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SHUTTLE

FINAL REPORT

SHUTTLE CRYOGENICS SUPPLY SYSTEM

OPTIMIZATION STUDY

VOLUME V A-1

USERS MANUAL FOR MATH MODELS

CONTRACT NAS9-11330

Prepared for Manned Spacecraft Center
by
Manned Space Programs, Space Systems Division

LOCKHEED MISSILES & SPACE COMPANY. INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

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USERS MANUAL FOR MATH MODELS

LOCKHEED MISSILES & SPACE COMPANY

FOREWORD

This Final Report provides the results obtained in the Shuttle Cryogenics Supply System Optimization Study, NAS 9-11330, performed by Lockheed Missiles & Space Company (LMSC) under contract to the National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas. The study was under the technical direction of Mr. T. L. Davies, Cryogenics Section of the Power Generation Branch, Propulsion and Power Division. Technical effort producing these results was performed in the period from October 1970 to June 1973.

The Final Report is published in eleven volumes*:

Volume I	–	Executive Summary
Volumes I, III, and IV	–	Technical Report
Volume VA-1 and VA-2 Math Model	–	Users Manual
Volume VB-1, VB-2, VB-3, and VB-4 Math Model	–	Programmer Manual
Volume VI	–	Appendixes

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*The Table of Contents for all volumes appears in Volume I only. Section 12 in Volume III contains the List of References for Volumes I through IV.

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CONTENTS

ILLUSTRATIONS

TABLES

Section 1.0

INTRODUCTION TO THE CRYOGENIC INTEGRATED MATH MODEL PROGRAM (TCIMM)

1.1 PROGRAM DESCRIPTION

The Integrated Math Model for Cryogenic Systems is a flexible, broadly applicable systems parametric analysis tool. The program will effectively accommodate systems of considerable complexity involving large numbers of performance dependent variables such as are found in the individual and integrated cryogen systems. Basically, the program logic structure pursues an orderly progression path through any given system in much the same fashion as is employed for manual systems analysis.

The system configuration schematic is converted to an alpha-numeric formatted configuration data table input starting with the cryogen consumer and identifying all components, such as lines, fittings, valves, etc., each in its proper order and ending with the cryogen supply source assembly. Then, for each of the constituent component assemblies, such as gas generators, turbo machinery, heat exchangers, accumulators, etc., the performance requirements are assembled in input data tabulations. Systems operating constraints and duty cycle definitions are further added as input data coded to the configuration operating sequence. Characteristic performance data over the range of temperatures, pressures and flow rates of interest for each of the functional component assemblies, is input to the program or table look-up data arrays to be called as needed in the analysis sequences. The use of table look-up data combined with closed-form solution analysis, where needed, permits the rapid computation of the desired parameters as the analysis proceeds through the system configuration.

The program will size the system to fit the operating demands and constraints and produces as output the component and system hardware size and weight, propellant (or reactant) weight, vented fluid weight, and such analytical information (i.e., computed performance values) as may be desired. The analytical results are displayed both as time dependent data tabulations and summary table data.

1.1.1 PROGRAM PURPOSE

The intended purpose of the program is to provide an analytical tool which permits rapid parametric evaluation of the various types of cryogenics spacecraft systems currently under study in the national space program. The mathematical techniques built into the program provides the capability for in-depth analysis (combined with rapid problem solution) for the production of a larger quantity of soundly based trade-study data than normally would be obtained in hand calculations. Program flexibility in accommodating advanced systems resides in its modular type programming which permits program growth with simple addition of new subroutines and the addition of variables to existing common banks. Conversely, the program is easily dismantled if it is desired to limit analysis to only one or two systems and utilize a smaller computing machine.

In summary, the purpose of the program may be said to be that of providing an improved general analysis tool for cryogen technology applications.

1.1.2 PROGRAM STRUCTURE

The Integrated Math Model for Cryogenic Systems consists essentially of three major sections as illustrated in Figure 1.1.2-1. Within each of the major sections the structure is further broken into block subsections, each of which is reserved for specific functions of data management, data utilization or analytical data display.

1.1.2.1 PROGRAM INPUT DATA LOGIC

Of necessity, the program requires a rather large data bank capable of providing characteristic performance data for the wide variety of component assemblies found in typical cryogen systems.

Program data requirements for the Integrated Math Model are divided into two types. The first type consists of the "semi-permanent" data tables which the program employs to compute performance, weight, property, and other characteristics as a function of up to four variables per run.

The table data bank contains the necessary component performance characterization data for the system configurations to be considered, as well as the required cryogen properties data and required material properties data.

The "source data", as obtained, is verified as being authoritative, and is then processed into a formatted tabular array which specifies the table name, ID codes,

PROGRAM INPUT

SYSTEM(S) CONFIGURATION
INPUT PARAMETERS (EACH SYSTEM)
TABLE DATA BANK (FUNCTIONAL PROPERTIES DATA)
PROGRAM OPTIONS (INPUT/OUTPUT CONTROL)
PROGRAM INSTRUCTIONS (COMPUTATION OPTIONS)

PROGRAM COMPUTATION

MASS TRANSFER - ENERGY REQUIREMENTS - FLUID STATE DETERMINATION - THERMODYNAMIC PROCESSES - RESIDUALS - FLUID FLOW COMPUTATIONS - HEAT TRANSFER - SIZING CALCULATIONS - WEIGHT DETERMINATIONS -

\- FOR -

CRYOGENIC CONSUMER - LINES - FITTINGS - CONTROLS - ACCUMULATORS - HEAT EXCHANGERS - GAS GENERATORS - TURBINES - MOTORS - PUMPS. FLUID CONDITIONERS - FLUID TANKS - PRESSURIZATION PROCESSES - ACQUISITION DEVICES - GAS PRESSURE BOTTLES

PROGRAM OUTPUT

OUTPUT FORMAT - HARD COPY
\- PLOT COPY
\- TAPE GENERATION
\- DRUM STORAGE
PARAMETRIC RECYCLE - DATA RETRIEVAL

FIGURE 1.1.2-1 MAJOR PROGRAM STRUCTURE

the dependent variables, and the independent variables--in order of use. The tabulated array data is carefully ordered such that curve fitting routines can extrapolate data points with good accuracy and speed. The prepared data array is punched into data card decks and verified for correctness. The procedure is illustrated in Figure 1.1.2-2. All data tables are logged as to reference, source, date of data acquisition, and pertinent data limitations such as range of application, etc.

Since a large volume of table data can be required by the program, a unique data management set of subroutines is employed to retrieve any particular table and extract the required information with remarkably high speed and accuracy. Additionally, a machine plotted and/or printed tabulation "echo" of the tables can be requested for easy table input checking.

The program currently contains forty-six tables and currently will accommodate up to fifty tables for a total of 7000 words.

The second type of input data is "variable" and contains the variable input parameters which may be perturbated for parametric system studies. These data include duty cycle characteristics, configuration description, and operational requirements of the system being studied. The variable input values are printed out just prior to the system computed data output as a means of input verification.

The general program input data requirements by type of data and source is illustrated in Figure 1.1.2-3.

1.1.2.2 PROGRAM COMPUTATION LOGIC

In order for the Integrated Math Model to accomodate the possible range of cryogenic systems likely to be considered and perform as a general systems analysis tool, the following three premises are established:

(1) Any logical combination of supply tanks, lines, fittings, valves, regulators, heat exchangers, gas generators, pumps, accumulators, and "cryogen-consumer" components can be specified as a system configuration point.

(2) The "cryogen-consumer" component may be any of the components being supplied with cryogenic fluids.

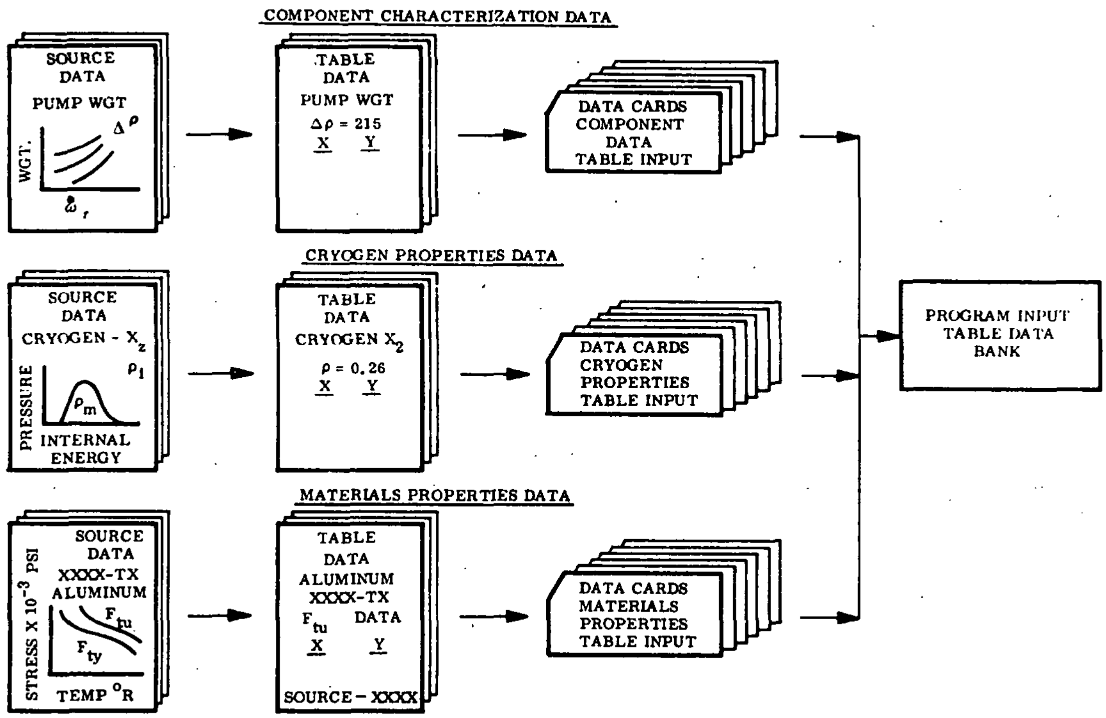

FIGURE 1.1.2-2 SOURCE DATA PREPARATION SEQUENCE

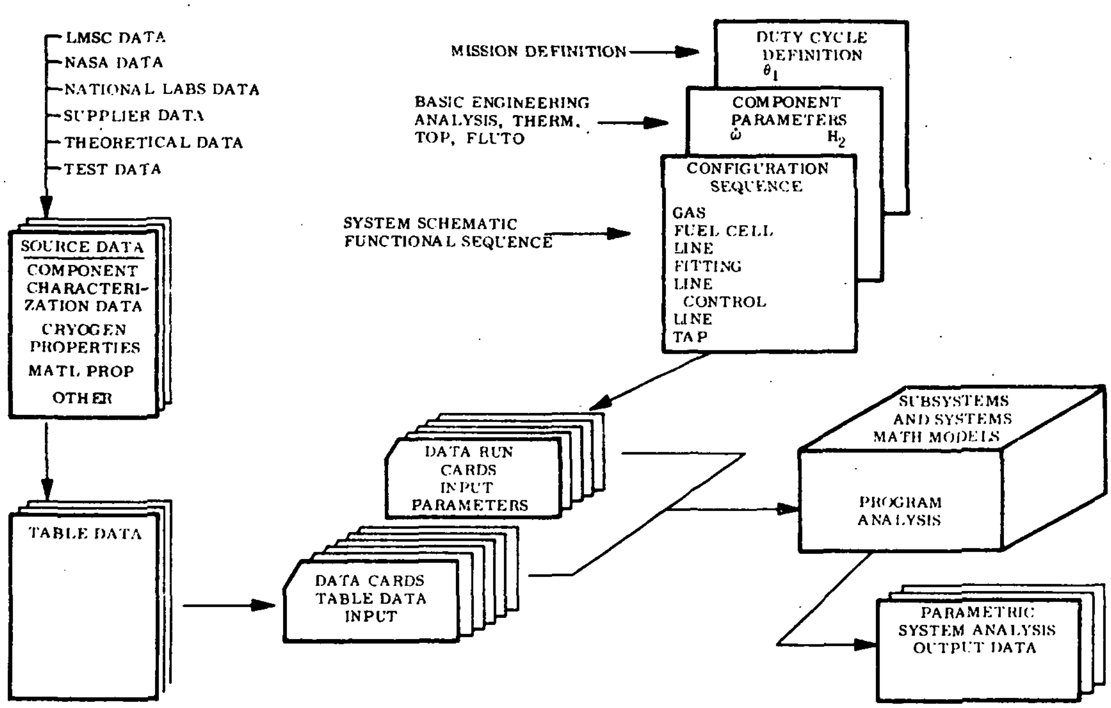

FIGURE 1.1.2-3 PROGRAM INPUT REQUIREMENTS BY TYPE OF DATA

(3) An integrated cryogenic system may contain a number of similar and/or different cryogen subsystems to be fed from a common cryogen supply source.

Although these premises appear to force the generation of a very large program,an examination of the six basic individual cryogen system concepts reveals a marked similarity and commonality of components by kind. Table 1.1.2-1 illustrates adequately the fact that there are less than twenty-five kinds of major component assemblies to be considered,additionally, the temperatures, pressures, and flow rates are for the most part within reasonable range spans, thus further reducing the quantity of data to be manipulated.

1.1.3 PROGRAM OPERATIONAL SEQUENCE

The program capability for accommodating a number of different kinds of systems analysis, derives from the use of built-in sequencing indices. The indices are stored as data statements in subroutine STØDTA, and are readily available to a programmer or knowledgeable program-user for restructuring, if necessary. The indices are used by the various system analysis subprograms to direct the analysis from one set of procedural steps to the next in a preprogrammed manner. The details of the program operational sequence for the various systems to be analyzed are explained in the following subparagraphs.

1.1.3.1 PROGRAM INTIATION AND CONTROL

Program initiation is accomplished through by the driver subroutine CØNTRL. This subroutine initializes the data storage subroutines and reads the first card of the input data deck for the user's name and program title. Following this a call to subroutine INTAB reads in table data deck (or file) to storage. As a check on the correctness of the data table input, subroutine INTAB causes an "echo" printout of the selected table numbers to be printed for visual reference. A typical "echo" print is illustrated in Table 1.1.3-1. Note that the "echo" also permits verification of the number of words in any given table, thus aiding the user in troubleshooting incomplete table entries. CØNTRL then reads in the name and type of system to be evaluated. This is followed by a call to subroutine CØMPIL which reads into core the cryogen system input data deck containing the system duty cycle, configuration sequence, and pertinent system and component parametric information.

COMPONENT LIST	ACPS		APU		FUEL CELL		EC/LSS		OMS	
	SUBCR	SUPCR	SUBCR	SUPCR	SUBCR	SUPCR	SUBCR	SUPCR	P.A.E.	P.A.T.
ENGINE (MAIN)									●	●
ENGINE (AUXILIARY)	●	●								
TURBINE - GENERATOR			●	●						
FUEL CELL					●	●				
CABIN ATMOSPHERE							●	●		
ENVIRONMENT CONTROL							●	●		
LINES	●	●	●	●	●	●	●	●	●	●
FITTINGS	●	●	●	●	●	●	●	●	●	●
VALVES	●	●	●	●	●	●	●	●	●	●
REGULATORS	●	●	●	●	●	●	●	●		
ACCUMULATORS	●	●	●	●						
HEAT EXCHANGERS	●	●	●	●	●	●	●	●		
HEAT SOURCES			●	●	●	●	●	●		
GAS GENERATORS	●	●	●	●						●
TURBINES	●									●
MOTORS			●							
PUMPS	●		●							●
TANKAGE	●	●	●	●	●	●	●	●		
THERMAL CONDITIONING UNIT	●		●						●	●
PRESSURE CONTROL	●	●	●	●		●	●	●	●	●
ACQUISITION	●		●						●	●
GAS STORAGE			●						●	●
CIRCULATION PUMPS				●		●				

TABLE 1.1.2-1 CRYOGEN SYSTEMS - COMPONENT SIMILARITY BY KIND

Subroutine CØNTRL next calls subroutine CRYCØN to process the calculations required for the system being considered. Completion of the required calculations causes program control to return from CRYCØN to CØNTRL. Subroutine CØNTRL then tests to see if additional system data decks are to be read in, if so, it does and repeats the cycle; if not, CØNTRL calls EXIT and terminates the run.

Brief flow-charts for CØNTRL, CØMPIL, and CRYCØN are presented in Figure 1.1.3-1, -2, and -3.

TABLE 1.1.3-1

DATA TABLE SELECTION "ECHO"

TABLE NUMBER	TITLE OF TABLE	NUMBER OF DIMENSIONS	NUMBER OF SUBTABLES	NUMBER OF WORDS
1	RCS-THRUSTER WEIGHT	4	6	122
2	RCS-VAC. SP. IMPULSE	3	3	68
3	SPEC.HT/LB OF O2 REMOVED	3	5	206
4	SPEC.HT/LB OF H2 REMOVED	3	5	184
5	TEMP. /LB. OF O2 REMOVED	3	5	184
6	TEMP. /LB. OF H2 REMOVED	3	5	192
7	RR/ VS PGG,M/R,PAMB,PCHP	5	12	95
8	KK VS PGG,M/R,PAMB,PCHP	5	12	95
9	OMS ENGINE WEIGHT	3	3	50
10	OMS VAC. SP. IMPULSE	3	3	68
11	HEX HOT GAS FLOW - LO2	5	24	133
12	HEX HOT GAS FLOW - LH2	5	12	71
13	GAS GENERATOR WEIGHT	4	10	220
14	LO2 TRANSFER PUMP WEIGHT	5	8	130
15	LH2 TRANSFER PUMP WEIGHT	5	8	138
16	MOTOR WEIGHT	3	5	120
17	VAC.JAC.DIA.VS.WEIGHT	2	1	34
18	PHI - HYDROGEN	3	5	172
19	TEMP. OF N2 VS RHO F(P)	3	5	180
20	HT.XFER.COEF.-H2	3	4	106
21	HT.XFER.COEF.-O2-N2	3	4	138
22	FTU OF 321/347 ST.STEEL	2	1	32
23	FTU OF 2219-T87 ALUM.	2	1	36
24	FTU OF 6061-T6 ALUMINUM	2	1	30
25	FTU OF INCONEL-718	2	1	30
26	FTU OF TI-6AL-4V	2	1	30
27	HEAD COEFFICIENT VS NS	2	1	34
28	ADIABATIC EFF. VS NS	2	1	44
29	EFFIC. QUOT.VS IMP. DIAM	2	1	46
30	BASE LINE STAGE WT VS DI	2	1	28
31	SATURATED STEAM. T.VS P.	2	1	46
32	SP.HT. OF O-H COMB.PROD.	3	4	114
33	OXYGEN INTERNAL ENERGY	3	5	166
34	HYDROGEN INTERNAL ENERGY	3	5	216
35	OXYGEN INTERNAL ENERGY	3	5	142
36	OXYGEN VAPOR PRESSURE	3	5	166
37	HYDROGEN VAPOR PRESSURE	3	5	216
38	OXYGEN VAPOR PRESSURE	3	5	142
39	ENTHALPY OF LO2	2	1	46
40	ENTHALPY OF LH2	2	1	24
41	ENTHALPY OF HELIUM	3	5	142
42	OXYGEN ENTHALPY (GAS)	3	5	98
43	HYDROGEN ENTHALPY (GAS)	3	5	122
44	BETA FACTOR	2	1	28
45	SIGMA-DELTAP FOR HEXELC	3	5	172
46	BETA VALUES FOR H2	3	5	168
			TOTAL TABLE STORAGE =	5024

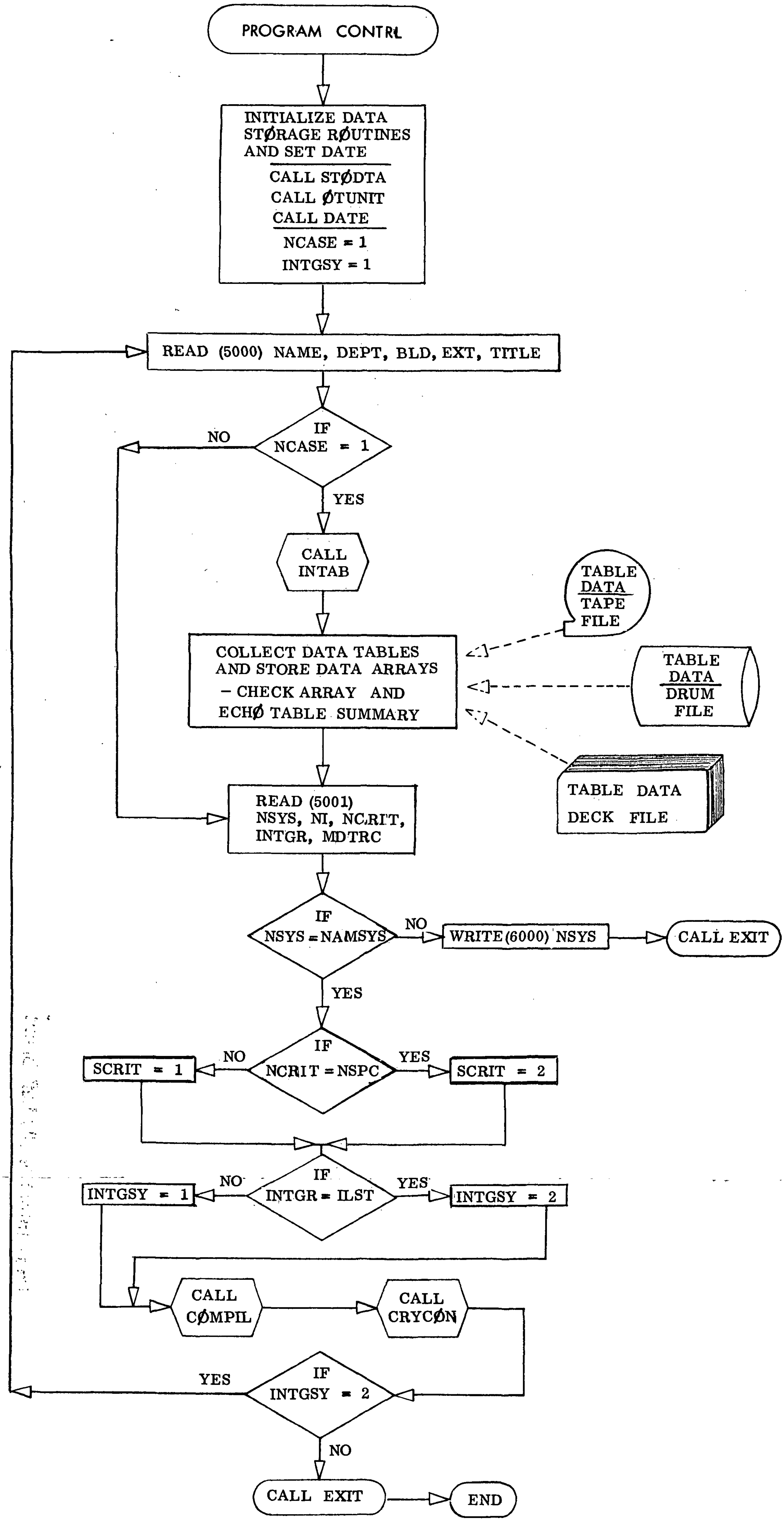

Fig. 1.1.3-1 Flow Chart For Subroutine CØNTROL

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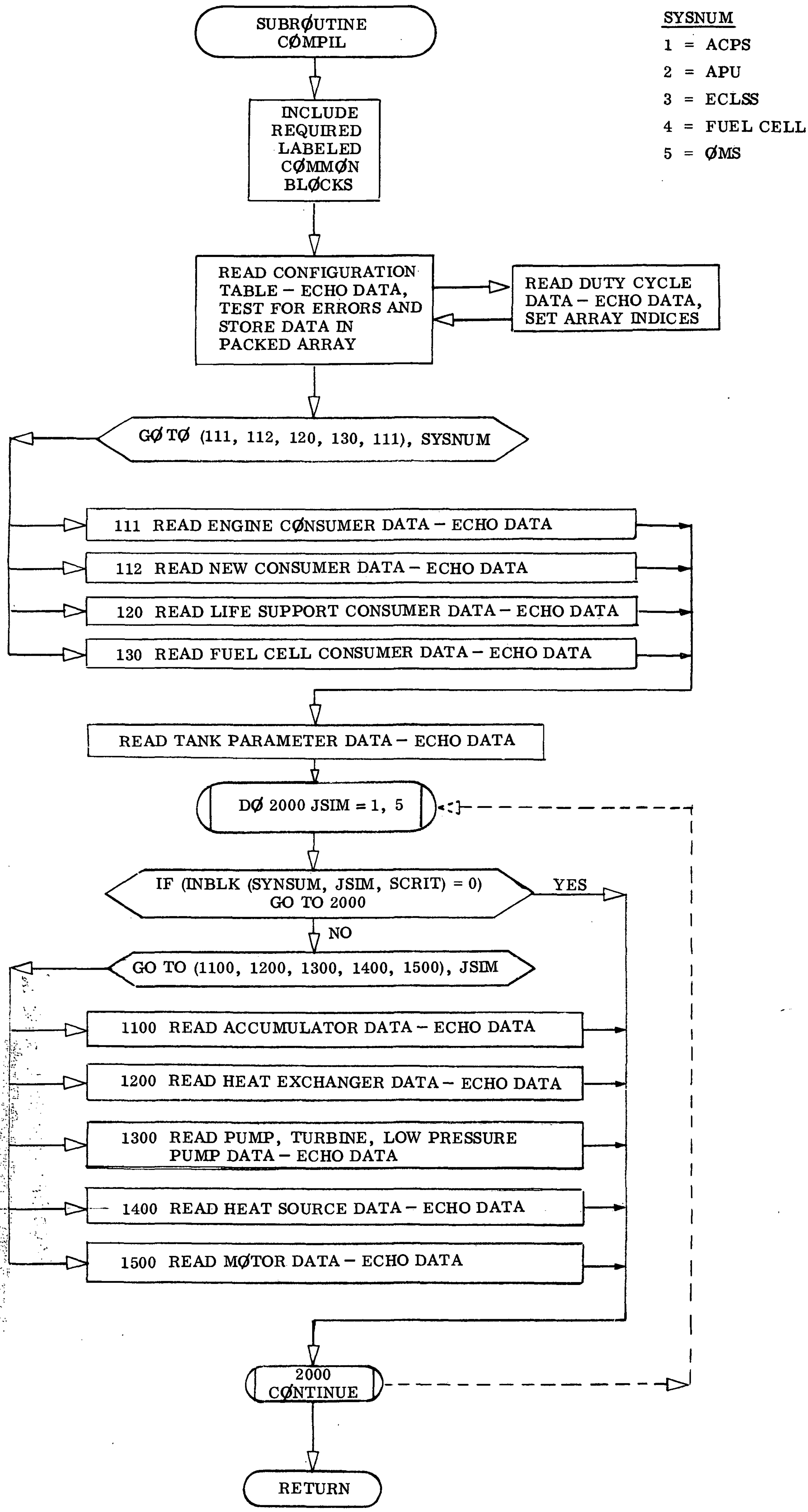

Fig. 1.1.3-2 Flow Chart for Subroutine CØMPIL (Simplified)

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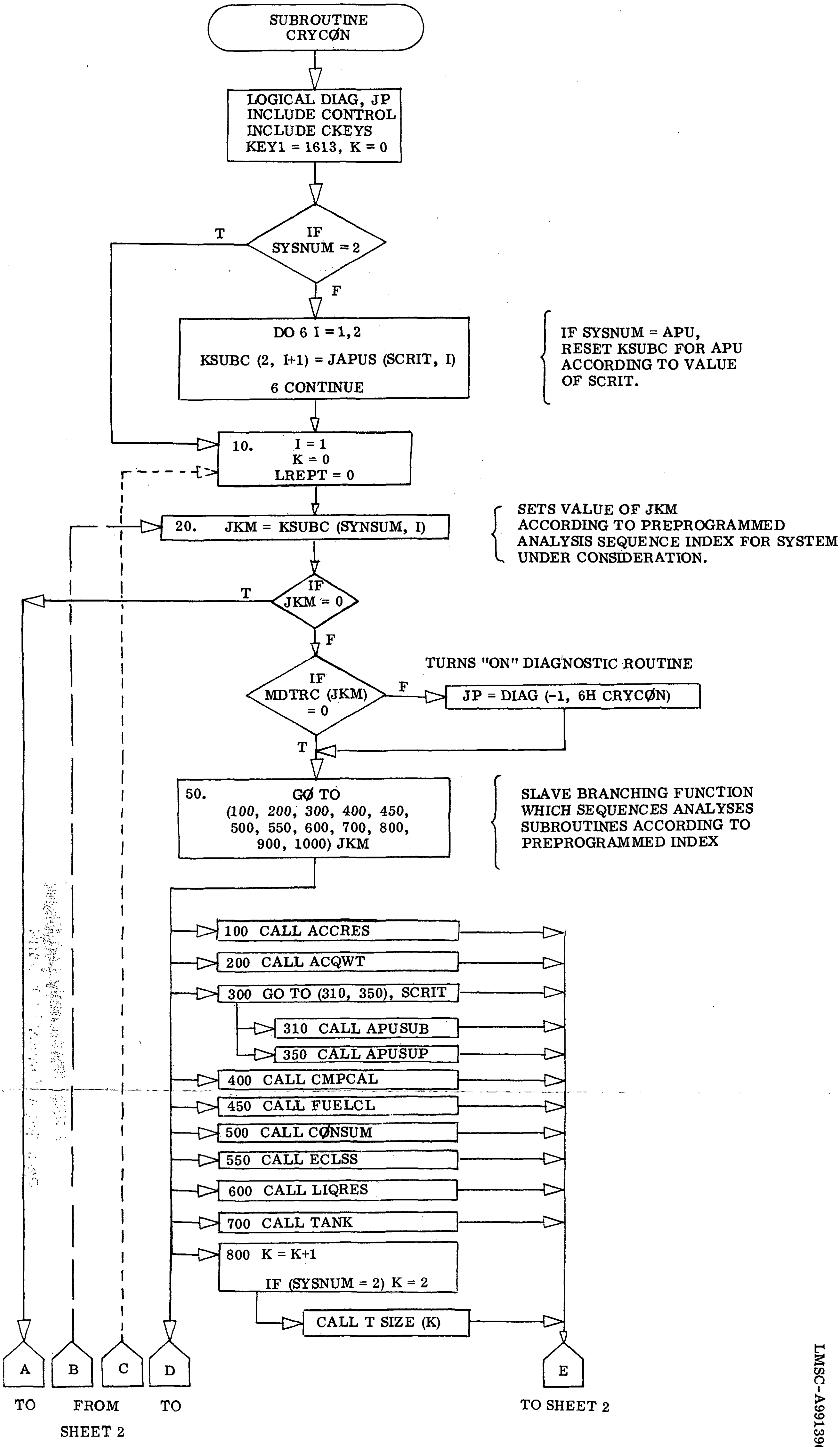

Fig. 1.1.3-3 Flow Chart for Subroutine CRYCØN (Sheet-1)

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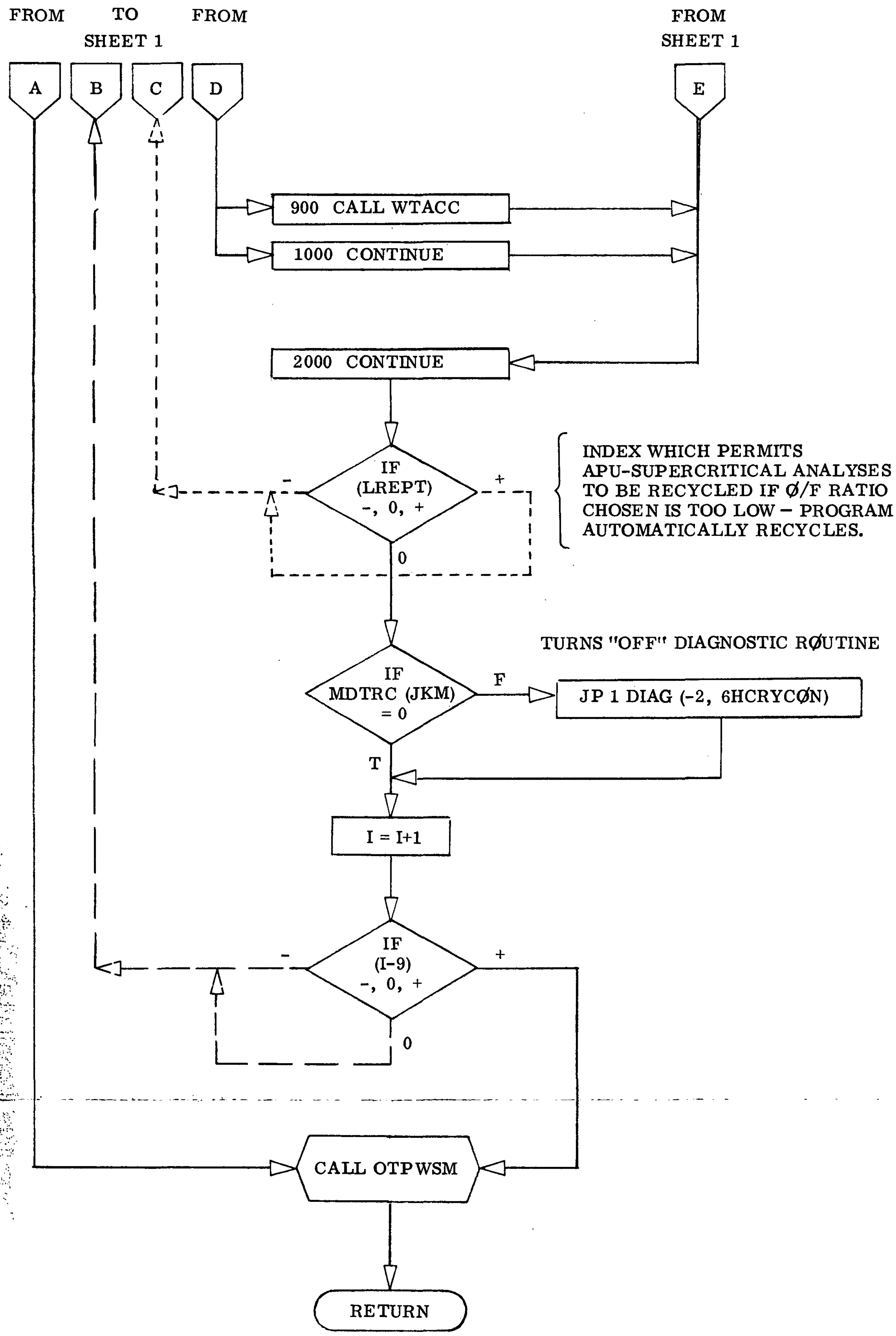

Fig. 1.1.3-3 Flow Chart for Subroutine CRYCØN (Sheet-2)

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1.1.3.2 Program Sequencing Subroutine. The mechanism for controlling the analysis sequencing is set up in Subroutine CRYCØN. This subroutine performs the major branching functions of calling in the various subprograms needed for each specific system type analysis. Key variables used by CRYCØN to effect this control over the analysis sequencing are SYSNUM and SCRIT. For each cryogen system (and system kind) there exists a preprogrammed set of induces stored on a data statement (KSUBC [SYSNUM, I]) which defines the order in which the major analytical subroutines will be called. This set of indices are used in CRYCØN for sequencing purposes.

1.1.3.2.1 Program Calculations Sequence. The initiation of specific system calculations occurs in Subroutine CRYCØN. For any of the five cryogen systems, CRYCØN will obtain from labeled common CCNTRL, the values for SYSNUM and SCRIT. This permits access to the indices stored in the preprogrammed set of data statements KSUBC (SYSNUM, I). The branching index JKM (see Fig. 1.1.3-3) then can assume the value of each stored sequencing index in a given KSUBC data statement as CRYCØN cycles through its "I" loop. Concurrently, as each JKM index is picked up, CRYCØN tests to see if the specified subprogram requires a "user signalled" diagnostic switch to be turned "ON" or left "OFF." This is an especially useful feature when debugging changes to subprogram coding. Values for MDTRC, the diagnostic indices, are entered by the user in the system run data deck (see Section 1.2). The KSUBC data statements are physically located in Subroutine STODTA and are available through labeled common CCNTRL via an INCLUDE statement.

The index "K" employed in CRYCØN is used to indicate initial or final conditions for subroutine TSIZEI (K). For the specific requirements of an Auxiliary Power System analysis (APU), the value of "K" can only be set equal to two (2). For all other system analysis "K" is set equal to one (1) the first time called and set equal to two (2) the second time called.

The index "LREPT" is employed, by CRYCØN, only when processing a super-critical APU system. Its use permits the recycling (starting over again) of subroutine APUSUP when that subprogram determines that the fuel mixture ratio (O/F) input value is too low and yields impossible temperature values. At that point the subprogram incrementally raises the O/F ratio and reruns the analysis. If three attempts fail, the subprogram quits and terminates the analysis.

The manner in which the sequential execution of CRYCØN can vary is explained in the subsections which follow.

1.1.3.2.2 <u>ACPS – OMS Systems Calculation Sequence.</u> If, for example, a sub-critical cryogenic reaction control system (ACPS) had been chosen for analysis, the following would be the sequence of events executed by subroutine CRYCØN. The values assigned to SYSNUM, SCRIT, and KSUBC (SYSNUM, I) would be:

SYSNUM = 1	(For ACPS)
SCRIT = 1	(Subcritical System)
KSUBC (1, I)	(KSUBC for ACPS)

and the preprogrammed Data Statement to be used would be:

DATA (KSUBC |1, I|, I = 1, NBRSR)/6, 4, 10, 9, 8, 1, 10, 11, 2/

where "NBRSR" is defined as 9 in PDP-CCNTRL.

There are, therefore, nine subprograms to be called in the reaction control system analysis.

Referring to the CRYCØN Flow Chart (Fig. 1.1.3-3), note that statement 10 sets I = 1 for the first pass in the calculation loop. Statement 20 then sets JKM = KSUBC (SYSNUM, I), or, literally equal to KSUBC (1, I) which is the first of the nine values defined in the data statement body. Thus JKM = 6 in the first loop pass. Statement 50 is a "computed" GO TO statement which in this instance literally says

GO TO the JKM (6th) value within the parenthesis, or GO TO Statement 500, which calls subroutine CØNSUM. Thus, the order of subprogram execution, in sequence, by subroutine CRYCØN for a reaction control system analysis would be as shown in the table below:

Table 1.1.3-2

CRYCØN EXECUTION SEQUENCE FOR ACPS ANALYSIS

Loop Pass	JKM Value	GØ TØ Statement	Subprogram Called
1	6	500	CØNSUM
2	4	400	CMPCAL
3	10	800	TSIZEI(1)
4	9	700	TANK
5	8	600	LIQRES
6	1	100	ACCRES
7	10	800	TSIZEI(2)
8	11	900	WTACC
9	2	200	ACQWT

The above table holds true for an orbit maneuvering system (subcritical cryogen) as well, since the only significant differences are larger engines and fewer, but larger, component parts.

Upon completion of nine loop passes through CRYCON, accomplishing all of the calculations required by the respective subprograms, the final step is a call to subroutine OTPWSM which extracts from the labeled common storage, the values needed for a system weight summary and outputs these data in a formatted weight summary table. Program control returns to subroutine CONTRL for either execution of a second case (system analysis) or termination. A general flow chart for a typical reaction control system analysis is presented in Figure 1.1.3-4.

1.1.3.2.3 <u>APU System Calculations Sequence.</u> For the Auxiliary Power System analysis, two operating system types are possible; a subcritical cryogen fluid supply subsystem and a supercritical cryogen fluid supply subsystem.

It is therefore necessary to provide a means of altering the preprogrammed values to accommodate both cryogen fluid supply subsystems. This is accomplished by pre-programming KSUBC (2,I) for the more likely supercritical fluids case, and modifying the data statement when considering the subcritical cryogen fluid supply subsystem. This data statement adjustment is automatically taken care of in subroutine CRYCON DO6 loop as shown in the Flow Chart (Ref. Fig. 1.1.3-4). The DO6 loop will reverse the second and third values of the data stored as KSUBC(2,I) depending upon the value assigned to SCRIT. JAPUS (SCRIT, I) is the variable accomplishing the switch in value. The data statements defining JAPUS are stored in subroutine STODTA.

<u>Subcritical Analysis</u>: For an APU system requiring a subcritical cryogen fluid supply subsystem, the values assigned, via input, to the variables SYSNUM, SCRIT and KSUBC (SYSNUM, I) would be

SYSNUM = 2 (For APU)
SCRIT = 1 (For Sub critical)

and KSUBC(2,I)

The preprogrammed data statement stored in core is
KSUBC(2 I) I = 1,9)/6 3 4 10 11 2 0 0 0/ which is actually the sequence for a

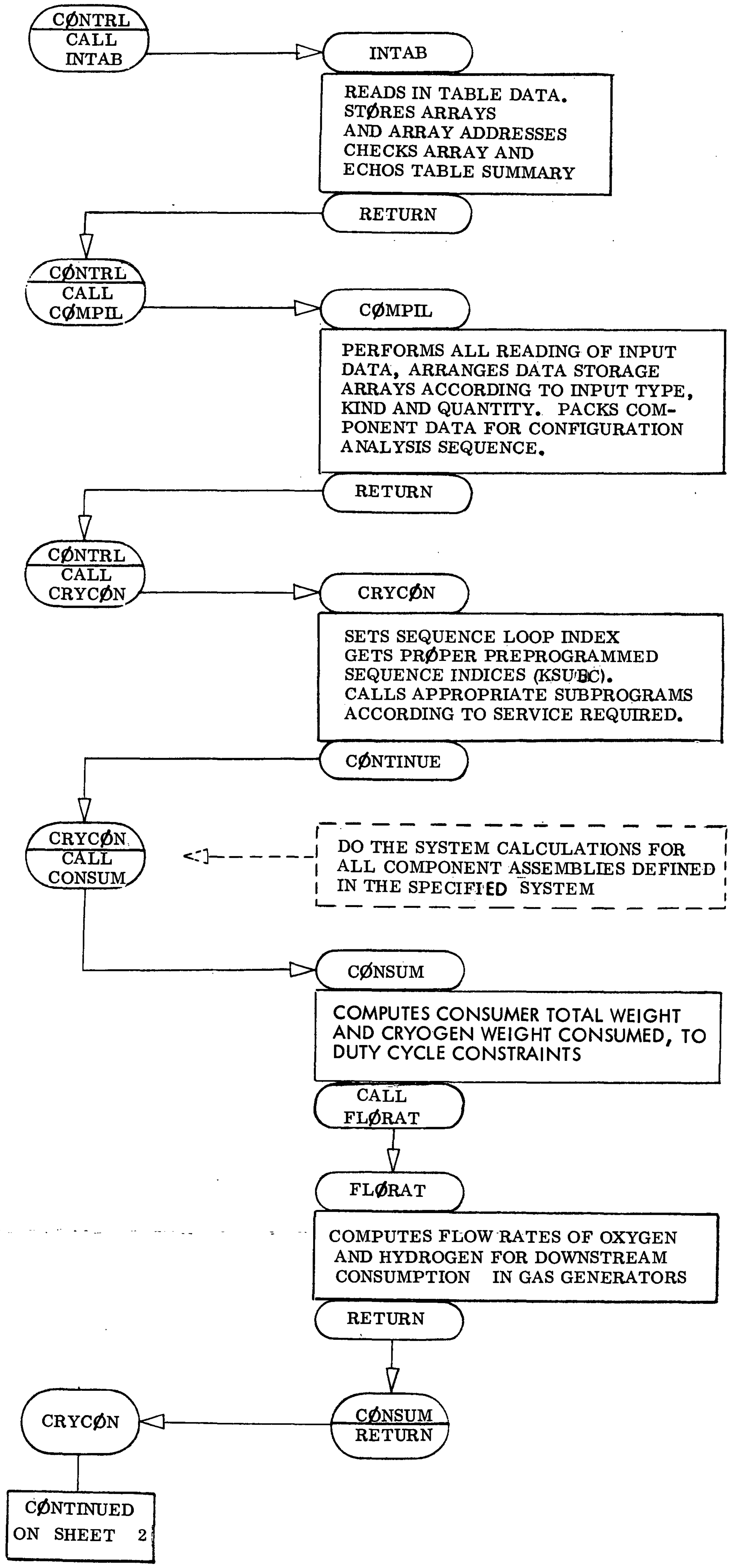

Fig. 1.1.3-4 General FLØW Chart For ACPS-ØMS System Analysis (Sheet -1)

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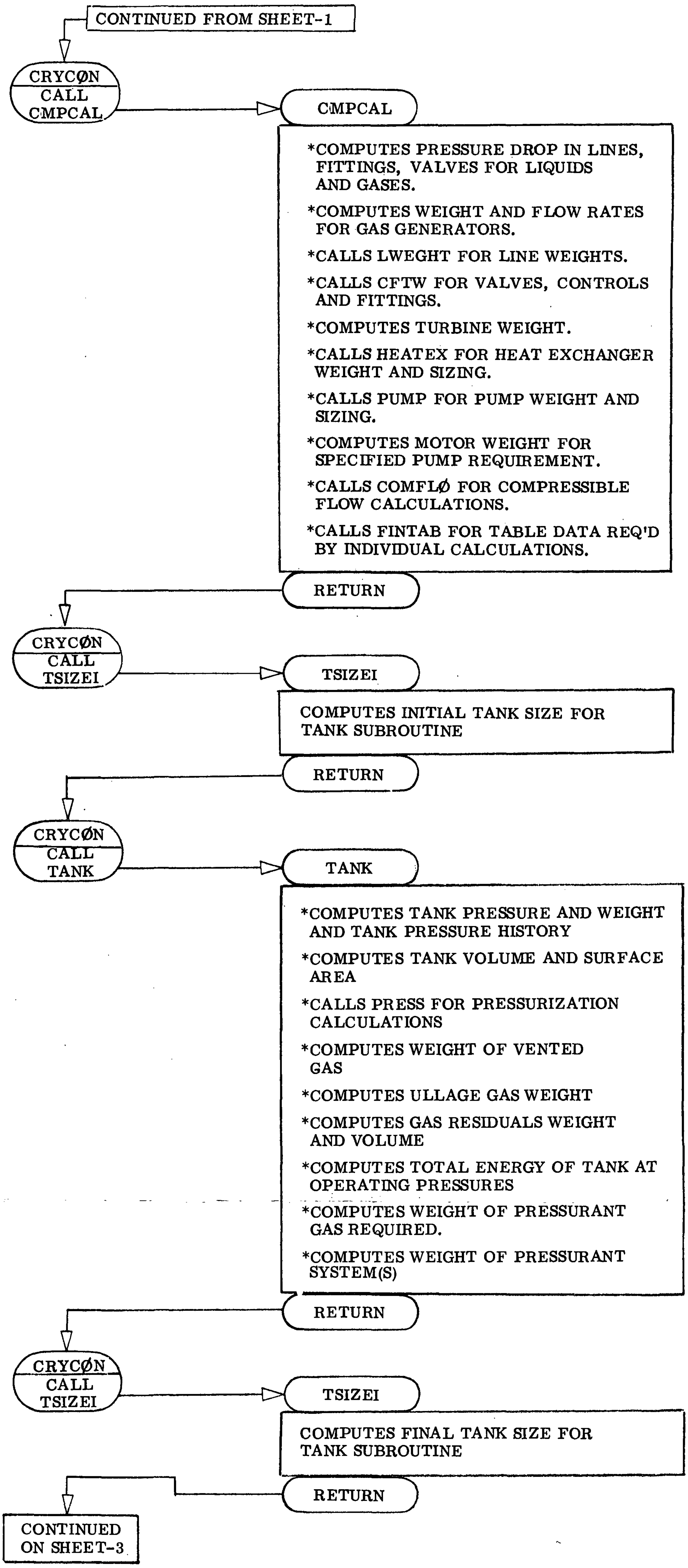

Fig. 1.1.3-4 General Flow Chart for ACAS-ØMS System Analyses (Sheet-2)

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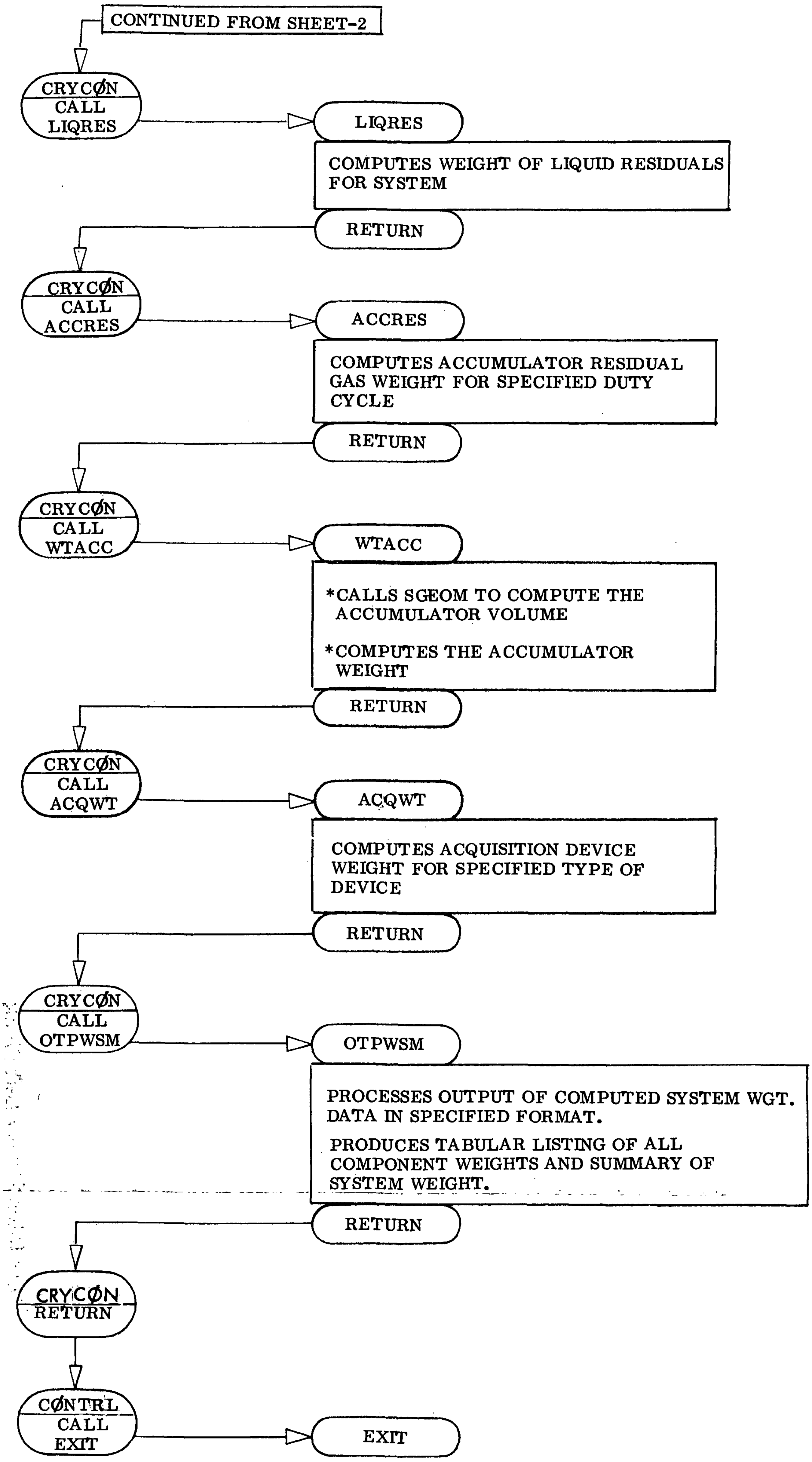

Fig. 1.1.3-4 General Flow Chart For ACPS-OMS System Analysis (Sheet 3)

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supercritical subsystem. Therefore, the first action by CRYCØN is to reset the second and third values in a two-step loop as follows:

1st; KSUBC(2,2) = JAPUS(1,1) = 4

2nd; KSUBC(2,3) = JAPUS(1,2) = 3

and the reversed data statement becomes:

KSUBC(2,I),F = 1,9/6, 4, 3, 10, 11, 2, 0, 0, 0/

Note that only six subprograms are called in an APU analysis. The order of subprogram execution, in sequence, is presented in the following table.

Table 1.1.3-3

CRYCON EXECUTION SEQUENCE FOR AN APU SUBCRITICAL SYSTEM ANALYSIS

Loop Pass	JKM Value	GØ TØ Statement	Subprogram Called
1	6	500	CØNSUM
2	4	400	CMPCAL
3	3	300	APUSUB
4	10	800	TSIZEI(2)
5	11	900	WTACC
6	2	200	ACQWT
7	0	2200	Terminates Loop

Upon leaving the sequence loop subroutine CRYCON calls subroutine OTPWSM to output the component and system weight summary. Program execution returns to subroutine CONTRL which checks to see if another case (same system, or, new one) is to be run, or if program termination is in order.

Super-critical Analysis:

For an APU system requiring a super-critical cryogen fluid supply subsystem, the input values assigned to the variables SYSNUM, SCRIT and KSUBC (SYSNUM, I) would be:

SYSNUM = 2 (For APU)
SCRIT = 2 (For Super-critical)

and KSUBC(2, I)

Assuming, for example, that the supercritical case is run as the second case in a multi-case run (not necessarily so) the preprogrammed data statement in core would still be, KSUBC(2, I), I = 1, 9)/6, 4, 3, 10, 11, 2, 0, 0, 0/. The first activity in CRYCON, since SYSNUM = 2, will be to reset the second and third value of the KSUBC data in a two-step loop as follows: (SCRIT = 2)

1st KSUBC(2,2) = 3
2nd KSUBC(2,3) = 4

and the revised data statement becomes;

KSUBC(2,I), I = 1, 9)/6, 3, 4, 10, 11, 2, 0, 0, 0/.

The order of sub-program execution, in sequence, is presented in the following table:

Table 1.1.3-4

CRYCØN EXECUTION SEQUENCE FOR AN APU SUPERCRITICAL SYSTEM ANALYSIS

Loop Pass	JKM Value	GØ TØ Statement	Subprogram Called
1	6	500	CØNSUM
2	3	300	APUSUP
3	4	400	CMPCAL
4	10	800	TSIZEI(2)
5	11	900	WTACC
6	2	200	ACQWT
7	0	2200	Terminates Loop

Upon leaving the sequence loop CRYCØN calls subroutine ØTPWSM to output the component and system weight summary, and then return program execution to subroutine CØNTRL.

1.1.3.2.4 Life Support System Calculation Sequence. For the Life Support System analysis, the cryogen fluid supply subsystem is by definition a supercritical subsystem with a relatively simple and straightforward plumbing structure. It is also unique among the other systems, in that the cryogen fluids employed are oxygen and nitrogen. Because of this fact, and the need to maintain overall program variable storage requirements at a level that will fit into core, it was decided not to expand the program variable arrays to accommodate a third cryogen fluid, but instead, to use those portions of the arrays normally used for the hydrogen fluid to store the nitrogen fluid parameter values. Consequently, the Life Support subprogram became a fairly large self-contained subprogram, designated as subroutine ECLSS. Hence, subroutine CRYCØN makes only one call for the subprogram. In the case of a Life Support System analysis, the values assigned, via input, to the variables SYSNUM, SCRIT and KSUBC (SYSNUM, I) would be,

SYSNUM = 3

SCRIT = 2

and KSUBC (3,I).

The preprogrammed data statement stored in core for this system analysis is, (KSUBC(3,I), I = 1,9)/7, 0, 0, 0, 0, 0, 0, 0, 0/. And the order of subprogram execution by subroutine CRYCON is as shown in the following table:

Table 1.1.3-5

CRYCON EXECUTION SEQUENCE FOR A LIFE SUPPORT SYSTEM ANALYSIS

LOOP PASS	JKM VALUE	GO TO STATEMENT	SUB-PROGRAM CALLED
1	7	550	ECLSS
2	0	2200	Terminates Loop

As stated previously CRYCON calls subroutine OTPWSM, outputs the weight summaries and returns to CONTRL for a new case, or termination of the program.

1.1.3.2.5 Fuel Cell System Calculation Sequence. The cryogen fuel cell system as defined by this study is a fuel cell array fed by a supercritical fluids storage and supply subsystem. Further, the energy required for conditioning the reactant fluids and maintaining their super-critical condition in storage is wholly derived from the reject heat of the fuel cells. The subprogram which characterizes the fuel cell system is subroutine FUELCL. This rather large sub-program performs the system sizing calculations based upon the mass and energy transfer requirements of the input performance and duty cycle constraints.

The individual fluid circuit components and line segments are sized and weighed by subroutine CMPCAL which additionally supplys pressure drop calculations for the main reactant circuits.

For a fuel cell analysis, subroutine CRYCØN has the values assigned, via input data, for SYSNUM, SCRIT and KSUBC (SYSNUM, I), as follows:

SYSNUM = 4

SCRIT = 2

and KSUBC (4,I)

The preprogrammed data statement stored in core for fuel cell system analysis is, (KSUBC(4,I),I = 1,9)/5, 4, 0, 0, 0, 0, 0, 0, 0/.

The order of sub-program execution is as given in the following table.

Table 1.1.3-6

CRYCØN EXECUTION SEQUENCE FOR A FUEL CELL SYSTEM ANALYSIS

Loop Pass	JKM Value	GØ TØ Statement	Subprogram Called
1	5	450	FUELCL
2	4	400	CMPCAL
3	0	2200	Terminates Loop

When the internal loop is terminated CRYCON calls subroutine OTPWSM, outputs the weight summaries and returns to CONTRL for a new case, or termination of the program.

1.1.3.2.6 <u>Orbit Maneuvering System Calculation Sequence</u> The orbit maneuvering system (OMS) employed in this study was defined to be a subcritical cryogen fluids pump-fed system. The OMS and ACPS analysis procedures are quite similar program-wise, with the principal differences being engine size, component size and the fact that the OMS has fewer, though larger components.

For an OMS analysis, SYSNUM, SCRIT and KSUBC (SYSNUM, I) will have the following values:

SYSNUM = 5
SCRIT = 1

and KSUBC (5,I).

The preprogrammed data statement stored in core for OMS analysis is:
(KSUBC(5,I),I = 1,9)/6, 4, 10, 9, 8, 1, 10, 11, 2/

The order of sub-program execution by sub-routine CRYCON is identical to the order given in Table 1.1.3-2, and the subsequent remarks following that table.

1.2 INPUT DATA

The input data deck structure will vary according to the system to be analyzed and the type of fluid storage system employed. All input data cards are read within the body of subroutine CONTRL. The segments of input data to be read are generally divided into two groups; (1) input data common to all system analyses and (2) input data specific to a given system analysis Necessarily a variety of read statement formats must be used and these are defined in labeled card formats given later in this discussion.

In general, a data input deck, for any system to be analyzed, will be made up of a set of card groups from the following group list:

(a) User Identification Card (First Header Card)
(b) Case Title Card (Second Header Card)
(c) Table Data Echo Control Card
(d) Add-File Card - To cause loading of "Table Data" file - or - Actual "Table Data" Deck may be placed here, replacing the Add-File card
(e) System Definition Card
(f) Configuration Definition Data Cards
(g) Duty Cycle Definition Data Cards
(h) Consumer Characterization Data Cards
(i) Fluid Storage Tanks Characterization and Configuration Data Cards
(j) Fluid Accumulator Characterization Data Card
(k) Heat Exchanger Characterization Data Cards
(l) Pump and Turbine Characterization Data Cards

(m) Heat Source Characterization Data Cards

(n) Motor Characterization Data Cards

Cards (a), (b), and (e) are read directly by subroutine CONTRL. Cards (c) and (d) are read by subroutine INTAB, called by CONTRL. Cards (f) through (n) are read by subroutine COMPIL, called by CONTRL.

1.2.1 Input Data - Card Definition and Description

Data definition and input card descriptions for data contained in the fourteen data card groups are presented in detail in the following subsections. Card data formats are presented in Subsection 1.2.

1.2 1.1 User I.D. and Case Title Cards.

Gp(a) Card-1

The User I.D. card identifies the analyst making the program run. This card is required in every run deck. The card contains the following information:

Name, Dept., Bldg., Extension

Gp(b) - Card-1

A case title card is to be provided for every system data deck as a means of providing run identification for the system being evaluated. Seventy-two (72) spaces are provided for the title. Short titles are to be centered in the 72 spaces.

1.2.1.2 Table Data Input Cards.

Gp(c) - Card-1

This card is the Table Data Echo control card. The variables contained on the card are: IFT, OFT, NPRT, NPRT2

IFT = Table Data Input Drum Unit

OFT = Table Data Output Drum Unit

NPRT = Table Data Echo Print Control

= 0, Print All Tables, One Table per Page

= 1, Print No Table Output

= 2, Print All Tables with no page eject - Table Dump

NPRT2 = Control for Table Summary

NPRT = 1 ⟩ Print Brief Table Summary
NPRT2 = 1

Gp(d) - Card-1 (Normal Setup)

If the Table Data has been entered and stored as a DATA File, then the Data File may be assigned and Card-1 here will be a simple:

@ ADD,P FILNAM

where

FILNAM is the Data File nemonic.

If the Table Data is on cards to be read in at this time, then the Gp(d) cards will be the actual table data card sets as described in detail in Subsection 1.2.6.

Alternate Table Deck Input: (N-sets)

Gp(d) Card-1

The Table I.D. and Control Card will contain the following information:

Title	–	Table Title (Description)
ND	–	Number of Dimensions in Table (MAX = 7, MIN = 2)
NC	–	Number of Comment Cards in Table
IP	–	Plot Option
		(O = No Plot, 1 = Plot Table)
NT	–	Table Number

GP(d) Card-2

Table Comment Card - Gives further description of table data and data reference sources. There may be NC comment cards.

Gp(d) Card-3

Table Subset Variable Card - Specifies additional variable and its values for Table Data Subsets.

LABV – Variable Label

NP – Number of Values to be used (is also number of data subsets)

TAB – Value, $Value_z$, ··· $Value_{np}$

There must be (ND-2) of these cards present in Table Set. (ND = Number of dimensions in Table)

Gp(d) Card-4

Table Plot Control Card - Contains X-axis label, Y-axis label, X-MIN value, X-MAX value. One card is required for each Table Set.

Gp(d) Card-5

Table Data Subset Characterization Card - card contains:

NV – Number of Data Point Sets (X,Y) or Number of coefficients

TYPE – Type of Data in Table

= 0, Coefficients of polynomial

= 1, Discrete data points from curve

= 2, Equation

NIP – Number of points to be used for data interpolation

$\leqslant$ NV

$>$ 1

= 2, Linear Interpolation

= 3, parabolic or hyperbolic interpolation

There must be one of these cards for each data sub-set in the Table Set.

Gp(d) Card-6

Table Data Card - :

For discrete data there are three data sets (X,Y) per card arranged in order of increasing values of X, for NV sets of points.

For coefficients; coefficients are arranged in order of power and NV coefficients are read. (For example: $C_1X^2 + C_2X + C_3 = 0$; Input as C_1, C_2, C_3 and NV = 3)

There are NV/3 discrete data cards required, or NV/6 coefficient data cards required.

There will be N sets of the Gp(d) table card sets, where N equals the number of Table Data sets required for the program.

1.2.1.3 System Definition Card

Gp(e) Card-1

The system definition card provides the system identification; specifies whether the system has a subcritical or super-critical fluid supply subsystem; specifies whether or not additional systems are to be read in for additional case consideration; and, specifies which subprogram diagnostic switches are to be activated. The variables which are read are:

NSYS — First three letters of system name
N1 — Additional six alpha spaces for rest of system name
NCRIT — First three letters of subcritical or super-critical
MDTRC — Diagnostic switch for eleven subprograms
0, or, blank for NO Diagnostics
1, turns ON Diagnostic switch as defined in PDP-CCNTRL

There must be one system definition card in each system input deck.

1.2.1.4 System Configuration Definition Data Cards

Gp(f) Card-1

The system configuration definition data represents the program image of the system schematic diagram. Only one (1) card format is employed which functions as a data input card, and as a configuration table END card. The flexibility of the data format card in providing different kinds of information resides in the technique of reading the array and changing the variable name to correspond to the value entered at any point in the array. Since each data card represents a specific item, such as, fluid, component, or line segment, and their associated parameters, the data array is conveniently manageable.

The variables which are allocated to the card are as follows:

CFUNCT – Six alpha characters which specify either the fluid, consumer assembly, or system component item, currently being considered. The allowable names are defined in DATA (FNAME) located in subroutine STODTA, and further described in PDP-CCNFIG

CFTYPE – A single, or, two digit number which characterizes the type or kind of fluid, consumer assembly, or system component item

CNOPER – Single digit number - for number of consumer assemblies, or component items operating in parallel; or, in the case of a fluid, the digit specifies the fluid state (i.e., 1 = gas; 2 = liquid)

CNSTBY – Single digit number - for the number of consumer assemblies or component items in parallel standby condition (not operating)

CMTYPE – Single Digit Number which specifies the material type for the system component item. CMTYPE values are defined in PDP-CCNFIG.

FRCOEF – Variable containing the friction coefficient applicable to the system component item being considered

LOD – Length over Diameter Ratio, or, Length applicable to the system component item under consideration (Real Number)

DIAM – Diameter (I.D. or Port) applicable to system component item being considered

CITYPE – Integer defining Insulation Type employed for system component item being considered

ITHICK — Insulation thickness (Real Number) for system component item under consideration

NBAR — Number (Real) of insulation layers per inch of thickness for component item being considered

CODE — Six alpha character code name for component item under consideration. (i.e., PS02, etc.)

There must be one card for; (a) each fluid and fluid state change, (b) each fluid system consumer, (c) each fluid system component item, and (d) each fluid system line segment item. The cards are arranged starting with the oxidizer fluid system side and working from the consumer toward the fluid supply source. This is followed by the same arrangement for the fuel fluid side of the system. A typical configuration table is illustrated in the Input Data Deck Example given in Subsection 2.5. The very last card in the configuration data set must have END entered in the CFUNCT field, since this is required in subroutine COMPIL to terminate the READ loop. (It is also advisable to use card columns 73-80 to number the configuration data cards.)

1.2.1.5 System Duty Cycle Definition Data Cards

Gp(g) Card-1

The system duty cycle definition data cards contain the cyclic operating interval data required for each analysis. The variables employed are as given below. Note that the variable DCYCLE is in an array in which are stored alternate values of operating and non-operating time intervals:

DCYCLE(I) — Operating Time Interval

DCYCLE(I+1) — Non-operating Time Interval

PSI — Minimum Impulse Bit Degradation

NEOP — Number of Consumers Operating (Engines, Fuel Cells, etc.)

HP – Horsepower-Average Value In Interval

PAMB – Ambient Pressure-Average Value In Interval

PKW – Power (KW)-Average Value In Interval

RPRTIM – Time required per repressurization (cabin or airlock) during a given duty cycle Interval

There must be one card for each of the defined duty cycle interval periods in total mission span considered.

There must be a duty cycle end-card consisting of a negative number (i.e., -1) in the DCYCLE (I+1) field

1.2.1.6 Consumer Characterization Data Cards. The consumer characterization data cards are specific to the system undergoing analysis and contribute the only significant change in the input data decks for the respective systems. Aside from the differing input data for the five kinds of consumer systems further differences occur when a given system has a sub-critical fluid supply subsystem, or when it has a super-critical fluid supply subsystem. Thus, there are seven separate consumer characterization data card sets which cover the range of program analysis capability.

1.2.1.6 1 Engine Consumer Data Cards: (ACPS or OMS).

Gp(h-l) Card-1

The engine consumer data card is utilized for both ACPS and OMS engine data since the required parameters are identical and the same variable names are used. The variables employed are defined as follows:

NENG – Integer number of engines operating

GITEMP – Fluid Inlet Temperature to Engine(s)

GIPRES – Fluid Inlet Pressure to Engine(s)

THRUST – Developed Thrust per Engine

PSUBC — Engine Combustion Chamber Pressure

EXPRAT — Engine Nozzle Expansion Ratio

MIXRAT — Engine Oxidizer to Fuel Mixture Ratio (Real Number)

The single card is usually marked by placing the term ENG in card columns 78-80.

1.2.1.6.2 APU Consumer Data Cards. The APU Consumer input data requires two cards for either a subcritical or super-critical fluid fed system. The first card used in both cases is identical, while the second cards contain different information. The input cards required are as follows:

Gp(h-2) Card-1 (APU-Basic)

The following variables are input on the APU-Basic card:

NAPU — Integer number of APUs operating

HPR — Horsepower Rating of a single APU (Assumes all are identical)

FMR — Oxidizer to Fuel Mixture Ratio of Gas Generator Driving APU Turbine

PGG — Exit Pressure of Gas Generator driving APU Turbine

TIT — Turbine Inlet Temperature (Assumed also to be exhaust temperature of gas generator driving APU turbine)

TD — Exhaust discharge temperature from fluid conditioning heat exchangers

Gp(h-2) Card-2 (APU-Subcritical)

The variables input on the APU-Subcritical card are as follows:

MRGGCH — Oxidizer to fuel mixture ratio for the gas generator driving the fuel fluid conditioning heat exchanger

MRGGCØ — Oxidizer to fuel mixture ratio for the gas generator driving the oxidizer fluid conditioning heat exchanger

TDGGH — Discharge temperature of gas generator for fuel conditioning heat exchanger

TDGGØ — Discharge temperature of gas generator for oxidizer conditioning heat exchanger

TVH — Temperature of residual vapor in fuel storage tank

TVØ — Temperature of residual vapor in oxidizer storage tank

TENV — Environment temperature around APU System

Gp(h-2) Card-3 (APU-Supercritical)

The variables entered in the APU Supercritical data card are as follows:

FMRG — Oxidizer to fuel mixture ratio for supplementary gas generator

PFH — Final fuel tank pressure

PFØ — Final oxidizer tank pressure

TFH — Final fuel tank temperature

TFØ — Final oxidizer tank temperature

TG — Exit gas temperature from supplemental gas generator

DELPCP — Pressure rise (Delta-P) in tank circulating pump

TENV — Environmental temperature around APU system

1.2.1.6.3 Life Support Consumer Data Cards. The Life Support Consumer Data Input variables require four input cards in two different card formats. The variables by card format are as follows:

Gp(h-3) Card-1 (Ø2 = Oxygen, N2 = Nitrogen)

MDAYS — Integer number of days in mission

NCREW — Integer number of crewmen on board spacecraft

NRPRES — Integer number of cabin or airlock prepressurization planned for mission

NDARES — Integer number of days of reserve fluids required

Ø2FNØM — Metabolic oxygen requirement (lbs. per man-day)

GLKRAT — Spacecraft atmosphere leakage rate (lbs. per day)

TLSNØM — Nominal temperature of gases supplied for life support (1) = $Ø_2$; (2) = N2

RHØBEG — Loading density at stored life support fluids (1) = $Ø_2$; (2) = N2

TKFTEM — Final fluid tank temperatures (1) = $Ø_2$; (2) = N2

TKFPRS — Final fluid tank pressures (1) = $Ø_2$; (2) = N2

TENVR — Environment temperature around life support fluid storage tanks

CABVØL — Cabin (or airlock) volume

Gp(h-3) Card-2

LINDIA — Fluid line diameter entering fluid conditioning heat exchanger
(1) = Ø2; (2) = N2

HTRFLX — Heater rating (BTU/HR-sq. in. ret. temp.)
(1) For heaters in conditioning heat exchanger
(2) For fluid tank heaters

PLSNØM — Nominal pressure of delivered gaseous life support fluids
(1) = Ø2; (2) = N2

HTRDIA — Fluid tank heater diameter
(1) = Ø2; (2) = N2

HTRLNG — Fluid tank heater length
(1) = Ø2; (2) = N2

PSET1 — Lower pressure limit setting for Ø2 storage tank

PSET2 — Lower pressure limit setting for N2 storage tank

1.2.1.6.4 Fuel Cell Consumer Data Cards. The fuel cell consumer data input variables require four data cards in three different card formats. The variables arranged by card format are as follows:

Gp(h-4) Card-1

MRFC — Oxygen to hydrogen reactant mixture ratio for fuel cell

SRCFC — Specific reactant consumption (lbs/KWH @ rated power output)

QDTFC — Fuel cell heat rejection rate (BTU/KWH @ rated power output)

SPWTFC — Fuel cell specific weight (LB/KW @ rated power output)

TFCNOM — Nominal fuel cell gas fired temperature
(1) = Ø2; (2) = H2

TF21IN — F21 coolant fuel cell exit temperature

TF21ØU — F21 coolant fuel cell inlet temperature

TFØFC — Final Ø2 reactant tank temperature

TFHFC — Final H2 reactant tank temperature

PFØFC — Final Ø2 reactant tank temperature

PFHFC — Final H2 reactant tank temperature

RHØFIL — Reactant tank fill densities
(1) = Ø2; (2) = H2

WØVENT — Estimated Ø2 vent quantity

WHVENT — Estimated H2 vent quantity

DELTCP — Pressure rise in reactant tank circulating compressor

TENV — Environment temperature around fuel cell system

PRFCØP — Fuel cell operating pressure

PØWNØM — Nominal fuel cell operating power level

Gp(h-4) Card-2

NFCØP — Integer number of fuel cells operating

NFCSTB – Integer number of fuel cells on standby

PLSET1 – Lower limit pressure setting for Ø2 reactant tank

PLSET2 – Lower limit pressure setting for H2 reactant tank

VJANUL – Vacuum jacket annulus spacing (inches)
(1) = Ø2; (2) = H2

TKMXDI – Maximum tank pressure vellel diameter permitted
(design constraint - inches)
(1) = Ø2; (2) = H2

Gp(h-4) Card-3

FCVØLT – Nominal fuel cell voltage

PRGRAT – Nominal fuel cell purge rate
(1) = Ø2; (2) = H2

PRGTIM – Nominal fuel cell purge time (duration each purge)
(1) = Ø2; (2) = H2

PRGINT – Purge interval in ampere hours
(1) = Ø2; (2) = H2

1.2.1.7 Fluid Tank Data Input Cards. The fluid tankage characterization data cards are common to systems encompassed in the major program. Variations which may occur in some systems are accommodated by simply entering zero values for the variables not used by the particular system considered. Tank geometry considerations are provided for in the program, with subprogram capability for calculating; spherical, cylindrical, cylindrical with hemispherical ends, cylindrical with conical ends, and combination tankage with a common bulkhead, hemispherical bottom and conical top with a hemispherical cap (such as the cryogen shuttle orbiter drop-tank). For special tank shapes having predetermined dimensions, the program will read in the dimensions and do the necessary calculations for volume and surface area. For simple spherical tanks, or, simple cylindrical tanks with hemispherical ends, the program skips the special geometry input cards, and they must not be present in the input deck. The conditions controlling this branching option are specified in the tank geometry characterization sub-paragraph.

1.2.1.7.1 Fluid Tank Characterization DATA CARDS. The variables which characterize the fluid tank conditions and constraints are as follows:

Gp(i-1) Cards 1-4

NØP – Number of tanks operating on line (same fluid)

SATYPE – Fluid acquisition device type

SITYPE – Tankage insulation type

SMTYPE – Tank construction material type

SPTYPE – Tank pressurization system type

SITEMP – Tank initial fluid temperature

SIPRES – Tank initial pressure

SPGTEM – Pressurant gas temperature (inlet condition)

SØPRES – Tank operating pressure
SVPRES – Tank vent pressure setting

SHFLUX – Heat leak flux into tank (BTU/HR-Sq. Ft.) (Optional)

SITHIK – Tank insulation thickness (inches)

FLDLØD – Wgt. of fluid loaded into tank (optional)

SULGPC – Percent ullage (initial value for tank)

SMDIAM — Maximum tank diameter (ft.)

SHØTEM — Tank conditioning heat exchanger cold fluid outlet temperature

SHDELP — Tank conditioning heat exchanger cold fluid pressure drop (psi)

SPDELP — Tank circulating pump pressure rise (psi)

SGØTEM — Tank conditioning heat exchanger gas generator outlet temperature

SGGPC — Tank conditioning heat exchanger gas generator chamber pressure (outlet pressure)

SGMRAT — Tank conditioning heat exchanger gas generator mixture ratio (Ø/F).

SNBAR — Number of layers per inch of tank insulation material. (multilayer insulation only)

Two sets of the above cards are read; the first set contains the data for the oxidizer tankage, and the second set contains the data for the fuel tankage. Two sets (8-cards) must be present in the data deck, even if one set is blank.

1.2.1.7.2 Fluid Tank Geometry Data Cards.

Gp(i-2) Card-5

Tank Option Card – Provides branching option to tank geometry subprograms when required for special tank shapes.

IWØP — Integer number specifying tank geometry option

NØSHAP — Integer number specifying number of tank shape cards to follow

Option Definitions

If IWOP = 1 — Subprogram will compute tank volume for a spherical tank. If diameter of spherical tank exceeds value of SMDIAM, subprogram will add a cylindrical section between hemispheres with diameter equal to SMDIAM to accommodate tank volume required. Subprogram prints out requirement for cylindrical tank giving length of cylinder and diameter.

If IWØP = 2 — Subprograms will compute all parameters for a "Specific General Tank Configuration" - to be specified on input cards following this card.

If IWØP = 3 — Subprograms will compute all parameters for a "Fitted General Tank Configuration" in which all tank segments are specified except the length of the major cylindrical section. This "Length" will be computed by the subprograms to "fit" the required tank volume generated by system fluid consumption computations.

If, IWØP < 2, and N0SHAP = 0, the IWØP = 1 Option is executed automatically, and there are no tank shape cards following the option card. If, IWØP ≥ 2, then NØSHAP must specify the number of tank shapes involved and that many "shape cards" will have to be present following the Tank Option Card.

Gp(i-3) Card-6

Tank shape card(s) - the tank shape cards specify the geometric shape(s) involved in the tank structure in their order of consideration, the fluid contained by the tank, and the dimensions associated with each shape segment. The variables input in this card are as follows:

JTKTYP – Integer value which specifies tank segment shape (see notes)

JFLTP – Integer value which specifies fluid contained in tank segment shape

XD — Shape "X" dimension (see notes)

YD — Shape "Y" dimension (see notes)

ZD — Shape "Z" dimension (see notes)

Notes: Variable Specifications

JTKTYP = 1, for cylinder
= 2, frustrum of cone
= 3, hemi-ellipsoid
= 4, cylinder plus hemi-ellipsoid
= -2, inverted frustrum of cone
= -3, inverted hemi-ellipsoid (bulkhead)

JFLTYP = 1, oxidizer fluid
= 2, fuel fluid
= -1 oxidizer at common bulkhead
= -2, fuel at common bulkhead

For JTKTYP = 1,
XD = Height (ft)
YD = Radius (ft)

For JTKTYP = 2, or, -2,
XD = height (ft.)
YD = radius of top (ft.)
ZD = radius of bottom (ft.)

For JTKTYP = 3, or, -3
XD = radius along axis of rotation (ft.)
YD = radius perpendicular to axis of rotation(ft.)

For JTKTYP = 4,
XD = radius (and cylinder height) along axis of rotation (ft.)
YD = radius perpendicular to axis of rotation (ft.)

One card is necessary for each tank segment shape and the order of input is from the tank "Bottom" to the tank "Top".

1.2.1.8 Accumulator Data Input Cards. For those systems requiring an accumulator tank for the storage of gaseous fluid, provision is made for inputing the required accumulator data. The branching function permitting the reading of data specified in this and the following subsections is controlled by preprogrammed data statements called "INBLK", defined as DATA ((INBLK(SYSNUM, I, J), I = 1,5), J = 1,2). The five data statements, one for each major system, define which of five sets of major component input data cards are to be read for any given system. The five INBLK data statements will be found in subroutine STØDTA, INBLK is defined in PDP-CCNTRL. If INBLK(SYSNUM, 1,J) is set equal to one (1), the system requires and will read in accumulator data; conversely, if INBLK (SYSNUM, 1,J) equals zero, no accumulator is required and the accumulator input cards will not be present in the input data deck.

The variables which are input in the accumulator data input cards are as follows: six cards (two sets) are required since the variables for each fluid accumulator are entered separately. The variables for the oxidizer accumulator are entered first, followed by the variables for the fuel fluid accumulator.

Gp(j) Cards 1-3

NAØP — Integer value for number of accumulators operating for one fluid

AITYPE — Accumulator insulation type

AMTYPE — Accumulator structural material type

ATEMP — Operating temperature for accumulator

APRES — Operating pressure for accumulator

AHFLUX — Heat leak rate into accumulator (Btu/hr-ft^2)

AITHIK — accumulator insulation thickness (inches)

AVØL — Accumulator volume (cu. ft.)

ADIAM — Accumulator maximum diameter (ft.)

ANDELP — Pressure drop swing allowed in accumulator (psi)

ANBAR — Number of insulation layers per inch of thickness (multilayer insulation only)

Note that if INBLK (SYSNUM, 1,J) is zero, then there will be no accumulator data cards in the input data deck.

1.2.1.9 Heat Exchanger Data Input Cards. A requirement for heat exchangers of one form or another usually exists in most of the cryogen systems one can envision, except for the liquid fed OMS system. And, (as described in subsection 1.2.1.8) if INBLK (SYSNUM, 2,J) = 1, then heat exchangers are required and input data cards must be present, otherwise they are deleted.

Heat exchangers in a two fluid system usually occur in pairs, except for the case where a single supplementary heat exchanger might be required to make up for a potential energy deficiency resulting from a limited heat source capability. For purposes of uniformity, heat exchanger data will always be input for pairs of exchangers even if one of the pair does not exist. In this case, the non-existent exchanger is represented by a dummy (or blank) data card.

The heat exchanger variables required for input employ only two card formats. The second card is repeated for each exchanger in sets of two. The first card contains data for the first oxidizer heat exchanger occuring upstream of the system consumer, and the second card contains data for its fuel side equivalent. Additional data sets are input for other heat exchangers encountered as the schematic layout progresses toward the fluid supply tanks. The variables which are input on the Heat Exchanger Data Input Cards are doubly subscripted and are stored in a double array.

For example, "HXCODE (4,1) = HX07" is the heat exchanger schematic code symbol for the oxidizer (4, 1) heat exchanger of the fourth (4, 1) set of heat exchangers occurring upstream of the cryogen consumer.

The variables employed as input are as follows:

Gp(k) Card-1

NUMHEX – Integer value for number of pairs of heat exchangers being considered

One card is required if heat exchanger data is to be input.

Gp(k) Card-2

HEXHIT – Hot fluid inlet temperature (^{o}R)

HEXHØT – Hot fluid outlet temperature (^{o}R)

HEXCIT – Cold fluid inlet temperature (^{o}R)

HEXCØT – Cold fluid outlet temperature (^{o}R)

HEXHIP – Hot fluid inlet pressure (psia)

HEXHØP – Hot fluid outlet pressure (psia)

HEXCIP – Cold fluid inlet pressure (psia)

HEXCØP – Cold fluid outlet pressure (psia)

HXHDLP – Hot fluid pressure drop (psi)

HXCDLP – Cold fluid pressure drop (psi)

HXMRAT – Heat exchanger gas generator Ø/F mixture ratio

HXCØDE – Heat exchanger identification code symbol

Two cards are required for each pair of exchangers; oxidizer unit first followed by fuel side unit, when data is to be input.

1.2.1.10 Pump and Turbine Data Input Cards. The requirement for pump, or turbine data for any of the systems considered is preprogrammed in the stored INBLK data. If INBLK (SYSNUM, 3, J) = 1, then either pump or pump and turbine data are required to be input, otherwise the data cards are deleted. The pump data input cards contain three separate sets of information; (a) Pump data (high pressure); (b) Transfer pump data; and (c) Turbine data.

The six cards which make up the pump and turbine data card set consist of two pump data cards (one for each fluid), two transfer pump data cards (one for each fluid), and two turbine data cards (one for each fluid). All six cards must be present if any of the data are required. Non-pertinent variables are simply left blank.

The variables required as input are as follows:

Gp (l) Cards 1-2

PTYPE – Interger value for pump type
PTYPE = 1, for pump only
PTYPE = 2, for turbopump assy

PEFF – Pump efficiency

PNPSH – Pump net positive suction head (psi)

PSSPED – Pump speed (rpm)

EPDELP – Estimated pump pressure rise (psi)

Gp (l) Cards 3-4

TPEFF – Transfer pump efficiency

TPNPSH – Transfer pump net positive suction head (psi)

TPDELP — Transfer pump pressure rise (psi)

TPWDØT — Transfer pump flow rate (lb/sec)

Gp (1) Cards 5-6

TEFF — Turbine efficiency

TITEMP — Turbine inlet temperature (^oR)

TØTEMP — Turbine outlet temperature (^oR)

TMRATØ — Turbine gas generator Ø/F mixture ratio

TGGPC — Exhaust pressure of turbine gas generator (psia)

Note: For high and medium pressure pumps subroutine PARPMP will calculate pump speed and net positive suction pressure required. Thus input values need only be nominal.

1.2.1.11 Heat Source Data Input Cards. The requirement for heat sources, usually in the form of gas generators, for any given cryogen system is usually associated with a requirement for heat exchangers and turbines where waste heat is not available, or, insufficient for the energy needed. For the defined cryogen systems, accommodated by the Math Model Program, the heat source requirements are imbedded in the stored INBLK data. Thus, if the value of INBLK (SYSNUM, 4, J) = 1, the heat source data are required, otherwise the data cards are deleted from the input deck.

Heat sources in a two fluid system usually occur in pairs, except for the case where a single supplementary heat source might be required to make up for an energy deficiency.

For purposes of uniformity in data handling, heat source data is always arranged such that data for a heat source in the oxidizer side of the system is input first, followed by the same data for the equivalent heat source in the fuel side of the system (i.e., paired sources). If one of the sources does not exist, then a dummy (or blank) card is entered in its place. The first pair of input data cards will contain data for the first pair of heat sources closest to the cryogen consumer. Additional data sets are then input for each pair of heat sources encountered while going through the system schematic toward the fluid supply tanks. As with the heat exchanger data, the variables are doubly subscripted and match the heat sources to the heat exchanger by position and fluid index.

The variables employed in heat source data input are as follows:

Gp (m) Card-1

NUMHSØ – Integer value for number of pairs of heat sources being considered

One card is required if heat source data is to be input.

GP (m) Card-2

HSTYPE – Integer value for heat source type
HSTYPE = 1, for gas generator only
HSTYPE = 2, for waste heat input only
HSTYPE = 3, for gas generator and waste heat combination

HSMRAT – Heat source Ø/F mixture ratio

HSØTEM – Heat source outlet temperature (^{o}R)

HSAEE – Heat source available energy (BTUs)

HSPRES – Heat source outlet pressure (psia)

Two cards are required for each pair of heat source units; oxidizer side unit first followed by fuel side unit – when data is to be input.

1.2.1.12 Electric Motor Data Input Cards. The requirement for motor driven pumps, transfer pumps, or compressors exists in some of the smaller cryogen systems where pumping horsepower needed is small, or the duty cycle is light. For the cryogen systems considered in this program, the requirement for using electric motor data has been embedded in the preprogrammed-stored INBLK data. If, for any specified system, the value of INBLK (SYSNUM, 5, J) = 1, the electric motor data are required; if otherwise, the data cards do not appear in the input data deck.

The variable employed for input at the electric motor data are as follows:

<u>Gp (n) Card-1</u>

MTYPE — Integer value for motor type

MEFF — Motor efficiency

MSS — Motor speed (rpm)

PDNSTY — Power density of battery driving electric motors

One card is used if motor data is required. If not required the card is deleted from the input deck.

1.2.2 Input Data Card and Card Format Description

The input data cards which make up the program input data deck are defined by the Read Statements located in Subroutines CØNTRØL, INTAB, and CØMPIL. This subsection presents a graphic description of each input card as an aid in visualizing and arranging the individual system input data decks needed for the analytical operation of the program. Included as aids, are several tables which explain and define the construction and insulation material types employed by the various subprograms. Included also as aids in program data setup are several tables which define and explain important variables that occur repeatedly. Table 1.2.2-1 presents the variable names employed for control, branching and switching purposes. Table 1.2.2-2 presents the configuration variable names and definition. Following the tables are the data sheets which present the input data card formats.

Table 1.2.2-1

VARIABLE NAMES EMPLOYED FOR CONTROL, BRANCHING, AND SWITCHING PURPOSES

1. System Identification: (Subroutine CØNTRL)

Variable Read	Alpha Input	Variable Equivalent	Integer Value	System Defined
NSYS	ACP	NAMSYS	1	Attitude Control Propulsion System (ACPS)
NSYS	APU	NAMSYS	2	Auxiliary Power Unit (APU)
NSYS	EC/	NAMSYS	3	Life Support System (EC/LSS)
NSYS	FUE	NAMSYS	4	Fuel Cell System (Fuel Cell)
NSYS	ØMS	NAMSYS	5	Orbit Maneuvering System (ØMS)

2. Control Variables: (Subroutine CØNTRL)

Control Variable		Integer Value	Description
SYSNUM	=	1	Controls Selection of Subprograms for ACPS
	=	2	Controls Selection of Subprograms for APU

Table 1.2.2-1 (Cont'd)

2. Control Variables (Subroutine CØNTRL) (Cont'd)

Control Variable		Integer Value	Description
SYSNUM	=	3	Controls Selection of Subprograms for ECLSS
(Cont'd)	=	4	Controls Selection of Subprograms for Fuel Cell
	=	5	Controls Selection of Subprograms for OMS
SCRIT	=	1	Specifies Subcritical Fluid Supply
	=	2	Specifies Supercritical Fluid Supply

3. Branching and Switching Variables:

MDTRC – Diagnostic Trace Switch, Read in by Subroutine CØNTRL, Used by CRYCØN. Defined in PDP-CCNTRL.

MDTRC ( )	=	Diagnostic Trace Switch for CRYCØN (OFF = 0)
(1)	=	1 Turn on ACCRES
(2)	=	1 Turn on ACQWT
(3)	=	1 Turn on APUSUB or APUSUP
(4)	=	1 Turn on CMPCAL
(5)	=	1 Turn on FUELCL
(6)	=	1 Turn on CØNSUM
(7)	=	1 Turn on ECLSS
(8)	=	1 Turn on LIQRES
(9)	=	1 Turn on TANK
(10)	=	1 Turn on TSIZEI
(11)	=	1 Turn on WTACC

MDTRC(1) is Card Column 70,---MDTRC(11) is Card Column 80 of the System Specification Card

INBLK – Controls input data selection in subroutine CØMPIL via preprogrammed set of switches.

System Specification

INBLK (SYSNUM, I, SGRIT) Input Selection Index

Fluid Subsystem Type

Table 1.2.2-1 (Cont'd)

DATA STATEMENT DEFINITION:

```
DATA  ((INBLK(1,I,J),I = 1,5),J = 1,2)/1,1,1,1,0,    1,1,0,1,0/
DATA  ((INBLK(2,I,J),I = 1,5),J = 1,2)/1,1,1,1,1,    1,1,0,1,0/
DATA  ((INBLK(3,I,J),I = 1,5),J = 1,2)/0,0,0,0,0,    0,1,0,0,0/
DATA  ((INBLK(4,I,J),I = 1,5),J = 1,2)/0,1,0,1,0,    0,1,1,0,1/
DATA  ((INBLK(5,I,J),I = 1,5),J = 1,2)/0,0,0,0,0,    0,0,1,0,0/
```

For:

I = 1, Read Accumulator Data – If INBLK = 1
  = 2, Read Heat Exchanger Data – If INBLK = 1
  = 3, Read Pump Data – If INBLK = 1
  = 4, Read Heat Source Data – If INBLK = 1
  = 5, Read Motor Data – If INBLK = 1

KSUBC – Preprogrammed Branching Variable for specified system analysis program selection – Used in subroutine CRYCØN. Defined in STØDTA.

System Specification

Subprogram Index

KSUBC (SYSNUM, I)

DATA STATEMENT DEFINITION:

```
DATA (KSUBC(1,I), I = 1, NBRSR) /6,4,10,9,8,1,10,11,2/
DATA (KSUBC(2,I), I = 1, NBRSR) /6,3,4,10,11,2,0,0,0/
DATA (KSUBC(3,I), I = 1, NBRSR) /7,0,0,0,0,0,0,0,0/
DATA (KSUBC(4,I), I = 1, NBRSR) /5,4,0,0,0,0,0,0,0/
DATA (KSUBC(5,I), I = 1, NBRSR) /6,4,10,9,8,1,10,11,2/
```

JAPUS – Switching variable which reverses order of subprogram selection for APU subcritical or supercritical analysis. Used in subroutine CRYCØN, values defined in subroutine STØDTA.

Fluid Subsystem Type

Subprogram Reordering Index

JAPUS (SCRIT, I)

DATA STATEMENT DEFINITION:

```
DATA JAPUS(1,1), JAPUS (1,2) /4,3/
DATA JAPUS(2,1), JAPUS (2,2) /3,4/
```

Table 1.2.2-2

CONFIGURATION VARIABLE NAMES AND DEFINITIONS

(Used by Subroutine CØMPIL, CMPCAL and LSSCMP)

1. Defined Configuration Names:

Defined Variable	Input Alpha	Variable Equivalent	Integer Value	Component Item
CFUNCT	GAS	FNAME	1	FLUID
CFUNCT	ENGINE	FNAME	2	ENGINE
CFUNCT	LINE	FNAME	3	LINE
CFUNCT	CØNTRL	FNAME	4	CØNTRØL
CFUNCT	FITTING	FNAME	5	FITTING
CFUNCT	TAP	FNAME	6	FLUID TAP
CFUNCT	TEE	FNAME	7	TEE
CFUNCT	ELBOW	FNAME	8	ELBOW
CFUNCT	VALVE	FNAME	9	VALVE
CFUNCT	REG	FNAME	10	REGULATOR
CFUNCT	ACCUM	FNAME	11	ACCUMULATOR
CFUNCT	TANK	FNAME	12	TANK
CFUNCT	PUMP	FNAME	13	PUMP
CFUNCT	HEX	FNAME	14	HEAT EXCHANGER
CFUNCT	TRBINE	FNAME	15	TURBINE
CFUNCT	F-CELL	FNAME	16	FUEL CELL
CFUNCT	EC/LSS	FNAME	17	LIFE SUPPORT
CFUNCT	END	FNAME	18	END OF TABLE

2. Configuration Variable Definitions:

CONFIGURATION FUNCTION CODE AND TYPE.

CFUNCT = 1, GAS	CFTYPE-1	= OXYGEN	2	= HYDROGEN
CFUNCT = 2, ENGINE	CFTYPE-1	= HI-PRESSURE	2	= LO-PRESSURE
CFUNCT = 3, LINE	CFTYPE	= 10A FIXED NUMBER		

Table 1.2.2-2 (Cont'd)

CFUNCT = 4, CONTROL	USES TWO DIGIT INDEX AS FOLLOWS,	
	IDV	= TENS DIGIT (10, 20, etc.)
	CFTYPE	= UNITS DIGIT (1, 2, etc.)
	IDV	= 10 FOR LIGHT WEIGHT CONTROL
		= 20 FOR MEDIUM WEIGHT CONTROL
		= 30 FOR HEAVY WEIGHT CONTROL
		= 40 FOR EXTRA HEAVY WEIGHT CONTROL
	CFTYPE	= 1 FOR VALVE
		= 2 FOR REGULATOR
		= 3 FOR ORIFICE
		= 4 FOR FLOW METER
CFUNCT = 5, FITTING	USES TWO DIGIT INDEX AS FOLLOWS,	
	LDV	= TENS DIGIT (10, 20, etc.)
	CFTYPE	= UNIT DIGIT (1, 2, etc.)
	LDV	= 10 FOR USE IN LINE ONLY
		= 20 FOR 4-WAY TEE
		= 30 FOR 3-WAY TEE
	CFTYPE	= 1 FOR TEE
CFUNCT = 6, TAP	USES TWO DIGIT INDEX AS FOLLOWS,	
	LDV	= TENS DIGIT (10, 20, etc.)
	CFTYPE	= UNITS DIGIT (1, 2, etc.)
	LDV	= 10 FOR USE IN LINE ONLY
		= 20 FOR 4-WAY TEE
		= 30 FOR 3-WAY TEE
	CFTYPE	= 1 FOR TEE
CFUNCT = 7, TEE	USES TWO DIGIT INDEX AS FOLLOWS,	
	LDV	= TENS DIGIT (10, 20, etc.)
	CFTYPE	= UNITS DIGIT (1, 2, etc.)
	LDV	= 10 FOR USE IN LINE ONLY
		= 20 FOR 4-WAY TEE
		= 30 FOR 3-WAY TEE

Table 1.2.2-2 (Cont'd)

CFUNCT = 8, ELBOW	USES TWO DIGIT INDEX AS FOLLOWS,
	LDV = TENS DIGIT (10, 20, etc.)
	CFTYPE = UNITS DIGIT (1, 2, etc.)
	LDV = 10 FOR USE IN LINE ONLY
	= 20 FOR 90 DEG ELBOW
	= 30 FOR 45 DEG ELBOW
	CFTYPE = 1 FOR ELBOW
CFUNCT = 9, VALVE	USES TWO DIGIT INDEX AS FOLLOWS,
	IDV = TENS DIGIT (10, 20, etc.)
	CFTYPE = UNITS DIGIT (1, 2, etc.)
	IDV = 10 FOR LIGHT WEIGHT CONTROL
	= 20 FOR MEDIUM WEIGHT CONTROL
	= 30 FOR HEAVY WEIGHT CONTROL
	= 40 FOR EXTRA HEAVY WEIGHT CONTROL
	CFTYPE = 1 FOR VALVE
CFUNCT = 10, REGULATOR	USES TWO DIGIT INDEX AS FOLLOWS,
	IDV = TENS DIGIT (10, 20, etc.)
	CFTYPE = UNITS DIGIT (1, 2, etc.)
	IDV = 10 FOR LIGHT WEIGHT CONTROL
	= 20 FOR MEDIUM WEIGHT CONTROL
	= 30 FOR HEAVY WEIGHT CONTROL
	= 40 FOR EXTRA HEAVY WEIGHT CONTROL
	CFTYPE = 1 FOR REGULATOR
CFUNCT = 11, ACCUM	NO OPTIONS
CFUNCT = 12, TANK	(SEE TANK ROUTINE)

Table 1.2.2-2 (Cont'd)

CFUNCT = 13, PUMP	USES TWO DIGIT INDEX AS FOLLOWS,	
	JOPTN	= TENS DIGIT (10, 20, etc.)
	CFTYPE	= UNITS DIGIT (1, 2, etc.)
	JOPTN	= 10 FOR MINIMUM POWER PUMP
		= 20 FOR MINIMUM WEIGHT PUMP
	CFTYPE	= 1 FOR HI-PRESSURE PUMP
	CFTYPE	= 2 FOR LO-PRESSURE PUMP
CFUNCT = 14, HEX	CFTYPE	= 1 FOR HI-PRESSURE
		= 2 FOR LO-PRESSURE
CFUNCT = 15, TURBINE	NO OPTIONS	
CFUNCT = 16, FUEL CELL	NO OPTIONS	
CFUNCT = 17, ECLSS	NO OPTIONS	
CFUNCT = 18, END	NO OPTIONS	

CMTYPE – CONFIGURATION MATERIAL TYPE

CMTYPE = 1, 321/347 STAINLESS STEEL
= 2, 2219-T87 ALUMINUM ALLOY
= 3, 6061-T6 ALUMINUM ALLOY
= 4, INCONEL-718 ALLOY
= 5, TITANIUM Ti-6Al-4V ALLOY
= 6, CRES VACUUM JACKETED LINE
= 7, 2219 VACUUM JACKETED LINE

CITYPE – CONFIGURATION INSULATION TYPE

CITYPE = 1, DOUBLE ALUMINUM MYLAR/SILK NET
= 2, DOUBLE GOLD MYLAR/SILK NET
= 3, DOUBLE ALUMINUM MYLAR/TISSUE GLASS

Table 1.2.2-2 (Cont'd)

CITYPE	= 4,	CRINK DOUBLE ALUMINUM MYLAR
	= 5,	NRC-2 CRINKLED ALUMINIZED MYLAR
	= 6,	SUPERFLOC
	= 7,	MICROSPHERES (104-135 MICRON)
	= 8,	POLYURETHANE FOAM
	= 9,	FIBERGLASS BATTING (JM)
CNOPER	–	NUMBER OF OPERATIONAL UNITS (CFUNCT)
CNSTBY	–	NUMBER OF STANDBY UNITS (CFUNCT)
CONFIG	–	CONFIGURATION TABLE

COLUMN 1	CONTAINS THE ABOVE SIX (6) VARIABLES PACKED ONE PER BYTE IN THE ORDER THEY ARE LISTED FROM LEFT TO RIGHT IN THE WORD.
COLUMN 2	CONTAINS THE FLOW FRICTION COEFFICIENT
COLUMN 3	CONTAINS THE LENGTH OF A LINE OR THE EFFECTIVE L/D FOR OTHER COMPONENTS
COLUMN 4	CONTAINS THE DIAMETER OF A LINE
COLUMN 5	CONTAINS THE INSULATION THICKNESS FOR A LINE

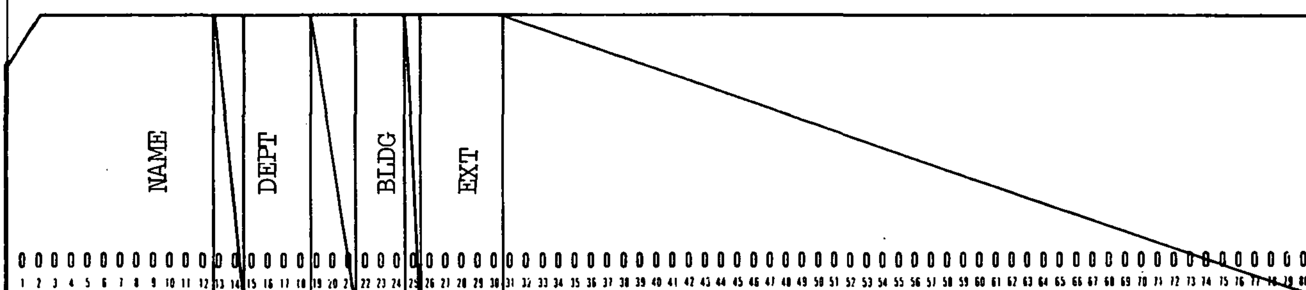
Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title USER ID CARD CASE TITLE CARD	Model
Approved by:	Date		Report No. 1.2.2.1

CARD TYPE - G_p(a) CARD-1

CARD FUNCTION - User Identification Card

READ BY - Subroutine CØNTRL

CARD FORMAT (2AC, 2XA4, 3XA3, 1XA5)

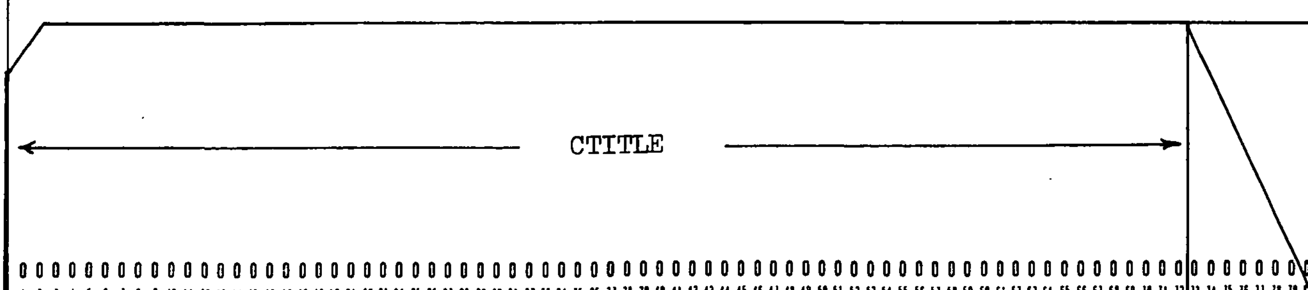


CARD TYPE - G_p(b) CARD-1

CARD FUNCTION - Case Title Card

READ BY - Subroutine CØNTRL

CARD FORMAT - (12AC)



FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title TABLE DATA CARDS (FOR STORED TABLE FILE)	Model
Approved by:	Date		Report No. 1.2.2.2

CARD TYPE - $G_p(c)$ CARD-1

CARD FUNCTION - TABLE DATA ECHO CONTROL CARD

READ BY - SUBROUTINE INTAB

CARD FORMAT - (5I5)

IFT	ØFT	NPRT	NPRT2	(BLANK)	
1–5	6–10	11–15	16–20	21–25	26–80

CARD TYPE - $G_p(d)$ CARD-1

CARD FUNCTION - TABLE DATA FILE - ADD CARD

READ BY - SUBROUTINE INTAB

CARD FORMAT - QADD,P FILNAM

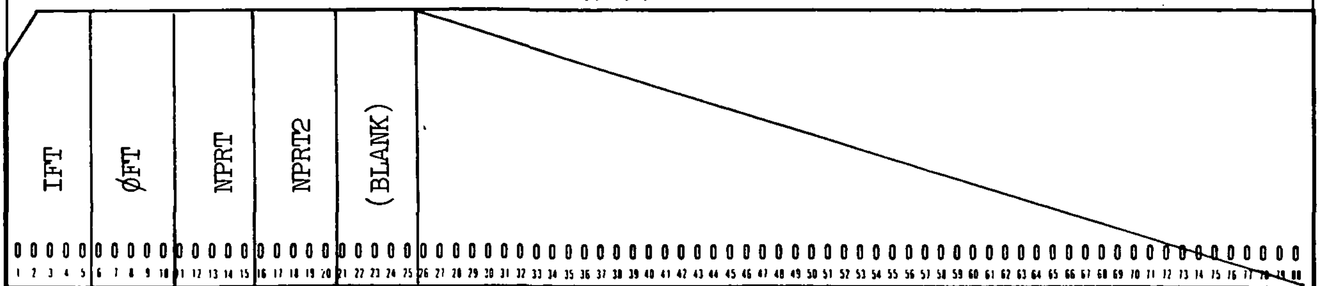
REF. - UNIVAC-1108 MANUAL

```
@ADD,P FILNAM
```

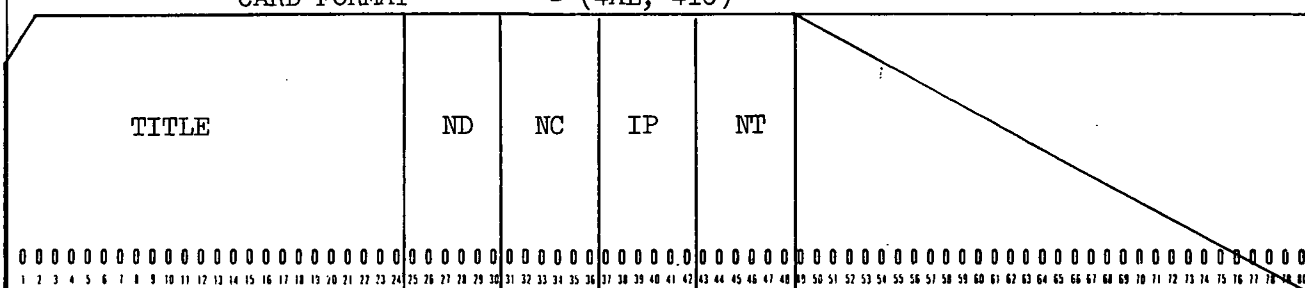
FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title ALTERNATE TABLE DATA INPUT -TABLE DATA DECKS-	Model
Approved by:	Date		Report No. 1.2.2.3

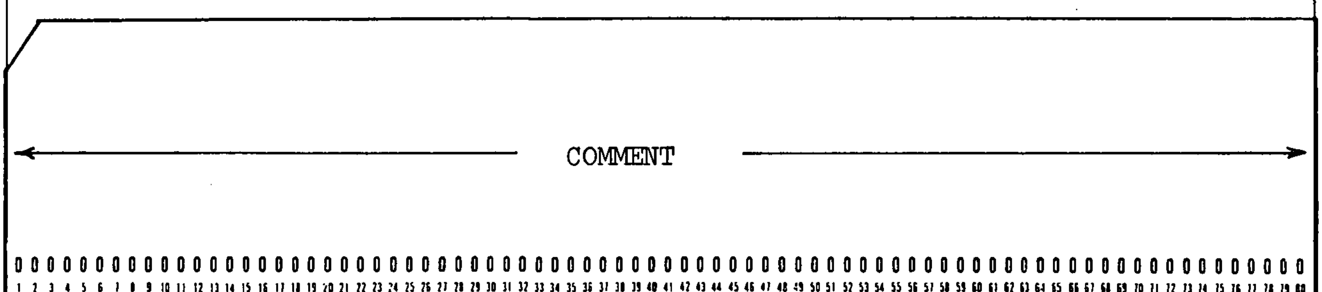
CARD TYPE - $G_p(c)$ CARD-1
CARD FUNCTION - TABLE DATA DECK ECHO CONTROL CARD
READ BY - SUBROUTINE INTAB
CARD FORMAT - (5I5)



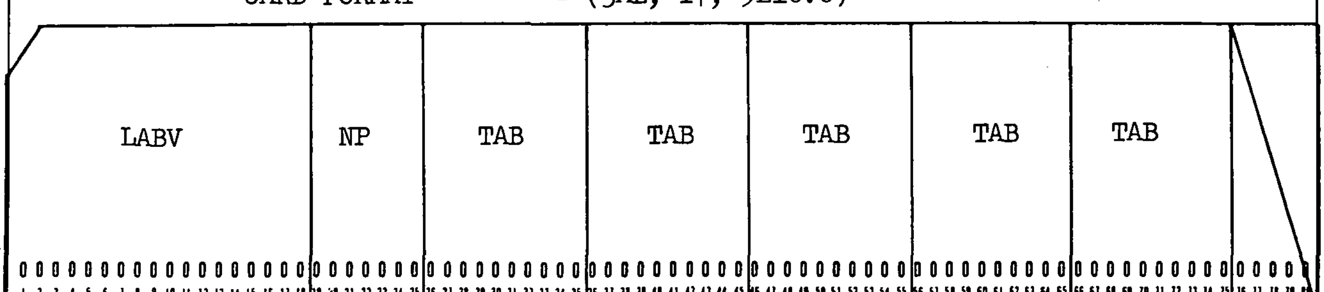
CARD TYPE - $G_p(d)$ CARD-1
CARD FUNCTION - TABLE I.D. AND CONTROL CARD
READ BY - SUBROUTINE INTAB
CARD FORMAT - (4AL, 4IC)



CARD TYPE - $G_p(d)$ CARD-2
CARD FUNCTION - TABLE COMMENT CARD
CARD FORMAT - (13AL, A2)



CARD TYPE - $G_p(d)$ CARD-3
CARD FUNCTION - TABLE SUBSET VARIABLE CARD
CARD FORMAT - (3AL, I7, 5E10.0)



Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title ALTERNATE TABLE DATA INPUT - TABLE DATA DECKS -	Model
Approved by:	Date		Report No. 1.2.2.3

CARD TYPE - $G_p(d)$ CARD-4
CARD FUNCTION - TABLE PLOT CONTROL CARD
READ BY - SUBROUTINE INTAB
CARD FORMAT - (3AL, 3AL, 2E12.0)

LABX	LABY	XMIN	XMAX	
1–18	19–36	37–48	49–60	61–80

CARD TYPE - $G_p(d)$ CARD-5
CARD FUNCTION - TABLE SUBSET DATA CARD
CARD FORMAT - (3IC)

NV	TYPE	NIP	
1–6	7–12	13–18	19–80

CARD TYPE - $G_p(d)$ CARD-6
CARD FUNCTION - TABLE DATA CARD (POLY NOMIAL COEFFICIENTS)
CARD FORMAT - (CE12.0)

XTAB	XTAB	XTAB	XTAB	XTAB	XTAB	
1–12	13–24	25–36	37–48	49–60	61–72	73–80

CARD TYPE - $G_p(d)$ CARD-6
CARD FUNCTION - TABLE DATA CARD (DISCRETE DATA)
CARD FORMAT - (6E12.0)

XTAB	XTAB	XTAB	XTAB	XTAB	XTAB	
1–12	13–24	25–36	37–48	49–60	61–72	73–80

FORM LMSC 362 B-3

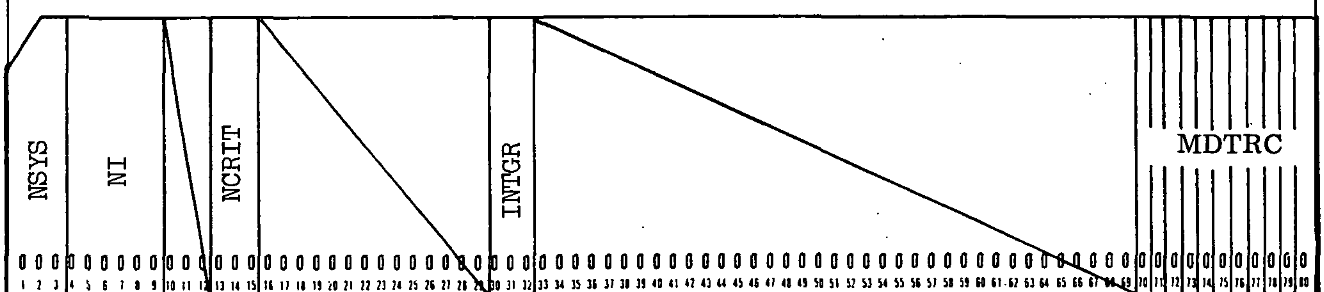
Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title SYSTEM DEFINITION INPUT CARD	Model
Approved by:	Date		Report No. 1.2.2.4

CARD TYPE - $G_p(e)$ CARD-1

CARD FUNCTION - SYSTEM DEFINITION CARD

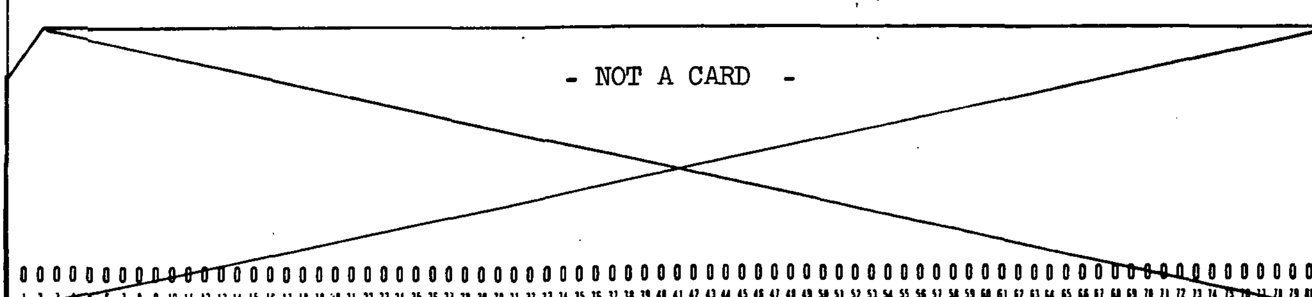
READ BY - SUBROUTINE CØNTRL

CARD FORMAT - (A3, A6, 3X, A3, 14X, A3, 37X, 11I1)



- THIS IS A BLANK SPACE -

GO TO NEXT PAGE



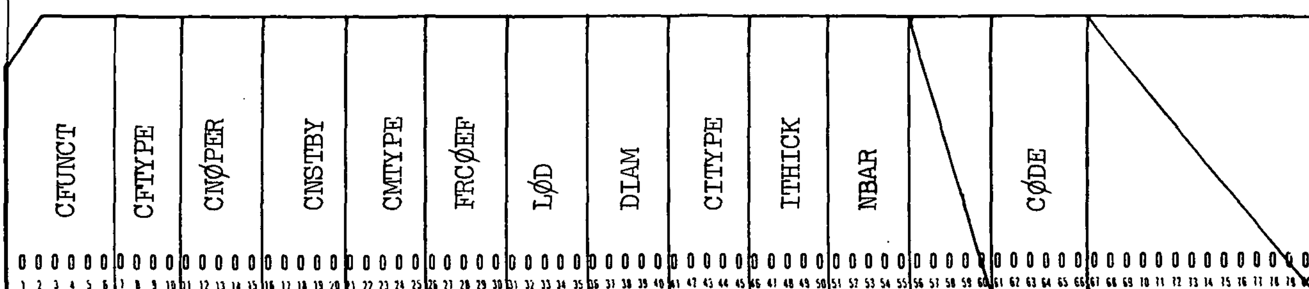
Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title CONFIGURATION DEFINITION DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.5

CARD TYPE - $G_p(f)$ CARD-1

CARD FUNCTION - CONFIGURATION DATA CARD

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - (A6, I4, 3I5, 3F5.0, I5, 2F5.0, 5X, A6)

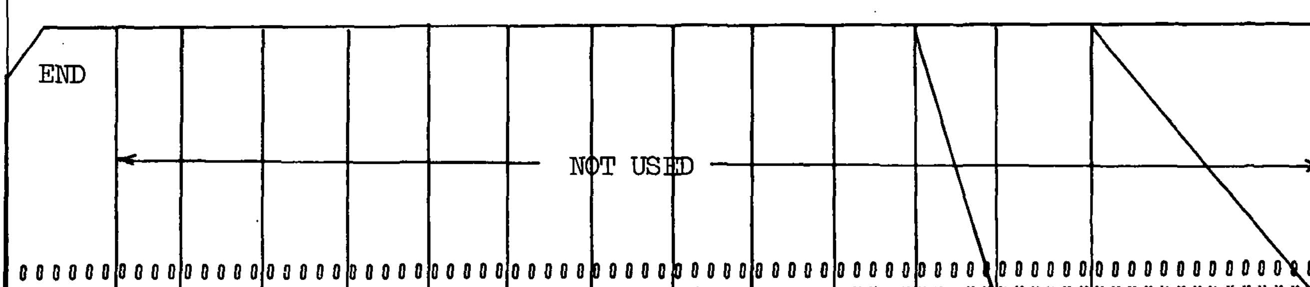


CARD TYPE - $G_p(f)$ CARD-2

CARD FUNCTION - CONFIGURATION DATA END CARD

READ BY - SUBROUTINE CØMPIL

FORMAT - (A6, I4, 3I5, 3F5.0, I5, 2F5.0, A6)



FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY, INC.	Page Temp. Perm.
Checked by:	Date	Title DUTY CYCLE DEFINITION DATA CARD	Model
Approved by:	Date		Report No. 1.2.2.6

CARD TYPE - $G_p(g)$ CARD-1

CARD FUNCTION - DUTY CYCLE DATA CARD

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - FØRMAT (3F10.0, I5, 3F10.0, F7.0)

DCYCLE (I)	DCYCLE (I+1)	PSI	NEØP	HP	PAMP	PKW	RPRTIM	
1–10	11–20	21–30	31–35	36–45	46–55	56–65	66–72	73–80

CARD TYPE - $G_p(g)$ CARD-1

CARD FUNCTION - DUTY CYCLE DATA END CARD

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - (3F10.0, I5, 3F10.0, F7.0)

NOT USED	-1	NOT USED
1–10	11–20	21–80

FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title ENGINE CONSUMER DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.7

CARD TYPE - G_p(h-1) CARD-1

CARD FUNCTION - ENGINE CONSUMER INPUT DATA CARD

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - (I5, 6F10.0)

NENG	GITEMP	GIPRES	THRUST	PSUBC	EXPRAT	MIXRAT	
0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5	6 7 8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23 24 25	26 27 28 29 30 31 32 33 34 35	36 37 38 39 40 41 42 43 44 45	46 47 48 49 50 51 52 53 54 55	56 57 58 59 60 61 62 63 64 65	66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

THIS CARD NOT USED

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title APU CONSUMER DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.8

CARD TYPE - G_p(h-2) CARD-1

CARD FUNCTION - APU CONSUMER INPUT DATA CARD - APU BASIC DATA

READ BY - SUBROUTINE CØMPIL

FORMAT - (I5, 5X, 5F10.0)

1–5	6–10	11–20	21–30	31–40	41–50	51–60	61–80
		HPR	FMR	PGG	TIT	TD	

CARD TYPE - G_p(h-2) CARD-2

CARD FUNCTION - APU CONSUMER INPUT DATA CARD-APU SUBCRITICAL DATA

FORMAT - (7F10.0)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
MRGGCH	MRGGCØ	TDGGH	TDGGØ	TVH	TVØ	TENV	

CARD TYPE - G_p(h-2) CARD-3

CARD FUNCTION - APU CONSUMER INPUT DATA CARD - APU SUPERCRITICAL DATA

CARD FORMAT - (7F10.0)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
FMRG	PFH	PFØ	TFH	TFØ	TG	DELPCP	

1–10	11–70	71–80
TENV	← NOT USED →	

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title LIFE SUPPORT CONSUMER DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.9

CARD TYPE - G_p (h-3) CARD-1
CARD FUNCTION - LIFE SUPPORT INPUT DATA CARDS
READ BY - SUBROUTINE CØMPIL
FORMAT - (4I5, 5F10.0/(7F10.0)

MDAYS	NCREW	NPPRES	NDARES	Ø2FNØM	GLKRAT	TLSNØM(1)	TLSNØM(2)	RHØBEG(1)	
1–5	6–10	11–15	16–20	21–30	31–40	41–50	51–60	61–70	71–80

RHØBEG(2)	TKFTEM(1)	TKFTEM(2)	TKFPRS(1)	TKFPRS(2)	TENVR	CABVØL	
1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80

CARD TYPE - G_p(h-3) CARD-2
CARD FUNCTION - LIFE SUPPORT INPUT DATA
CARD FORMAT - (7F10.0/5F10.0)

LINDIA(1)	LINDIA(2)	HTRFLX(1)	HTRFLX(2)	PLSNØM(1)	PLSNØM(2)	HTRDIA(1)	
1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80

HTRDIA(2)	HTRLNG(1)	HTRLNG(2)	PSET1	PSET2	
1–10	11–20	21–30	31–40	41–50	51–80

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY, INC.	Page Temp. Perm.
Checked by:	Date	Title: FUEL CELL CONSUMER DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.10

CARD TYPE - G_p(h-4) CARD-1
CARD FUNCTION - FUEL CELL INPUT DATA CARDS
READ BY - SUBROUTINE CØMPIL
CARD FORMAT - (10F7.0)

MRFC	SRCFC	QPTFC	SPWTFC	TFCNOM(1)	TFCNOM(2)	TF21IN	TF21ØU	TFØFC	TFHFC	
1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	71-80

PFØFC	PFHFC	RHØFIL(1)	RHØFIL(2)	WØVENT	WHVENT	DELTCP	TENV	PRFCØP	PØWNØM	
1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	71-80

CARD TYPE - G_p(h-4) CARD-2
CARD FUNCTION - FUEL CELL INPUT DATA
CARD FORMAT - (2I5, 6F10.0)

NFCØP	NFCSTB	PLSET1	PLSET2	VJANUL(1)	VJANUL(2)	TKMXDI(1)	TKMXDI(2)	
1-5	6-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80

CARD TYPE - G_p(h-4) CARD-3
CARD FUNCTION - FUEL CELL INPUT DATA
CARD FORMAT - (7F10.0)

FCVØLT	PRGRAT(1)	PRGRAT(2)	PRGTIM(1)	PRGTIM(2)	PRGINT(1)	PRGINT(2)	
1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. / Perm.
Checked by:	Date	Title TANK CHARACTERIZATION INPUT DATA	Model
Approved by:	Date		Report No. 1.2.2.11

CARD TYPE - G_p(i-1) CARD-1
CARD FUNCTION - TANK CHARACTERIZATION INPUT DATA CARDS
READ BY - SUBROUTINE CØMPIL
CARD FORMAT - (5I5)

NØP	SATYPE	SITYPE	SMTYPE	SPTYPE	
1-5	6-10	11-15	16-20	21-25	26-80

CARD TYPE - G_p(i-1) CARD-2
CARD FUNCTION - TANK DATA
CARD FORMAT - (8F10.0)

SITEMP	SIPRES	SPGTEM	SØPRES	SVPRES	SHFLUX	SITHIK	FLDLØD
1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80

CARD TYPE - G_p(i-1) CARD-3
CARD FUNCTION - TANK DATA
CARD FORMAT - (8F10.0)

SULGPC	SMDIAM	SHØTEM	SHDELP	SPDELP	SGØTEM	SGGPC	SGMRAT
1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80

CARD TYPE - G_p(i-1) CARD-4
CARD FUNCTION - TANK DATA
CARD FORMAT - (F10.0)

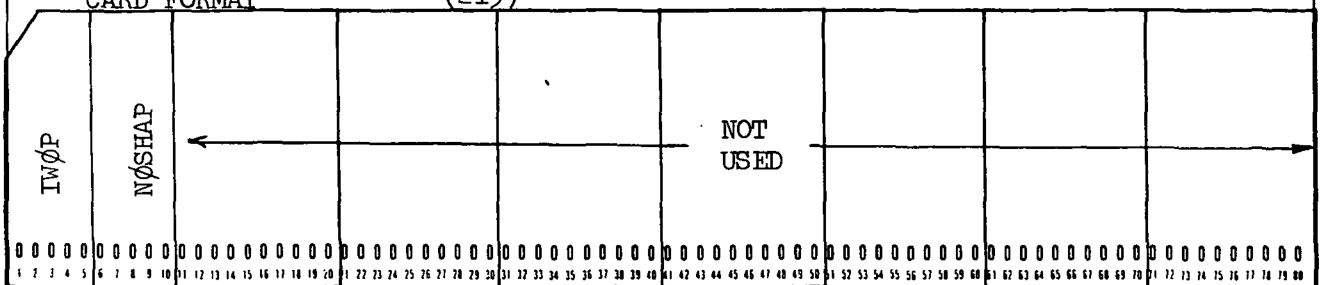
SNBAR	
1-10	11-80

NOTE: TWO SETS OF THE ABOVE CARDS ARE REQUIRED

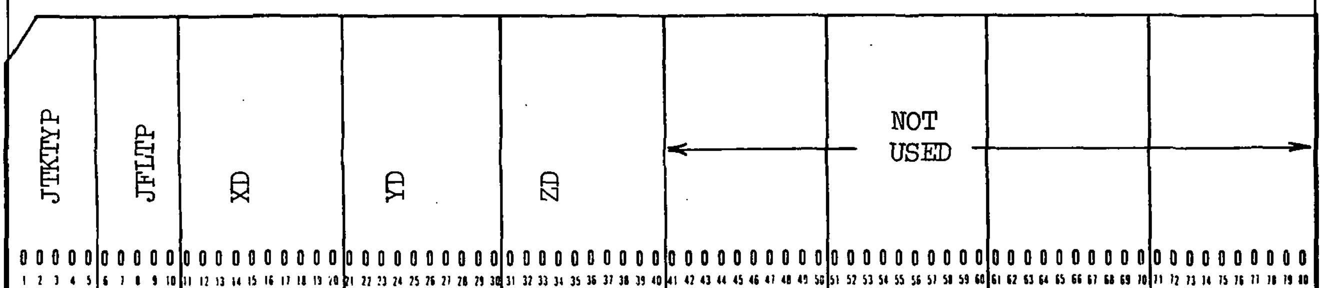
FORM LMSC 362 B-3

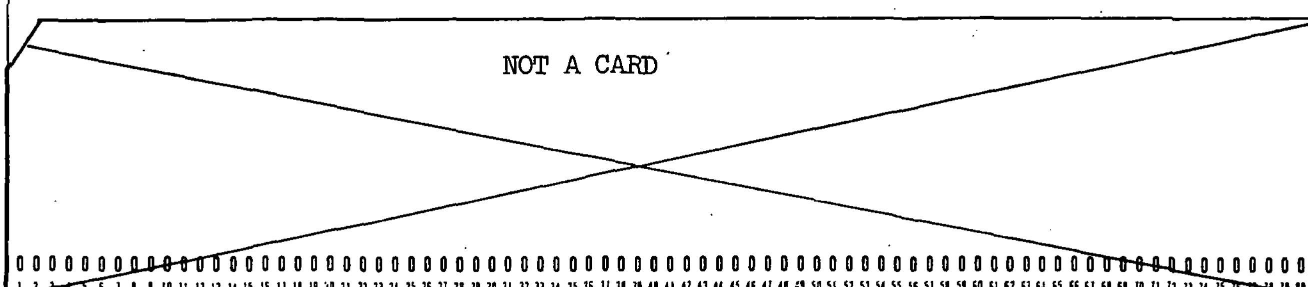
Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title TANK GEOMETRY INPUT DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.12

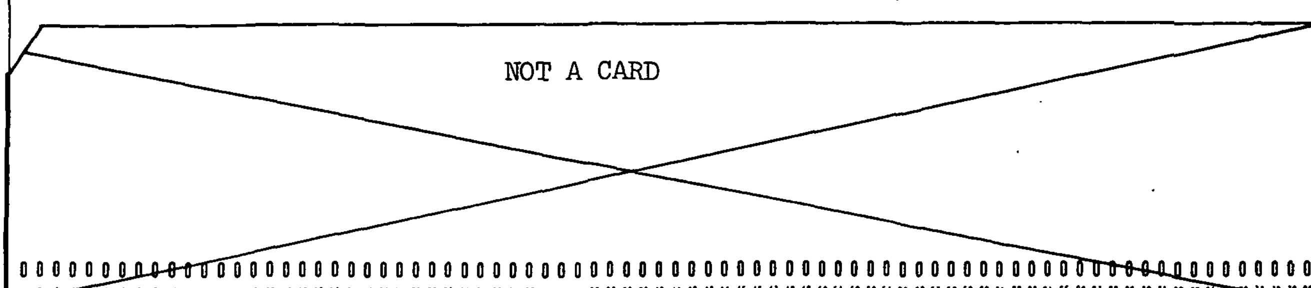
CARD TYPE - G_p(i-2) CARD-5
CARD FUNCTION - TANK GEOMETRY OPTION CARD
READ BY - SUBROUTINE CØMPIL
CARD FORMAT - (2I5)



CARD TYPE - G_p(i-3) - CARD-6
CARD FUNCTION - TANK SEGMENT SHAPE CARD
CARD FORMAT - (2I5, 7F10.0)





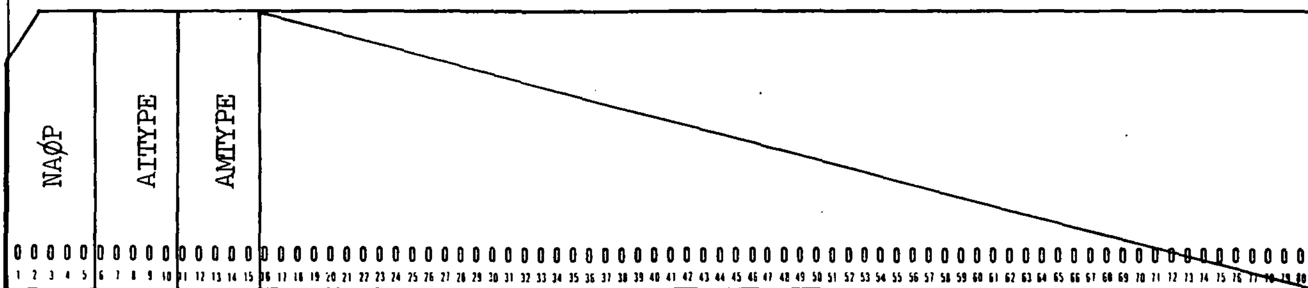


FORM LMSC 362 B-3

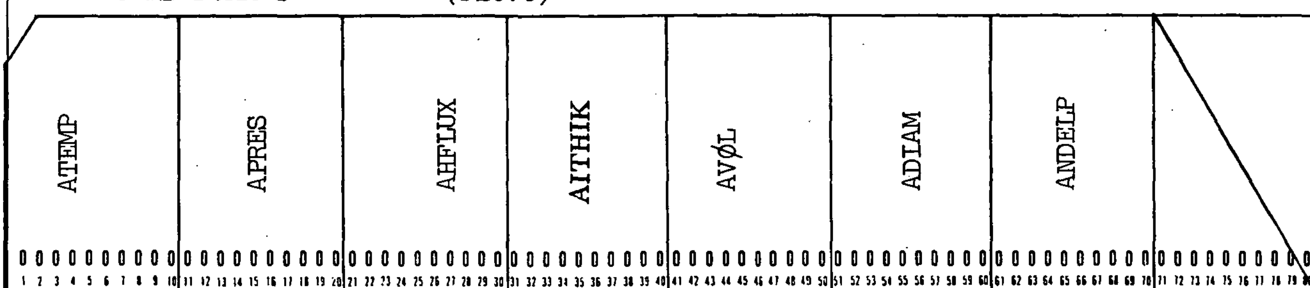
Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY, INC.	Page Temp. Perm.
Checked by:	Date	Title ACCUMULATOR CHARACTERIZATION INPUT DATA CARDS	Model
Approved by:	Date		Report No. 1.2.2.13

CARD TYPE - $G_p(j)$ CARD-1

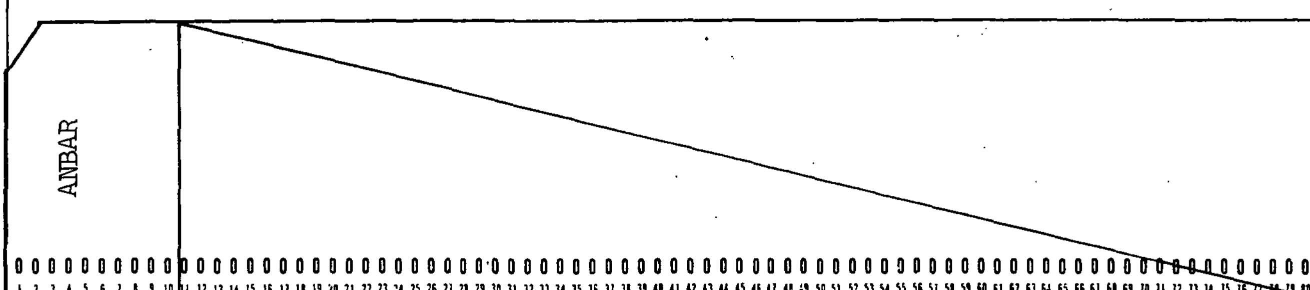
CARD FUNCTION - ACCUMULATOR DATA INPUT CARDS
READ BY - SUBROUTINE CØMPIL
CARD FORMAT - (3I5)



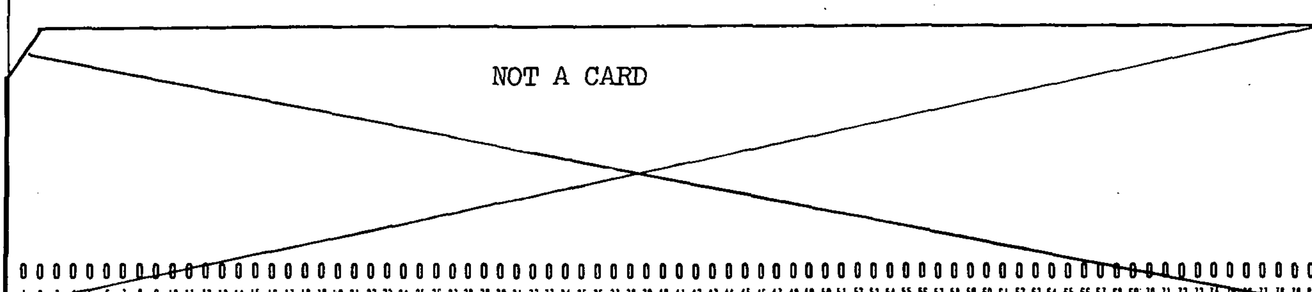
CARD TYPE - $G_p(j)$ CARD-2
CARD FUNCTION - ACCUMULATOR DATA
CARD FORMAT - (F10.0)



CARD TYPE - $G_p(j)$ CARD-3
CARD FUNCTION - ACCUMULATOR DATA
CARD FORMAT - (10.0)



<u>NOTE</u>: TWO SETS OF THE ABOVE CARDS ARE NEEDED IF ACCUMULATOR DATA IS REQUIRED.



FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title HEAT EXCHANGER CHARACTERIZATION DATA INPUT CARDS	Model
Approved by:	Date		Report No. 1.2.2.14

Heat Exchanger Data Input (when required) will always be in pairs. Use dummy blank card if one heat exchanger does not exist. Oxidizer side unit will be entered first followed by fuel side unit.

CARD TYPE - $G_p(k)$ CARD-1

CARD FUNCTION - HEAT EXCHANGER DATA INPUT CARDS

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - (I5)

1–5	6–80
NUMHEX	

CARD TYPE - $G_p(k)$ CARD-2

CARD FUNCTION - HEAT EXCHANGER DATA

CARD FORMAT - (11F6.0, 6X,A6)

(OXIDIZER SIDE)

1–6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60	61–66	67–72	73–78	79–80
HEXHIT	HEXHOT	HEXCIT	HEXCØT	HEXHIT	HEXHØT	HEXCIP	HEXCØP	HXHDLP	HXCDLP	HXMRAT		HXCØDE	

(FUEL SIDE)

1–6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60	61–66	67–72	73–78	79–80
HEXHIT	HEXHØT	HEXCIT	HEXCØT	HEXHIT	HEXHIT	HEXCIP	HEXCØP	HXHDLP	HXCDLP	HXMRAT		HXCØDE	

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title PUMP AND TURBINE CHARACTERIZATION DATA INPUT CARDS	Model
Approved by:	Date		Report No. 1.2.2.15

Pump and turbine input data (when required) will always be input in pairs. Six cards (3 pair sets) are always required. Non-pertinent variables will be left as blanks. If no data are required, then all cards are omitted from input data deck.

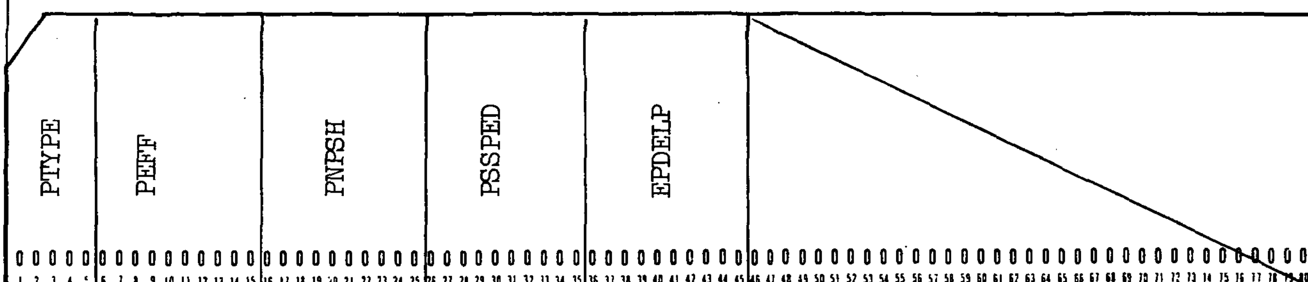
CARD TYPE - G_p(1) CARD-1-2

CARD FUNCTION - PUMP AND TURBINE INPUT DATA CARDS

READ BY - SUBROUTINE CØMPIL

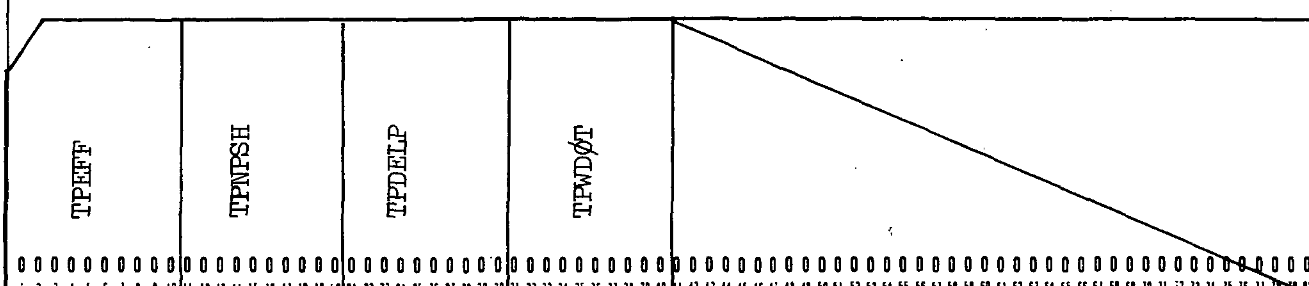
CARD FORMAT - (I5, 4F10.0)

1. OXIDIZER SIDE
2. FUEL SIDE



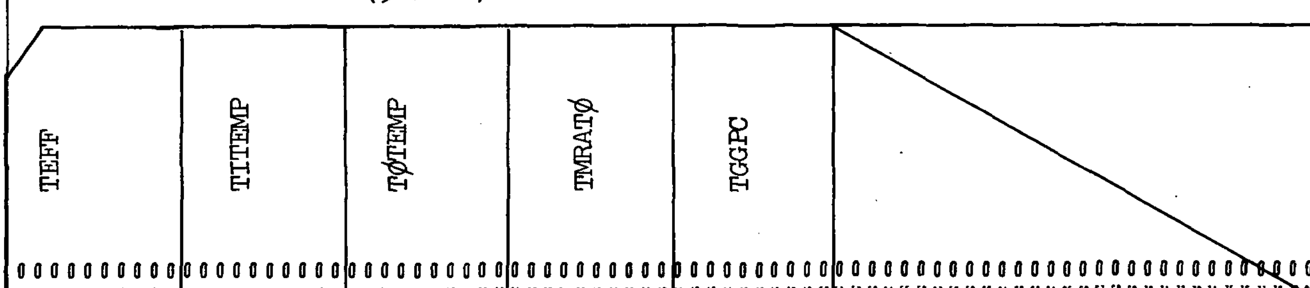
CARD TYPE - G_p(1) CARDS 3-4
CARD FUNCTION - TRANSFER PUMP DATA
CARD FORMAT - (4F10.0)

3. OXIDIZER SIDE
4. FUEL SIDE



CARD TYPE - G_p(1) CARDS 5-6
CARD FUNCTION - TURBINE DATA
CARD FORMAT - (5F10.0)

5. OXIDIZER SIDE
6. FUEL SIDE



FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title HEAT SOURCE CHARACTERIZATION DATA INPUT CARDS	Model
Approved by:	Date		Report No. 1.2.2.16

Heat source data input (when required) will always be in sets of two cards, one each for oxidizer and fuel sides of system. Use dummy (blank) card when one unit does not exist. Oxidizer side unit will be entered first followed by fuel side unit.

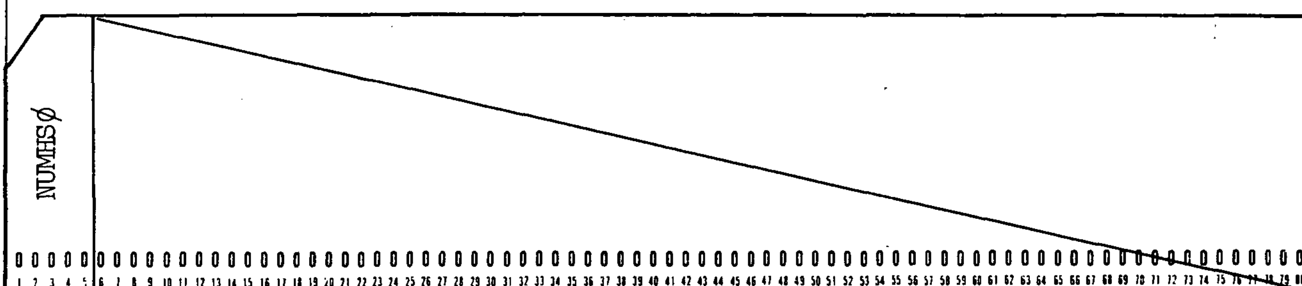
HEAT SOURCE INPUT DATA CARDS

CARD TYPE - $G_p(m)$ CARD-1

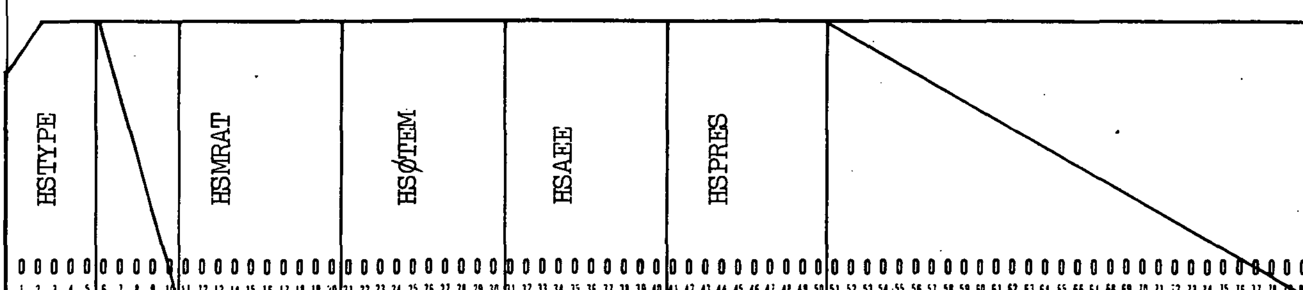
CARD FUNCTION - HEAT SOURCE DATA

READ BY - SUBROUTINE CØMPIL

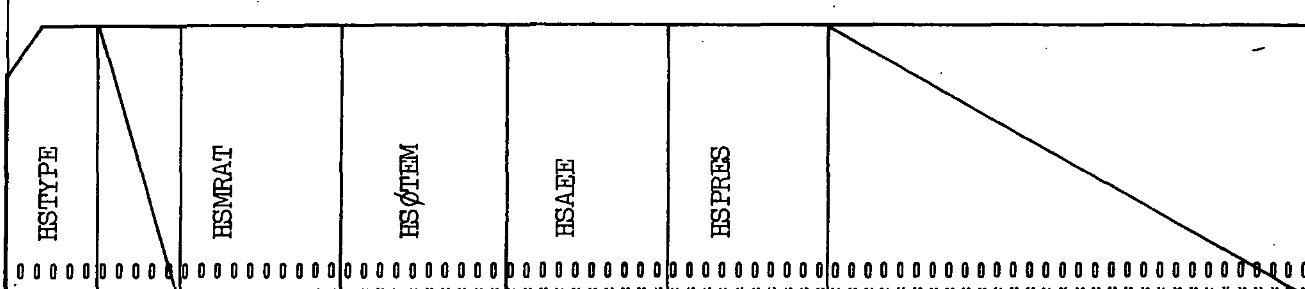
CARD FORMAT - (I5)



CARD TYPE - $G_p(m)$ CARD-2
CARD FUNCTION - HEAT SOURCE DATA
CARD FORMAT - (I5,5X, 4F10.0) (OXIDIZER SIDE)



CARD TYPE - $G_p(m)$ CARD-2
CARD FUNCTION - HEAT SOURCE DATA
CARD FORMAT - (I5, 5X, 4F10.0) (FUEL SIDE)



FORM LMSC 362 B-3

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title MOTOR CHARACTERIZATION DATA INPUT CARD	Model
Approved by:	Date		Report No. 1.2.2.17

Electric Motor Data (when required) is input currently with a single card. If additional motor types and characteristics are to be added, the data input will need to be expanded. When adding variables, take care to insure proper dimensioning is accomplished in the appropriate PDP.

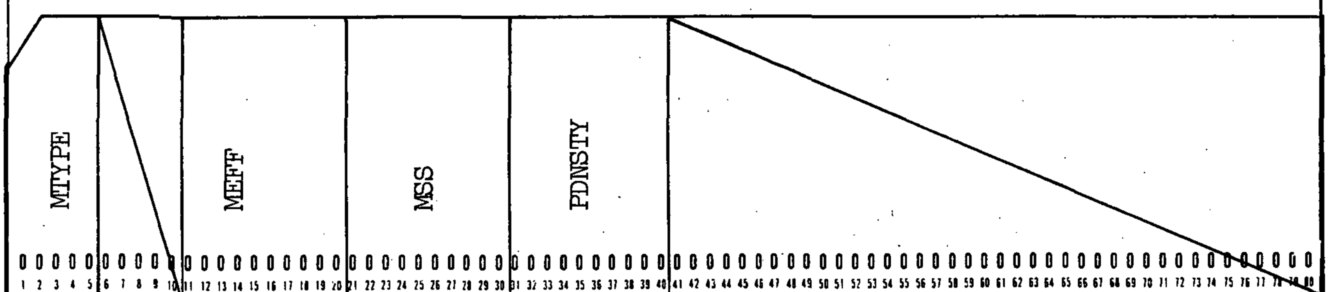
MOTOR INPUT DATA CARD

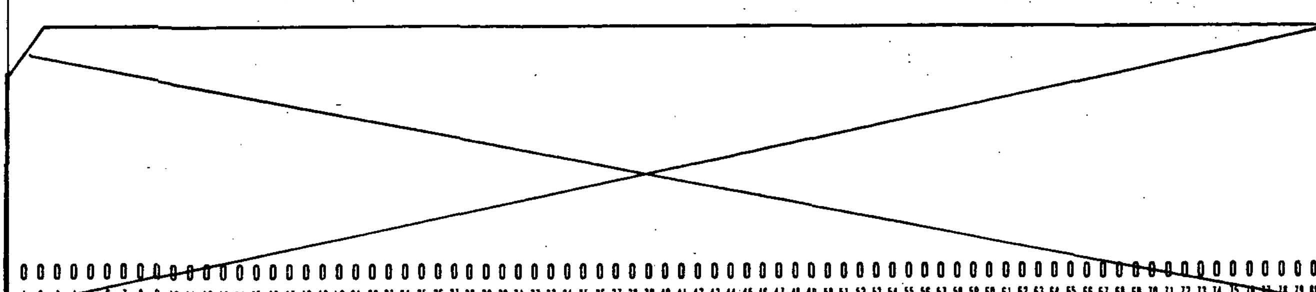
CARD TYPE - $G_p(n)$ CARD-1

CARD FUNCTION - MOTOR INPUT DATA

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - (I5, 5X, 3F10.0)





1.2.3 Table Data Cards

The use of semi-permanent table data and the general means of acquiring such data has been previously discussed in subsection 1.1.2.1, and graphically outlined in Fig. 1.1.2.2. However, the use of an actual example will serve better to illustrate, and demonstrate, the procedure to be used in setting up tables for the users own specific applications.

The example chosen is the Electrical Heat Exchanger Heat Transfer Performance Data for Hydrogen Gas utilized in Data Table 20 of the current program table set. The data (Ref. 1) is presented in graphic form in Figure 1.2.3-1 and represents a typical data source obtained from study reports. The heat transfer coefficient as a function of hydrogen gas mass velocity, over a given range, is given for four pressures. The data is given for a one inch square section of a specific flow element diagram which is described in detail in the referenced (Ref. 1) report.

In translating curve data to table data, the limitations of computer data array manipulation must be kept in mind. Normally, if a computer independent variable is slightly off the end of a curve, the analyst simply takes a ships curve, or straight-edge and fits the curve to extend the graphic function. But a computer table look-up program will only see the first or last value in the curve point data array and (if programmed) states that the value currently considered is out of range for the table. This problem is avoided by extending (extrapolation) each curve in the set (both ends) to insure that the resulting table is adequate for the data range required in the planned analysis. For the example it was determined that the range for the independent variable (mass velocity) should be 0.1 to 6.0 lbs/hr-sq.in. The resulting points taken from the curve are given in the following table.

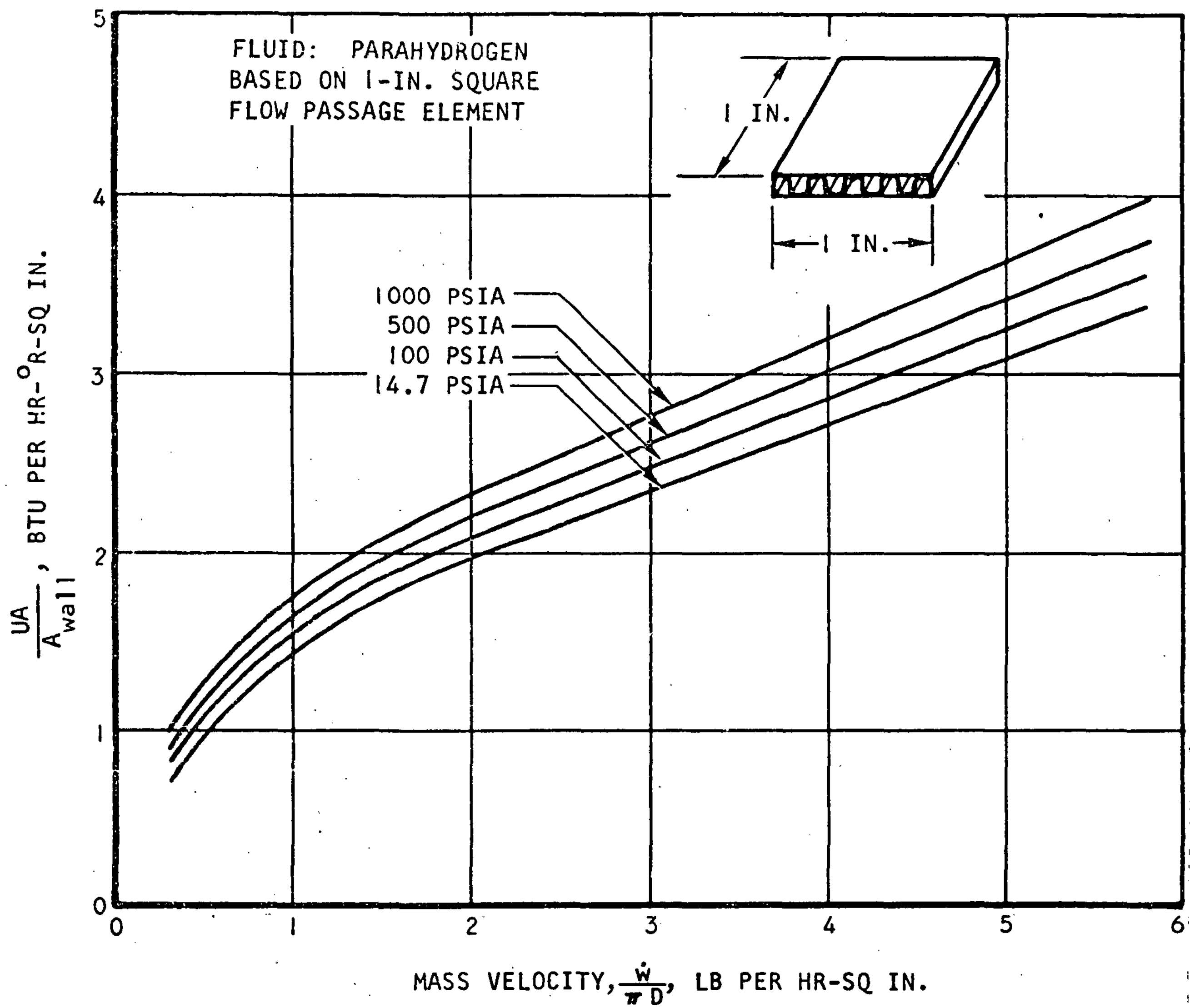


Figure 1.2.3-1 Hydrogen Electrical Heater Heat Transfer Performance

Table 1.2.3-1

ELECTRICAL HEAT EXCHANGER – HEAT TRANSFER PERFORMANCE FOR HYDROGEN GAS (REF. FIG. 1.2.3-1)

Mass Velocity (lb/hr-sq. in.)	Heat Transfer Coefficient (BTU/Hr-^{O}R-Sq. In.) at:			
	14.7 (psia)	100 (psia)	500 (psia)	1000 (psia)
0.10	.27	.35	.45	.50
0.30	.70	.78	.88	.99
0.50	.96	1.10	1.20	1.30
0.75	1.21	1.35	1.45	1.55
1.00	1.42	1.53	1.65	1.76
1.50	1.75	1.85	1.96	2.08
2.00	1.97	2.09	2.22	2.34
3.00	2.35	2.48	2.61	2.78
4.00	2.73	2.87	3.04	3.22
5.00	3.09	3.25	3.42	3.65
6.00	3.45	3.65	3.82	4.09

Translation of the data from Table 1.2.3-1 into the table data card format then consists of assigning the program variable names and values in the order illustrated in Fig. 1.2.3-2.

Taking the variables as they appear for each of the table cards shown in Figure 1.2.3-2, the following assignments are made:

Card-1, Title Card

Title = HEAT XFER.COEFF.-H2
ND = 3 (Number of variables in table)
NC = 4 (Number of command cards)
IP = (Blank) (Table will not be plotted)
NT = 20 (Table I.D. number)

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page Temp. Perm.
Checked by:	Date	Title TABLE DATA INPUT CARD FORMAT Figure 1.2.3-2	Model
Approved by:	Date		Report No.

CARD TYPE - $G_p(d)$ CARD-1
CARD FUNCTION - TABLE IDENTIFICATION AND CONTROL CARD

TITLE (4A6)	ND (I6)	NC (I6)	IP (I6)	NT (I6)	
1–24	25–30	31–36	37–42	43–48	49–80

CARD TYPE - $G_p(d)$ CARD-2
CARD FUNCTION - TABLE COMMENT CARD

← COMMENT (13A6,A2) →
1–80

CARD TYPE - $G_p(d)$ CARD-3
CARD FUNCTION - TABLE SUBSET VARIABLE CARD

LABV (3A6)	NP (I7)	TAB_1 (E10.0)	TAB_2 (E10.0)	TAB_3 (E10.0)	TAB_4 (E10.0)	TAB_{NP} (E10.0)	
1–19	20–25	26–35	36–45	46–55	56–65	66–75	76–80

CARD TYPE - $G_p(d)$ CARD-4
CARD FUNCTION - TABLE DATA PLOT CONTROL CARD

LABX (3A6)	LABY (3A6)	XMIN (E12.0)	XMAX (E12.0)	
1–18	19–36	37–48	49–60	61–80

CARD TYPE - $G_p(d)$ CARD-5
CARD FUNCTION - TABLE SUBSET DATA CARD

NV (I6)	TYPE (I6)	NIP (I6)	
1–6	7–12	13–18	19–80

CARD TYPE - $G_p(d)$ CARD-6
CARD FUNCTION - TABLE DATA CARD (DISCRETE DATA)

XTAB (E12.0	YTAB (E12.0)	XTAB (E12.0)	YTAB (E12.0)	XTAB (E12.0)	YTAB (E12.0)	
1–12	13–24	25–36	37–48	49–60	61–72	73–80

FORM LMSC 362 B-3

Card-2, Command Card

Four Command Cards are used (NC = 4). Three cards contain description of table and source data reference, while the fourth card is simply used as a spare card.

Card-3, Table Subset Variable Card

This card contains the names of the third variable in Table 1.2.3-1, the number of values the variable can take on, and the values themselves.

LABV	=	Pressure (psia)	(Third variable)
NP	=	4	(Four pressure values)
TAB_1	=	14.7	(First value)
TAB_2	=	100	(Second value)
TAB_3	=	500	(Third value)
TAB_4	=	1000	(Fourth value)

Card-4, Table Plot Control Card

This card is used to enter the X-AXIS and Y-AXIS labels and the X value minima and maxima for plot output of table data.

LABX	=	MASS VELOCITY	(X variable)
LABY	=	HEAT TRANS. COEF.	(Y variable)
XMIN	=	0.1	(if used)
XMAX	=	6.0	(if used)

Card-5, Table Subset Data Card

There will be a subtable of X and Y values for each value that LABV can assume. Since NP = 4, there will be four subtables arranged in the increasing order of TAB_i. Each subtable will have a Card 5 giving the number of X, Y sets of points in the subtable, the "type" of data, and the number of points to be used for interpolation.

NV	= 11	(Eleven sets of X,Y values per table subset)
TYPE	= 1	(Discrete data points from curve)
NIP	= 3	(Use 3 points for interpolation since curve is somewhat parabolic)

Card-6, Table Data Card

Use 4 data cards per table-subset, entering three sets of X,Y data per card with the last card having two sets of X,Y data (NV = 11). Thus, the first table-subset card starts with Mass Velocity and Heat Transfer Coefficient values for the 14.7 psia pressure curve.

$XTAB_1$ = 0.10
$YTAB_1$ = 0.27
$XTAB_2$ = 0.30
$YTAB_2$ = 0.70
$XTAB_3$ = 0.50
$YTAB_3$ = 0.96

The completed Table 20 is illustrated as a card listing in Table 1.2.3-2.

Table 1.2.3-2

HEAT TRANSFER PERFORMANCE DATA FOR HYDROGEN

DATA TABLE NUMBER 20

```
HT.XFER.COEF.-H2                        3     4          20
  OVERALL HEAT TRANSFER COEFFICIENT FOR H2 ELECTRIC POWERED HEX AS A
  FUNCTION OF MASS VELOCITY AND FLUID INLET PRESSURE.
  REF. AR-71-7535.
```

PRESSURE (PSIA)	4	14.7	100.	500.	1000.
MASVEL(LB/HR-IN)	U (BTU/HR-R-SQ.IN)				
11 1	3				
.10	.27	.30	.70	.50	.96
.75	1.21	1.00	1.42	1.50	1.75
2.00	1.97	3.00	2.35	4.00	2.73
5.00	3.09	6.00	3.45		
11 1	3				
.10	.35	.30	.78	.50	1.10
.75	1.35	1.00	1.53	1.50	1.85
2.00	2.09	3.00	2.48	4.00	2.87
5.00	3.25	6.00	3.64		
11 1	3				
.10	.45	.30	.88	.50	1.20
.75	1.45	1.00	1.65	1.50	1.96
2.00	2.22	3.00	2.61	4.00	3.04
5.00	3.42	6.00	3.82		
11 1	3				
.10	.50	.30	.99	.50	1.30
.75	1.55	1.00	1.76	1.50	2.08
2.00	2.34	3.00	2.78	4.00	3.22
5.00	3.65	6.00	4.09		

1.2.4 Use of Program Files and Data Files

In the use of the Math Model Program as an operational analysis tool, it can be quite inconvenient to have to load the entire program, data tables, and problem deck each time a run is to be made. It is therefore recommended that the program and data tables be maintained on stored files in the facility FASTRAND drum or DISC storage.

1.2.4.1 Program File. The Math Model Program as currently structured contains approximately 16,000 source cards including the thermodynamic properties subprograms. The program therefore is usually maintained on a master tape which takes quite awhile to read into core. It is considerably more convenient to maintain the program file on FASTRAND Drum or DISC storage and simply call in the file and copy it for use in a run.

For the UNIVAC-1108, the procedure in setting up a mass-storage file and using it are generally as follows:

Creating a Program File

Assume that the mnemonic TCIMM is used as the program file name, then the file creation cards are as follows: (A Master Tape and Program File will be created)

```
@ RUN        \
              >  varies with facility operating procedures
@ LID        /

@ DELETE,C    TCIMM TAPE.          (Purges tape name)
@ DELETE,C    TCIMM.               (Purges file record)
@ ASG,UP      TCIMM TAPE.,T        (Assigns tape requirement)
@ ASG,UP      TCIMM.,FD4           (Assigns file on DISC)

[ @ PDP,IFL   CACCUM           ]   Source Deck
[ @ FØR,IS    ACCRES, ACCRES   ]   Cards for
[ @ FØR,IS    ZFIND,ZFIND      ]   Entire Program
```

@ CØPY	TPF$.,TCIMM.	(Creates program file)
@ TIC	TCIMM.,TCIMM TAPE.	(Makes tape label)
@ CØPØUT	TCIMM.,TCIMM TAPE.	(Writes tape)
@ FREE	TCIMM TAPE.	(Frees tape)
@ FREE	TCIMM.	(Frees TCIMM file)
@ FIN or @ EØF		(Ends run)

A run is made and the Program File and Program Master Tape are created and logged in the Facility Program Library. The user is now protected in the event of a system crash which causes the loss of the stored program file since the Master Tape is a backup file.

Using the Program File

The stored Program File (TCIMM.) may be called in for use in the following fashion:

@ RUN		
@ LID		
@ ASG,A	TCIMM.	(Assigns file)
@ COPY,P	TCIMM..TPF$.	(Copy file to user free of core)
@ FREE	TCIMM.	(Free file to storage)

(Reference Figure 1.2.4-1)

1.2.4.2 Data Table File. Similarly, for the DATA TABLES which currently require approximately 1,300 source cards and could reach several thousand cards for newer systems, it is advisable to maintain a stored file and backup tapes. In this case a DATA file is preferred for the storage mechanism since file editing can be easily done from a DEMAND terminal, if the facility is so equipped.

The creation of a data file in the UNIVAC-1108 (EXEC-8) is accomplished as follows:

Creating a DATA File

Assume TNUMBAG. will be the file name chosen for TABLE DATA DECK.

```
@ RUN CARD  \
             >  Varies with facility operating procedures
@ LID CARD  /
@ DELETE,C     TNUMBAG.         (Deletes slot file
@ ASG,UP       TNUMBAG.,F04     (Disc storage)
@ DATA,IL      TNUMBAG.         (Data processor)
 [ TABLE DATA DECK
   FOLLOWED BY
   ONE BLANK CARD ]
@ END
@ FIN or @ EOF
```

A run is made and is listed by the Data Processor. File is now stored on disc or drum.

Using the Data File

The stored data file (TNUMBAG.) may be called in for use by placing an ASG card just before the program execution card and an ADD file card after the third card in the problem data input deck, as follows:

```
@ ASG,A        TNUMBAG.
@ XQT
  DATA DECK    USER CARD
               TITLE Header Card
               TABLE ECHO CONTROL CARD
@ ADD          TNUMBAG.
               SYSTEM DEFINITION CARD
                 .
               (Rest of data deck)
                 .
@ FIN or   EØF
```

(Reference Figure 1.2.4-1)

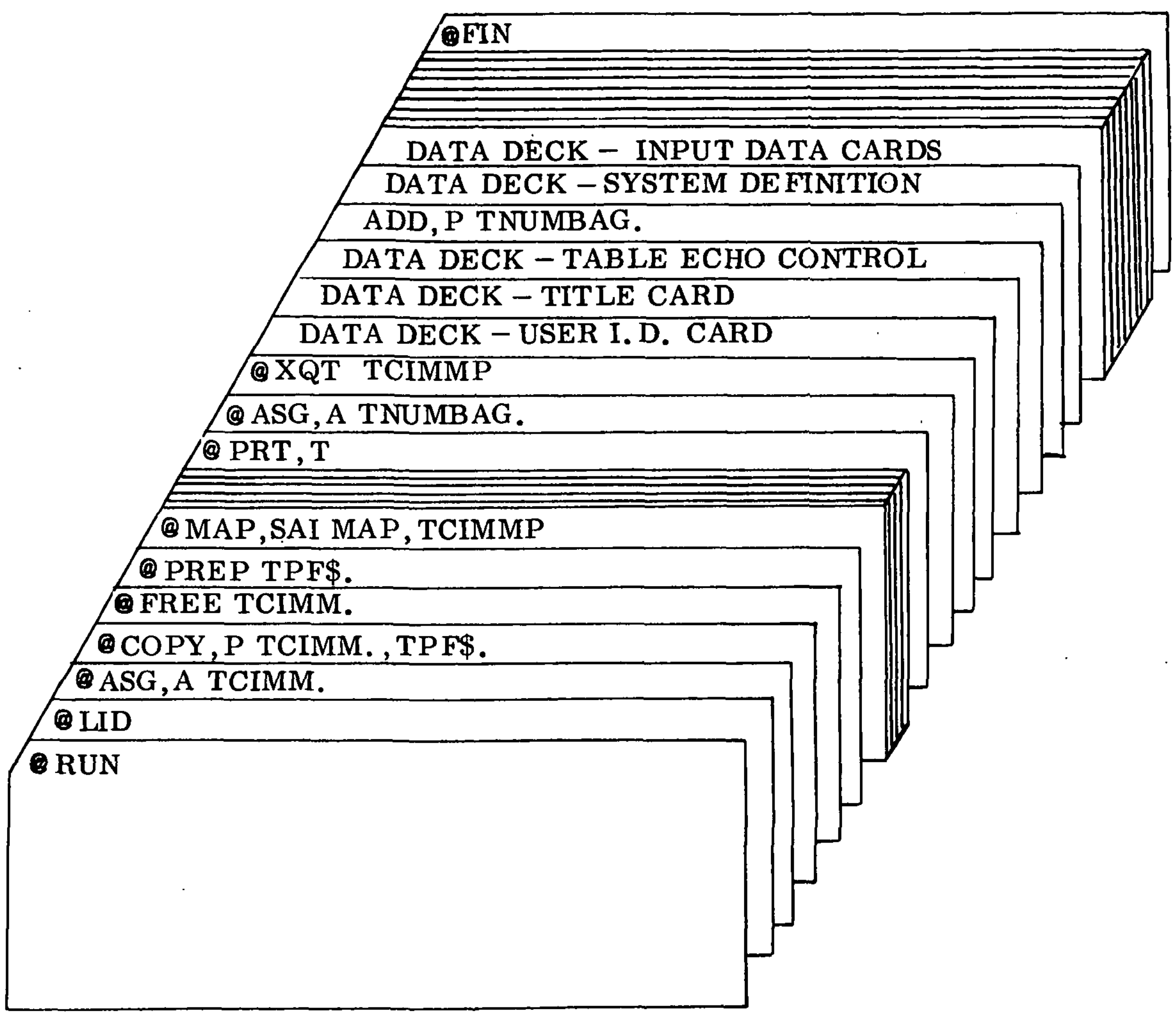


FIG. 1.2.4-1 TCIMM RUN DECK SET UP TO USE PROGRAM FILE AND DATA TABLE FILE

1.2.4.3 Input Deck Data File. For the case where a group of analyses are desired for a given cryogen system and the "run to run" changes in the data deck are relatively few, it is often advantageous to place the input data deck into a data file and simply use change cards to alter the file when it is called in. Or, if the facility has a DEMAND system with terminals, it is possible to use the system EDITØR processor and alter the data file prior to calling it in for a run.

The use of change cards to alter the data deck is a simple procedure however, and the original Input Deck Data file can be preserved for repeated use simply by creating a temporary file containing the changes. Assume the nemonic ACPSDATA. to be the file name for the ACPS Data Input Deck file. It is desired to change the value of NPRT2 to zero to suppress all table output on the TABLE ECHO CONTROL CARD. This requires a zero in column 20 of the card. The new file will be temporary for one run only and for this purpose use TACPS DATA. on the temporary file name.

The procedure and deck setup to be used, follows:

(a) Before the run XQT card, insert these cards:

```
@ASG,A      ACPSDATA.
@ASG,T      TACPSDATA.
@DATA,L     ACPSDATA.,TACPSDATA.
 -3,3
          10     1     0
```

(b) After the XQT card, and in place of a data input deck, insert this card:

```
@ADD,P      TACPSDATA.
```

The program will now run using the temporary TACPSDATA. file, and, will list TACPSDATA. as a record of the temporary input data used in the run. The temporary file vanishes and the original unchanged file is still available for use.

1.2.5 Sample Input Data Deck Listing

As an aid in following the information presented in subsections 1.2.1 through 1.2.4, a listing of a typical Math Model data input deck is provided. The listing presented is the Attitude Control Propulsion System test problem which will be discussed in depth in Section 2.0 of this manual. Table 1.2.5-1 contains the complete test problem data input deck.

1.2.6 Data Table Deck List

The Data Tables currently employed in the program were set up to permit development and checkout of the subprograms required for the basic five types of system analysis. It, therefore, must be recognized that for systems which are more advanced, new data tables will probably be required. Direct substitution of tables is easily accomplished provided the table contains the same number of variables, arranged in the same order as used in the original table.

As an aid to future users of the program, a complete listing is presented of the current table to illustrate the diversity of table forms accommodated by the Math Model.

TABLE 1.2.5-1

ACPS INPUT DATA DECK LISTING

```
USERS NAME    6213    104 30235
                            ACPS - TEST DEMONSTRATION PROBLEM
            10       1      1
*ADD               TNUMBAG.
ACPS               SUBCRITICAL       LAST CARD

GAS          1       1      0                                                 O2-VAP      CONFIG 1
ENGINE       0       3      0                                                 ENG1        CONFIG 2
LINE        10       3      0   1.0095 110.   2.0     4    .5   30.           LN01        CONFIG 3
TEE         21       1      0   1.0095126.3                                   FT01        CONFIG 4
LINE        10       1      0   1.0095150.0   2.0     4    .5   30.           LN02        CONFIG 5
TAP         31       1      0   1.0095 10.5                                   FT02        CONFIG 6
LINE        10       1      0   1.0095 24.0   2.0     4    .5   30.           LN03        CONFIG 7
VALVE       31       1      0   1.0095 10.5                                   IV01        CONFIG 8
LINE        10       1      0   1.0095 12.0   2.0     4    .5   30.           LN04        CONFIG 9
VALVE       21       1      0   1.0095135.0                                   CV02        CONFIG10
LINE        10       1      0   1.0095 40.0   2.0     4    .5   30.           LN05        CONFIG11
TAP         31       1      0   1.0095 10.5                                   FT03        CONFIG12
LINE        10       1      0   1.0095 20.0   2.0     4    .5   30.           LN06        CONFIG13
REG         32       1      0   1.0095336.8                                   PR01        CONFIG14
LINE        10       1      0   1.0095 30.0   2.0     4    .5   30.           LN07        CONFIG15
ACCUM        0       1      0   1                     4   2.0   30.           AC01        CONFIG16
LINE        10       1      0   1.0095 24.0   2.0     4    .5   30.           LN08        CONFIG17
HEX          1       1      0   1                                             HX01        CONFIG18
GAS          1       2      0                                                 O2-LIQ      CONFIG19
LINE        10       1      0   1.0180 12.0   1.0     4    .5   30.           LN09        CONFIG20
VALVE       31       1      0   1.0180                                        CV01        CONFIG21
LINE        10       1      0   1.0180 12.0   1.0     4    .5   30.           LN10        CONFIG22
PUMP        21       1      0   1                                             HP01        CONFIG23
LINE        10       1      0   1.0180160.0   1.5     4    .5   30.           LN11        CONFIG24
VALVE       21       1      0   1.0150 6.67                                   SV01        CONFIG25
LINE        10       1      0   1.0150 12.0   2.5     4    .5   30.           LN12        CONFIG26
TAP         31       1      0   1.0150 6.67                                   FT04        CONFIG27
LINE        10       1      0   1.0150 24.0   2.5     4    .5   30.           LN13        CONFIG28
TANK         0       1      0   2                     4   2.0   30.           TK01        CONFIG29
GAS          2       1                                                        H2-VAP      CONFIG30
ENGINE       0       3      0                                                 ENG1        CONFIG31
LINE        10       3      0   1 .011 110. 1.75      4   2.0   30.           LN21        CONFIG32
TEE         21       1      0   1 .011 109.                                   FT21        CONFIG33
LINE        10       1      0   1 .011 150. 1.75      4   2.0   30.           LN22        CONFIG34
TAP         31       1      0   1 .011   9.                                   FT22        CONFIG35
LINE        10       1      0   1 .011  24. 1.75      4   2.0   30.           LN23        CONFIG36
VALVE       31       1      0   1 .011   9.                                   IV02        CONFIG37
LINE        10       1      0   1 .011  12. 1.75      4   2.0   30.           LN24        CONFIG38
VALVE       21       1      0   1 .011  86.                                   CV04        CONFIG39
LINE        10       1      0   1 .011  40. 1.75      4   2.0   30.           LN25        CONFIG40
TAP         31       1      0   1 .011   9.                                   FT23        CONFIG41
LINE        10       1      0   1 .011  20. 1.75      4   2.0   30.           LN26        CONFIG42
REG         32       1      0   1 .011336.4                                   PR02        CONFIG43
LINE        10       1      0   1 .011  30. 1.75      4   2.0   30.           LN27        CONFIG44
ACCUM        0       1      0   1                     4   2.0   30.           AC02        CONFIG45
LINE        10       1      0   1 .011  24. 1.50      4   2.0   30.           LN28        CONFIG46
HEX          1       1      0   1                                             HX03        CONFIG47
GAS          2       2                                                        H2-LIQ      CONFIG48
LINE        10       1      0   1 .011  12. 1.50      4   2.0   30.           LN29        CONFIG49
VALVE       31       1      0   1 .011   9.                                   CV03        CONFIG50
LINE        10       1      0   1 .011  12. 1.50      4   2.0   30.           LN30        CONFIG51
```

TABLE 1.2.5-1

ACPS INPUT DATA DECK LISTING (CONTD)

```
PUMP     21     1     0     1                                               HP02          CONFIG52
LINE     10     1     0     1  .018  120.   2.0      4   2.0   30.          LN31          CONFIG53
VALVE    21     1     0     1  .018   5.6                                   SV02          CONFIG54
LINE     10     1     0     1  .018   12.   2.0      4   2.0   30.          LN32          CONFIG55
TAP      31     1     0     1  .018   5.6                                   FT24          CONFIG56
LINE     10     1     0     1  .018   24.   2.0      4   2.0   30.          LN33          CONFIG57
TANK      0     1     0     2                        4   2.0   30.          TK02          CONFIG58
END                                                                                       ENDCFG59

     4.58         540.          .9       3                                                  DCYL01
     6.15        7975.          .9       3                                                  DCYL02
     3.58        2094.          .9       3                                                  DCYL03
    38.80         536.          .9       3                                                  DCYL04
     7.43        2061.          .9       3                                                  DCYL05
     3.58         593.          .9       3                                                  DCYL06
    66.10         536.          .9       3                                                  DCYL07
    32.30         714.          .9       3                                                  DCYL08
   104.10         568.          .9       3                                                  DCYL09
    31.90        1876.          .9       3                                                  DCYL10
    16.16      571048.          .9       3                                                  DCYL11
   100.00        9584.          .9       3                                                  DCYL12
                  -1.                                                                       ENDINPUT

     3     350.       400.       1750.       250.        40.        4.                     ENGINE

     1     1     2     2     2                                                         SMAL.TK.02
   165.        16.        170.       26.7       31.7        .2         2.
   3.          5.066

     1     1     2     2     2                                                         SMAL.TK.H2
   37.         16.        40.        19.1       24.1        .3         2.
   3.          5.

     1     0                                                                           IWOP ! 1

     1     4     1                                                                     ACCUM-O2
       350.       2000.        .1         2.         2.5        2.05        500.       ACCUM-O2

     1     4     1                                                                     ACCUM-H2
       350.       2000.        .2         2.         72.5       5.20        500.       ACCUM-H2

     1                                                                                 NUMHEX
  2000. 1100.  173.  350.  245.  215. 2030. 2000.   30.   30.    1.                    HX01    1
  2000. 1028.   42.  350.  500.  470. 2010. 2000.   30.   10.    1.                    HX03    1

     2     .52       8.7       20000.     2023.                                          PUMP1
     2     .54       1.1       70000.     2023.                                          PUMP2

                                                                                       TRPUMP  1
                                                                                       TRPUMP  2

     .55      2000.      1160.      .891       250.                                    TURBN   1
     .36      2000.      1160.      .891       500.                                    TURBN   2

     1                                                                                 NUMHSO
     1              1.0       2060.               245.                                 HSORC   1
     1              1.0       2060.               500.                                 HSORC   2
```

1.2.6.1 LISTING OF DATA TABLES

DATA TABLE -1

```
RCS-THRUSTER WEIGHT            4      5              1
 HIGH PRESSURE APS THRUSTER
 REGEN. SLOT TYPE CU. CHAMBER
 QUAD REDUNDANT VALVES, RAD. NOZZLE
 EXPANSION RATIO SET TO 40 FOR THIS DEMONSTRATION TABLE

  TO = TF (R)                  2 200.       500.
 PC (PSIA)                     3 100.       300.        500.
  THRUST (LB-F)    TCA WEIGHT (LB-M)
      8         1     2
100.          19.1          300.         29.          600.          40.3
1000.         54.           1500.         70.         3000.         118.
6000.0        234.0         10000.0      475.0
      8         1     2
100.          15.9          300.         20.9         600.          26.8
1000.         33.5          1500.        41.          3000.          64.
6000.0        118.0         10000.0      218.0
      8         1     2
100.          15.           300.         18.9         600.          23.1
1000.         28.2          1500.        33.9         3000.         49.8
6000.0        81.0          10000.0      131.0
      8         1     2
100.          19.1          300.         29.          600.          40.3
1000.         54.           1500.         70.         3000.         118.
6000.0        234.0         10000.0      475.0
      8         1     2
100.          15.9          300.         20.9         600.          26.8
1000.         33.5          1500.        41.          3000.          64.
6000.0        118.0         10000.0      218.0
      8         1     2
100.          15.           300.         18.9         600.          23.1
1000.         28.2          1500.        33.9         3000.         49.8
6000.0        81.0          10000.0      131.0
```

DATA TABLE -2

```
RCS-VAC. SP. IMPULSE           3      4              2
 HIGH PRESSURE APS THRUSTER
 THEORETICAL PERFORMANCE FOR GASEOUS HYDROGEN/GASEOUS OXYGEN
 EXPANSION RATIO SET TO 40 FOR THIS DEMONSTRATION TABLE

PROPELLANT TEMP.              3 100.       250.        540.
MIXTURE RATIO(O/F)ISP(LBF-SEC/LBM)
      9         1     3
1.            360.          1.5          392.         2.            418.
2.5           435.5         3.           445.5        3.5           451.
4.            454.          5.           455.         7.            442.
      9         1     3
1.            398.          1.5          425.         2.            441.5
2.5           451.          3.           457.5        3.5           461.5
4.            463.5         5.           463.5        7.            448.
      9         1     3
1.            429.          1.5          447.         2.            459.
2.5           467.          3.           472.         3.5           474.
4.            474.          5.           470.5        7.            452.
```

DATA TABLE -3

```
SPEC.HT/LB OF O2 REMOVED      3     4            3
   SPECIFIC HEAT PER LB. OF O2 WITHDRAWN
     (SPEC. HEAT) VS (DENSITY) AT A GIVEN PRESSURE
       DENSITY = F (PCT,WITHDRAWN,PF/(ZF*TF))

   PRESSURE (PSIA)        5    700.       1000.       1500.      2000.      3000.
  PLOT LABEL
    23       1       3
    2.056       235.88          2.241      212.94          2.402       196.04
    2.590       179.47          2.811      163.24          -3.285      163.24
    3.527       126.64          4.059      108.76          4.567        95.90
    5.097        85.38          7.168       59.81          8.578        50.10
     10.           44.          15.           33.7          20.          29.1
     25.           28.8         30.           31.5          35.          38.
     40.           47.5         45.           59.5          50.          75.
     60.          115.          70.126      164.
    20       1       3
    2.917       235.24          3.109      217.76          3.412       194.90
    3.784       172.64          4.254      151.02          4.871       129.96
    5.058       124.75          7.041       87.87          9.068        67.80
     10.           60.          15.           45.8          20.          39.5
     25.           37.9         30.           39.6          35.          44.8
     40.           53.5         45.           64.9          50.          80.
     60.          119.5         70.126      166.9
    17       1       3
    4.312       233.81          5.061      192.89          5.967       159.50
    7.047       132.88          8.113      114.61          9.143       101.45
   10.235        90.65         14.772       64.65         19.854        53.02
     25.           51.          30.           51.1          35.          55.
     40.           62.2         45.           72.5          50.          85.7
     60.          121.7         70.126      170.
    17       1       3
    5.657       232.12          6.046      214.14          7.022       179.50
    8.140       152.18          9.022      136.45         10.150       121.05
   12.662        97.93         15.476       82.05         19.617        68.68
     25.           64.7         30.           63.2          35.          65.3
     40.           70.9         45.           79.9          50.          90.8
     60.          126.          70.126      174.
    15       1       3
    8.185       228.51          9.205      198.44         10.240       175.72
   12.818       139.40         14.457      126.25         16.553       113.42
     20.           99.          25.           86.1          30.          81.5
     35.           82.          40.           86.9          45.          95.6
     50.          107.4         60.          137.7          70.126     180.8
```

DATA TABLE -4

```
SPEC.HT/LB OF H2 REMOVED      3     4            4
   SPECIFIC HEAT PER LB. OF H2 WITHDRAWN
     (SPEC. HEAT) VS (DENSITY) AT A GIVEN PRESSURE
       DENSITY = F(PCT,WITHDRAWN,PF/(ZF*TF))

   PRESSURE (PSIA)        5    300.       500.        700.       1000.      1500.
  PLOT LABEL
    15       1       3
     .214       999.41          .313       565.51          .383       414.05
    .40       362.             .43       326.             .46       296.
     .5           274.          1.           151.          1.5         119.
     2.           111.          2.5          124.          3.0         153.
     3.5          192.          4.0          238.          4.365       272.
    15       1       3
     .218      1589.88          .420       786.88          .642       410.93
    .73       370.             .76       340.             .80       316.
     .86          293.          1.           245.          1.5         183.
     2.           162.          2.5          164.          3.0         185.
```

3.5	217.	4.0	258.	4.365	292.
17	1 3				
.213	2158.33	.318	1542.80	.423	1194.40
.532	901.90	.647	674.37	.899	412.82
.98	378.	1.03	360.	1.10	348.
1.19	313.	1.5	256.	2.0	208.5
2.5	202.	3.0	217.	3.5	245.
4.0	282.	4.365	312.		
16	1 3				
.203	3208.73	.408	1683.98	.595	1209.78
.821	798.49	1.02	571.99	1.27	425.33
1.36	390.	1.40	378.	1.50	352.
1.55	341.	2.0	283.5	2.5	261.5
3.0	265.	3.5	284.	4.0	315.
4.365	342.				
18	1 3				
.254	3654.70	.415	2264.82	.614	1642.97
.815	1285.33	1.023	984.78	1.244	755.41
1.400	647.35	1.723	505.19	1.876	455.42
1.95	422.	2.00	414.	2.05	408.
2.18	391.	2.5	363.	3.0	344.5
3.5	347.5	4.0	369.	4.365	393.

DATA TABLE -5

TEMP. /LB. OF O2 REMOVED 3 4 5
TEMPERATURE (DEG-R) PER LB. OF O2 WITHDRAWN
(TEMP.) VS (DENSITY) AT A GIVEN PRESSURE
DENSITY = F(PCT.WITHDRAWN,PF/(ZF)TF))

PRESSURE (PSIA 5 700. 1000. 1500. 2000. 3000.
PLOT LABEL

21	1 3				
2.056	1000.	2.241	920.	2.402	860.
2.590	800.	2.811	740.	3.285	640.
3.527	600.	4.059	530.	4.567	480.
5.097	440.	7.168	350.	8.578	320.
10.209	300.	14.492	280.	18.617	276.19
25.	276.19	36.171	276.19	44.345	270.
51.605	255.	60.023	225.	72.252	160.
18	1 3				
2.917	1000.	3.109	940.	3.412	860.
3.784	780.	4.254	700.	4.871	620.
5.058	600.	7.041	460.	9.069	390.
10.000	370.	14.702	320.	21.749	300.
26.969	295.	34.160	290.	42.970	280.
51.612	260.	60.710	225.	72.510	160.
15	1 3				
4.312	1000.	5.061	860.	5.967	740.
7.047	640.	8.113	570.	9.143	520.
10.235	480.	14.772	390.	19.854	350.
25.288	330.	34.878	310.	42.293	295.
51.137	270.	60.725	230.	72.926	160.
15	1 3				
5.657	1000.	6.046	940.	7.022	820.
8.140	720.	9.022	660.	10.150	600.
12.662	510.	15.476	450.	19.617	400.
26.117	360.	34.914	330.	45.084	300.
50.769	280.	60.741	235.	72.559	165.
12	1 3				
8.185	1000.	9.205	900.	10.240	820.
12.818	680.	14.459	620.	16.553	560.
20.909	480.	31.139	390.	41.334	340.
51.263	295.	60.791	245.	72.618	170.

DATA TABLE -6

```
TEMP. /LB. OF H2 REMOVED      3      4               6
   TEMPERATURE (DEG-R) PER LB. OF H2 WITHDRAWN
     (TEMP) VS (DENSITY) AT A GIVEN PRESSURE
       DENSITY = F(PCT.WITHDRAWN,PF/(ZF*TF))

  PRESSURE (PSIA)         5    300.      500.      700.     1000.     1500.
 PLOT LABEL
   17       1       3
    .214     260.0          .313     180.0          .333     150.0
   .40      148.           .43      130.           .46      124.
   .50      115.           .75      89.           1.00       78.5
   1.25        73.         1.5         69.8         2.         66.
   2.5         64.3        3.          62.          3.5        58.
   4.          51.         4.365       43.5
   16       1       3
    .218     420.0          .420     220.0          .642     150.0
   .73      130.           .76      127.           .80      123.5
    .85        120.        1.          107.8         1.25       95.5
   1.5         67.5        2.          79.          2.5        73.3
   3.          68.3        3.5         62.3         4.0        54.7
   4.365       48.5
   18       1       3
    .213     600.0          .318     400.0          .423     300.0
    .532     240.0          .647     200.0          .899     150.0
   .98      132.          1.03      128.5         1.10      123.0
   1.2         119.         1.25       116.          1.5        104.8
   2.0         90.5        2.5         80.8         3.0        74.2
   3.5         66.5        4.          58.          4.365      51.
   16       1       3
    .203     900.0          .408     440.0          .559     320.0
    .621     220.0         1.02      180.0         1.27      150.0
  1.36      140.5         1.40      138.0         1.50      131.0
   1.55        129.        2.          108.         2.5        94.4
   3.          84.1        3.5         74.4         4.         63.9
   4.365       55.5
   18       1       3
    .254    1100.           .415     650.0          .614     425.0
    .815     320.          1.023     250.0         1.244     215.0
   1.400     190.          1.723     160.          1.876     150.0
  1.95      143.0         2.0       139.0         2.05      137.0
   2.18        130.        2.5         117.         3.         101.
   3.5         86.9        4.0         73.9         4.365      65.
```

DATA TABLE -7

```
RR/ VS PGG,M/R,PAMB,PCHP        5       3          7
   REFERENCE REACTANT FLOW AT T.I.T.= 2060 DEG R.
   (RR)  VS (PCT.HP.) AT A GIVEN (PRES.OF GG),(MIX.RATIO),(P-AMBIENT)

PRES. GAS GEN PSIA         3    300.      600.      900.
MIXTURE RATIO              2      .5       1.0
AMBIENT PRESSURE           2     0.       14.7
PLOT RR1
     2      1      2
     0.            0.        100.          7.52
     2      1      2
     0.            1.23      100.          8.57
     2      1      2
     0.            0.        100.          9.60
     2      1      2
     0.            3.00      100.         10.47
     2      1      2
     0.            0.        100.          6.53
     2      1      2
     0.             .84      100.          7.13
```

```
2       1      2
0.             0.          100.          8.58
2       1      2
0.              .780       100.          9.30
2       1      2
0.             0.          100.          6.42
2       1      2
0.              .762       100.          6.65
2       1      2
0.             0.          100.          8.45
2       1      2
0.              .81        100.          8.70
```

DATA TABLE -8

```
KK VS PGG,M/R,PAMB,PCHP          5     4          8
  (RR)  REFERENCE REACTANT AT T.I.T. = 2060 DEG R
   KK -- CONVERSION FACTOR FOR REFERENCE REACTANT RR
  (KK) VS (PCT,HP,) AT A GIVEN (PRES OF GG),(MIX,RATIO),(P-AMBIENT)

PRES. GAS GEN PSIA          3    300.       600.       900.
MIXTURE RATIO               2     .5        1.0
AMBIENT PRESSURE            2    0.        14.7
PLOT KI
     2       1      2
     0.             1.078       100.          1.078
     2       1      2
     0.             1.037       100.          1.069
     2       1      2
     0.             1.062       100.          1.062
     2       1      2
     0.             1.035       100.          1.055
     2       1      2
     0.             1.087       100.          1.087
     2       1      2
     0.             1.05        100.          1.082
     2       1      2
     0.             1.067       100.          1.067
     2       1      2
     0.             1.044       100.          1.064
     2       1      2
     0.             1.09        100.          1.09
     2       1      2
     0.             1.052       100.          1.088
     2       1      2
     0.             1.068       100.          1.068
     2       1      2
     0.             1.047       100.          1.068
```

DATA TABLE -9

```
OMS ENGINE WEIGHT                3     4          9
  ADIABATIC WALL ENGINE
  EXPANSION RATIO FIXED AT 40.
  REFERENCE - AEROJET PARAMETRIC DATA FOR LIQUID BIPROP. ENGINES.6-2-69.

  PC (PSIA)             3 100.     250.      500.
 THRUST (LB-F)     ENG.WGT. (LB-M)
     6       1     2
   200.           13.0      1500.        42.5     3000.        77.5
  4500.          112.0      6000.       147.0     8000.       186.5
     6       1     2
   200.            6.0      1500.        21.4     3000.        36.8
  4500.           52.5      6000.        67.8     8000.        88.5
     6       1     2
   200.            4.6      1500.        14.6     3000.        21.0
  4500.           34.0      6000.        43.7     8000.        57.0
```

DATA TABLE -10

```
ONS VAC. SP. IMPULSE            3      4           10
 PUMP FED ENGINE
 EXPANSION RATIO FIXED AT 40.
 REFERENCE - AEROJET PARAMETRIC DATA FOR LIQUID BIPROP. ENGINES.6-2-69.

  PC (PSIA)                 3 100.      250.       500.
MIXTURE RATIO(O/F)ISP(LBF-SEC/LBM)
    9       1     3
   1.0         290.0          1.2        296.2          1.4         300.4
   1.6         300.5          1.8        298.5          2.0         296.0
   2.2         292.0          2.4        287.5          2.6         282.5
    9       1     3
   1.0         293.5          1.2        302.0          1.4         308.0
   1.6         309.7          1.8        310.5          2.0         308.5
   2.2         306.0          2.4        301.2          2.6         299.5
    9       1     3
   1.0         297.0          1.2        306.5          1.4         312.8
   1.6         316.5          1.8        318.0          2.0         318.5
   2.2         315.8          2.4        310.8          2.6         314.1
```

DATA TABLE -11

```
HEX HOT GAS FLOW - LO2        5     8          11
HEAT EXCHANGER HOT GAS FLOW TO PROVIDE CONDITIONED OXYGEN - HIGH PRESSURE
     SCALED FROM AEROJET PRESENTATION DATA OF 1/30/70

                         HOT GAS SIDE                     COLD GAS SIDE

  TIN                       2000 R                           175 R
  TOUT                       700 R                          AS SHOWN
  PIN                     150-250 PSIA                      PARAMETER
PIN COLD (PSIA)             4 250.        450.       650.        1200.
TOUT HOT (R)                2 500.        1000.
TOUT COLD (R)               3 200.        300.       400.
LO2 FLOW (LB/SEC) G.G. FLOW (LB/SEC)        0.              14.
      2      0
.005928      0.
      2      0
.048         0.
      2      0
.086428      0.
      2      0
.005928      0.
      2      0
.048         0.
      2      0
.086428      0.
      2      0
.005614      0.
      2      0
.045428      0.
```

```
       2        0
 .081857         0.
       2        0
 .005614         0.
       2        0
 .045428         0.
       2        0
 .081857         0.
       2        0
 .005114         0.
       2        0
 .041428         0.
       2        0
 .074571         0.
       2        0
 .005114         0.
       2        0
 .041428         0.
       2        0
 .074571         0.
       2        0
 .003714         0.
       2        0
 .030142         0.
       2        0
 .054142         0.
       2        0
 .003714         0.
       2        0
 .030142         0.
       2        0
 .054142         0.
```

DATA TABLE -12

```
HEX HOT GAS FLOW - LH2          5       8             12
HEAT EXCHANGER HOT GAS FLOW TO PROVIDE CONDITIONED HYDROGEN - HIGH PRESSURE
     SCALED FROM AEROJET PRESENTATION DATA OF 1/30/70

                          HOT GAS SIDE                  COLD GAS SIDE

  TIN                        2000 R                          50 R
  TOUT                        700 R                       AS SHOWN
  PIN                     150,200 PSIA               250,450 - 1200 PSIA
PIN COLD (PSIA)             2 100.       1000.
TOUT HOT (R)                2 500.       1000.
TOUT COLD (R)               3 200.       300.      400.
LH2 FLOW (LB/SEC) G.G. FLOW (LB/SEC)       0.            14.
      2        0
.255714         0.
      2        0
.411428         0.
      2        0
.599285         0.
      2        0
.255714         0.
      2        0
.411428         0.
      2        0
.599285         0.
      2        0
```

.255714	0.
2	0
.411428	0.
2	0
.599285	0.
2	0
.255714	0.
2	0
.411428	0.
2	0
.599285	0.

DATA TABLE -13

GAS GENERATOR WEIGHT 4 7 13
GAS GENERATOR ASSEMBLY WEIGHT AS A FUNCTION OF GAS GENERATOR FLOW RATE
GAS GENERATOR ASSEMBLY WEIGHT CONSIDERS -

1. BIPROPELLANT POPPET VALVES AND ACTUATORS WITH IGNITER ASSEMBLY AND EXCITER BOX AND CABLE.

2. MIXTURE RATIO OF 1.1 AND FUEL INLET TEMPERATURE OF 350 R.

TOUT (R) 2 1000. 3000.
PC (PSIA) 5 100. 200. 250.0 300.0 500.
G.G. FLOW (LB/SEC)G.G.A. WEIGHT (LB)

9	1	3			
0.	15.	2.	26.	4.	38.2
5.	46.1	6.	58.6	7.	78.
9.0	117.	11.0	161.	12.	179.
9	1	3			
0.	15.	2.	22.4	4.	30.9
5.	36.1	6.	42.8	7.	54.9
9.0	73.5	11.0	98.	12.	110.
9	1	3			
0.	15.	2.	20.1	4.	26.5
5.	30.7	6.	37.	7.	47.6
9.0	64.0	11.0	84.0	12.	95.0
9	1	3			
0.	15.	2.	19.1	4.	24.
5.	27.4	6.	32.3	7.	40.2
9.0	55.5	11.0	72.0	12.	81.0
9	1	3			
0.	15.	2.	17.6	4.	21.6
5.	24.3	6.	28.	7.	33.4
9.0	42.5	11.0	53.0	12.	58.5
9	1	3			
0.	15.	2.	26.	4.	38.2
5.	46.1	6.	58.6	7.	78.
9.0	117.	11.0	161.	12.	179.
9	1	3			
0.	15.	2.	22.4	4.	30.9
5.	36.1	6.	42.8	7.	54.9
9.0	73.5	11.0	98.	12.	110.
9	1	3			
0.	15.	2.	20.1	4.	26.5
5.	30.7	6.	37.	7.	47.6
9.0	64.0	11.0	84.0	12.	95.0
9	1	3			
0.	15.	2.	19.1	4.	24.
5.	27.4	6.	32.3	7.	40.2
9.0	55.5	11.0	72.0	12.	81.0

	9	1	3		
0.	15.	2.	17.6	4.	21.6
5.	24.3	6.	28.	7.	33.4
9.0	42.5	11.0	53.0	12.	58.5

DATA TABLE -14

LO2 TRANSFER PUMP WEIGHT 5 2 14

***** NOTE *****

THIS DATA IS AN APPROXIMATION ONLY AND WILL BE REPLACED

EFFICIENCY	260.	80.
NPSH (PSI)	20.	3.
HEAD RISE (PSI)	25.	50.

LO2 FLOW (LB/SEC) PUMP WEIGHT (LB)

	6	1	3		
0	5.	5.	15.	10.	25.
20.	56.	30.	110.	70.	900.
	6	1	3		
0.	5.	5.	24.	10.	47.
20.	122.	30.	260.	70.	2300.
	6	1	3		
0	5.	5.	15.	10.	25.
20.	56.	30.	110.	70.	900.
	6	1	3		
0.	5.	5.	24.	10.	47.
20.	122.	30.	260.	70.	2300.
	6	1	3		
0	5.	5.	15.	10.	25.
20.	56.	30.	110.	70.	900.
	6	1	3		
0.	5.	5.	24.	10.	47.
20.	122.	30.	260.	70.	2300.
	6	1	3		
0	5.	5.	15.	10.	25.
20.	56.	30.	110.	70.	900.
	6	1	3		
0.	5.	5.	24.	10.	47.
20.	122.	30.	260.	70.	2300.

DATA TABLE -15

LH2 TRANSFER PUMP WEIGHT 5 2 15

***** NOTE *****

THIS DATA IS AN APPROXIMATION ONLY AND WILL BE REPLACED

EFFICIENCY	2 60.	80.
NPSH (PSI)	2 0.	3.
HEAD RISE (PSI)	2 5.	50.

LH2 FLOW (LB/SEC) PUMP WEIGHT (LB)

	6	1	3		
0.	5.	5.	9.	10.	13.8
15.	19.4	20.	26.9	50.	120.
	7	1	3		
0.	5.	5.	14.	10.	23.
15.	33.2	20.	47.	30.	80.25
50.0	150.0				
	6	1	3		
0.	5.	5.	9.	10.	13.8
15.	19.4	20.	26.9	50.	120.
	7	1	3		
0.	5.	5.	14.	10.	23.
15.	33.2	20.	47.	30.	80.25
50.0	150.0				
	6	1	3		
0.	5.	5.	9.	10.	13.8

15.	19.4	20.	26.9	50.	120.
7	1 3				
0.	5.	5.	14.	10.	23.
15.	33.2	20.	47.	30.	80.25
50.0	150.0				
6	1 3				
0.	5.	5.	9.	10.	13.8
15.	19.4	20.	26.9	50.	120.
7	1 3				
0.	5.	5.	14.	10.	23.
15.	33.2	20.	47.	30.	80.25
50.0	150.0				

DATA TABLE -16

MOTOR WEIGHT 3 8 16

NOTE - BRUSHLESS D-C MOTOR WEIGHT INCLUDES
ELECTRONICS (FIXED SIZE FOR EACH POWER LEVEL)
ROTOR
STATOR
BEARINGS
SHAFT
HOUSINGS

HORSEPOWER 5 1. 5. 25. 100. 200.
SHAFT SPEED (RPM) MOTOR WEIGHT (LB)

10	1 6				
2.0	+0311.8	5.0	+038.5	7.5	+035.78
10.0	+035.28	15.0	+034.8	20.0	+034.58
30.0	+034.39	40.0	+034.25	50.0	+034.20
100.0	+034.20				
12	1 3				
2.0	+0334.2	5.0	+0327.6	7.5	+0326.05
10.0	+0325.1	15.0	+0324.0	20.0	+0323.5
30.0	+0322.9	40.0	+0322.4	50.0	+0322.1
60.0	+0322.0	80.0	+0322.0	100.0	+0322.0
9	1 6				
2.	+03111.	5.	+0399.5	10.	+0394.
15.	+0391.	20.	+0390.	30.	+0388.65
40.	+0388.	50.	+0388.	100.	+0388.
9	1 4				
2.	+03289.	5.	+03265.	10.	+03255.7
15.	+03252.25	20.	+03250.7	30.	+03250.
40.	+03250.	50.	+03250.	100.	+03250.
9	1 5				
2.	+03502.	5.	+03462.	10.	+03440.
15.	+03435.5	20.	+03434.	30.	+03433.
40.	+03432.	50.	+03432.	100.	+03432.

DATA TABLE -17

VAC.JAC.DIA.VS.WEIGHT 2 3 17
VACUUM JACKET WEIGHT AS A FUNCTION OF VACUUM JACKET DIAMETER FOR
ALUMINUM HONEYCOMB. REF. LMSC A981608.

DIAMETER (INCHES) WEIGHT (LBS)

15	1 3				
15.9	.396	24.0	.365	30.0	.355
36.0	.350	42.0	.360	48.0	.370
60.0	.400	72.0	.436	84.0	.478
96.0	.520	108.0	.568	120.0	.618
132.0	.660	144.0	.715	156.0	.762

DATA TABLE -18

PHI - HYDROGEN 3 4 18
ENERGY DERIVATIVE (PSIA-CU.FT./BTU) FOR HYDROGEN

(PHI) VS (DENSTY) AT A GIVEN PRESSURE
(DENSITY) = F(PCT.FLUID WITHDRAWN,PF/(ZF*TF))

PRESSURE (PSIA)	5 200.		400.		600.		800.		1000.
RHO (LB/CU-FT)	PHI(PSIA-CUFT/BTU)								
15 1	3								
.08097	2.028	.09797	1.923	.1434	1.912				
.209	2.494	.311	3.415	.383	3.703				
.51	3.909	.856	4.017	1.133	3.909				
2.299	3.971	3.068	6.610	3.582	8.116				
4.007	9.493	4.305	10.480	4.466	11.088				
15 1	3								
.08258	2.168	.1233	2.149	.1605	2.053				
.2304	1.899	.476	2.933	.580	3.425				
.760	3.905	1.061	4.271	1.403	4.522				
2.329	5.293	3.100	6.817	3.467	7.779				
4.085	9.616	4.349	10.484	4.498	11.040				
15 1	3								
.0743	2.122	.1232	2.180	.1578	2.184				
.2038	2.143	.2611	2.033	.3221	1.945				
.4589	2.099	.9248	3.740	1.3910	4.479				
2.3077	5.511	3.098	6.878	3.517	7.879				
3.9630	9.117	4.231	9.943	4.459	10.716				
15 1	3								
.0743	2.035	.0988	2.129	.1634	2.193				
.2090	2.201	.260	2.174	.3024	2.123				
.4517	1.973	.7367	2.519	1.1753	3.832				
1.8787	4.952	3.1546	7.010	3.6572	8.163				
3.9463	8.944	4.1993	9.696	4.421	10.420				
15 1	3								
.0743	1.931	.0927	2.040	.1832	2.197				
.2278	2.213	.2789	2.215	.3466	2.175				
.4270	2.088	.7493	2.219	1.0274	2.919				
1.9648	4.943	3.1912	7.044	3.7605	8.332				
4.0147	9.010	4.2447	9.691	4.4517	10.363				

DATA TABLE -19

TEMP. OF N2 VS RHO F(P) 3 5 19
TEMPERATURE OF NITROGEN AS A FUNCTION OF DENSITY AND PRESSURE.
T VS RHO AT GIVEN PRESSURE
REF - THERMO.PROPS.OF O2 AND N2 - PART I (N2), STEWART,JACOBSEN,MYERS,
DATED 7-31-72, UNIV.OF IDAHO, NAS9-12078 FINAL REPT.

PRESSURE	5 100.		300.		600.		800.		1000.
RHO (LB/CU-FT)	TEMP (DEG-R)								
17 1	3								
0.26029	1000.	0.32550	800.	0.37226	700.				
0.43491	600.	0.52374	500.	0.65890	400.				
0.89566	300.	1.0076	270.	1.21764	230.				
1.32607	215.	1.41267	205.	1.51513	195.				
1.76471	176.882	43.65099	176.882	47.02511	160.				
50.44270	140.	51.97474	130.						
17 1	3								
0.77626	1000.	0.97151	800.	1.11245	700.				
1.30313	600.	1.57750	500.	2.01333	400.				
2.85722	300.	3.31995	270.	4.43380	230.				
5.31260	215.	5.90023	209.176	35.37826	209.176				
41.23298	190.	45.50434	170.	49.04794	150.				
50.64242	140.	52.13136	130.						
15 1	3								

1.53854	1000.	1.92725	800.	2.21038	700.
2.59834	600.	3.17019	500.	4.12812	400.
6.32072	300.	7.95007	270.	10.36763	250.
27.95726	230.	37.27237	210.	42.17850	190.
46.06018	170.	49.40493	150.	52.35831	130.
15	1	3			
2.03884	1000.	2.55502	800.	2.93297	700.
3.45464	600.	4.23447	500.	5.58290	400.
9.04166	300.	12.32699	270.	19.38695	250.
32.02713	230.	38.28876	210.	42.72110	190.
46.40105	170.	49.63097	150.	52.50466	130.
15	1	3			
2.53277	1000.	3.17489	800.	3.64719	700.
4.30329	600.	5.29619	500.	7.06164	400.
12.07741	300.	17.61068	270.	26.07201	250.
33.93609	230.	39.12311	210.	43.21232	190.
46.72206	170.	49.84845	150.	52.64729	130.

DATA TABLE -20

HT.XFER.COEF.-H2 3 4 20
OVERALL HEAT TRANSFER COEFFICIENT FOR H2 ELECTRIC POWERED HEX AS A FUNCTION OF MASS VELOCITY AND FLUID INLET PRESSURE.
REF. AR-71-7535.

PRESSURE (PSIA) 4 14.7 100. 500. 1000.
MASVEL(LB/HR-IN) U (BTU/HR-R-SQ.IN)

11	1	3			
.10	.27	.30	.70	.50	.96
.75	1.21	1.00	1.42	1.50	1.75
2.00	1.97	3.00	2.35	4.00	2.73
5.00	3.09	6.00	3.45		
11	1	3			
.10	.35	.30	.78	.50	1.10
.75	1.35	1.00	1.53	1.50	1.85
2.00	2.09	3.00	2.48	4.00	2.87
5.00	3.25	6.00	3.64		
11	1	3			
.10	.45	.30	.88	.50	1.20
.75	1.45	1.00	1.65	1.50	1.96
2.00	2.22	3.00	2.61	4.00	3.04
5.00	3.42	6.00	3.82		
11	1	3			
.10	.50	.30	.99	.50	1.30
.75	1.55	1.00	1.76	1.50	2.08
2.00	2.34	3.00	2.78	4.00	3.22
5.00	3.65	6.00	4.09		

DATA TABLE -21

HT.XFER.COEF.-O2-N2 3 4 21
OVERALL HEAT TRANSFER COEFFICIENTS FOR O2 AND N2 ELECTRIC POWERED HEX AS A FUNCTION OF MASS VELOCITY AND FLUID INLET PRESSURE.
REF. AR 71-7535

PRESSURE (PSIA) 4 14.7 100. 500. 1000.
MASVEL(LB/HR-IN) U (BTU/HR-R-SQ.IN)

15	1	3			
.2	.13	.4	.17	.6	.195
.8	.22	1.0	.24	1.4	.27
2.0	.31	4.0	.40	6.0	.49
8.0	.57	12.0	.76	16.0	.935
20.	1.1	25.	1.31	30.	1.53
15	1	3			

.2	.14	.4	.18	.6	.205
.8	.225	1.0	.245	1.4	.285
2.0	.33	4.0	.42	6.0	.51
8.0	.595	12.0	.78	16.0	.96
20.	1.14	25.	1.35	30.	1.57
15 1	3				
.2	.175	.4	.22	.6	.255
.8	.27	1.0	.30	1.4	.34
2.0	.38	4.0	.495	6.0	.60
8.0	.700	12.0	.92	16.0	1.14
20.	1.35	25.	1.615	30.	1.68
15 1	3				
.2	.26	.4	.31	.6	.36
.8	.39	1.0	.42	1.4	.47
2.0	.52	4.0	.67	6.0	.82
8.0	.96	12.0	1.255	16.0	1.56
20.	1.835	25.	2.195	30.	2.555

DATA TABLE -22

FTU OF 321/347 ST.STEEL 2 3 22
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF 321/347 STAINLESS STEEL
REF. SEC.8-LMSC A981608,PAGE 8.1.1-8

TEMPERATURE (R) ULT.STRENGTH (PSI)

14 1	2				
36.7	266500.	59.7	251000.	159.7	207000.
259.7	173000.	359.7	143000.	459.7	121000.
559.7	108000.	659.7	91000.	859.7	75000.
1059.7	70000.	1259.7	66000.	1459.7	63000.
1659.7	50000.	1859.7	32000.		

DATA TABLE -23

FTU OF 2219-T87 ALUM. 2 3 23
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF 2219-T87 ALUMINUM
REF. SEC.8-LMSC A981608,PAGE 8.1.1-8

TEMPERATURE (R) ULT.STRENGTH (PSI)

16 1	2				
36.7	94000.	100.0	82400.	150.0	76000.
200.0	72000.	250.0	68500.	300.0	67800.
350.0	67000.	400.0	66300.	450.0	65000.
500.0	63800.	550.0	62000.	600.0	60000.
650.	58000.	859.7	38400.	1059.7	16600.
1259.7	6400.				

DATA TABLE -24

FTU OF 6061-T6 ALUMINUM 2 3 24
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF 6061-T6 ALUMINUM ALLOY
REF. MIL HANDBOOK -5

TEMPERATURE (R) ULT.STRENGTH (PSI)

13 1	3				
36.7	63840.	100.0	57330.	150.0	53340.
200.0	50610.	250.0	48384.	300.0	46830.
350.0	45696.	400.0	44940.	450.0	43848.
500.0	42840.	550.0	41496.	600.0	40152.
650.0	38556.				

DATA TABLE -25

FTU OF INCONEL-718 2 3 25
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF INCONEL-718
REF. MIL HANDBOOK -5.

TEMPERATURE (R) ULT.STRENGTH (PSI)
13 1 3

36.7	219600.	100.0	213660.	150.0	210240.
200.0	206100.	250.0	201240.	300.0	196200.
350.0	193140.	400.0	189000.	450.0	185400.
500.0	182160.	550.0	179460.	600.0	177300.
650.0	175140.				

DATA TABLE -26

FTU OF TI-6AL-4V 2 3 26
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF TITANIUM TI-6AL-4V
REF. MIL HANDBOOK -5.

TEMPERATURE (R) ULT.STRENGTH (PSI)
13 1 3

36.7	288320.	100.	261600.	150.	244480.
200.0	226880.	250.	212800.	300.	200960.
350.0	190720.	400.	181280.	450.	173120.
500.0	165280.	550.	158720.	600.	154240.
650.0	145600.				

DATA TABLE -27

HEAD COEFFICIENT VS NS 2 3 27

HEAD COEF. VS NS (SPEC. SPEED)

HEAD COEF
15 1 2

70.	.665	80.	.660	90.	.655
100.	.65	200.	.639	400.	.619
600.	.60	1000.	.571	2000.	.518
3000.	.472	5000.	.400	6000.	.363
7000.	.323	8000.	.281	9800.	.192

DATA TABLE -28

ADIABATIC EFF. VS NS 2 3 28

ADIABATIC EFFICIENCY VS NS (SPEC. SPEED)

ADIAB. EFF
20 1 2

70.	.00	80.	.03	90.	.06
100.	.08	127.	.20	200.	.30
250.	.37	300.	.44	350.	.505
400.	.555	500.	.635	600.	.695
700.	.74	800.	.77	1000.	.81
1500.	.845	2000.	.86	3000.	.875
5000.	.887	10000.	.893		

DATA TABLE -29

EFFIC. QUOT.VS IMP. DIAM 2 3 29

EFFICIENCY QUOTIENT VS IMPELLER DIAMETER

EFF. QUOT.
21 1 2

.05	.0	.20	.30	.30	.42
.40	.515	.50	.60	.70	.695
.90	.755	1.20	.82	1.60	.88
2.00	.918	2.40	.945	3.20	.975
4.00	.985	5.0	.988	6.0	.991
7.0	.994	8.0	.997	9.0	.999
10.0	.9995	11.0	.9999	12.0	1.000

DATA TABLE -30

BASE LINE STAGE WT VS DI 2 3 30

BASE LINE STAGE WEIGHT VS IMPELLER DIAMETER

STAGE WT.
12 1 2

.56	.40	.70	.415	.90	.44
1.10	.48	1.50	.63	2.0	1.02
2.50	1.72	3.5	3.8	5.0	9.0
6.00	13.80	7.0	20.0	9.0	36.2

DATA TABLE -31

SATURATED STEAM. T.VS P. 2 3 31
SATURATED WATER VAPOR - SATURATION PRESSURE AND TEMPERATURE TABLE GIVING TEMPERATURE AS A FUNCTION OF PRESSURE.

PSATWV (PSIA) TSATWV (DEG.R)
21 1 2

.08854	492.0	.12170	500.0	.20	513.14
.40	532.86	.60	545.21	.80	554.38
1.0	561.74	2.0	586.08	4.0	612.97
7.5	639.94	10.0	653.21	14.696	672.00
30.0	710.33	50.0	741.01	60.0	752.71
80.0	772.03	100.0	787.81	150.0	818.42
200.0	841.79	300.0	877.33	400.0	909.59

DATA TABLE -32

SP.HT. OF O-H COMB.PROD. 3 3 32
O/F RATIO FROM SP.HT. OF OXYGEN AND HYDROGEN COMBUSTION PRODUCTS AS A FUNCTION OF TEMPERATURE - FOR CONSTANT PRESSURE.

TEMP. - DEG.R 4 700. 1500. 2500. 3500.
OFRAT (RATIO) CPBAR (BTU/LB-R)
12 1 3

0.50	2.315	1.00	1.755	1.50	1.420
2.00	1.193	2.50	1.035	3.00	0.915
3.50	0.824	4.00	0.748	5.00	0.637
6.00	0.556	7.00	0.495	8.00	0.442

12 1 3

0.50	2.420	1.00	1.845	1.50	1.705
2.00	1.270	2.50	1.098	3.00	0.980
3.50	0.892	4.00	0.817	5.00	0.703
6.00	0.626	7.00	0.561	8.00	0.512

12	1 3				
0.50	2.585	1.00	1.994	1.50	1.638
2.00	1.398	2.50	1.217	3.00	1.090
3.50	0.995	4.00	0.918	5.00	0.798
6.00	0.717	7.00	0.658	8.00	0.608
12	1 3				
0.50	2.805	1.00	2.185	1.50	1.795
2.00	1.540	2.50	1.353	3.00	1.207
3.50	1.102	4.00	1.023	5.00	0.898
6.00	0.810	7.00	0.758	8.00	0.710

DATA TABLE -33

OXYGEN INTERNAL ENERGY 3 2 33

OXYGEN INTERNAL ENERGY AS A FUNCTION OF VAPOR PRESSURE ALONG ISOCHORES
DENSITY (LB/CU FT) 5 40. 50. 60. 65. 70.
VAPOR PRESS (PSIA)INT.ENERGY(BTU/LB)

16	1 2				
1.	-71.576	3.	-66.661	5.	-63.982
10.	-59.824	20.	-54.901	40.	-48.963
60.	-44.881	80.	-41.650	100.	-38.920
250.	-26.086	400.	-16.568	650.	-4.123
1100.	-0.169	1400.	4.516	2000.	5.423
2600.	9.973				
14	1 2				
1.	-71.596	3.	-66.716	5.	-64.068
10.	-59.982	16.	-56.820	20.	-55.189
40.	-49.484	60.	-45.617	70.	-44.025
100.	-43.469	550.	-42.716	1200.	-41.725
1800.	-40.664	3000.	-38.575		
14	1 2				
1.	-71.594	3.	-66.709	5.	-64.056
10.	-59.961	16.	-56.789	20.	-55.150
40.	-49.415	60.	-45.518	80.	-42.462
100.	-39.901	250.	-33.400	650.	-32.411
1500.	-31.050	2600.	-28.379		
17	1 2				
1.	-71.586	3.	-66.690	5.	-64.027
10.	-59.906	16.	-56.706	20.	-55.050
40.	-49.234	60.	-45.264	80.	-42.137
100.	-39.509	250.	-27.382	400.	-18.507
700.	-15.264	1100.	-13.829	1400.	-12.766
2000.	-10.666	2600.	-8.579		
11	1 2				
1.	-71.599	3.	-66.722	5.	-64.078
10.	-60.000	16.	-56.847	20.	-55.222
40.	-54.360	200.	-54.345	1000.	-53.411
1500.	-52.714	2600.	-51.198		

DATA TABLE -34

HYDROGEN INTERNAL ENERGY 3 2 34

HYDROGEN INTERNAL ENERGY AS A FUNCTION OF VAPOR PRESSURE ALONG ISOCHORES
DENSITY (LB/CU FT) 5 .5 1.0 3.0 4.0 4.4
VAPOR PRESS (PSIA)INT ENERGY(BTU/LB)

23	1 2				
1.022	-130.455	3.00	-120.531	7.00	-106.738
12.5	-89.46	25.	-64.31	37.5	-40.23
50.	-18.76	62.5	2.34	75.	22.11
87.5	41.32	92.3	49.	100.	53.
112.5	59.5	125.	65.9	137.5	72.2
150.	78.8	162.5	85.1	175.	91.8
187.5	98.1	200.	104.6	500.	259.4
800.	580.662	1000.	768.689		

24	1 2				
1.022	-131.786	3.0	-124.043	7.0	-114.008
12.5	-102.97	25.	-85.48	37.5	-70.77
50.	-57.48	62.5	-45.16	75.	-33.52
87.5	-22.47	100.	-11.85	112.5	-1.
125.	9.47	137.5	19.48	150.	30.07
155.1	34.1	162.5	36.1	175.	39.6
187.5	42.9	200.	46.1	240.	57.0
500.	119.461	800.	197.957	1000.	271.725
24	1 2				
1.022	-132.672	3.0	-126.385	7.0	-118.855
12.5	-111.66	25.	-100.16	37.5	-91.4
50.	-83.83	62.5	-77.12	75.	-70.92
87.5	-65.1	100.	-59.58	112.5	-54.31
125.	-49.23	137.5	-44.28	150.	-39.48
151.7	-39.	162.5	-38.3	175.	-37.9
187.5	-37.1	200.	-36.3	240.	-34.2
500.	-20.858	800.	-6.132	1000.	2.862
13	1 2				
1.0	-132.784	5.0	-122.649	10.0	-115.617
20.0	-106.153	30.0	-98.897	40.0	-92.691
50.0	-87.349	100.0	-85.024	200.0	-83.497
350.	-78.572	500.	-76.946	800.	-67.869
1000.	-62.404				
13	1 2				
1.0	-132.813	3.0	-126.757	5.0	-122.774
7.0	-119.626	10.0	-115.839	15.0	-110.613
35.0	-109.632	100.0	-108.846	200.0	-105.896
350.	-102.346	500.	-99.733	800.	-93.689
1000.	-89.093				

DATA TABLE -35

OXYGEN INTERNAL ENERGY 3 3 35
OXYGEN INTERNAL ENERGY AS A FUNCTION OF VAPOR PRESSURE ALONG ISOCHORES
FOR LOW DENSITIES

DENSITY (LB/CU FT) 5 .1 .3 1.0 20. 40.
VAPOR PRESS (PSIA) INT.ENERGY(BTU/LB)

5	1 2				
1.0	-50.134	5.	23.105	10.	46.217
14.696	68.129	20.	93.279		
8	1 2				
1.0	-64.464	5.	-34.285	10.	-5.399
14.696	18.785	20.	30.938	30.	46.280
40.	61.659	50.	77.295		
13	1 2				
1.0	-70.286	5.0	-58.596	10.0	-49.953
14.696	-43.418	20.0	-36.927	30.0	-26.125
40.0	-16.442	50.0	-7.469	60.0	.999
70.0	9.082	80.0	16.858	90.0	24.382
100.0	29.474				
18	1 2				
1.	-71.522	3.	-66.518	5.	-63.757
10.	-59.413	16.	-55.965	20.	-54.152
40.	-47.608	60.	-42.970	80.	-39.212
100.	-35.978	250.	-19.604	400.	-6.875
500.	0.555	700.	16.127	1100.	22.634
1400.	29.610	2000.	40.081	2600.	49.817
16	1 2				
1.	-71.576	3.	-66.661	5.	-63.982
10.	-59.824	20.	-54.901	40.	-48.963
60.	-44.881	80.	-41.650	100.	-38.920
250.	-26.086	400.	-16.568	650.	-4.123
1100.	-0.169	1400.	4.516	2000.	5.423
2600.	9.973				

DATA TABLE -36

OXYGEN VAPOR PRESSURE 3 2 36

OXYGEN VAPOR PRESSURE AS A FUNCTION OF INTERNAL ENERGY ALONG ISOCHORES
DENSITY (LB/CU FT) 5 40. 50. 60. 65. 70.
INT.ENERGY(BTU/LB)VAPOR PRESS (PSIA)

16	1	2			
-71.576	1.	-66.661	3.	-63.982	5.
-59.824	10.	-54.901	20.	-48.963	40.
-44.881	60.	-41.650	80.	-38.920	100.
-26.086	250.	-16.568	400.	-4.123	650.
-0.169	1100.	4.516	1400.	5.423	2000.
9.973	2600.				
17	1	2			
-71.586	1.	-66.690	3.	-64.027	5.
-59.906	10.	-56.706	16.	-55.050	20.
-49.234	40.	-45.264	60.	-42.137	80.
-39.509	100.	-27.382	250.	-18.507	400.
-15.264	700.	-13.829	1100.	-12.766	1400.
-10.666	2000.	-8.579	2600.		
14	1	2			
-71.594	1.	-66.709	3.	-64.056	5.
-59.961	10.	-56.789	16.	-55.150	20.
-49.415	40.	-45.518	60.	-42.462	80.
-39.901	100.	-33.400	250.	-32.411	650.
-31.050	1500.	-28.379	2600.		
14	1	2			
-71.596	1.	-66.716	3.	-64.068	5.
-59.982	10.	-56.820	16.	-55.189	20.
-49.484	40.	-45.617	60.	-44.025	70.
-43.469	100.	-42.716	550.	-41.725	1200.
-40.664	1800.	-38.575	3000.		
11	1	2			
-71.599	1.	-66.722	3.	-64.078	5.
-60.000	10.	-56.847	16.	-55.222	20.
-54.360	40.	-54.345	200.	-53.411	1000.
-52.717	1500.	-51.198	2600.		

DATA TABLE -37

HYDROGEN VAPOR PRESSURE 3 2 37

HYDROGEN VAPOR PRESSURE AS A FUNCTION OF INTERNAL ENERGY ALONG ISOCHORES
DENSITY (LB/CU FT) 5 .5 1.0 3.0 4.0 4.4
INT ENERGY(BTU/LB)VAPOR PRESS (PSIA)

23	1	2			
-130.455	1.022	-120.531	3.0	-106.738	7.0
-89.46	12.5	-64.31	25.	-40.23	37.5
-18.76	50.	2.34	62.5	22.11	75.
41.32	87.5	49.	92.3	53.	100.
59.5	112.5	65.9	125.	72.2	137.5
78.8	150.	85.1	162.5	91.8	175.
98.1	187.5	104.6	200.	259.4	500.
580.662	800.	768.689	1000.		
24	1	2			
-131.786	1.022	-124.043	3.0	-114.008	7.0
-102.97	12.5	-85.48	25.	-70.77	37.5
-57.48	50.	-45.16	62.5	-33.52	75.
-22.47	87.5	-11.58	100.	-1.	112.5
9.47	125.	19.48	137.5	30.07	150.
34.1	155.1	36.1	162.5	39.6	175.
42.9	187.5	46.1	200.	57.	240.
119.461	500.	197.957	800.	271.725	1000.

24	1	2			
-132.672	1.022	-126.385	3.	-118.855	7.0
-111.6	12.5	-100.16	25.	-91.4	37.5
-83.83	50.	-77.12	62.5	-70.92	75.
-65.1	87.5	-59.58	100.	-54.31	112.5
-49.23	125.	-44.28	137.5	-39.48	150.
-39.	151.7	-38.3	162.5	-37.9	175.
-37.1	187.5	-36.3	200.	-34.2	240.
-20.858	500.	-6.132	800.	2.862	1000.
13	1	2			
-132.784	1.	-122.649	5.	-115.617	10.
-106.153	20.	-93.897	30.	-92.691	40.
-87.349	50.	-85.024	100.	-83.497	200.
-78.572	350.	-76.946	500.	-67.869	800.
-62.404	1000.				
13	1	2			
-132.813	1.	-126.757	3.	-122.774	5.
-119.626	7.	-115.839	10.	-110.613	15.
-109.632	35.	-108.846	100.	-105.896	200.
-102.346	350.	-99.733	500.	-93.689	800.
-89.093	1000.				

DATA TABLE -38

OXYGEN VAPOR PRESSURE 3 3 38
OXYGEN VAPOR PRESSURE AS A FUNCTION OF INTERNAL ENERGY ALONG ISOCHORES
FOR LOW DENSITIES

DENSITY 5 .1 .4 1.6 20. 40.
INT.ENERGY(BTU/LB)VAPOR PRESS (PSIA)

5	1	2			
-50.134	1.0	23.105	5.0	46.217	10.
68.129	14.696	93.279	20.0		
8	1	2			
-64.464	1.0	-34.285	5.0	-5.399	10.
18.785	14.696	30.938	20.0	46.280	30.
61.657	40.0	77.295	50.0		
13	1	2			
-70.286	1.0	-58.596	5.0	-49.953	10.0
-43.418	14.696	-36.927	20.0	-26.125	30.0
-16.442	40.0	-7.469	50.0	.999	60.0
9.082	70.0	16.858	80.0	24.382	90.0
29.474	100.0				
18	1	2			
-71.522	1.	-66.518	3.	-63.757	5.
-59.413	10.	-55.965	16.	-54.152	20.
-47.608	40.	-42.970	60.	-39.212	80.
-35.978	100.	-19.604	250.	-6.875	400.
0.555	500.	16.127	700.	22.634	1100.
29.610	1400.	40.081	2000.	49.817	2600.
16	1	2			
-71.576	1.	-66.661	3.	-63.982	5.
-59.824	10.	-54.901	20.	-48.963	40.
-44.881	60.	-41.650	80.	-38.920	100.
-26.086	250.	-16.568	400.	-4.123	650.
-0.169	1100.	4.516	1400.	5.423	2000.
9.973	2600.				

DATA TABLE -39

ENTHALPY OF LO2 2 2 39

ENTHALPY OF SATURATED LIQUID OXYGEN - REF. NBS TN 384, 7/1/71.
PSAI (PSIA) H SUB L (BTU/LB)

21	1	3			
.594	-73.599	1.102	-71.208	5.061	-64.007
10.009	-59.977	20.200	-55.096	40.434	-49.310
62.194	-45.093	85.013	-41.650	105.755	-39.018
157.926	-33.588	201.664	-29.809	253.498	-25.852
314.262	-21.640	348.270	-19.427	404.159	-15.937
466.319	-12.166	511.521	-9.433	559.968	-6.438
611.917	-3.028	650.000	-0.253	700.000	4.414

DATA TABLE -40

ENTHALPY OF LH2 2 0 0 40
PSAI H SUB L

10	1	3			
10.0	-115.02	20.0	-105.06	30.0	-97.32
40.0	-90.61	50.0	-84.51	60.0	-78.80
70.0	-73.35	80.0	-68.06	90.0	-62.86
100.0	-57.71				

DATA TABLE -41

ENTHALPY OF HELIUM 3 3 41

ENTHALPY OF HELIUM AS A FUNCTION OF VAPOR PRESSURE ALONG CONSTANT TEMPERATURE. REF. NBS REPORT 9762, AUG. 1970
TEMPERATURE (R) 5 30. 100. 200. 400. 600.
VAPOR PRESS (PSIA) ENTHALPY (BTU/LB)

12	1	2			
0.01	43.53	1.	43.51	10.	43.29
20.	43.06	30.	42.82	40.	42.59
50.	42.36	60.	42.13	70.	41.90
80.	41.67	90.	41.45	100.	41.23
12	1	2			
0.01	130.38	1.	130.38	10.	130.41
20.	130.44	30.	130.47	40.	130.51
50.	130.54	60.	130.57	70.	130.60
80.	130.63	90.	130.66	100.	130.69
12	1	2			
0.01	254.44	1.	254.45	10.	254.53
20.	254.61	30.	254.69	40.	254.76
50.	254.84	60.	254.92	70.	255.00
80.	255.08	90.	255.16	100.	255.24
12	1	2			
0.01	502.58	1.	502.59	10.	502.68
20.	502.77	30.	502.87	40.	502.96
50.	503.06	60.	503.16	70.	503.25
80.	503.35	90.	503.44	100.	503.54
12	1	2			
0.01	750.71	1.	750.72	10.	750.81
20.	750.91	30.	751.01	40.	750.11
50.	750.20	60.	751.30	70.	751.40
80.	751.50	90.	751.60	100.	751.69

DATA TABLE -42

OXYGEN ENTHALPY (GAS) 3 3 42
ENTHALPY OF OXYGEN GAS AS A FUNCTION OF VAPOR PRESSURE FOR SPECIFIED DENSITIES. REF. NBS-TN-384,JULY 1971 AND NBS OXYGEN COMPUTER PROGRAM.

DENSITY (LB/CU FT) 5 .25 .60 1.0 1.6 2.0
VAPOR PRESS (PSIA)ENTHALPY (BTU/LB)

5	1 2				
14.696	36.146	20.0	51.865	30.0	77.698
40.0	103.937	50.0	129.235		
6	1 2				
14.696	-14.958	20.0	0.450	30.0	27.309
40.0	43.431	50.0	54.171	60.0	63.633
9	1 2				
14.696	-32.084	20.0	-21.990	30.0	-4.666
40.0	11.291	50.0	26.360	60.0	40.453
70.0	45.781	80.0	52.173	100.0	65.269
9	1 2				
14.696	-41.717	20.0	-34.612	30.0	-22.653
40.0	-11.812	50.0	-1.682	60.0	7.943
70.0	17.183	80.0	26.116	100.0	41.214
9	1 2				
14.696	-44.928	20.0	-38.820	30.0	-28.649
40.0	-19.513	50.0	-11.029	60.0	-3.004
70.0	4.673	80.0	12.076	100.0	26.243

DATA TABLE -43

HYDROGEN ENTHALPY (GAS) 3 3 43
ENTHALPY OF HYDROGEN GAS AS A FUNCTION OF VAPOR PRESSURE FOR SPECIFIED DENSITIES. REF-NBS REPORT 9288 AND 9711.

DENSITY (LB/CU FT) 5 .05 .20 .50 1.0 2.0
VAPOR PRESS (PSIA)ENTHALPY (BTU/LB)

10	1 2				
10.0	93.266	20.0	185.4	30.0	281.128
40.0	380.721	50.0	495.624	60.0	619.830
70.0	747.701	80.0	880.510	90.0	1022.595
100.0	1162.921				
10	1 2				
15.0	34.000	20.0	45.212	30.0	57.007
40.0	92.852	50.0	115.055	60.0	138.126
70.0	161.610	80.0	183.764	90.0	207.222
100.0	230.212				
10	1 2				
15.0	-80.643	20.0	-74.984	30.0	-43.292
40.0	-20.679	50.0	.944	60.0	20.952
70.0	40.356	80.0	59.747	90.0	78.699
100.0	90.340				
10	1 2				
15.0	-97.193	20.	-89.093	30.	-74.273
40.0	-60.771	50.	-48.187	60.	-36.542
70.0	-25.279	80.	-14.324	90.	-3.629
100.0	6.833				
10	1 2				
15.	-105.468	20.	-99.849	30.	-89.764
40.	-80.817	50.	-72.753	60.	-65.289
70.	-58.097	80.	-51.360	90.	-44.792
100.	-38.389				

DATA TABLE -44

BETA FACTOR 2 4 44
CORRECTION FACTOR FOR PHITWO IN H2-O2-N2 ELECTRIC POWERER HEAT
EXCHANGER. BETA IS A FUNCTION OF CRITICAL PRESSURE RATIO.
REF. AR 71-7535.

P OVER PC	BETA				
12	1 2				
.01	.33	.1	.33	.12	.33
.20	.35	.40	.39	.60	.44
.80	.48	1.0	.52	1.4	.52
1.8	.52	2.2	.52	2.6	.52

DATA TABLE -45

SIGMA-DELTAP FOR HEXELC 3 4 45
PRESENTS SIGMA-DELTAP AS A FUNCTION OF MASS VELOCITY AND HEAT
EXCHANGER LENGTH.
REF. AR 71-7535.

HEX-LENGTH (IN) 5	4.	8.	16.	32.	64.
MASVEL(LB/HR-IN)	SIG-DELTAP (PSI)				
15 1	3				
.10	.000032	.20	.00011	.40	.00042
.60	.00094	.80	.00165	1.00	.0025
2.00	.0095	4.00	.0360	6.00	.075
8.00	.14	10.00	.200	20.00	.78
30.	1.6	40.00	2.8	60.00	6.0
15 1	3				
.10	.000052	.20	.00020	.40	.00078
.60	.00165	.80	.00295	1.00	.0045
2.00	.0170	4.00	.061	6.00	.140
8.00	.230	10.00	.350	20.00	1.30
30.00	2.9	40.00	4.7	60.00	10.0
15 1	3				
.10	.000098	.20	.00037	.40	.00136
.60	.0030	.80	.0050	1.00	.0080
2.00	.0295	4.00	.115	6.00	.240
8.00	.41	10.00	.64	20.00	2.40
30.00	5.0	40.00	8.5	60.00	16.00
15 1	3				
.10	.000165	.20	.00062	.40	.0024
.60	.0054	.80	.0093	1.00	.0140
2.00	.0540	4.00	.20	6.00	.43
8.00	.76	10.00	1.2	20.00	4.30
30.00	9.2	40.00	14.8	60.00	32.0
15 1	3				
.10	.0003	.20	.00113	.40	.0043
.60	.0095	.80	.0165	1.00	.0250
2.00	.092	4.00	.35	6.00	.74
8.00	1.3	10.00	2.0	20.00	7.60
30.00	14.7	40.00	26.0	60.00	57.0

DATA TABLE -46

BETA VALUES FOR H2 3 4 46
VOLUME EXPANSIVITY (BETA) FOR HYDROGEN AS A FUNCTION OF PRESSURE AND
TEMPERATURE.
REF. - NBS-TN-617,APRIL 1972, NAT.BUR.STANDARDS,BOULDER,COLORADO.

PRESSURE (PSIA) 5 50.0		100.0	200.0	300.0	400.0
TEMPERATURE(DEG-R)	BETA (PER DEG-R)				
13 1	2				
30.0	.0068682	36.0	.0087034	42.0	.0120937
45.406	.0154794	45.406	.0425479	60.0	.0214360
80.0	.0140154	125.0	.0082872	200.0	.0050429
340.0	.0029425	440.0	.0022710	540.0	.0018497
700.0	.0014268				

15	1	2			
30.0	.0066720	40.0	.0101009	50.0	.0220225
52.072	.0305221	50.072	.0669217	54.0	.0492883
60.0	.0303448	70.0	.0203346	80.0	.0158545
125.0	.0085774	200.0	.0050846	340.0	.0029435
440.0	.0022692	540.0	.0018476	700.0	.0014250
15	1	2			
30.0	.0063024	40.0	.0091823	50.0	.0166397
58.0	.0595100	60.0	.6211455	62.0	.1125254
66.0	.0484820	70.0	.0336912	90.0	.0157847
125.0	.0091577	200.0	.0051645	340.0	.0029448
440.0	.0022652	540.0	.0018431	700.0	.0014214
15	1	2			
30.0	.0059902	40.0	.0084433	50.0	.0137881
60.0	.0360359	64.0	.0856922	66.0	.1174762
70.0	.0683492	80.0	.0282269	90.0	.0189064
125.0	.0097206	200.0	.0052391	340.0	.0029450
440.0	.0022609	540.0	.0018386	700.0	.0014177
15	1	2			
30.0	.0056750	40.0	.0078461	50.0	.0119866
60.0	.0229678	66.0	.0428049	70.0	.0600390
75.0	.0514055	85.0	.0273007	95.0	.0186681
125.0	.0102432	200.0	.0053075	340.0	.0029442
440.0	.0022563	540.0	.0018339	700.0	.0014140

1.3 INPUT DECK SETUP

The Math Model Program has a built-in capability to process either a single system analysis run or multiple system runs. The multiple system runs can be several runs of the same system or different systems. Average system run times will vary from approximately 90 seconds (UNIVAC-1108, Exec 8) for an ACPS run to approximately 180 seconds for a fuel cell analysis.

1.3.1 Single System Deck Setup

For a single system setup the input deck setup is of the same general form as given in Fig. 1.2.4-1, where the system definition card continues the phrase, "LAST CARD" beginning in Field 4.

1.3.2 Multiple System Deck Setup

For a multiple system deck setup several adjustments are made to the input decks. First, since the Data Tables are only to be read-in once, only the first data deck will contain the ADD Card calling for Data Table input. Secondly, the System Definition card in each input deck, except the last one, will omit the phrase, "LAST CARD" (Field 4). This phrase must appear in the last deck in order to provide proper run termination. A typical multi-run deck setup is illustrated in Fig. 1.3.2-1, showing the card requirements. The illustration assumes the program and Data Tables are stored in files.

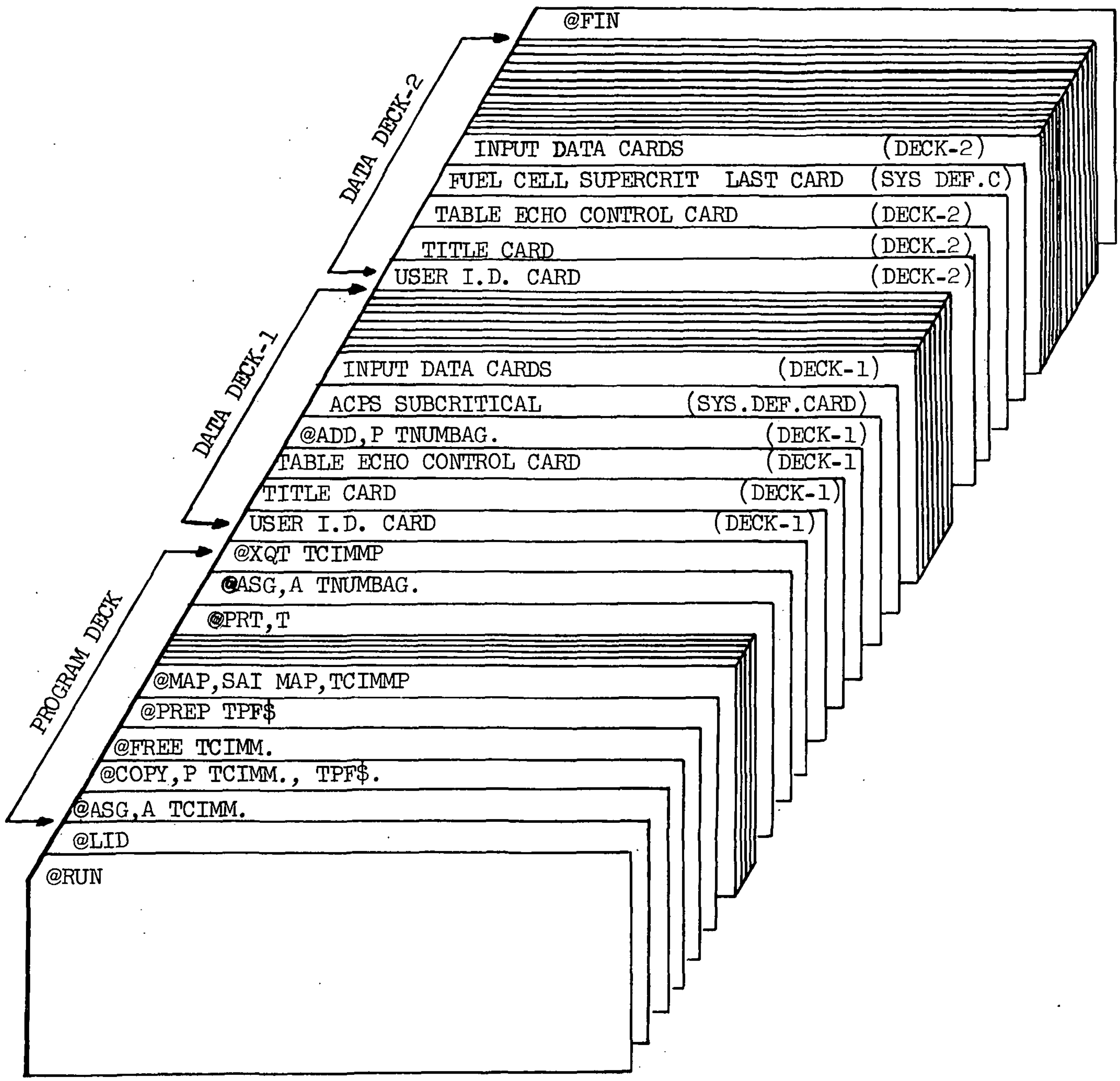


FIGURE 1.3.2-1 MULTI-SYSTEM DATA DECK

1.4 MATH MODEL PROGRAM MACHINE REQUIREMENTS

The program as it is currently configured requires in excess of 65,000 words of core storage for both the instruction and data banks. It is, therefore necessary, to either chain or overlay the program in order to avoid core overflow and truncation. Since the machine for which the program is intended is also a UNIVAC 1108 multi-processor, operating under the EXEC-8 system, the option chosen is the use of a mapped program segment overlay. A third choice, of course, is to break the large program into two or three small programs which could each process one or two of the cryogen system analyses. For specialized analysis which concentrated on, for example, the life support and fuel cell systems, it would be preferrable to use only those subprograms required and reduce both core loading requirements and program run time.

The procedures required for developing a program segment overlay are documented in the UNIVAC manuals (Reference 1.4-1), describing the COLLECTOR processor. The discussion given in this manual will be limited to the program segment overlay employed for the Math Model Program.

1.4.1 Segmented Overlay Procedure

The construction of a segmented overlay for a program is accomplished by manipulation of the order in which relocatable elements are collected by the computer operating system for the production of an executable absolute element. Under the EXEC-8 operating system, this function is accomplished by the COLLECTOR, a system processor designed to provide a user with a means of gathering relocatable elements from many sources (programs) which may then be used in the construction of overlay segments in order to produce an absolute element ready for execution. Optionally, the COLLECTOR can be used to produce one relocatable element from a collection of relocatable elements. The COLLECTOR may be called explicitly by the ATMAP executive control statement, or, implicitly as a result of the user requesting execution (ATXQT) of a program which is not in the absolute form. Only absolute elements procued by the COLLECTOR can be executed.

The procedure for structuring the overlay segments involved the use of the following control statements and directives:

(1) Setup the Entry Point Table (ATPREP)

(2) Invoke the COLLECTOR with a ATMAP control statement.

(3) Use the SEG directive to define each program segment in its preselected order.

(4) Use the IN directive to call explicitly the main or subprogram assigned in each segment.

(5) Use IN directives to call in BLOCK DATA elements where required in a segment.

(6) Use the END directive to define the end of source language statements to be processed.

The SEG directive, or control statement is used to define the relationship and contents of segments within a program. The format employed is SEG, NAME 1, NAME 2 where NAME 1 is the name of the segment and must be specified. NAME 2 gives the names of other segments to which the segment NAME 1 is being related. The first segment named in the source input is called the main segment and is not overlayed by other segments.

The IN directive, or control statement, allows the user to include any, or all, elements from any member of files in his collection specifically in the segment named by the preceding SEG statement.

The structured collection of source statements which make up the map for the Math Model Overlay is given in Table 1.4.1-1.

Table 1.4.1-1

MATH MODEL MAP OVERLAY

```
@MAP,LAI                      MAP, TCIMMP
C     MAPPING DECK FOR TCIMM PROGRAM
          SEG MAIN
           IN CONTRL
           IN SPHTDA
          SEG LVL1A*,(MAIN)
           IN INTAB
           IN COMPIL
          SEG LVL1B*,LVL1A
           IN CRYCON
          SEG LVL2A*,(LVL1B)
           IN ACCRES
           IN LIQRES
           IN TANK
           IN VENT
          SEG LVL2B*, (LVL1B)
           IN APUSUB,APUSUP
          SEG LVL2C*, (LVL1B)
           IN ECLSS
          SEG LVL2D*, (LVL1B)
           IN FUELCL
          END
```

When the COLLECTOR precessor is invoked by means of a ATMAP control statement followed by a set of source statement mapping instructions, the collector will provide, as output, the starting addresses of all subprograms and common blocks in the order defined by the SEG and IN directives. An abbreviated illustration of segment loading addresses is given in Table 1.4.1-2.

Additionally, the collector presents a graphic representation of the segment MAP generated giving the quantity of work contained in each segment. The graphic representation generated for the Math Model Map is presented in Table 1.4.1-3.

TABLE 1.4.1-2

LOADING ADDRESSES FOR SEGMENTED OVERLAY

```
ADDRESS LIMITS      001000 064471        065000 154233
SEGMENT LOAD TABLE                       065000 065033
INDIRECT LOAD TABLE                      065034 065732
STARTING ADDRESS    011161

WORDS DECIMAL        26426 IBANK          28316 DBANK


SEGMENT MAIN                  001000 011363      065733 132600


SEGMENT LVL1A*                011364 021155      132601 134317
FOLLOWS SEGMENT MAIN


SEGMENT LVL1B*                011364 056044      132601 151310
HAS THE SAME STARTING ADDRESS AS SEGMENT LVL1A


SEGMENT LVL2A*                056045 063416      151311 154233
FOLLOWS SEGMENT LVL1B


SEGMENT LVL2B*                056045 062401      151311 152114
FOLLOWS SEGMENT LVL1B


SEGMENT LVL2C*                056045 064436      151311 153765
FOLLOWS SEGMENT LVL1B


SEGMENT LVL2D*                056045 064471      151311 153544
FOLLOWS SEGMENT LVL1B
```

TABLE 1.4.1-3

COMPUTER DRAWN OVERLAY MAP

```
DBANK SEGMENTS DRAWN TO SCALE:   400 WORDS DECIMAL PER DASH

MAIN (18854)
-----------------------------------------------
                                               LVL1A* (847)
                                               --
                                               LVL1B* (7495)
                                               -------------------
                                                                  LVL2A* (1491)
                                                                  ----
                                                                  LVL2B* (368)
                                                                  -
                                                                  LVL2C* (1324)
                                                                  ---
                                                                  LVL2D* (1161)
                                                                  ---

IBANK SEGMENTS DRAWN TO SCALE:   400 WORDS DECIMAL PER DASH

MAIN (4340)
-----------
           LVL1A* (3962)
           ----------
           LVL1B* (18736)
           -----------------------------------------------
                                                          LVL2A* (2794)
                                                          -------
                                                          LVL2B* (2269)
                                                          ------
                                                          LVL2C* (3321)
                                                          --------
                                                          LVL2D* (3263)
                                                          --------
```

1.5 ERROR MESSAGES

The size and relative complexity of the Math Model Program is such that the user must have some means other than the standard computer disgnostics and error messages to indicate and flag run problems.

Accordingly, several means of detecting run problems and error causing input values have been incorporated into the program itself. The two main techniques employed are out-of-range warning messages and built-in error termination. Troubleshooting the program is simplified by providing within the more sensitive subprograms, a built-in diagnostic trace technique which will output and flag intermediate values for the intermediate calculations not normally shown in the program output.

Normally, if no changes have been made in the subprogram coding, an error will usually be the result of an input data error, either as a wrong input value or the omission of the value. Since the input data decks are sometimes rather large, new decks should be very closely checked for keypunch errors and card omissions.

1.5.1 Built-In Diagnostic Trace

The built-in diagnostic trace technique consists of a set of diagnostic flag indices, a subprogram which verifies the flag and sets the "switch" position, and a set of diagnostic write statements placed in sensitive subprograms. The diagnostic flag index permits either single or multiple subprogram diagnosis as desired by the user.

1.5.1.1 <u>The Diagnostic Flag.</u> The diagnostic flag for any of the using subprograms is controlled through the variable "MDTRC" defined in Procedure Definition Processor CCNTRL. Input values for MDTRC are placed on the System Definition input data card described in subparagraph 1.2.2.4.

MDTRC may have a value of either zero or one, and is placed in specific system definition card positions to activate the diagnostic write statements in any of eleven (11) subprograms. The card columns utilized for MDTRC are as follows:

Card Column	MDTRC ( ) = DIAGNOSTIC TRACE SWITCH FOR CRYCØN (OFF = 0)
(70)	(1) = 1 Turn on ACCRES
(71)	(2) = 1 Turn on ACQWT
(72)	(3) = 1 Turn on APUSUB or APUSUP
(73)	(4) = 1 Turn on CMPCAL
(74)	(5) = 1 Turn on FUELCL
(75)	(6) = 1 Turn on CØNSUM
(76)	(7) = 1 Turn on ECLSS
(77)	(8) = 1 Turn on LIQRES
(78)	(9) = 1 Turn on TANK
(79)	(10) = 1 Turn on TSIZEI
(80)	(11) = 1 Turn on WTACC

MDTRC(1) is Card Column 70,---MDTRC(11) is Card Column 80 of the System Definition Card.

The values for MDTRC are read in the main driver routine CØNTRL and are stored in CØMMØN/CCNTRL/ for later use in the executive sequencing subroutine CRYCØN.

1.5.1.2 Diagnostic Control Subprogram. The flag MDTRC is tested in subroutine CRYCØN as each of the analytical subprograms are sequenced. If MDTRC is not zero then subroutine CRYCØN will turn ON the diagnostic switch for the subprogram being sequenced. Any other routines or functions called by this subprogram will also yield diagnostics if equipped to do so. When the diagnostic switch is ON. a function routine called DIAG is also activated and prints as output the name of the subroutine being entered and states that a diagnostic trace is in progress. Each time in the subprogram that a diagnostic write statement is encountered, DIAG is tested and if found to be activated the write statement is executed. Upon leaving the subprogram the function DIAG again states the subprogram name and the fact that the subprogram has been exited.

An illustration of the diagnostic trace output is given in Fig. 1.5-1 for a short trace used internally in the APU subprogram. The diagnostic trace was setup to be activated for an APU supercritical analysis, to examine the process of looking up ultimate strength values in Dat Table-22.

```
                         NAME                 * * * * * * * * * * * * * * * * * * * * * * PAGE   75
                         DEPT 6213            *       THE INTEGRATED MATH MODEL          * DATE 05 FEB 73
                         EXT. 30235           *                                          * TIME 10:10:01
                         BLD. 104             *                   AT4307                 * CASE   1
                         * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                                        TEST CASE - SUPERCRITICAL APU PROBLEM, MIXRAT=0.90

**DIAGNOSTIC TRACE**
FINTAB ENTRED        22            2283
FINTAB EXITED         2               4              2              3              0              0
                                  .700000+03     .500000+03     .200000+03     .000000        .000000
                                  .150000+04     .100000+04     .300000+03     .000000        .000000
                                  .250000+04     .250000+03     .400000+03     .000000        .000000
                                  .350000+04     .300000+03     .000000        .000000        .000000
                                  .100000+04     .500000+03     .000000        .000000        .000000
MIPE   ENTRED         1               4              2              3              0              0
                                  .500000+03
LOCATE ENTRED       1      1 2284
LOCATE EXITED      14      1     2 2300     .367000+02     .185970+04     .266500+06     .320000+05
MIPE   EXITED         2               1              2              1              0              0
                                  .115761+06
FINTAB ENTRED        22            2283
FINTAB EXITED         2               4              2              3              0              0
                                  .700000+03     .500000+03     .200000+03     .000000        .000000
                                  .150000+04     .100000+04     .300000+03     .000000        .000000
                                  .250000+04     .250000+03     .400000+03     .000000        .000000
                                  .350000+04     .300000+03     .000000        .000000        .000000
                                  .100000+04     .500000+03     .000000        .000000        .000000
MIPE   ENTRED         1               4              2              3              0              0
                                  .500000+03
LOCATE ENTRED       1      1 2284
LOCATE EXITED      14      1     2 2300     .367000+02     .185970+04     .266500+06     .320000+05
MIPE   EXITED         2               1              2              1              0              0
                                  .115761+06
```

FIGURE 1.5-1   DIAGNOSTIC TRACE ILLUSTRATIONS

Since the only subprograms having diagnostic write statements within subroutine APUSUP were subroutines FINTAB, LØCAT and the function MIPE, the table look-up procedure examination was straightforward.

As noted in Fig. 1.5-1, DIAG caused the notation DIAGNOSTIC TRACE to be printed as subroutine FINTAB was called in. DIAG noted that FINTAB was entered and Data Table-22 was found and copied. FINTAB was exited and a summary of the X-array printed out. Function MIPE was then entered followed by a call to LØCAT which was entered to locate the X,Y subtable which bracketed the desired value of 500^{o}R. The array subtable limits were output and LØCAT was exited. Function MIPE then performed a linear interpolation of the X and Y arrays to obtain an ultimate stress value of 115761 psi at the desired temperature of 500^{o}R for the stainless steel oxygen accumulator tank material. MIPE was then exited with the required data. The sequence was repeated a second time for the hydrogen accumulator and since operating temperature and material selection was identical to the first accumulator, the answer obtained was the same as before. In this instance, the diagnostic output was not labeled by variable name, however, in other subprograms the diagnostic data appears in variable labeled format.

Diagnostic write statements will be easily recognized in the various subprograms since they all start with an IF statement, for example:

```
IF(DIAG(0,6HFLØRAT))WRITE(IØT,6020)WDØTI, etc.
```

which says, if the diagnostic switch is turned ON, write out that FLØRAT was entered and writeout the subroutine input variables starting with flowrate, etc.

1.5.2 Error Diagnostics

In addition to the diagnostic trace for checking out program computation procedures, there are a number of Error Diagnostics built into the various subprograms which give a warning if ranges are exceeded, or if things show up out of order. For example, subroutine CMPCAL computers pressure drops and keeps track of the required system pressure as the analysis proceeds to work its way toward the supply tanks. If, upon arriving at the tank, the subprogram finds the input tank pressure lower than the required pressure, it will reset the tank pressure equal to the calculated required pressure and print the following message:

"DIAGNOSTIC* TANK INPUT PRESSURE IS LESS THAN THE REQUIRED PRESSURE. TANK PRESSURE SET = REQUIRED PRESSURE. TANK INPUT PRESSURE = -----. REQUIRED PRESSURE = ----.

Similar messages warn of the failure of data to converge, or the failure of data to match preset convergence ranges.

1.5.3 Preset Error Terminations

A number of preset error terminations are provided in the program, in order to prevent the generation of meaning less data and expenditure of costly run time. Typical conditions causing error terminations are as follows:

Errors in naming the system on the System Definition Card will always abort the run. The system name must begin with the three alpha character mnemonics specified in DATA NAMSYS given in subroutine STØDTA.

A negative temperature or pressure value will terminate the program in a number of subprograms.

A temperature or pressure out of preset ranges will terminate the program in several of the thermodynamic property subprograms.

1.5.4 Errors in Reading Table Data

Subroutine INTAB is provided with a specific set of diagnostic messages in order to permit rapid isolation of problems in the DATA TABLE input. Usually the trouble occurs during table update or replacement, however, simple card juxtaposition can also cause a lot of trouble.

The following is a list of Table Data error messages and the table data cards to examine:

ERROR	THE NUMBER OF DIMENSIONS IS WRONG. ND = _______. (See Gp(d) CARD-1).
ERROR	THE NUMBER OF POINTS IS WRONG. NP = _______. (See Gp(d) CARD-3).
ERROR	THE NUMBER OF DATA POINTS IS WRONG. NV = _______. (See Gp(d) CARD-5).
ERROR	THE TABLE TYPE IS WRONG. TYPE = _______. (See Gp(d) CARD-5).
DIAGNOSTIC	THE NUMBER OF INTERPOLATION POINTS IS WRONG. NIP = _______. NIP IS SET EQUAL TO = _______. (See Gp(d) CARD-5).
ERROR	THE ABOVE TABLE NUMBER IS LESS THAN 0 AND GREATER THAN 50. (See Gp(d) CARD-1 (NT)).
DIAGNOSTIC	THE ABOVE TABLE HAS ALREADY BEEN INPUT. THIS TABLE SHALL REPLACE THE PREVIOUS TABLE. (Check table numbers-NT.)
ERROR	THE TOTAL SIZE OF THE TABLES HAS EXCEEDED 7000. THE REQUIRED SIZE IS _______. RUN TERMINATED.

Any of the foregoing messages requires action by the user to correct the Table Data Deck or File.

1.6 PROGRAM RESTRICTIONS

Program restrictions for the current version of TCIMM are largely self-imposed by the range of the data used in cryogenic system evaluation. Array size for many of the program variables can be conveniently changed by adjustment of the PARAMETER definition statements found in each of the Procedure Definition Processors which define the common arrays. The array dimensions as currently defined, however, are adequate for current system concepts.

1.6.1 Program Analytical Range

The program currently accommodates the use of four cryogen fluids: oxygen, hydrogen, helium, and nitrogen.

Temperature ranges extend to $800^{o}R$ for O_2, H_2, and He and to well over $1000^{o}R$ for N_2. Pressure ranges extend to 2500 psia for O_2, H_2, and N_2. In this respect all table data ranges can be extended by simply enlarging the tables.

The configuration table will currently accommodate one hundred components and can be extended by changing the appropriate PARAMETER statement in PDP-CCNFIG.

1.6.2 Table Data Limits

Current Table Data capacity is limited to 50 tables containing a total of 7000 words. The number of tables can be changed by altering the value of the NTBN in PDP-CTAB from 50 to the desired number of tables. The total number of table words can be changed by alterning the value of MXWRD in PDP-CTABA to the value desired. If MXWRD is changed, then the "error message" in FORMAT statement 6170 of subroutine INTAB should also be changed.

1.7 TAPE AND DRUM ASSIGNMENTS

For those facilities which have limited or no mass storage capability in the form of FASTRAND or DISC program storage, tape operation will be required for Program file and Data Table file loading only. The making of the files on tape will follow whatever local procedures are used compatible with local machine requirements. The program uses no scratch or intermediate tapes or drums for data storage, hence, there will be no requirement for mounting extra tapes.

1.7.1 Data Table Tape Preparation

Provisions have been made in the program to produce and use a binary data table tape, where this is preferred over Data Table Card input, or because of mass storage limitations.

A binary data table tape can be produced in the course of a normal program run utilizing existing coding in subroutine INTAB which is controllable from the input data, "Table Data Echo Control Card" (Ref. Gp(c) CARD-1, Sub.sec. 1.2.2.2).

The variables IFT and ØFT which occupy the first two fields of the Table Data Echo Control Card are utilized for the tape preparation and tape utilization functions.

The defined values to be used in the variables are as follows:

IF:	IFT = 0	Table Data Input is from Source Cards, or Mass Storage.
	IFT = 1 or 2	Table Data Input is from Binary Tape loaded from Tape Unit-15.

	IFT > 2	Table Data Input is from Binary Tape loaded from Tape Unit IFT. Where IFT specifies tape unit number (Example: IFT = 17)
IF:	∅FT = 0	No binary data tape is to be made.
	∅FT = 1 or 2	Binary Data Table Tape will be produced on Tape Unit - 15.
	∅FT > 2	Binary Data Table Tape will be made on Tape Unit ∅FT. Where ∅FT specifies Tape Unit Number (Example: ∅FT = 16)

To make a binary data tape of the Data Tables, the simplest procedure is as follows:

(a) Assign a blank tape to be loaded in Tape Unit 15, to be reserved.
(b) Set IFT = 0 in Table Data Echo Control Card.
(c) Set ∅FT = 1 on Table Data Echo Control Card.
(d) Set NPRT = 1, NPRT2 = 1 } To print Table Echo Summary
(e) Load data Table Cards immediately following Table Data Echo Control Card.

The program will generate a binary data trap and those proceed with the execution of the run.

1.7.2 Data Table Tape Utilization

To use the binary data tape produced by the program, the following procedure applies:

(a) Assign the Data Table Tape to be read in on Tape Unit 15.
(b) Set IFT = 1 on Table Data Echo Control Card.
(c) Set ØFT = 0 on Table Data Echo Control Card.
(d) Set NPRT = 1 } To Print Table Echo Summary
NPRT2 = 1
(e) Omit Data Table Cards from Input Deck.

The program will now load in the Data Tables from Tape and procede to execute the run.

1.7.3 Drum and Disc Utilization

Where a facility is equipped with Drum and/or Disc file storage hardware, both the program and the Data Tables may be conveniently stored as files in mass storage. Assigning and calling in the files becomes a simple matter involving only a few control cards.

Detailed procedures for program file generation as well as DATA file generation are adequately described in the UNIVAC-1108 manuals.

Section 2
MATH MODEL SAMPLE PROBLEM

In order to illustrate the application of the Math Model Program, a sample problem for an Attitude Control Propulsion System was assembled and run. The ACPS problem was chosen because it exercises more of the major subprograms than the other systems. The sample problem graphically illustrates the conversion of the system concept schematic and supporting data into a problem data input deck and the analytical output obtained in the program run.

2.1 THE PROBLEM STATEMENT

The ACPS concept considered was chosen from among similar concepts previously studied under this contract (Ref. 2.1-1). The concept is illustrated in the schematic presented in Fig. 2.1-1. The concept is a cold helium pressurized, subcritical cryogen fluid supplied, bi-propellant gas fed propulsion system. The cryogens are stored as fluids under low pressure and converted to gasses at high pressure through the use of high pressure liquid pumps. The high pressure liquids are vaporized in gas generator fired heat exchangers. The resulting gaseous propellants are then fed to high pressure accumulators for storage until needed for the engines. Propellant feed to the engines is through pressure regulations which drop the feed pressure to the value required for the engines. Oxygen and hydrogen gas at engine feed pressure and temperature are available to other systems via taps in the engine feed line.

The initial run of the system sample problem will establish the nominal case values for the ACPS concept and provide the base-line temperatures, pressures, pressure drops, flow rates, and component and system weights for the specified duty cycle and performance constraints. Subsequent runs of the sample case would consider the effects of perturbing the base-line input data in whatever manner is of interest to the analyst. The collected series of runs would then provide the basis for wide range performance and trade-off analysis conclusions and recommendations.

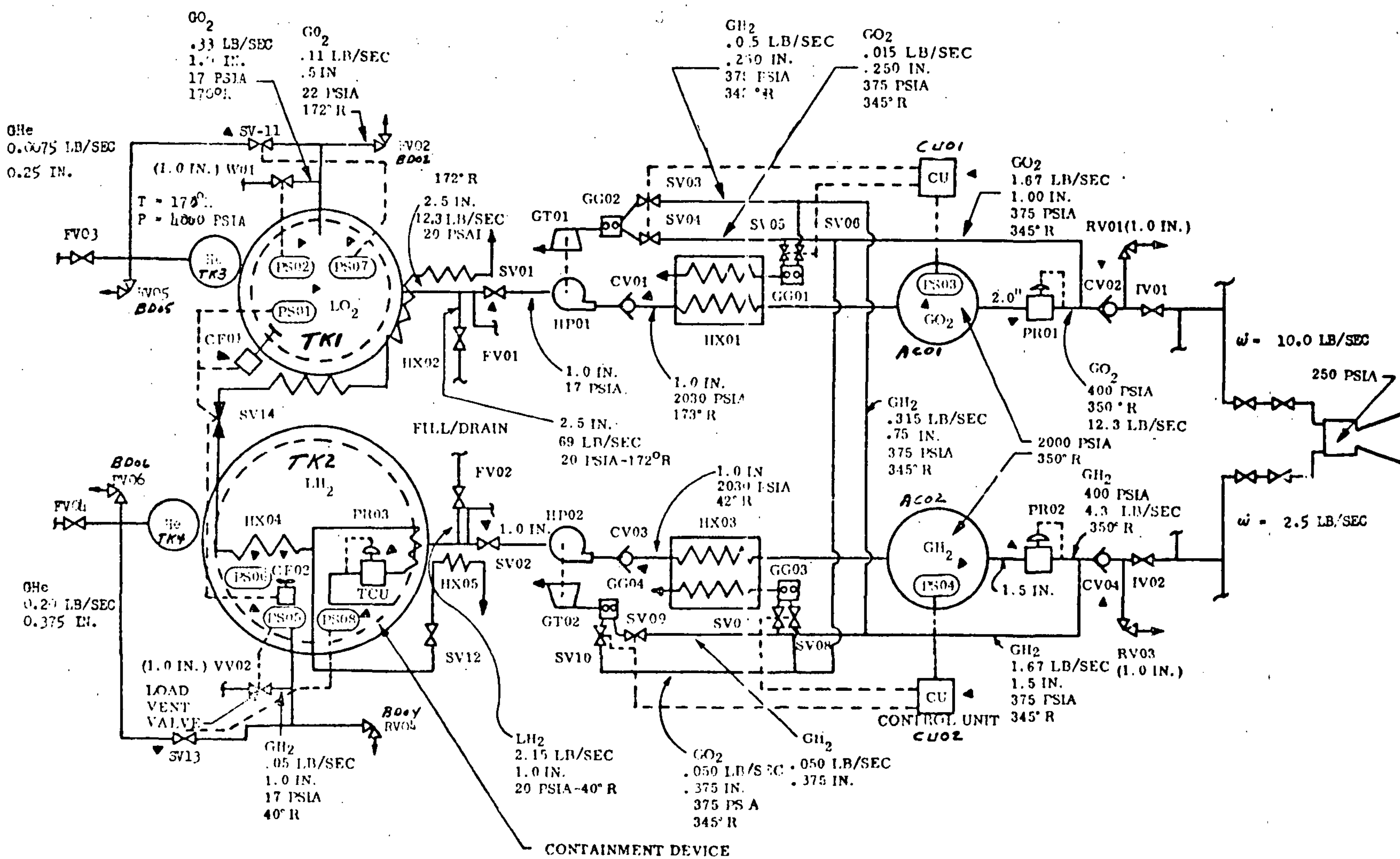
FIGURE 2.1-1

ATTITUDE CONTROL PROPULSION SYSTEM

HIGH PRESSURE - SUBCRITICAL STORAGE

CONCEPT 1A

STORED HELIUM PRESSURIZATION



The sample case run herein presented is the starting point, or, base-line concept analysis.

2.2 PROBLEM OUTLINE – DATA ACQUISITION

The problem outline will be provided to the analyst in the form of a preliminary study of some sort which will probably need elaboration. Specifically, the analyst will need to assure himself that the following data sources are in fact available:

Mission Duty Cycle
Concept Schematic
Engine Concept Details
Tankage Concept Details
Heat Exchanger Requirements
Pump and Turbine Requirements
Gas Generator Requirements
Subsystem Constraints
Plumbing Layout and Approximate (at least) Line Lengths

It should not be considered unusual if the analyst finds that the data supplied is not adequate to build an input data deck and that further source interrogation is required. Assuming the required sources are available, then the task of assembling the information into the input data deck format can be accomplished. The following subparagraphs elaborate on the data reduction aspects of this task.

2.2.1 Sample System Performance and Component Data

2.2.1.1 Duty Cycle. For the ACPS sample problem a twelve burn duty cycle representative of the total burn and coast times for a typical orbiter seven day mission was selected. The duty cycle events and pertinent propellant consumption data obtained from the referenced study are presented in Table 2.2-1.

TABLE 2.2-1

ACPS DUTY CYCLE

Event	Activity	Duration (sec)	Mission Time (min.)	O_2-Used (lbs)	H_2-Used (lbs)
1	Coast-1	540 sec	0-9.0	-	-
2	Burn-1	4.58 sec	9.0-9.07	50	14
3	Coast-2	7975 sec	9.07-142.	-	-
4	Burn-2	6.15 sec	142.0-142.1	67	19
5	Coast-3	2094 sec	142.1-177	-	-
6	Burn-3	3.58	177.0-177.06	39	11
7	Coast-4	536 sec	177.06-186	-	-
8	Burn-4	38.8 sec	186.0-186.65	423	120
9	Coast-5	2061 sec	186.65-221	-	-
10	Burn-5	7.43 sec	221.0-221.12	81	23
11	Coast-6	593 sec	221.12-231	-	-
12	Burn-6	3.58 sec	231.0-231.06	39	11
13	Coast-7	536 sec	231.06-240.	-	-
14	Burn-7	66.1 sec	240.0-241.1	720	204
15	Coast-8	714 sec	241.1-253.	-	-
16	Burn-8	32.3 sec	253.0-253.54	352	100
17	Coast-9	568 sec	253.54-263.	-	-
18	Burn-9	104.1 sec.	263.0-264.74	1135	320
19	Coast-10	1876 sec.	264.74-296	-	-
20	Burn-10	31.9 sec	296.0-296.53	348	96
21	Coast-11	571,048 sec	296.53-9814.	-	-
22	Burn-11	16.16 sec	9814.0-9814.27	176	50
23	Coast-12	9584 sec	9814.27-9974	-	-
24	Burn-12	100 sec	9974.0-9975.67	1090	310
	Total Deliverable			4520	1278
			Total Propellant:	5798	

M.I.B. degradation: = 0.90

2.2.1.2 Engine Data. The rocket engine characteristics employed in the problem are given as follows:

Number of Engines	3
Engine Thrust	1750 lb
Engine I_{sp}	420 sec
Expansion Ratio	40:1
Ø/F Mixture Ratio	4:1
Propellant Inlet Temp	$350^{\circ}R$
Propellant Inlet Pressure	400 psia
Chamber Pressure	250 psia

2.2.1.3 Accumulator Data. The system requires two high pressure accumulators, one for each of the propellant gases. The accumulator characteristics employed in the sample problem are as follows:

Characteristic	02-Accum.	H2-Accum.
Accumulator Code	AC01	AC02
Maximum Diameter (ft)	2.05	5.2
Volume (ft^3)	2.5	72.5
Nominal Temp ($^{\circ}R$)	350.	350.
Nominal Press. (psia)	2000.	2000.
Material Type	5.5.	5.5.
Insulation Type	CDAM/T.G.	CDAM/T.G.
Insulation Thickness (in.)	2.0	2.0
Est. Heal Leak Rate (Btu/hr)	0.1	0.2
Allowed Pressure Swing (psi)	500.	500.

2.2.1.4 Heat Exchanger Data. The concept requires two heat exchanger-gas generator sets for vaporization of the cryogen fluids. The heat exchanger and heat source characteristics employed in the problem are given as follows:

Characteristic	Oxygen Side	Hydrogen Side
Heat Exchangers:		
Heat Exchanger Code	HX01	HX03
Hot Fluid Inlet Temp (°R)	2000.	2000.
Hot Fluid Outlet Temp (°R)	1100.	1028.
Cold Fluid Inlet Temp (°R)	173.	42.
Cold Fluid Outlet Temp (°R)	350.	350.
Hot Fluid Nominal Pressure (psia)	245.	500.
Cold Fluid Nominal Pressure (psia)	2000.	2000.
Hot Side Delta-P (psi)	30.	30.
Cold Side Delta-P (psi)	30.	10.
Hot Side Nominal Flow Rate (lb/sec)	0.6	2.6
Cold Side Nominal Flow Rate (lb/sec)	12.3	4.3
Heat Source:		
Type	Gas Gen	Gas Gen
Ø/F Mixture Ratio	1:1	1:1
Outlet Temperature (°R)	2060.	2060.
Chamber Pressure (psia)	245.	500.
External Available Energy (Btu)	0.	0.

2.2.1.5 Pump and Turbine Data. Two pump and drive turbine sets are required for the concept being considered. The pump and turbine characteristics employed for the sample problem are presented as follows:

Characteristic	Oxygen Side	Hydrogen Side
Pump:		
Pump Code	HP01	HP02
Type	Turbo-Pump	Turbo-Pump
Pump Efficiency (%)	52.	54.

Characteristic	Oxygen Side	Hydrogen Side
Pump: (Cont)		
Pump NPSP (psia)	8.7	1.1
Pump Shaft Speed (rpm)	20,000	70,000
Pump Outlet Pressure (psia)	2023.	2023.
Pump Inlet Pressure (psia)	17.	17.
Pump Inlet Temperature (^oR)	165.	37.
Pump Drive: – Gas Turbine		
Turbine Code	GT01	GT02
Turbine Mixture Ratio	0.891	0.891
Turbine Inlet Temperature (^oR)	2000.	2000.
Turbine Delta-P (psi)	230.	480.
Turbine Delta-T (^oR)	840.	840.
Turbine Efficiency (%)	55.	36.
Turbine Inlet Pressure (psia)	250.	500.

2.2.1.6 Cryogen Supply Tankage Data. One tank is required for each cryogen fluid. Initially, it is assumed that the tanks are spherical since the program will add cylindrical sections to the tanks if the fluid volume exceeds that of a sphere having an input maximum diameter.

The tankage characteristics employed in this problem are as follows:

Characteristic	LO_2 Tank	LH_2 Tank
Tank Material	2219-Al	2219-Al
Number of Tanks	1.	1.
Tank Code	TK01	TK02
Acquisition Device	Surf Tension	Surf Tension
Insulation Type	DGM/SN	DGM/SN
Pressurization Type	Cold He	Cold He
Fluid Initial Temp (^oR)	165.	37.

Characteristic	LO_2 Tank	LH_2 Tank
Tank Initial Pressure (psia)	16.	16.
Pressurant Gas Temp (^{O}R)	170.	40.
Tank Operating Pressure (psia)	26.7	19.1
Tank Vent Pressure (psia)	31.7	24.1
Estimated Heat Leak (Btu/hr-ft^2)	0.1	0.2
Insulation Thickness (in.)	2.0	2.0
Optional Input – Fluid Loaded (lb)	(Omit)	(Omit)
Initial Percent Ullage	3.0	3.0
Tank Maximum Diameter (ft)	5.07	5.0
Tank Heat Exchanger Outlet Temp (^{O}R)	NA	NA
Tank Heat Exchanger Delta-P (psi)	NA	NA
Tank Circular Pump Delta-P (psi)	NA	NA
Tank Heat Exchanger –		
Gas Gen Outlet Temp (^{O}R)	NA	NA
Gas Gen Chamber Pressure (psia)	NA	NA
Gas Gen Mixture Ratio (Ø/F)	NA	NA
Tank Insulation – Layers/Inch (Optional)	(Omit)	(Omit)

2.2.1.7 Lines, Controls, and Fittings Data. For the sample problem, all lines, valves and fittings are stainless steel, and are insulated where necessary with one-half inch of CDAM/TG insulation having a layer density of thirty layers per inch.

2.2.1.8 System Configuration Data. The remaining data to be assembled quite often proves to be somewhat time consuming, primarily, because in the concept stage (or, even in the early design stages) no one seems to know how long the pipes are. Therefore, one obtains a large set of vehicle drawings and proceeds to obtain approximate lengths even though they are subject to changes. The task, at hand, is to convert the system process schematic into a configuration table with a close resemblance to what the actual system will look like. This is best accomplished by detailing the data for the oxidizer side of the system first, followed by the data for the fuel side. The data collected should be listed in the order required for data deck input. Considerable time may be saved by using 80 column keypunch worksheets with appropriately ruled and labeled columns for data collecting sheets and data card production. The basic information required for the configuration data table as derived from Fig. 1.2-1 and supporting data is presented in Tables 2.2-2 and 2.2-3. The data table will also require the use of some of the information developed for the larger components discussed in previous subsections.

2.3 PROBLEM DATA DECK

The sample problem data previously collected (subsection 2.2) can now be readied for the creation of an input data deck. Formatting information for the necessary data cards will be found in subsection 1.2.2 in the card format illustration sheets (1.2.2.1 through 1.2.2.17). The ACPS sample problem data input deck produced from the foregoing procedure is listed in Table 1.2.5-1.

Input Data Decks for other systems are created in the same general fashion as employed for the sample problem.

2.4 PROBLEM TABLE DATA REQUIREMENTS

While the data tables currently included in the Math Model Program, are adequate for the sample and test problems used for program checkout, there is no assurance that this is so for more advanced systems. Therefore, it is incumbent upon the program user to examine his system carefully for new table data requirements and make the necessary table substitutions as needed. The following tables are most likely to need either updating or the substitution of a complete new table of data:

Table Number	Descriptive Title	Number of Dimensions
1	RCS – Thruster Weight	4
2	RCS – Vac Sp Impulse	3
9	ØMS – Engine Weight	3
10	ØMS – Vac Sp Impulse	3

Table 2.2-2

CONFIGURATION DATA FOR ACPS – OXYGEN SIDE

Item I.D.	Item Code	Number Oper	Number Stby	Diameter (in.)	Length (in.)	Friction Factor	f (L/D)	Fluid State
Gas	Ø2-VAP							G
Engine	ENG1	3	0					G
Line	LN01	3	0	2.0	110.0	0.0095	—	G
Tee	FT01	1	0			0.0095	126.3	G
Line	LN02	1	0	2.0	150.0	0.0095		G
Tap	FT02	1	0			0.0095	10.5	G
Line	LN03	1	0	2.0	24.0	0.0095		G
Valve	IV01	1	0			0.0095	10.5	G
Line	LN04	1	0	2.0	12.0	0.0095		G
Valve	CV02	1	0			0.0095	135.0	G
Line	LN05	1	0	2.0	40.0	0.0095		G
Tap	FT03	1	0			0.0095	10.5	G
Line	LN06	1	0	2.0	20.0	0.0095		G
Reg	PR01	1	0			0.0095	336.8	G
Line	LN07	1	0	2.0	30.0	0.0095		G
Accum	AC01	1	0			NA		G
Line	LN08	1	0	2.0	24.0	0.0095		G
HEX	HX01	1	0			NA		G/L
Gas	Ø2-LIQ					NA		L
Line	LN09	1	0	1.0	12.0	0.0180		L
Valve	CV01	1	0			0.0180	65.5	L
Line	LN10	1	0	1.0	12.0	0.0180		L
Pump	HP01	1	0			NA		L
Line	LN11	1	0	1.5	160.0	0.0180		L
Valve	SV01	1	0			0.0180	6.7	L
Line	LN12	1	0	2.5	12.0	0.0180		L
Tap	FT04	1	0			0.0180	6.7	L
Line	LN13	1	0	2.5	24.0	0.0180		L
Tank	TK01	1	0			NA		L

Table 2.2-3

CONFIGURATION DATA FOR ACPS – HYDROGEN SIDE

Item I.D.	Item Code	Number Oper	Number Stby	Diameter (in.)	Length (in.)	Friction Factor	f (L/D)	Fluid State
Gas	H2-VAP							G
Engine	ENG1	3	0					G
Line	LN21	3	0	1.75	110.0	0.011		G
Tee	FT21	1	0			0.011	109.0	G
Line	LN22	1	0	1.75	150.0	0.011		G
Tap	FT22	1	0			0.011	9.0	G
Line	LN23	1	0	1.75	24.0	0.011		G
Valve	IV02	1	0			0.011	9.0	G
Line	LN24	1	0	1.75	12.0	0.011		G
Valve	CV04	1	0			0.011	86.0	G
Line	LN25	1	0	1.75	40.0	0.011		G
Tap	FT23	1	0			0.011	9.0	G
Line	LN26	1	0	1.75	20.0	0.011		G
Reg	PR02	1	0			0.011	336.4	G
Line	LN27	1	0	1.75	30.0	0.011		G
Accum	AC02	1	0					G
Line	LN28	1	0	1.50	24.0	0.011		G
HEX	HX03	1	0					G
Gas	H2-LIQ							G/L
Line	LN29	1	0	1.50	12.0	0.011		L
Valve	CV03	1	0			0.011	9.0	L
Line	LN30	1	0	1.50	12.0	0.011		L
Pump	HP02	1	0					L
Line	LN31	1	0	2.0	120.0	0.018		L
Valve	SV02	1	0			0.018	5.6	L
Line	LN32	1	0	2.0	12.0	0.018		L
Tap	FT24	1	0			0.018	5.6	L
Line	LN33	1	0	2.0	24.0	0.018		L
Tank	TK02	1	0					L
End								

Table Number	Descriptive Title	Number of Dimensions
11	HEX HØt Gas Flow – $LØ_2$	5
12	HEX HØt Gas Flow – LH_2	5
13	Gas Generator Weight	4
14	$LØ_2$ – Transfer Pump Weight	5
15	LH_2 – Transfer Pump Weight	5
16	Motor Weight (Elec)	3
17	Vac Jacket Diameter vs Weight	2

Care should be exercised in constructing the new table to insure using the same number of dimensions (variables) as in the original table, otherwise, the coding in the sub-program table-calling sequence will have to be changed for each place the table is called upon.

2.5 PROBLEM DATA OUTPUT

This subsection presents the entire output for the ACPS sample problem. The output, which follows, is indexed by page number in the header-box top left corner. This index will be used in describing the several output sections produced in the run.

2.5.1 Output Description

Page 1	Table Data Input Summary – Lists the tables loaded for the program run.
Page 2	System Input Verification – Verifies the system name called for on System Definition Card.
Pages 3,5	System Configuration and Duty Cycle Data – Echo of data in Input Data Deck.
Pages 6, 11	Echo of Major System Component Data – From Input Data Deck.
Page 12	Start of Program Calculations: Computed Engine Parameters – Characterizes engine weight, propellant consumption and I_{sp}.
Page 13	Computed Flowrate Data – Presents flowrate required for subsystem cryogen consumers and total flowrate from fluid tanks.
Pages 14,15	Computed System Configuration Parameters – Presents computed temperature, pressure, flowrate, flow condition and weight for each component item in system configuration.
Pages 16, 17	Computed Heat Exchanger and Gas Generator Characteristic Parameters – Presents summary characteristics and weight data for heat exchangers and associated gas generators.
Page 18	Computed Pump and Turbine Characteristics – Presents summary characteristics and weight data for pumps, turbines and turbine gas generators.
Page 19	Initial Tank Sizing Calculations – Presents initial tank size and weight data computed on first estimate basis.

Pages 20, 32	Tank and Vent Parameter Calculations – Characterizes oxygen tank history conditions for each Coast and Burn period of mission duty cycle.
Pages 33, 45	Tank and Vent Parameter Calculations – Characterizes hydrogen tank history conditions for each Coast and Burn period of mission duty cycle.
Page 46	Final Tank Sizing Calculations – Presents final tank size and weight data based upon detailed calculation of fluid requirements over integrated mission duty cycle span.
Page 47	Accumulator Sizing Calculations – Presents accumulator sizing and weight data computed in program.
Page 48	Tank Propellant Acquisition – Device Computation – Presents acquisition device computed weight, trapped propellant weight, and tank residual-propellant weight.
Page 49	Component Weight Summary and System Weight Summary – Presents a summary of individual component weights and corresponding insulation weights. Presents subsystem and systems weight totals.

The following pages present the detailed sample problem output.

```
NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE      1
DEPT 6213         *      THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:01:40
BLD. 104          *                AT4307                 * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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ACPS - TEST DEMONSTRATION PROBLEM

TABLE INPUT SUMMARY

TABLE NUMBER	TITLE OF TABLE	NUMBER OF DIMENSIONS	NUMBER OF SUBTABLES	NUMBER OF WORDS
1	RCS-THRUSTER WEIGHT	4	6	122
2	RCS-VAC. SP. IMPULSE	3	3	68
3	SPEC.HT/LB OF O2 REMOVED	3	5	206
4	SPEC.HT/LB OF H2 REMOVED	3	5	184
5	TEMP. /LB. OF O2 REMOVED	3	5	184
6	TEMP. /LB. OF H2 REMOVED	3	5	192
7	RR/ VS PGG,M/R,PAMB,PCHP	5	12	95
8	KK VS PGG,M/R,PAMB,PCHP	5	12	95
9	OMS ENGINE WEIGHT	3	3	50
10	OMS VAC. SP. IMPULSE	3	3	68
11	HEX HOT GAS FLOW - LO2	5	24	133
12	HEX HOT GAS FLOW - LH2	5	12	71
13	GAS GENERATOR WEIGHT	4	10	220
14	LO2 TRANSFER PUMP WEIGHT	5	8	130
15	LH2 TRANSFER PUMP WEIGHT	5	8	138
16	MOTOR WEIGHT	3	5	120
17	VAC.JAC.DIA.VS.WEIGHT	2	1	34
18	PHI - HYDROGEN	3	5	172
19	TEMP. OF N2 VS RHO F(P)	3	5	180
20	HT.XFER.COEF.-H2	3	4	106
21	HT.XFER.COEF.-O2-N2	3	4	138
22	FTU OF 321/347 ST.STEEL	2	1	32
23	FTU OF 2219-T87 ALUM.	2	1	36
24	FTU OF 6061-T6 ALUMINUM	2	1	30
25	FTU OF INCONEL-718	2	1	30
26	FTU OF TI-6AL-4V	2	1	30
27	HEAD COEFFICIENT VS NS	2	1	34
28	ADIABATIC EFF. VS NS	2	1	44
29	EFFIC. QUOT.VS IMP. DIAM	2	1	46
30	BASE LINE STAGE WT VS DI	2	1	28
31	SATURATED STEAM, T.VS P.	2	1	46
32	SP.HT. OF O-H COMB.PROD.	3	4	114
33	OXYGEN INTERNAL ENERGY	3	5	166
34	HYDROGEN INTERNAL ENERGY	3	5	216
35	OXYGEN INTERNAL ENERGY	3	5	142
36	OXYGEN VAPOR PRESSURE	3	5	166
37	HYDROGEN VAPOR PRESSURE	3	5	216
38	OXYGEN VAPOR PRESSURE	3	5	142
39	ENTHALPY OF LO2	2	1	46
40	ENTHALPY OF LH2	2	1	24
41	ENTHALPY OF HELIUM	3	5	142
42	OXYGEN ENTHALPY (GAS)	3	5	98
43	HYDROGEN ENTHALPY (GAS)	3	5	122
44	BETA FACTOR	2	1	28
45	SIGMA-DELTAP FOR HEXELC	3	5	172
46	BETA VALUES FOR H2	3	5	168

TOTAL TABLE STORAGE = 5024

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * * * PAGE      2
DEPT 6213         *      THE INTEGRATED MATH MODEL          * DATE 17 APR 73
EXT. 30235        *                                         * TIME 15:01:49
BLD. 104          *               AT4307                    * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                  ACPS - TEST DEMONSTRATION PROBLEM
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*** YOU HAVE CALLED FOR THE SYSTEM ACPS ***

ACPS - TEST DEMONSTRATION PROBLEM

***** S Y S T E M   C O N F I G U R A T I O N *****

COMP NAME	COMP CODE	FUNC. TYPE	NUMB. OPER.	NUMB. STBY.	MATRL. TYPE	FLOW FRICTION COEFICIENT	LINE LENGTH OR L-OVER-D	LINE DIAMETER	INSULATION TYPE	INSULATION THICKNESS	NO. LAYERS INSULATION
GAS	O2-VAP	1	1	0	0	.00000000	.00	.00	0	.00	.0
ENGINE	ENG1	0	3	0	0	.00000000	.00	.00	0	.00	.0
LINE	LN01	10	3	0	1	.95000000-02	110.00	2.00	4	.50	30.0
TEE	FT01	21	1	0	1	.95000000-02	126.30	.00	0	.00	.0
LINE	LN02	10	1	0	1	.95000000-02	150.00	2.00	4	.50	30.0
TAP	FT02	31	1	0	1	.95000000-02	10.50	.00	0	.00	.0
LINE	LN03	10	1	0	1	.95000000-02	24.00	2.00	4	.50	30.0
VALVE	IV01	31	1	0	1	.95000000-02	10.50	.00	0	.00	.0
LINE	LN04	10	1	0	1	.95000000-02	12.00	2.00	4	.50	30.0
VALVE	CV02	21	1	0	1	.95000000-02	135.00	.00	0	.00	.0
LINE	LN05	10	1	0	1	.95000000-02	40.00	2.00	4	.50	30.0
TAP	FT03	31	1	0	1	.95000000-02	10.50	.00	0	.00	.0
LINE	LN06	10	1	0	1	.95000000-02	20.00	2.00	4	.50	30.0
REG	PR01	32	1	0	1	.95000000-02	336.80	.00	0	.00	.0
LINE	LN07	10	1	0	1	.95000000-02	30.00	2.00	4	.50	30.0
ACCUM	AC01	0	1	0	1	.00000000	.00	.00	4	2.00	30.0
LINE	LN08	10	1	0	1	.95000000-02	24.00	2.00	4	.50	30.0
HEX	HX01	1	1	0	1	.00000000	.00	.00	0	.00	.0
GAS	O2-LIQ	1	2	0	0	.00000000	.00	.00	0	.00	.0
LINE	LN09	10	1	0	1	.18000000-01	12.00	1.00	4	.50	30.0
VALVE	CV01	31	1	0	1	.18000000-01	.00	.00	0	.00	.0
LINE	LN10	10	1	0	1	.18000000-01	12.00	1.00	4	.50	30.0
PUMP	HP01	21	1	0	1	.00000000	.00	.00	0	.00	.0
LINE	LN11	10	1	0	1	.18000000-01	160.00	1.50	4	.50	30.0
VALVE	SV01	21	1	0	1	.15000000-01	6.67	.00	0	.00	.0
LINE	LN12	10	1	0	1	.15000000-01	12.00	2.50	4	.50	30.0
TAP	FT04	31	1	0	1	.15000000-01	6.67	.00	0	.00	.0
LINE	LN13	10	1	0	1	.15000000-01	24.00	2.50	4	.50	30.0
TANK	TK01	0	1	0	2	.00000000	.00	.00	4	2.00	30.0
GAS	H2-VAP	2	1	0	0	.00000000	.00	.00	0	.00	.0
ENGINE	ENG1	0	3	0	0	.00000000	.00	.00	0	.00	.0
LINE	LN21	10	3	0	1	.11000000-01	110.00	1.75	4	2.00	30.0
TEE	FT21	21	1	0	1	.11000000-01	109.00	.00	0	.00	.0
LINE	LN22	10	1	0	1	.11000000-01	150.00	1.75	4	2.00	30.0
TAP	FT22	31	1	0	1	.11000000-01	9.00	.00	0	.00	.0
LINE	LN23	10	1	0	1	.11000000-01	24.00	1.75	4	2.00	30.0
VALVE	IV02	31	1	0	1	.11000000-01	9.00	.00	0	.00	.0
LINE	LN24	10	1	0	1	.11000000-01	12.00	1.75	4	2.00	30.0
VALVE	CV04	21	1	0	1	.11000000-01	86.00	.00	0	.00	.0
LINE	LN25	10	1	0	1	.11000000-01	40.00	1.75	4	2.00	30.0
TAP	FT23	31	1	0	1	.11000000-01	9.00	.00	0	.00	.0
LINE	LN26	10	1	0	1	.11000000-01	20.00	1.75	4	2.00	30.0
REG	PR02	32	1	0	1	.11000000-01	336.40	.00	0	.00	.0
LINE	LN27	10	1	0	1	.11000000-01	30.00	1.75	4	2.00	30.0
ACCUM	AC02	0	1	0	1	.00000000	.00	.00	4	2.00	30.0

ACPS - TEST DEMONSTRATION PROBLEM

***** S Y S T E M   C O N F I G U R A T I O N *****

COMP NAME	COMP CODE	FUNC. TYPE	NUMB. OPER.	NUMB. STBY.	MATRL. TYPE	FLOW FRICTION COEFICIENT	LINE LENGTH OR L-OVER-D	LINE DIAMETER	INSULATION TYPE	INSULATION THICKNESS	NO. LAYERS INSULATION
LINE	LN28	10	1	0	1	.11000000-01	24.00	1.50	4	2.00	30.0
HEX	HX03	1	1	0	1	.00000000	.00	.00	0	.00	.0
GAS	H2-LIQ	2	2	0	0	.00000000	.00	.00	0	.00	.0
LINE	LN29	10	1	0	1	.11000000-01	12.00	1.50	4	2.00	30.0
VALVE	CV03	31	1	0	1	.11000000-01	9.00	.00	0	.00	.0
LINE	LN30	10	1	0	1	.11000000-01	12.00	1.50	4	2.00	30.0
PUMP	HP02	21	1	0	1	.00000000	.00	.00	0	.00	.0
LINE	LN31	10	1	0	1	.18000000-01	120.00	2.00	4	2.00	30.0
VALVE	SVC2	21	1	0	1	.18000000-01	5.60	.00	0	.00	.0
LINE	LN32	10	1	0	1	.18000000-01	12.00	2.00	4	2.00	30.0
TAP	FT24	31	1	0	1	.18000000-01	5.60	.00	0	.00	.0
LINE	LN33	10	1	0	1	.18000000-01	24.00	2.00	4	2.00	30.0
TANK	TKC2	0	1	0	2	.00000000	.00	.00	4	2.00	30.0
END		0	0	0	0	.00000000	.00	.00	0	.00	.0

ACPS - TEST DEMONSTRATION PROBLEM

***** D U T Y C Y C L E D A T A *****

OPER.TIME	NON-OPERATING	MIB-DEGRAD.	UNITS OPER.	HORSEPOWER	AMB.PRESSURE	POWER-KW	REPRES.TIME
.45800000+01	.54000000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.61500000+01	.79750000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.35800000+01	.20940000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.38800000+02	.53600000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.74300000+01	.20610000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.35800000+01	.59300000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.66100000+02	.53600000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.32300000+02	.71400000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.10410000+03	.56800000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.31900000+02	.18760000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.16160000+02	.57104800+06	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.10000000+03	.95840000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.00000000	-.10000000+01	.00000000	0	.00000000	.00000000	.00000000	.00000000

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE      6
DEPT 6213         *      THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:01:51
BLD. 104          *                AT4307                 * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                        ACPS - TEST DEMONSTRATION PROBLEM

                       ***** E N G I N E   D A T A *****

                           3  NUMBER OF ENGINES
               .35000000+03  GAS INLET TEMP.
               .40000000+03  GAS INLET PRES.
               .17500000+04  ENGINE THRUST
               .25000000+03  CHAMBER PRES.
               .40000000+02  EXPANSION RATIO
               .40000000+01  MIXTURE RATIO
```

ACPS - TEST DEMONSTRATION PROBLEM

***** T A N K   D A T A *****

1	1	NUMBER OPERATING (NOP)
1	1	ACQUISITION TYPE
2	2	INSULATION TYPE
2	2	MATERIAL TYPE
2	2	PRESSURIZATION TYPE
.16500000+03	.37000000+02	INITIAL TEMPERATURE (R)
.16000000+02	.16000000+02	INITIAL PRESSURE
.17000000+03	.40000000+02	PRESSURANT GAS TEMP. (R)
.26700000+02	.19100000+02	OPERATING PRESS. (PSIA)
.31700000+02	.24100000+02	VENTING PRESSURE
.20000000+00	.30000000+00	HEAT FLUX (BTU/HR-FT**2)
.20000000+01	.20000000+01	INSULATION THICKNESS
.00000000	.00000000	INITIAL FLUID LOAD (OPT)
.30000000+01	.30000000+01	PERCENT ULLAGE VOLUME
.50660000+01	.50000000+01	MAXIMUM DIAMETER (FT)
.00000000	.00000000	HEX OUTLET TEMP. (R)
.00000000	.00000000	HEX DELTA PRESS. (PSIA)
.00000000	.00000000	PUMP DELTA PRESS. (PSIA)
.00000000	.00000000	GAS GEN OUTLET TEMP (R)
.00000000	.00000000	P SUB C OF GAS GEN (PSIA
.00000000	.00000000	GAS GEN MIXTURE RATIO
.00000000	.00000000	NUMBER INSULATION LAYERS

1	TANK WEIGHT-CONFIGURATION OPTION CONSIDERED
0	NUMBER OF TANK SHAPES IN CONFIGURATION

ACPS - TEST DEMONSTRATION PROBLEM

***** A C C U M U L A T O R D A T A *****

1	1	NUMBER OPERATING (NOP)
4	4	INSULATION TYPE
1	1	MATERIAL TYPE
.35000000+03	.35000000+03	OPERATING TEMP. (DEG R)
.20000000+04	.20000000+04	OPERATING PRESS. (PSIA)
.10000000+00	.20000000+00	HEAT FLUX (BTU/HR-FT**2)
.20000000+01	.20000000+01	INSULATION THICKNESS
.25000000+01	.72500000+02	TANK VOLUME (CU. FT.)
.20500000+01	.52000000+01	MAXIMUM DIAMETER (FT)
.50000000+03	.50000000+03	NOMINAL OPER. DELTA PRES
.00000000	.00000000	NUMBER INSULATION LAYERS

ACPS - TEST DEMONSTRATION PROBLEM

***** H E A T   E X C H A N G E R   D A T A *****

NUMBER OF HEAT EXCHANGERS INPUT = 1

- 1 - OXYGEN	- 1 - HYDROGEN	- 2 - OXYGEN	- 2 - HYDROGEN	HEAT EXCHANGER NUMBER
2000.0	2000.0	.0	.0	HEX HOT INLET TEMP.
1100.0	1028.0	.0	.0	HEX HOT OUTLET TEMP.
173.0	42.0	.0	.0	HEX COLD INLET TEMP.
350.0	350.0	.0	.0	HEX COLD OUTLET TEMP.
245.0	500.0	.0	.0	HEX HOT INLET PRES.
215.0	470.0	.0	.0	HEX HOT OUTLET PRES.
2030.0	2010.0	.0	.0	HEX COLD INLET PRES.
2000.0	2000.0	.0	.0	HEX COLD OUTLET PRES.
30.0	30.0	.0	.0	HEX HOT SIDE DELTA-P
30.0	10.0	.0	.0	HEX COLD SIDE DELTA-P
1.0	1.0	.0	.0	HEX GAS GEN. O/F RATIO

- 3 - OXYGEN	- 3 - HYDROGEN	- 4 - OXYGEN	- 4 - HYDROGEN	- 5 - OXYGEN	- 5 - HYDROGEN	HEAT EXCHANGER NUMBER
.0	.0	.0	.0	.0	.0	HEX HOT INLET TEMP.
.0	.0	.0	.0	.0	.0	HEX HOT OUTLET TEMP.
.0	.0	.0	.0	.0	.0	HEX COLD INLET TEMP.
.0	.0	.0	.0	.0	.0	HEX COLD OUTLET TEMP.
.0	.0	.0	.0	.0	.0	HEX HOT INLET PRES.
.0	.0	.0	.0	.0	.0	HEX HOT OUTLET PRES.
.0	.0	.0	.0	.0	.0	HEX COLD INLET PRES.
.0	.0	.0	.0	.0	.0	HEX COLD OUTLET PRES.
.0	.0	.0	.0	.0	.0	HEX HOT SIDE DELTA-P
.0	.0	.0	.0	.0	.0	HEX COLD SIDE DELTA-P
.0	.0	.0	.0	.0	.0	HEX GAS GEN. O/F RATIO

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE      10
DEPT 6213         *       THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                        * TIME 15:01:51
BLD. 104          *              AT4307                    * CASE       1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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ACPS - TEST DEMONSTRATION PROBLEM

***** H I G H   P R E S   P U M P   D A T A *****

2	2	TYPE
.52000000+00	.54000000+00	EFFICIENCY
.87000000+01	.11000000+01	NET + SUCTION HEAD
.20000000+05	.70000000+05	SHAFT SPEED
.20230000+04	.20230000+04	ESTIMATED DELTA PRES.

***** L O W   P R E S   P U M P   D A T A *****

.00000000	.00000000	PUMP EFFICIENCY
.00000000	.00000000	NET POS. SUCTION HEAD
.00000000	.00000000	PUMP PRESSURE RISE
.00000000	.00000000	PUMP FLOW RATE

***** T U R B I N E   D A T A *****

.55000000+00	.36000000+00	TURBINE EFFICIENCY
.20000000+04	.20000000+04	TURBINE INLET TEMP.
.11600000+04	.11600000+04	TURBINE OUTLET TEMP.
.89100000+00	.89100000+00	TURBINE MIXTURE RATIO
.25000000+03	.50000000+03	TURBINE GAS GEN. PSUBC

ACPS - TEST DEMONSTRATION PROBLEM

***** H E A T   S O U R C E   D A T A *****

NUMBER OF HEAT SOURCES INPUT = 1

- 1 -		- 2 -		- 3 -		- 4 -		- 5 -		HEAT SOURCE NUMBER
OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	
1	1	0	0	0	0	0	0	0	0	HEAT SOURCE TYPE
1.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE MIX. RATIO
2060.0	2060.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE OUTLET TEMP.
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE AVAIL.ENERGY
245.0	500.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE PRESSURE

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE     12
DEPT 6213         *       THE INTEGRATED MATH MODEL       * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:01:53
BLD. 104          *                AT4307                 * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                           ACPS - TEST DEMONSTRATION PROBLEM

          *** INITIATE PROGRAM AND CHARACTERIZE CONSUMER PARAMETERS ***


                                 * COMPUTED ENGINE PARAMETERS *

                  ENGINE ISP                                  .46712069+03
                  ENGINE WEIGHT - (LBS)                       .15937500+03
                  TOTAL ENGINE FLOW - (LB/SEC)                .12487850+02
                  ONE ENGINE OXID.FLOW RATE-(LB/SEC)          .99902804+01
                  ONE ENGINE FUEL FLOW RATE-(LB/SEC)          .24975701+01
                  THRUST IMPULSE PROPELLANT WGT.              .51784617+04
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ACPS - TEST DEMONSTRATION PROBLEM

*** COMPUTED FLOWRATE DATA ***

	OXIDYZER	FUEL
WDOT OX-TURB.-G.G.	.551258-01	.618696-01
WDOT HY-TURB.-G.G.	.370016+00	.415281+00
WDOT BOTH TURB.-GG	.425141+00	.477151+00
WDOT OXY HEX.-G.G.	.300310+00	.300310+00
WDOT HYD HEX.-G.G.	.132594+01	.132594+01
WDOT BOTH HEX.-G.G	.162626+01	.162626+01
TOTAL FLOWRATE **	.120417+02	.460098+01

ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED SYSTEM CONFIGURATION PARAMETERS ***

F	CODE	FT	NO	NS	IS	IDX	G	GS	FCOEF	L/D	DIAM	ITHICK	PRES	TEMP	WDOT	WEIGHT	MACH	MFLAG
GAS	O2-VAP	1	1	0	1	1	1	1	.000000	.0000	.0000	.0000	.00	.00	.00	.000	.0000000	
ENG	ENG1	0	3	0	1	2	1	1	.000000	.0000	.0000	.0000	400.00	350.00	9.99	159.375	.0000000	
LIN	LN01	0	3	0	1	3	1	1	.009500	110.0000	2.0000	.5000	400.35	350.00	9.99	4.009	.1307953	
TEE	FT01	1	1	0	1	4	1	1	.009500	126.3000	2.0000	.0000	407.49	350.00	9.99	.433	.1280855	
LIN	LN02	0	1	0	1	5	1	1	.009500	150.0000	2.0000	.5000	411.66	350.00	9.99	5.466	.1265442	
TAP	FT02	1	1	0	1	6	1	1	.009500	10.5000	2.0000	.0000	412.25	350.00	12.04	.342	.1522731	
LIN	LN03	0	1	0	1	7	1	1	.009500	24.0000	2.0000	.5000	413.21	350.00	12.04	.875	.1518509	
VAL	IV01	1	1	0	1	8	1	1	.009500	10.5000	2.0000	.0000	414.05	350.00	12.04	6.314	.1514840	
LIN	LN04	0	1	0	1	9	1	1	.009500	12.0000	2.0000	.5000	414.53	350.00	12.04	.437	.1512755	
VAL	CV02	1	1	0	1	10	1	1	.009500	135.0000	2.0000	.0000	425.15	350.00	12.04	4.406	.1467768	
LIN	LN05	0	1	0	1	11	1	1	.009500	40.0000	2.0000	.5000	426.70	350.00	12.04	1.458	.1461381	
TAP	FT03	1	1	0	1	12	1	1	.009500	10.5000	2.0000	.0000	427.51	350.00	12.04	.342	.1458060	
LIN	LN06	0	1	0	1	13	1	1	.009500	20.0000	2.0000	.5000	428.29	350.00	12.04	.729	.1454915	
REG	PR01	2	1	0	1	14	1	1	.009500	336.8000	2.0000	.0000	1750.00	350.00	12.04	9.630	.0000000	
LIN	LN07	0	1	0	1	15	1	1	.009500	30.0000	2.0000	.5000	1750.20	350.00	12.04	1.913	.0180427	
ACC	AC01	0	1	0	1	16	1	1	.000000	.0000	.0000	2.0000	2000.00	350.00	12.04	.000	.0000000	
LIN	LN08	0	1	0	1	17	1	1	.009500	24.0000	2.0000	.5000	2000.14	350.00	12.04	1.531	.0155240	
HEX	HX01	1	1	0	1	18	1	1	.000000	.0000	.0000	.0000	2022.29	173.00	12.04	22.655	.0000000	
GAS	O2-LIQ	1	2	0	1	19	1	2	.000000	.0000	.0000	.0000	2022.29	173.00	12.04	.000	.0000000	
LIN	LN09	0	1	0	1	20	1	2	.018000	12.0000	1.0000	.5000	2023.94	173.00	12.04	.383	.0000000	
VAL	CV01	1	1	0	1	21	1	2	.018000	.0000	1.0000	.0000	2023.94	173.00	12.04	9.000	.0000000	
LIN	LN10	0	1	0	1	22	1	2	.018000	12.0000	1.0000	.5000	2025.58	173.00	12.04	.383	.0000000	
LIN	LN13	0	1	0	-1	28	1	2	.015000	24.0000	2.5000	.5000	15.97	165.00	12.04	1.093	.0000000	
TAP	FT04	1	1	0	-1	27	1	2	.015000	6.6700	2.5000	.0000	15.95	165.00	12.04	.534	.0000000	
LIN	LN12	0	1	0	-1	26	1	2	.015000	12.0000	2.5000	.5000	15.94	165.00	12.04	.547	.0000000	
VAL	SV01	1	1	0	-1	25	1	2	.015000	6.6700	1.5000	.0000	15.79	165.00	12.04	4.142	.0000000	
LIN	LN11	0	1	0	-1	24	1	2	.018000	160.0000	1.5000	.5000	12.98	165.00	12.04	4.373	.0000000	
PUM	HP01	1	1	0	1	23	1	2	.000000	.0000	.0000	.0000	12.98	165.00	12.04	73.362	.0000000	
TAN	TK01	0	1	0	1	29	1	2	.000000	.0000	.0000	2.0000	16.00	165.00	12.04	.000	.0000000	

ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED SYSTEM CONFIGURATION PARAMETERS - CONTD. ***

F	CODE	FT	NO	NS	IS	IDX	G	GS	FCOEF	L/D	DIAM	ITHICK	PRES	TEMP	WDOT	WEIGHT	MACH	MFLAG
GAS	H2-VAP	2	1	0	1	30	2	1	.000000	.0000	.0000	.0000	.00	.00	.00	.000	.0000000	
ENG	ENG1	0	3	0	1	31	2	1	.000000	.0000	.0000	.0000	400.00	350.00	2.50	159.375	.0000000	
LIN	LN21	0	3	0	1	32	2	1	.011000	110.0000	1.7500	2.0000	400.12	350.00	2.50	3.508	.2095926	
TEE	FT21	1	1	0	1	33	2	1	.011000	109.0000	1.7500	.0000	401.92	350.00	2.50	.331	.2086492	
LIN	LN22	0	1	0	1	34	2	1	.011000	150.0000	1.7500	2.0000	403.33	350.00	2.50	4.783	.2079167	
TAP	FT22	1	1	0	1	35	2	1	.011000	9.0000	1.7500	.0000	403.48	350.00	4.60	.262	.3828795	*
LIN	LN23	0	1	0	1	36	2	1	.011000	24.0000	1.7500	2.0000	404.24	350.00	4.60	.765	.3821540	*
VAL	IV02	1	1	0	1	37	2	1	.011000	9.0000	1.7500	.0000	404.74	350.00	4.60	6.121	.3816802	*
LIN	LN24	0	1	0	1	38	2	1	.011000	12.0000	1.7500	2.0000	405.12	350.00	4.60	.383	.3813205	*
VAL	CV04	1	1	0	1	39	2	1	.011000	86.0000	1.7500	.0000	409.86	350.00	4.60	4.255	.3768958	*
LIN	LN25	0	1	0	1	40	2	1	.011000	40.0000	1.7500	2.0000	411.11	350.00	4.60	1.275	.3757436	*
TAP	FT23	1	1	0	1	41	2	1	.011000	9.0000	1.7500	.0000	411.60	350.00	4.60	.262	.3752932	*
LIN	LN26	0	1	0	1	42	2	1	.011000	20.0000	1.7500	2.0000	412.22	350.00	4.60	.638	.3747235	*
REG	PR02	2	1	0	1	43	2	1	.011000	336.4000	1.7500	.0000	1750.00	350.00	4.60	9.392	.0000000	
LIN	LN27	0	1	0	1	44	2	1	.011000	30.0000	1.7500	2.0000	1750.24	350.00	4.60	1.674	.0938032	
ACC	AC02	0	1	0	1	45	2	1	.000000	.0000	.0000	2.0000	2000.00	350.00	4.60	.000	.0000000	
LIN	LN28	0	1	0	1	46	2	1	.011000	24.0000	1.5000	2.0000	2000.36	350.00	4.60	1.148	.1132123	
HEX	HX03	1	1	0	1	47	2	1	.000000	.0000	.0000	.0000	2010.19	42.00	4.60	61.123	.0000000	
GAS	H2-LIQ	2	2	0	1	48	2	2	.000000	.0000	.0000	.0000	2010.19	42.00	4.60	.000	.0000000	
LIN	LN29	0	1	0	1	49	2	2	.011000	12.0000	1.5000	2.0000	2010.23	42.00	4.60	.574	.0000000	
VAL	CV03	1	1	0	1	50	2	2	.011000	9.0000	1.5000	.0000	2010.28	42.00	4.60	9.214	.0000000	
LIN	LN30	0	1	0	1	51	2	2	.011000	12.0000	1.5000	2.0000	2010.32	42.00	4.60	.574	.0000000	
LIN	LN33	0	1	0	-1	57	2	2	.018000	24.0000	2.0000	2.0000	15.97	37.00	4.60	.875	.0000000	
TAP	FT24	1	1	0	-1	56	2	2	.018000	5.6000	2.0000	.0000	15.96	37.00	4.60	.342	.0000000	
LIN	LN32	0	1	0	-1	55	2	2	.018000	12.0000	2.0000	2.0000	15.94	37.00	4.60	.437	.0000000	
VAL	SV02	1	1	0	-1	54	2	2	.018000	5.6000	2.0000	.0000	15.93	37.00	4.60	4.406	.0000000	
LIN	LN31	0	1	0	-1	53	2	2	.018000	120.0000	2.0000	2.0000	15.77	37.00	4.60	4.373	.0000000	
PUM	HP02	1	1	0	1	52	2	2	.000000	.0000	.0000	.0000	15.77	37.00	4.60	34.569	.0000000	
TAN	TK02	0	1	0	1	58	2	2	.000000	.0000	.0000	2.0000	16.00	37.00	4.60	.000	.0000000	

ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED HEAT EXCHANGER CHARACTERISTICS ***

FOR UNITS	HX01	HX03
HEAT EXCHANGER CHARACTERISTICS	OXYGEN	HYDROGEN
COLD FLUID INLET TEMP	.173000+03	.420000+02
COLD FLUID OUTLET TEMP	.350000+03	.350000+03
COLD FLUID SPECIFIC HEAT	.485697+00	.373836+01
COLD FLUID FLOW RATE	.120417+02	.460098+01
HOT FLUID INLET TEMP	.200000+04	.200000+04
HOT FLUID OUTLET TEMP	.110000+04	.102800+04
HOT FLUID SPECIFIC HEAT	.185245+01	.184709+01
HOT FLUID FLOW RATE	.620922+00	.295072+01
COLD SIDE EFFECTIVENESS	.968801-01	.157303+00
HOT SIDE EFFECTIVENESS	.492611+00	.496425+00
TOTAL EFFECTIVENESS	.589491+00	.653728+00
HEX SUBUNIT TYPE ***	SUP-CRITICAL	SUP-CRITICAL
THERML CONDUCTANCE RATIO	.784822+00	.551711+00
HOT FLUID FLOW RATE	.323065+00	.101027+00
COLD FLUID DELTA - P	.780449+01	.171191+00
CAPACITY RATIO	.116889+00	.179012-01
NUMBER OF TRANSFER UNITS	.715320+00	.691449+00
COMPUTED VALUE OF UA	.154113+04	.464504+03
COMPUTED VALUE OF W/UA	.587501-02	.649877-02
WEIGHT OF SUBUNIT	.137806+02	.418989+01
HEX SUBUNIT TYPE ***	PARALLEL-FLO	PARALLEL-FLO
THERML CONDUCTANCE RATIO	.790265+00	.140564+01
HOT FLUID FLOW RATE	.297075+00	.284969+01
COLD FLUID DELTA - P	.143533+02	.965759+01
CAPACITY RATIO	.797778-01	.298971+00
NUMBER OF TRANSFER UNITS	.769651+00	.809568+00
COMPUTED VALUE OF UA	.152479+04	.153405+05
COMPUTED VALUE OF W/UA	.582023-02	.371129-02
WEIGHT OF SUBUNIT	.887461+01	.569331+02
WEIGHT OF HEAT EXCHANGER	.226552+02	.611230+02

ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED HEAT EXCHANGER-GAS GENERATOR CHARACTERISTICS ***

GAS GENERATOR CHARACTERISTICS	OXYGEN	HYDROGEN
GAS GEN. FLOW RATE - (LB/SEC)	.620922+00	.295072+01
GAS GEN. PROPELLANT WGT.-(LBS)	.257484+03	.122361+04
GAS GENERATOR WEIGHT - (LBS)	.136186+02	.161016+02
WEIGHT OF HEX-GAS GEN. ASSY.	.362738+02	.772246+02
CUMULATIVE GAS GEN. PROP. WTG.	.257484+03	.122361+04
CUMULATIVE HEAT REQD. - (BTU)	.000000	.000000
CUMULATIVE HOT FLUID - (LBS)	.000000	.000000

ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED PUMP CHARACTERISTICS FOR THE SYSTEM ***

PUMP CHARACTERISTICS	OXYGEN	HYDROGEN
TEMPERATURE	.165000+03	.370000+02
PRESSURE	.129757+02	.157742+02
FLOW RATE	.120417+02	.460098+01
DELTA-PRESSURE	.201261+04	.199454+04
NPSH AVIALABLE	.870000+01	.110000+01
DENSITY OF FLUID	.708162+02	.443309+01
NUMBER OF STAGES REQD.	1	5
COMPUTED NPSP REQD	.218270+01	.336251+00
COMPUTED PUMP EFF.	.725520+00	.766746+00
COMPUTED PUMP VOL.	.490617+02	.133186+03
COMPUTED PUMP WGT.	.146742+01	.359000+01
COMPUTED PUMP PWR.	.123499+03	.706864+03
COMPUTED PUMP SPD.	.174980+05	.834961+05
SELECTED PUMP OPTION	2	2

*** SUMMARY OF COMPUTED TURBINE CHARACTERISTICS FOR THE SYSTEM ***

TURBINE CHARACTERISTICS	OXYGEN	HYDROGEN
TURBINE ROTOR MEAN DIAMETER	.850669+01	.274264+01
WGT. OF PWR. TRANSMISSION ASSY	.137516+02	.103401+02
WGT. OF TURBINE ROTOR	.696344+01	.233372+00
WGT. OF MANIFOLD AND NOZZLE	.339364+02	.140023+01
WEIGHT OF INDUCER	.500000+01	.500000+01
WEIGHT OF TURBINE ASSY.	.596515+02	.186073+02

*** SUMMARY OF COMPUTED TURBINE GAS GENERATOR CHARACTERISTICS ***

GAS GENERATOR CHARACTERISTICS	OXYGEN	HYDROGEN
GAS GEN. FLOW RATE - (LB/SEC)	.879073-01	.554576+00
GAS GEN. PROPELLANT WGT.-(LBS)	.364534+02	.229972+03
GAS GENERATOR WEIGHT - (LBS)	.122426+02	.123712+02

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE     19
DEPT 6213          *       THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235         *                                        * TIME 15:02:03
BLD. 104           *               AT4307                   * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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ACPS - TEST DEMONSTRATION PROBLEM

*** INITIAL TANK SIZING CALCULATIONS ***

	OXYGEN	HYDROGEN
NUMBER OF TANKS	1	1
MATERIAL TYPE	2	2
FLUID WGT. (TOTAL)	.510113+04	.194820+04
FLUID VOLUME /TANK	.720333+02	.439468+03
WGT ADDED CYL SECT	.306852+00	.197408+02
DIAMETER (FT)/TANK	.506600+01	.500000+01
SURFACE AREA /TANK	.855106+02	.388627+03
TANK VOLUME / TANK	.742612+02	.453059+03
TANK WGT. (LB) TOT	.426906+02	.192650+03
HEAT LEAK BTU/H/FT	.475059-02	.323856-01

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * * * PAGE    20
DEPT 6213         *        THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                         * TIME 15:02:03
BLD. 104          *                  AT4307                 * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                            ACPS - TEST DEMONSTRATION PROBLEM

                    *** TANK AND VENT PARAMETER CALCULATIONS ***

         *** INITIAL TANK CONDITIONS ***

FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE        =   163.91     TANK INITIAL PRESSURE =    16.00
WGT.OF LIQ. PROP.    =  5101.13        WGT. PROP. VAPOR         =     .741     WGT. LIQ. + VAPOR     =  5101.87
WGT. HELIUM IN VAPOR =      .00        TOTAL FLUIDS IN TANK     =  5101.87     VOL. OF LIQUID FLUID  =    71.80
PART.PRES.PROP.VAPOR =  16.000         PART.PRES.HELIUM GAS     =     .000     ULLAGE VOLUME IN TANK =     2.46
TANK VOLUME          =    74.26        EFF. TANK DENSITY        =   68.702     EFF. INTERNAL ENERGY  =   -.56810388+02

          ******************** COAST NUMBER =   1     PRESS.SYS.NO. =   0 ********************

         *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE        =   163.99     COAST DURATION - SEC. =     540.
WGT.OF LIQ. PROP.    = 5101.125        WGT. PROP. VAPOR         =     .744     WGT.HELIUM IN VAPOR   =     .000
PART.PRES.PROP.VAPOR =    16.074       PART.PRES.HELIUM GAS     =     .000     CURRENT TANK PRESSURE =   16.074
EFF.INTERNAL ENERGY  =   -.56809686+02

          ******************** BURN NUMBER =   1     PRESS.SYS.NO. =   2 ********************

         *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN          BURN DURATION - SEC.     =       5.     FLOWRATE FOR THRUST   =    9.990
THRUST PROP.REMAINING =  4235.05       PROPELLANT IN TANK       =  5101.13     EFF. INTERNAL ENERGY  =   -.56809886+02
EFF. TANK ENERGY     =   -.28672176+06                                         TOTAL FLOWRATE        =   12.033

         *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN =    55.113       TOTAL FLUIDS IN TANK     =  5046.76     PROPELLANT LIQ.+VAP.  =  5046.76
THRUST PROP.REMAINING =  4189.29       NEW EFF. TANK DENSITY    =  67.9596     PART.PRES.PROP.VAPOR  =   16.056
NEW INTERNAL ENERGY  =   -.56813077+02

         *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =   163.97       STORED HELIUM TEMP.      =   170.00     NEW TANK ULLAGE VOL.  =    3.230
NEW PROP. LIQ. VOLUME =    71.03       PROP. LIQ. REMAINING     =  5045.78     WGT. OF PROP. VAPOR   =    .9742
HELIUM PART.PRESSURE =   10.644        TOTAL PRES. *PPV+PHE*    =   16.056     NOM. OPERATING PRES.  =   26.700
HELIUM FLOW  RATE    =   .1644-01      WEIGHT OF HELIUM USED    =   .7528-01   NEW TANK PRESSURE     =   26.700
TOTAL HELIUM CONSUMED =     .075
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER = 2 PRESS.SYS.NO. = 2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -      OXYGEN          FLUID TEMPERATURE       =   164.00      COAST DURATION - SEC. =     7975.
WGT.OF LIQ. PROP.       = 5045.781      WGT. PROP. VAPOR        =     .976      WGT.HELIUM IN VAPOR   =      .075
PART.PRES.PROP.VAPOR  =    16.084       PART.PRES.HELIUM GAS    =   10.269      CURRENT TANK PRESSURE =    26.353
EFF.INTERNAL ENERGY   =    -.56805571+02
```

******************** BURN NUMBER = 2 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -      OXYGEN          BURN DURATION - SEC.    =       6.      FLOWRATE FOR THRUST     =     9.990
THRUST PROP.REMAINING = 4189.29         PROPELLANT IN TANK      =  5046.76      EFF. INTERNAL ENERGY    =  -.56805571+02
EFF. TANK ENERGY      =    -.28250102+06                                         TOTAL FLOWRATE          =    12.035
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN  =    74.016       TOTAL FLUIDS IN TANK    =  4972.74      PROPELLANT LIQ.+VAP.    =  4972.74
THRUST PROP.REMAINING = 4127.85         NEW EFF. TANK DENSITY   =  66.9629      PART.PRES.PROP.VAPOR    =    16.061
NEW INTERNAL ENERGY   =    -.56809925+02
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =   163.97        STORED HELIUM TEMP.     =   170.00      NEW TANK ULLAGE VOL.    =     4.275
NEW PROP. LIQ. VOLUME =    69.90        PROP. LIQ. REMAINING    =  4971.45      WGT. OF PROP. VAPOR     =    1.2898
HELIUM PART.PRESSURE  =    10.639       TOTAL PRES. *PPV+PHE*   =   23.817      NOM. OPERATING PRES.    =    26.700
HELIUM FLOW RATE      =   .3955-02      WEIGHT OF HELIUM USED   =  .2432-01     NEW TANK PRESSURE       =    26.700
TOTAL HELIUM CONSUMED =      .100
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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE     22
DEPT 6213         *       THE INTEGRATED MATH MODEL       * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:02:03
BLD. 104          *                AT4307                 * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                           ACPS - TEST DEMONSTRATION PROBLEM

                  *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***


        ******************** COAST NUMBER =   3     PRESS.SYS.NO. =   2 ********************

       *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -    OXYGEN          FLUID TEMPERATURE     =   163.98       COAST DURATION - SEC. =    2094.
WGT.OF LIQ. PROP.     = 4971.450      WGT. PROP. VAPOR      =     1.290      WGT.HELIUM IN VAPOR  =     .100
PART.PRES.PROP.VAPOR  =   16.069      PART.PRES.HELIUM GAS  =    10.263      CURRENT TANK PRESSURE =   26.332
EFF.INTERNAL ENERGY   =   -.56807924+02

        ******************** BURN NUMBER =   3     PRESS.SYS.NO. =   2 ********************

       *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -    OXYGEN          BURN DURATION - SEC.  =       4.       FLOWRATE FOR THRUST    =    9.990
THRUST PROP.REMAINING =  4127.85      PROPELLANT IN TANK    =  4972.74       EFF. INTERNAL ENERGY   =  -.56807924+02
EFF. TANK ENERGY      =   -.28005587+06                                      TOTAL FLOWRATE         =   12.035

       *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =   43.086      TOTAL FLUIDS IN TANK  =  4929.65       PROPELLANT LIQ.+VAP.   =  4929.65
THRUST PROP.REMAINING =  4092.09      NEW EFF. TANK DENSITY =  66.3827       PART.PRES.PROP.VAPOR   =   16.055
NEW INTERNAL ENERGY   =   -.56810441+02

       *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =   163.97      STORED HELIUM TEMP.   =   170.00       NEW TANK ULLAGE VOL.   =    4.886
NEW PROP. LIQ. VOLUME =    69.38      PROP. LIQ. REMAINING  =  4928.18       WGT. OF PROP. VAPOR    =   1.4735
HELIUM PART.PRESSURE  =   10.645      TOTAL PRES. *PPV+PHE* =   25.035       NOM. OPERATING PRES.   =   26.700
HELIUM FLOW  RATE     =   .3990-02    WEIGHT OF HELIUM USED =   .1428-01     NEW TANK PRESSURE      =   26.700
TOTAL HELIUM CONSUMED =     .114
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER = 4 PRESS.SYS.NO. = 2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -      OXYGEN         FLUID TEMPERATURE        =   163.97     COAST DURATION - SEC. =     536.
WGT.OF LIQ. PROP.       = 4928.181     WGT. PROP. VAPOR         =    1.474     WGT.HELIUM IN VAPOR  =     .114
PART.PRES.PROP.VAPOR    =   16.058     PART.PRES.HELIUM GAS     =   10.268     CURRENT TANK PRESSURE =   26.326
EFF.INTERNAL ENERGY     =   -.56809925+02
```

******************** BURN NUMBER = 4 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -      OXYGEN         BURN DURATION - SEC.     =      39.     FLOWRATE FOR THRUST     =    9.990
THRUST PROP.REMAINING = 4092.09        PROPELLANT IN TANK       =  4929.65     EFF. INTERNAL ENERGY    =  -.56809925+02
EFF. TANK ENERGY        =   -.25365855+06                                      TOTAL FLOWRATE          =   12.035
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN    =  466.961     TOTAL FLUIDS IN TANK     =  4462.69     PROPELLANT LIQ.+VAP.    =  4462.69
THRUST PROP.REMAINING = 3704.47        NEW EFF. TANK DENSITY    =  60.0946     PART.PRES.PROP.VAPOR    =   15.918
NEW INTERNAL ENERGY     =   -.56839786+02
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =   163.82       STORED HELIUM TEMP.      =   170.00     NEW TANK ULLAGE VOL.    =   11.516
NEW PROP. LIQ. VOLUME =    62.75       PROP. LIQ. REMAINING     =  4459.25     WGT. OF PROP. VAPOR     =   3.4458
HELIUM PART.PRESSURE  =   10.782       TOTAL PRES. *PPV+PHE*    =   20.270     NOM. OPERATING PRES.    =   26.700
HELIUM FLOW  RATE     =  .4072-02      WEIGHT OF HELIUM USED    = .1580+00     NEW TANK PRESSURE       =   26.700
TOTAL HELIUM CONSUMED =     .272
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER = 5 PRESS.SYS.NO. = 2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE       =   163.84     COAST DURATION - SEC. =    2061.
WGT.OF LIQ. PROP.      = 4459.244      WGT. PROP. VAPOR        =    3.450     WGT.HELIUM IN VAPOR  =     .272
PART.PRES.PROP.VAPOR  =   15.939       PART.PRES.HELIUM GAS    =   10.392     CURRENT TANK PRESSURE =   26.332
EFF.INTERNAL ENERGY   =   -.56837592+02
```

******************** BURN NUMBER = 5 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -     OXYGEN          BURN DURATION - SEC.    =       7.     FLOWRATE FOR THRUST    =    9.990
THRUST PROP.REMAINING =  3704.47       PROPELLANT IN TANK      =  4462.69     EFF. INTERNAL ENERGY   =  -.56837592+02
EFF. TANK ENERGY      =   -.24858964+06                                       TOTAL FLOWRATE         =   12.035
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN  =   89.421       TOTAL FLUIDS IN TANK    =  4373.27     PROPELLANT LIQ.+VAP.   =  4373.27
THRUST PROP.REMAINING =  3630.24       NEW EFF. TANK DENSITY   =  58.8904     PART.PRES.PROP.VAPOR   =   15.912
NEW INTERNAL ENERGY   =   -.56842927+02
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =   163.81       STORED HELIUM TEMP.     =   170.00     NEW TANK ULLAGE VOL.   =   12.780
NEW PROP. LIQ. VOLUME =    61.48       PROP. LIQ. REMAINING    =  4369.45     WGT. OF PROP. VAPOR    =   3.8229
HELIUM PART.PRESSURE  =   10.788       TOTAL PRES. *PPV+PHE*   =   25.273     NOM. OPERATING PRES.   =   26.700
HELIUM FLOW  RATE     =  .4042-02      WEIGHT OF HELIUM USED   =  .3003-01    NEW TANK PRESSURE      =   26.700
TOTAL HELIUM CONSUMED =     .302
```

```
                         ACPS - TEST DEMONSTRATION PROBLEM

              *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER =   6     PRESS.SYS.NO. =   2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN         FLUID TEMPERATURE        =    163.81     COAST DURATION - SEC. =     593.
WGT.OF LIQ. PROP.      = 4369.449     WGT. PROP. VAPOR         =     3.824     WGT.HELIUM IN VAPOR   =     .302
PART.PRES.PROP.VAPOR   =   15.916     PART.PRES.HELIUM GAS     =    10.396     CURRENT TANK PRESSURE =   26.313
EFF.INTERNAL ENERGY    =   -.56842283+02

******************** BURN NUMBER =   6     PRESS.SYS.NO. =   2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN         BURN DURATION - SEC.     =        4.     FLOWRATE FOR THRUST     =    9.990
THRUST PROP.REMAINING =  3630.24      PROPELLANT IN TANK       =   4373.27     EFF. INTERNAL ENERGY    =   -.56842283+02
EFF. TANK ENERGY       =   -.24614875+06                                       TOTAL FLOWRATE          =   12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN   =   43.086     TOTAL FLUIDS IN TANK  =  4330.19     PROPELLANT LIQ.+VAP.    =  4330.19
THRUST PROP.REMAINING =   3594.47     NEW EFF. TANK DENSITY =  58.3103     PART.PRES.PROP.VAPOR    =   15.903
NEW INTERNAL ENERGY    =   -.56844824+02

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    163.80     STORED HELIUM TEMP.      =    170.00     NEW TANK ULLAGE VOL.    =   13.391
NEW PROP. LIQ. VOLUME =     60.87     PROP. LIQ. REMAINING     =   4326.18     WGT. OF PROP. VAPOR     =   4.0035
HELIUM PART.PRESSURE  =    10.797     TOTAL PRES. *PPV+PHE*    =    25.824     NOM. OPERATING PRES.    =   26.700
HELIUM FLOW  RATE     =   .4101-02    WEIGHT OF HELIUM USED    =   .1468-01    NEW TANK PRESSURE       =   26.700
TOTAL HELIUM CONSUMED =      .317
```

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * PAGE    26
DEPT 6213         *       THE INTEGRATED MATH MODEL          * DATE 17 APR 73
EXT. 30235        *                                          * TIME 15:02:04
BLD. 104          *                  AT4307                  * CASE    1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                          ACPS - TEST DEMONSTRATION PROBLEM

                  *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

        ******************** COAST NUMBER =   7     PRESS.SYS.NO. =   2 ********************

        *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE      =   163.80     COAST DURATION - SEC. =      536.
WGT.OF LIQ. PROP.      = 4326.183      WGT. PROP. VAPOR       =    4.004     WGT.HELIUM IN VAPOR  =      .317
PART.PRES.PROP.VAPOR  =    15.906      PART.PRES.HELIUM GAS   =   10.404     CURRENT TANK PRESSURE =    26.310
EFF.INTERNAL ENERGY   =    -.56844236+02

        ******************** BURN NUMBER =   7     PRESS.SYS.NO. =   2 ********************

        *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN          BURN DURATION - SEC.   =      66.     FLOWRATE FOR THRUST     =    9.990
THRUST PROP.REMAINING =  3594.47       PROPELLANT IN TANK     =  4330.19     EFF. INTERNAL ENERGY    =  -.56844236+02
EFF. TANK ENERGY      =    -.20112651+06                                     TOTAL FLOWRATE          =   12.035

        *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =  795.519       TOTAL FLUIDS IN TANK   =  3534.67     PROPELLANT LIQ.+VAP.    =  3534.67
THRUST PROP.REMAINING =  2934.12       NEW EFF. TANK DENSITY  =  47.5978     PART.PRES.PROP.VAPOR    =   15.752
NEW INTERNAL ENERGY   =    -.56901096+02

        *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    163.63      STORED HELIUM TEMP.    =   170.00     NEW TANK ULLAGE VOL.    =   24.656
NEW PROP. LIQ. VOLUME =     49.61      PROP. LIQ. REMAINING   =  3527.36     WGT. OF PROP. VAPOR     =   7.3072
HELIUM PART.PRESSURE  =    10.948      TOTAL PRES. *PPV+PHE*  =   21.396     NOM. OPERATING PRES.    =   26.700
HELIUM FLOW  RATE     =  .4152-02      WEIGHT OF HELIUM USED  =  .2744+00    NEW TANK PRESSURE       =   26.700
TOTAL HELIUM CONSUMED =      .591
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER = 8 PRESS.SYS.NO. = 2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -        OXYGEN          FLUID TEMPERATURE      =    163.68     COAST DURATION - SEC. =      714.
WGT.OF LIQ. PROP.         = 3527.344      WGT. PROP. VAPOR       =      7.325    WGT.HELIUM IN VAPOR  =      .591
PART.PRES.PROP.VAPOR  =      15.793       PART.PRES.HELIUM GAS   =     10.541    CURRENT TANK PRESSURE =    26.334
EFF.INTERNAL ENERGY   =    -.56900137+02
```

******************** BURN NUMBER = 8 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -        OXYGEN          BURN DURATION - SEC.   =       32.     FLOWRATE FOR THRUST     =    9.990
THRUST PROP.REMAINING =  2934.12          PROPELLANT IN TANK     =   3534.67     EFF. INTERNAL ENERGY    =   -.56900137+02
EFF. TANK ENERGY      =    -.17910453+06                                         TOTAL FLOWRATE          =   12.035
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN  =   388.733         TOTAL FLUIDS IN TANK   =   3145.94     PROPELLANT LIQ.+VAP.    =  3145.94
THRUST PROP.REMAINING =  2611.43          NEW EFF. TANK DENSITY  =   42.3631     PART.PRES.PROP.VAPOR    =   15.902
NEW INTERNAL ENERGY   =    -.56932047+02
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =    163.80         STORED HELIUM TEMP.    =    170.00     NEW TANK ULLAGE VOL.    =   30.124
NEW PROP. LIQ. VOLUME =     44.14         PROP. LIQ. REMAINING   =   3136.93     WGT. OF PROP. VAPOR     =   9.0060
HELIUM PART.PRESSURE  =    10.798         TOTAL PRES. *PPV+PHE*  =    24.536     NOM. OPERATING PRES.    =   26.700
HELIUM FLOW  RATE     =    .3752-02       WEIGHT OF HELIUM USED  =    .1212+00   NEW TANK PRESSURE       =   26.700
TOTAL HELIUM CONSUMED =      .712
```

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * PAGE    28
DEPT 6213          *       THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235         *                                        * TIME 15:02:05
BLD. 104           *                 AT4307                 * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                              ACPS - TEST DEMONSTRATION PROBLEM

                    *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

        ******************** COAST NUMBER =   9     PRESS.SYS.NO. =   2 ********************

        *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE       =   163.82     COAST DURATION - SEC. =     568.
WGT.OF LIQ. PROP.      = 3136.918      WGT. PROP. VAPOR        =    9.017     WGT.HELIUM IN VAPOR  =     .712
PART.PRES.PROP.VAPOR  =   15.924       PART.PRES.HELIUM GAS    =   10.406     CURRENT TANK PRESSURE =   26.330
EFF.INTERNAL ENERGY    =    -.56931190+02

        ******************** BURN NUMBER =   9     PRESS.SYS.NO. =   2 ********************

        *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN          BURN DURATION - SEC.    =     104.     FLOWRATE FOR THRUST      =    9.990
THRUST PROP.REMAINING =  2611.43       PROPELLANT IN TANK      =  3145.94     EFF. INTERNAL ENERGY     =   -.56931190+02
EFF. TANK ENERGY       =    -.10821124+06                                     TOTAL FLOWRATE           =   12.035

        *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN   = 1252.852      TOTAL FLUIDS IN TANK    =  1893.08     PROPELLANT LIQ.+VAP.     = 1893.08
THRUST PROP.REMAINING =  1571.44       NEW EFF. TANK DENSITY   =  25.4922     PART.PRES.PROP.VAPOR     =   14.508
NEW INTERNAL ENERGY    =    -.57161386+02

        *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    162.19      STORED HELIUM TEMP.     =   170.00     NEW TANK ULLAGE VOL.     =   47.937
NEW PROP. LIQ. VOLUME =     26.32      PROP. LIQ. REMAINING    =  1879.91     WGT. OF PROP. VAPOR      =  13.1757
HELIUM PART.PRESSURE  =    12.192      TOTAL PRES. *PPV+PHE*   =   20.982     NOM. OPERATING PRES.     =   26.700
HELIUM FLOW  RATE     =  .5449-02      WEIGHT OF HELIUM USED   = .5673+00     NEW TANK PRESSURE        =   26.700
TOTAL HELIUM CONSUMED =     1.280
```

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE     29
DEPT 6213         *        THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                         * TIME 15:02:05
BLD. 104          *                   AT4307                * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                              ACPS - TEST DEMONSTRATION PROBLEM

                    *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

    ******************** COAST NUMBER =  10     PRESS.SYS.NO. =   2 ********************

    *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE       =    162.38     COAST DURATION - SEC. =     1876.
WGT.OF LIQ. PROP.      = 1879.780      WGT. PROP. VAPOR        =    13.302     WGT.HELIUM IN VAPOR  =     1.280
PART.PRES.PROP.VAPOR  =    14.660      PART.PRES.HELIUM GAS    =    11.646     CURRENT TANK PRESSURE =    26.306
EFF.INTERNAL ENERGY   =   -.57156679+02

    ******************** BURN NUMBER =  10     PRESS.SYS.NO. =   2 ********************

    *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN          BURN DURATION - SEC.    =       32.     FLOWRATE FOR THRUST      =    9.990
THRUST PROP.REMAINING =  1571.44       PROPELLANT IN TANK      =   1893.08     EFF. INTERNAL ENERGY     =   -.57156679+02
EFF. TANK ENERGY      =   -.86250527+05                                        TOTAL FLOWRATE           =   12.035

    *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =   383.919      TOTAL FLUIDS IN TANK    =   1509.16     PROPELLANT LIQ.+VAP.     =  1509.16
THRUST PROP.REMAINING =  1252.75       NEW EFF. TANK DENSITY   =   20.3224     PART.PRES.PROP.VAPOR     =   14.350
NEW INTERNAL ENERGY   =   -.57151208+02

    *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    162.00      STORED HELIUM TEMP.     =    170.00     NEW TANK ULLAGE VOL.     =   53.344
NEW PROP. LIQ. VOLUME =     20.92      PROP. LIQ. REMAINING    =   1494.65     WGT. OF PROP. VAPOR      =  14.5152
HELIUM PART.PRESSURE  =    12.350      TOTAL PRES. *PPV+PHE*   =    24.791     NOM. OPERATING PRES.     =   26.700
HELIUM FLOW  RATE     =    .5102-02    WEIGHT OF HELIUM USED   =   .1628+00    NEW TANK PRESSURE        =   26.700
TOTAL HELIUM CONSUMED =     1.442
```

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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * * PAGE     30
DEPT 6213         *       THE INTEGRATED MATH MODEL       * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:02:06
BLD. 104          *                 AT4307                * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                         ACPS - TEST DEMONSTRATION PROBLEM

                 *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***


    ******************** COAST NUMBER =  11     PRESS.SYS.NO. =   2 ********************

    *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN            FLUID TEMPERATURE        =   165.93     COAST DURATION - SEC. =  571048.
WGT.OF LIQ. PROP.      = 1491.376        WGT. PROP. VAPOR         =   17.788     WGT.HELIUM IN VAPOR  =    1.442
PART.PRES.PROP.VAPOR  =   17.914         PART.PRES.HELIUM GAS     =   12.055     CURRENT TANK PRESSURE =   29.969
EFF.INTERNAL ENERGY   =     -.55353647+02

    ******************** BURN NUMBER =  11     PRESS.SYS.NO. =   2 ********************

    *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN            BURN DURATION - SEC.     =      16.     FLOWRATE FOR THRUST      =     9.990
THRUST PROP.REMAINING =  1252.75         PROPELLANT IN TANK       =  1509.16     EFF. INTERNAL ENERGY     =   -.55353647+02
EFF. TANK ENERGY      =     -.72687199+05                                        TOTAL FLOWRATE           =    12.035

    *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =  194.487         TOTAL FLUIDS IN TANK  =  1314.68        PROPELLANT LIQ.+VAP.     =  1314.68
THRUST PROP.REMAINING =  1091.31         NEW EFF. TANK DENSITY =  17.7034        PART.PRES.PROP.VAPOR     =   16.731
NEW INTERNAL ENERGY   =     -.55289029+02

    *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =   164.70         STORED HELIUM TEMP.      =   170.00     NEW TANK ULLAGE VOL.     =   55.961
NEW PROP. LIQ. VOLUME =    16.30         PROP. LIQ. REMAINING     =  1297.15     WGT. OF PROP. VAPOR      =  17.5271
HELIUM PART.PRESSURE  =   11.406         TOTAL PRES. *PPV+PHE* =   28.137        NOM. OPERATING PRES.     =   26.700
HELIUM FLOW  RATE     =   .0000          WEIGHT OF HELIUM USED =    .0000        NEW TANK PRESSURE        =   28.137
TOTAL HELIUM CONSUMED =    1.442
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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE    31
DEPT 6213         *      THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:02:06
BLD. 104          *                 AT4307                * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                       ACPS - TEST DEMONSTRATION PROBLEM

                  *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

        ******************** COAST NUMBER =  12     PRESS.SYS.NO. =   2 ********************

       *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE       =   164.77     COAST DURATION - SEC. =    9584.
WGT.OF LIQ. PROP.      = 1297.085      WGT. PROP. VAPOR        =   17.592     WGT.HELIUM IN VAPOR  =    1.442
PART.PRES.PROP.VAPOR   =   16.798      PART.PRES.HELIUM GAS    =   11.410     CURRENT TANK PRESSURE =   28.208
EFF.INTERNAL ENERGY    =   -.55254397+02

        ******************** BURN NUMBER =  12     PRESS.SYS.NO. =   2 ********************

       *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -     OXYGEN          BURN DURATION - SEC.    =     100.     FLOWRATE FOR THRUST    =    9.990
THRUST PROP.REMAINING =  1091.31       PROPELLANT IN TANK      =  1314.68     EFF. INTERNAL ENERGY   =   -.55254397+02
EFF. TANK ENERGY       =   -.49881426+04                                      TOTAL FLOWRATE         =   12.035

       *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  = 1203.508       TOTAL FLUIDS IN TANK    =   111.17     PROPELLANT LIQ.+VAP.   =   111.17
THRUST PROP.REMAINING =    92.28       NEW EFF. TANK DENSITY   =   1.4970     PART.PRES.PROP.VAPOR   =   14.580
NEW INTERNAL ENERGY    =   -.44870217+02

       *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =   162.28       STORED HELIUM TEMP.     =   170.00     NEW TANK ULLAGE VOL.   =   72.986
NEW PROP. LIQ. VOLUME =     1.27       PROP. LIQ. REMAINING    =    91.02     WGT. OF PROP. VAPOR    =  20.1522
HELIUM PART.PRESSURE  =   12.120       TOTAL PRES. *PPV+PHE*   =   23.197     NOM. OPERATING PRES.   =   26.700
HELIUM FLOW  RATE     =  .4943-02      WEIGHT OF HELIUM USED   = .4943+00     NEW TANK PRESSURE      =   26.700
TOTAL HELIUM CONSUMED =    1.937
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** FINAL ENGINE SHUTDOWN PROPELLANT TANK CONDITIONS ********************

*** COMPUTE FINAL TANK CONDITIONS ***

```
FLUID CONSIDERED -     OXYGEN          FLUID TEMPERATURE       =   163.01      COAST DURATION - SEC. =    300.
WGT.OF LIQ. PROP.      =   90.226      WGT. PROP. VAPOR        =   20.942      WGT.HELIUM IN VAPOR  =   1.937
PART.PRES.PROP.VAPOR   =   15.206      PART.PRES.HELIUM GAS    =   11.622      CURRENT TANK PRESSURE =  26.828
EFF.INTERNAL ENERGY    =   -.44857398+02

FINAL TANK TEMP.       =  163.012      TOTAL VENTED GAS WGT. =      .000      WGT. OF GAS RESIDUALS =  22.879
WGT. OF LIQ.RESIDUALS =   90.226
```

*** COMPUTE PRESSURIZATION SYSTEM WEIGHT ***

```
TOTAL HELIUM GAS REQD =    1.937      WGT.PRESSURANT SYSTEM =   42.905
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS ***

*** INITIAL TANK CONDITIONS ***

```
FLUID CONSIDERED -    HYDROGEN        FLUID TEMPERATURE      =    37.05     TANK INITIAL PRESSURE =     16.00
WGT.OF LIQ. PROP.    =  1948.20       WGT. PROP. VAPOR       =    1.204     WGT. LIQ. + VAPOR     =   1949.40
WGT. HELIUM IN VAPOR =      .00       TOTAL FLUIDS IN TANK   =  1949.40     VOL. OF LIQUID FLUID  =    439.63
PART.PRES.PROP.VAPOR =   16.000       PART.PRES.HELIUM GAS   =     .000     ULLAGE VOLUME IN TANK =     13.43
TANK VOLUME          =   453.06       EFF. TANK DENSITY      =    4.303     EFF. INTERNAL ENERGY  =  -.11041192+03
```

******************** COAST NUMBER = 1 PRESS.SYS.NO. = 0 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -    HYDROGEN        FLUID TEMPERATURE      =    37.95     COAST DURATION - SEC. =      540.
WGT.OF LIQ. PROP.    = 1948.037       WGT. PROP. VAPOR       =    1.365     WGT.HELIUM IN VAPOR   =      .000
PART.PRES.PROP.VAPOR =   18.365       PART.PRES.HELIUM GAS   =     .000     CURRENT TANK PRESSURE =    18.365
EFF.INTERNAL ENERGY  =   -.11040295+03
```

******************** BURN NUMBER = 1 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -    HYDROGEN        BURN DURATION - SEC.   =       5.     FLOWRATE FOR THRUST   =     2.498
THRUST PROP.REMAINING =  1066.76      PROPELLANT IN TANK     =  1948.20     EFF. INTERNAL ENERGY  =  -.11040295+03
EFF. TANK ENERGY     =  -.21299417+06                                       TOTAL FLOWRATE        =     4.561
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN =   20.890       TOTAL FLUIDS IN TANK   =  1928.51     PROPELLANT LIQ.+VAP.  =   1928.51
THRUST PROP.REMAINING =  1055.32      NEW EFF. TANK DENSITY  =   4.2566     PART.PRES.PROP.VAPOR  =    17.366
NEW INTERNAL ENERGY  =  -.11044483+03
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =   37.58       STORED HELIUM TEMP.    =    40.00     NEW TANK ULLAGE VOL.  =    16.385
NEW PROP. LIQ. VOLUME =  436.67       PROP. LIQ. REMAINING   =  1926.93     WGT. OF PROP. VAPOR   =    1.5824
HELIUM PART.PRESSURE =    1.734       TOTAL PRES. *PPV+PHE*  =   17.366     NOM. OPERATING PRES.  =    19.100
HELIUM FLOW RATE     = .5777-01       WEIGHT OF HELIUM USED  = .2646+00     NEW TANK PRESSURE     =    19.100
TOTAL HELIUM CONSUMED =    .265
```

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                       ACPS - TEST DEMONSTRATION PROBLEM

            *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER =   2     PRESS.SYS.NO. =   2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -    HYDROGEN         FLUID TEMPERATURE      =    38.56    COAST DURATION - SEC. =    7975.
WGT.OF LIQ. PROP.     = 1926.778       WGT. PROP. VAPOR       =    1.734    WGT.HELIUM IN VAPOR  =     .265
PART.PRES.PROP.VAPOR  =    19.267      PART.PRES.HELIUM GAS   =    1.671    CURRENT TANK PRESSURE =   20.938
EFF.INTERNAL ENERGY   =   -.11031090+03

******************** BURN NUMBER =   2     PRESS.SYS.NO. =   2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -    HYDROGEN         BURN DURATION - SEC.   =       6.    FLOWRATE FOR THRUST     =    2.498
THRUST PROP.REMAINING =  1055.32       PROPELLANT IN TANK     =  1928.51    EFF. INTERNAL ENERGY    =  -.11031090+03
EFF. TANK ENERGY      =   -.20976858+06                                     TOTAL FLOWRATE          =    4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =    28.069      TOTAL FLUIDS IN TANK   =  1900.44    PROPELLANT LIQ.+VAP.    =  1900.44
THRUST PROP.REMAINING =  1039.96       NEW EFF. TANK DENSITY  =    4.1947   PART.PRES.PROP.VAPOR    =   17.676
NEW INTERNAL ENERGY   =   -.11037879+03

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    37.69       STORED HELIUM TEMP.    =    40.00    NEW TANK ULLAGE VOL.    =   22.481
NEW PROP. LIQ. VOLUME =   430.58       PROP. LIQ. REMAINING   =  1898.24    WGT. OF PROP. VAPOR     =   2.2065
HELIUM PART.PRESSURE  =    1.424       TOTAL PRES. *PPV+PHE*  =   18.867    NOM. OPERATING PRES.    =   19.100
HELIUM FLOW  RATE     =  .5471-02      WEIGHT OF HELIUM USED  =  .3365-01   NEW TANK PRESSURE       =   19.100
TOTAL HELIUM CONSUMED =     .298
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                     *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

          ******************** COAST NUMBER =   3     PRESS.SYS.NO. =   2 ********************

          *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -   HYDROGEN          FLUID TEMPERATURE        =      37.84     COAST DURATION - SEC. =    2094.
WGT.OF LIQ. PROP.       = 1898.193     WGT. PROP. VAPOR         =      2.250     WGT.HELIUM IN VAPOR  =      .298
PART.PRES.PROP.VAPOR  =    18.059      PART.PRES.HELIUM GAS     =      1.347     CURRENT TANK PRESSURE =   19.406
EFF.INTERNAL ENERGY   =   -.11034311+03

          ******************** BURN NUMBER =   3     PRESS.SYS.NO. =   2 ********************

          *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -   HYDROGEN          BURN DURATION - SEC.     =         4.     FLOWRATE FOR THRUST      =     2.498
THRUST PROP.REMAINING =  1039.96       PROPELLANT IN TANK       =    1900.44     EFF. INTERNAL ENERGY     =   -.11034311+03
EFF. TANK ENERGY      =   -.20795540+06                                          TOTAL FLOWRATE           =     4.564

          *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =    16.339      TOTAL FLUIDS IN TANK     =    1884.10     PROPELLANT LIQ.+VAP.     =   1884.10
THRUST PROP.REMAINING =  1031.02       NEW EFF. TANK DENSITY    =     4.1586     PART.PRES.PROP.VAPOR     =    17.334
NEW INTERNAL ENERGY   =   -.11037366+03

          *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =     37.57      STORED HELIUM TEMP.      =      40.00     NEW TANK ULLAGE VOL.     =    26.715
NEW PROP. LIQ. VOLUME =    426.34      PROP. LIQ. REMAINING     =    1881.53     WGT. OF PROP. VAPOR      =    2.5757
HELIUM PART.PRESSURE  =     1.766      TOTAL PRES. *PPV+PHE*    =     18.460     NOM. OPERATING PRES.     =    19.100
HELIUM FLOW  RATE     =    .3943-01    WEIGHT OF HELIUM USED    =    .1412+00    NEW TANK PRESSURE        =    19.100
TOTAL HELIUM CONSUMED =      .439
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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * PAGE    36
DEPT 6213         *        THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                         * TIME 15:02:07
BLD. 104          *                 AT4307                  * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                         ACPS - TEST DEMONSTRATION PROBLEM

                  *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***


          ******************** COAST NUMBER =   4     PRESS.SYS.NO. =   2 ********************

          *** PRE- OF NON-VENT CONDITIONS ***

FLUID CONSIDERED -   HYDROGEN          FLUID TEMPERATURE        =    37.61      COAST DURATION - SEC. =     536.
WGT.OF LIQ. PROP.        = 1881.512    WGT. PROP. VAPOR         =    2.591      WGT.HELIUM IN VAPOR  =     .439
PART.PRES.PROP.VAPOR  =    17.449      PART.PRES.HELIUM GAS     =    1.660      CURRENT TANK PRESSURE =   19.110
EFF.INTERNAL ENERGY   =    -.11036445+03

          ******************** BURN NUMBER =   4     PRESS.SYS.NO. =   2 ********************

          *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -   HYDROGEN          BURN DURATION - SEC.     =      39.      FLOWRATE FOR THRUST       =   2.498
THRUST PROP.REMAINING =  1031.02       PROPELLANT IN TANK       =  1884.10      EFF. INTERNAL ENERGY      =  -.11036445+03
EFF. TANK ENERGY      =    -.18892080+06                                        TOTAL FLOWRATE            =   4.564

          *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =   177.087      TOTAL FLUIDS IN TANK  =  1707.02         PROPELLANT LIQ.+VAP.      =  1707.02
THRUST PROP.REMAINING =   934.12       NEW EFF. TANK DENSITY =   3.7678         PART.PRES.PROP.VAPOR      =   14.841
NEW INTERNAL ENERGY   =    -.11067308+03

          *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    36.57       STORED HELIUM TEMP.      =    40.00      NEW TANK ULLAGE VOL.      =   70.609
NEW PROP. LIQ. VOLUME =   382.45       PROP. LIQ. REMAINING     =  1701.11      WGT. OF PROP. VAPOR       =   5.9096
HELIUM PART.PRESSURE  =    4.259       TOTAL PRES. *PPV+PHE*    =   15.452      NOM. OPERATING PRES.      =   19.100
HELIUM FLOW  RATE     =   .6082-01     WEIGHT OF HELIUM USED    =   .2360+01    NEW TANK PRESSURE         =   19.100
TOTAL HELIUM CONSUMED =    2.799
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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * PAGE     37
DEPT 6213         *        THE INTEGRATED MATH MODEL      * DATE 17 APR 73
EXT. 30235        *                                       * TIME 15:02:07
BLD. 104          *                  AT4307               * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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               *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

  ******************** COAST NUMBER =   5     PRESS.SYS.NO. =   2 ********************

 *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -    HYDROGEN        FLUID TEMPERATURE       =     36.62     COAST DURATION - SEC. =    2061.
WGT.OF LIQ. PROP.      = 1701.064     WGT. PROP. VAPOR        =     5.953     WGT.HELIUM IN VAPOR  =    2.799
PART.PRES.PROP.VAPOR  =    14.962     PART.PRES.HELIUM GAS    =     3.899     CURRENT TANK PRESSURE =   18.860
EFF.INTERNAL ENERGY   =   -.11063398+03

  ******************** BURN NUMBER =   5     PRESS.SYS.NO. =   2 ********************

 *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -    HYDROGEN        BURN DURATION - SEC.    =        7.     FLOWRATE FOR THRUST    =    2.498
THRUST PROP.REMAINING =    934.12     PROPELLANT IN TANK      =   1707.02     EFF. INTERNAL ENERGY   =   -.11063398+03
EFF. TANK ENERGY      =   -.18513058+06                                       TOTAL FLOWRATE         =    4.564

 *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =    33.911     TOTAL FLUIDS IN TANK    =   1673.11     PROPELLANT LIQ.+VAP.   =  1673.11
THRUST PROP.REMAINING =    915.56     NEW EFF. TANK DENSITY   =    3.6929     PART.PRES.PROP.VAPOR   =   14.818
NEW INTERNAL ENERGY   =   -.11065086+03

 *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =     36.56     STORED HELIUM TEMP.     =     40.00     NEW TANK ULLAGE VOL.   =   78.406
NEW PROP. LIQ. VOLUME =    374.65     PROP. LIQ. REMAINING    =   1666.55     WGT. OF PROP. VAPOR    =   6.5528
HELIUM PART.PRESSURE  =     4.282     TOTAL PRES. *PPV+PHE*   =    16.323     NOM. OPERATING PRES.   =   19.100
HELIUM FLOW  RATE     =   .4390-01    WEIGHT OF HELIUM USED   =   .3262+00    NEW TANK PRESSURE      =   19.100
TOTAL HELIUM CONSUMED =     3.125
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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * PAGE    38
DEPT 6213         *       THE INTEGRATED MATH MODEL      * DATE 17 APR 73
EXT. 30235        *                                      * TIME 15:02:07
BLD. 104          *                AT4307                * CASE    1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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              *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***


         ******************** COAST NUMBER =   6     PRESS.SYS.NO. =   2 ********************

         *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -   HYDROGEN         FLUID TEMPERATURE        =    36.57     COAST DURATION - SEC. =     593.
WGT.OF LIQ. PROP.     = 1666.543      WGT. PROP. VAPOR         =    6.562     WGT.HELIUM IN VAPOR  =    3.125
PART.PRES.PROP.VAPOR  =   14.841      PART.PRES.HELIUM GAS     =    3.915     CURRENT TANK PRESSURE =  18.756
EFF.INTERNAL ENERGY   =  -.11063939+03

         ******************** BURN NUMBER =   6     PRESS.SYS.NO. =   2 ********************

         *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -   HYDROGEN         BURN DURATION - SEC.     =       4.     FLOWRATE FOR THRUST     =    2.498
THRUST PROP.REMAINING =   915.56      PROPELLANT IN TANK       =  1673.11     EFF. INTERNAL ENERGY    =  -.11063939+03
EFF. TANK ENERGY      =  -.18331533+06                                         TOTAL FLOWRATE          =    4.564

         *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =   16.339      TOTAL FLUIDS IN TANK     =  1656.77     PROPELLANT LIQ.+VAP.    =  1656.77
THRUST PROP.REMAINING =   906.62      NEW EFF. TANK DENSITY    =   3.6568     PART.PRES.PROP.VAPOR    =   14.773
NEW INTERNAL ENERGY   =  -.11064647+03

         *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =    36.54      STORED HELIUM TEMP.      =    40.00     NEW TANK ULLAGE VOL.    =   82.200
NEW PROP. LIQ. VOLUME =   370.86      PROP. LIQ. REMAINING     =  1649.92     WGT. OF PROP. VAPOR     =   6.8510
HELIUM PART.PRESSURE  =    4.327      TOTAL PRES. *PPV+PHE*    =   18.504     NOM. OPERATING PRES.    =   19.100
HELIUM FLOW  RATE     =  .5178-01     WEIGHT OF HELIUM USED    =  .1854+00    NEW TANK PRESSURE       =   19.100
TOTAL HELIUM CONSUMED =    3.311
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER = 7 PRESS.SYS.NO. = 2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -   HYDROGEN        FLUID TEMPERATURE      =    36.55     COAST DURATION - SEC. =      536.
WGT.OF LIQ. PROP.    = 1649.908      WGT. PROP. VAPOR       =    6.858     WGT.HELIUM IN VAPOR  =     3.311
PART.PRES.PROP.VAPOR =   14.791      PART.PRES.HELIUM GAS   =    3.953     CURRENT TANK PRESSURE =   18.744
EFF.INTERNAL ENERGY  =   -.11063599+03
```

******************** BURN NUMBER = 7 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -   HYDROGEN        BURN DURATION - SEC.   =      66.     FLOWRATE FOR THRUST    =     2.498
THRUST PROP.REMAINING =   906.62      PROPELLANT IN TANK     =  1656.77     EFF. INTERNAL ENERGY   = -.11063599+03
EFF. TANK ENERGY     =   -.15012108+06                                     TOTAL FLOWRATE         =     4.564
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN =  301.686      TOTAL FLUIDS IN TANK   =  1355.08     PROPELLANT LIQ.+VAP.   =   1355.08
THRUST PROP.REMAINING =  741.53      NEW EFF. TANK DENSITY  =   2.9910     PART.PRES.PROP.VAPOR   =    13.513
NEW INTERNAL ENERGY  =   -.11078394+03
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =   36.00      STORED HELIUM TEMP.    =    40.00     NEW TANK ULLAGE VOL.   =   152.365
NEW PROP. LIQ. VOLUME =  300.69      PROP. LIQ. REMAINING   =  1343.37     WGT. OF PROP. VAPOR    =   11.7113
HELIUM PART.PRESSURE =    5.587      TOTAL PRES. *PPV+PHE*  =   15.613     NOM. OPERATING PRES.   =    19.100
HELIUM FLOW RATE     =  .6976-01     WEIGHT OF HELIUM USED  =  .4611+01    NEW TANK PRESSURE      =    19.100
TOTAL HELIUM CONSUMED =   7.922
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NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * * PAGE    40
DEPT 6213         *        THE INTEGRATED MATH MODEL          * DATE 17 APR 73
EXT. 30235        *                                           * TIME 15:02:08
BLD. 104          *                   AT4307                  * CASE     1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                       ACPS - TEST DEMONSTRATION PROBLEM

          *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER =   8     PRESS.SYS.NO. =   2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -   HYDROGEN        FLUID TEMPERATURE      =    36.09    COAST DURATION - SEC. =     714.
WGT.OF LIQ. PROP.      = 1343.198    WGT. PROP. VAPOR       =    11.882   WGT.HELIUM IN VAPOR   =    7.922
PART.PRES.PROP.VAPOR   =   13.730    PART.PRES.HELIUM GAS   =     5.041   CURRENT TANK PRESSURE =   18.771
EFF.INTERNAL ENERGY    =   -.11076687+03

******************** BURN NUMBER =   8     PRESS.SYS.NO. =   2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -   HYDROGEN        BURN DURATION - SEC.   =      32.    FLOWRATE FOR THRUST     =    2.498
THRUST PROP.REMAINING =  741.53      PROPELLANT IN TANK     =  1355.08    EFF. INTERNAL ENERGY    =   -.11076687+03
EFF. TANK ENERGY       =   -.13372769+06                                  TOTAL FLOWRATE          =    4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN  =  147.420     TOTAL FLUIDS IN TANK   =  1207.66    PROPELLANT LIQ.+VAP.    =  1207.66
THRUST PROP.REMAINING =  660.86      NEW EFF. TANK DENSITY  =   2.6656    PART.PRES.PROP.VAPOR    =   12.991
NEW INTERNAL ENERGY    =   -.11073291+03

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =   35.76      STORED HELIUM TEMP.    =    40.00    NEW TANK ULLAGE VOL.    =  186.312
NEW PROP. LIQ. VOLUME =  266.75      PROP. LIQ. REMAINING   =  1193.84    WGT. OF PROP. VAPOR     =  13.8188
HELIUM PART.PRESSURE  =    6.109     TOTAL PRES. *PPV+PHE*  =   17.075    NOM. OPERATING PRES.    =   19.100
HELIUM FLOW  RATE     =   .8258-01   WEIGHT OF HELIUM USED  =   .2667+01  NEW TANK PRESSURE       =   19.100
TOTAL HELIUM CONSUMED =   10.589
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ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

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******************** COAST NUMBER =    9     PRESS.SYS.NO. =    2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -    HYDROGEN          FLUID TEMPERATURE        =     35.82     COAST DURATION - SEC. =      568.
WGT.OF LIQ. PROP.      = 1193.713       WGT. PROP. VAPOR         =    13.947     WGT.HELIUM IN VAPOR  =    10.589
PART.PRES.PROP.VAPOR   =   13.124       PART.PRES.HELIUM GAS     =     5.469     CURRENT TANK PRESSURE =   18.593
EFF.INTERNAL ENERGY    =    -.11071768+03

******************** BURN NUMBER =    9     PRESS.SYS.NO. =    2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -    HYDROGEN          BURN DURATION - SEC.     =      104.     FLOWRATE FOR THRUST     =    2.498
THRUST PROP.REMAINING =    660.86       PROPELLANT IN TANK       =   1207.66     EFF. INTERNAL ENERGY    =   -.11071768+03
EFF. TANK ENERGY       =    -.80652389+05                                        TOTAL FLOWRATE          =    4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN   =   475.122      TOTAL FLUIDS IN TANK     =    732.54     PROPELLANT LIQ.+VAP.    =   732.54
THRUST PROP.REMAINING  =    400.86      NEW EFF. TANK DENSITY    =    1.6169     PART.PRES.PROP.VAPOR    =   11.072
NEW INTERNAL ENERGY    =    -.11009992+03

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE  =     34.83      STORED HELIUM TEMP.      =     40.00     NEW TANK ULLAGE VOL.    =  294.714
NEW PROP. LIQ. VOLUME  =    158.35      PROP. LIQ. REMAINING     =    713.62     WGT. OF PROP. VAPOR     =  18.9178
HELIUM PART.PRESSURE   =     8.028      TOTAL PRES. *PPV+PHE*    =    14.433     NOM. OPERATING PRES.    =   19.100
HELIUM FLOW  RATE      =    .1096+00    WEIGHT OF HELIUM USED    =   .1141+02    NEW TANK PRESSURE       =   19.100
TOTAL HELIUM CONSUMED  =    22.001
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ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

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******************** COAST NUMBER =  10     PRESS.SYS.NO. =   2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -   HYDROGEN        FLUID TEMPERATURE      =    35.14     COAST DURATION - SEC. =    1876.
WGT.OF LIQ. PROP.    =  712.672      WGT. PROP. VAPOR       =   19.866     WGT.HELIUM IN VAPOR  =   22.001
PART.PRES.PROP.VAPOR =   11.689      PART.PRES.HELIUM GAS   =    7.050     CURRENT TANK PRESSURE =   18.739
EFF.INTERNAL ENERGY  =   -.11001698+03

******************** BURN NUMBER =  10     PRESS.SYS.NO. =   2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -   HYDROGEN        BURN DURATION - SEC.   =      32.     FLOWRATE FOR THRUST    =     2.498
THRUST PROP.REMAINING =  400.86      PROPELLANT IN TANK     =   732.54     EFF. INTERNAL ENERGY   =  -.11001698+03
EFF. TANK ENERGY     =   -.64112928+05                                     TOTAL FLOWRATE         =     4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN =  145.594      TOTAL FLUIDS IN TANK   =   586.94     PROPELLANT LIQ.+VAP.   =    586.94
THRUST PROP.REMAINING =  321.19      NEW EFF. TANK DENSITY  =   1.2955     PART.PRES.PROP.VAPOR   =    11.374
NEW INTERNAL ENERGY  =   -.10923182+03

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =   34.98      STORED HELIUM TEMP.    =    40.00     NEW TANK ULLAGE VOL.   =  327.458
NEW PROP. LIQ. VOLUME =  125.60      PROP. LIQ. REMAINING   =   565.41     WGT. OF PROP. VAPOR    =  21.5356
HELIUM PART.PRESSURE =    7.726      TOTAL PRES. *PPV+PHE*  =   17.689     NOM. OPERATING PRES.   =   19.100
HELIUM FLOW  RATE    =   .4791-01    WEIGHT OF HELIUM USED  =   .1528+01   NEW TANK PRESSURE      =   19.100
TOTAL HELIUM CONSUMED =   23.529
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                                    ACPS - TEST DEMONSTRATION PROBLEM

                          *** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

              ******************** COAST NUMBER =  11     PRESS.SYS.NO. =   2 ********************

             *** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -   HYDROGEN          FLUID TEMPERATURE       =     43.03     COAST DURATION - SEC. =  571048.
WGT.OF LIQ. PROP.      =  522.176      WGT. PROP. VAPOR        =    64.768     WGT.HELIUM IN VAPOR   =  23.529
PART.PRES.PROP.VAPOR   =   37.502      PART.PRES.HELIUM GAS    =     8.313     CURRENT TANK PRESSURE =   45.816
EFF.INTERNAL ENERGY    =   -.77723276+02

             *** POST VENT CONDITIONS ***

TANK VENT PRESSURE     =    24.10      WGT.VENTED FLUIDS       =     54.91     WGT.OF LIQ.IN TANK    =  495.18
WGT.VAPOR IN TANK      =   36.853      WGT.HELIUM IN VAPOR     =   13.105      TOTAL FLUIDS IN TANK  =   545.14
PART.PRES.PROP.VAPOR   =   19.762      PART.PRES.HELIUM GAS    =     4.338     VENTED TANK PRESSURE  =   24.100
EFF.INTERNAL ENERGY    =   -.94977942+02

              ******************** BURN NUMBER =  11     PRESS.SYS.NO. =   2 ********************

             *** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -   HYDROGEN          BURN DURATION - SEC.    =       16.     FLOWRATE FOR THRUST   =    2.498
THRUST PROP.REMAINING  =   321.19      PROPELLANT IN TANK      =    495.18     EFF. INTERNAL ENERGY  =   -.94977942+02
EFF. TANK ENERGY       =   -.45225773+05                                       TOTAL FLOWRATE        =    3.851

             *** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN   =   62.225      TOTAL FLUIDS IN TANK    =    482.91     PROPELLANT LIQ.+VAP.  =   469.81
THRUST PROP.REMAINING  =   280.83      NEW EFF. TANK DENSITY   =    1.0370     PART.PRES.PROP.VAPOR  =   20.339
NEW INTERNAL ENERGY    =   -.93651651+02

             *** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE  =    38.89      STORED HELIUM TEMP.     =     40.00     NEW TANK ULLAGE VOL.  =  354.452
NEW PROP. LIQ. VOLUME  =    98.61      PROP. LIQ. REMAINING    =    430.36     WGT. OF PROP. VAPOR   =  39.4450
HELIUM PART.PRESSURE   =    3.862      TOTAL PRES. *PPV+PHE*   =    24.201     NOM. OPERATING PRES.  =   19.100
HELIUM FLOW  RATE      =    .0000      WEIGHT OF HELIUM USED   =     .0000     NEW TANK PRESSURE     =   24.201
TOTAL HELIUM CONSUMED  =   23.529
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ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** COAST NUMBER = 12 PRESS.SYS.NO. = 2 ********************

*** PRE- OR NON-VENT CONDITIONS ***

```
FLUID CONSIDERED -    HYDROGEN      FLUID TEMPERATURE       =    39.03    COAST DURATION - SEC. =    9584.
WGT.OF LIQ. PROP.      =  429.512   WGT. PROP. VAPOR        =    40.298   WGT.HELIUM IN VAPOR   =   13.105
PART.PRES.PROP.VAPOR   =   20.813   PART.PRES.HELIUM GAS    =     3.875   CURRENT TANK PRESSURE =   24.688
EFF.INTERNAL ENERGY    =  -.92990993+02
```

*** POST VENT CONDITIONS ***

```
TANK VENT PRESSURE     =   24.10    WGT.VENTED FLUIDS       =     1.40    WGT.OF LIQ.IN TANK     =  428.93
WGT.VAPOR IN TANK      =   39.484   WGT.HELIUM IN VAPOR  =   12.654      TOTAL FLUIDS IN TANK   =  481.07
PART.PRES.PROP.VAPOR   =   20.317   PART.PRES.HELIUM GAS    =     3.783   VENTED TANK PRESSURE   =   24.100
EFF.INTERNAL ENERGY    =  -.93436532+02
```

******************** BURN NUMBER = 12 PRESS.SYS.NO. = 2 ********************

*** COMPUTE ENERGY BALANCE FOR BURN ***

```
FLUID CONSIDERED -    HYDROGEN      BURN DURATION - SEC.    =     100.    FLOWRATE FOR THRUST    =    2.498
THRUST PROP.REMAINING =  280.83     PROPELLANT IN TANK      =   428.93    EFF. INTERNAL ENERGY   =  -.93436532+02
EFF. TANK ENERGY       =  -.49783530+04                                   TOTAL FLOWRATE         =    3.815
```

*** COMPUTE RESULTING TANK CONDITIONS ***

```
PROPELLANT WITHDRAWN  =  381.474    TOTAL FLUIDS IN TANK  =     99.59     PROPELLANT LIQ.+VAP.   =   86.94
THRUST PROP.REMAINING =   31.07     NEW EFF. TANK DENSITY =     .1919     PART.PRES.PROP.VAPOR   =   17.623
NEW INTERNAL ENERGY   =  -.49986179+02
```

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

```
TANK LIQ. TEMPERATURE =   37.67     STORED HELIUM TEMP.    =    40.00     NEW TANK ULLAGE VOL.   =  443.180
NEW PROP. LIQ. VOLUME =    9.88     PROP. LIQ. REMAINING   =    43.56     WGT. OF PROP. VAPOR    =   43.3789
HELIUM PART.PRESSURE  =   2.888     TOTAL PRES. *PPV+PHE*  =    20.512    NOM. OPERATING PRES.   =   19.100
HELIUM FLOW RATE      =   .0000     WEIGHT OF HELIUM USED  =    .0000     NEW TANK PRESSURE      =   20.512
TOTAL HELIUM CONSUMED =   23.529
```

ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

******************** FINAL ENGINE SHUTDOWN PROPELLANT TANK CONDITIONS ********************

*** COMPUTE FINAL TANK CONDITIONS ***

```
FLUID CONSIDERED -   HYDROGEN       FLUID TEMPERATURE      =    37.68     COAST DURATION - SEC. =      300.
WGT.OF LIQ. PROP.    =   43.505     WGT. PROP. VAPOR       =   43.436     WGT.HELIUM IN VAPOR  =   12.654
PART.PRES.PROP.VAPOR =   17.649     PART.PRES.HELIUM GAS   =    2.889     CURRENT TANK PRESSURE =   20.537
EFF.INTERNAL ENERGY  =   -.49874429+02

FINAL TANK TEMP.     =   37.684     TOTAL VENTED GAS WGT. =    56.304     WGT. OF GAS RESIDUALS =   56.090
WGT. OF LIQ.RESIDUALS =  43.505
```

*** COMPUTE PRESSURIZATION SYSTEM WEIGHT ***

```
TOTAL HELIUM GAS REQD =  23.529     WGT.PRESSURANT SYSTEM =    75.294
```

```
NAME  USERS NAME  * * * * * * * * * * * * * * * * * * * * * * * * * PAGE     46
DEPT 6213         *        THE INTEGRATED MATH MODEL        * DATE 17 APR 73
EXT. 30235        *                                         * TIME 15:02:10
BLD. 104 .        *                 AT4307                  * CASE    1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

ACPS - TEST DEMONSTRATION PROBLEM

*** FINAL TANK SIZING CALCULATIONS ***

	OXYGEN	HYDROGEN
NUMBER OF TANKS	1	1
MATERIAL TYPE	2	2
INSULATION TYPE	2	2
FLUID WGT. (TOTAL)	.543008+04	.225820+04
FLUID VOLUME /TANK	.766785+02	.509397+03
WGT ADDED CYL SECT	.544434+00	.234124+02
DIAMETER (FT)/TANK	.506600+01	.500000+01
SURFACE AREA /TANK	.892918+02	.446301+03
TANK VOLUME / TANK	.790500+02	.525151+03
TANK WGT. (LB) TOT	.448476+02	.221240+03
INSUL. THICKNESS	.200000+01	.200000+01
INSUL. WT (LB) TOT	.364608+02	.182240+03

ACPS - TEST DEMONSTRATION PROBLEM

*** ACCUMULATOR SIZING CALCULATIONS ***

	OXYGEN	HYDROGEN
NUMBER OF TANKS	1	1
MATERIAL TYPE	1	1
INSULATION TYPE	4	4
WGT ADDED CYL SECT	.000000	.000000
DIAMETER (FT)/TANK	.168389+01	.517344+01
SURFACE AREA /TANK	.890794+01	.840832+02
TANK VOLUME / TANK	.250000+01	.725000+02
TANK WGT. (LB) TOT	.347921+02	.100850+04
INSUL. THICKNESS	.200000+01	.200000+01
INSUL. WT (LB) TOT	.124117+01	.117156+02
GAS RESIDUALS WT.	.683188+02	.695175+02

```
NAME  USERS NAME   * * * * * * * * * * * * * * * * * * * * * * * * * PAGE     48
DEPT 6213          *        THE INTEGRATED MATH MODEL       * DATE 17 APR 73
EXT. 30235         *                                        * TIME 15:02:10
BLD. 104           *                 AT4307                 * CASE      1
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                          ACPS - TEST DEMONSTRATION PROBLEM

             *** TANK PROPELLANT ACQUISITION DEVICE COMPUTATION***

                                                  OXYGEN            HYDROGEN

  TYPE ACQ. DEVICE                             SURF TENSION       SURF TENSION
  DEVICE WT. (LBS)                              .190053+02         .751981+02
  TRAPPED BY DEVICE                             .112225+03         .435049+02
  RESID. PROPELLANT                             .902258+02         .435049+02
```

ACPS - TEST DEMONSTRATION PROBLEM

*** COMPONENT WEIGHT SUMMARY ***

... OXIDYZER ...					... FUEL ...			
COMPONENT	CODE	COMPONENT WT. (LBS)	INSULATION WT. (LBS)		COMPONENT	CODE	COMPONENT WT. (LBS)	INSULATION WT. (LBS)
LINE	LN01	4.009	.188	.	LINE	LN21	3.508	.920
TEE	FT01	.433	.000	.	TEE	FT21	.331	.000
LINE	LN02	5.466	.256	.	LINE	LN22	4.783	1.254
TAP	FT02	.342	.000	.	TAP	FT22	.262	.000
LINE	LN03	.875	.041	.	LINE	LN23	.765	.201
VALVE	IV01	6.314	.000	.	VALVE	IV02	6.121	.000
LINE	LN04	.437	.021	.	LINE	LN24	.383	.100
VALVE	CV02	4.406	.000	.	VALVE	CV04	4.255	.000
LINE	LN05	1.458	.068	.	LINE	LN25	1.275	.334
TAP	FT03	.342	.000	.	TAP	FT23	.262	.000
LINE	LN06	.729	.034	.	LINE	LN26	.638	.167
REG	PR01	9.630	.000	.	REG	PR02	9.392	.000
LINE	LN07	1.913	.051	.	LINE	LN27	1.674	.251
ACCUM	AC01	34.792	1.241	.	ACCUM	AC02	1008.496	11.716
LINE	LN08	1.531	.041	.	LINE	LN28	1.148	.182
HEX	HX01	22.655	.000	.	HEX	HX03	61.123	.000
LINE	LN09	.383	.011	.	LINE	LN29	.574	.091
VALVE	CV01	9.000	.000	.	VALVE	CV03	9.214	.000
LINE	LN10	.383	.011	.	LINE	LN30	.574	.091
PUMP	HP01	73.362	.000	.	PUMP	HP02	34.569	.000
LINE	LN11	4.373	.213	.	LINE	LN31	4.373	1.094
VALVE	SV01	4.142	.000	.	VALVE	SV02	4.406	.000
LINE	LN12	.547	.025	.	LINE	LN32	.437	.109
TAP	FT04	.534	.000	.	TAP	FT24	.342	.000
LINE	LN13	1.093	.050	.	LINE	LN33	.875	.219
TANK	TK01	63.853	36.461	.	TANK	TK02	296.438	182.240

*** COMPONENT WEIGHT SUMMARY TOTALS ***

CONSUMER WEIGHT - LBS	.159375+03
OXIDYZER SYSTEM WT. -LBS	.253000+03
OXID INSULATION WT - LBS	.387139+02
FUEL SYSTEM WT. - LBS	.145622+04
FUEL INSULATION WT - LBS	.198969+03
TOTAL SYSTEM WT. - LBS	.210628+04

@ FIN

Section 3
REFERENCES

1.0 External Pressurization Systems for Cryogenic Storage System, AR-71-7535, Design Reference Manual, AiResearch Mfg Co., 10 Sept 1971 (Section 6)

1.4-1 UNIVAC 1100 Series Systems, Manual UP-4144 (Rev 2), Section 10.2 – COLLECTOR Processor, Sperry-Rang Corporation.

2.1-1 "Shuttle Cryogenic Supply System Optimization Study," Interim Report, Volume II, Section 9, ACPS; Contract NAS 9-11330, LMSC-SS-1109, 15 Dec 1971