (PR,TR)
6-10	I5	NEBLOW	Oxygen enthalpy curve number, H (P,T)
11-15	I5	NDPLCG	LCG pressure drop curve number, $DP(\dot{W},T)$
16-20	I5	NTOUTW	Sublimator water outlet temperature curve number, $T(\dot{W},T_{inlet})$
21-25	I5	NFANCR	PLSS fan pressure curve number
Card 25			
1-5	I5	NSLEAK	Suit leakage rate curve number
6-10	I5	NWLEAK	Water leakage rate curve number
11-15	I5	NXM	Metabolic rate curve number

Columns	Format	Title	Description
Card 25 (Continued)			
16-20	I5	NUEFF	Man efficiency curve number
21-25	I5	NPSUIT	Suit gas pressure curve number
26-30	I5	NGRAV	Gravity multiplying factor curve number
31-35	I5	NVCAB	Cabin freestream velocity curve number
36-40	I5	NVEFF	Cabin ventilation efficiency curve number
41-45	I5	NPCAB	Cabin gas pressure curve number
46-50	I5	NOXYFL	Suit inlet gas flow curve number
51-55	I5	NWTRFL	LCG inlet flowrate curve number

All curves on this card are type 34.

Card 26

1-5	I5	NPOXY	Fan exit pressure curve number
6-10	I5	NNPOS	Primary oxygen system On/Off curve number
11-15	I5	NNDIV	Diverter valve position curve number
16-20	I5	NQEMAX	Sublimator maximum heat load curve number
21-25	I5	NOPS	OPS flowrate curve number
26-30	I5	NHMOD	Helmet mode curve number
31-35	I5	NEMODE	EMU configuration mode curve number
36-40	I5	NAXRSV	Auxiliary reservoir shut-off valve curve number

All curves on this card are type 35.

5.7.2 FLUID DATA CARDS

Card 27

1-5	I5	NFLT	Number of types of fluid lumps

Columns	Format	Title	Description
Card 28 (Type Data Cards)			
1-25			Blank
26-30	I5	NKPDC	Head loss coefficient curve number
31-35	I5	NHHH	= 0, Use regular equation for HHH ≠ 0, Curve number for HHH = f ($\dot{w}$)
36-45	F10.5	FLL	Fluid lump length, inches
46-55	F10.5	CSA	Fluid cross sectional area, sq. in.
56-62	F7.5	WP	Wetted perimeter, inches
63-67	F5.4	FRE	Factor for computing friction factor as a function of Reynold's number. Routine sets to 1.0 if left blank
68-72	I5	LTYPE	Type number

Repeat Card 28 for each fluid type.

Card 29	(Fluid Lump Cards)		
1-5	I5	LN	Lump number
6-10	I5	NLU	Lump upstream. NLU = 0 for first lump in every tube.
11-15	I5	NTB	Tube number
16-20	I5	NTYPEF	Type number
21-30	F10.5	FTI	Initial temperature, ^{o}F

Repeat Card 29 for every fluid lump.

5.7.3 TUBE DATA CARDS

Card 30			
1-5	I5	NMLT	Number of types of tube lumps

Columns	Format	Title	Description
Card 31	(Type Data Cards)		
1-5	F5.0	WGTT	Weight of tube lump, lbs
6-10	I5	NCØNCT	Conductivity curve number
11-15	I5	NSHCT	Specific heat curve number
16-20	I5	NTCT	Number of tube lumps 'conducted to' by tube lumps of this type
21-25	I5	NFCTT	Number of structure lumps 'conducted to' by tube lumps of this type
26-30	I5	NTRT	Number of tube lumps 'radiated to' by tube lumps of this type
31-35	I5	NFRTT	Number of structure lumps 'radiated to' by tube lumps of this type
36-45	F10.5	AHT	Area of heat transfer to enclosed fluid lump, sq. in.
46-55	F10.5	AERT	Area of surface for incident heat application, sq. in.
56-65	F10.5	FAC	Factor for dividing conduction distances. Routine sets to 1.0 if left blank
66-70	I5	LTYPE	Type number
Card 32	(Conduction Data, required for all lumps conducted to by tube lumps of this type)		
1-5	F5.5	$R1_1$	Conduction data for tube lumps of this type of the first lump listed in the connections on the tube lump card
6-10	F5.5	$R2_1$	$U = \dfrac{1}{\dfrac{R_{1_1}}{K_1} + \dfrac{R_{2_1}}{K_2}}$ Resistor values are input in pairs, but R_2 may be left blank when thermal conductivity is constant.
11-15	F5.5	$R1_2$	Conduction data for tube lumps of this type to the second lump listed in the connections on the tube lump cards
16-20	F5.5	$R2_2$	
.	.	.	.
.	.	.	.
.	.	.	.

Columns	Format	Title	Description

Card 32 (Continued)

Columns	Format	Title	Description
61-65	F5.5	$R1_7$	Conduction data for tube lumps of this type to the seventh lump listed in the connections on the tube lump card
66-70	F5.5	$R2_7$	

Repeat Card 32 as many times as needed to supply conduction data for the total number of lumps conducted to by tube lumps of this type. Data must be given as follows: (1) all conduction data to tube lumps, (2) all conduction data to structure lumps.

Card 33 (Radiation Data, required for all lumps radiated to by tube lumps of this type)

Columns	Format	Title	Description
1-5	F5.0	FA1	Gray-body shape factor, FA (sq. in.) between tube lumps of this type and the first lump 'radiated to' listed in the connections on the tube lump cards.
6-10	F5.0	FA2	Gray-body shape factor between tube lumps of this type and the second lump 'radiated to' listed in the connections on the tube lump card
.	.	.	.
.	.	.	.
.	.	.	.
66-70	F5.0	FA14	Gray-body shape factor between tube lumps of this type and the 14th lump 'radiated to' listed in the connections on the tube lump cards

Repeat Card 33 as many times as needed to supply the gray-body shape factor for the total number of lumps radiated to by tube lumps of this type. Data must be given as follows: (1) all radiation data to tube lumps, (2) all radiation data to structure lumps.

Repeat Card 31 (followed by Cards 32 and 33 if needed) for each tube type.

Card 34 (Tube Lump Cards)

Columns	Format	Title	Description
1-5	I5	LN	Lump number
6-10	I5	NFL	Enclosed fluid lump number
11-15	I5	NTYPET	Type number
16-25	F10.5	TTI	Initial temperature, °F

Columns	Format	Title	Description
Card 34 (Continued)			
26-30	I5	NQICT	Incident heat curve number
31-35	I5	NTL1	First lump to which this tube lump has a connection either by conduction or radiation
.	.	.	.
.	.	.	.
.	.	.	.
66-70	I5	NTL8	Eighth lump to which this tube lump has a connection
Card 35	(Additional connections, if required)		
1-5	I5	NTL9	Ninth lump to which this tube lump has a connection
.	.	.	.
.	.	.	.
.	.	.	.
66-70	I5	NTL22	Twenty-second lump to which this tube lump has a connection

The order of the connected lumps is the same as the other in which the conduction and radiation data were given on the corresponding type card.

Recall that the connections should be listed as follows; conduction to tube lumps, conduction to structure lumps, radiation to tube lumps and radiation to structure lumps. Repeat Card 35 if needed to supply all lumps to which the tube lump has a connection.

Repeat Card 34 (followed by Card 35, if required) for every tube lump.

5.7.4 STRUCTURE DATA CARDS

Columns	Format	Title	Description
Card 36			
1-5	I5	NT	Number of types of structure lumps
Card 37	(Type Data Cards)		
1-5	F5.0	WGTS	Weight of structure lump, lbs
6-10	I5	NCØNCS	Conductivity curve number
11-15	I5	NSHCS	Specific heat curve number

Columns	Format	Title	Description
Card 37 (Continued)			
16-20	I5	NFCTS	Number of structure lumps 'conducted to' by structure lumps of this type
21-25	I5	NFRTS	Number of structure lumps 'radiated to' by structure lumps of this type
26-35	F10.5	AERS	Area of surface for incident heat application, sq. in.
36-45	F10.5	FAC	Factor for dividing conduction distances. Routine sets to 1.0 is left blank.
66-70	I5	LTYPE	Type number

Card 38 (Conduction Data, required for all lumps conducted to by structure lumps of this type)

Columns	Format	Title	Description
1-5	F5.5	$R1_1$	Conduction data for structure lumps of this type to the first lump listed in the connections on the structure lump card
6-10	F5.5	$R2_1$	
.	.	.	.
.	.	.	.
.	.	.	.
61-65	F5.5	$R1_7$	
66-70	F5.5	$R2_7$	

Repeat Card 38 as needed.

Card 39 (Radiation Data, required for all lumps radiated to by structure lumps of this type)

Columns	Format	Title	Description
1-5	F5.0	FA1	Gray-body shape factor, FA(in^2), between structure lumps of this type and the first lump 'radiated to' listed in the connections on the structure lump cards.
.	.	.	.
.	.	.	.
.	.	.	.
66-70	F5.0	FA14	

Repeat Card 39 as needed.

Repeat Card 37 (followed by Cards 38 and 39, if needed) for each structure type.

Columns	Format	Title	Description
Card 40	(Structure Lump Cards)		
1-5	I5	LN	Lump number
6-10	I5	NTYPES	Type number
11-20	F10.5	STI	Initial temperature, °F
21-25	I5	NQICS	Incident heat curve number
26-30	I5	NTL1	First lump to which this structure lump has a connection either by conduction or radiation
.	.	.	.
.	.	.	.
.	.	.	.
66-70	I5	NTL9	Ninth lump to which this structure lump has a connection

Card 41	(Additional connections, if required)		
1-5	I5	NTL10	10th lump
.	.	.	.
.	.	.	.
.	.	.	.
66-70	I5	NTL23	23rd lump

The order of the connected lumps is the same as the order in which the conduction and radiation data were given on the corresponding type card.

Repeat Card 41 as needed to supply all lumps to which the structure lump has a connection.

Repeat Card 40 (followed by Card 41, if needed) for each structure lump.

5.7.5 LOCAL TEMPERATURE PERTURBATION DATA CARDS

Card 42			
1-5	I5	NLOCPT	Number of local temperature perturbations (LTP) (enter zero if none desired and omit Card 43)
Card 43			
1-5	I5	NSKIN	Skin area number = 1, Trunk = 2, Right arm = 3, Left arm = 4, Right leg = 5, Left leg = 6, Head

Columns	Format	Title	Description
Card 43 (Continued)			
			= 7, Right hand = 8, Left hand = 9, Right foot = 10, Left foot
6-10	I5	NNODE	Skin tube lump number (loc. pert. model)
11-15	I5	NUGNOD	Undergarment tube lump number (loc. pert. model) Zero if no undergarment over skin
16-20	I5	NFLUID	Fluid (gas) lump number (loc. pert. model) (Must be in tube 43)
21-25	I5	NLCGLP	LCG tube lump number (loc. pert. model)
26-30	I5	NLCGBS	LCG tube lump number of baseline EMU model corresponding to the skin area
31-35	I5	NKRDIFF	Diffusion factor curve number (Type 29)
36-40	I5	NKRSWT	Sweat factor curve number (Type 29)
41-45	I5	NKRHHH	Heat transfer factor curve number (Type 29)

5.7.6 HEAT LEAK DATA CARDS

Columns	Format	Title	Description
Card 44			
1-5	I5	NGRHL	Number of groups of heat leak calculations (Enter zero if none desired and omit Cards 45 and 46)
Card 45			
1-5	I5	NG1	Number of paths of heat leak in group 1
10-15	A6	ID1	Six character identification of group 1
Card 46			
1-4	I4	JNODE	J node number
5	A1	JTYPE	J node code T = tube node S = structure node

Columns	Format	Title	Description
Card 46 (Continued)			
6-10	I5	NCØND	Connection number for conduction value - has values 1 to n where n is the number of connections input on Card 34 or Card 40
11-15	I5	NRAD	Connection number for radiation value - has values 1 to n where n is the number of connections input on Card 34 or Card 40
16-19	I4	JNODE	J node number
20	A1	JTYPE	J node code T = tube node S = structure node
21-25	I5	NCØND	Connection number for conduction value - has values 1 to n where n is the number of connections input on Card 34 or Card 40
26-30	I5	NRAD	Connection number for radiation value - has values 1 to n where n is the number of connections input on Card 34 or Card 40

Two heat leak paths are input per card and Card 46 is repeated as necessary to supply NG1 paths. Repeat Card 45 followed by Card 46 as needed for NGRHL groups.

5.7.7 HEAT STORAGE DATA CARDS

Columns	Format	Title	Description
Card 47			
1-5	I5	NGRSH	Number of group of nodes for heat storage calculations (Enter zero if none desired and omit Cards 48 and 49)
Card 48			
1-5	I5	NGS1	Number of nodes in group 1
10-15	A6	IDS1	Six character identification of group 1
Card 49			
1-4	I4	NØDE1	First node number
5	A1	TYPE1	First node code F = fluid T = tube node S = structure node

Columns	Format	Title	Description
Card 49 (Continued)			
6-9	I4	NØDE2	Second node number
10	A1	TYPE2	Second node code F = fluid node T = tube node S = structure node

.
.
.

etc. through column 70

Repeat Card 49 as necessary until NGS1 nodes have been supplied. Repeat Card 48 followed by Card 49 for NGRSH groups.

5.7.8 HELMET AND VISOR DATA CARDS

Card 50

Columns	Format	Title	Description
1-5	I5	NHVPOS	Number of positions on helmet and visor (Enter zero if none desired and omit Card 51)

Card 51

Columns	Format	Title	Description
1-5	I5	NPOS	Position number
6-10	I5	NTYPE	Position type 1 - Sun visor 2 - Impact visor 3 - Top of helmet 4 - Pressure bubble 5 - Face
11-15	I5	NØDE1	Node number for Mode 1 (Both visors down)
16-20	I5	NR1	Incident IR flux curve number
21-25	I5	NS1	Incident solar flux curve number
26-30	I5	NØDE2	Node number for Mode 2 (Sun visor up)
31-35	I5	NR2	Incident IR flux curve number
36-40	I5	NS2	Incident solar flux curve number
41-45	I5	NØDE3	Node number for Mode 3 (Both visors up)
46-50	I5	NR3	Incident IR flux curve number
51-55	I5	NS3	Incident solar flux curve number

Repeat Card 51 NHVPOS times.

5.7.9 SUIT, GLOVES, AND EV BOOTS NODE IDENTIFICATION CARDS

Columns	Format	Title	Description
Card 52			
1-5	I5	NLMPID	Total number of structure node comprising suit, gloves, & boots (Enter zero if none desired and omit Card 53)
Card 53			
1-4	I4	LUMP	Node number
5	A1	IDEN	Identification code G = Glove node S = Suit node B = EV boot node

.
.
.
etc. through column 70

Repeat Card 53 as necessary to identify all suit, glove, and boot nodes.

5.7.10 CONFIGURATION/ASSOCIATED NODE IDENTIFICATION CARDS

Card 54			
1-5	I5	NLMPEN	Number of structure nodes to be identified with a configuration mode. (Enter zero if none desired and omit Card 55)
Card 55			
1-5	I5	LMP1	First structure node number
6-10	I5	NEN1	First configuration mode identification code

.
.
.
etc. through column 70

Repeat Card 55 as necessary to supply NLMPEN sets of node number and code.

5.7.11 HEAT FLUX CURVE ASSIGNMENT DATA CARDS (USED FOR TYPES 19 AND 20 ONLY)

Card 56			
1-5	I5	NNEVAH	Number of nodes with type 19 incident heat curves (Enter zero if none desired and omit Card 57)

Columns	Format	Title	Description
Card 57			
1-4	I4	NØDE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 19 incident heat curve number
11-14	I4	NØDE2	Second node number
15	A1	TYPE2	Second node code T = tube node S = structure node
16-20	I5	KURVE2	Second type 19 incident heat curve number

.
.
.
etc. through column 70

Repeat Card 57 as necessary to assign curve numbers to NNEVAH nodes.

Columns	Format	Title	Description
Card 58			
1-5	I5	NNEVAT	Number of nodes with type 20 contact temperature history curves (Enter zero if none desired and omit Card 59)
Card 59			
1-4	I4	NØDE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 20 contact temperature curve number
11-14	I4	NØDE2	Second node number
15	A1	TYPE2	Second node code T = tube node S = structure node

Columns	Format	Title	Description

Card 59 (Continued)

Columns	Format	Title	Description
16-20	I5	KURVE2	Second type 20 contact temperature curve number

.
.
.
etc. through column 70

Repeat Card 59 as necessary to assign curve numbers to NNEVAT nodes.

5.7.12 PRESCRIBED WALL TEMPERATURE DATA CARDS (USED FOR TYPES 10 AND 11 ONLY)

Card 60

Columns	Format	Title	Description
1-5	I5	NPRTEM	Number of lumps which have type 10 prescribed wall temperature curves (Enter zero if none desired and omit Card 61)

Card 61

Columns	Format	Title	Description
1-4	I4	NØDE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 10 prescribed temperature curve number
11-14	I4	NØDE2	Second node number
15	A1	TYPE2	Second node code
16-20	I5	KURVE2	Second type 10 prescribed temperature curve number

.
.
.
etc. through column 70

Repeat Card 61 as necessary to assign curve numbers to NPRTEM nodes.

Card 62 (LRV Prescribed Temperature Data Cards)

Columns	Format	Title	Description
1-5	I5	NPTLRV	Number of LRV structure lumps which have type 11 prescribed wall temperature curves (Enter zero if none desired and omit Card 63)

Columns	Format	Title	Description
Card 63			
1-5	I5	NØDE1	First node number
6-10	I5	KURVE1	First type 11 prescribed temperature curve number
11-15	I5	NØDE2	Second node number
16-20	I5	KURVE2	Second type 11 prescribed temperature curve number

.
.
.
etc. through column 70

5.7.13 TIME VARIANT NODE DATA CARDS

Card 64

1-5	I5	NUMTVW	Number of nodes with type 30 time variant mass (Enter zero if none desired and omit Card 65)

Card 65

1-4	I4	NØDE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 30 time variant mass factor curve number
11-14	I4	NØDE2	Second node number
15	A1	TYPE2	Second node code
16-20	I5	KURVE2	Second type 30 time variant mass factor curve number

.
.
.
etc. through column 70

Repeat Card 65 as necessary to assign curve numbers to NUMTVW nodes.

5.7.14 TIME VARIANT NODAL CONNECTION DATA CARDS

Columns	Format	Title	Description
Card 66			
1-5	I5	NUMTVC	Number of type 30 time variant connections (Enter zero if none desired and omit Card 67)
Card 67			
1-4	I4	NØDE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	NLØC1	Connection number - has values 1 to n where n is the number of connections input on Card 34 or Card 40
11-15	I5	KURVE1	Type 30 time variant multiplying factor curve number
16-19	I4	NØDE2	Second node number
20	A1	TYPE2	Second node code T = tube node S = structure node
21-25	I5	NLØC2	Connection number
26-30	I5	KURVE2	Type 30 time variant multiplying factor curve number

.
.
.
etc. through column 60

Repeat Card 67 as necessary to supply NUMTVC time variant connections.

5.7.15 SPECIAL TUBE/FLUID CONNECTION DATA CARDS

Columns	Format	Title	Description
Card 68			
1-5	I5	NSPCON	Number of special connections (Enter zero if none desired and omit Card 69)
Card 69			
1-5	I5	NFLDND1	Fluid lump number of special connection number 1

Columns	Format	Title	Description
Card 69 (Continued)			
6-10	I5	NTUBND1	Tube lump number of special connection number 1
11-20	F10.5	AREASP1	Area for heat transfer of special connection number 1
21-25	I5	NFLØND2	Fluid lump number of special connection number 2
26-30	I5	NTUBND2	Tube lump number of special connection number 2
31-40	F10.5	AREASP2	Area for heat transfer of special connection number 2
41-45	I5	NFLØND3	Fluid lump number of special connection number 3
46-50	I5	NTUBND3	Tube lump number of special connection number 3
51-70	F10.5	AREASP3	Area for heat transfer of special connection number 3

Repeat Card 69 as needed to input NSPCON sets of data.

5.7.16 CURVE DATA CARDS

Card 70 (Curve Header Card)

Columns	Format	Title	Description
1-5	I5	KCRV	Curve type
		0	Head loss coefficient = f (R_e)
		1	Fluid density, (lbm/ft^3) = f (°F)
		2	Fluid viscosity, $(\frac{lb_m}{ft^2 sec})$ = f (°F)
		3	Friction factor for fluid (used when Re> 2000) F = f (R_e)
		4	Conductivity, (K/K_i) = f (°F)
		5	Specific heat, $(Btu/lb_m\ °F)$ = f (°F)
		9	Incident heat, $(\frac{Btu}{hr\ ft^2})$ = f (hrs)
		10	Wall temp, °F = f (hrs)
		11	LRV wall temp, °F = f (hrs)
		12	Fluid temperature, °F = f (τ)
		19	Combined heat fluxes, (Btu/hr) = f (τ)
		20	Prescribed temperature histories, (°F) = f (τ)
		21	Radiant Interchange Mode 1. = Mode 1 2. = Mode 2 3. = Mode 3

Columns	Format	Title	Description
		24	HHH Curve, $\left(\frac{BTU}{hr\text{-}ft^{2}{}^{o}F}\right)$ = f (lb/hr)
		29	Local perturbation multiplying factor
		30	Time variant factors:
			Mass factor = f (τ)
			Connection factor = f (τ)
		33	Bivariant curves:
			Compressibility factor, Z = f (PR,TR)
			Oxygen enthalpy, h = f (P,T)
			LCG pressure drop, ΔP = f ($\dot{W}$,T)
			Sublimator water outlet temperature,
			T = f ($\dot{W}$,T_{in})
			Fan flowrate, $\dot{W}$ = f (P_{sys}, ΔP_{sys})
		34	Time variant curves:
			Suit leak rate, lb/hr = f (τ)
			Multiple water connector leak rate,
			lb/hr = f (τ)
			Metabolic load, Btu/hr = f (τ)
			Man efficiency, Percent/100 = f (τ)
			Suit gas pressure, psia = f (τ)
			Gravity factor, fraction = f (τ)
			Cabin freestream velocity, ft/min = f (τ)
			Cabin ventilation efficiency, percent/
			100 = f (τ)
			Cabin gas pressure, psia = f (τ)
			ARS suit flowrate, lb/hr = f (τ)
			LCG flowrate, lb/hr = f (τ)
		35	System control curves:
			Fan exit pressure, psia = f (τ)
			0. = fan off
			POS on/off = f (τ)
			0. = off
			1. = on
			Diverter valve position = f (τ)
			0. = pump off
			1. = maximum cooling
			2. = intermediate cooling
			3. = minimum cooling
			4. = automatic control
			Maximum sublimator heat load,
			Btu/hr = f (τ), zero load indicates
			feedwater shut off
			OPS flowrate, lb/hr = f (τ)
			zero indicates OPS off
			Helmet mode = f (τ)
			0. = LEVA off
			1. = both visors down
			2. = sun visor up
			3. = both visors up
			EMU configuration mode = f (τ)
			Auxiliary water reservoir shut-off valve
			0. = valve closed
			1. = valve open

Columns	Format	Title	Description
6-10	I5	NC	Curve number
11-15	I5	NP	Number of points on curve, if KCRV = 33 NP equal the number of independent variable input first
16-20	Blank except for KCRV = 33		
	I5	NTU	Number of independent variables input second
21-25	Blank		
26-72	7A6	CTITLE	May be used for curve title

Card 71	(If KCRV ≠ 33)		
1-10	F10.5	X_1	Independent variable
11-20	F10.5	X_2	
21-30	F10.5	X_3	
etc.			
	F10.5	Y_1	Dependent variable
	F10.5	Y_2	
	F10.5	Y_3	

etc.

Start Y_1 in the first field after X_{NP}. Do not write beyond column 70. If the number of points is 1, the value in columns 11-20 will be used for the dependent variable.

Card 71	(If KCRV = 33)		
1-5	F5.4	FR_1	Values of the first independent variable
6-10	F5.4	FR_2	
11-15	F5.4	FR_3	
etc.			
	F5.4	TU_1	Values of the second independent variable
	F5.4	TU_2	
	F5.4	TU_3	

etc.

Columns	Format	Title	Description
Card 71 (Continued)			
	F5.4	$P(FR_1,TU_1)$	Values of dependent variable
	F5.4	$P(FR_1,TU_2)$	
	F5.4	$P(FR_1,TU_3)$	
etc.			
	F5.4	$P(FR_2,TU_1)$	
	F5.4	$P(FR_2,TU_2)$	
	F5.4	$P(FR_2,TU_3)$	
etc.			
End of Data			
1-5	I5	LCD	Input the number 13

5.8 Output Description

An example of EMU Simulator paper printout is shown in Appendix B. An explanation of the terms appearing in the paper printout is given below with units where applicable.

Parameters Print

The beginning of a print interval is indicated by the output of the following parameters at the top of a page.

MISSION TIME	Mission time in hours
COMPUTER TIME	The amount of computer time used to this point in minutes
ROUTINE INTERATIONS	The current iteration number

Consumables and Man Print

Both of these printouts have sufficient descriptions and unit indications for the quantities printed as to be self-explanatory.

Heat Leak and Stored Heat Print

These occur only if such calculations were requested in the data (see Sections 5.7.6 and 5.7.7). The six character identification specified for each group is printed before the quantity. Six groups are printed per line. The units are BTU/hr for heat leak and BTU for stored heat.

Flow Rates

Flow rates are printed in numerical order for each flow tube. The units are lbs/hr. Ten flow rates are output on each line with the tube number of the tenth flow rate printed to the right of it.

Pressure Drops

Pressure drops are printed in numerical order for each flow tube. The units are psi. Ten pressure drops are printed out per line with the tube number of the tenth pressure drop printed out to the right of it.

Temperatures

The temperatures are grouped according to fluid, tube, and structure designations with each group printed in increasing numerical order. All the temperatures are printed in degrees Fahrenheit. The temperatures are printed ten per line with a wider space between the fifth and sixth temperatures and lump numbers at each end of the line to aid in locating lump temperatures.

6.0 LIST OF SYMBOLS

Alphabetic

A_f	Area for convective heat transfer, square inches
A_{ij}	Effective conduction or radiation area between lumps, square inches
c, c_p	Specific heat, BTU/lb-°F
CSA	Cross sectional area, square inches
D_h	Hydraulic diameter, inches
f	Friction factor used for turbulent or laminar flow pressure drop computations
(αA)	Gray-body configuration factor between lumps, square inches
FLL	Fluid lump length, inches
FRE	Factor applied to laminar flow friction factor to account for non-circular pipe flow
h_f, HHH	Heat transfer coefficient, BTU/hr-ft^2-°F
i	Lump number
j	Adjacent lump number
K	Fluid dynamic head losses
K	Thermal conductivity, BTU/hr-ft-°F
k_i	Thermal conductivity of a lump at the present temperature normalized by the thermal conductivity at which R_i was evaluated, e.g., K_i/K_{Ri} or K_j/K_{RJ}
L	Length from tube entrance, inches
Nu	Nusselt number
P	Pressure, psia
P_{SYS}	System pressure, psia
Pr	Prandtl number
$\dot{Q}$	Energy flux relative to a control volume

Re	Reynolds number
R_i, R_1	That portion of the conduction resistance from lump i to j which is attributed to i = $Y_j/K_j\ A_{ij}$, hr-°F/BTU
R_j, R_2	That portion of the conduction resistance from lump i to j which is attributed to j = $Y_j/K_j\ A_{ij}$, hr-°F/BTU
T	Temperature of a lump at time τ
T'	Temperature of a lump at time $\tau + \Delta\tau$
T'_{fu}	Upstream fluid lump temperature, °R
U_{ij}	Conductance between adjacent structure lumps, BTU/hr-°F
V	Fluid velocity, ft/sec
$\dot{w}$	Fluid flow rate, lb/hr
w	Weight of lump, lbs
WP	Wetted perimeter, inches
Y	A portion of the conduction path length between nodes, e.g., Y_i is that portion of the conduction path length between nodes i and j which lies in lump i

<u>Greek Symbols</u>

(αA)	Surface absorptance times incident heat application area, square inches
ΔP	Pressure drop, psi
$\Delta\tau$	Calculation time increment, hrs
σ	Stefan-Boltzmann constant $.173 \times 10^{-8}\ \frac{BTU}{hr\ ft^2(°R)^4}$
τ	Time, hours
μ	Fluid viscosity, lbs/ft-sec

<u>Subscripts</u>

f	Fluid lump
fu	Upstream fluid lump
i	Lump under consideration
j	Lump adjacent to lump i
t	Tube

7.0 REFERENCES

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APPENDIX A

The purpose of this Appendix is to present additional descriptive information on the baseline thermal model. Table A-1 is arranged in the order of increasing tube node number. Each tube node has the fluid node it encloses listed along with a brief node description or an identifying location. Tube nodes 110 through 116 and 236 through 241 do not show the suit ventilation gas node association made in Special Tube/Fluid Connection Data (Section 5.7.15).

Note that there is a difference in tube node numbers for MAN No. 1 and MAN No. 2. This designation refers to the BSLSS rescue simulation. MAN No. 1 data includes the BSLSS bag and umbilical nodes. The first 197 tube nodes and the first 625 structure nodes are identical for both Man 1 and 2 data tapes. LRV structure nodes are included on the Man No. 1 data tape.

TABLE A-1
EMU BASELINE MODEL NODAL BREAKDOWN DATA

TUBE NODE	FLUID NODE	LOCATION/DESCRIPTION
1	1	INVOLUTE FAN HOUSING
2	2	TUBE DOWNSTREAM OF FAN
3	3	VENTILATION GAS FLOW SENSOR
4	4	TUBE FROM VENT GAS SENSOR TO WELDED JUNCTION
5	5	TUBE FROM WELDED JUNCTION TO BACKFLOW CHECKVALVE
6	6	INLET OXYGEN UMBILICAL
7	7	CREWMAN HEAD SKIN
8	8	CREWMAN TRUNK SKIN
9	9	DUMMY (SUIT OUTLET)
10	10	CREWMAN SKIN RIGHT ARM
11	11	CREWMAN SKIN RIGHT HAND
12	12	CREWMAN SKIN RIGHT LEG
13	13	CREWMAN SKIN RIGHT FOOT
14	14	OUTLET OXYGEN UMBILICAL
15	15	LIOH CANISTER SHELL
16	16	SUBLIMATOR - GAS SIDE
17	17	TUBE BETWEEN SUBLIMATOR AND WATER SEPARATOR
18	18	WATER SEPARATOR
19	19	TUBE BETWEEN WATER SEPARATOR AND FAN (PART OF SEPARATOR)
20	20	TUBE BETWEEN POS TANK AND REGULATOR
21	21	POS REGULATOR
22	22	POS FLOW SENSOR
23	23	TUBE BETWEEN FLOW SENSOR AND PRESSURE SENSOR HOUSING
24	24	PRESSURE SENSOR HOUSING
25	25	TUBE DOWNSTREAM OF PRESSURE SENSOR HOUSING
26	26	TUBE WELDED TO VENT GAS TUBE, DOWNSTREAM OF VENT GAS SENSOR
27	27	WATER SEPARATOR DRAIN TUBE TO FIRST SPLICE JOINT
28	28	TUBE BETWEEN WATER SEPARATOR AND S/O VALVE BETWEEN SPLICE JOINT
29	29	WATER SEPARATOR DRAIN TUBE SECTION WELDED TO S/O VALVE
30	30	SUBLIMATOR FEEDWATER TUBE SECTION WELDED TO S/O VALVE
31	31	TUBE BETWEEN TUBE NODE 30 AND CHECK/RELIEF VALVE
32	32	TUBE BETWEEN CHECK/RELIEF VALVE AND DOWNSTREAM SPLICE JOINT
33	33	TUBE IMMEDIATELY UPSTREAM OF SUBLIMATOR IN FEEDWATER LOOP
34	34	TUBE BETWEEN CHECK/RELIEF VALVE AND TRANSPORT LOOP TUBING
35	35	DIFFERENTIAL TEMPERATURE TRANSDUCER
36	36	TUBE BETWEEN DIFF. TEMP. XDUCER AND PUMP
37	37	WATER PUMP

38	38	TEE DOWNSTREAM OF WATER PUMP
39	39	TUBE BETWEEN TEE AND WATER SIDE OF SUBLIMATOR
40	40	SUBLIMATOR - WATER SIDE
41	41	TUBE IMMEDIATELY DOWNSTREAM OF SUBLIMATOR IN TRANSPORT LOOP
42	42	TUBE BETWEEN SPLICE JOINT AND FAN MOTOR COOLANT TUBE
43	43	FAN MOTOR COOLANT TUBE
44	44	TUBE BETWEEN FAN MOTOR COOLANT AND SPLICE JOINT
45	45	TUBE BETWEEN SPLICE JOINTS DOWNSTREAM OF FAN MOTOR COOLANT TUBE
46	46	TUBE DOWNSTREAM OF TUBE NODE 45, WELDED TO DIVERTER VALVE
47	47	TUBE BETWEEN TEE AND DIVERTER VALVE SPLICE JOINTS
48	48	TUBE DOWNSTREAM OF TUBE 47, WELDED TO DIVERTER VALVE
49	49	DIVERTER VALVE
50	50	TUBE OUTLET TO DIVERTER VALVE, WELDED TO VALVE
51	51	DIFFERENTIAL TEMPERATURE TRANSDUCER
52	52	LCG INLET TEMPERATURE TRANSDUCER
53	53	LCG INLET UMBILICAL
54	54	LCG
55	55	LCG OUTLET UMBILICAL
56	56	OPS REGULATOR
57	57	TUBE BETWEEN OPS REGULATOR AND OPS UMBILICAL
58	58	OXYGEN BACKFLOW CHECK VALVE
59	59	OPS UMBILICAL
60	60	TUBE BETWEEN LIOH CANISTER AND SUBLIMATOR
61	61	CO2 SENSOR
62	7	PGA INTERIOR-NECK AREA
63	7	PGA INTERIOR-NECK AREA
64	8	PGA INTERIOR-TRUNK
65	8	PGA INTERIOR-TRUNK
66	8	PGA INTERIOR-TRUNK
67	8	PGA INTERIOR-TRUNK
68	8	PGA INTERIOR-TRUNK
69	8	PGA INTERIOR-TRUNK
70	114	PGA INTERIOR-LEFT ARM
71	10	PGA INTERIOR-RIGHT ARM
72	114	PGA INTERIOR-LEFT ARM
73	10	PGA INTERIOR-RIGHT ARM
74	10	PGA INTERIOR-RIGHT ARM
75	114	PGA INTERIOR-LEFT ARM
76	10	PGA INTERIOR-RIGHT ARM
77	114	PGA INTERIOR-LEFT ARM
78	11	PGA INTERIOR-RIGHT HAND
79	11	PGA INTERIOR-RIGHT HAND
80	115	PGA INTERIOR-LEFT HAND
81	115	PGA INTERIOR-LEFT HAND
82	81	UPSTREAM OF FAN (TUBE 15 REQUIRES 2 LUMPS)
83	7	PRESSURE BUBBLE

84	7	PRESSURE BUBBLE
85	7	PRESSURE BUBBLE
86	7	PRESSURE BUBBLE
87	7	PRESSURE BUBBLE
88	7	PRESSURE BUBBLE
89	7	PRESSURE BUBBLE
90	7	PRESSURE BUBBLE
91	7	PRESSURE BUBBLE
92	7	PRESSURE BUBBLE
93	7	PRESSURE BUBBLE
94	7	PRESSURE BUBBLE
95	7	PRESSURE BUBBLE
96	7	PRESSURE BUBBLE
97	7	PRESSURE BUBBLE
98	7	PRESSURE BUBBLE
99	62	TUBE BETWEEN S/O VALVE AND WATER RESERVOIR
100	63	TUBE BETWEEN WATER RESERVOIR AND S/O VALVE
101	64	WATER SHUT OFF AND RELIEF VALVE
102	65	DUMMY (NECESSARY)
103	66	OPS HEATER
104	67	DUMMY (NECESSARY) OPS
105	68	LIOH CANISTER INLET
106	69	LIOH CARTRIDGE
107	70	DUMMY (FIRST LUMP OF TUBE 9, ARS ENTRY POINT)
108	71	DUMMY (NECESSARY)
109	72	LCG TUBING IN CONTACT WITH TRANSPORT WATER
110	73	LCG TUBING IN CONTACT WITH TRANSPORT WATER
111	74	LCG TUBING IN CONTACT WITH TRANSPORT WATER
112	75	LCG TUBING IN CONTACT WITH TRANSPORT WATER
113	76	LCG TUBING IN CONTACT WITH TRANSPORT WATER
114	77	LCG TUBING IN CONTACT WITH TRANSPORT WATER
115	78	LCG TUBING IN CONTACT WITH TRANSPORT WATER
116	79	LCG TUBING IN CONTACT WITH TRANSPORT WATER
117	80	LCG TUBING IN CONTACT WITH TRANSPORT WATER
118	82	LOCAL PERTURBATIONS MODEL (SKIN)
119	82	LOCAL PERTURBATIONS MODEL (UNDERGARMENT)
120	82	LOCAL PERTURBATIONS MODEL (LCG)
121	7	PRESSURE BUBBLE
122	7	PRESSURE BUBBLE
123	7	PRESSURE BUBBLE
124	7	PRESSURE BUBBLE
125	7	PRESSURE BUBBLE
126	7	PRESSURE BUBBLE
127	7	PRESSURE BUBBLE
128	7	PRESSURE BUBBLE
129	7	PRESSURE BUBBLE
130	7	PRESSURE BUBBLE
131	7	PRESSURE BUBBLE
132	7	PRESSURE BUBBLE
133	7	PRESSURE BUBBLE
134	7	PRESSURE BUBBLE
135	7	PRESSURE BUBBLE
136	7	PRESSURE BUBBLE
137	7	PRESSURE BUBBLE
138	7	PRESSURE BUBBLE

139	7	PRESSURE BUBBLE
140	7	PRESSURE BUBBLE
141	7	PRESSURE BUBBLE
142	7	PRESSURE BUBBLE
143	7	PRESSURE BUBBLE
144	7	PRESSURE BUBBLE
145	7	PRESSURE BUBBLE
146	7	PRESSURE BUBBLE
147	7	PRESSURE BUBBLE
148	7	PRESSURE BUBBLE
149	7	PRESSURE BUBBLE
150	7	PRESSURE BUBBLE
151	7	PRESSURE BUBBLE
152	7	PRESSURE BUBBLE
153	7	PRESSURE BUBBLE
154	7	PRESSURE BUBBLE
155	7	PRESSURE BUBBLE
156	7	PRESSURE BUBBLE
157	7	PRESSURE BUBBLE
158	7	PRESSURE BUBBLE
159	7	PRESSURE BUBBLE
160	7	PRESSURE BUBBLE
161	7	PRESSURE BUBBLE
162	7	PRESSURE BUBBLE
163	7	PRESSURE BUBBLE
164	7	PRESSURE BUBBLE
165	7	PRESSURE BUBBLE
166	7	PRESSURE BUBBLE
167	12	PGA INTERIOR-RIGHT LEG
168	116	PGA INTERIOR-LEFT LEG
169	12	PGA INTERIOR-RIGHT LEG
170	116	PGA INTERIOR-LEFT LEG
171	12	PGA INTERIOR-RIGHT LEG
172	116	PGA INTERIOR-LEFT LEG
173	12	PGA INTERIOR-RIGHT LEG
174	116	PGA INTERIOR-LEFT LEG
175	13	PGA INTERIOR-RIGHT FOOT
176	117	PGA INTERIOR-LEFT FOOT
177	13	PGA INTERIOR-RIGHT FOOT
178	117	PGA INTERIOR-LEFT FOOT
179	13	PGA INTERIOR-RIGHT FOOT
180	117	PGA INTERIOR-LEFT FOOT
181	8	PGA ELECTRICAL CONNECTOR
182	8	MULTIPLE WATER CONNECTOR, INLET
183	8	OPS OXYGEN INLET CONNECTOR
184	8	PLSS OXYGEN INLET CONNECTOR
185	8	OXYGEN PURGE VALVE
186	8	PLSS OXYGEN OUTLET CONNECTOR
187	10	SUIT PRESSURE GAGE
188	10	SUIT PRESSURE RELIEF VALVE
189	8	MULTIPLE WATER CONNECTOR, OUTLET
190	8	UNDERGARMENT (TRUNK)
191	10	UNDERGARMENT-RIGHT ARM
192	12	UNDERGARMENT-RIGHT LEG
193	13	UNDERGARMENT-RIGHT FOOT

	194	7	NECKRING (LEFT FRONT)
	195	7	NECKRING (LEFT REAR)
	196	7	NECKRING (RIGHT FRONT)
	197	7	NECKRING (RIGHT REAR)
MAN NO. 1	198	83	SLSS UMBILICAL (SUPPLY)
	199	84	SLSS UMBILICAL (SUPPLY)
	200	85	SLSS UMBILICAL (SUPPLY)
	201	86	SLSS UMBILICAL (SUPPLY)
	202	87	SLSS UMBILICAL (SUPPLY)
	203	88	SLSS UMBILICAL (SUPPLY)
	204	89	SLSS UMBILICAL (SUPPLY)
	205	90	SLSS UMBILICAL (SUPPLY)
	206	91	SLSS UMBILICAL (SUPPLY)
	207	92	SLSS UMBILICAL (SUPPLY)
	208	93	SLSS UMBILICAL (SUPPLY)
	209	94	SLSS UMBILICAL (SUPPLY)
	210	95	SLSS UMBILICAL (SUPPLY)
	211	96	SLSS UMBILICAL (SUPPLY)
	212	97	SLSS UMBILICAL (SUPPLY)
	213	98	SLSS UMBILICAL (RETURN)
	214	99	SLSS UMBILICAL (RETURN)
	215	100	SLSS UMBILICAL (RETURN)
	216	101	SLSS UMBILICAL (RETURN)
	217	102	SLSS UMBILICAL (RETURN)
	218	103	SLSS UMBILICAL (RETURN)
	219	104	SLSS UMBILICAL (RETURN)
	220	105	SLSS UMBILICAL (RETURN)
	221	106	SLSS UMBILICAL (RETURN)
	222	107	SLSS UMBILICAL (RETURN)
	223	108	SLSS UMBILICAL (RETURN)
	224	109	SLSS UMBILICAL (RETURN)
	225	110	SLSS UMBILICAL (RETURN)
	226	111	SLSS UMBILICAL (RETURN)
	227	112	SLSS UMBILICAL (RETURN)
	228	113	GAS SEPARATOR
	229	114	UNDERGARMENT LEFT ARM
	230	116	UNDERGARMENT LEFT LEG
	231	117	UNDERGARMENT LEFT FOOT
	232	114	CREWMAN SKIN LEFT ARM
	233	116	CREWMAN SKIN LEFT LEG
	234	117	CREWMAN SKIN LEFT FOOT
	235	115	CREWMAN SKIN LEFT HAND
	236	118	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	237	119	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	238	120	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	239	121	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	240	122	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	241	123	LCG TUBING IN CONTACT WITH TRANSPORT WATER

MAN NO. 2	198	83	GAS SEPARATOR
	199	84	UNDERGARMENT LEFT ARM
	200	86	UNDERGARMENT LEFT LEG
	201	87	UNDERGARMENT LEFT FOOT
	202	84	CREWMAN SKIN LEFT ARM
	203	86	CREWMAN SKIN LEFT LEG
	204	87	CREWMAN SKIN LEFT FOOT
	205	85	CREWMAN SKIN LEFT HAND
	206	88	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	207	89	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	208	90	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	209	91	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	210	92	LCG TUBING IN CONTACT WITH TRANSPORT WATER
	211	93	LCG TUBING IN CONTACT WITH TRANSPORT WATER

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TABLE A-2
EMU BASELINE MODEL NODAL BREAKDOWN DATA

STRUCTURE NODE	LOCATION/DESCRIPTION
1	LEVA THERMAL COVER
2	LEVA THERMAL COVER
3	LEVA THERMAL COVER
4	LEVA THERMAL COVER
5	LEVA THERMAL COVER
6	LEVA THERMAL COVER
7	LEVA THERMAL COVER
8	LEVA THERMAL COVER
9	LEVA THERMAL COVER
10	LEVA THERMAL COVER
11	SUN VISOR (HELMET MODE 1)
12	SUN VISOR (HELMET MODE 1)
13	SUN VISOR (HELMET MODE 1)
14	SUN VISOR (HELMET MODE 1)
15	SUN VISOR (HELMET MODE 1)
16	SUN VISOR (HELMET MODE 1)
17	PROTECTIVE VISOR (HELMET MODE 1)
18	PROTECTIVE VISOR (HELMET MODE 1)
19	PROTECTIVE VISOR (HELMET MODE 1)
20	PROTECTIVE VISOR (HELMET MODE 1)
21	PROTECTIVE VISOR (HELMET MODE 1)
22	PROTECTIVE VISOR (HELMET MODE 1)
23	FAN SWITCH, RCU
24	PUMP SWITCH, RCU
25	SELECTOR SWITCH, RCU
26	VOLUME CONTROL POTENTIOMETER, RCU
27	RCU HARDSHELL
28	RCU HARDSHELL
29	RCU HARDSHELL
30	RCU HARDSHELL
31	RCU HARDSHELL
32	RCU HARDSHELL
33	ELECTRICAL UMBILICAL, RCU
34	RCU THERMAL COVER
35	RCU THERMAL COVER
36	RCU THERMAL COVER
37	RCU THERMAL COVER
38	RCU THERMAL COVER
39	ITMG EXTERIOR
40	ITMG EXTERIOR
41	ITMG EXTERIOR
42	ITMG EXTERIOR
43	ITMG EXTERIOR
44	ITMG EXTERIOR
45	ITMG EXTERIOR
46	ITMG EXTERIOR
47	ITMG EXTERIOR
48	ITMG EXTERIOR
49	ITMG EXTERIOR
50	ITMG EXTERIOR

51	ITMG EXTERIOR
52	ITMG EXTERIOR
53	ITMG EXTERIOR
54	ITMG EXTERIOR
55	ITMG EXTERIOR
56	ITMG EXTERIOR
57	ITMG EXTERIOR
58	ITMG EXTERIOR
59	ITMG EXTERIOR
60	ITMG INSULATION
61	ITMG INSULATION
62	ITMG INSULATION
63	ITMG INSULATION
64	ITMG INSULATION
65	ITMG INSULATION
66	ITMG INSULATION
67	ITMG INSULATION
68	ITMG INSULATION
69	ITMG INSULATION
70	ITMG INSULATION
71	ITMG INSULATION
72	ITMG INSULATION
73	ITMG INSULATION
74	ITMG INSULATION
75	ITMG INSULATION
76	ITMG INSULATION
77	ITMG INSULATION
78	ITMG INSULATION
79	ITMG INSULATION
80	ITMG INSULATION
81	ITMG INTERIOR
82	ITMG INTERIOR
83	ITMG INTERIOR
84	ITMG INTERIOR
85	ITMG INTERIOR
86	ITMG INTERIOR
87	ITMG INTERIOR
88	ITMG INTERIOR
89	ITMG INTERIOR
90	ITMG INTERIOR
91	ITMG INTERIOR
92	ITMG INTERIOR
93	ITMG INTERIOR
94	ITMG INTERIOR
95	ITMG INTERIOR
96	ITMG INTERIOR
97	ITMG INTERIOR
98	ITMG INTERIOR
99	ITMG INTERIOR
100	ITMG INTERIOR
101	ITMG INTERIOR
102	RCU THERMAL INSULATION
103	OPS ACTIVATION SWITCH BRACKET (RCU MOUNTED)
104	OPS OXYGEN TANK, LEFT
105	OPS OXYGEN TANK, RIGHT

106	OPS FRAME
107	OPS PLATE
108	OPS (DUMMY)
109	OPS (DUMMY)
110	OPS OXYGEN TANK SUPPORT
111	OPS OXYGEN TANK SUPPORT
112	OPS FRAME
113	OPS FRAME
114	OPS FRAME
115	OPS FRAME
116	OPS FRAME
117	OPS FRAME
118	OPS FRAME
119	OPS FRAME
120	OPS FRAME
121	OPS HARDSHELL (BACK)
122	OPS HARDSHELL (L.S.)
123	OPS HARDSHELL (R.S.)
124	OPS HARDSHELL (TOP)
125	OPS THERMAL COVER (BACK INTERIOR)
126	OPS THERMAL COVER (L.S. INTERIOR)
127	OPS THERMAL COVER (R.S. INTERIOR)
128	OPS THERMAL COVER (TOP INTERIOR)
129	OPS THERMAL COVER (FRONT INTERIOR)
130	OPS THERMAL COVER (BACK EXTERIOR)
131	OPS THERMAL COVER (L.S. EXTERIOR)
132	OPS THERMAL COVER (R.S. EXTERIOR)
133	OPS THERMAL COVER (TOP EXTERIOR)
134	OPS THERMAL COVER (FRONT EXTERIOR)
135	OPS HARDSHELL (FRONT)
136	EVCS
137	OXYGEN BOTTLE SHIELD
138	FAN MOTOR
139	UPPER CONFORMAL PAD
140	LOWER CONFORMAL PAD
141	MAIN POWER SUPPLY
142	PLSS HARDSHELL MOUNTING BRACKET
143	PLSS HARDSHELL MOUNTING BRACKET
144	RCU ELECTRICAL UMBILICAL CONNECTOR
145	PLSS SWITCH BRACKET
146	PLSS HARDSHELL (BOTTOM)
147	PLSS HARDSHELL (R.S.)
148	PLSS HARDSHELL (L.S.)
149	PLSS HARDSHELL (LOWER BACK)
150	SPACE NODE
151	PLSS HARDSHELL (UPPER BACK)
152	PLSS HARDSHELL (R.S. TOP)
153	PLSS HARDSHELL (L.S. TOP)
154	PLSS THERMAL COVER (BOT. INTERIOR)
155	PLSS THERMAL COVER (BOT. EXTERIOR)
156	PLSS THERMAL COVER (L.S. INTERIOR)
157	PLSS THERMAL COVER (L.S. EXTERIOR)
158	PLSS THERMAL COVER (R.S. INTERIOR)
159	PLSS THERMAL COVER (R.S. EXTERIOR)
160	PLSS THERMAL COVER (LOWERBACK INTERIOR)

161	PLSS THERMAL COVER (LOWERBACK EXTERIOR)
162	PLSS THERMAL COVER (UPPER BACK INTERIOR)
163	PLSS THERMAL COVER (UPPER BACK EXTERIOR)
164	PLSS THERMAL COVER (TOP INTERIOR)
165	PLSS THERMAL COVER (TOP EXTERIOR)
166	TERMINAL BOX A-1
167	TERMINAL BOX A-2
168	WATER RESERVOIR ASSY
169	WATER PUMP MOTOR
170	WATER RESERVOIR CAP
171	PRIMARY OXYGEN BOTTLE
172	OXYGEN IN PRIMARY OXYGEN BOTTLE
173	OXYGEN IN LEFT HAND OPS BOTTLE
174	OXYGEN IN RIGHT HAND OPS BOTTLE
175	WATER IN WATER RESERVOIR ASSY
176	OPS THERMAL COVER (BOTTOM INTERIOR)
177	OPS THERMAL COVER (BOTTOM EXTERIOR)
178	FLOOR
179	PLSS THERMAL COVER (FRONT EXTERIOR)
180	PLSS THERMAL COVER (FRONT INSULATION)
181	SUN VISOR (HELMET MODE 2)
182	SUN VISOR (HELMET MODE 2)
183	SUN VISOR (HELMET MODE 2)
184	SUN VISOR (HELMET MODE 2)
185	SUN VISOR (HELMET MODE 2)
186	SUN VISOR (HELMET MODE 2)
187	PROTECTIVE VISOR (HELMET MODE 2)
188	PROTECTIVE VISOR (HELMET MODE 2)
189	PROTECTIVE VISOR (HELMET MODE 2)
190	PROTECTIVE VISOR (HELMET MODE 2)
191	PROTECTIVE VISOR (HELMET MODE 2)
192	PROTECTIVE VISOR (HELMET MODE 2)
193	SUN VISOR (HELMET MODE 3)
194	SUN VISOR (HELMET MODE 3)
195	SUN VISOR (HELMET MODE 3)
196	SUN VISOR (HELMET MODE 3)
197	SUN VISOR (HELMET MODE 3)
198	SUN VISOR (HELMET MODE 3)
199	PROTECTIVE VISOR (HELMET MODE 3)
200	PROTECTIVE VISOR (HELMET MODE 3)
201	PROTECTIVE VISOR (HELMET MODE 3)
202	PROTECTIVE VISOR (HELMET MODE 3)
203	PROTECTIVE VISOR (HELMET MODE 3)
203	PROTECTIVE VISOR (HELMET MODE 3)
204	PROTECTIVE VISOR (HELMET MODE 3)
205	LEVA THERMAL COVER (HELMET MODE 2)
206	LEVA THERMAL COVER (HELMET MODE 2)
207	LEVA THERMAL COVER (HELMET MODE 2)
208	LEVA THERMAL COVER (HELMET MODE 2)
209	LEVA THERMAL COVER (HELMET MODE 2)
210	LEVA THERMAL COVER (HELMET MODE 2)
211	DEEP SPACE(HELMENT MODE 2)
212	DEEP SPACE(HELMENT MODE 1)
213	PLSS MOUNTING PLATE R.S.
214	PLSS MOUNTING PLATE L.S.

215	DUMMY
216	DUMMY
217	PGA EXTERIOR
218	PGA EXTERIOR
219	PGA EXTERIOR
220	PGA EXTERIOR
221	PGA EXTERIOR
222	PGA EXTERIOR
223	PGA EXTERIOR
224	PGA EXTERIOR
225	PGA EXTERIOR
226	PGA EXTERIOR
227	PGA EXTERIOR
228	PGA EXTERIOR
229	PGA EXTERIOR
230	PGA EXTERIOR
231	PGA EXTERIOR
232	PGA EXTERIOR
233	PGA EXTERIOR
234	PGA EXTERIOR
235	PGA EXTERIOR
236	PGA EXTERIOR
237	PGA EXTERIOR
238	SUN VISOR (HELMET MODE 1)
239	SUN VISOR (HELMET MODE 1)
240	SUN VISOR (HELMET MODE 1)
241	SUN VISOR (HELMET MODE 1)
242	SUN VISOR (HELMET MODE 1)
243	SUN VISOR (HELMET MODE 1)
244	SUN VISOR (HELMET MODE 1)
245	SUN VISOR (HELMET MODE 1)
246	SUN VISOR (HELMET MODE 1)
247	SUN VISOR (HELMET MODE 1)
248	SUN VISOR (HELMET MODE 1)
249	SUN VISOR (HELMET MODE 1)
250	SUN VISOR (HELMET MODE 1)
251	SUN VISOR (HELMET MODE 1)
252	SUN VISOR (HELMET MODE 1)
253	SUN VISOR (HELMET MODE 1)
254	SUN VISOR (HELMET MODE 1)
255	SUN VISOR (HELMET MODE 1)
256	SUN VISOR (HELMET MODE 2)
257	SUN VISOR (HELMET MODE 2)
258	SUN VISOR (HELMET MODE 2)
259	SUN VISOR (HELMET MODE 2)
260	SUN VISOR (HELMET MODE 2)
261	SUN VISOR (HELMET MODE 2)
262	SUN VISOR (HELMET MODE 2)
263	SUN VISOR (HELMET MODE 2)
264	SUN VISOR (HELMET MODE 2)
265	SUN VISOR (HELMET MODE 2)
266	SUN VISOR (HELMET MODE 2)
267	SUN VISOR (HELMET MODE 2)
268	SUN VISOR (HELMET MODE 2)
269	SUN VISOR (HELMET MODE 2)

270	SUN VISOR (HELMET MODE 2)
271	SUN VISOR (HELMET MODE 2)
272	SUN VISOR (HELMET MODE 2)
273	SUN VISOR (HELMET MODE 2)
274	SUN VISOR (HELMET MODE 3)
275	SUN VISOR (HELMET MODE 3)
276	SUN VISOR (HELMET MODE 3)
277	SUN VISOR (HELMET MODE 3)
278	SUN VISOR (HELMET MODE 3)
279	SUN VISOR (HELMET MODE 3)
280	SUN VISOR (HELMET MODE 3)
281	SUN VISOR (HELMET MODE 3)
282	SUN VISOR (HELMET MODE 3)
283	SUN VISOR (HELMET MODE 3)
284	SUN VISOR (HELMET MODE 3)
285	SUN VISOR (HELMET MODE 3)
286	SUN VISOR (HELMET MODE 3)
287	SUN VISOR (HELMET MODE 3)
288	SUN VISOR (HELMET MODE 3)
289	SUN VISOR (HELMET MODE 3)
290	SUN VISOR (HELMET MODE 3)
291	SUN VISOR (HELMET MODE 3)
292	PLSS THERMAL COVER (FRONT INTERIOR)
293	PROTECTIVE VISOR (HELMET MODE 1)
294	PROTECTIVE VISOR (HELMET MODE 1)
295	PROTECTIVE VISOR (HELMET MODE 1)
296	PROTECTIVE VISOR (HELMET MODE 1)
297	PROTECTIVE VISOR (HELMET MODE 1)
298	PROTECTIVE VISOR (HELMET MODE 1)
299	PROTECTIVE VISOR (HELMET MODE 1)
300	PROTECTIVE VISOR (HELMET MODE 1)
301	PROTECTIVE VISOR (HELMET MODE 1)
302	PROTECTIVE VISOR (HELMET MODE 1)
303	PROTECTIVE VISOR (HELMET MODE 1)
304	PROTECTIVE VISOR (HELMET MODE 1)
305	PROTECTIVE VISOR (HELMET MODE 1)
306	PROTECTIVE VISOR (HELMET MODE 1)
307	PROTECTIVE VISOR (HELMET MODE 1)
308	PROTECTIVE VISOR (HELMET MODE 1)
309	PROTECTIVE VISOR (HELMET MODE 1)
310	PROTECTIVE VISOR (HELMET MODE 1)
311	PROTECTIVE VISOR (HELMET MODE 2)
312	PROTECTIVE VISOR (HELMET MODE 2)
313	PROTECTIVE VISOR (HELMET MODE 2)
314	PROTECTIVE VISOR (HELMET MODE 2)
315	PROTECTIVE VISOR (HELMET MODE 2)
316	PROTECTIVE VISOR (HELMET MODE 2)
317	PROTECTIVE VISOR (HELMET MODE 2)
318	PROTECTIVE VISOR (HELMET MODE 2)
319	PROTECTIVE VISOR (HELMET MODE 2)
320	PROTECTIVE VISOR (HELMET MODE 2)
321	PROTECTIVE VISOR (HELMET MODE 2)
322	PROTECTIVE VISOR (HELMET MODE 2)
323	PROTECTIVE VISOR (HELMET MODE 2)
324	PROTECTIVE VISOR (HELMET MODE 2)

325	PROTECTIVE VISOR (HELMET MODE 2)
326	PROTECTIVE VISOR (HELMET MODE 2)
327	PROTECTIVE VISOR (HELMET MODE 2)
328	PROTECTIVE VISOR (HELMET MODE 2)
329	PROTECTIVE VISOR (HELMET MODE 3)
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345	PROTECTIVE VISOR (HELMET MODE 3)
346	PROTECTIVE VISOR (HELMET MODE 3)
347	LEVA SHELL
348	LEVA SHELL
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384	LEVA SHELL
385	LEVA THERMAL COVER
386	LEVA THERMAL COVER
387	LEVA THERMAL COVER
388	LEVA THERMAL COVER
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405	LEVA THERMAL COVER
406	LEVA THERMAL COVER
407	ITMG EXTERIOR
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460	ITMG EXTERIOR
461	ITMG EXTERIOR
462	ITMG EXTERIOR
463	ITMG EXTERIOR
464	ITMG EXTERIOR
465	ITMG EXTERIOR
466	BOOT SOLE
467	ITMG EXTERIOR
468	ITMG EXTERIOR
469	ITMG EXTERIOR
470	ITMG EXTERIOR
471	ITMG EXTERIOR
472	ITMG EXTERIOR
473	BOOT SOLE
474	SUIT ELECTRICAL CONNECTOR (EXTERIOR)
475	LCG WATER CONNECTOR (EXTERIOR)
476	RIGHT HAND INLET O2 CONNECTOR (EXTERIOR)
477	LEFT HAND INLET O2 CONNECTOR (EXTERIOR)
478	RIGHT HAND OUTLET O2 CONNECTOR (EXTERIOR)
479	LEFT HAND OUTLET O2 CONNECTOR (EXTERIOR)
480	SUIT PRESSURE GAGE THERMAL COVER (EXTERIOR)
481	SUIT RELIEF VALVE THERMAL COVER (EXTERIOR)
482	ITMG INSULATION
483	ITMG INSULATION
484	ITMG INSULATION
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561	PGA EXTERIOR
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571	PGA EXTERIOR
572	PGA EXTERIOR
573	SUIT PRESSURE GAGE THERMAL COVER INSULATION
574	SUIT PRESSURE GAGE THERMAL COVER INTERIOR
575	SUIT PRESSURE GAGE
576	SUIT RELIEF VALVE THERMAL COVER INSULATION
577	SUIT RELIEF VALVE THERMAL COVER INTERIOR
578	SUIT RELIEF VALVE
579	OPS O2 UMBILICAL SHEATH EXTERIOR
580	OPS O2 UMBILICAL SHEATH INSULATION
581	OPS O2 UMBILICAL SHEATH INTERIOR
582	OPS O2 UMBILICAL SHEATH EXTERIOR
583	OPS O2 UMBILICAL SHEATH INSULATION
584	OPS O2 UMBILICAL SHEATH INTERIOR
585	OPS O2 UMBILICAL SHEATH EXTERIOR
586	OPS O2 UMBILICAL SHEATH INSULATION
587	OPS O2 UMBILICAL SHEATH INTERIOR
588	RCU ELECTRICAL UMBILICAL SHEATH EXTERIOR
589	RCU ELECTRICAL UMBILICAL SHEATH INSULATION
590	RCU ELECTRICAL UMBILICAL SHEATH INTERIOR
591	RCU ELECTRICAL UMBILICAL SHEATH EXTERIOR
592	RCU ELECTRICAL UMBILICAL SHEATH INSULATION
593	RCU ELECTRICAL UMBILICAL SHEATH INTERIOR
594	RCU ELECTRICAL UMBILICAL SHEATH EXTERIOR
595	RCU ELECTRICAL UMBILICAL SHEATH INSULATION
596	RCU ELECTRICAL UMBILICAL SHEATH INTERIOR
597	SUIT O2 INLET UMBILICAL SHEATH EXTERIOR
598	SUIT O2 INLET UMBILICAL SHEATH INSULATION
599	SUIT O2 INLET UMBILICAL SHEATH INTERIOR

	600	SUIT O2 INLET UMBILICAL SHEATH EXTERIOR
	601	SUIT O2 INLET UMBILICAL SHEATH INSULATION
	602	SUIT O2 INLET UMBILICAL SHEATH INTERIOR
	603	SUIT O2 INLET UMBILICAL SHEATH EXTERIOR
	604	SUIT O2 INLET UMBILICAL SHEATH INSULATION
	605	SUIT O2 INLET UMBILICAL SHEATH INTERIOR
	606	SUIT O2 OUTLET UMBILICAL SHEATH EXTERIOR
	607	SUIT O2 OUTLET UMBILICAL SHEATH INSULATION
	608	SUIT O2 OUTLET UMBILICAL SHEATH INTERIOR
	609	SUIT O2 OUTLET UMBILICAL SHEATH EXTERIOR
	610	SUIT O2 OUTLET UMBILICAL SHEATH INSULATION
	611	SUIT O2 OUTLET UMBILICAL SHEATH INTERIOR
	612	SUIT O2 OUTLET UMBILICAL SHEATH EXTERIOR
	613	SUIT O2 OUTLET UMBILICAL SHEATH INSULATION
	614	SUIT O2 OUTLET UMBILICAL SHEATH INTERIOR
	615	LCG UMBILICAL SHEATH EXTERIOR
	616	LCG UMBILICAL SHEATH INSULATION
	617	LCG UMBILICAL SHEATH INTERIOR
	618	LCG UMBILICAL SHEATH EXTERIOR
	619	LCG UMBILICAL SHEATH INSULATION
	620	LCG UMBILICAL SHEATH INTERIOR
	621	LCG UMBILICAL SHEATH EXTERIOR
	622	LCG UMBILICAL SHEATH INSULATION
	623	LCG UMBILICAL SHEATH INTERIOR
	624	ITMG INTERIOR
	625	PGA EXTERIOR
MAN NO. 1	626	SLSS STORAGE BAG TOP EXTERIOR
	627	SLSS STORAGE BAG BOTTOM EXTERIOR
	628	SLSS STORAGE BAG LEFT SIDE EXTERIOR
	629	SLSS STORAGE BAG RIGHT SIDE EXTERIOR
	630	SLSS STORAGE BAG BACK EXTERIOR
	631	SLSS STORAGE BAG FRONT EXTERIOR
	632	SLSS STORAGE BAG TOP INTERIOR
	633	SLSS STORAGE BAG BOTTOM INTERIOR
	634	SLSS STORAGE BAG LEFT SIDE INTERIOR
	635	SLSS STORAGE BAG RIGHT SIDE INTERIOR
	636	SLSS STORAGE BAG BACK INTERIOR
	637	SLSS STORAGE BAG FRONT INTERIOR
	638	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
	639	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
	640	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
	641	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
	642	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
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	651	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
	652	SLSS (STOWED) UMBILICAL SHEATH (EXTERIOR)
	653	SLSS UMBILICAL SHEATH (INTERIOR)
	654	SLSS UMBILICAL SHEATH (INTERIOR)

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665	SLSS UMBILICAL SHEATH (INTERIOR)
666	SLSS UMBILICAL SHEATH (INTERIOR)
667	SLSS UMBILICAL SHEATH (INTERIOR)
668	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
669	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
670	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
671	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
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677	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
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680	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
681	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
682	SLSS (DEPLOYED) UMBILICAL SHEATH (EXTERIOR)
683	AUXILIARY WATER RESERVOIR
684	AUXILIARY WATER RESERVOIR SHUT/OFF VALVE
685	ALARM SYSTEM PACKAGE
686	AUXILIARY WATER RESERVOIR WATER
687	WHEEL RIGHT FRONT,FACING LRV
688	WHEEL RIGHT REAR ,FACING LRV
689	WHEEL LEFT REAR ,FACING LRV
690	WHEEL LEFT FRONT,FACING LRV
691	FENDER RIGHT FRONT,FACING LRV
692	FENDER RIGHT REAR ,FACING LRV
693	FENDER LEFT REAR ,FACING LRV
694	FENDER LEFT FRONT,FACING LRV
695	DISPLAY CONSOLE,FORWARD TPP
696	DISPLAY CONSOLE,BACK
697	DISPLAY CONSOLE,LEFT SIDE
698	DISPLAY CONSOLE,RIGHT SIDE
699	CONTROL BOX,TOP
700	CONTROL BOX,LEFT SIDE
701	CONTROL BOX,RIGHT SIDE
702	CONTROL BOX,BACK
703	FORWARD EQUIP. SECTION,LEFT SIDE
704	FORWARD EQUIP. SECTION,BACK
705	FORWARD EQUIP. SECTION,RIGHT SIDE
706	FORWARD EQUIP. SECTION,TOP
707	DISPLAY CONSOLE HANDHOLD
708	LEFT SEAT HANDHOLD
709	FOOTREST

	710	TV CAMERA,TOP
	711	TV CAMERA,LEFT SIDE
	712	TV CAMERA,BACK
	713	T-HANDLE
	714	ARM REST
	715	LCRU RIGHT SIDE
	716	LCRU LEFT SIDE
	717	LCRU TOP
	718	PANEL CENTER CHASSIS TOP
	719	PANEL REAR CHASSIS TOP
	720	TOOL BOX FRONT,MAN NO. 1
	721	TOOL BOX TOP,MAN NO. 1
	722	NO. 2 MAN,PLSS-OPS,LEFT SIDE
	723	NO. 2 MAN,PLSS BACK
	724	NO. 2 MAN,VISOR
	725	NO. 2 MAN,LEVA
	726	NO. 2 MAN,SHOULDER
	727	NO. 2 MAN,CHEST
	728	NO. 2 MAN,ARM AND SIDE
	729	NO. 2 MAN, LAP
	730	NO. 2 MAN,LEG
	731	NO. 2 MAN,SHIN
	732	NO. 2 MAN,CALF
	733	NO. 2 MAN,TOE
	734	PAYLOAD TOP
	735	PAYLOAD FRONT
	736	PAYLOAD LEFT SIDE
	737	ANTENNA
	738	SEAT BELT,SIDE
	739	SEAT BELT,TOP
	740	BSLSS REAR SURFACE
	741	EMU SEAT TOP SURFACE
	742	EMU SEAT BACK,REAR SURFACE
	743	EMU SEAT BACK,FRONT SURFACE
	744	EMU SEAT ,BOTTOM SURFACE
	745	NO. 2 EMU SEAT BACK,REAR SURFACE
MAN NO. 2	626	AUXILIARY WATER RESERVOIR
	627	AUXILIARY WATER RESERVOIR SHUT/OFF VALVE
	628	ALARM SYSTEM PACKAGE
	629	AUXILIARY WATER RESERVOIR WATER
00112		

APPENDIX B

SPECIAL RUN TO SAVE E TAPE

MISSION TIME= 3.5000 HOURS COMPUTER TIME= 5.805 MINUTES ROUTINE ITERATIONS= 40

CONSUMABLES

OXYGEN IN OPS BOTTLES(LB)	5.7000	PRESSURE IN OPS BOTTLES(PSI)	5916.4661
OXYGEN IN PRIMARY BOTTLE(LB)	1.8500	PRESSURE IN PRIMARY BOTTLE(PSI)	1426.3573
CONDENSATION RATE IN TUBE 11(LB/HR)	.0029	TOTAL CONDENSATION IN TUBE 11(LB)	.0030
CONDENSATION RATE IN TUBE 12(LB/HR)	.0621	TOTAL CONDENSATION IN TUBE 12(LB)	.0164
USABLE WATER IN RESERVOIR(LB)	8.0000	UNUSABLE WATER IN RESERVOIR(LB)	.4510
USABLE WATER IN AUXILIARY RESERVOIR(LB)	2.9200	UNUSABLE WATER IN AUXILIARY RESERVOIR(LB)	.1400
LITHIUM HYDROXIDE IN CANISTER(LB)	3.0945	SUBLIMATOR HEAT LOAD(BTU/HR)	.0000

MAN TEMPERATURES(DEGREES F)

HEAD CORE	98.002	HEAD MUSCLE	95.880	HEAD FAT	93.681	HEAD SKIN	92.098
TRUNK CORE	98.682	TRUNK MUSCLE	98.348	TRUNK FAT	94.598	TRUNK SKIN	91.278
RT. ARM CORE	96.338	RT. ARM MUSCLE	95.987	RT. ARM FAT	92.729	RT. ARM SKIN	91.661
LT. ARM CORE	96.338	LT. ARM MUSCLE	95.987	LT. ARM FAT	92.722	LT. ARM SKIN	91.647
RT. LEG CORE	97.740	RT. LEG MUSCLE	97.817	RT. LEG FAT	94.452	RT. LEG SKIN	92.882
LT. LEG CORE	97.740	LT. LEG MUSCLE	97.817	LT. LEG FAT	94.436	LT. LEG SKIN	92.846
RT. HAND CORE	96.582	RT. HAND MUSCLE	96.604	RT. HAND FAT	96.223	RT. HAND SKIN	95.898
LT. HAND CORE	96.581	LT. HAND MUSCLE	96.603	LT. HAND FAT	96.221	LT. HAND SKIN	95.894
RT. FOOT CORE	95.168	RT. FOOT MUSCLE	95.100	RT. FOOT FAT	94.664	RT. FOOT SKIN	94.175
LT. FOOT CORE	95.169	LT. FOOT MUSCLE	95.103	LT. FOOT FAT	94.668	LT. FOOT SKIN	94.182
CENTRAL BLOOD	97.866	AVERAGE SKIN	92.484	AVERAGE MUSCLE	98.224		

MAN'S SENSIBLE HEAT LOSS(BTU/HR)	313.5056	MAN'S EVAPORATION HEAT LOSS(BTU/HR)	.0000
MAN'S LATENT HEAT LOSS(BTU/HR)	62.2487	MAN'S STORAGE RATE(BTU/HR)	218.4490
MAN'S SHIVER RATE(BTU/HR)	19.9633	HEAT STORED IN MAN(BTU)	-10.9542
SUIT INLET SPECIFIC HUMIDITY	.0631	SUIT OUTLET SPECIFIC HUMIDITY	.0710
PARTIAL PRESSURE OF CO2 IN HELMET(MM HG)	2.6443	DEW POINT TEMPERATURE IN HELMET(DEG F)	82.5333
UNREMOVED SWEAT(LB)	.0000	LCG DELTA TEMPERATURE	-.8151

HEAT LEAK(BTU/HR)

PHB -24.55 PGA -175.64 PLSS -6.21 OPS .23 P-HOLE -46.64 O-HOLE 1.29

TOTAL PGA= -200.20 TOTAL EMU= -251.54

FLOW RATES (LB/HR)

1	8.09	8.09	.08	.00	8.01	.00	.00	.00	8.01	8.07	10
11	8.07	7.99	7.89	7.89	7.98	.10	.00	.00	.00	.00	20
21	.00	.00	.00	.00	.00	8.05	3.02	1.01	8.05	3.02	30
31	1.01	.00	.00	.00	.00	.00	.00	.00	3.02	1.01	40
41	3.02	1.01	.00	.00	.00						

PRESSURE DROPS (PSI)

1	.00092	.00049	.00000	.00000	.00760	.00000	.00000	.00000	.05522	.00000	10
11	.04016	.03559	.06777	.00000	.00000	.00010	.00000	.00000	.00000	.00000	20
21	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	30
31	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	40
41	.00000	.00000	.00000	.00000	.00000						

FLUID LUMP TEMPERATURES (DEG F)

1	82.84	82.72	82.71	82.58	82.33	79.70	92.47	86.50	84.43	84.95	10
11	84.64	87.01	83.95	83.43	83.03	79.51	79.19	79.19	79.11	70.31	20
21	71.59	70.00	70.00	70.00	70.00	79.94	74.83	72.94	72.51	70.00	30

SPECIAL RUN TO SAVE E TAPE

31	70.00	81.55	73.34	70.00	71.68	74.76	80.00	80.00	80.18	79.51	40
41	76.71	81.75	95.31	86.74	75.58	80.00	74.49	80.00	80.00	80.00	50
51	72.49	70.66	75.27	75.27	75.23	71.59	71.67	82.11	70.70	82.96	60
61	70.93	72.11	70.00	70.00	79.19	70.00	70.00	83.21	84.38	79.70	70
71	79.70	70.00	78.38	89.64	78.38	88.99	78.03	90.75	78.03	70.00	80
81	79.11	84.81	69.95	69.94	69.95	69.96	69.95	69.96	69.95	69.97	90
91	69.96	69.97	69.96	69.99	69.93	69.95	69.95	69.95	69.96	69.95	100
101	69.96	69.95	69.96	69.95	69.97	69.96	69.97	69.96	69.99	69.93	110
111	69.95	69.95	70.01	84.81	84.50	86.65	84.04	78.38	89.60	78.37	120
121	78.03	90.65	78.03								

TUBE LUMP TEMPERATURES (DEG F)

1	84.33	81.62	70.68	80.71	81.26	77.38	92.10	91.28	70.00	91.66	10
11	95.90	92.88	94.18	82.58	81.94	79.51	73.78	77.25	79.86	70.31	20
21	71.59	70.98	70.00	70.00	70.00	79.94	74.81	72.98	70.00	70.00	30
31	70.00	81.74	73.41	70.00	71.66	74.76	82.58	80.76	80.36	79.51	40
41	76.81	82.20	96.04	87.50	75.54	71.19	74.45	71.19	71.42	70.84	50
51	72.48	70.69	75.37	75.27	75.30	71.59	71.67	80.88	70.70	81.27	60
61	70.86	89.94	87.98	82.25	80.20	81.42	81.13	80.83	80.53	79.27	70
71	79.69	79.24	79.81	80.16	79.96	80.59	80.12	83.33	83.28	83.07	80
81	83.23	81.28	42.18	40.54	44.73	44.75	40.82	43.22	50.87	39.14	90
91	44.31	44.42	39.58	42.49	40.79	40.88	45.16	45.48	70.00	70.00	100
101	70.00	70.00	71.63	70.00	82.46	84.76	79.70	70.00	70.00	89.01	110
111	89.65	89.01	88.99	88.62	90.75	88.62	70.00	93.70	70.00	90.75	120
121	41.93	43.18	48.44	47.57	53.22	53.80	49.33	46.18	86.45	86.34	130
131	87.52	87.52	86.35	87.04	86.27	87.06	88.13	88.13	87.07	87.67	140
141	86.44	87.04	88.13	88.13	87.04	87.68	86.27	86.96	88.28	88.28	150
151	86.96	87.99	75.20	75.40	74.56	73.66	73.27	73.32	73.75	74.67	160
161	74.79	73.83	73.32	73.28	73.79	74.69	82.13	80.36	82.38	81.74	170
171	83.29	83.19	83.64	83.32	79.47	79.99	78.72	78.66	81.13	81.15	180
181	81.92	70.01	70.57	70.22	70.40	70.54	70.36	70.10	70.01	89.59	190
191	90.24	91.46	93.50	73.25	73.27	73.29	73.31	69.83	69.83	69.81	200
201	69.86	69.82	69.86	69.84	69.88	69.84	69.88	69.85	69.96	69.75	210
211	69.80	69.80	69.83	69.83	69.81	69.86	69.82	69.86	69.84	69.88	220
221	69.84	69.88	69.85	69.96	69.75	69.80	69.80	70.05	90.20	91.37	230
231	93.52	91.65	92.85	94.18	95.89	89.01	89.61	89.01	88.62	90.45	240
241	88.62										

STRUCTURE LUMP TEMPERATURES (DEG F)

1	60.83	63.15	68.45	68.45	63.35	65.29	61.61	62.48	67.48	67.48	10
11	70.40	70.34	70.40	70.41	70.38	70.41	81.25	63.31	75.34	75.66	20
21	67.69	71.62	70.06	70.08	70.00	70.03	70.09	70.03	70.14	70.00	30
31	71.05	75.48	71.39	258.24	65.17	57.14	3.22	184.56	40.47	156.40	40
41	202.31	53.03	79.14	63.28	123.68	121.51	204.81	83.36	46.05	46.97	50
51	67.59	69.65	91.17	108.46	100.27	279.09	130.50	125.68	113.60	72.49	60
61	79.73	84.62	81.83	82.15	81.97	82.23	77.38	81.68	73.61	72.40	70
71	73.03	73.12	74.39	74.64	75.12	74.52	88.42	75.19	75.32	74.43	80
81	79.42	82.89	76.52	75.30	75.21	75.15	76.75	75.91	74.77	76.59	90
91	74.68	75.91	74.49	74.02	75.75	74.57	75.40	74.71	75.29	77.31	100
101	74.13	520.55	81.80	71.85	72.00	71.44	71.56	70.00	70.00	71.86	110
111	71.61	71.58	71.53	71.32	71.71	71.80	70.92	71.77	71.33	71.33	120
121	70.36	70.32	70.92	70.34	70.88	66.17	78.71	66.12	69.09	74.08	130

131	49.24	110.76	49.33	65.73	73.58	76.15	70.39	99.90	71.75	70.77	140
141	70.99	78.62	77.54	72.16	71.44	71.45	73.75	71.71	69.93	-459.69	150
151	70.54	75.52	75.53	84.22	125.52	71.91	77.26	97.80	167.89	61.15	160
161	21.77	74.32	89.21	71.89	68.56	72.45	82.03	70.29	86.03	70.28	170
171	70.47	70.15	71.92	72.04	70.17	70.88	68.05	70.31	148.70	88.32	180
181	70.40	70.34	70.40	70.41	70.38	70.41	81.25	63.31	75.34	75.66	190
191	67.69	71.62	70.40	70.34	70.40	70.41	70.38	70.41	81.25	63.31	200
201	75.34	75.66	67.69	71.62	62.48	64.71	56.68	64.22	79.93	80.23	210
211	-459.69	-459.69	71.58	71.59	70.00	70.00	87.57	83.88	79.20	77.61	220
221	78.36	77.98	78.60	78.06	76.90	77.49	76.84	77.70	77.21	76.90	230
231	77.97	77.18	79.23	78.81	79.15	79.53	77.16	70.40	70.36	70.49	240
241	70.49	70.36	70.40	70.38	70.35	70.37	70.37	70.35	69.91	70.38	250
251	70.35	70.37	70.37	70.35	69.94	70.40	70.36	70.49	70.49	70.36	260
261	70.40	70.38	70.35	70.37	70.37	70.35	69.91	70.38	70.35	70.37	270
271	70.37	70.35	69.94	70.40	70.36	70.49	70.49	70.36	70.40	70.38	280
281	70.35	70.37	70.37	70.35	69.91	70.38	70.35	70.37	70.37	70.35	290
291	69.94	84.48	84.40	61.29	74.19	76.82	71.64	71.22	57.25	65.64	300
301	82.06	88.92	88.80	84.76	48.48	66.54	81.90	93.78	105.26	95.06	310
311	84.40	61.29	74.19	76.82	71.64	71.22	57.25	65.64	82.06	88.92	320
321	88.80	84.76	48.48	66.54	81.90	93.78	105.26	95.06	84.40	61.29	330
331	74.19	76.82	71.64	71.22	57.25	65.64	82.06	88.92	88.80	84.76	340
341	48.48	66.54	81.90	93.78	105.26	95.06	70.09	69.93	69.96	69.96	350
351	69.93	68.46	70.18	69.92	69.93	69.93	69.92	68.29	70.01	69.96	360
361	70.36	70.37	69.97	70.04	70.11	69.89	69.96	70.00	70.03	70.03	370
371	73.51	71.32	71.39	70.43	70.73	72.03	72.56	75.59	73.44	75.73	380
381	91.68	90.48	73.98	72.15	64.38	67.31	61.37	59.97	66.18	67.05	390
391	66.27	67.32	184.15	112.30	68.90	141.39	376.57	389.67	199.91	116.82	400
401	88.82	95.05	58.30	52.28	71.08	38.11	59.17	160.67	112.54	161.78	410
411	198.33	107.37	113.30	101.79	127.96	173.20	172.45	92.25	113.75	155.59	420
421	133.69	129.82	161.07	131.77	134.80	78.26	54.52	118.19	79.98	89.99	430
431	141.15	124.20	50.61	24.67	94.61	57.06	51.89	110.48	122.41	44.82	440
441	51.90	110.51	71.22	142.49	71.05	153.64	136.37	111.02	46.09	145.01	450
451	133.01	103.50	63.96	54.75	64.19	111.95	82.56	122.90	93.25	134.49	460
461	103.91	70.21	141.42	103.42	99.74	74.20	125.64	118.41	69.28	87.40	470
471	95.00	519.11	74.25	83.28	71.67	72.24	70.61	71.46	72.37	79.49	480
481	85.78	72.02	77.40	74.44	77.19	79.84	75.40	75.55	76.32	76.51	490
491	78.45	78.22	75.92	75.59	81.39	77.79	76.93	78.48	77.17	77.42	500
501	73.48	72.42	76.28	74.73	73.63	75.65	76.36	72.37	71.04	74.40	510
511	72.75	72.56	74.70	75.00	71.33	71.89	74.56	72.28	76.81	73.78	520
521	76.93	76.50	74.65	71.44	76.79	76.25	74.20	72.37	71.65	72.17	530
531	74.62	73.24	75.31	73.92	75.67	73.25	71.60	75.80	73.34	73.09	540
541	70.79	75.11	74.79	72.14	73.08	73.46	126.66	70.80	77.83	76.46	550
551	75.73	75.66	76.86	76.09	73.66	75.42	74.69	74.50	72.22	72.22	560
561	79.91	78.94	79.38	79.30	80.09	79.57	76.46	77.52	76.57	76.45	570
571	77.89	77.90	70.27	70.23	70.23	70.20	70.11	70.03	113.48	73.15	580
581	71.69	115.02	73.33	71.78	75.86	70.43	70.44	167.25	77.46	73.92	590
591	91.24	71.65	71.28	100.19	72.21	71.52	54.78	72.70	74.71	45.25	600
601	72.03	74.40	76.24	73.90	75.23	71.68	78.44	80.18	78.92	78.77	610
611	80.30	77.60	78.43	80.17	58.31	73.40	74.61	301.62	95.28	81.70	620
621	74.91	74.13	74.82	75.59	79.34	-136.57	141.04	-128.62	-130.15	-151.79	630
631	59.25	-120.82	136.39	-110.23	-112.39	-149.25	60.64	36.10	37.34	32.76	640
641	42.43	35.35	41.92	36.80	47.31	36.18	44.13	39.28	61.23	17.42	650
651	27.02	28.00	68.25	68.31	68.08	68.57	68.21	68.56	68.30	68.82	660
661	68.28	68.68	68.43	69.55	67.36	67.84	67.89	36.10	37.34	32.76	670
671	42.43	35.35	41.92	36.80	47.31	36.18	44.13	39.28	61.23	17.42	680
681	27.02	28.00	73.44	73.05	70.12	73.37	70.00	70.00	70.00	70.00	690

691	70.00	70.00	70.00	70.0n	70.00	70.00	70.00	70.00	70.00	70.00	700
701	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	71.22	70.00	710
711	70.00	70.00	65.59	63.92	70.00	70.00	70.00	70.00	70.00	70.00	720
721	70.00	70.00	70.00	70.0n	70.00	70.00	70.00	70.00	70.00	70.00	730
731	70.00	70.00	70.00	70.0n	70.00	70.00	70.00	72.72	70.00	70.00	740
741	44.19	70.00	-39.89	70.un	70.00						

COMPUTER TIME EXCEEDED TIME REQUESTED

DUMP TAPE HAS BEEN WRITTEN

APPENDIX C

SPECIAL RUN TO SAVE E TAPE


```
TIME   =   3.30000  TINCHN=    .00500  PLTINC=   .05000  DELTAU=   .10000  TAU    =  10.60000  SSTEST=   .01000
RTIME  =   5.00000  TMPTIM=   3.30000  OPTOL  =  .01000  NCKOUT=        0  NSTEAD=          0  ISTART=        0
INDATA=          2  NEWTMP=         0  NPRTCD=        1  IPLOTN=        1  IDUMP=           1  NBSY=          1
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         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

  123  241  745  281    1    2    1                                        10003 • NEW CARD 3, SECTION 5.7.1
    1    1               ABSORBED HEAT ON EMU    NODE   39                 10004 •-  1 CARD 4,
  113   1.                                                                 10005       CARD 5,
    2    1               ABSORBED HEAT ON EMU    NODE   40                 10006
  112   1.                                                                 10007
    3    1               ABSORBED HEAT ON EMU    NODE   41                 10008
  111   1.                                                                 10009
    4    1               ABSORBED HEAT ON EMU    NODE   42                 10010
  110   1.                                                                 10011
    5    1               ABSORBED HEAT ON EMU    NODE   43                 10012
  109   1.                                                                 10013
    6    1               ABSORBED HEAT ON EMU    NODE   44                 10014
  108   1.                                                                 10015
    7    1               ABSORBED HEAT ON EMU    NODE   45                 10016
  115   1.                                                                 10017
    8    1               ABSORBED HEAT ON EMU    NODE   46                 10018
  114   1.                                                                 10019
    9    4               ABSORBED HEAT ON EMU    NODE   47                 10020
   96   1.   97   1.   98   1.  101   1.                                   10021
   10    6               ABSORBED HEAT ON EMU    NODE   48                 10022
  142   1.  143   1.  144   1.  149   1.  150   1.  151   1.               10023
   11    1               ABSORBED HEAT ON EMU    NODE   49                 10024
  148   1.                                                                 10025
   12    6               ABSORBED HEAT ON EMU    NODE   50                 10026
  136   1.  137   1.  138   1.  145   1.  146   1.  147   1.               10027
   13    5               ABSORBED HEAT ON EMU    NODE   51                 10028
   93   1.   94   1.   95   1.   99   1.  100   1.                         10029
   14    6               ABSORBED HEAT ON EMU    NODE   52                 10030
  120   1.  121   1.  122   1.  129   1.  130   1.  131   1.               10031
   15    1               ABSORBED HEAT ON EMU    NODE   53                 10032
  132   1.                                                                 10033
   16    6               ABSORBED HEAT ON EMU    NODE   54                 10034
  126   1.  127   1.  128   1.  133   1.  134   1.  135   1.               10035
   17    6               ABSORBED HEAT ON EMU    NODE   55                 10036
  102   1.  106   1.  107   1.  123   1.  124   1.  125   1.               10037
   18    6               ABSORBED HEAT ON EMU    NODE   56                 10038
  103   1.  104   1.  105   1.  139   1.  140   1.  141   1.               10039
   19    1               ABSORBED HEAT ON EMU    NODE   57                 10040
   90   1.                                                                 10041
   20    1               ABSORBED HEAT ON EMU    NODE   58                 10042
   89   1.                                                                 10043
   21    1               ABSORBED HEAT ON EMU    NODE   59                 10044
   88   1.                                                                 10045
   22    1               ABSORBED HEAT ON EMU    NODE  407                 10046
   87   1.                                                                 10047
   23    1               ABSORBED HEAT ON EMU    NODE  408                 10048
   86   1.                                                                 10049
   24    1               ABSORBED HEAT ON EMU    NODE  409                 10050
   85   1.                                                                 10051
   25    1               ABSORBED HEAT ON EMU    NODE  410                 10052
   92   1.                                                                 10053
   26    1               ABSORBED HEAT ON EMU    NODE  411                 10054
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0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

  230    1.  231    1.  232    1.  233    1.  234    1.  235    1.  236    1.    10523
  237    1.  238    1.  239    1.  240    1.  241    1.  242    1.  243    1.    10524
  244    1.  245    1.  246    1.  247    1.  248    1.  249    1.  250    1.    10525
  251    1.  252    1.  253    1.                                               10526
  260    1              ABSORBED HEAT ON EMU NODE 626                           10527
  397.1615                                                                      10528
  261    1              ABSORBED HEAT ON EMU NODE 627                           10529
  254.2946                                                                      10530
  262    1              ABSORBED HEAT ON EMU NODE 628                           10531
  399 .229                                                                      10532
  263    1              ABSORBED HEAT ON EMU NODE 629                           10533
  364 .801                                                                      10534
  264    1              ABSORBED HEAT ON EMU NODE 630                           10535
  403  1.0                                                                      10536
  265    1              ABSORBED HEAT ON EMU NODE 668 AND 669                   10537
   48 .157                                                                      10538
  266    1              ABSORBED HEAT ON EMU NODE 670                           10539
   48 .132                                                                      10540
  267    2              ABSORBED HEAT ON EMU NODE 671 AND 678                   10541
   48 .193   256 .040                                                           10542
  268    2              ABSORBED HEAT ON EMU NODE 672                           10543
   48 .150   256 .031                                                           10544
  269    2              ABSORBED HEAT ON EMU NODE 673                           10545
   48 .201   256 .041                                                           10546
  270    2              ABSORBED HEAT ON EMU NODE 674                           10547
   48 .162   256 .033                                                           10548
  271    2              ABSORBED HEAT ON EMU NODE 675                           10549
   48 .283   256 .049                                                           10550
  272    2              ABSORBED HEAT ON EMU NODE 676                           10551
   48 .181   256 .037                                                           10552
  273    2              ABSORBED HEAT ON EMU NODE 677                           10553
   48 .245   256 .05                                                            10554
  274    2              ABSORBED HEAT ON EMU NODE 679                           10555
   48 .283   256 .058                                                           10556
  275    2              ABSORBED HEAT ON EMU NODE 680                           10557
   48 .212   256 .044                                                           10558
  276    2              ABSORBED HEAT ON EMU NODE 681                           10559
   48 .287   256 .059                                                           10560
  277    1              ABSORBED HEAT ON EMU NODE 682                           10561
   48 .290                                                                      10562
  278    1              ABSORBED HEAT ON EMU NODE 49T                           10563
  263   1.                                                                      10564
  279    1              ABSORBED HEAT ON EMU NODE 155                           10565
  264   1.                                                                      10566
  280    1              ABSORBED HEAT ON EMU NODE 143                           10567
  265   1.                                                                      10568
  281    1              ABSORBED HEAT ON EMU NODE 142                           10569
  266   1.                                                                      10570
    1    1                   CONTACT TEMP. ON BOOTS                             10571
    1   1.                                                                      10572
  1.062E-5      1.862   4.58E-6      2.044   1.28E-5      1.55                  10573   CARD 6
  7.3107E-6     2.142 1.583E-20     8.2023     240.0       0.0                  10574   CARD 7
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0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
   69   16   18   40  175  686                                             10575  CARD 8
  103   57       30.0      80.0          0.                                10576  CARD 9
  173  104      3.999     7500.                                            10577  CARD 10
  174  105      3.999     750n.                                            10578  CARD 11
  172  171      1.565     1427.                                            10579  CARD 12
     161.0      378.0  0.086942      0.36                                  10580  CARD 13
       8.0       0.43      2.92       .14    340.07       0.0              10581  CARD 14
    8   10  232   12  233    7   11  235   13  234                         10582  CARD 15
  190  191  229  192  230    0    0    0  193  231                         10583  CARD 16
     3.12         0.0       1.3    0.3415   0.67939     0.232              10584  CARD 17
.1         .09       .09       .06       .28       .339      .325          10585  CARD 18
.76        .9        .42       .125                                        10586  CARD 19
.89        .89       .905      .89       .99                               10587  CARD 20
    1    2    3    4    5                                                  10588  CARD 21
   11   12   13   14    5                                                  10589  CARD 22
    1    2    3    4    5                                                  10590  CARD 23
    1    2    3    4    5                                                  10591  CARD 24
    1    2    3    4    5    6    7    8    9   10   11                    10592  CARD 25
    1    2    3    4    5    6    7    8                                   10593  CARD 26
   66                         --FLUID TYPE DATA--                          10594  CARD 27 , SECTION 5.7.2
    1    2    3    4    5                  1.        1.      0.        1   10595  CARD 28
    1    2    3    4    5                3.48     .3630  2.1363        2   10596
    1    2    3    4    5               .0298     .3630  2.1363        3   10597
    1    2    3    4    5         1        1.        1.      0.        4   10598
    1    2    3    4    5               10.57     .0222   .5278        5   10599
    1    2    3    4    5              10.557     .0799  1.0022        6   10600
    1    2    3    4    5                2.97     .1072  1.1608        7   10601
    1    2    3    4    5               8.345     .0799  1.0022        8   10602
   11   12   13   14    5               17.16     .0254   .5655        9   10603
   11   12   13   14    5               6.956     .0254   .5655       10   10604
   11   12   13   14    5               3.066     .0730   .9582 4.24  11   10605
   11   12   13   14    5              17.493     .0730   .9582 2.56  12   10606
   11   12   13   14    5                 14.     .0730   .9582 3.58  13   10607
   11   12   13   14    5               7.745     .0730   .9582 3.13  14   10608
   11   12   13   14    5                2.20     .0730   .9582 1.96  15   10609
    1    2    3    4    5                4.70     .3337  1.3355       16   10610
   11   12   13   14    5                  1.        1.      0.       17   10611
    1    2    3    4    5               2.891     .0799  1.0022       18   10612
   11   12   13   14    5               7.369     .0254   .5655       19   10613
   11   12   13   14    5               3.624     .0809  1.0085 6.16  20   10614
   11   12   13   14    5               9.632     .0730   .9582 4.34  21   10615
   11   12   13   14    5                  4.     .0730   .9582 3.24  22   10616
   11   12   13   14    5                3.94     .0730   .9582 4.99  23   10617
   11   12   13   14    5                1.69     .0730   .9582 4.69  24   10618
   11   12   13   14    5               4.376     .0809  1.0085 5.27  25   10619
   11   12   13   14    5               2.157     .0740      0.       26   10620
   11   12   13   14    5                2.94     .0740      0.       27   10621
    1    2    3    4    5                1.83     .3630  2.1363       28   10622
    1    2    3    4    5                6.25     .3630  2.1363       29   10623
    1    2    3    4    5               22.10     .4420    2.36       30   10624
    1    2    3    4    5               24.95     .4420    2.36       31   10625
    1    2    3    4    5               8.815     .3630  2.1363       32   10626
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0         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789 0

  11   12   13   14    5            2.02     .0730     0.  10.3   33  10627
   1    2    3    4    5           42.75     .442  2.36           34  10628
                               6      1.        1.      1.        35  10629
   1    2    3    4    5           8.494    2.9657   2.96         36  10630
   1    2    3    4    5            .875    1.2849    0.          37  10631
  11   12   13   14    5      1.83      .0254            0.       38  10632
  11   12   13   14    5      28.97     .1075     1.1624  11.2    39  10633
  11   12   13   14    5      39.87     .1075     1.1624  10.6    40  10634
  11   12   13   14    5      9.95      .0254     .5655            41  10635
  11   12   13   14    5      8.364     .0254     .5655            42  10636
   1    2    3    4    5             2.0    2.964    2.92         43  10637
  11   12   13   14    5            5.58    .0254     0.          44  10638
   1    2    3    4    5       2      1.        1.      0.         45  10639
   1    2    3    4    5       3      1.        1.      0.         46  10640
   1    2    3    4    5       4     50.        1.      0.         47  10641
   1    2    3    4    5       4     98.2       1.      0.         48  10642
   1    2    3    4    5       5      1.        1.      0.         49  10643
  11   12   13   14    5             .745     .057    .848        50  10644
                              5.2       .4301     1.1624          51  10645
                              4.37      .4301     1.1624          52  10646
                              6.37      .4301     1.1624          53  10647
                              4.95      .4301     1.1624          54  10648
                              6.65      .4301     1.1624          55  10649
                              5.35      .4301     1.1624          56  10650
                              7.80      .4301     1.1624          57  10651
                              6.00      .4301     1.1624          58  10652
                              8.10      .4301     1.1624          59  10653
                              6.35      .4301     1.1624          60  10654
                              9.35      .4301     1.1624          61  10655
                              7.        .4301     1.1624          62  10656
                              9.5       .4301     1.1624          63  10657
                              9.6       .4301     1.1624          64  10658
                             4       100.      .2830    1.88      65  10659
                             7        1.        1.      0.        66  10660
   1    0    1   49   80.                                             10661  CARD 29
   2    1    1    2   80.                                             10662
   3    0    2    3   80.                                             10663
   4    3    2   28   80.                                             10664
   5    0    5   29   80.                                             10665
   6   58    5   30   80.                                             10666
   7    0   29    1   75.                                             10667
   8    0   26    1   75.                                             10668
   9    0   10    1   70.                                             10669
  10    0   27    1   75.                                             10670
  11    0   30    1   75.                                             10671
  12    0   28    1   75.                                             10672
  13    0   31    1   75.                                             10673
  14    0   11   31   80.                                             10674
  15    0   12   47   80.                                             10675
  16   60   12    1   80.                                             10676
  17    0   13   36   80.                                             10677
  18   17   13    1   80.                                             10678
```

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0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

  123  122   37   66       70.                                               10783
  152                         --TUBE TYPE DATA--                             10784  CARD 30 , SECTION 5.7.3
.9935    6    7    1    2    0    0     144.                          1   10785  CARD 31
.85       .5        1.                                                1   10786  CARD 32
.0171    6    7                  7.434                                2   10787
.2116    6    7    1             .0637                                3   10788
11.17                                                                 3   10789
.0022    6    7    1    2        5.579                                4   10790
200.0     200.0     26.65                                             4   10791
.2790    6    7    1    1    0    0       10.                         5   10792
10.       .454                                                        5   10793
.1573    6    7    1             10.                                  6   10794
.355                                                                  6   10795
.0097    6    7    1             10.58                                7   10796
23.07                                                                 7   10797
.0084    6    7                  8.363                                8   10798
.0129    6    7    1             9.704                                9   10799
15.6                                                                  9   10800
.0154    6    7    1             3.934                               10   10801
15.6                                                                 10   10802
.0089    6    7                  2.938                               11   10803
.2753    6    7    1    1        10.                                 12   10804
3.525     .189                                                       12   10805
.0197    6    7    1    1        16.76                               13   10806
15.6      15.6                                                       13   10807
1.053    6    7    0    1    0    2       10.                        14   10808
1.                                                                   14   10809
53.6 5.810                                                           14   10810
.0170    6    7    1             13.41                               15   10811
15.6                                                                 15   10812
.0124    6    7    1             7.421                               16   10813
15.6                                                                 16   10814
.046     6    7    1    0    0   110.                                17   10815  CARD 31
.1065                                                                17   10816  CARD 32
1.632                                                                17   10817  CARD 33
.0493    6    7         1        2.108                               18   10818
.2675                                                                18   10819
  .27    6    7                  144.                                19   10820
.0113    6    7    1    0    0    2      9.62                        20   10821
2.54                                                                 20   10822
.9970   3.                                                           20   10823
2.024    6    7    0    6    1    4      171.2                       21   10824
1.335     6.18      19.1      9.58      .8        .933               21   10825
58.10 6.28 2.44 2.44 1.6                                             21   10826
1.078    6    7    1    0    0    1      100.                        22   10827
2.                                                                   22   10828
5.810                                                                22   10829
.112     6    7    2             10.                                 23   10830
.850     20.75                                                       23   10831
.2       6    7    0    0    0    0      10.                         24   10832
.0104    6    7    2            3.909                                25   10833
6.855     6.31                                                       25   10834
```

0 1 2 3 4 5 6 7 8
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

.0058	6	7					99.09	134	11095
.0022	6	7	1	0	0	0	3.75	135	11096
.425								135	11097
.1	6	7	5	0	0	0	6.28	136	11098
3.5	1.		2.		3.		4.	136	11099
.0591	6	7	1	1	0	1	6.05	137	11100
50.	10.98							137	11101
1.295								137	11102
.0497	6	7	1	1	0	1	5.09	138	11103
50.	13.06							138	11104
1.088								138	11105
.0724	6	7	1	1	0	1	7.43	139	11106
50.	8.959							139	11107
1.586								139	11108
.0563	6	7	1	1	0	1	5.76	140	11109
50.	11.53							140	11110
1.233								140	11111
.0756	6	7	1	1	0	1	7.74	141	11112
50.	8.582							141	11113
1.656								141	11114
.0608	6	7	1	1	0	1	6.62	142	11115
50.	10.67							142	11116
1.332								142	11117
.0887	6	7	1	1	0	1	9.06	143	11118
50.	7.317							143	11119
1.943								143	11120
.0682	6	7	1	1	0	1	6.97	144	11121
50.	9.512							144	11122
1.494								144	11123
.0921	6	7	1	1	0	1	9.42	145	11124
50.	7.046							145	11125
2.017								145	11126
.0722	6	7	1	1	0	1	7.39	146	11127
50.	8.988							146	11128
1.581								146	11129
.1063	6	7	1	1	0	1	10.88	147	11130
50.	6.104							147	11131
2.329								147	11132
.0796	6	7	1	1	0	1	8.15	148	11133
50.	8.15							148	11134
1.742								148	11135
.1080	6	7	1	1	0	1	11.05	149	11136
50.	6.007							149	11137
2.366								149	11138
.1092	6	7	1	1	0	1	11.16	150	11139
50.	5.945							150	11140
2.391								150	11141
.125	6	7	0	1	0	1	144.0	151	11142
10.								151	11143
9.								151	11144
.325	6	7	0	1	2	1	144.	152	11145
1.33								152	11146

12.8	1.094	4.62									152	11147	
1	1	1	90.	82	138	683						11148	CARD 34
2	2	2	70.									11149	
3	3	3	70.	15								11150	
4	4	25	70.	5	26							11151	
5	5	38	70.	58	68							11152	
6	6	39	70.	599	602	605	599	602	605			11153	
7	7	41	70.									11154	
8	8	42	70.	190								11155	
9	9	24	70.									11156	
10	10	43	70.	191								11157	
11	11	44	70.									11158	
12	12	45	70.	192								11159	
13	13	46	70.	193								11160	
14	14	40	70.	608	611	614	608	611	614			11161	
15	15	21	75.	168	166	171	139	142	143	16	166	11162	
171	139	142										11163	
16	16	22	80.	15	150							11164	
17	17	49	70.	18	15							11165	
18	18	23	70.	19	27							11166	
19	19	50	70.									11167	
20	20	4	70.	21	171	168						11168	
21	21	5	70.	168	101							11169	
22	22	6	70.	21								11170	
23	23	7	70.	24								11171	
24	24	27	70.	25								11172	
25	25	8	70.									11173	
26	26	28	70.									11174	
27	27	29	70.									11175	
28	28	9	70.	37								11176	
29	29	51	70.	101								11177	
30	30	86	70.	101								11178	
31	31	24	70.									11179	
32	32	54	70.	15	138							11180	
33	33	10	70.	60								11181	
34	34	55	70.									11182	
35	35	30	70.	168								11183	
36	36	11	70.									11184	
37	37	12	70.	38	169							11185	
38	38	47	70.									11186	
39	39	13	70.	1	138							11187	
40	40	14	80.	136	136	150						11188	
41	41	31	70.	60	15							11189	
42	42	32	70.	43								11190	
43	43	33	70.	44	138							11191	
44	44	34	70.									11192	
45	45	15	70.	21								11193	
46	46	35	70.	49								11194	
47	47	16	70.	21								11195	
48	48	35	70.	49								11196	
49	49	17	70.	21	150							11197	
50	50	36	70.	49								11198	

FORM 1411-3

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         0         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

   206   91  144       70.      221  661  661                                  11355
   207   92  145       70.      222  662  662                                  11356
   208   93  146       70.      223  663  663                                  11357
   209   94  147       70.      224  664  664                                  11358
   210   95  148       70.      225  665  665                                  11359
   211   96  149       70.      226  666  666                                  11360
   212   97  150       70.      227  667  667                                  11361
   213   98  137       70.      198  653  653                                  11362
   214   99  137       70.      199  654  654                                  11363
   215  100  138       70.      200  655  655                                  11364
   216  101  139       70.      201  656  656                                  11365
   217  102  140       70.      202  657  657                                  11366
   218  103  141       70.      203  658  658                                  11367
   219  104  142       70.      204  659  659                                  11368
   220  105  143       70.      205  660  660                                  11369
   221  106  144       70.      206  661  661                                  11370
   222  107  145       70.      207  662  662                                  11371
   223  108  146       70.      208  663  663                                  11372
   224  109  147       70.      209  664  664                                  11373
   225  110  148       70.      210  665  665                                  11374
   226  111  149       70.      211  666  666                                  11375
   227  112  150       70.      212  667  667                                  11376
   228  113  151       70.      146  685                                       11377
   229  114  132       70.      237                                            11378
   230  116  133       70.      240                                            11379
   231  117  134       70.                                                     11380
   232  114   43       70.      229                                            11381
   233  116   45       70.      230                                            11382
   234  117   46       70.      231                                            11383
   235  115   44       70.                                                     11384
   236  118   87       70.                                                     11385
   237  119   95       70.       70   72   75   77                             11386
   238  120   87       70.                                                     11387
   239  121   87       70.                                                     11388
   240  122   96       70.      168  170  172  174                             11389
   241  123   87       70.                                                     11390
   425                        --STRUCTURE TYPE DATA--                          11391   CARD 36, SECTION 5.7.4
 .0035    6    8    1    1                                              1      11392   CARD 37
  305.                                                                  1      11393   CARD 38
  .772                                                                  1      11394   CARD 39
 .0026    6    8    1    1                                              2      11395
  403.                                                                  2      11396
  .584                                                                  2      11397
 .0003    6    8    1    1                                              3      11398
 4111.                                                                  3      11399
  .057                                                                  3      11400
 .0005    6    8    1    1                                              4      11401
 1970.                                                                  4      11402
  .120                                                                  4      11403
 .0131    6    8    1    1                                              5      11404
  807.                                                                  5      11405
  .292                                                                  5      11406
```

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PRINTED IN U.S.A.

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0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

   725  416    70.0                                                         13175
   726  416    70.0                                                         13176
   727  416    70.0                                                         13177
   728  416    70.0                                                         13178
   729  416    70.0                                                         13179
   730  416    70.0                                                         13180
   731  416    70.0                                                         13181
   732  416    70.0                                                         13182
   733  416    70.0                                                         13183
   734  416    70.0                                                         13184
   735  416    70.0                                                         13185
   736  416    70.0                                                         13186
   737  416    70.0                                                         13187
   738  423    70.0          414  415                                       13188
   739  422    70.0          416                                            13189
   740  416    70.0                                                         13190
   741  425    70.0     741  179  150                                       13191
   742  416    70.0                                                         13192
   743  424    70.0     743  412  150                                       13193
   744  416    70.0                                                         13194
   745  416    70.0                                                         13195
     1                             --LOCAL TEMPERATURE PERTURBATIONS--      13196 CARD 42, SECTION 5.7.5
     3  118  119   82   120  115    1    2    3                             13197 CARD 43
     6                             --HEAT LEAK DATA--                       13198 CARD 44, SECTION 5.7.6
    86    PHB                                                               13199 CARD 45
   83T    0    6  84T    0    5                                             13200 CARD 46
   85T    0    5  86T    0    5                                             13201
   87T    0    5  88T    0    4                                             13202
   89T    0    5  90T    0    4                                             13203
   91T    0    4  92T    0    4                                             13204
   93T    0    4  94T    0    3                                             13205
   95T    0    6  96T    0    4                                             13206
   97T    0    4  98T    0    4                                             13207
  121T    0    4 122T    0    3                                             13208
  123T    0    5 124T    0    4                                             13209
  125T    0    4 126T    0    4                                             13210
  127T    0    4 128T    0    2                                             13211
   83T    0    8  84T    0    7                                             13212
   85T    0    7  86T    0    7                                             13213
   87T    0    7  88T    0    6                                             13214
   89T    0    7  90T    0    6                                             13215
   91T    0    6  92T    0    6                                             13216
   93T    0    6  94T    0    5                                             13217
   95T    0    8  96T    0    6                                             13218
   97T    0    6  98T    0    6                                             13219
  121T    0    6 122T    0    5                                             13220
  123T    0    7 124T    0    6                                             13221
  125T    0    6 126T    0    6                                             13222
  127T    0    6 128T    0    4                                             13223
  129T    0    5 130T    0    4                                             13224
  131T    0    4 132T    0    4                                             13225
  133T    0    4 134T    0    3                                             13226
```

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0         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789O

   135T   0    5 136T   0    4                                             13227
   137T   0    4 138T   0    4                                             13228
   139T   0    4 140T   0    3                                             13229
   141T   0    5 142T   0    4                                             13230
   143T   0    4 144T   0    4                                             13231
   145T   0    4 146T   0    3                                             13232
   147T   0    5 148T   0    4                                             13233
   149T   0    4 150T   0    4                                             13234
   151T   0    4 152T   0    2                                             13235
   153T   0    8 154T   0    8                                             13236
   155T   0    3 156T   0    3                                             13237
   157T   0    2 158T   0    2                                             13238
   159T   0    3 160T   0    3                                             13239
   161T   0    3 162T   0    3                                             13240
   163T   0    2 164T   0    2                                             13241
   165T   0    3 166T   0    3                                             13242
     42   PGA                                                              13243
    62T   1    3  63T   1    3                                             13244
    64T   1    3  65T   1    3                                             13245
    66T   1    3  67T   1    3                                             13246
    68T   1    3  69T   1    3                                             13247
    70T   1    3  71T   1    3                                             13248
    72T   1    3  73T   1    3                                             13249
    74T   1    3  75T   1    3                                             13250
    76T   1    3  77T   1    3                                             13251
    78T   1    3  79T   1    3                                             13252
    80T   1    3  81T   1    3                                             13253
   167T   1    3 168T   1    3                                             13254
   169T   1    3 170T   1    3                                             13255
   171T   1    3 172T   1    3                                             13256
   173T   1    3 174T   1    3                                             13257
   175T   1    3 176T   1    3                                             13258
   177T   1    3 178T   1    3                                             13259
   179T   1    3 180T   1    3                                             13260
   181T   1    0 182T   1    0                                             13261
   183T   1    0 184T   1    0                                             13262
   185T   1    0 186T   1    0                                             13263
   187T   1    0 188T   1    0                                             13264
      9   PLSS                                                             13265
   146S   4    5 147S   4    5                                             13266
   148S   4    5 149S   3    5                                             13267
   151S   3    5 152S   1    0                                             13268
   153S   1    0 164S   1    2                                             13269
   292S   1    4                                                           13270
      6   OPS                                                              13271
   121S   7    8 122S   3    4                                             13272
   123S   3    4 124S   1    2                                             13273
   135S   6    7 176S   1    2                                             13274
      5   P-HOLE                                                           13275
    16T   0    2  40T   0    3                                             13276
    49T   0    2 142S   0    2                                             13277
   143S   0    2                                                           13278
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         0         1         2         3         4         5         6         7         8
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

         1    O-HOLE                                                          13279
      1355    0    8                                                          13280
         0                        --HEAT STORAGE DATA--                       13281  CARD 47, SECTION 5.7.7
       112                        --HELMET AND VISOR DATA--                   13282  CARD 50, SECTION 5.7.8
         1    1   11  197  135  181    0    0  193    0    0                  13283  CARD 51
         2    1   12  198  136  182    0    0  194    0    0                  13284
         3    1   13  199  137  183    0    0  195    0    0                  13285
         4    1   14  200  138  184    0    0  196    0    0                  13286
         5    1   15  201  139  185    0    0  197    0    0                  13287
         6    1   16  202  140  186    0    0  198    0    0                  13288
         7    1  238  203  141  256    0    0  274    0    0                  13289
         8    1  239  204  142  257    0    0  275    0    0                  13290
         9    1  240  205  143  258    0    0  276    0    0                  13291
        10    1  241  206  144  259    0    0  277    0    0                  13292
        11    1  242  207  145  260    0    0  278    0    0                  13293
        12    1  243  208  146  261    0    0  279    0    0                  13294
        13    1  244  209  147  262    0    0  280    0    0                  13295
        14    1  245  210  148  263    0    0  281    0    0                  13296
        15    1  246  211  149  264    0    0  282    0    0                  13297
        16    1  247  212  150  265    0    0  283    0    0                  13298
        17    1  248  213  151  266    0    0  284    0    0                  13299
        18    1  249  214  152  267    0    0  285    0    0                  13300
        19    1  250  215  153  268    0    0  286    0    0                  13301
        20    1  251  216  154  269    0    0  287    0    0                  13302
        21    1  252  217  155  270    0    0  288    0    0                  13303
        22    1  253  218  156  271    0    0  289    0    0                  13304
        23    1  254  219  157  272    0    0  290    0    0                  13305
        24    1  255  220  158  273    0    0  291    0    0                  13306
        25    2   17    0  135  187  197  135  199    0    0                  13307
        26    2   18    0  136  188  198  136  200    0    0                  13308
        27    2   19    0  137  189  199  137  201    0    0                  13309
        28    2   20    0  138  190  200  138  202    0    0                  13310
        29    2   21    0  139  191  201  139  203    0    0                  13311
        30    2   22    0  140  192  202  140  204    0    0                  13312
        31    2  293    0  141  311  203  141  329    0    0                  13313
        32    2  294    0  142  312  204  142  330    0    0                  13314
        33    2  295    0  143  313  205  143  331    0    0                  13315
        34    2  296    0  144  314  206  144  332    0    0                  13316
        35    2  297    0  145  315  207  145  333    0    0                  13317
        36    2  298    0  146  316  208  146  334    0    0                  13318
        37    2  299    0  147  317  209  147  335    0    0                  13319
        38    2  300    0  148  318  210  148  336    0    0                  13320
        39    2  301    0  149  319  211  149  337    0    0                  13321
        40    2  302    0  150  320  212  150  338    0    0                  13322
        41    2  303    0  151  321  213  151  339    0    0                  13323
        42    2  304    0  152  322  214  152  340    0    0                  13324
        43    2  305    0  153  323  215  153  341    0    0                  13325
        44    2  306    0  154  324  216  154  342    0    0                  13326
        45    2  307    0  155  325  217  155  343    0    0                  13327
        46    2  308    0  156  326  218  156  344    0    0                  13328
        47    2  309    0  157  327  219  157  345    0    0                  13329
        48    2  310    0  158  328  220  158  346    0    0                  13330
```

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0         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789 0

   101    4   96    0  148   96    0  148   96  210  148                         13383
   102    4   97    0  149   97    0  149   97  211  149                         13384
   103    4   98    0  150   98    0  150   98  212  150                         13385
   104    4  121    0  151  121    0  151  121  213  151                         13386
   105    4  122    0  152  122    0  152  122  214  152                         13387
   106    4  123    0  153  123    0  153  123  215  153                         13388
   107    4  124    0  154  124    0  154  124  216  154                         13389
   108    4  125    0  155  125    0  155  125  217  155                         13390
   109    4  126    0  156  126    0  156  126  218  156                         13391
   110    4  127    0  157  127    0  157  127  219  157                         13392
   111    4  128    0  158  128    0  158  128  220  158                         13393
   112    5    7    0  259    7    0  259    7    0  259                         13394
   257                        --IDENT. SUIT,GLOVES,BOOTS STRUCT NODES--          13395   CARD 52, SECTION 5.7.9
   39S  40S  41S  42S  43S  44S  45S  46S  47S  48S  49S  50S  51S  52S          13396   CARD 53
   53S  54S  55S  56S  57S  58S  59S 407S 408S 409S 410S 411S 412S 413S          13397
  414S 415S 416S 417S 418S 419S 420S 421S 422S 423S 424S 425S 426S 427S          13398
  428S 429S 430S 431S 432S 433S 434S 435S 436S 437S 438S 439S 440S 441S          13399
  442S 443S 444S 445S 446S 447S 448S 449S 450S 451S 452G 453G 454G 455G          13400
  456G 457G 458G 459G 460B 461B 462B 463B 464B 465B 466B 467B 468B 469B          13401
  470B 471B 472B 473B 474S 475S 476S 477S 478S 479S 480S 481S  60S  61S          13402
   62S  63S  64S  65S  66S  67S  68S  69S  70S  71S  72S  73S  74S  75S          13403
   76S  77S  78S  79S  80S 482S 483S 484S 485S 486S 487S 488S 489S 490S          13404
  491S 492S 493S 494S 495S 496S 497S 498S 499S 500S 501S 502S 503S 504S          13405
  505S 506S 507S 508S 509S 510S 511S 512S 513S 514S 515S 516S 517S 518S          13406
  519S 520S 521S 522S 523S 524S 525S 526S 527G 528G 529G 530G 531G 532G          13407
  533G 534G 535B 536B 537B 538B 539B 540B 541B 542B 543B 544B 545B 546B          13408
  547B 548B  81S  82S  83S  84S  85S  86S  87S  88S  89S  90S  91S  92S          13409
   93S  94S  95S  96S  97G  98G  99G 100S 101S 549S 550S 551S 552S 553S          13410
  554S 555B 556B 557B 558B 559B 560B 217S 218S 219S 220S 221S 222S 223S          13411
  224S 225S 226S 227S 228S 229S 230S 231S 232S 233G 234G 235G 236S 561S          13412
  562S 563S 564S 565S 566S 567S 568S 569S 570S 571S 572S 573S 574S 575S          13413
  576S 577S 578S 624G 625G                                                       13414
     0                        --ENVIRON.-ASSOC. NODE IDENT.--                    13415   CARD 54, SECTION 5.7.10
   159                        --EVA(TYPE 19) HF CURVE ASSIGN.--                  13416   CARD 56, SECTION 5.7.11
   39S    1  40S    2  41S    3  42S    4  43S    5  44S    6  45S    7          13417
   46S    8  47S    9  48S   10  49S   11  50S   12  51S   13  52S   14          13418
   53S   15  54S   16  55S   17  56S   18  57S   19  58S   20  59S   21          13419
  407S   22 408S   23 409S   24 410S   25 411S   26 412S   27 413S   28          13420
  414S   29 415S   30 416S   31 417S   32 418S   33 419S   34 420S   35          13421
  421S   36 422S   37 423S   38 424S   39 425S   40 426S   41 427S   42          13422
  428S   43 429S   44 430S   45 431S   46 432S   47 433S   48 434S   49          13423
  435S   50 436S   51 437S   52 438S   53 439S   54 440S   55 441S   56          13424
  442S   57 443S   58 444S   59 445S   60 446S   61 447S   62 448S   63          13425
  449S   64 450S   65 451S   66 452S   67 453S   68 454S   69 455S   70          13426
  456S   71 457S   72 458S   73 459S   74 460S   75 461S   76 462S   77          13427
  463S   78 464S   79 465S   80 466S   81 467S   82 468S   83 469S   84          13428
  470S   85 471S   86 472S   87 473S   88 474S   89 475S   90 476S   91          13429
  477S   92 478S   93 479S   94 480S   95 481S   96 579S   97 582S   98          13430
  585S   99 588S  100 591S  101 594S  102 597S  103 600S  104 603S  105          13431
  606S  106 609S  107 612S  108 615S  109 618S  110 621S  111 155S  112          13432
  157S  113 161S  114 163S  115 159S  116 165S  117 179S  118 131S  119          13433
  130S  120 132S  121 133S  122 134S  123 177S  124  38S  125  36S  126          13434
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          1         2         3         4         5         6         7         8
 1234567890123456789012345678901234567890123456789012345678901234567890123456789 0

  35S  127  37S  128  34S  129 102S  130 146S  134 626S  260 627S  261      13435
 628S  262 629S  263 630S  264 668S  265 649S  265 670S  266 671S  267      13436
 672S  268 673S  269 674S  270 675S  271 676S  272 677S  273 678S  267      13437
 679S  274 680S  275 681S  276 682S  277 103S  131  16T  132  40T  132      13438
 135S  133  49T  278 155S  279 143S  280 142S  281                         13439
    1                      --EVA(TYPE 20) PT CURVE ASSIGN.--               13440  CARD 58
 178S    1                                                                 13441  CARD 59
    3                      --PRESCRIBED WALL TEMP. CURVES--                13442  CARD 60,  SECTION 5.7.12
 150S  150 211S  211 212S  212                                             13443  CARD 61
   49                      --LRV TYPE 11 CURVES--                          13444  CARD 62
  691  691  692  692  693  693  694  694  695  695  696  696  697  697      13445  CARD 63
  698  698  699  699  700  700  701  701  702  702  703  703  704  704      13446
  705  705  706  706  710  710  711  711  712  712  715  715  716  716      13447
  717  717  718  718  719  719  720  720  721  721  722  722  723  723      13448
  724  724  725  725  726  726  727  727  728  728  729  729  730  730      13449
  731  731  732  732  733  733  734  734  735  735  736  736  737  737      13450
  740  740  744  744  745  745  687  687  688  688  689  689  690  690      13451
    0                      --TIME VARIANT MASS DATA--                      13452  CARD 64,  SECTION 5.7.13
  173                      --TIME VARIANT CONNECTION DATA--                13453  CARD 66,  SECTION 5.7.14
  83T    8   15  84T    7   15  85T    7   15  86T    7   15               13454  CARD 67
  87T    7   15  88T    6   15  89T    7   15  90T    6   15               13455
  91T    6   15  92T    6   15  93T    6   15  94T    5   15               13456
  95T    8   15  96T    6   15  97T    6   15  98T    6   15               13457
 121T    6   15 122T    5   15 123T    7   15 124T    6   15               13458
 125T    6   15 126T    6   15 127T    6   15 128T    4   15               13459
 129T    5   16 130T    4   16 131T    4   16 132T    4   16               13460
 133T    4   16 134T    3   16 135T    5   16 136T    4   16               13461
 137T    4   16 138T    4   16 139T    4   16 140T    3   16               13462
 141T    5   16 142T    4   16 143T    4   16 144T    4   16               13463
 145T    4   16 146T    3   16 147T    5   16 148T    4   16               13464
 149T    4   16 150T    4   16 151T    4   16 152T    2   16               13465
 420S    1    6 420S    2    7 421S    1    8 421S    2    9               13466
 428S    1    8 428S    2    9 429S    1    6 429S    2    7               13467
 638S    1    1 638S    2    1 638S    3    1 638S    4    1               13468
 638S    5    1 639S    1    1 639S    2    1 639S    3    1               13469
 639S    4    1 639S    5    1 640S    1    1 640S    2    1               13470
 640S    3    1 640S    4    1 640S    5    1 641S    1    1               13471
 641S    2    1 641S    3    1 641S    4    1 641S    5    1               13472
 642S    1    1 642S    2    1 642S    3    1 642S    4    1               13473
 642S    5    1 643S    1    1 643S    2    1 643S    3    1               13474
 643S    4    1 643S    5    1 644S    1    1 644S    2    1               13475
 644S    3    1 644S    4    1 644S    5    1 645S    1    1               13476
 645S    2    1 645S    3    1 645S    4    1 645S    5    1               13477
 646S    1    1 646S    2    1 646S    3    1 646S    4    1               13478
 646S    5    1 647S    1    1 647S    2    1 647S    3    1               13479
 647S    4    1 647S    5    1 648S    1    1 648S    2    1               13480
 648S    3    1 648S    4    1 648S    5    1 649S    1    1               13481
 649S    2    1 649S    3    1 649S    4    1 649S    5    1               13482
 650S    1    1 650S    2    1 650S    3    1 650S    4    1               13483
 650S    5    1 651S    1    1 651S    2    1 651S    3    1               13484
 651S    4    1 651S    5    1 668S    1    2 668S    2    2               13485
 669S    1    2 669S    2    2 670S    1    2 670S    2    2               13486
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0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

 671S     1    2 671S    2    2 672S    1    2 672S    2    2                    13487
 673S     1    2 673S    2    2 674S    1    2 674S    2    2                    13488
 675S     1    2 675S    2    2 676S    1    2 676S    2    2                    13489
 677S     1    2 677S    2    2 678S    1    2 678S    2    2                    13490
 679S     1    2 679S    2    2 680S    1    2 680S    2    2                    13491
 681S     1    2 681S    2    2 682S    1    2 682S    2    2                    13492
 713S     3    3 708S    1    4 709S    1    5 709S    2    5                    13493
 713S     1    4 714S    1    5 714S    2    5 738S    1    5                    13494
 738S     2    5 739S    1    5 741S    1    5 743S    1    5                    13495
 456S     1   10 456S    2   11 161S    1   12 741S    2   13                    13496
 743S     2   14                                                                 13497
   13                    --SPECIAL CONNECTIONS--                                 13498   CARD 68,  SECTION 5.7.15
    8   110    35.232    8  112    35.232    8  113    35.232                    13499   CARD 69
    8   114    35.232    8  116    35.232    8  236    35.232                    13500
    8   238    35.232    8  239    35.232    8  241    35.232                    13501
   10   111    99.376  114  237    99.376   12  115   220.006                    13502
  116   240   220.006                                                            13503
    1     1     1                GAS DENSITY                                     13504   CARD 70,  SECTION 5.7.16
        .019                                                                     13505   CARD 71
    1    11     1                LIQ DENSITY                                     13506
               62.4                                                              13507
    2     4     1                GAS VISCOSITY                                   13508
          .00001241                                                              13509
    2    14     6            LIQ VISCOSITY                                       13510
     31.0      68.0     104.0     140.0     176.0     212.0  0.001205            13511
0.000676 0.0004255 0.0003162 0.0002384 0.0001894                                 13512
    4     2     1               GAS CONDUCTIVITY                                 13513
              .01516                                                             13514
    4     6     1               CONDUCTIVITY                                     13515
                  1.                                                             13516
    4    12     1               LIQ COND                                         13517
               .345                                                              13518
    4    20     1                     CONDUCTIVITY                               13519
                  1.                                                             13520
    4   100     1           LRV COMPONENTS THERMAL CONDUCTIVITY                  13521
                114.                                                             13522
    3     6     7               FRICTION FACTOR                                  13523
      0.0    2000.0    4000.0   10000.0   25000.0  100000.0 10000000.            13524
  0.00000   0.01250   0.01000   0.00825   0.00625   0.00450   0.00375            13525
    5     8     1            SPECIFIC HEAT                                       13526
                4.0                                                              13527
    5     3     1               GAS SPECIFIC HEAT                                13528
              .2402                                                              13529
    5     7     1            SPECIFIC HEAT                                       13530
          1.                                                                     13531
    5    13     1            LIQ SPECIFIC HEAT                                   13532
                  1.                                                             13533
    5    30     1                     SPECIFIC HEAT                              13534
                  1.                                                             13535
    5   100     1          LRV COMPONENTS SPECIFIC HEAT                          13536
                  1.                                                             13537
    9    61     1          CO2 SENSOR HEAT GEN. (1 WATT)                         13538
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         0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

          0.0       .0001     5.59      70.       70.       70.               13643 * NEW
      11  733       3         LRV NO. 2 MAN TOE                                 13644 *-  1
          0.0       .0001     5.59      70.       70.       70.               13645 * NEW
      11  734       3         LRV PAYLOAD TOP                                   13646 *-  1
          0.0       .0001     5.59      70.       70.       70.               13647 * NEW
      11  735       3         LRV PAYLOAD FRONT                                 13648 *-  1
          0.0       .0001     5.59      70.       70.       70.               13649 * NEW
      11  736       3         LRV PAYLOAD LEFT SIDE                             13650 *-  1
          0.0       .0001     5.59      70.       70.       70.               13651 * NEW
      11  737       3         LRV ANTENNA                                       13652 *-  1
          0.0       .0001     5.59      70.       70.       70.               13653 * NEW
      11  740       3         LRV BSLSS REAR SURFACE                            13654 *-  1
          0.0       .0001     5.59      70.       70.       70.               13655 * NEW
      11  744       3         LRV EMU SEAT BOTTOM SURFACE                       13656 *-  1
          0.0       .0001     5.59      70.       70.       70.               13657 * NEW
      11  745       3         LRV NO. 2 MAN SEAT BACK REAR SURFACE              13658 *-  1
          0.0       .0001     5.59      70.       70.       70.               13659 * NEW
      12   1        1         CABIN GAS TEMPERATURE                             13660 *-  1
             70.                                                                13661
      12   2        1         CABIN GAS DEW PT. TEMP                            13662
             50.                                                                13663
      12   3        1         SUIT INLET DEW PT. TEMP                           13664
             50.                                                                13665
      12   4        1         SUIT INLET TEMP                                   13666
             70.                                                                13667
      12   5        1         LCG INLET TEMP                                    13668
             45.                                                                13669
      21   1        2          RADIANT INTERCHANGE CODE                         13670
             1.                                                                 13671
      24   1        1              HHH CURVE                                    13672
          0.0       0.5                                                         13673
      24   2        1              HHH IN OPS HEATER                            13674
             100.                                                               13675
      24   3        1          HA FOR LIOH BED IN CANISTER                      13676
             6.                                                                 13677
      24   4        1          HA FOR CANISTER SHELL                            13678
             2.                                                                 13679
      24   5        1         HA FOR FAN HOUSING                                13680
             5.                                                                 13681
      24   6        1         HA FOR CO2 SENSOR                                 13682
             3.413                                                              13683
      24   7        1              LCG FILM COEFFICIENT (WATER)                 13684
                    60.                                                         13685
      29   1        1         MULT. FACTOR ON Q DIFF.          LOC PERT.        13686
                     .5                                                         13687
      29   2        1         MULT. FACTOR ON Q SWEAT          LOC PERT.        13688
                     .5                                                         13689
      29   3        1         MULT. FACTOR ON HEAT XFER COEFF LOC PERT.         13690
                     .5                                                         13691
      30   1        1         TVC- 1. CONNECTS BSLSS UMBIL TO BAG               13692
                     1.                                                         13693
      30   2        1         TVC- 1. CONNECTS BSLSS UMBIL TO SPACE             13694
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0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

3.        2.        2.        1.        1.                                 13878
    35    7    4            EMU CONFIGURATION MODE                           13879
48.       49.47     49.4701   58.       1.        1.        -1.              13880
-1.                                                                        13881
    35    8    1            AUX. WTR RESERVOIR SHUT/OFF VALVE                13882
                    1.                                                     13883
    13                                                                     13884  END OF DATA
```