NASA CR-134389

FINAL REPORT FOR NASA-JSC
CONTRACT NO. NAS9-12580

SKYLAB EXTRAVEHICULAR MOBILITY UNIT THERMAL SIMULATOR

FINAL REPORT NO. T194-06

July 1974

Submitted by:

VOUGHT SYSTEMS DIVISION
LTV Aerospace Corporation
P. O. Box 5907 - Dallas, Texas 75222

To

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Johnson Space Center - Houston, Texas

(NASA-CR-134389) SKYLAB EXTRAVEHICULAR
MOBILITY UNIT THERMAL SIMULATOR Final
Report (LTV Aerospace Corp.) 111 p HC
$8.75 CSCL 14B
N74-31743
Unclas
G3/11 47011

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1.0 SUMMARY

This report presents the analytical methods, thermal model, and user's instructions for the Skylab Extravehicular Mobility Unit (SEMU) routine. This digital computer program was developed for detailed thermal performance predictions of the SEMU on the NASA-JSC Univac 1108 computer system. It accounts for conductive, convective, and radiant heat transfer as well as fluid flow and special component characterization. The program provides thermal performance predictions for a 967 node thermal model in one thirty-sixth (1/36) of mission time when operated at a calculating interval of three minutes (mission time).

The program has the operational flexibility to : (1) accept card or magnetic tape data input for the thermal model describing the SEMU structure, fluid systems, crewman and component performance, (2) accept card and/or magnetic tape input of internally generated heat and heat influx from the space environment, and (3) output tabular or plotted histories of temperature, flow rates, and other parameters describing system operating modes.

The user's manual and supporting appendices provide a complete program description including instructions for problem submission in compliance with current NASA-JSC Computation and Analysis Division procedures.

This document is a final report defining the final version of the SEMU routine and thermal model.

2.0 INTRODUCTION

This report describes the Skylab EMU digital simulator being developed by the Environment Control/Life Support Group of the Vought Systems Division (VSD), of LTV Aerospace Corporation. The routine was created by modifying the Apollo EMU simulator which was used to analyze an astronaut during lunar extravehicular activities. The thermal model was created from the hardware manufacturer's (AiResearch) drawings and component specifications.

The routine simulates the suited crewman using the Pressure Control Unit (PCU) or the Secondary Oxygen Pack in a vacuum environment. A companion routine (EHFR-5) documented in Reference [11] supplies incident and absorbed heat flux on the Skylab EMU exterior surfaces (nodes). EMU flux self-blockage and multiple reflections effects are accounted for by the EHFR-5 while direct workstation surface/EMU exchange is calculated in the EMU digital simulator.

Program checkout involved comparison of component simulation results to performance specifications. Flow system performance has been verified using data from the Development Verification Tests conducted by NASA.

3.0 ANALYTICAL METHODS

Sections 3.1 through 3.4 describe generalized heat balance and flow system calculation methods used in this computer routine which may be applied to other thermal simulation models. Sections 3.5 through 3.11 describe specialized analytical characterizations which have been created for the Skylab Extravehicular Mobility Unit (EMU) program formulation.

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

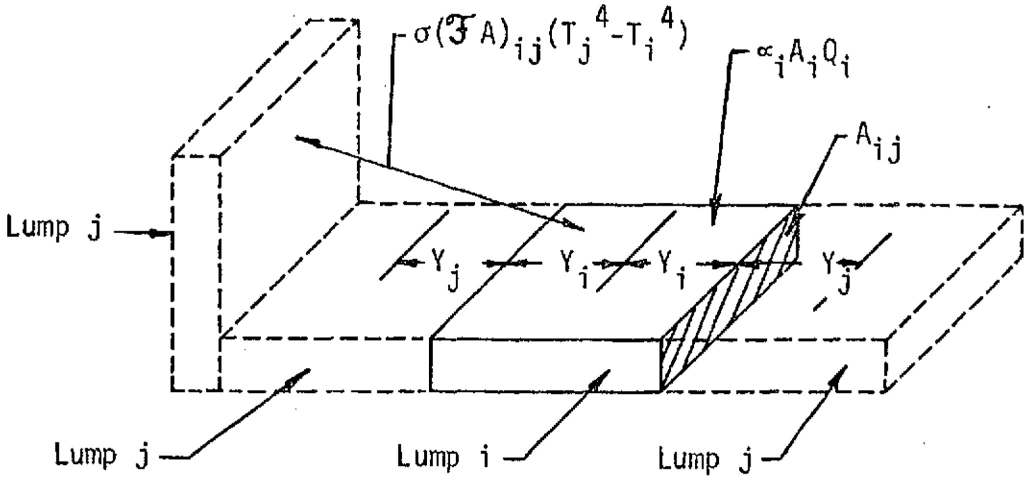
3.1 Thermal Analysis

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

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

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

3.1.1 Structure Lumps (illustrated by the sketch below)



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

Heat Stored Net Heat Flux

Equation (1) may be rewritten in the form:

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

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

where: i = lump number (data input)

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

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

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

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

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

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

$$U_{ij} = \frac{1}{\frac{R_i}{k_i} + \frac{R_j}{k_j}} \tag{3}$$

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

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

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

where:

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

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

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

K_i = is the thermal conductivity of lump i

K_j = is the thermal conductivity of lump j

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

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

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

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

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

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

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

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

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

3.1.2 Tube Lumps

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

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

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

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

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

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

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

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

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

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

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

3.1.3 Fluid Lumps

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

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

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

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

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

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

3.2 Convergence and Accuracy Criteria

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

3.2.1 Stability

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

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

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

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

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

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

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

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

3.2.2 Oscillation

Even though a solution is stable, it may oscillate around a correct mean value. An oscillatory condition is dependent on the problem boundary conditions and the node spacing. In cases where oscillation occurs, this undesirable condition may be damped or eliminated by use of a $\Delta\tau$ smaller than the limiting value specified by equation (9). This is accommodated by the input of TINCMN described in Section 3.2.4.

3.2.3 Truncation Error

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

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

3.2.4 Steady State Nodes

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

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

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

Substitute (11) into (10) and

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

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

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

3.3 Fluid Heat Transfer Coefficient

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

The use of theoretical solutions based on the assumption of constant fluid properties may introduce errors for fluids where viscosity is a strong function of temperature. The EMU uses two fluids; oxygen and water, the latter has a significant viscosity variation with temperature. This variation is accounted for through curve data input (Section 5.7.15).

3.3.1 Laminar Flow

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

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

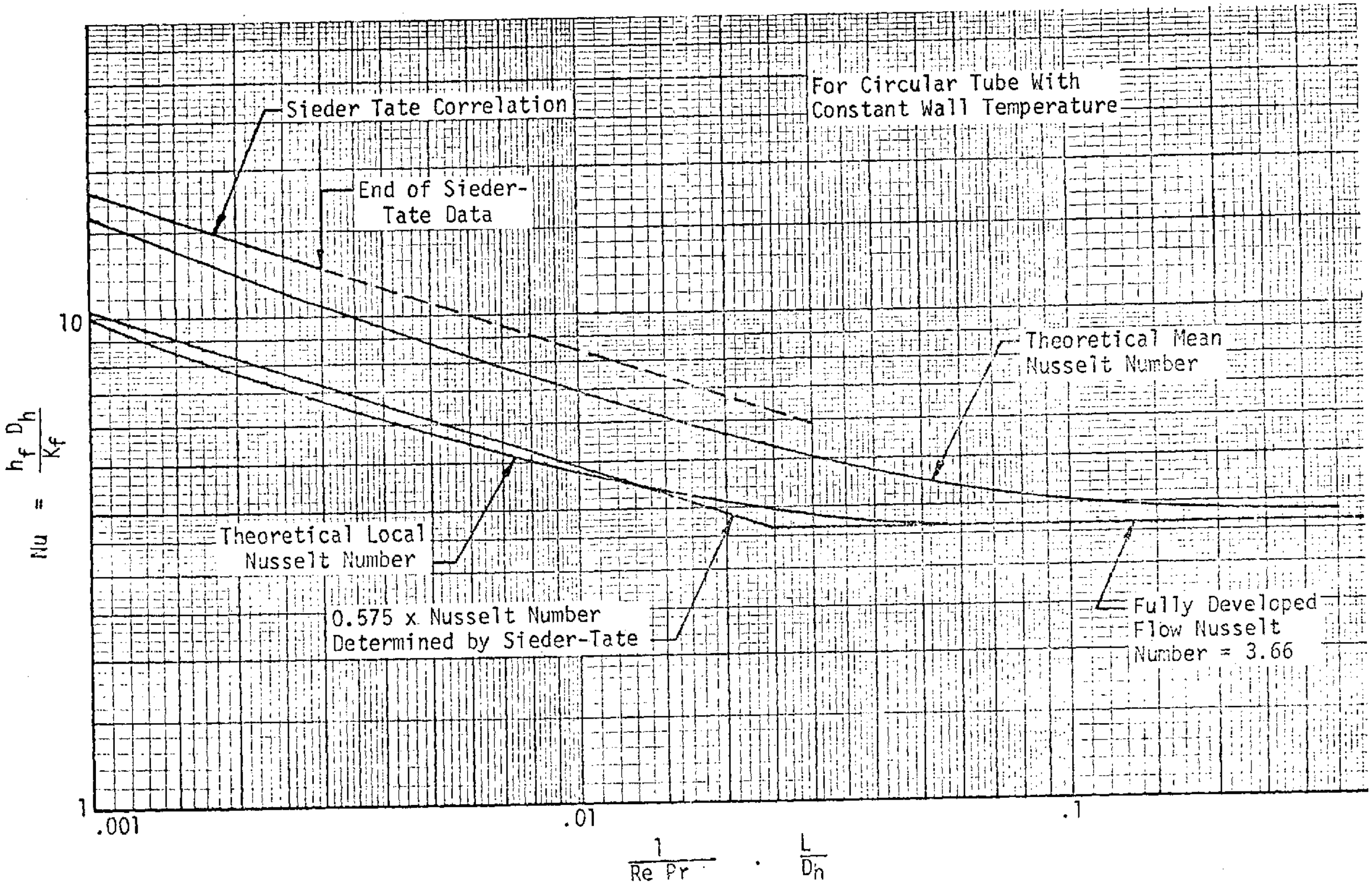


FIGURE 3-1 LAMINAR FLOW NUSSELT NUMBERS

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

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

where:

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

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

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

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

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

3.3.2 Turbulent Flow

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

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

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

3.4 Fluid Pressure Loss

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

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

where

f = friction factor 16/Re for Reynolds Numbers less than 2000 and is read from input data for Reynolds Numbers greater than 2000 (NFFC, Fluid Data Card 2). The laminar flow friction factor may also be multiplied by FRE, Fluid Data Card 2 to account for non-circular pipe flow.

FLL = fluid lump length (not necessarily equal to tube lump length)

K = number of fluid dynamic head losses

$\dot{w}$ = tube fluid flow rate, lb/hr

WP = wetted perimeter, ft (data input - in)

CSA = fluid cross section area, ft^2 (data input - in^2)

D_h = tube hydraulic diameter - 4 CSA/WP, ft

ρ = fluid density, lb/ft^3

v = fluid velocity, ft/hr

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

3.5 Flow System Characterization

There are three flow systems in the PCU and SOP (Figures 3-2 and 3-3) and all three are simulated in the Skylab EMU simulator. Figure 3-2 shows the oxygen supply systems which provide life sustaining oxygen to the crewman at a comfortable temperature. Both the primary Airlock Module (AM) through PCU oxygen system and the emergency SOP oxygen system are blowdown

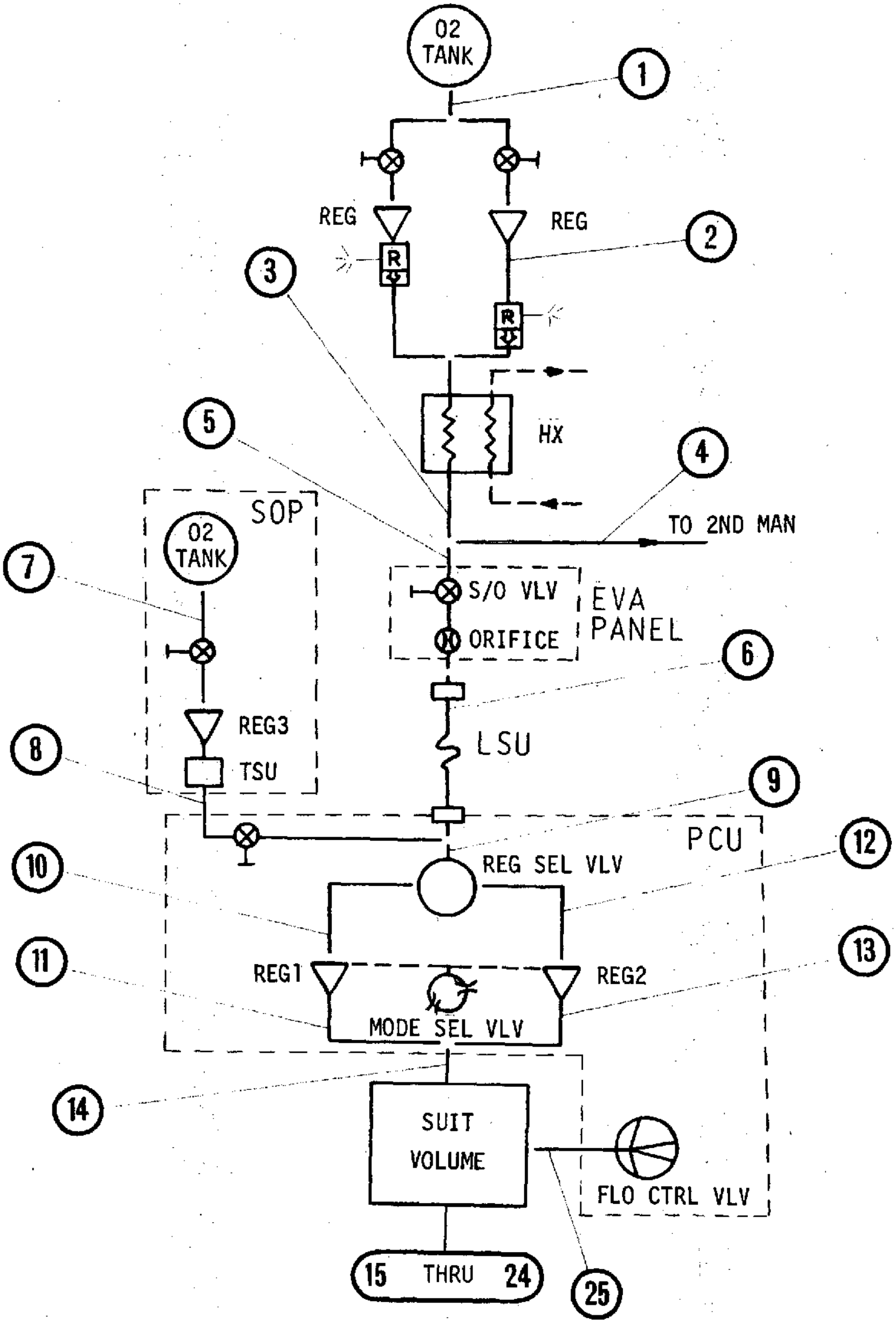


FIGURE 3-2 SKYLAB EMU OXYGEN SUPPLY

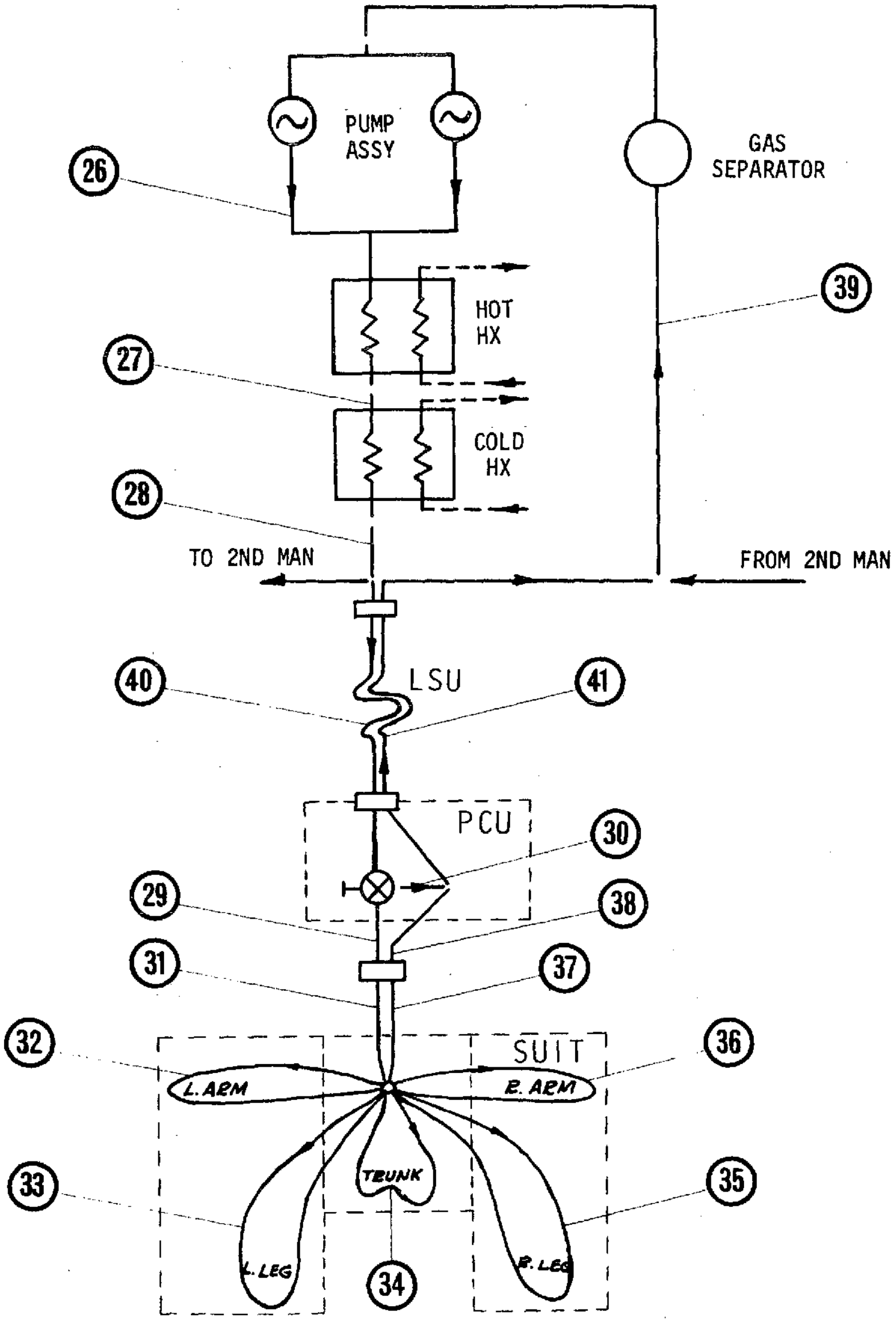


FIGURE 3-3 SKYLAB EMU SUIT COOLING LOOP

systems. All oxygen flow regardless of origination (AM or SOP) is regulated by the PCU and controlled by the flow control valve downstream of the crewman and pressure suit. The primary oxygen system supplies flow to two crewmen through the EVA panel. When the SOP is activated, the expanded/cooled oxygen gas leaving the SOP regulator flows through a thermal storage unit (TSU) to raise the oxygen temperature before it enters the suit.

The suit cooling loop (Figure 3-3) is a closed system which circulates water through AM heat exchangers and the crewman's liquid cooling garment (LCG). As with the oxygen system, two crewmen are supplied cooling water simultaneously with this system. The crewman varies his cooling by reducing the water flow through his LCG.

3.6 Crewman Characterization

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

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

3.7 Oxygen Bottle Blowdown Characterization

The primary oxygen supply to the PCU is from the Skylab vehicle while an emergency or purge supply (SOP) is carried by the crewman. The flowrate from the SOP oxygen bottles is known as a function of time.

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

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

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

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

3.8 Heat Leak Calculation

The EMU simulator has the capability of calculating the heat flux between any two nodes. Data input format (see Section 5.7.6) permits the user to group pairs of nodes to create the desired control volume. Figure 3-4 presents a typical heat leak model to calculate the heat transferred across the boundary of a control volume. The input data would be set up with one group consisting of five heat leak paths. Semantically, the analysis per heat leak path is:

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

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

In the SEMU simulator, heat leak groups for the Skylab Extravehicular Visor Assembly (SEVA), Pressure Garment Assembly (PGA), and several other components of interest are set up. There is no program limit on the number of groups or the number of heat leak paths (node pairings) per group. One restriction is made; and it requires the first group to be the SEVA heat leak group. This requirement arises because the SEVA visor material transmits solar wavelength energy through "node j". The energy entering the SEVA through the visors is automatically added to the first heat leak group. There are other unique features associated with the visor analysis as explained in Section 3.10.

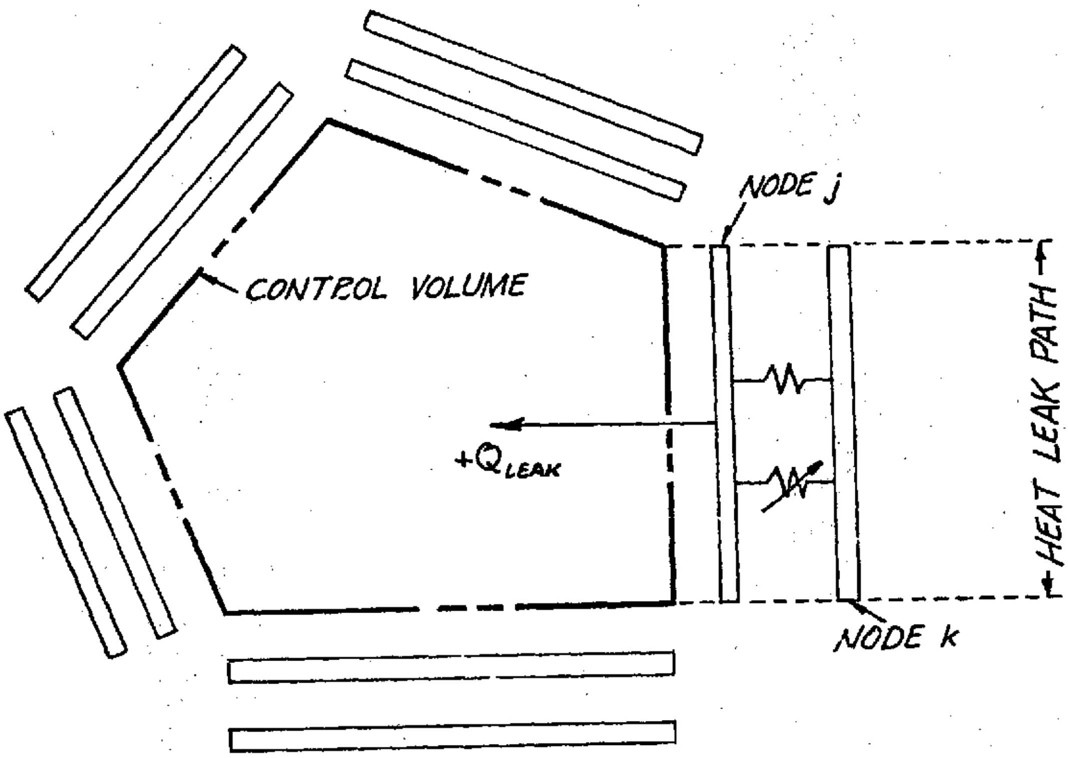


FIGURE 3-4 TYPICAL HEAT LEAK MODEL

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

3.9 Heat Storage Calculation

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

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

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

3.10 SEVA Visor Analysis

The crewman's face is protected by two retractable visors and a pressure bubble. The retractable visors have special coatings which transmit radiation in the visible spectrum and block infrared radiation. A visor analysis is required to calculate the fraction of external incident energy absorbed by each visor and the crewman's face. The analysis is complicated by the fact that the visors may be positioned in three unique configurations (see Figure 3-5); both visors down, sun visor up, and both sun visor and impact visor up.

The fraction of incident energy absorbed by a visor surface can be determined from coating properties and has been done by A. J. Chapman as recorded in informal documentation received October 1966. Chapman numbers the surfaces 1 to seven with one being the crewman's face and seven, the outer surface of the sun visor (Figure 3-5). This same convention is followed below as well as Chapman's notation of the energy fraction. $F_i^{(k)}$ refers to the fraction of the external incident radiation on the ith surface for the kth visor configuration. To shorten the equations we define R_{ij} as the fraction, $1/(1-\rho_i\rho_j)$, where ρ is the solar reflectivity and i and j are visor surfaces.

Each node on the visor and helmet surfaces is assigned a position number; one to the total number of nodes on the visor and helmet surfaces. In addition to a position number, the user inputs a position type (see Section 5.7.8) to associate the correct surface properties with the visor, helmet, and face nodes. The visor analysis is a two band spectral distribution analysis with the separation point between solar and infrared radiation established by the flux data input from the Environmental Heat Flux Routine (Reference 11).

With both visors retracted - n = 1

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

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

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

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

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

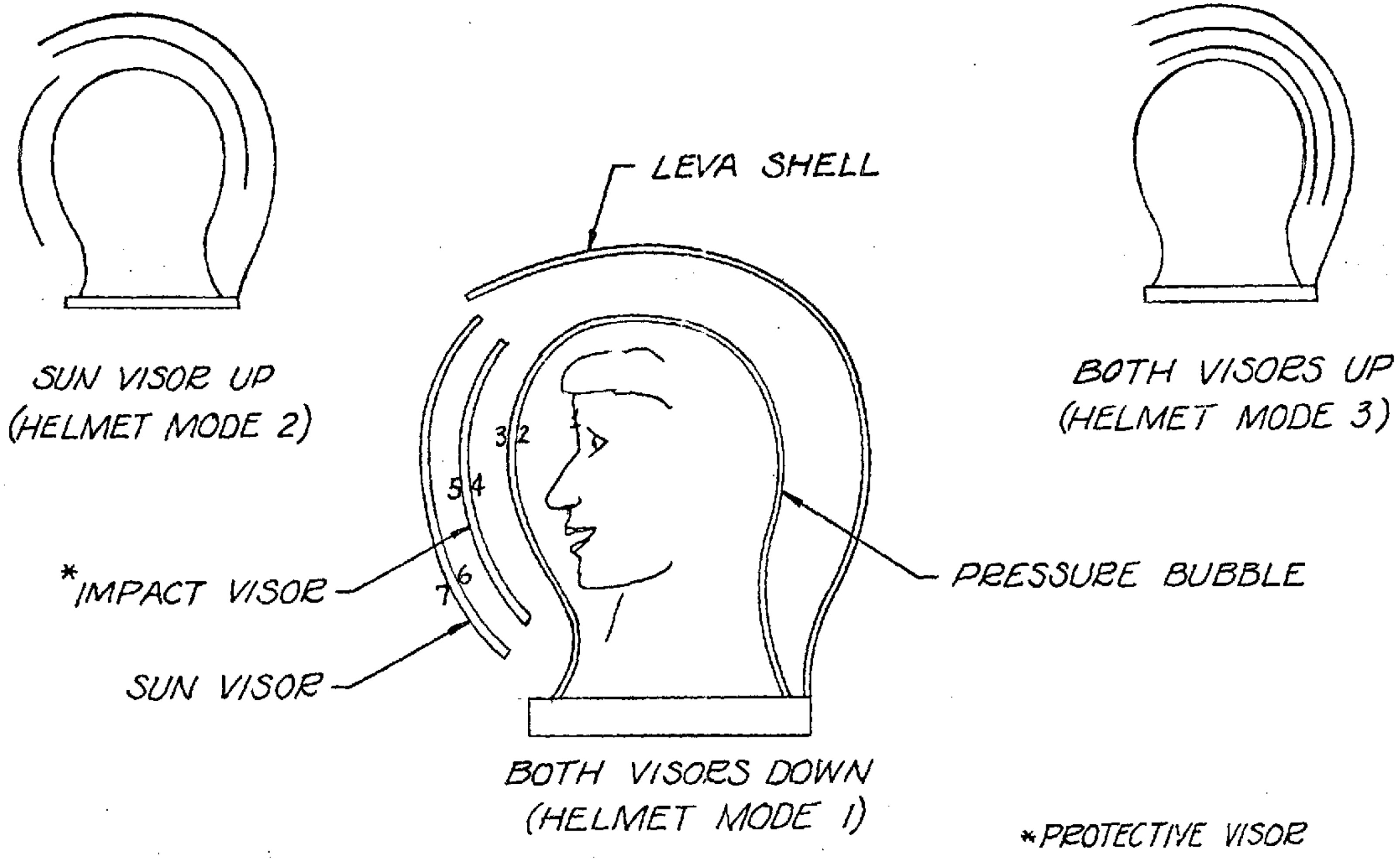


FIGURE 3-5 SKYLAB EXTRAVEHICULAR VISOR ASSEMBLY (SEVA)

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

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

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

With sun visor down - n = 3

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

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

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

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

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

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

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

3.11 Local Temperature Perturbation (LTP) Calculation

The simulator has the capability of calculating the effect of a perturbed suit condition on the crewman. By perturbed suit condition is meant the local compression of the suit against the crewman due to sitting, kneeling, gripping with the gloves, etc. The purpose of the capability is to determine crewman comfort (skin temperature below threshhold of pain) when engaged in any activity which involves "shorting" the suit multilayer insulation. Section 5.7.5 details the input data for local temperature perturbation calculations. It is important to remember when preparing data for the LTP model that this model is completely independent of the basic EMU model and has no feedback to it. Notice should be made that LTP model lump numbers are described in the regular data and that Section 5.7.5 provides additional information which identifies certain lump numbers as LTP lump numbers. All LTP Model fluid (gas) lumps must be input in tube 42 which satisfies the data input requirement for a flow tube but the order of fluid lumps in tube 42 is arbitrary.

3.12 Thermal Model Data Options

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

3.12.1 Configuration-Associated Node Identification

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

3.12.2 Heat Flux Curve Assignment

The simulator uses the Environmental Heat Flux Routine (EHFR) described in Reference 11 as a source of input flux data representing various Skylab work stations. The EHFR has geometric heat flux models of the EMU and the Orbital Work Station (OWS) which are consistent with the surface areas of the simulator baseline thermal model. Section 5.7.1, Cards 4 and 5 give instructions on the manipulation of the EHFR generated flux data actually creating heat flux curves. Although the curves have been created and are available, heat flux curve assignment data is required to apply the flux to a particular thermal model node. All EHFR input data is assigned through the data described in Section 5.7.10.

3.12.3 Prescribed Wall Temperature Data

The simulator has two types of prescribed wall temperatures excluding the contact temperature associated with the EHFR. These prescribed temperatures are designated as type numbers 10 and 11 in Sections 5.7.11 and 5.7.15. Type 10 is used to create a "deep space" node held constant at -459.69°F or other prescribed temperatures where the entire curve can be put on the data tape. Type 11 is used to input prescribed temperature either the complete curve or segments of a large curve contained on an independent input tape. Variable NPRTCD on Card 2 (Section 5.7.1) designates how the Skylab workstation temperatures may be input. The simulator will interrogate NPRTCD and, if 1, will read additional temperature data when the largest time of the segment of the curve in the computer is less than mission time.

3.12.4 Time Variant Node Data

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

3.12.5 Special Tube/Fluid Connection Data

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

4.0 BASELINE THERMAL MODEL

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

1. ITMG - Integrated Thermal/Meteoroid Garment (3 layer)
2. PGA - Pressure Garment Assembly
3. LCG - Liquid Cooling Garment
4. Boots - Skylab Configuration
5. Gloves - Extravehicular Configuration
6. SEVA - Skylab Extravehicular Visor Assembly
7. PCU - Pressure Control Unit
8. SOP - Secondary Oxygen Pack
9. CREWMAN - 41 Node Man (Ref. 10)
10. SKYLAB

The model is composed of the three types of nodes described in Section 3.1. The number of flow tubes in the simulator is 42. The simulator is programmed to expect the number of tubes indicated above and program modifications are required to change the tube arrangement. Although the user is limited in the extent to which he can change the basic thermal model, important options are open as to the fineness of the model breakdown and the amount and type of data output.

The ITMG, PGA, Boots, and Gloves were broken up into 98 surface nodes and 4 nodes through the thickness. Figure 4-1 shows the surface nodes as numbered in the baseline thermal model. Table 4-1 presents the complete suit node numbering with the "EXTERIOR ITMG NODE" column corresponding to the nodes on Figure 4-1. The multilayer insulation has the same fineness of nodal breakdown as the exterior suit surface, but the two interior node layers have fewer nodes as indicated by the duplication of node numbers in Table 4-1 connecting two or more insulation nodes to an "EXTERIOR PGA" node. Figure 4-1 presents a surface area lumping of a more detailed geometric suit model found in Reference 12. Conductance values for the multilayer buildup for this interior version were generated from manned suit test data obtained from NASA and edited into the baseline thermal model data tape.

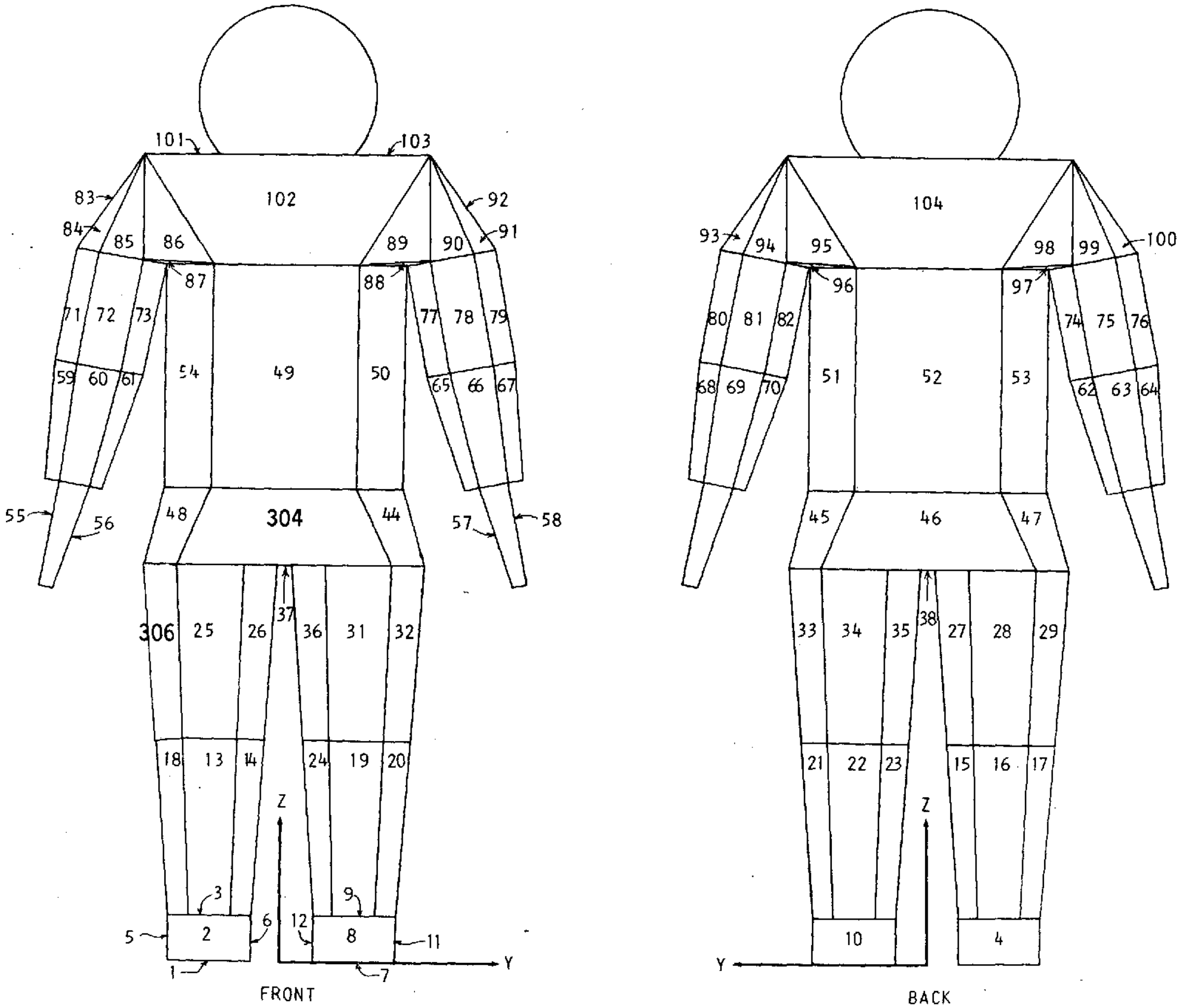


FIGURE 4-1 Suit, Boots, and Gloves Baseline Thermal Model

TABLE 4-1

NODAL NUMBERING THROUGH SPACE SUIT

EXTERIOR ITMG NODE	INTERIOR ITMG NODE (INSULATION)	EXTERIOR PGA NODE	INTERIOR PGA NODE
1	164	272	1
2	165	273	2
3	166	273	2
4	167	274	3
5	168	273	2
6	169	273	2
7	170	275	4
8	171	276	5
9	172	276	5
10	173	277	6
11	174	276	5
12	175	276	5
13	176	278	7
14	177	278	7
15	178	279	8
16	179	279	8
17	180	279	8
18	181	278	7
19	182	280	9
20	183	280	9
21	184	281	10
22	185	281	10
23	186	281	10
24	187	280	9
25	188	282	11
26	189	282	11
27	190	283	12
28	191	283	12
29	192	283	12
31	194	284	13
32	195	284	13
33	196	285	14
34	197	285	14
35	198	285	14
36	199	284	13
37	200	286	15
38	201	287	16
44	207	286	15
45	208	287	16
46	209	287	16
47	210	287	16
48	211	286	15
49	212	288	17
50	213	288	17

51	214	289	18
52	215	289	18
53	216	289	18
54	217	288	17
55	218	290	19
56	219	291	20
57	220	292	21
58	221	293	22
59	222	294	23
60	223	294	23
61	224	294	23
62	225	295	24
63	226	295	24
64	227	295	24
65	228	296	25
66	229	296	25
67	230	296	25
68	231	297	26
69	232	297	26
70	233	297	26
71	234	298	27
72	235	298	27
73	236	298	27
74	237	299	28
75	238	299	28
76	239	299	28
77	240	300	29
78	241	300	29
79	242	300	29
80	243	301	30
81	244	301	30
82	245	301	30
83	246	298	27
84	247	298	27
85	248	298	27
86	249	302	31
87	250	302	31
88	251	302	31
89	252	302	31
90	253	300	29
91	254	300	29
92	255	300	29
93	256	301	30
94	257	301	30
95	258	303	32
96	259	303	32
97	260	303	32
98	261	303	32
99	262	299	28
100	263	299	28
101	264	302	31
		303	32
102	265	302	31
103	266	302	31
		303	32
104	267	303	32
304	305	286	15
306	307	282	11

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

The SEVA thermal model consists of the sun visor, protective visor, pressure bubble, and SEVA shell as presented in Figures 4-2 through 4-4. Tables 4-2 and 4-3 are to be used in conjunction with Figures 4-2 and 4-3 respectively in interpreting the thermal model data. The simulator allows the user to specify visor configuration changes throughout the mission. The three helmet modes illustrated in Figure 3-5 require connections between nodes peculiar to an individual helmet mode, therefore for the sun visor (SV) and protective visor (PV) there is a set of nodes for each helmet mode. When the helmet is in MODE 1, only the nodes corresponding to this mode for the SV and the PV are analyzed; however the other nodes are updated each iteration. A change to a different helmet mode changes the set of nodes being analyzed and the initial temperatures for the new nodes are the last temperatures calculated for MODE 1 because of the continuous iteration update. A similar discussion applies when the helmet mode is begun in MODE 2 or MODE 3.

There is a single set of nodes for the SEVA shell layer. The surface area nodal breakdown is a modified version of that found in Reference 12. Nodes near the side of the helmet were increased in area and an additional row of node areas were created along the vertical centerline maintaining a constant number of nodes.

The pressure bubble is modeled as the tube nodes because the inside of the bubble is in contact with the suit oxygen flow. A single set of nodes is used for all three visor configurations and the nodes are analyzed continuously as are the SEVA shell nodes. Two types of connections from the pressure bubble tube nodes must be made a function of the helmet mode. The first is the pressure bubble connection to space when both visors are up and the second is the connection to the interior of the SEVA shell when both visors

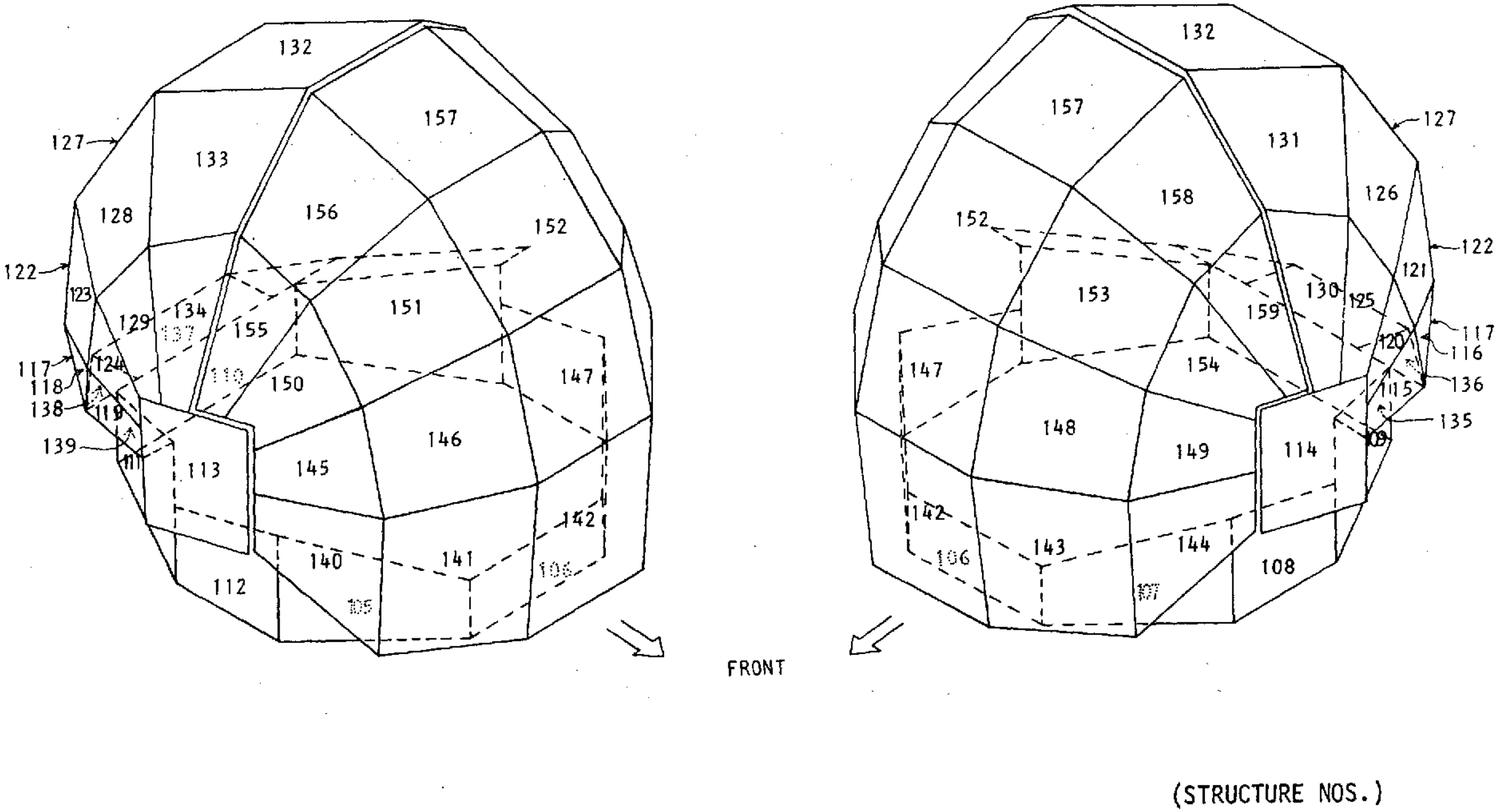
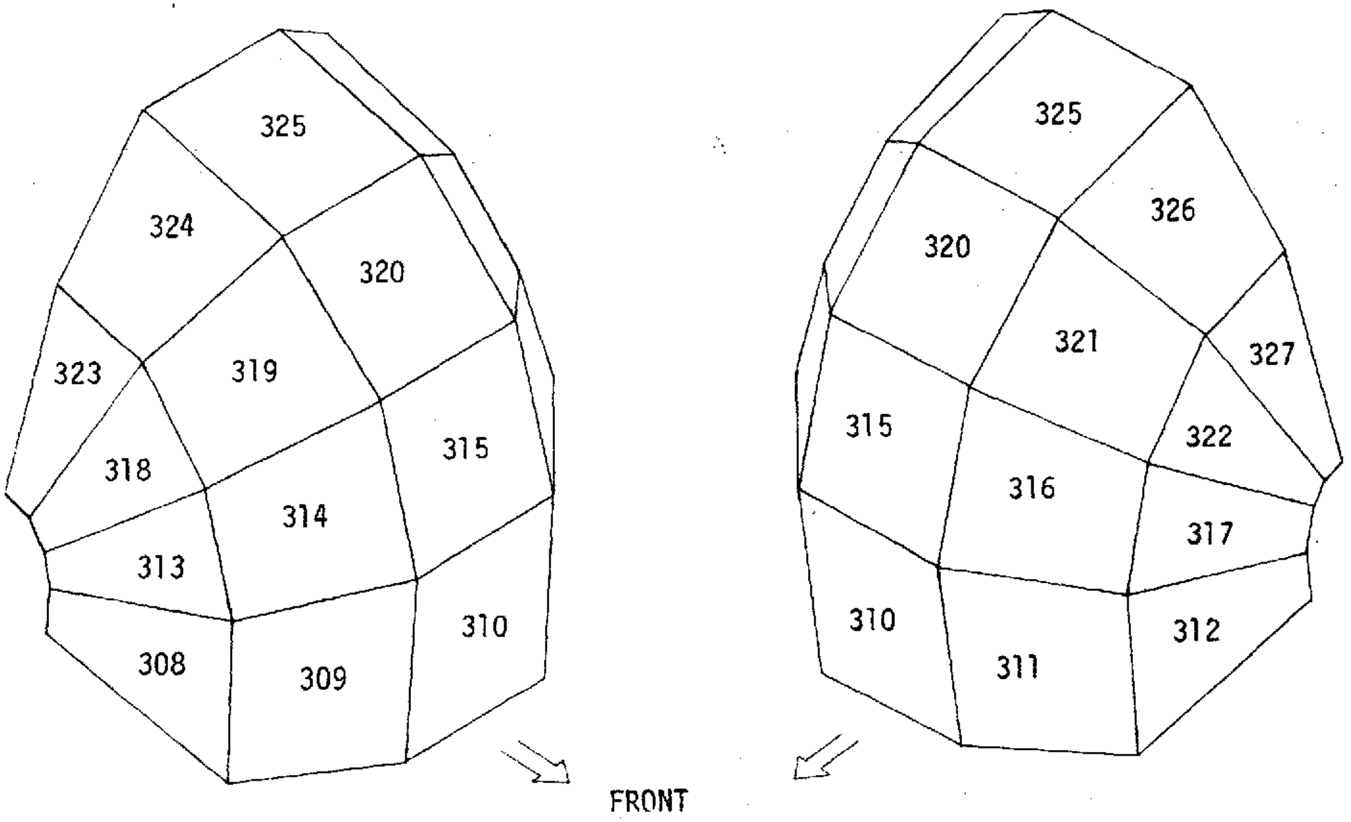


FIGURE 4-2 Sun Visor and Shell Thermal Model

TABLE 4-2

SUN VISOR NODE CORRESPONDENCE FOR HELMET MODES

MODE 1 (SUN VISOR DOWN)	MODE 2 (SUN VISOR ONLY UP)	MODE 3 (BOTH VISORS UP)
140	328	368
141	329	369
142	330	370
143	331	371
144	332	372
145	333	373
146	334	374
147	335	375
148	336	376
149	337	377
150	338	378
151	339	379
152	340	380
153	341	381
154	342	382
155	343	383
156	344	384
157	345	385
158	346	386
159	347	387



(STRUCTURE NOS.)

FIGURE 4-3 Protective Visor Thermal Model

TABLE 4-3

PROTECTIVE VISOR NODE CORRESPONDENCE FOR HELMET MODES

MODE 1 (SUN VISOR DOWN)	MODE 2 (SUN VISOR ONLY UP)	MODE 3 (BOTH VISORS UP)
308	348	388
309	349	389
310	350	390
311	351	391
312	352	292
313	353	393
314	354	394
315	355	395
316	356	396
317	357	397
318	358	398
319	359	399
320	360	400
321	361	401
322	362	402
323	363	403
324	364	404
325	365	405
326	366	406
327	367	407

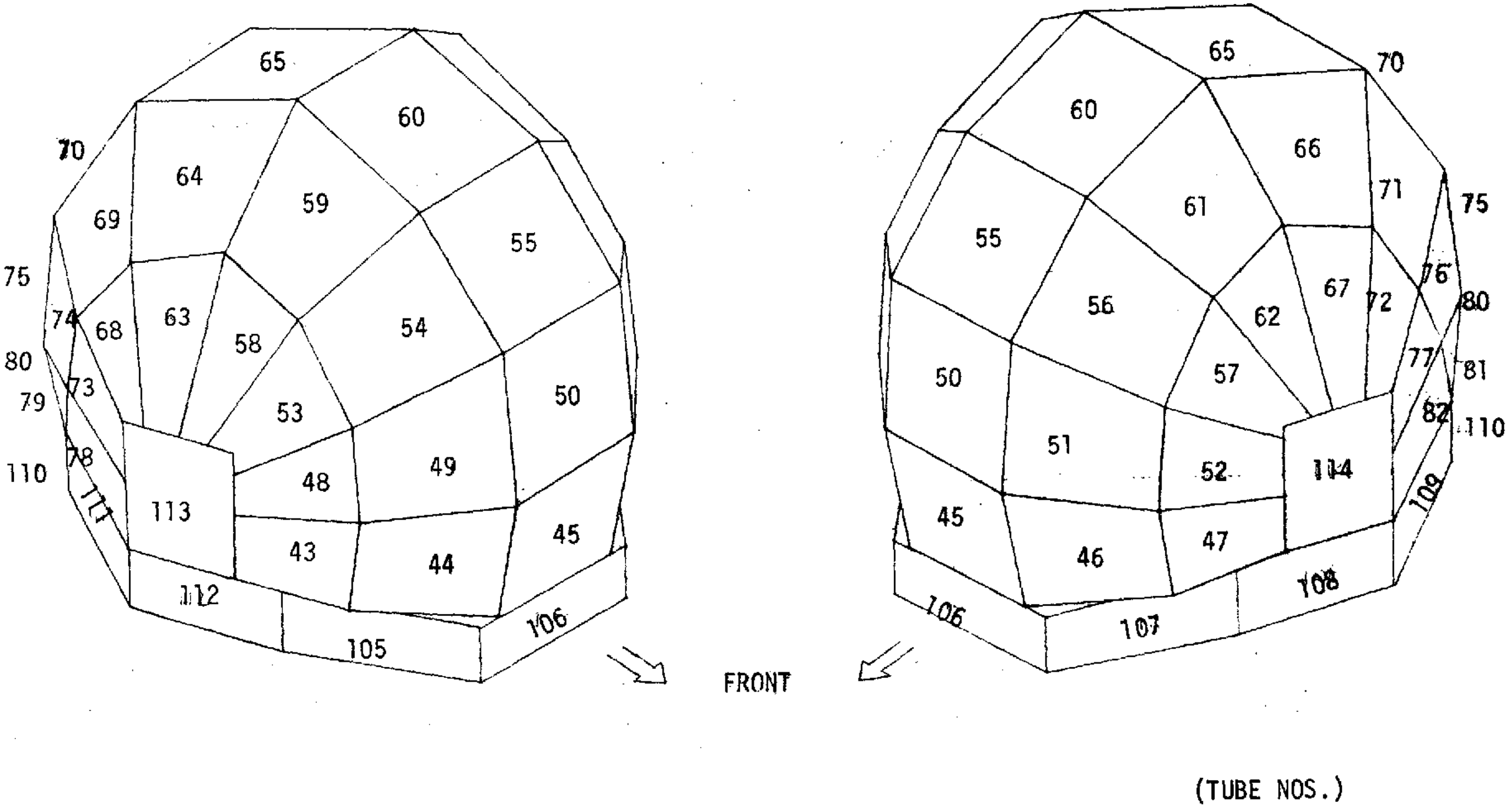


FIGURE 4-4 Pressure Bubble Helmet Thermal Model

are down. Since both the pressure bubble, the space node, and the SEVA nodes are analyzed continuously, some method of making and breaking the connections described above is required. The simulator has such a capability called Time Variant Connections (Section 3.12.4) and it is used to coordinate pressure bubble connections with the visor connections which are determined by the set of visor nodes analyzed. No intermediate positions of the visors are allowed; a visor is either all the way up or all the way down. The SEVA has three sun shades which may be varied by the crewman through an infinite number of positions. These sun shades are not modeled in the baseline thermal model.

Figure 4-5 shows the nodal breakdown of the PCU and SOP thermal covers and inner hardcover structure. The Life Support Umbilical (LSU) is modeled as four 15-foot nodes with two nodes through the multilayer insulation sheath. The LSU is composed of four umbilicals; one electrical, one oxygen, and two water umbilicals. Table 4-4 presents the node correspondence for these umbilicals with exterior sheath nodes. Table 4-5 details the tube/fluid correspondence with particular tubes (flowpaths). Figures 4-6 through 4-9 show the four Skylab workstation models and the significant surfaces of each which influence the crewman's environment when he visits these workstations. The crewman sketch was deleted from the figures for sake of clarity.

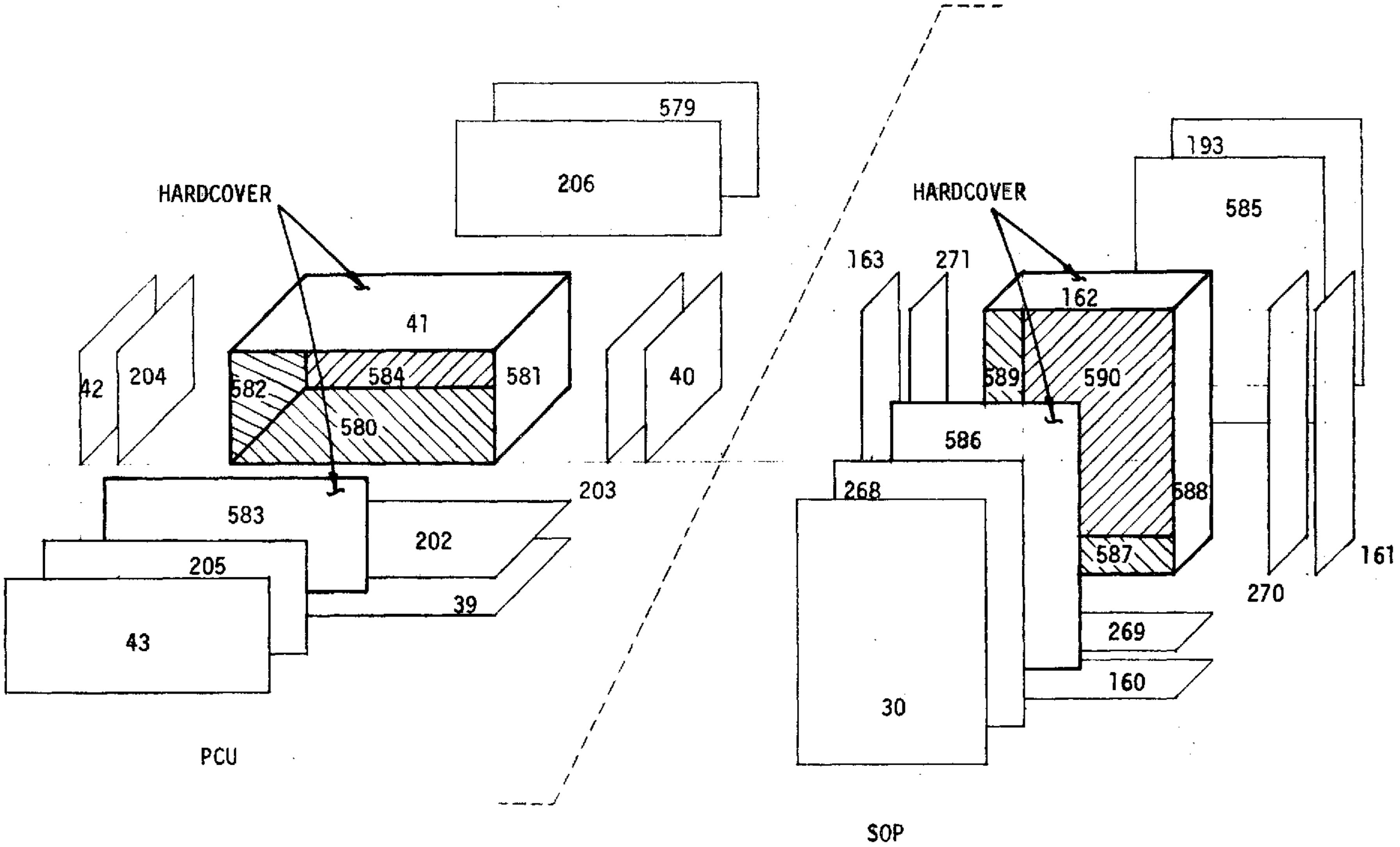


FIGURE 4-5

Nodal Breakdown of PCU and SOP Thermal and Hardcover

TABLE 4-4

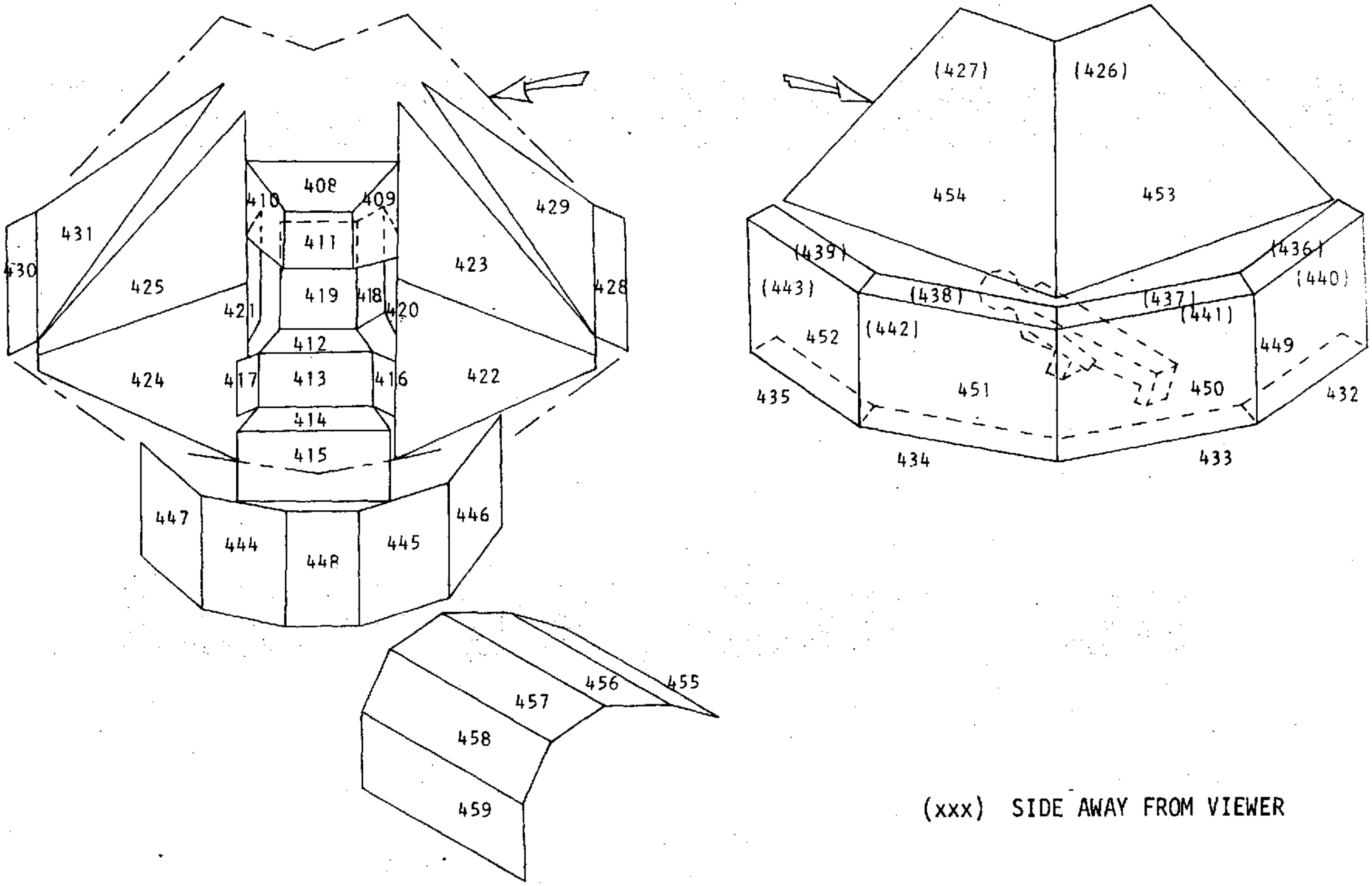
LSU NODE CORRESPONDENCE

	AM			PCU
OUTSIDE INSULATION	599	600	601	602
INSIDE INSULATION	595	596	597	598
ELECTRICAL CABLE	591	592	593	594
O2 SUPPLY	148T	149T	150T	151T
H2O SUPPLY	128T	129T	130T	131T
H2O RETURN	147T	146T	145T	144T

TABLE 4-5

TUBE LUMPS AND FLUID LUMPS IN EACH TUBE

TUBE NUMBER	TUBE LUMP NUMBERS	FLUID LUMP NUMBERS
1	199	95
2	181-189	77-85
3	190-196	86-92
4	197	93
5	198	94
6	148-152	44-48
7	153-156	49-52
8	157-164	53-60
9	165,166	61,62
10	167,168	63,64
11	169	65
12	170	66
13	171	67
14	172-176	68-72
25	177-180	73-76
26	200,201	96,97
27	202	98
28	203-209	99-105
29	135-138	31-34
30	134	30
31	101	125
32	125-127	21-23
33	122-124	18-20
34	121	17
35	118-120	14-16
36	115-117	11-13
37	102	126
38	139-141	35-37
39	100,212-227	124,108-123
40	210,128-133	106,24-29
41	142-147,211	38-43,107
42	LOCAL TEMPERATURE PERTURBATION NODES	



(xxx) SIDE AWAY FROM VIEWER

FIGURE 4-6 FAS Workstation Surface Nodes

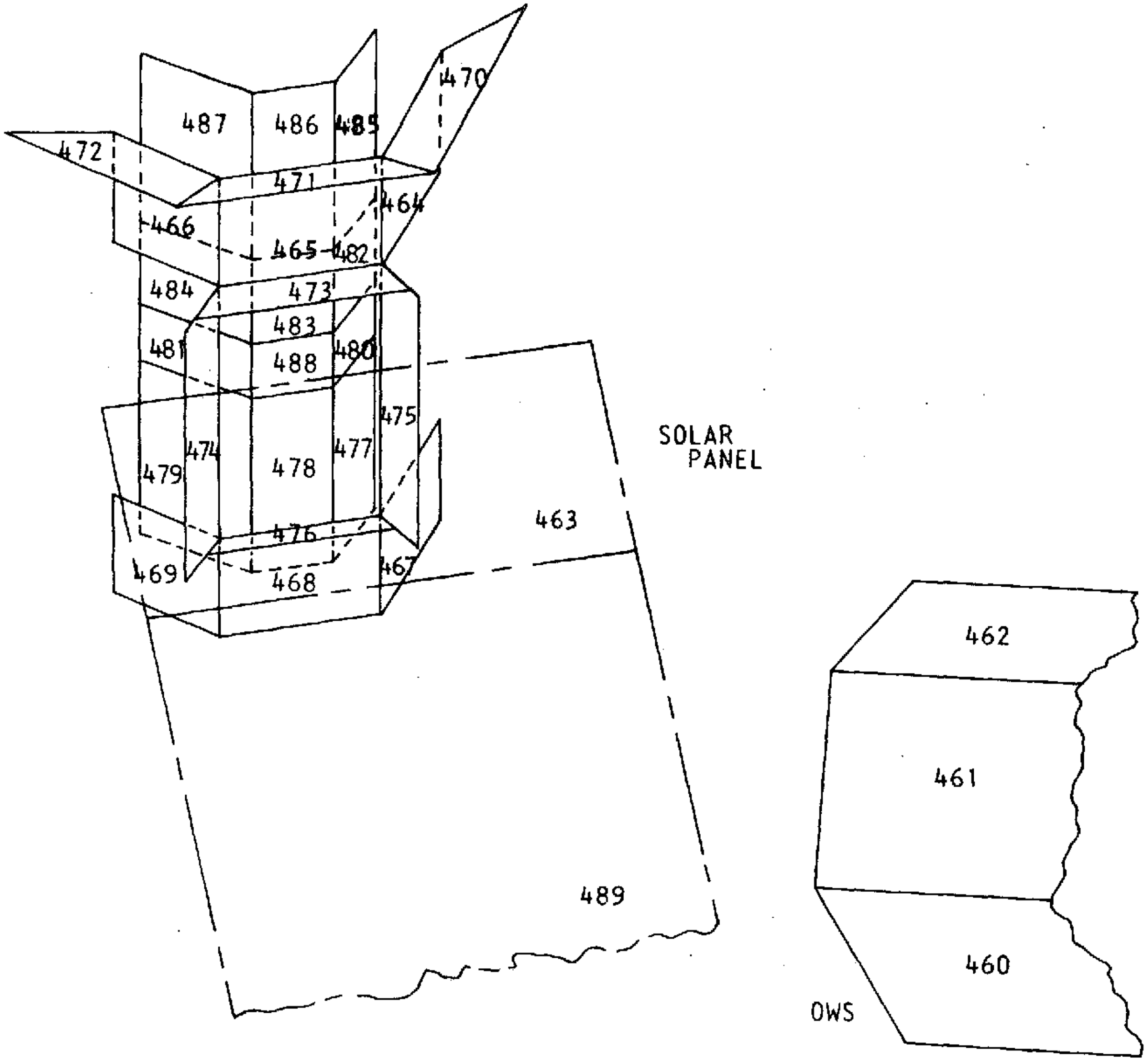


FIGURE 4-7 Center Workstation Surface Nodes

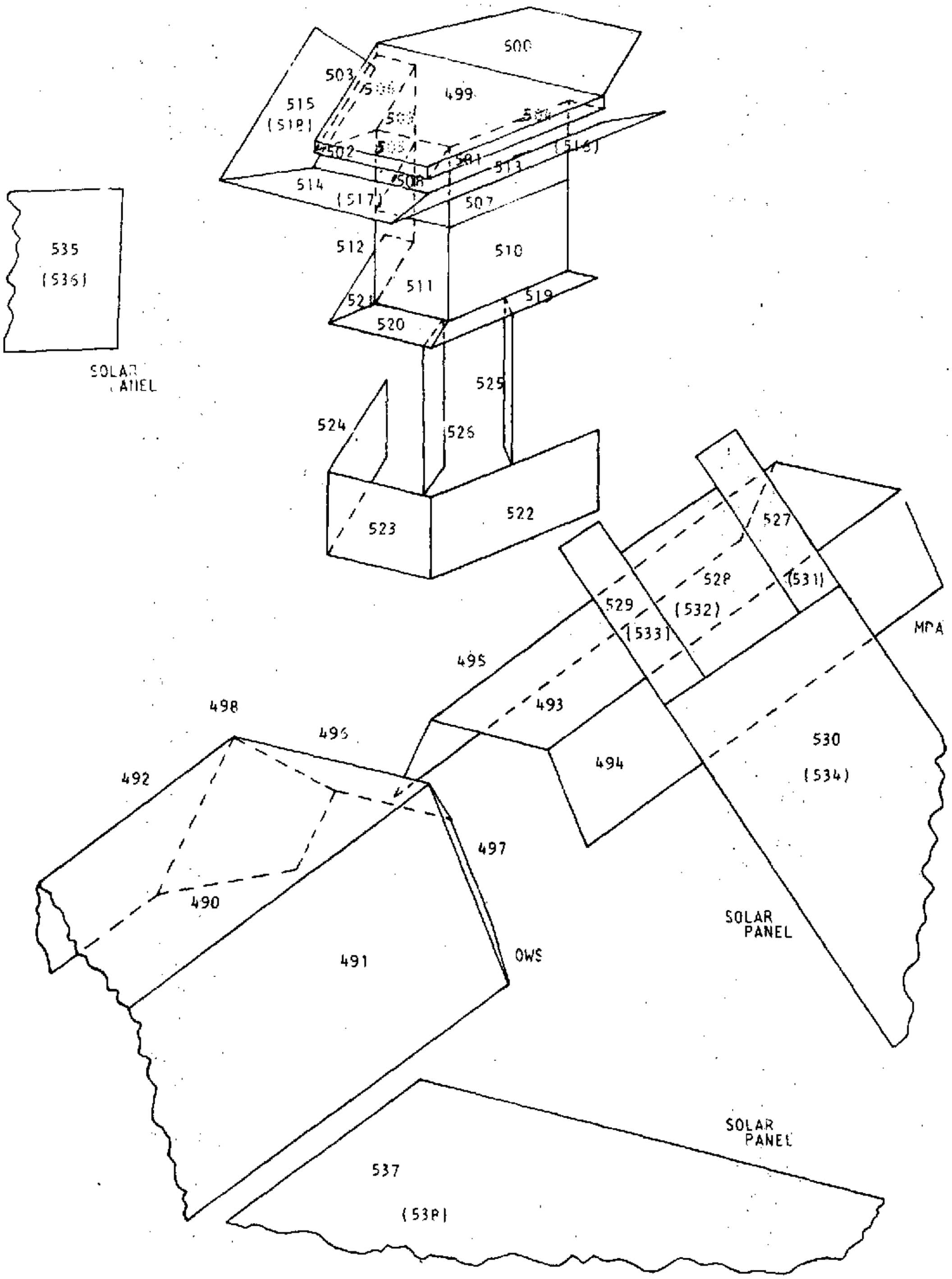


FIGURE 4-8 Transfer Workstation Surface Nodes

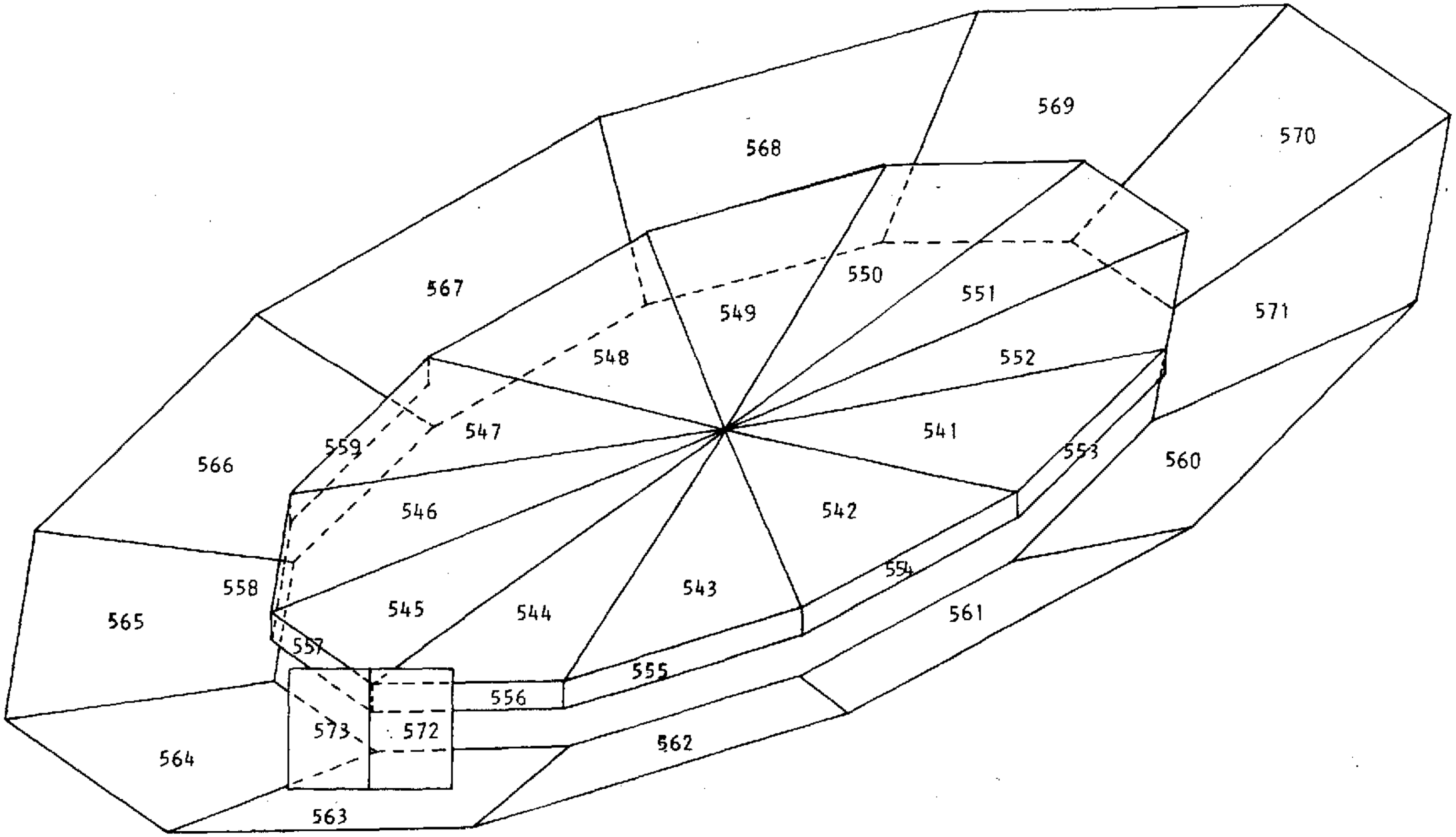


FIGURE 4-9 Sun End Workstation Surface Nodes

5.0 USER'S MANUAL

5.1 Program Description

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

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

5.2 List of System Subroutines Used

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

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

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

5.3 JSC Run Submission Requirements

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

The SEMU deck set up is as follows:

```
* 7
  8Z_RUN

* 7
  8N_MSG

  7
  8_ASG_A=AXXXXX (Input Program Tape Number)

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

  7
  8S_ASG_B=DATA (Output New Data Tape)

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

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

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

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

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

  7
  8_ASG_H=AXXXXX (Input NEWTMP Tape Number)

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

  7
  8_ASG_J=AXXXXX (Input Restart Tape Number)

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

  7
  8_XQT_CUR

  __TRW_A
```

```
_ _IN_A

_ _TRI_A

7
8_XQT_PROG

DATA (See Section 5.7)

7
8_EOF
```

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

Description of Tape Units Used:

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

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

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

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

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

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

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

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

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

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

** See Section 5.7 curve Data Cards

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

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

5.4 Run Time and Output Estimation

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

$$RTIME = AI + \left(\frac{FL + TL + SL}{130,200}\right)\left(\frac{TAU - TIME}{TINCMN}\right)$$

where:

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

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

Output from EMU may be estimated using the following equation:

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

where:

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

5.5 Restrictions

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

5.5.1 Programming

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

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

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

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

D. Tubes 16, 17, 21, 15, 18, 22, 19, 23, 20, and 24 contain the vent gas flow over the trunk, right arm, right leg, head, right hand, right foot, left arm, left leg, left hand and left foot respectively and must contain one and only one fluid lump. Each preceding fluid lump must be enclosed by at least two tube lumps one of which must be the corresponding skin tube lump number. Additional tube lumps, enclosing the suit fluid lumps and representing the inside suit wall, are required by the program.

E. The structure lump of oxygen in the SOP bottle must not have any connections.

J. In the special tube/fluid connection data the fluid lump must be a lump surrounding the man and the tube lump must be a man skin lump or a lump in tubes 31 through 37.

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

5.5.2 Analytical

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

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

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

5.5.3 Core Storage Space

The computer program requires approximately 15,000 core locations. In addition, a blank common block of 33,970 is allocated for storing input and calculated data. The largest part of the common block is assigned to an array called DATA. Basically the size of this array is determined by the size of core and the size of the SUB7 link. For operation on the Univac 1108 the dimensioned size of DATA is 33,000 locations. The DATA array is divided into three sections: transient, permanent and temporary. The transient section has two blocks, iteration and configuration, which share the 12,000 locations available. Only one block is stored in core at a time, while the other is stored on a drum. The iteration block occupies core all the time except when an EMU configuration change takes place and the configuration block is in core to make necessary changes to the permanent section. The permanent and temporary sections have variable length which cannot exceed 21,000 locations.

5.6 Program Options

5.6.1 Plot Tape

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

The format of the plot tape is:

Record No. 1

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

Record No. 2

Time, LCG delta temperature, crewman stored heat, partial pressure of CO_2 in helmet, dewpoint temperature in helmet, X,X,X, pressure in SOP bottles, X,X,X, crewman sensible heat loss, crewman evaporation heat loss, crewman latent heat loss, crewman storage rate, crewman shiver rate, crewman metabolic rate, X, oxygen in SOP bottles, X,X,X,X,X, unremoved sweat on crewman, crewman temperatures, flowrates, pressure drops, fluid lump temperatures, tube lump temperatures, and structure lump temperatures.

Record No. 3

Time, etc.

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

5.6.2 Skylab Prescribed Temperature Curves on Tape

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

Restrictions on the option are:

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

(2) The initial block of curve data must be input on cards or data tape in the usual manner (Section 5.7.15)

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

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

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

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

Record No. 1

First Read Time, 9A6

Record No. 2

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

Record No. 3

Second Read Time, 9A6

Record No. 4

Same as Record No. 2

Record No. 5

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

Etc. until all blocks of data are on tape.

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

5.6.3 Restart

Requested Dump for Restarting

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

Automatic Dump for Restarting

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

Restart Procedure

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

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

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

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

5.6.4 EDIT

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

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

(1) INDATA = 0, All data is supplied on cards.
(2) INDATA = 1, All data is supplied on cards and the card images are written on tape on UNIT B. (Should be specified as an output tape on job card).
(3) INDATA = 3, Use data input on tape on UNIT C with desired changes on cards to write a new data tape on UNIT B. (C is input tape and B is output tape)
(4) INDATA = 3, Use the data read in from UNIT B without change. Parameter cards 1 and 2 are read in from cards. (B is input tape)

If INDATA = 2, the card images are punched as they are written on UNIT B.

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

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

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

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

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

5.6.5 Imposed Node Temperature History

It is possible to impose a temperature history on structure nodes for the duration of the problem. The temperature history is called a prescribed wall temperature and data preparation is given in Section 5.7.11.

5.6.6 Heat Flux and Prescribed Temperature Data From EHFR

The Environmental Heat Flux Routine (EHFR) outputs on a tape, incident heat in two wavelength bands (solar and infrared) for each helmet and visor node of its geometrical model of the EMU. Absorbed heat for each remaining node and a contact temperature is also output on the tape. This tape is used as input to the EMU simulator on tape UNIT D when NENVTP = 2. This parameter is specified in column 30 of parameter card 3. When NENVTP = 2, the EMU simulator reads data from UNIT D and creates on UNIT E curves of absorbed heat, incident solar heat, incident infrared heat, and contact temperature as specified on parameter cards 4 and 5. The incident solar and incident infrared heat curves are assigned in the Helmet and Visor Data (Section 5.7.8) while the absorbed heat and contact temperature curves are assigned in the Curve Assignment Data (Section 5.7.10). The tape created on UNIT E on one run can be used on other runs as an input tape by specifying NENVTP = 1. The user can, by specifying NENVTP = 0, input curves requested on parameter card 3 in the Curve Data (Section 5.7.15) as type 19 and type 20 curves. Parameter cards 4 and 5 must be omitted and tapes are not specified for UNIT D and UNIT E. If NENVTP = 0 and NRIC = 1, the user must supply a type 21 (radiant interchange mode) curve. This curve determines the set of radiant interchange connection values to be used from UNIT G as a function of time. The connection values should correspond to the variation in EHFR heat flux which is a function of the EMU geometric configuration.

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

5.7 DATA CARD PREPARATION FOR SKYLAB EMU

5.7.1 PARAMETER CARDS

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

Columns	Format	Title	Description
Card 2 (Continued)			
65-66	I2	NPRTCD	= 0, Use current Skylab prescribed temperature tables = 1, Skylab prescribed temperature tables supplied by UNIT L
67-68	I2	IPLOTN	= 0, No temperature history = 1, Write temperature history on UNIT I
69-70	I2	IDUMP	= 0, No dump tape to be written = 1, Dump data on UNIT I
71-72	I2	NENVTP	Code for heat flux curves, type 19, and prescribed temperature curves, type 20, = 0, Curves supplied in curve data = 1, Heat flux and prescribed temperature curves read from UNIT E, = 2, Heat flux and prescribed temperature curves created on UNIT E from EHFR output on UNIT D
73-74	I2	NRIC	= 0, No radiant interchange tape = 1, Read radiant interchange tape on UNIT G
Card 3			
1-5	I5	NTFL	Total number of fluid lumps
6-10	I5	NTML	Total number of tube lumps
11-15	I5	NSL	Total number of structure lumps
16-20	I5	NIHEVA	Number of heat flux curves to be created from EHFR output or supplied in curve data. If none, enter zero.
21-25	I5	NPTEVA	Number of prescribed temperatures history curves to be created from EHFR output or supplied in curve data. If none enter zero.
Card 4			
1-5	I5	NUM	Curve number assigned to this group of combined heat fluxes (or temperature histories)

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

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

Columns	Format	Title	Description
Card 6			
1-10	F10.5	LPA1	Aneroid pressure of Reg 1
11-20	F10.5	LPA2	Aneroid pressure of Reg 2
21-30	F10.5	LPRV1	Relief valve pressure of Reg 1
31-40	F10.5	LPRV2	Relief valve pressure of Reg 2
41-50	F10.5	LPS1	Spring pressure of Reg 1
51-60	F10.5	LPS2	Spring pressure of Reg 2

Columns	Format	Title	Description
Card 7			
1-10	F10.5	POTANK	Pressure out of main O_2 tank, psi
11-20	F10.5	POMREG	Pressure out of main O_2 regulator, psi
21-30	F10.5	POREG3	Pressure out of O_2 regulator 3 (SOP), psi
Card 8			
1-5	I5	LMISOP	Structure lump no. of O_2 in SOP tank
6-10	I5	LMOSOP	Structure lump no. of shell of SOP tank
11-20	F10.5	HASOP	HA for SOP tank, BTU/hr-°F
21-30	F10.5	PO2SOP	Initial pressure of SOP tank, psi
31-40	F10.5	VOLSOP	O_2 tank volume, in^3
Card 9			
1-5	I5	LMPGSP	Gas separator fluid lump no.
6-15	F10.5	C1	Suit ΔP(psi) $C1*\frac{T_{in}}{P_{in}} * \dot{W}^{END1}$
16-25	F10.5	END1	
26-35	F10.5	VOLHMT	Net helmet volume, in^3
36-45	F10.5	CO2WGT	Initial weight of CO_2 in helmet, lb.
Card 10			
1-5	I5	L1	Trunk Skin tube lump no.
6-10	I5	L2	Rt. Arm skin tube lump no.
11-15	I5	L3	Lt. Arm skin tube lump no.
16-20	I5	L4	Rt. leg skin tube lump no.
21-25	I5	L5	Lt. leg skin tube lump no.
26-30	I5	L6	Head skin tube lump no.
31-35	I5	L7	Rt. hand skin tube lump no.

Columns	Format	Title	Description
Card 10 (Continued)			
36-40	I5	L8	Lt. hand skin tube lump no.
41-45	I5	L9	Rt. foot skin tube lump no.
46-50	I5	L10	Lt. foot skin tube lump no.
Card 11			
1-5	I5	L11	Tank undergarment tube lump no.
6-10	I5	L12	Rt. arm undergarment tube lump no.
11-15	I5	L13	Lt. arm undergarment tube lump no.
16-20	I5	L14	Rt. leg undergarment tube lump no.
21-25	I5	L15	Lt. leg undergarment tube lump no.
26-30	I5	L16	Head undergarment tube lump no.
31-35	I5	L17	Rt. hand undergarment tube lump no.
36-40	I5	L18	Lt. hand undergarment tube lump no.
41-45	I5	L19	Rt. foot undergarment tube lump no.
46-50	I5	L20	Lt. foot undergarment tube lump no.
Card 12			
1-10	F10.5	RF1	Solar reflectivity of astronaut's face
11-20	F10.5	RF2	Solar reflectivity of inside of pressure bubble
21-30	F10.5	RF3	Solar reflectivity of outside of pressure bubble
31-40	F10.5	RF4	Solar reflectivity of inside of impact visor
41-50	F10.5	RF5	Solar reflectivity of outside of impact visor
51-60	F10.5	RF6	Solar reflectivity of inside of sun visor
61-70	F10.5	RF7	Solar reflectivity of outside of sun visor

Columns	Format	Title	Description
Card 13			
1-10	F10.5	RFT	Solar reflectivity of helmet top
11-20	F10.5	T23	Solar transmissivity of pressure bubble
21-30	F10.5	T45	Solar transmissivity of impact visor
31-40	F10.5	T67	Solar transmissivity of sun visor
Card 14			
1-10	F10.5	EM1	Infrared emittance of outer surface of sun visor
11-20	F10.5	EM2	Infrared emittance of outer surface of impact visor
21-30	F10.5	EM3	Infrared emittance of outer surface of helmet top
31-40	F10.5	EM4	Infrared emittance of outer surface of pressure bubble
41-50	F10.5	EM5	Infrared emittance of man's face
Card 15			
1-10	F10.5	PORDIA	Orifice diameter in EVA panel, in.
11-20	F10.5	SORDIA	Diameter of shuttle valve, in.
21-30	F10.5	REGDIA	Regulator selector valve dia, in.
31-40	F10.5	DIA1	Flow control valve IVA mode dia, in.
41-50	F10.5	DIA2	Flow control valve EVA norm dia, in.
51-60	F10.5	DIA3	Flow control valve EVA HI dia, in.
Card 16			
1-5	F5.5	EO2HX	Effectiveness of O_2 HX
6-10	F5.5	EMWCHX	Effectiveness of multiple water connector HX
11-15	F5.5	EHWHX	Effectiveness of hot H_2O HX

Columns	Format	Title	Description
Card 16 (Continued)			
16-20	F5.5	ECWHX	Effectiveness of cold H_2O HX
21-25	F5.5	EFFPAR	Effectiveness of parallel HX
26-30	F5.5	EFFCNT	Effectiveness of counter flow HX
31-40	F10.0	AMBFLO	Airlock module bypass flow constant
41-50	F10.0	AMCCP	Airlock module coolant specific heat
51-60	F10.0	T1OUT	Temperature out of thermal valve 1, °F
61-70	F10.0	T2OUT	Temperature out of thermal valve 2, °F
Card 17			
1-5	I5	NO2HXT	Curve # of temp into side 2 of O_2 HX
6-10	I5	NO2TMP	O_2 inlet temp curve no.
11-15	I5	NTCOLD	Airlock module cold temperature curve no.
16-20	I5	NTHOT	Airlock module hot temperature curve no.
21-25	I5	NTEQP	Airlock module equipment HX temp curve no.

All curves on this card are type 12.

Columns	Format	Title	Description
Card 18			
1-5	I5	NOXCON	Curve no. of O_2 conductivity (type 4)
6-10	I5	NOXSPH	Curve no. of O_2 specific heat (type 33)
11-15	I5	NOXVIS	Curve no. of O_2 viscosity (type 33)
16-20	I5	NOXENT	Curve no. of O_2 enthalpy (type 33)
21-25	I5	NOXENX	Curve no. of O_2 reverse enthalpy (type 33)
26-30	I5	NWRCON	Curve no. of H_2O conductivity (type 4)
31-35	I5	NWRVIS	Curve no. of H_2O viscosity (type 2)

Columns	Format	Title	Description
Card 19			
1-5	I5	NZFACT	Compressibility factor curve no.
6-10	I5	NDPHHX	Delta P across hot HX curve no.
11-15	I5	NDPCHX	Delta P across cold HX curve no.
16-20	I5	NDPBYP	Delta P across bypass valve curve no.
21-25	I5	NDPLCG	Delta P across LCG curve no.
26-30	I5	NDPGSP	Delta P across gas separator curve no.
31-35	I5	HDPGHX	Delta P across O_2 HX curve no.

All curves on this card are type 33.

Columns	Format	Title	Description
Card 20			
1-5	I5	NSLEAK	Suit leakage rate curve no.
6-10	I5	NXM	Metabolic rate curve no.
11-15	I5	NUEFF	Man efficiency curve no.
16-20	I5	NAMCFR	Airlock module coolant flowrate curve no.
21-25	I5	NFLOT4	O_2 flowrate to 2nd crewman curve no.
26-30	I5	NDIV	Bypass valve position curve no.
31-35	I5	NPAMB	Ambient pressure curve no.
36-40	I5	NBFLO1	Bleed flow from Reg 1 curve no.
41-45	I5	NBFLO2	Bleed flow from Reg 2 curve no.
46-50	I5	NFLORV	O_2 relief valve flow from main Reg curve no.
51-55	I5	NPOPI	Pressure out/pressure in ratio curve no.
56-60	I5	NPUMP	Pump curve no.
61-65	I5	NQMAN2	Heat load of second crewman curve no.

All curves on this card are type 34.

Columns	Format	Title	Description
Card 21			
1-5	I5	NFRWTR	Pump curve code/initial flow curve no.
6-10	I5	NREGSV	Regulator selector valve code curve no.
11-15	I5	NMODSV	Mode selector valve code curve no.
16-20	I5	NFLOCV	Flow control valve code curve no.
21-25	I5	NSOPFV	SOP flow control valve code curve no.
26-30	I5	NHMOD	Helmet mode curve no.
31-35	I5	NEMODE	EMU configuration mode curve no.
36-40	I5	NMAN2	Operating code for 2nd crewman curve no.

All curves on this card are type 35.

5.7.2 FLUID DATA CARDS

Card 22

Columns	Format	Title	Description
1-5	I5	NFLT	Number of types of fluid lumps

Card 23 (Type Data Cards)

Columns	Format	Title	Description
1-10	F10.5	FLL	Fluid lump length, inches
11-20	F10.5	CSA	Fluid cross sectional area, in^2
21-30	F10.5	WP	Wetted perimeter, in.
31-35	F5.4	FRE	Friction factor multiplying factor
36-40	I5	KLOSS	Head loss coefficient curve no.
41-45	I5	NHHH	= 0, use reg eq for HHH ≠ 0, curve No. for HHH = f($\dot{w}$)
46-50	I5	LTYPE	Type no.

Card 24 (Fluid Lump Cards)

Columns	Format	Title	Description
1-5	I5	LN	Lump number
6-10	I5	NLU	Lump upstream. NLU = 0 for first lump in every tube.

Columns	Format	Title	Description
Card 24 (Fluid Lump Cards) (Continued)			
11-15	I5	NTB	Type number
16-20	I5	NTYPEF	Type number
21-30	F10.5	FT1	Initial temperature, °F
Repeat Card 24 for every fluid lump			
5.7.3	TUBE DATA CARDS		
Card 25			
I-5	I5	NMLT	Number of types of tube lumps
Card 26 (Type Data Cards)			
1-5	F5.0	WGTT	Weight of tube lump, lbs.
6-10	I5	NCONCT	Conductivity curve number
11-15	I5	NSHCT	Specific heat curve number
16-20	I5	NTCT	Number of tube lumps 'conducted to' by tube lumps of this type
21-25	I5	NFCTT	Number of structure lumps 'conducted to' by tube lumps of this type
26-30	I5	NTRT	Number of tube lumps 'radiated to' by tube lumps of this type
31-35	I5	NFRTT	Number of structure lumps 'radiated to' by tube lumps of this type
36-45	F10.5	AHT	Area of heat transfer to enclosed fluid lump, sq. in.
46-55	F10.5	AERT	Area of surface for incident heat application, sq. in.
56-65	F10.5	FAC	Factor for dividing conduction distances. Routine sets to 1.0 if left blank
66-70	I5	LTYPE	Type number

Card 27 (Conduction Data, required for all lumps conducted to by tube lumps of this type)

Columns	Format	Title	Description
1-5	F5.0	$R1_1$	Conduction data for tube lumps of this type of the first lump listed in the connections on the tube lump card
6-10	F5.0	$R2_1$	$U = \dfrac{1}{\dfrac{R1_1}{K_1} + \dfrac{R2_1}{K_2}}$ Resistor values are input in pairs, but R_2 may be left blank when thermal conductivity is constant.
11-15	F5.0	$R1_2$	Conduction data for tube lumps of this type to the second lump listed in the connections on the tube lump cards
16-20	F5.0	$R2_2$	
⋮	⋮	⋮	⋮
61-65	F5.0	$R1_7$	Conduction data for tube lumps of this type to the seventh lump listed in the connections on the tube lump card
66-70	F5.0	$R2_7$	

Repeat Card 27 as many times as needed to supply conduction data for the total number of lumps conducted to by tube lumps of this type. Data must be given as follows; (1) all conduction data to tube lumps, (2) all conduction data to structure lumps.

Card 28 (Radiation Data, required for all lumps radiated to by tube lumps of this type)

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

Columns	Format	Title	Description
Card 28 (Continued)			
66-70	F5.0	FA14	Gray-body shape factor between tube lumps of this type and the 14th lump 'radiated to' listed in the connections on the tube lump cards

Repeat Card 28 as many times as needed to supply the gray-body shape factor for the total number of lumps radiated to by tube lumps of this type. Data must be given as follows: (1) all radiation data to tube lumps, (2) all radiation data to structure lumps.

Repeat Card 26 (followed by Cards 27 and 28 if needed) for each tube type.

Card 29 (Tube Lump Cards)

Columns	Format	Title	Description
1-5	I5	LN	Lump number
6-10	I5	NFL	Enclosed fluid lump number
11-15	I5	NTYPET	Type number
16-25	F10.5	TTI	Initial temperature, °F
26-30	I5	NQICT	Incident heat curve number
31-35	I5	NTL1	First lump to which this tube lump has a connection either by conduction or radiation
.	.	.	.
.	.	.	.
.	.	.	.
66-70	I5	NTL8	Eighth lump to which this tube lump has a connection

Card 30 (Additional connections, if required)

Columns	Format	Title	Description
1-5	I5	NTL9	Ninth lump to which this tube lump has a connection
.	.	.	.
.	.	.	.
.	.	.	.
66-70	I5	NTL22	Twenty-second lump to which this tube lump has a connection

Columns	Format	Title	Description

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

Recall that the connections should be listed as follows; conduction to tube lumps, conduction to structure lumps, radiation to tube lumps and radiation to structure lumps. Repeat Card 30 if needed to supply all lumps to which the tube lump has a connection.

Repeat Card 29 (followed by Card 30, if required) for every tube lump.

5.7.4 STRUCTURE DATA CARDS

Card 31

1-5	I5	NT	Number of types of structure lumps

Card 32 (Type Data Cards)

1-5	F5.0	WGTS	Weight of structure lump, lbs.
6-10	I5	NCONCS	Conductivity curve number
11-15	I5	NSHCS	Specific heat curve number
16-20	I5	NFCTS	Number of structure lumps 'conducted to' by structure lumps of this type
21-25	I5	NFRTS	Number of structure lumps 'radiated to' by structure lumps of this type
26-35	F10.5	AERS	Area of surface for incident heat application, sq. in.
36-45	F10.5	FAC	Factor for dividing conduction distances. Routine sets to 1.0 if left blank.
66-70	I5	LTYPE	Type number

Card 33 (Conduction Data, required for all lumps conducted to by structure lumps of this type)

1-5	F5.0	$R1_1$	Conduction data for structure lumps of this type to the first lump listed in the connections on the structure lump card
6-10	F5.0	$R2_1$	
⋮	⋮	⋮	⋮

Columns	Format	Title	Description
Card 33 (Continued)			
61-65	F5.0	$R1_7$	Conduction data for tube lumps of this type to the seventh lump listed in the connections on the tube lump card
66-70	F5.0	$R2_7$	

Repeat Card 33 as needed.

Card 34 (Radiation Data, required for all lumps radiated to by structure lumps of this type)

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

Repeat Card 34 as needed

Repeat Card 32 (followed by Cards 33 and 34 if needed) for each structure type.

Card 35 (Structure Lump Cards)

1-5	I5	LN	Lump number
6-10	I5	NTYPES	Type number
21-25	I5	NQICS	Incident heat curve number
26-30	I5	NTL1	First lump to which this structure lump has a connection either by conduction or radiation
⋮	⋮	⋮	⋮
66-70	I5	NTL9	Ninth lump to which this structure lump has a connection

Card 36 (Additional connections, if required)

1-5	I5	NTL10	10th lump
⋮	⋮	⋮	⋮

Columns	Format	Title	Description
Card 36 (Continued)			
66-70	I5	NTL23	23rd lump

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

Repeat Card 36 as needed to supply all lumps to which the structure lump has a connection.

Repeat Card 35 (followed by Card 36, if needed) for each structure lump.

5.7.5 LOCAL TEMPERATURE PERTURBATION DATA CARDS

Card 37

1-5	I5	NLOCPT	Number of local perturbations (Enter zero if none desired and omit Card 38)

Card 38

1-5	I5	NSKIN	Skin area number = 1, Trunk = 2, Right arm = 3, Left arm = 4, Right leg = 5, Left leg = 6, Head = 7, Right hand = 8, Left hand = 9, Right foot =10, Left foot
6-10	I5	NNODE	Skin tube lump number (loc. pert. model)
11-15	I5	NUGNOD	Undergarment tube lump number (loc. pert. model) Zero if no undergarment over skin
16-20	I5	NFLUID	Fluid (gas) lump number (loc. pert. model) (Must be in tube 42)
21-25	I5	NLCGLP	LCG tube lump number (loc. pert. model)
26-30	I5	NLCGBS	LCG tube lump number (regular model)
31-35	I5	NKRDIFF	Diffusion factor curve number (Type 29)
36-40	I5	NKRSWT	Sweat factor curve number (Type 29)
41-45	I5	NKRHHH	Heat transfer factor curve no. (Type 29)

Columns	Format	Title	Description
5.7.6	HEAT LEAK DATA CARDS		
Card 39			
1-5	I5	NGRHL	Number of groups of heat leak calculations (Enter zero if none desired and omit Cards 40 and 41)
Card 40			
1-5	I5	NG1	Number of paths of heat leak in group 1
10-15	A6	IDI	Six character identification of group 1
Card 41			
1-4	I4	JNODE	J node number
5	A1	JTYPE	J node code T = tube node S = structure node
6-10	I5	NCOND	Connection number for conduction value - has values 1 to n where n is the number of connections input on Card 29 or Card 35
11-15	I5	NRAD	Connection number for radiation value - has values 1 to n where n is the number of connections input on Card 29 or Card 35
16-19	I4	JNODE	J node number
20	A1	JTYPE	J node code T = tube node S = structure node
21-25	I5	NCOND	Connection number for conduction value-has values 1 to n where n is the number of connections input on Card 29 or Card 35
26-30	I5	NRAD	Connection number for radiation value-has values 1 to n where n is the number of connections input on Card 29 or Card 35

Two heat leak paths are input per card and Card 41 is repeated as necessary to supply NG1 paths. Repeat Card 40 followed by Card 41 as needed for NGRHL groups.

5.7.7 HEAT STORAGE DATA CARDS

Columns	Format	Title	Description
Card 42			
1-5	I5	NGRSH	Number of group of nodes for heat storage calculations. (Enter zero if none desired and omit Cards 43 and 44)
Card 43			
1-5	I5	NGS1	Number of nodes in group 1
10-15	A6	IDS1	Six character identification of group 1
Card 44			
1-4	I4	NODE1	First node number
5	A1	TYPE1	First node code F = fluid T = tube node S = structure node
6-9	I4	NODE2	Second node number
10	A1	TYPE2	Second node code F = fluid node T = tube node S = structure node

.
.
.
etc. through column 70

Repeat Card 44 as necessary until NGS1 nodes have been supplied. Repeat Card 43 followed by Card 44 for NGRSH groups.

5.7.8 HELMET AND VISOR DATA CARDS

Card 45			
1-5	I5	NHVPOS	Number of positions on helmet and visor (Enter zero if none desired and omit Card 46)
Card 46			
1-5	I5	NPOS	Position number

Columns	Format	Title	Description
Card 46 (Continued)			
6-10	I5	NTYPE	Position type 1 - Sun visor 2 - Impact visor 3 - Top of helmet 4 - Pressure bubble 5 - Face
11-15	I5	NODE1	Node number for Mode 1 (Both visors down)
16-20	I5	NR1	Incident IR flux curve number
21-25	I5	NS1	Incident solar flux curve number
26-30	I5	NODE2	Node number for Mode 2 (Sun visor up)
31-35	I5	NR2	Incident IR flux curve number
36-40	I5	NS2	Incident solar flux curve number
41-45	I5	NODE3	Node number for Mode 3 (Both visors up)
46-50	I5	NR3	Incident IR flux curve number
51-55	I5	NS3	Incident solar flux curve number

Repeat Card 46 NHVPOS times.

5.7.9 CONFIGURATION - ASSOCIATED MODE IDENTIFICATION CARDS

Card 47

Columns	Format	Title	Description
1-5	I5	NLMPEN	Number of structure nodes to be identified with an environment mode (Enter zero if none desired and omit Card 48)

Card 48

Columns	Format	Title	Description
1-5	I5	LMP1	First structure node number
6-10	I5	NEN1	First environment mode identification code

.
.
.

etc. through column 70

Repeat Card 48 as necessary to supply NLMPEN sets of node number and code.

Columns	Format	Title	Description
5.7.10	HEAT FLUX CURVE ASSIGNMENT DATA CARDS (USED FOR TYPES 19 & 20 ONLY)		
Card 49			
1-5	I5	NNEVAH	Number of nodes with type 19 incident heat curves (Enter zero if none desired and omit Card 50)
Card 50			
1-4	I4	NODE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I4	KURVE1	First type 19 incident heat curve number
11-14	I4	NODE2	Second node number
15	A1	TYPE2	Second node code T = tube node S = structure node
16-20	I5	KURVE2	Second type 19 incident heat curve number

.
.
.

etc. through column 70

Repeat Card 50 as necessary to assign curve numbers to NNEVAH nodes.

Card 51			
1-5	I5	NNEVAT	Number of nodes with type 20 prescribed temperature history curves (Enter zero if none desired and omit Card 52)
Card 52			
1-4	I4	NODE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 20 prescribed temperature curve number
11-14	I4	NODE2	Second node number

Columns	Format	Title	Description
Card 52 (Continued)			
15	A1	TYPE2	Second node code T = tube node S = structure node
16-20	I5	KURVE2	Second type 20 prescribed temperature curve number

⋮

etc. through column 70

Repeat Card 52 as necessary to assign curve numbers to NNEVAT nodes.

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

Card 53

1-5	I5	NPRTEM	Number of lumps which have type 10 prescribed wall temperature curves (Enter zero if none desired and omit Card 54)

Card 54

1-4	I4	NODE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 10 prescribed temperature curve number
11-14	I4	NODE2	Second node number
15	A1	TYPE2	Second node code
16-20	I5	KURVE2	Second type 10 prescribed temperature curve number

⋮

etc. through column 70

Repeat Card 54 as necessary to assign curve numbers to NTVARL nodes.

Columns	Format	Title	Description
Card 55			
1-5	I5	NPTLRV	Number of Skylab structure lumps which have type 11 prescribed wall temperature curves (Enter zero if none desired and omit Card 56)
Card 56			
1-5	I5	NODE1	First node number
6-10	I5	KURVE1	First type 11 prescribed temperature curve number
11-15	I5	NODE2	Second node number
16-20	I5	KURVE2	Second type 11 prescribed temperature curve number

.
.
.

etc. through column 70

5.7.12 TIME VARIANT NODAL DATA CARDS

Columns	Format	Title	Description
Card 57			
1-5	I5	NUMTVW	Number of nodes with type 30 time variant mass (Enter zero if none desired and omit Card 58)
Card 58			
1-4	I4	NODE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	KURVE1	First type 30 time variant mass factor curve number
11-14	I4	NODE2	Second node number
15	A1	TYPE2	Second node code
16-20	I5	KURVE2	Second type 30 time variant mass factor curve number

.
.
.

etc. through column 70

Columns	Format	Title	Description

Repeat Card 58 as necessary to assign curve numbers to NUMTVW nodes.

5.7.13 TIME VARIANT NODAL CONNECTION DATA CARDS

Card 59

Columns	Format	Title	Description
1-5	I5	NUMTVC	Number of type 30 time variant connections (Enter zero if none desired and omit Card 60)

Card 60

Columns	Format	Title	Description
1-4	I4	NODE1	First node number
5	A1	TYPE1	First node code T = tube node S = structure node
6-10	I5	NLOC1	Connection number - has values 1 to n where n is the number of connections input on Card 29 or Card 35
11-15	I5	KURVE1	Type 30 time variant multiplying factor curve number
16-19	I4	NODE2	Second node number
20		TYPE2	Second node code T = tube node S = structure node
21-25	I5	NLOC2	Connection number
26-30	I5	KURVE2	Type 30 time variant multiplying factor curve number

.
.
.

etc. through column 60

Repeat Card 60 as necessary to supply NUMTVC time variant connections.

5.7.14 SPECIAL TUBE/FLUID CONNECTION DATA CARDS

Card 61

Columns	Format	Title	Description
1-5	I5	NSPCON	Number of special connections (Enter zero if none desired and omit Card 62)

Columns	Format	Title	Description
Card 62			
1-5	I5	NFLDND1	Fluid lump number of special connection number 1
6-10	I5	NTUBND1	Tube lump number of special connection number 1
11-20	F10.5	AREASP1	Area for heat transfer of special connection number 1
21-25	I5	NFLOND2	Fluid lump number of special connection number 2
26-30	I5	NTUBND2	Tube lump number of special connection number 2
31-40	F10.5	AREASP2	Area for heat transfer of special connection number 2
41-45	I5	NFLOND3	Fluid lump number of special connection number 3
46-50	I5	NTUBND3	Tube lump number of special connection number 3
51-70	F10.5	AREASP3	Area for heat transfer of special connection number 3

Repeat Card 62 as needed to input NSPCON sets of data.

5.7.15 CURVE DATA CARDS

Card 63 (Curve Header Card)

1-5	I5	KCRV	Curve type
		0	Head loss coefficient = f(Re)
		2	H_2O viscosity, (lbm/ft^2sec) = f(°F)
		4	Conductivity, (K/Ki) = f(°F)
		5	Specific heat, ($BTU/lb_m°F$) = f(°F)
		9	Incident heat, ($BTU/hr-ft^2$) = f(hrs)
		10	Wall temperature, (°F) = f(hrs)
		11	Skylab wall temperature, (°F) = f(hrs)
		12	O_2 HX inlet temperature side 2,(°F)=f(hrs)
			O_2 inlet temperature, (°F) = f(hrs)

Columns	Format	Title	Description
			Airlock module cold temperature, (°F)=f(hrs)
			Airlock module hot temperature,(°F)=f(hrs)
			Airlock module equipment HX temperature, (°F) = f(hrs)
		19	Combined heat fluxes, (BTU/hr) = f(hrs)
		20	Prescribed temperature histories,(°F)=f(hrs)
		21	Radiant interchange mode = f (hrs) 1. = mode 1 2. = mode 2 3. = mode 3 4. = mode 4 5. = mode 5
		24	HHH, (BTU/hr-ft^2°F) = f(lb/hr)
		29	Local perturbation diffusion factor = f (hrs)
			Local perturbation sweat factor = f(hrs)
			Local perturbation heat transfer factor = f (hrs)
		30	Time variant mass multiplying factor = f (hrs)
			Time variant connection multiplying factor = f (hrs)
		33	Compressibility factor (Z) = f(PR,TR)
			Hot HX pressure drop (ΔP) = f($\dot{w}$°F)
			Cold HX pressure drop (ΔP) = f($\dot{w}$,T)
			Bypass valve pressure drop (ΔP) = f($\dot{w}$,°F)
			LCG pressure drop (ΔP) = f($\dot{w}$,T)
			Gas separator pressure drop (ΔP) = f($\dot{w}$,°F)
			O_2 HX pressure drop (ΔP) = f($\dot{w}$,°F)
			O_2 specific heat (BTU/lb$_m$°F) = f(psig,°F)

Columns	Format	Title	Description
Card 63	(Continued)		
			O_2 Viscosity, (lbm/ft^{2}sec) = f(Psia,°F)
			O_2 enthalpy, (H) = f (Psia, °F)
		34	Suit leak rate, (lb/hr) = f(hrs)
			Metabolic lead, (Btu/hr) = f (hrs)
			Man efficiency (Percent/100) = f(hrs)
			Airlock module coolant flowrate ($\dot{w}$) = f (hrs)
			O_2 flowrate to second crewman ($\dot{w}$) = f (hrs)
			Ambient pressure, (Psia) = f (hrs)
			Reg 1 bleed flow ($\dot{w}$) = f(hrs)
			Reg 2 bleed flow, ($\dot{w}$) = f(hrs)
			Main O_2 reg relief valve flow ($\dot{w}$) = f (hrs)
			Pressure out/pressure in ratio = f($\dot{w}/\dot{w}i$)
			Pump (ΔP) = f($\dot{w}$)
			Heat load of second crewman, (Q) = f(hrs)
			Bypass valve position = f(hrs)
		35	Initial H_2O flowrate, ($\dot{w}$) = f (hrs) 0 = pump off
			Regulator selector valve = f (hrs) 0. = off 1. = reg 1 operating 2. = reg 2 operating 3. = both regulators operating
			Mode selector valve = f (hrs) 0. = closed 1. = open

Columns	Format	Title	Description
Card 63 (Continued)			
			Flow control valve = f (hrs) 0. = closed 1. = IVA 2. = EVA normal 3. = EVA high
			SOP flow control valve = f (hrs) 0. = closed 1. = open
			Helmet mode = f (hrs) 0. = SEVA off 1. = both visors down 2. = sun visor up 3. = both visors up
			EMU configuration mode = f (hrs) ±1. = EVA ±2. = IVA
			Operating code for second crewman 0. = no 1. = yes
6-10	I5	NC	Curve number
11-15	I5	NP	Number of points on curve, if KCRV = 33 NP equal the number of independent variable input first
16-20	Blank except for KCRV = 33		
	I5	NTU	Number of independent variables input second
21-25	Blank		
26-72	7A6	CTITLE	May be used for curve titles
Card 64 (If KCRV ≠ 33)			
1-10	F10.5	X_1	Independent variable
11-20	F10.5	X_2	
21-30	F10.5	X_3	
etc.			

Columns	Format	Title	Description
Card 64 (Continued)			
	F10.5	Y_1	Dependent variable
	F10.5	Y_2	
	F10.5	Y_3	
etc.			

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

Card 64 (If KCRV = 33)			
1-5	F5.4	FR_1	Values of the first independent variable
6-10	F5.4	FR_2	
11-15	F5.4	FR_3	
etc.			
	F5.4	TU_1	Values of the second independent variable
	F5.4	TU_2	
	F5.4	TU_3	
etc.			
	F5.4	$P(FR_1,TU_1)$	Values of dependent variable
	F5.4	$P(FR_1,TU_2)$	
	F5.4	$P(FR_1,TU_3)$	
etc.			
	F5.4	$P(FR_2,TU_1)$	
	F5.4	$P(FR_2,TU_2)$	
	F5.4	$P(FR_2,TU_3)$	
etc.			
End of Data			
1-5	I5	LCD	Input the number 13

5.8 Output Description

An explanation of the terms appearing in the paper printout is given below with units where applicable.

Parameters Print

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

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

Man Print

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

Heat Leak and Stored Heat Print

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

Flow Rates

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

Pressure Drops

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

Temperatures

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

6.0 LIST OF SYMBOLS

Alphabetic

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

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

Greek Symbols

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

Subscripts

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

7.0 REFERENCES

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APPENDIX A

TABLE A-1

SEMU BASELINE MODEL NODAL BREAKDOWN DATA

TUBE NODE	FLUID NODE	DESCRIPTION
1	1	INTERIOR PGA-RT. FOOT
2	1	INTERIOR PGA-RT. FOOT
3	1	INTERIOR PGA-RT. FOOT
4	2	INTERIOR PGA-LT. FOOT
5	2	INTERIOR PGA-LT. FOOT
6	2	INTERIOR PGA-LT. FOOT
7	3	INTERIOR PGA-RT. CALF
8	3	INTERIOR PGA-RT. CALF
9	4	INTERIOR PGA-LT. CALF
10	4	INTERIOR PGA-LT. CALF
11	3	INTERIOR PGA-RT. THIGH
12	3	INTERIOR PGA-RT. THIGH
13	4	INTERIOR PGA-LT. THIGH
14	4	INTERIOR PGA-LT. THIGH
15	5	INTERIOR PGA-WAIST
16	5	INTERIOR PGA-WAIST
17	5	INTERIOR PGA-CHEST
18	5	INTERIOR PGA-CHEST
19	6	INTERIOR PGA-RT. HAND
20	6	INTERIOR PGA-RT. HAND
21	7	INTERIOR PGA-LT. HAND
22	7	INTERIOR PGA-LT. HAND
23	8	INTERIOR PGA-RT. FOREARM
24	8	INTERIOR PGA-RT. FOREARM
25	7	INTERIOR PGA-LT. FOREARM
26	7	INTERIOR PGA-LT. FOREARM
27	8	INTERIOR PGA-RT. BICEP AND SHOULDER
28	8	INTERIOR PGA-RT. BICEP AND SHOULDER
29	9	INTERIOR PGA-LT. BICEP AND SHOULDER
30	9	INTERIOR PGA-LT. BICEP AND SHOULDER
31	5	INTERIOR PGA-UPPER CHEST
32	5	INTERIOR PGA-UPPER BACK
33	1	DUMMY
34	1	DUMMY
35	1	DUMMY
36	1	DUMMY
37	1	DUMMY
38	1	DUMMY
39	1	DUMMY
40	1	DUMMY
41	1	DUMMY

42	1	DUMMY
43	10	PRESSURE BUBBLE
44	10	PRESSURE BUBBLE
45	10	PRESSURE BUBBLE
46	10	PRESSURE BUBBLE
47	10	PRESSURE BUBBLE
48	10	PRESSURE BUBBLE
49	10	PRESSURE BUBBLE
50	10	PRESSURE BUBBLE
51	10	PRESSURE BUBBLE
52	10	PRESSURE BUBBLE
53	10	PRESSURE BUBBLE
54	10	PRESSURE BUBBLE
55	10	PRESSURE BUBBLE
56	10	PRESSURE BUBBLE
57	10	PRESSURE BUBBLE
58	10	PRESSURE BUBBLE
59	10	PRESSURE BUBBLE
60	10	PRESSURE BUBBLE
61	10	PRESSURE BUBBLE
62	10	PRESSURE BUBBLE
63	10	PRESSURE BUBBLE
64	10	PRESSURE BUBBLE
65	10	PRESSURE BUBBLE
66	10	PRESSURE BUBBLE
67	10	PRESSURE BUBBLE
68	10	PRESSURE BUBBLE
69	10	PRESSURE BUBBLE
70	10	PRESSURE BUBBLE
71	10	PRESSURE BUBBLE
72	10	PRESSURE BUBBLE
73	10	PRESSURE BUBBLE
74	10	PRESSURE BUBBLE
75	10	PRESSURE BUBBLE
76	10	PRESSURE BUBBLE
77	10	PRESSURE BUBBLE
78	10	PRESSURE BUBBLE
79	10	PRESSURE BUBBLE
80	10	PRESSURE BUBBLE
81	10	PRESSURE BUBBLE
82	10	PRESSURE BUBBLE
83	10	CREWMAN SKIN-HEAD
84	5	CREWMAN SKIN-TRUNK
85	8	CREWMAN SKIN-RT. ARM
86	9	CREWMAN SKIN-LT. ARM
87	6	CREWMAN SKIN-RT. HAND
88	7	CREWMAN SKIN-LT. HAND
89	3	CREWMAN SKIN-RT. LEG
90	4	CREWMAN SKIN-LT. LEG
91	1	CREWMAN SKIN-RT. FOOT
92	2	CREWMAN SKIN-LT. FOOT
93	5	UNDERGARMENT-TRUNK
94	8	UNDERGARMENT-RT. ARM
95	9	UNDERGARMENT-LT. ARM
96	3	UNDERGARMENT-RT. LEG

97	4	UNDERGARMENT-LT. LEG
98	1	UNDERGARMENT-RT. FOOT
99	2	UNDERGARMENT-LT. FOOT
100	124	GAS SEPARATOR IN AM H2O TUBE 39
101	125	LCG-INLET (TUBE 31)
102	126	LCG-OUTLET (TUBE 37)
103	1	DUMMY
104	1	DUMMY
105	10	PRESSURE BUBBLE
106	10	PRESSURE BUBBLE
107	10	PRESSURE BUBBLE
108	10	PRESSURE BUBBLE
109	10	PRESSURE BUBBLE
110	10	PRESSURE BUBBLE
111	10	PRESSURE BUBBLE
112	10	PRESSURE BUBBLE
113	10	PRESSURE BUBBLE
114	10	PRESSURE BUBBLE
115	11	LCG-TRUNK
116	12	LCG-RT. ARM
117	13	LCG-TRUNK
118	14	LCG-TRUNK
119	15	LCG-RT. LEG
120	16	LCG-TRUNK
121	17	LCG-TRUNK
122	18	LCG-TRUNK
123	19	LCG-LT. LEG
124	20	LCG-TRUNK
125	21	LCG-TRUNK
126	22	LCG-LT. ARM
127	23	LCG-TRUNK
128	24	H2O INLET-LSU
129	25	H2O INLET-LSU
130	26	H2O INLET-LSU
131	27	H2O INLET-LSU
132	28	H2O INLET-PCU
133	29	H2O INLET-UPSTREAM OF BYPASS
134	30	H2O BYPASS LINE
135	31	H2O INLET-DOWNSTREAM OF BYPASS
136	32	H2O INLET-PCU
137	33	H2O INLET-PCU
138	34	H2O INLET-HOSE,PCU TO MWC
139	35	H2O OUTLET-HOSE,MWC TO PCU
140	36	H2O OUTLET-PCU
141	37	H2O OUTLET-UPSTREAM OF BYPASS
142	38	H2O OUTLET-DOWNSTREAM OF BYPASS
143	39	H2O OUTLET-PCU
144	40	H2O OUTLET-LSU
145	41	H2O OUTLET-LSU
146	42	H2O OUTLET-LSU
147	43	H2O OUTLET-LSU
148	44	O2 HOSE-LSU
149	45	O2 HOSE-LSU
150	46	O2 HOSE-LSU
151	47	O2 HOSE-LSU

152	48	O2 MANIFOLD-LSU INLET
153	49	TUBE OUT OF SOP TANK
154	50	TUBE TO FILL AND SHUTOFF VALVE
155	51	SOP FILL AND SHUTOFF VALVE
156	52	TUBE TO SOP REGULATOR
157	53	SOP HIGH PRESSURE REGULATOR
158	54	INLET TUBE TO THERMAL STORAGE UNIT
159	55	THERMAL STORAGE UNIT
160	56	OUTLET TUBE FROM THERMAL STORAGE UNIT
161	57	SOP EXTERNAL FLEX HOSE
162	58	SOP FLOW SENSOR
163	59	TUBE-SENSOR TO O2 MANIFOLD
164	60	O2 MANIFOLD-SOP INLET
165	61	TUBE FROM MANIFOLD TO REG SEL VALVE
166	62	REGULATOR SELECTOR VALVE
167	63	REG 1 FLOW SENSOR
168	64	TUBE FROM SENSOR TO REG 1
169	65	REGULATOR NO. 1
170	66	TUBE FROM REG SEL VLV TO REG 2
171	67	REGULATOR NO. 2
172	68	O2 HOSE
173	69	O2 TUBE
174	70	SENSOR AND TUBE
175	71	SUIT O2 INLET HOSE
176	72	CONNECTOR-INLET HOSE TO SUIT
177	73	CONNECTOR-SUIT TO OUTLET HOSE
178	74	SUIT O2 OUTLET HOSE
179	75	O2 DEBRIS FILTER
180	76	O2 FLOW CONTROL VALVE
181	77	AM O2 TUBE 2
182	78	AM O2 TUBE 2
183	79	AM O2 TUBE 2
184	80	AM O2 TUBE 2
185	81	AM O2 TUBE 2
186	82	AM O2 TUBE 2
187	83	AM O2 TUBE 2
188	84	AM O2 TUBE 2
189	85	AM O2 TUBE 2
190	86	AM O2 TUBE 3
191	87	AM O2 TUBE 3
192	88	AM O2 TUBE 3
193	89	AM O2 TUBE 3
194	90	AM O2 TUBE 3
195	91	AM O2 TUBE 3
196	92	AM O2 TUBE 3
197	93	AM O2 TUBE 4
198	94	AM O2 TUBE 5
199	95	AM O2 TUBE 1
200	96	AM H2O TUBE 26
201	97	AM H2O TUBE 26
202	98	AM H2O TUBE 27
203	99	AM H2O TUBE 28
204	100	AM H2O TUBE 28

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205   101     AM H2O TUBE 28
206   102     AM H2O TUBE 28
207   103     AM H2O TUBE 28
208   104     AM H2O TUBE 28
209   105     AM H2O TUBE 28
210   106     AM H2O TUBE 28
211   107     AM H2O TUBE 39
212   108     AM H2O TUBE 39
213   109     AM H2O TUBE 39
214   110     AM H2O TUBE 39
215   111     AM H2O TUBE 39
216   112     AM H2O TUBE 39
217   113     AM H2O TUBE 39
218   114     AM H2O TUBE 39
219   115     AM H2O TUBE 39
220   116     AM H2O TUBE 39
221   117     AM H2O TUBE 39
222   118     AM H2O TUBE 39
223   119     AM H2O TUBE 39
224   120     AM H2O TUBE 39
225   121     AM H2O TUBE 39
226   122     AM H2O TUBE 39
227   123     AM H2O TUBE 39
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TABLE A-2

SEMU BASELINE MODEL NODAL BREAKDOWN DATA

STRUCTURE NODE	LOCATION/DESCRIPTION
1	RT. BOOT, BOTTOM
2	RT. BOOT, FRONT
3	RT. BOOT, TOP
4	RT. BOOT, REAR
5	RT. BOOT, RT. SIDE
6	RT. BOOT, LT. SIDE
7	LT. BOOT, BOTTOM
8	LT. BOOT, FRONT
9	LT. BOOT, TOP
10	LT. BOOT, REAR
11	LT. BOOT, LT. SIDE
12	LT. BOOT, RT. SIDE
13	EXTERIOR ITMG
14	EXTERIOR ITMG
15	EXTERIOR ITMG
16	EXTERIOR ITMG
17	EXTERIOR ITMG
18	EXTERIOR ITMG
19	EXTERIOR ITMG
20	EXTERIOR ITMG
21	EXTERIOR ITMG
22	EXTERIOR ITMG
23	EXTERIOR ITMG
24	EXTERIOR ITMG
25	EXTERIOR ITMG
26	EXTERIOR ITMG
27	EXTERIOR ITMG
28	EXTERIOR ITMG
29	EXTERIOR ITMG
30	SOP THERMAL COVER, FRONT, OUTSIDE
31	EXTERIOR ITMG
32	EXTERIOR ITMG
33	EXTERIOR ITMG
34	EXTERIOR ITMG
35	EXTERIOR ITMG
36	EXTERIOR ITMG
37	EXTERIOR ITMG
38	EXTERIOR ITMG
39	PCU THERMAL COVER, BOTTOM, OUTSIDE
40	PCU THERMAL COVER, OUTER LT. SIDE
41	PCU TOP SURFACE
42	PCU THERMAL COVER, OUTER RT. SIDE
43	PCU THERMAL COVER, FRONT, OUTSIDE
44	EXTERIOR ITMG
45	EXTERIOR ITMG
46	EXTERIOR ITMG

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47              EXTERIOR ITMG
48              EXTERIOR ITMG
49              EXTERIOR ITMG
50              EXTERIOR ITMG
51              EXTERIOR ITMG
52              EXTERIOR ITMG
53              EXTERIOR ITMG
54              EXTERIOR ITMG
55              EXTERIOR ITMG
56              EXTERIOR ITMG
57              EXTERIOR ITMG
58              EXTERIOR ITMG
59              EXTERIOR ITMG
60              EXTERIOR ITMG
61              EXTERIOR ITMG
62              EXTERIOR ITMG
63              EXTERIOR ITMG
64              EXTERIOR ITMG
65              EXTERIOR ITMG
66              EXTERIOR ITMG
67              EXTERIOR ITMG
68              EXTERIOR ITMG
69              EXTERIOR ITMG
70              EXTERIOR ITMG
71              EXTERIOR ITMG
72              EXTERIOR ITMG
73              EXTERIOR ITMG
74              EXTERIOR ITMG
75              EXTERIOR ITMG
76              EXTERIOR ITMG
77              EXTERIOR ITMG
78              EXTERIOR ITMG
79              EXTERIOR ITMG
80              EXTERIOR ITMG
81              EXTERIOR ITMG
82              EXTERIOR ITMG
83              EXTERIOR ITMG
84              EXTERIOR ITMG
85              EXTERIOR ITMG
86              EXTERIOR ITMG
87              EXTERIOR ITMG
88              EXTERIOR ITMG
89              EXTERIOR ITMG
90              EXTERIOR ITMG
91              EXTERIOR ITMG
92              EXTERIOR ITMG
93              EXTERIOR ITMG
94              EXTERIOR ITMG
95              EXTERIOR ITMG
96              EXTERIOR ITMG
97              EXTERIOR ITMG
98              EXTERIOR ITMG
99              EXTERIOR ITMG
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100          EXTERIOR ITMG
101          EXTERIOR ITMG
102          EXTERIOR ITMG
103          EXTERIOR ITMG
104          EXTERIOR ITMG
105          SEVA SHELL
106          SEVA SHELL
107          SEVA SHELL
108          SEVA SHELL
109          SEVA SHELL
110          SEVA SHELL
111          SEVA SHELL
112          SEVA SHELL
113          SEVA RT. HINGE POINT
114          SEVA LT. HINGE POINT
115          SEVA SHELL
116          SEVA SHELL
117          SEVA SHELL
118          SEVA SHELL
119          SEVA SHELL
120          SEVA SHELL
121          SEVA SHELL
122          SEVA SHELL
123          SEVA SHELL
124          SEVA SHELL
125          SEVA SHELL
126          SEVA SHELL
127          SEVA SHELL
128          SEVA SHELL
129          SEVA SHELL
130          SEVA SHELL
131          SEVA SHELL
132          SEVA SHELL
133          SEVA SHELL
134          SEVA SHELL
135          SEVA SHELL
136          SEVA SHELL
137          SEVA SHELL
138          SEVA SHELL
139          SEVA SHELL
140          SUN VISOR (MODE 1)
141          SUN VISOR (MODE 1)
142          SUN VISOR (MODE 1)
143          SUN VISOR (MODE 1)
144          SUN VISOR (MODE 1)
145          SUN VISOR (MODE 1)
146          SUN VISOR (MODE 1)
147          SUN VISOR (MODE 1)
148          SUN VISOR (MODE 1)
149          SUN VISOR (MODE 1)
150          SUN VISOR (MODE 1)
151          SUN VISOR (MODE 1)
152          SUN VISOR (MODE 1)
153          SUN VISOR (MODE 1)
154          SUN VISOR (MODE 1)
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155        SUN VISOR (MODE 1)
156        SUN VISOR (MODE 1)
157        SUN VISOR (MODE 1)
158        SUN VISOR (MODE 1)
159        SUN VISOR (MODE 1)
160        SOP THERMAL COVER, BOTTOM, OUTSIDE
161        SOP THERMAL COVER, OUTER LT. SIDE
162        SOP TOP SURFACE
163        SOP THERMAL COVER, OUTER RT. SIDE
164        INTERIOR ITMG
165        INTERIOR ITMG
166        INTERIOR ITMG
167        INTERIOR ITMG
168        INTERIOR ITMG
169        INTERIOR ITMG
170        INTERIOR ITMG
171        INTERIOR ITMG
172        INTERIOR ITMG
173        INTERIOR ITMG
174        INTERIOR ITMG
175        INTERIOR ITMG
176        INTERIOR ITMG
177        INTERIOR ITMG
178        INTERIOR ITMG
179        INTERIOR ITMG
180        INTERIOR ITMG
181        INTERIOR ITMG
182        INTERIOR ITMG
183        INTERIOR ITMG
184        INTERIOR ITMG
185        INTERIOR ITMG
186        INTERIOR ITMG
187        INTERIOR ITMG
188        INTERIOR ITMG
189        INTERIOR ITMG
190        INTERIOR ITMG
191        INTERIOR ITMG
192        INTERIOR ITMG
193        SOP THERMAL COVER, REAR OUTSIDE
194        INTERIOR ITMG
195        INTERIOR ITMG
196        INTERIOR ITMG
197        INTERIOR ITMG
198        INTERIOR ITMG
199        INTERIOR ITMG
200        INTERIOR ITMG
201        INTERIOR ITMG
202        PCU THERMAL COVER, BOTTOM, INSIDE
203        PCU THERMAL COVER, INNER LT. SIDE
204        PCU THERMAL COVER, INNER RT. SIDE
205        PCU THERMAL COVER, FRONT, INSIDE
206        PCU THERMAL COVER, REAR, INSIDE
207        INTERIOR ITMG
208        INTERIOR ITMG
209        INTERIOR ITMG
210        INTERIOR ITMG
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211	INTERIOR ITMG
212	INTERIOR ITMG
213	INTERIOR ITMG
214	INTERIOR ITMG
215	INTERIOR ITMG
216	INTERIOR ITMG
217	INTERIOR ITMG
218	INTERIOR ITMG
219	INTERIOR ITMG
220	INTERIOR ITMG
221	INTERIOR ITMG
222	INTERIOR ITMG
223	INTERIOR ITMG
224	INTERIOR ITMG
225	INTERIOR ITMG
226	INTERIOR ITMG
227	INTERIOR ITMG
228	INTERIOR ITMG
229	INTERIOR ITMG
230	INTERIOR ITMG
231	INTERIOR ITMG
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233	INTERIOR ITMG
234	INTERIOR ITMG
235	INTERIOR ITMG
236	INTERIOR ITMG
237	INTERIOR ITMG
238	INTERIOR ITMG
239	INTERIOR ITMG
240	INTERIOR ITMG
241	INTERIOR ITMG
242	INTERIOR ITMG
243	INTERIOR ITMG
244	INTERIOR ITMG
245	INTERIOR ITMG
246	INTERIOR ITMG
247	INTERIOR ITMG
248	INTERIOR ITMG
249	INTERIOR ITMG
250	INTERIOR ITMG
251	INTERIOR ITMG
252	INTERIOR ITMG
253	INTERIOR ITMG
254	INTERIOR ITMG
255	INTERIOR ITMG
256	INTERIOR ITMG
257	INTERIOR ITMG
258	INTERIOR ITMG
259	INTERIOR ITMG
260	INTERIOR ITMG
261	INTERIOR ITMG
262	INTERIOR ITMG
263	INTERIOR ITMG
264	INTERIOR ITMG
265	INTERIOR ITMG
266	INTERIOR ITMG

267	INTERIOR ITMG
268	SOP THERMAL COVER, FRONT, INSIDE
269	SOP THERMAL COVER, BOTTOM, INSIDE
270	SOP THERMAL COVER, INNER LT. SIDE
271	SOP THERMAL COVER, INNER RT. SIDE
272	EXTERIOR PGA
273	EXTERIOR PGA
274	EXTERIOR PGA
275	EXTERIOR PGA
276	EXTERIOR PGA
277	EXTERIOR PGA
278	EXTERIOR PGA
279	EXTERIOR PGA
280	EXTERIOR PGA
281	EXTERIOR PGA
282	EXTERIOR PGA
283	EXTERIOR PGA
284	EXTERIOR PGA
285	EXTERIOR PGA
286	EXTERIOR PGA
287	EXTERIOR PGA
288	EXTERIOR PGA
289	EXTERIOR PGA
290	EXTERIOR PGA
291	EXTERIOR PGA
292	EXTERIOR PGA
293	EXTERIOR PGA
294	EXTERIOR PGA
295	EXTERIOR PGA
296	EXTERIOR PGA
297	EXTERIOR PGA
298	EXTERIOR PGA
299	EXTERIOR PGA
300	EXTERIOR PGA
301	EXTERIOR PGA
302	EXTERIOR PGA
303	EXTERIOR PGA
304	EXTERIOR ITMG
305	EXTERIOR ITMG
306	EXTERIOR ITMG
307	EXTERIOR ITMG
308	PROTECTIVE VISOR (MODE 1)
309	PROTECTIVE VISOR (MODE 1)
310	PROTECTIVE VISOR (MODE 1)
311	PROTECTIVE VISOR (MODE 1)
312	PROTECTIVE VISOR (MODE 1)
313	PROTECTIVE VISOR (MODE 1)
314	PROTECTIVE VISOR (MODE 1)
315	PROTECTIVE VISOR (MODE 1)
316	PROTECTIVE VISOR (MODE 1)
317	PROTECTIVE VISOR (MODE 1)
318	PROTECTIVE VISOR (MODE 1)
319	PROTECTIVE VISOR (MODE 1)
320	PROTECTIVE VISOR (MODE 1)

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321          PROTECTIVE VISOR   (MODE 1)
322          PROTECTIVE VISOR   (MODE 1)
323          PROTECTIVE VISOR   (MODE 1)
324          PROTECTIVE VISOR   (MODE 1)
325          PROTECTIVE VISOR   (MODE 1)
326          PROTECTIVE VISOR   (MODE 1)
327          PROTECTIVE VISOR   (MODE 1)
328          SUN VISOR   (MODE 2)
329          SUN VISOR   (MODE 2)
330          SUN VISOR   (MODE 2)
331          SUN VISOR   (MODE 2)
332          SUN VISOR   (MODE 2)
333          SUN VISOR   (MODE 2)
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342          SUN VISOR   (MODE 2)
343          SUN VISOR   (MODE 2)
344          SUN VISOR   (MODE 2)
345          SUN VISOR   (MODE 2)
346          SUN VISOR   (MODE 2)
347          SUN VISOR   (MODE 2)
348          PROTECTIVE VISOR   (MODE 2)
349          PROTECTIVE VISOR   (MODE 2)
350          PROTECTIVE VISOR   (MODE 2)
351          PROTECTIVE VISOR   (MODE 2)
352          PROTECTIVE VISOR   (MODE 2)
353          PROTECTIVE VISOR   (MODE 2)
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358          PROTECTIVE VISOR   (MODE 2)
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361          PROTECTIVE VISOR   (MODE 2)
362          PROTECTIVE VISOR   (MODE 2)
363          PROTECTIVE VISOR   (MODE 2)
364          PROTECTIVE VISOR   (MODE 2)
365          PROTECTIVE VISOR   (MODE 2)
366          PROTECTIVE VISOR   (MODE 2)
367          PROTECTIVE VISOR   (MODE 2)
368          SUN VISOR   (MODE 3)
369          SUN VISOR   (MODE 3)
370          SUN VISOR   (MODE 3)
371          SUN VISOR   (MODE 3)
372          SUN VISOR   (MODE 3)
373          SUN VISOR   (MODE 3)
374          SUN VISOR   (MODE 3)
375          SUN VISOR   (MODE 3)
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377          SUN VISOR   (MODE 3)
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378          SUN VISOR  (MODE 3)
379          SUN VISOR  (MODE 3)
380          SUN VISOR  (MODE 3)
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383          SUN VISOR  (MODE 3)
384          SUN VISOR  (MODE 3)
385          SUN VISOR  (MODE 3)
386          SUN VISOR  (MODE 3)
387          SUN VISOR  (MODE 3)
388          PROTECTIVE VISOR  (MODE 3)
389          PROTECTIVE VISOR  (MODE 3)
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400          PROTECTIVE VISOR  (MODE 3)
401          PROTECTIVE VISOR  (MODE 3)
402          PROTECTIVE VISOR  (MODE 3)
403          PROTECTIVE VISOR  (MODE 3)
404          PROTECTIVE VISOR  (MODE 3)
405          PROTECTIVE VISOR  (MODE 3)
406          PROTECTIVE VISOR  (MODE 3)
407          PROTECTIVE VISOR  (MODE 3)
408          FAS WORK STATION
409          FAS WORK STATION
410          FAS WORK STATION
411          FAS WORK STATION
412          FAS WORK STATION
413          FAS WORK STATION
414          FAS WORK STATION
415          FAS WORK STATION
416          FAS WORK STATION
417          FAS WORK STATION
418          FAS WORK STATION
419          FAS WORK STATION
420          FAS WORK STATION
421          FAS WORK STATION
422          FAS WORK STATION
423          FAS WORK STATION
424          FAS WORK STATION
425          FAS WORK STATION
426          FAS WORK STATION
427          FAS WORK STATION
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574	SPACE NODE (FOR ALL BUT VISORS)
575	SPACE NODE (VISOR MODE 1)
576	SPACE NODE (VISOR MODE 2)
577	DUMMY MDA INTERIOR (CONSTANT 70 DEGREES)
578	DUMMY ATM INTERIOR (CONSTANT 0. DEGREES)
579	PCU THERMAL COVER, REAR, OUTSIDE
580	PCU HARD COVER, BOTTOM
581	PCU HARD COVER, LT. SIDE
582	PCU HARD COVER, RT. SIDE
583	PCU HARD COVER, FRONT
584	PCU HARD COVER, REAR
585	SOP THERMAL COVER, REAR, INSIDE
586	SOP HARD COVER, FRONT
587	SOP HARD COVER, BOTTOM
588	SOP HARD COVER, LT. SIDE
589	SOP HARD COVER, RT. SIDE
590	SOP HARD COVER, REAR
591	LSU ELECTRICAL CABLE
592	LSU ELECTRICAL CABLE
593	LSU ELECTRICAL CABLE
594	LSU ELECTRICAL CABLE
595	LSU INTERIOR INSULATION
596	LSU INTERIOR INSULATION
597	LSU INTERIOR INSULATION
598	LSU INTERIOR INSULATION

599	LSU EXTERIOR INSULATION
600	LSU EXTERIOR INSULATION
601	LSU EXTERIOR INSULATION
602	LSU EXTERIOR INSULATION
603	PCU H2O HOSE COVER, INTERIOR
604	PCU H2O HOSE COVER, EXTERIOR
605	SUIT O2 INLET HOSE COVER, INTERIOR
606	SUIT O2 INLET HOSE COVER, EXTERIOR
607	SUIT O2 OUTLET HOSE COVER, INTERIOR
608	SUIT O2 OUTLET HOSE COVER, EXTERIOR
609	SOP OXYGEN TANK
610	OXYGEN IN SOP TANK
611	SOP UPPER MOUNTING BRACKET
612	SOP LOWER MOUNTING BRACKET
613	SOP HOSE THERMAL COVER, INTERIOR
614	SOP HOSE THERMAL COVER, EXTERIOR