MISSILES AND SPACE DIVISION

LTV AEROSPACE CORPORATION

P. O. Box 6267 Dallas, Texas 75222

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ULTRA-FAST MISSION ANALYSIS ROUTINE FOR APOLLO BLOCK II ENVIRONMENTAL CONTROL SYSTEM RADIATORS

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Submitted by

MISSILES AND SPACE DIVISION - TEXAS
LTV AEROSPACE CORPORATION
P.O. Box 6267 - Dallas, Texas 75222

To

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER - Houston, Texas

Prepared by

C. W. Hixon

J. E. French

H. R. Howell

Reviewed by

R. J. French

Approved by

F. T. Esenwein
Manager - Propulsion and Environment

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1.0 SUMMARY

This report presents analytical methods, program description, sample results and user's instructions for a digital computer routine for transient space radiator performance predictions. The routine was written specifically for analysis of the Apollo Block II Environmental Control System (ECS) radiators.

Specific equations for a simplified thermal model of the radiators are written directly in the program. All equations necessary to obtain the radiator outlet temperature, heat rejection and pressure drop are contained in the routine. The temperature equations for each node in the thermal model are solved by an implicit finite difference method. All thermal properties are considered to be constant with the exception of the radiator coolant viscosity. The routine includes a characterization of the flow proportioning and bypass valves which are contained in the radiator systems. Provisions are also included for single panel and redundant loop operation.

Radiator absorbed heat data for four vehicle environments (two lunar orbit orientations, a translunar thermal cycle and zero absorbed heat) are contained in the routine. A mission code determines which set of absorbed heat flux data is used. Provisions are also included for inputting absorbed heat data as a function of time. A cyclic repeat of the heat flux data is utilized allowing multiple periods to be analyzed with heat flux data supplied for only one period.

Inputs for the first four missions consist of mission code, print interval, inlet temperature and total flow rate. The input mission requires mission code, print interval, total mission time and time dependent tables of incident heats, inlet temperature and flow rate. Output for all the missions includes heat rejection, pressure drop, low load heater on/off operation, flow rate and outlet fluid temperature printed at the times defined by the print interval and (following completion of the mission) maximum, minimum and average values for heat rejection, pressure drop and fluid outlet temperature and total heat dissipated by the low load heater.

Computer time required to analyze a 4.08 hour lunar orbit mission (two orbits) with a calculation and print interval of .02 hours is 25 seconds on the Univac 1108 computer. This represents a routine run speed of better than 500 times real time.

The Apollo Block II ECS radiator performance predictions obtained by the computer program described herein have been compared to detailed thermal model predictions which have been verified by predicting test results. All of the expected operating modes and environmental conditions of the Block II ECS radiator were considered. All active controls (bypass valve, proportioning valve, isolation valve and low load heater) were exercised. Both the primary and redundant system performance predictions were compared. It has been determined that the computer routine provides adequate Block II ECS radiator performance predictions for a wide variety of conditions with a minimum of computer time required.

2.0 INTRODUCTION

In the design of thermal control flow systems, whether it be that of individual components or overall systems, the ability to determine a design's adequacy is enhanced by the capability to simulate its performance while it is subjected to a variety of mission parameters. The space radiators used in the Apollo Block II Environmental Control System (ECS) are components critical to the operation of the ECS and as such, their response to various combinations of environmental parameters has been established. Computer analysis of these space radiators has required large quantities of computer time for the many missions required for a comprehensive study.

This report summarizes the creation of a program which computes approximate radiator performance rapidly enough to permit a large number of parametric mission analyses with minimum computer time. The work was done under Contract NAS9-6807, which requires modification of the Block II component subroutine described in Reference 1. The thermal model of Reference 1 has been improved and additional analyses have been made to verify the performance predictions of the program. The revised routine also contains the redundant loop, the low load heater and provisions for single panel operation. In addition to the four missions built into the parent subroutine, a fifth mission has been created to permit the card input of time-dependent tables of incident heats, system fluid inlet temperature, and total flow rate. Provision is also made for dynamic printout of heat rejection, pressure drop, flow rate, and outlet fluid temperature at selected intervals for all five missions. A User's Manual for the program thus formed is included.

The stated objective of the computer routine requires the prediction of suitable radiator performance in any environment and with any heat load. In order to evaluate the adequacy of the computer routine predictions it is necessary to establish a baseline to which the predictions can be compared. No flight data are available and test data are available for only a limited number of conditions. The approach taken herein is to use the results of a detailed computer routine and thermal model as a baseline for evaluating the results of the simplified computer routine. The detailed baseline model has been verified by predicting the results of the Qualification Test of the Apollo Block II ECS radiator. Baselines have been established for a wide variety of conditions using the detailed model.

3.0 ANALYTICAL METHODS

This section presents the methods used in the Apollo Block II ECS radiator computer routine (AB2RAD) for heat transfer and fluid flow analysis. The equations used in the temperature and pressure drop calculations are given along with the flow control valve characterizations.

3.1 Heat Transfer Analysis

The temperature of each fluid, tube and structure node in the thermal model is determined from the general temperature equation below:

$$T_j'' = \frac{T_j^{(\tau)} + \sum_k D_{jk} T_k'' + F_j - E_j T_j''^4}{1 + \sum_k D_{jk}}$$

The above equation is derived in Reference 2 and the symbols are defined in the List of Symbols (page 40) and Table 1.

An implicit backward-difference method is used to determine the temperature of each node. First the coefficients in the above equation are determined for each node. These coefficients are detailed in Table 1. All coefficients are a function of the computing time increment. The fluid upstream temperature coefficient is a function of the flow rate and the tube and structure absorbed heat coefficients are a function of the incident heat. All other terms in the coefficients given in Table 1 are determined from the radiator physical characteristics and input as constants in the routine.

The resulting set of non-linear temperature equations are solved simultaneously by a modified point-iterative method known as "successive overrelaxation (SOR)" to yield the temperature of each lump at the end of the computing time increment. The method is as follows:

1. Assume an initial temperature matrix called T.

2. Set matrices T_1 and T_2 to T.

3. Using the values of temperature in T_2, calculate values of temperature from the general temperature equation above, one lump at a time. Call this iterate T' for the particular lump. The T_2 value is determined by the equation $T_2 = T_1 + \phi\,(T'-T_1)$, ϕ being the overrelaxation parameter ($\phi = 1.3$). This procedure is continued until each lump's equation has been iterated.

TABLE 1 - TEMPERATURE EQUATION COEFFICIENTS

Type Lump j	D_{jk}	T_k	E_j	F_j
Fluid	$\frac{\dot{w}\Delta\tau}{w_f}$	T_{fu}	0	0
	$\frac{h_f A_f \Delta\tau}{w_f\ c_f}$	T_t		
Tube	$\frac{h_f A_f \Delta\tau}{w_t\ c_t}$	T_f	$\frac{\epsilon_j \sigma A_{ej} \Delta\tau}{w_t\ c_t}$	$\frac{\alpha_j Qt_j A_{ej} \Delta\tau}{w_t\ c_t}$
	$\frac{U_{jk} \Delta\tau}{w_t\ c_t}$	T_s		
Structure	$\frac{U_{jk} \Delta\tau}{w_s\ c_s}$	T_s.	$\frac{\epsilon_j \sigma A_{ej} \Delta\tau}{w_s\ c_s}$	$\frac{\alpha_j Qs_j A_{ej} \Delta\tau}{w_s\ c_s}$

The quantities used in Table 1 are defined as the following:

$\dot{w}_j$ - flow rate in the tube containing fluid lump j. This is a variable quantity calculated at the beginning of each calculation time increment.

$\Delta\tau$ - calculation time increment. This value is set internally in the routine as 0.02 hour.

w - weight of lump j.

T_{fu} - temperature of fluid lump upstream of lump j.

h_f - heat transfer coefficient.

A_f - internal area for heat transfer.

c - specific heat

T_k - temperature of neighboring lump in communication with lump j.

ϵ_j - emissivity of lump j.

σ - Stefan-Boltzmann constant.

$\alpha_j Q_j$ - incident heat absorbed by lump j.

TABLE 1 - TEMPERATURE EQUATION COEFFICIENTS (Cont'd)

A_{ej} - external area for radiation of lump j.

$U_{jk} = A_c \left[\frac{k}{Y_j + Y_k}\right]$ - conductance between lump j and neighboring lump k.

k - thermal conductivity.

A_c - conduction area between lumps j and k.

Y_j, Y_k - conduction path lengths.

Subscripts

f - fluid

t - tube

s - structure (fin)

All temperature calculations in the subroutines are carried out in degrees Rankine.

4. The new matrix of T_2 thus determined is compared to the T_1 matrix term by term. If $|T_2 - T_1|$ is less than the iteration limit ($\Theta = 0.10$) the iteration of this particular equation is temporarily suspended. If $|T_2 - T_1|$ is less than Θ for each lump, the solution is achieved.

5. The T_1 matrix is set to the T_2 matrix and the process is repeated from step 3. As soon as the last lump satisfies the $|T_2 - T_1| < \Theta$, if all equations were not iterated, the process is again begun for each lump from step 3.

The standard SOR procedure is modified in that those equations which satisfy the $|T_2 - T_1| < \Theta$ are not iterated until all equations have satisfied the relation.

3.2 Pressure Drop

The pressure drop in the radiators and connecting tubes is calculated by the following equation and is restricted to Reynolds numbers less than 2000.

$$\Delta P_j = \sum_i B_i \, \mu_i \, \dot{w}_j$$

The constants, B_i, are obtained from the density and geometry of the fluid lump. The dynamic viscosity, μ, of each fluid lump is determined from the fluid lump temperature by table look-up.

The flow rates in the five parallel tubes of each radiator panel are determined by requiring the pressure drop for each of the parallel flow paths to be equal. Therefore defining:

$$AK_j = \Delta P_j / \dot{w}_j$$

then the flow rate in tube j is

$$\dot{w}_j = (AK_1)(\dot{w}_1)/AK_j$$

$$\dot{w}_{total} = \sum_j \dot{w}_j$$

The flow rate in tube 1 is

$$\dot{w}_1 = \frac{\dot{w}_{total}}{1 + \sum_j \frac{AK_1}{AK_j}} \qquad j \neq 1$$

3.3 Bypass Valve Characterization

The bypass valve in the Apollo Block II ECS radiator system controls the heat rejection by regulating the flow through the radiator. The bypass line and valve pressure losses are not calculated since they are in parallel with the radiator, and their pressure loss will equal the radiator pressure loss. The valve is programed to route flow through the radiator such that the mixed temperature is controlled to a nominal 45°F if obtaining this temperature at the end of each computing interval is within the valve response capability. The valve's position (fraction bypass) is determined according to the difference between the mixed outlet temperature after each iteration and the desired temperature (45°F). A deadband is included in the valve logic such that the valve is not activated until the above temperature difference exceeds 0.75°F. The fraction bypass is characterized in AB2RAD by the equation:

$$Z = Z_{previous} + \Delta Z$$

where Z is the fraction bypassed. The term, ΔZ, is calculated from the valve response characteristics and computing time increment. The usual valve response characteristics were altered to desensitize the valve in order to eliminate problems with the larger time increments used in the routine. The valve rate factor used in AB2RAD is 0.0003 (fraction of full travel per °F per second) and the rate limit is 0.0033 (fraction of full travel per second). The actual valve constants are 0.00258 for the rate factor and 0.0465 for the rate limit.

3.4 Proportioning Valve

The proportioning of flow through the two parallel radiators in the Apollo Block II ECS radiator subsystem is controlled by a proportioning valve located at the junction of the inlets to the radiators. Temperature sensors located near the outlets of the radiators provide signals for valve control. The valve is designed to respond by increasing flow to the radiator with the lower outlet temperature. This arrangement is utilized to provide maximum heat rejection when the two radiator panels operate in significantly different incident heat environments.

The proportioning valve simulation in the computer routine is designed to reproduce the characteristics of the actual valve that will be used in the Apollo Block II subsystem. The basic equation describing the operation of the valve is:

$$X = X_{previous} + \frac{\Delta\tau}{t_c}\left[(X_i - X_{previous}) + G\,(T_{RT} - T_{LT})\right]$$

where:

- G = valve gain
- t_c = valve time constant
- $\Delta\tau$ = computing time increment
- X_i = initial valve position (from left)
- $X_{previous}$ = valve position at previous iteration
- X = new valve position
- T_{RT}, T_{LT} = temperature of sensors in right and left tubes

This equation is valid only when the computing time increment is small compared with the valve time constant. The computing time increment used in AB2RAD (0.02 hours) is much greater than the valve time constant (0.000833 hours) and the valve position is obtained by the equation:

$$X = X_i + G\,(T_{RT} - T_{LT})$$

After the position, X, is determined, it is used to define the pressure drops in each side of the valve by the relations:

$$\Delta P_{RT} = H\left[\frac{\dot{w}_{RT}}{X_2}\right]^2$$

$$\Delta P_{LT} = H\left[\frac{\dot{w}_{LT}}{X_1}\right]^2$$

where:

H = proportionality factor for valve pressure drop
$\dot{w}_{RT}$, $\dot{w}_{LT}$ = right and left side flow rates
X_1 = valve position from left
X_2 = valve position from right

The valve pressure drops are considered together with the pressure drops in the remainder of the right and left hand flow paths to determine flow rates that give a pressure balance for both sides. Considering the pressure drop of the radiator to be a linear function of flow rate, such that $\Delta P = K\,\dot{w}$, the pressure balance in the radiator and valve can be written as:

$$K_{RT}\,\dot{w}_{RT} + H\left[\frac{\dot{w}_{RT}}{X_2}\right]^2 = K_{LT}\,\dot{w}_{LT} + H\left[\frac{\dot{w}_{RT}}{X_1}\right]^2$$

where:

K_{RT} = ΔP of radiator right branch/right side flow rate
K_{LT} = ΔP of radiator left branch/left side flow rate
$\dot{w}_{RT}$, $\dot{w}_{LT}$ = right and left flow rates

Substituting $\dot{w}_{RT} = \dot{w}_{TOT} - \dot{w}_{LT}$ and rearranging yields a solution for $\dot{w}_{LT}$ in the standard quadratic form:

$$H\left[\frac{1}{X_1^2} - \frac{1}{X_2^2}\right]\dot{w}_{LT}^2 + \left[K_{LT} + K_{RT} + \frac{2\,H\,\dot{w}_{TOT}}{X_2^2}\right]\dot{w}_{LT} - \left[K_{RT}\,\dot{w}_{TOT} + \frac{H(\dot{w}_{TOT})^2}{X_2^2}\right] = 0$$

The standard quadratic equation solution is used in the AB2RAD to solve the above equation for the flow rate in the left branch of the radiator system as determined by the proportioning valve position.

4.0 RADIATOR CHARACTERIZATION

The AB2RAD calculates heat rejection and pressure drop as a function of time. This section describes the thermal model used, the orientations available and a comparison of predicted results to a detailed analysis of the Block II ECS radiator.

4.1 Thermal Model

The thermal model used in AB2RAD consists of two radiator panels connected in parallel. Each panel is composed of a five flow tube stagnation panel plus a single flow tube in series downstream of the selective stagnation panel. Figure 1 shows the thermal model for the complete radiator system including valves as analyzed by AB2RAD.

The thermal model is a coarse breakdown of the actual Apollo Block II ECS radiator panels. The primary and redundant flow tubes in the stagnation panel were divided into two equal length isothermal nodes. This coarse division resulted in twelve tube and fluid nodes and eight fin nodes per stagnation panel. Each series panel has four fluid and tube nodes (two each for the primary and redundant loop) and two fin nodes. The inlet and outlet manifold tubes and other connecting tubes shown in Figure 1 were considered adiabatic, and therefore did not affect the thermal balance.

4.2 Absorbed Heat

Heat flux data for two 80 nautical mile ecliptic plane lunar orbits, a 1.0 RPH translunar thermal cycle and a deep space environment are contained in AB2RAD. A description of these thermal environments follows:

1. Lunar Orbit Broadside Orientation - The longitudinal axis of the vehicle is always parallel to the lunar surface and passes through the subsolar point. The vehicle orbits with one radiator panel always facing the Moon while the diametrically opposed panel alternately sees deep space and the solar flux.

2. Lunar Orbit Nose Down Orientation - The longitudinal axis of the vehicle is always perpendicular to the lunar surface and the vehicle passes through the subsolar point. The mid-point of both the leading and lagging radiator panels are in the plane of the orbit.

3. Translunar Thermal Cycle - The longitudinal axis of the vehicle is perpendicular to the sun's rays. The vehicle rolls at a rate of one revolution per hour.

4. Deep Space - The radiator panels are positioned so as to receive zero incident heat.

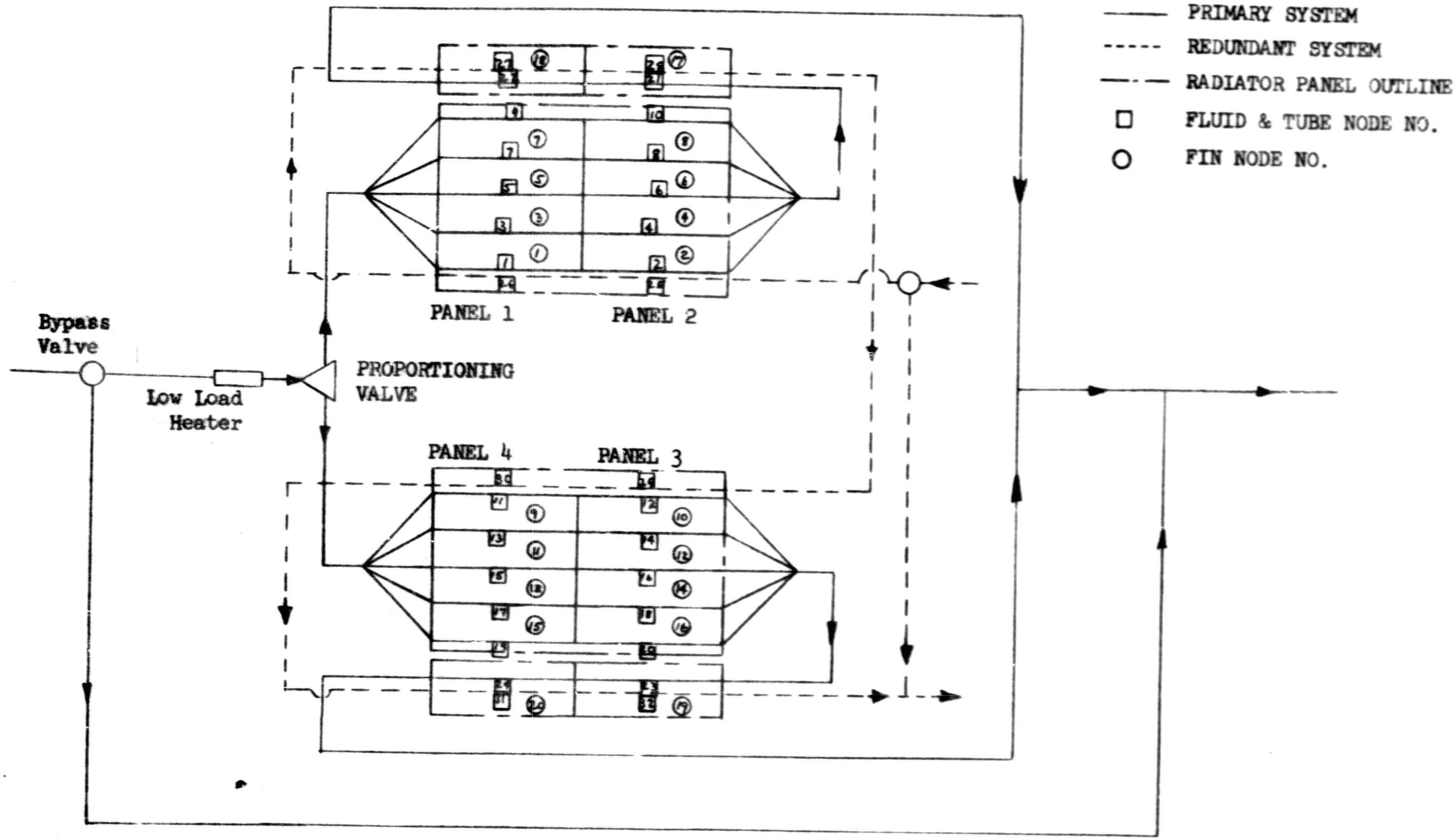


FIGURE 1 APOLLO BLOCK II ECS RADIATOR SIMPLIFIED THERMAL MODEL

Absorbed heat data for the two lunar orbits above were obtained by use of the digital computer routine of Reference 3. The solar absorbtivity and emissivity used in this analysis were 0.20 and 0.92 respectively. Figures 2 through 4 show the absorbed heat for the lunar broadside orientation, lunar nose down orientation and a 1.0 RPH thermal cycle respectively. The data shown are for a flat plate inclined at an angle of 30° from the radiator mid point. It was determined that these flat plate values of absorbed heat represented an average value for the curved radiator surface.

The absorbed heat data for each of the above conditions are written into the routine for one orbit for the lunar orbits and one vehicle revolution for the thermal cycle. A cyclic repeat of the curves is provided to obtain data for four orbits (8.1676 hours of mission time) and four vehicle revolutions (4.0 hours of mission time). In addition to the absorbed heat data contained in the routine, AB2RAD provides for the tabular input of any heat flux data desired. Input data requirements and instructions are given in Section 5.0.

4.3 CAPABILITY

The AB2RAD is intended to be suitable for predicting radiator performance in any environment and with any heat load. In order to evaluate the adequacy of the AB2RAD predictions, comparisons have been made to the detailed analysis results presented in References 4 and 5 for the Block II ECS radiator. The baseline model used in Reference 4 has been verified by predicting the results of the Qualification Test of the Block II ECS radiators (Reference 5). It should be noted that the baseline thermal model and Qualification Test hardware assumed adiabatic conditions between the radiator supply and return lines and the Service Module structure. Recent tests of the complete Block II ECS (2TV-1) and preliminary analyses have indicated that a significant amount of heat can be added to the radiator outlet line from the Service Module structure. Since the AB2RAD is based on the thermal model of Reference 4, the effect of the Service Model structure on the supply and return lines is not included in the results. The baseline model has a total of 1141 nodes and yields 2.5 hours of mission time for each hour of computer time as compared to the AB2RAD total of 84 nodes and run speed of better than 500 hours of mission time for each hour of computer time. Both models were run on the Univac 1108 computer. Performance comparisons were made between the baseline analyses and the AB2RAD results for the following conditions:

(1) Lunar orbit, broadside orientation, 8500 BTU/hr heat load, primary system operating.

(2) Lunar orbit, broadside orientation, 3470 BTU/hr heat load, primary system operating.

(3) Lunar orbit, broadside orientation, 5600 BTU/hr heat load, redundant system and one primary system panel operating.

(4) Translunar thermal cycle, 2.5 RPH, 6880 BTU/hr heat load, redundant system and one primary system panel operating.

(5) Earth orbit, broadside orientation, 8800 BTU/hr heat load, primary system operating.

(6) Deep space transient from a heat load of 4415 BTU/hr to 9275 BTU/hr.

A total flow rate of 200 lb/hr was used for both the primary and redundant systems with the inlet temperatures computed from the heat load for each case.

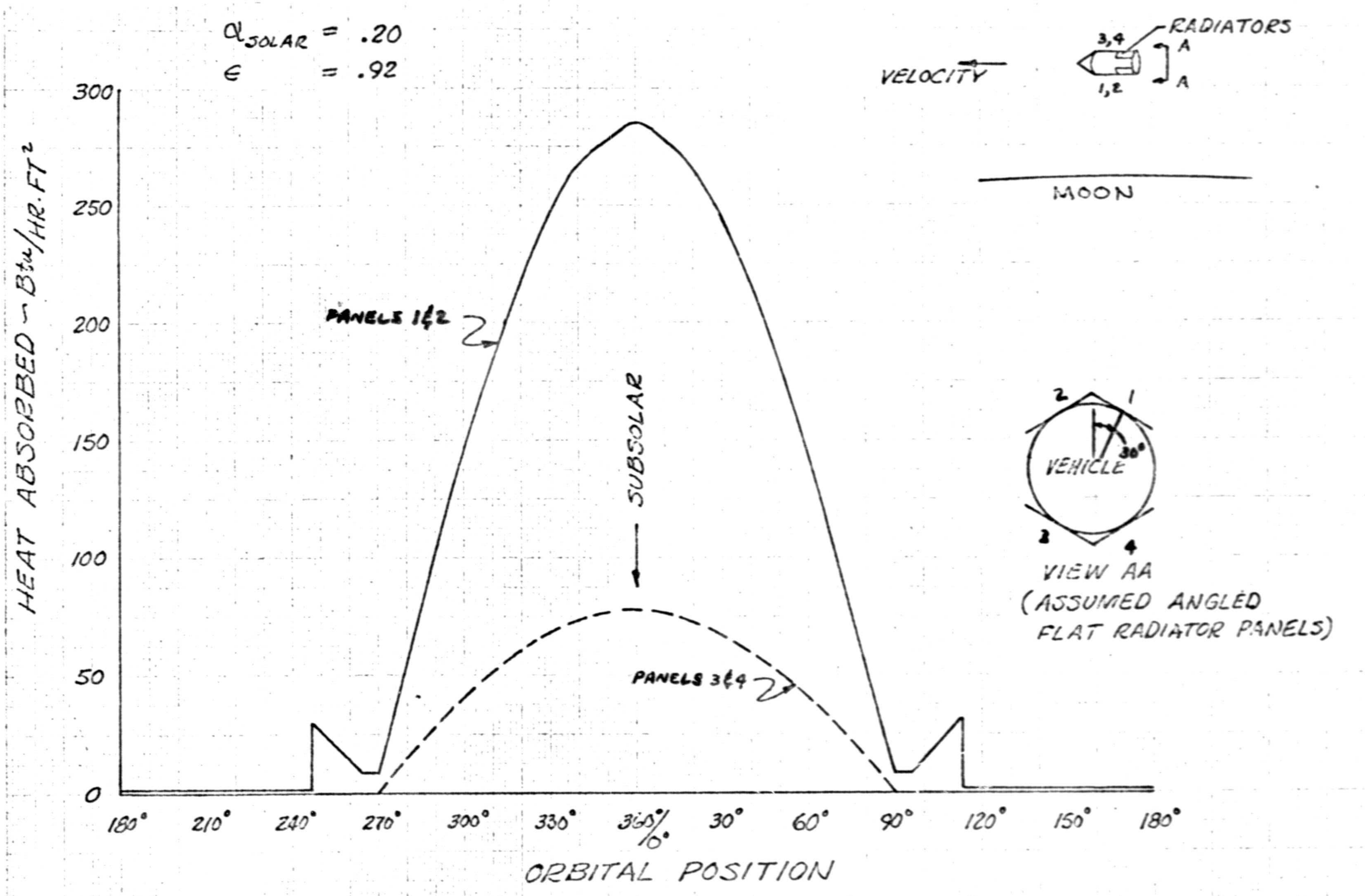


FIGURE 2 ABSORBED HEAT DATA FOR LUNAR ORBIT BROADSIDE ORIENTATION

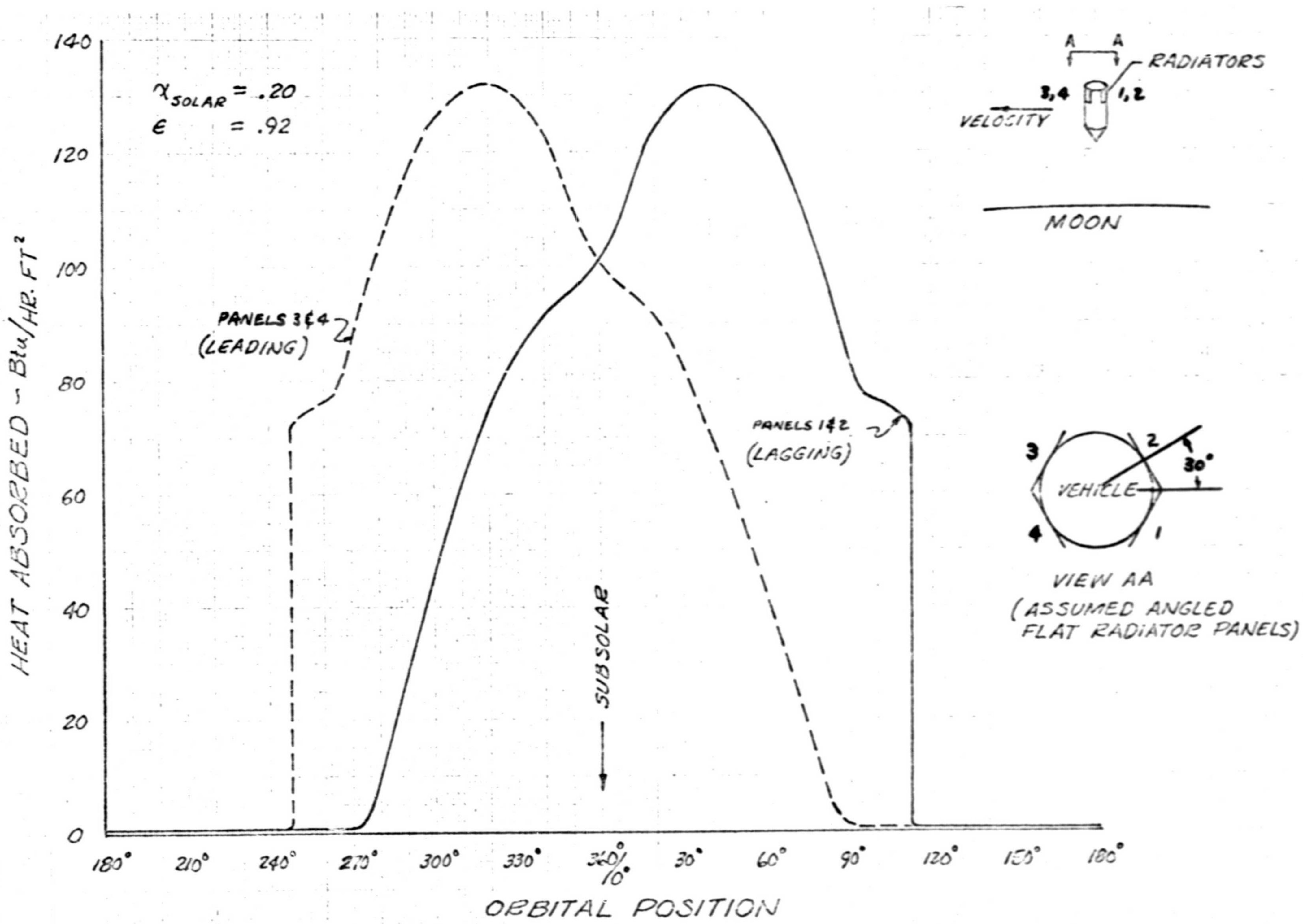


FIGURE 3 ABSORBED HEAT DATA FOR LUNAR ORBIT NOSE DOWN ORIENTATION

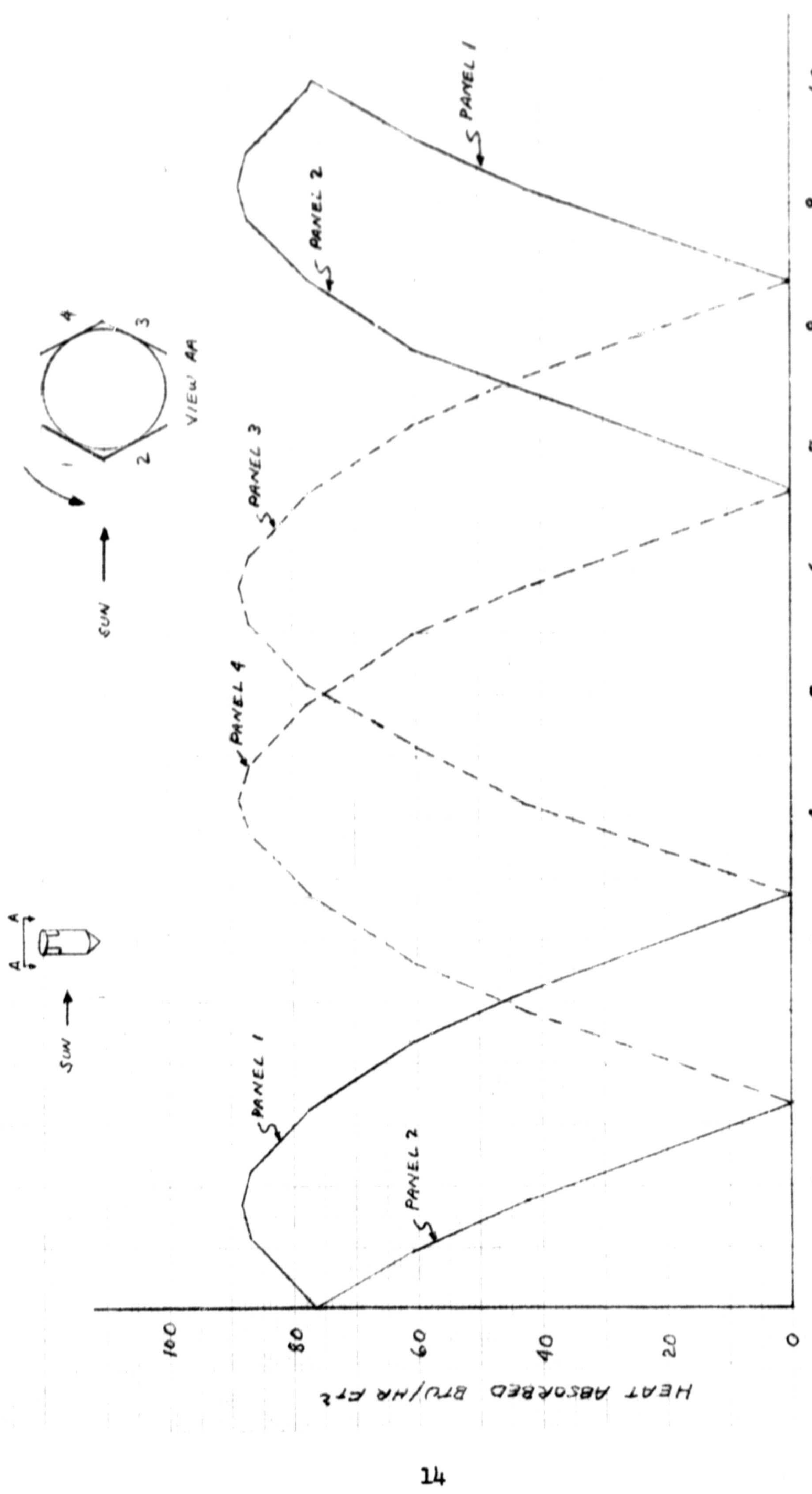


FIGURE 4 ABSORBED HEAT DATA FOR 1.0 RPH THERMAL CYCLE

Figures 5 through 20 present the results of the analysis for each of the above conditions. Comparisons of heat rejected, panel flowrate, radiator outlet temperature, and radiator pressure drop are presented for the first 5 conditions. Only the radiator outlet temperature and heat rejection are compared for the deep space transient since the baseline for this condition was taken directly from reference 5 and the flow rate and pressure drop results were not available. A summary of the results for the six conditions compared is given in Table 2. The average heat rejection errors (Table 2) are based on the integrated heat rejection rates over the period of an orbit, or a single revolution in the case of translunar thermal cycle. Water boiling rates are based on the assumption that the water boiler is "on" when the coolant temperature is above 48°F, and that enough water is boiled to reduce the coolant temperature to 41.5°F. These assumptions yield the maximum amount of water which can be boiled based on hardware specification limits.

The results indicate that the AB2RAD provides adequate performance predictions for a variety of environment and heat load conditions. All predicted performance parameters show a reasonable agreement with the baseline analysis except for the panel outlet temperatures on Figures 6 and 9. The AB2RAD predicts that the outlet temperature of the panel facing the moon, during the sunlight portion of the orbit, gets much hotter than predicted by the baseline analysis. Since the flow rate to the "hot" panel is less than 10 lb/hr (due to the proportioning valve action) the hotter panel outlet has very little effect on overall radiator performance. It should be noted that during the Block II ECS radiator Qualification Test (Reference 5) the "hot" panel outlet temperatures were measured to be approximately 160°F. The baseline thermal model predicted a maximum of 103°F (Reference 5) for the test conditions. This can be attributed to the fact that the explicit finite-difference technique used for temperature calculations in the baseline analysis, in combination with a large computing time increment, does not provide for the proper propagation of a temperature front in a flowing tube. Therefore, the hot fluid in the radiator panel was not propagated to the radiator outlet. In the AB2RAD routine, an implicit backward-difference technique is used to calculate temperatures. This method inherently provides for the propagation of a temperature front. Thus, in this case the AB2RAD prediction may actually better represent the radiator performance.

Figure 12 indicates that the AB2RAD predicted outlet temperatures for the redundant system are higher than the baseline predictions. During the baseline analysis, the low load heater was inadvertantly deactivated. When the redundant system outlet falls below 47°F, the heater should be activated to increase the inlet temperature. In the AB2RAD analysis, the heater controls the outlet to 45-47°F, but the baseline predicted outlet reaches a minimum of 37.5°F with no heater. This is also reflected in the heat rejection comparison (Figure 11). The AB2RAD maximum heat rejection is reduced by the heater increasing the redundant system outlet temperature.

During the deep space transient (Figure 20) the panel outlet temperatures falls below -15°F and the low-load heater is activated. However, the AB2RAD predictions react much faster to the low-load heater than the baseline analysis. As the radiator inlet temperature is increased by the

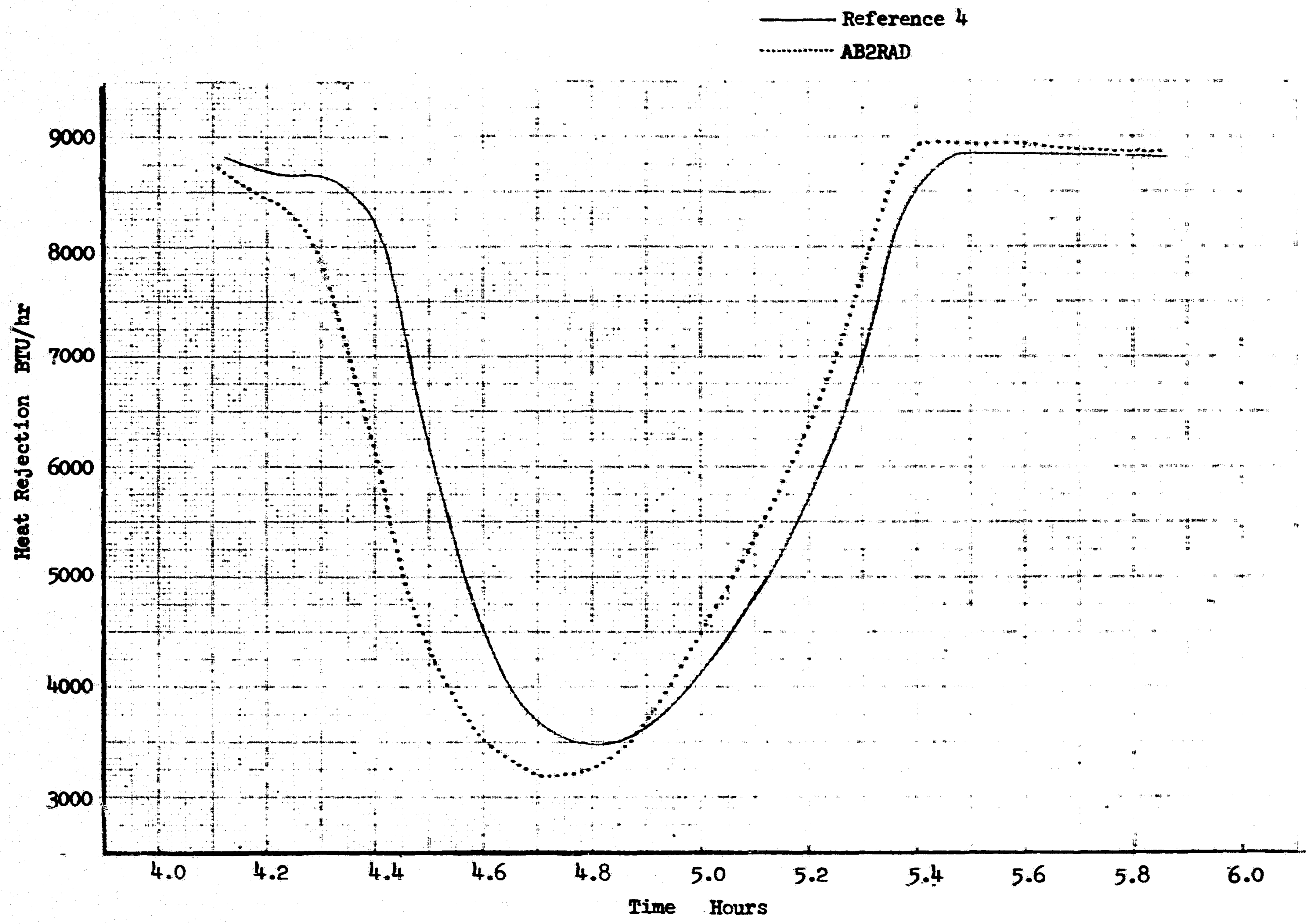


FIGURE 5 COMPARISON OF PREDICTED HEAT REJECTION IN LUNAR ORBIT; HEAT LOAD = 8500 BTU/HR

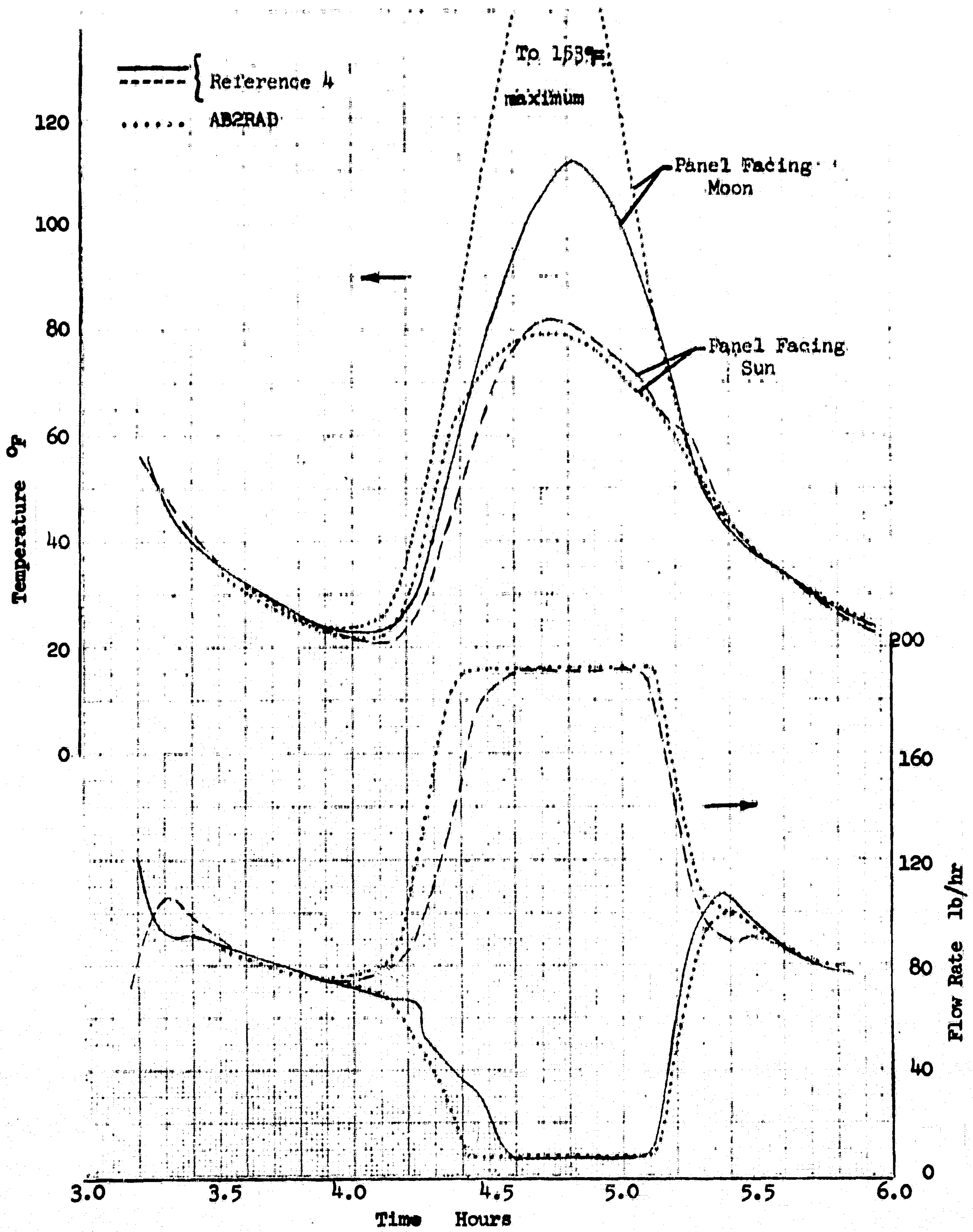


FIGURE 6 COMPARISON OF PREDICTED PANEL FLOW RATES AND OUTLET TEMPERATURES IN LUNAR ORBIT; HEAT LOAD = 8500 BTU/HR

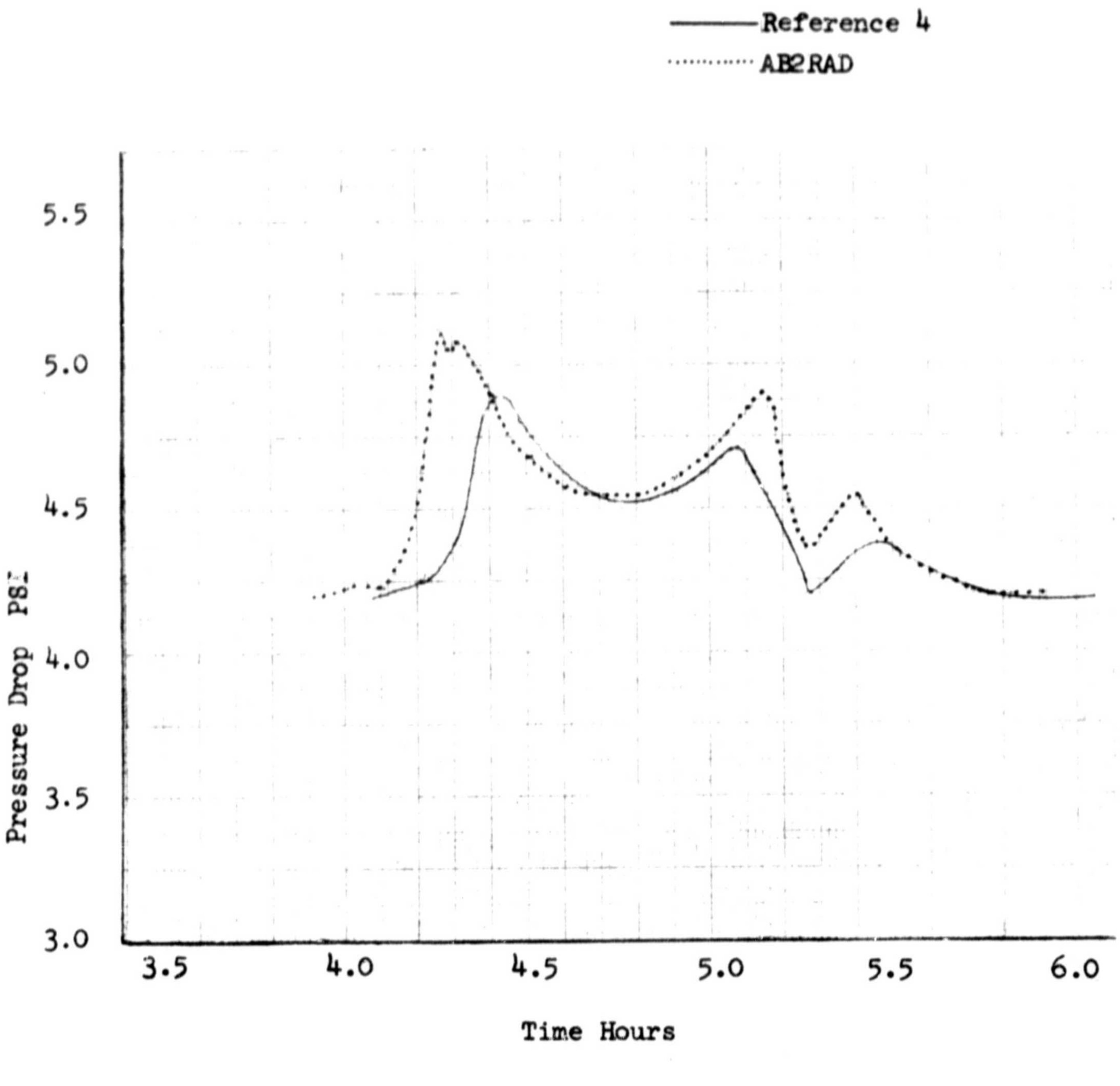


Figure 7 Comparison of Predicted Pressure Drops in Lunar Orbit; Heat Load = 8500 BTU/hr

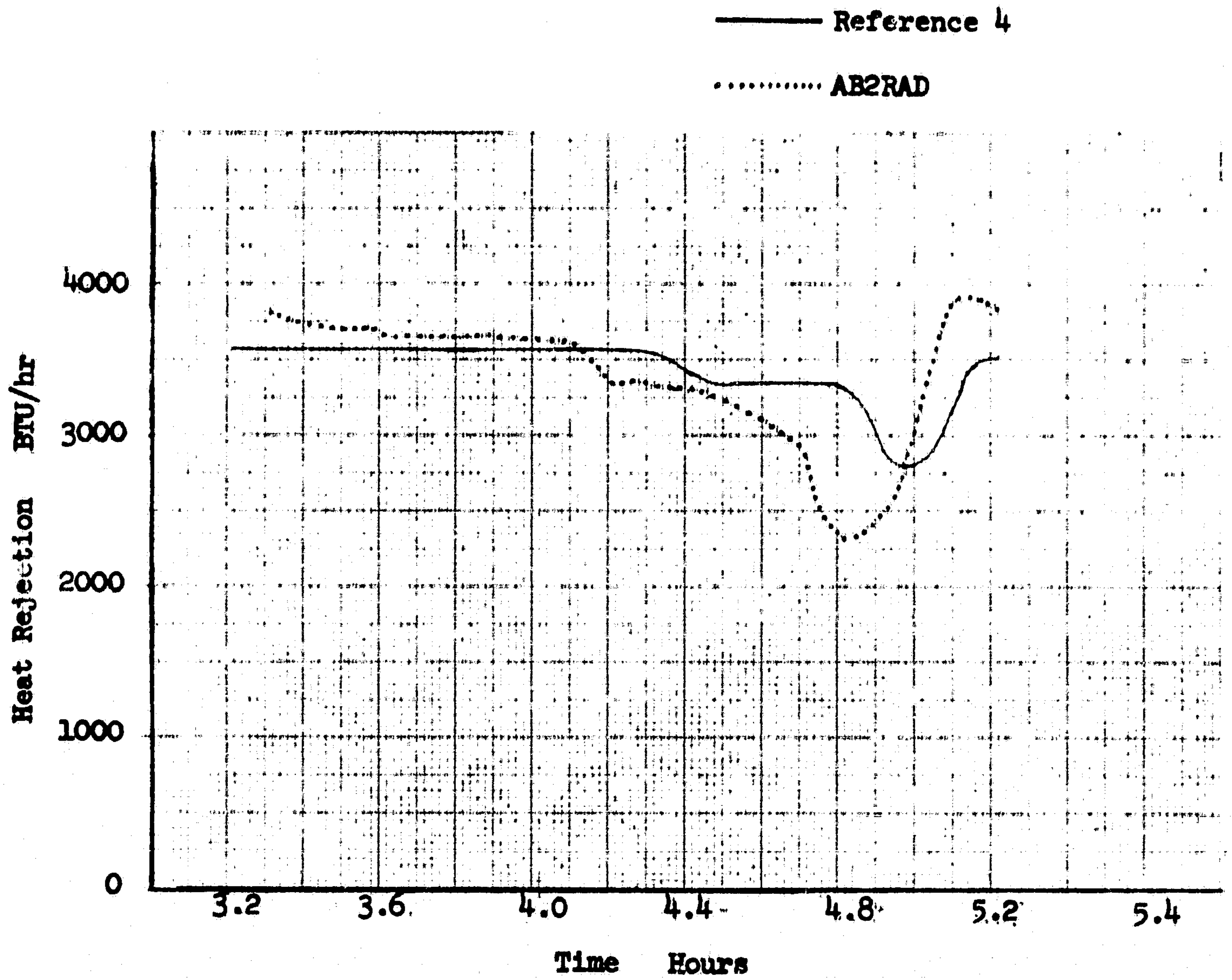


FIGURE 8 COMPARISON OF PREDICTED HEAT REJECTION IN LUNAR ORBIT; HEAT LOAD = 3470 BTU/HR

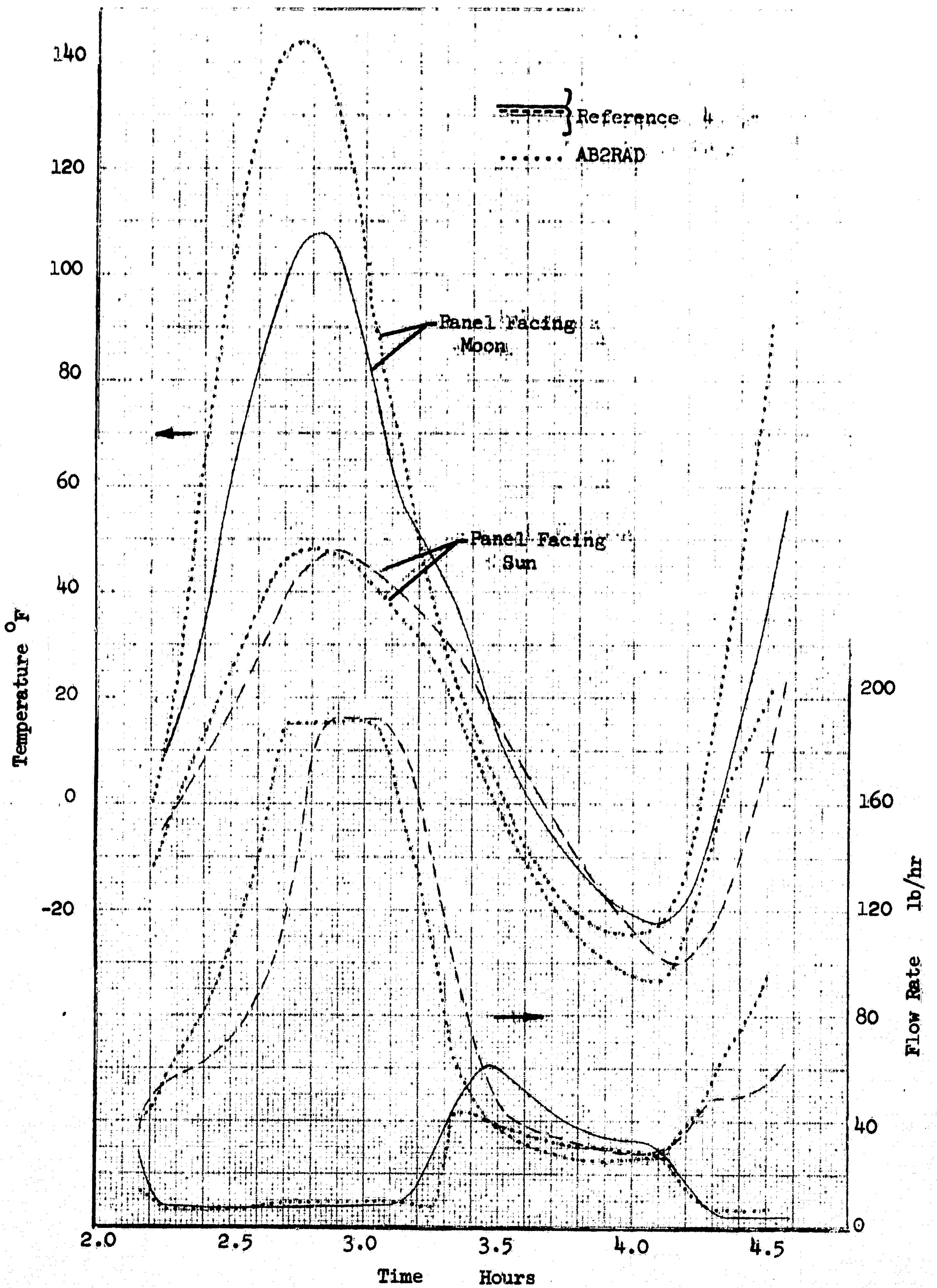


Figure 9 Comparison of Predicted Panel Flow Rates and Outlet Temperatures in Lunar Orbit; Heat Load = 3470 BTU/hr

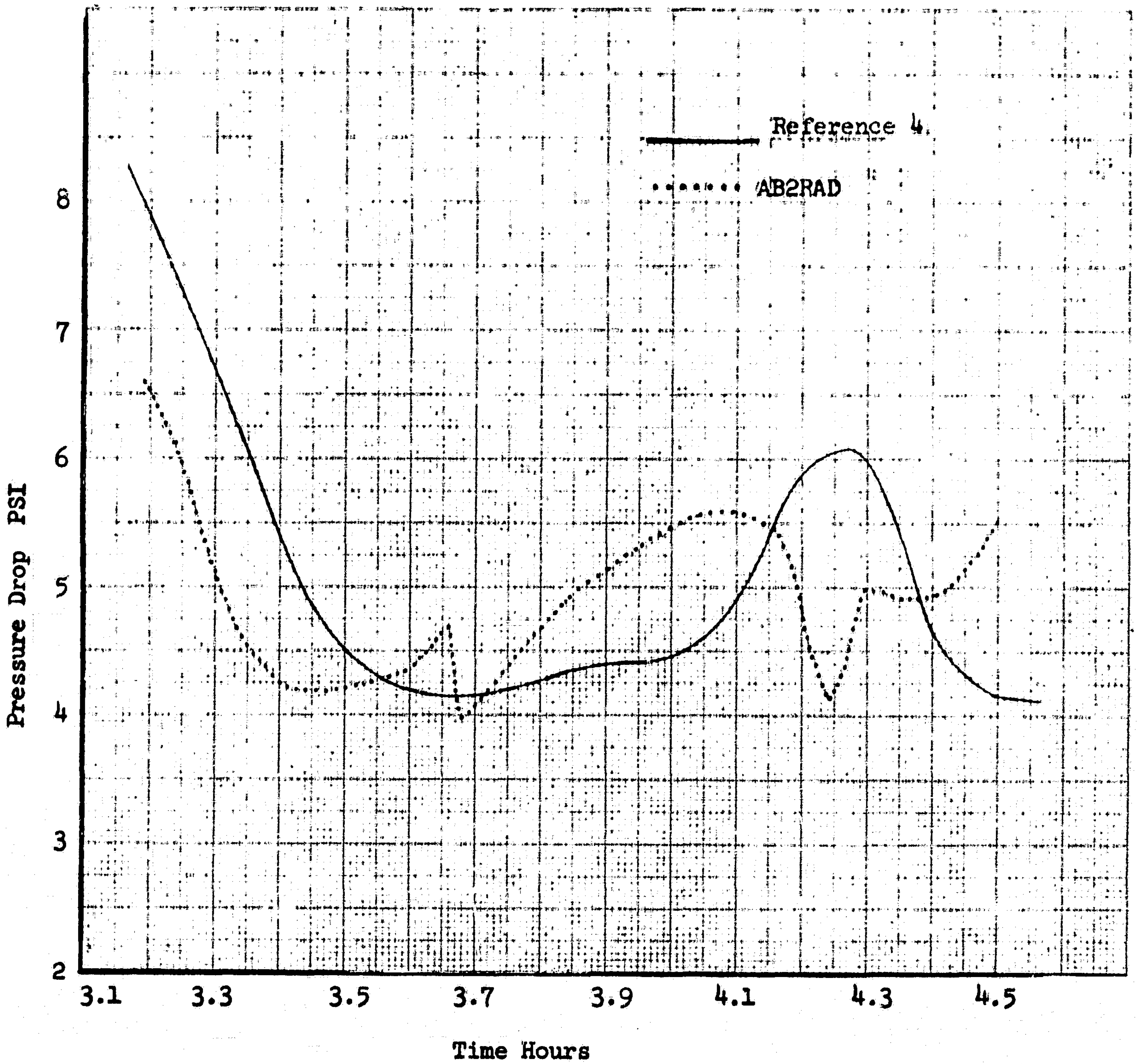


Figure 10 Comparison of Predicted Pressure Drops in Lunar Orbit; Heat Load = 3470 BTU/hr

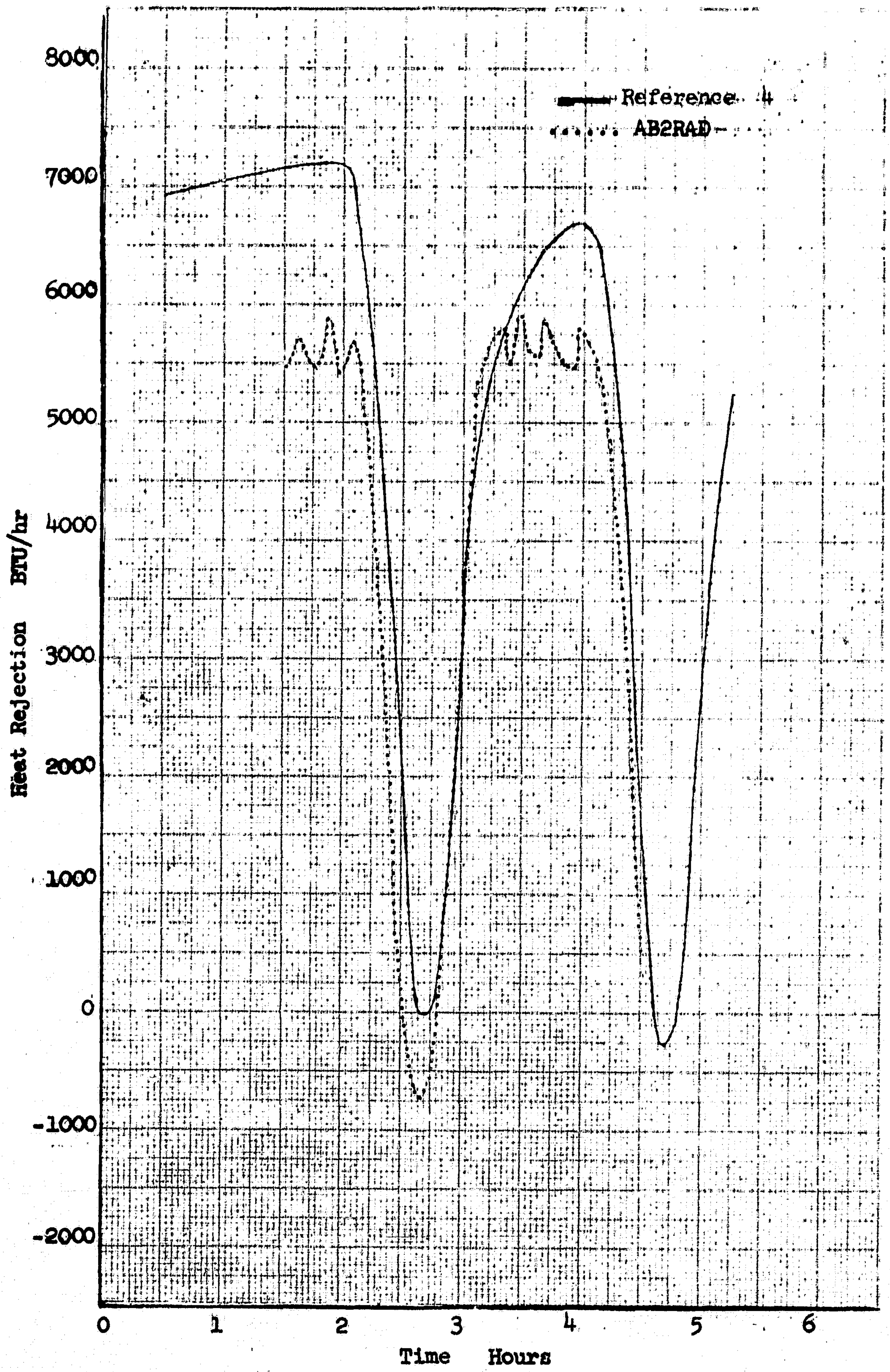


FIGURE 11 COMPARISON OF PREDICTED HEAT REJECTION IN LUNAR ORBIT; SINGLE PANEL AND REDUNDANT SYSTEM OPERATION, HEAT LOAD = 5600 BTU/HR

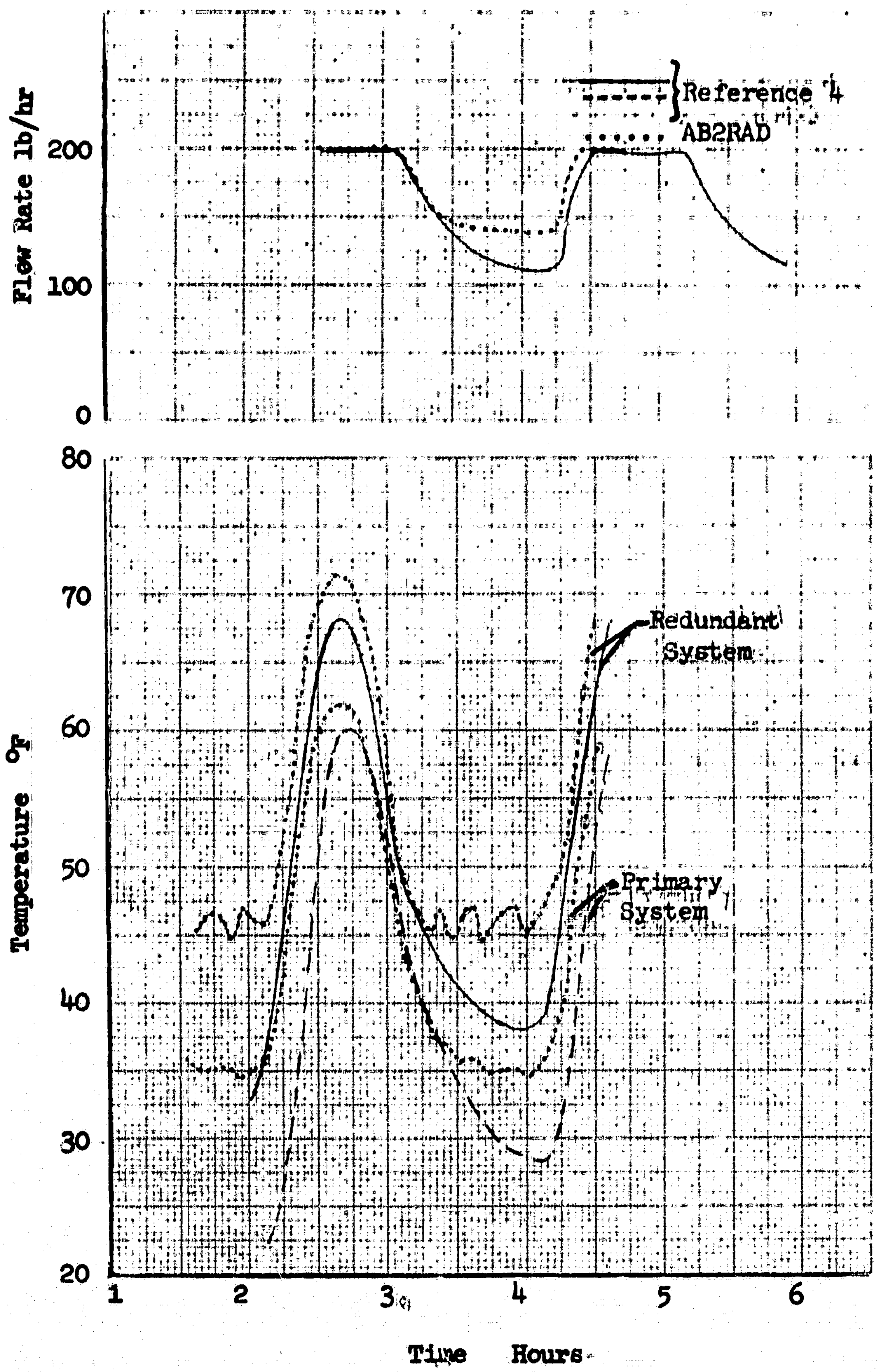


FIGURE 12 COMPARISON OF PREDICTED PANEL FLOW RATES AND OUTLET TEMPERATURES IN LUNAR ORBIT; SINGLE PANEL AND REDUNDANT SYSTEM OPERATION, HEAT LOAD = 5600 BTU/HR

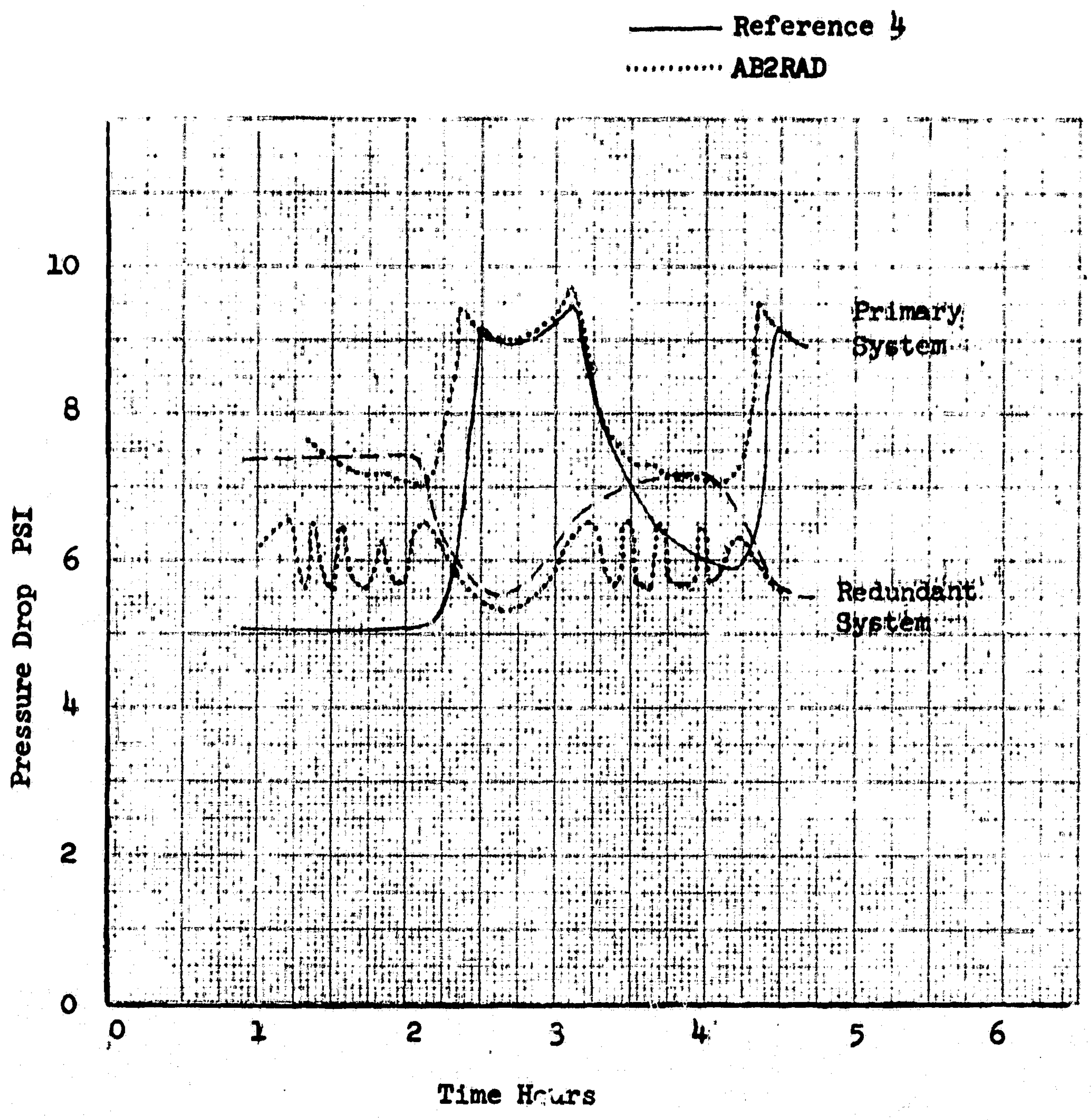


Figure 13 Comparison of Predicted Pressure Drops in Lunar Orbit; Single Panel and Redundant System Operation, Heat Load = 5600 BTU/hr

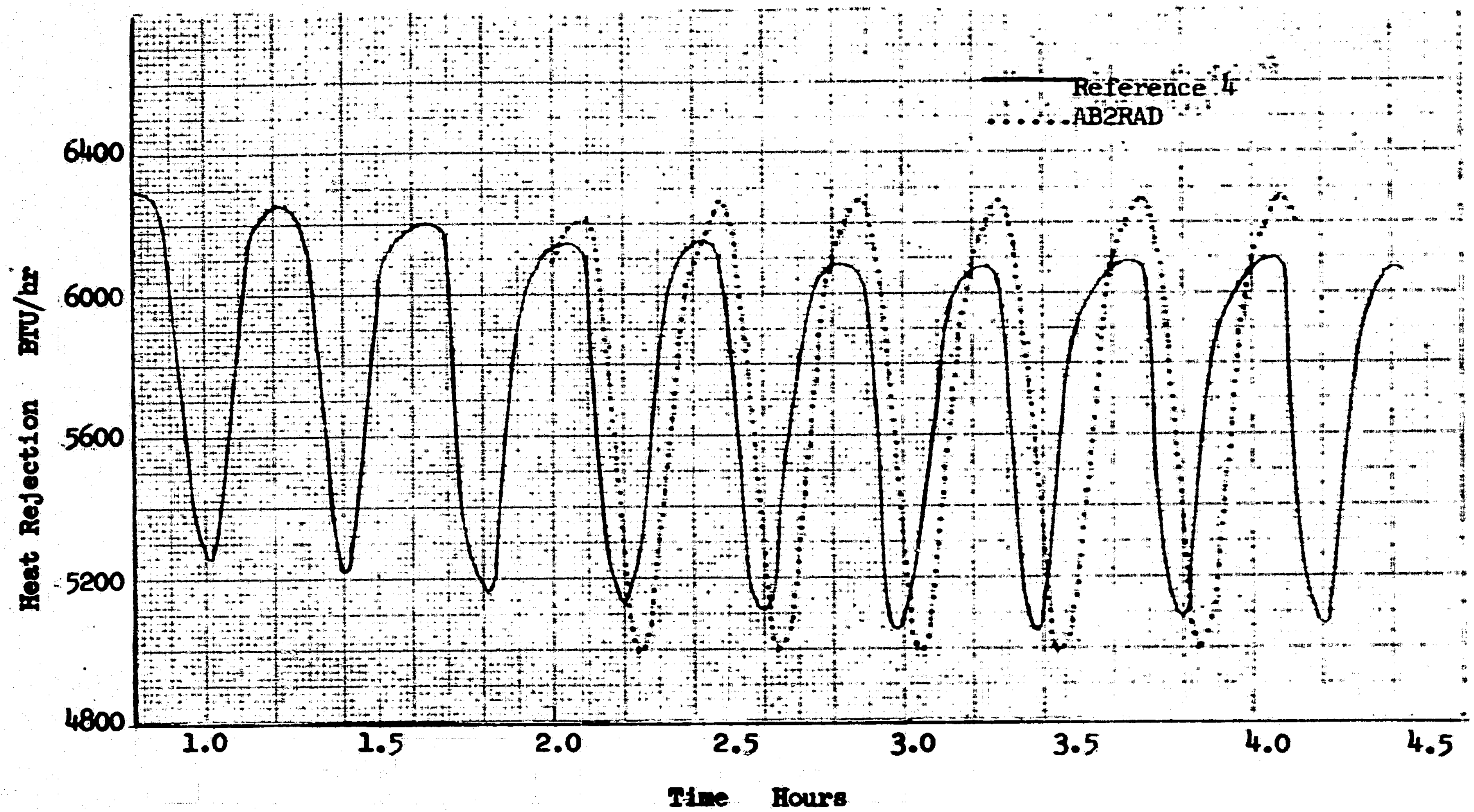


FIGURE 14 COMPARISON OF PREDICTED HEAT REJECTION IN TRANSLUNAR THERMAL CYCLE; SINGLE PANEL AND REDUNDANT SYSTEM OPERATION

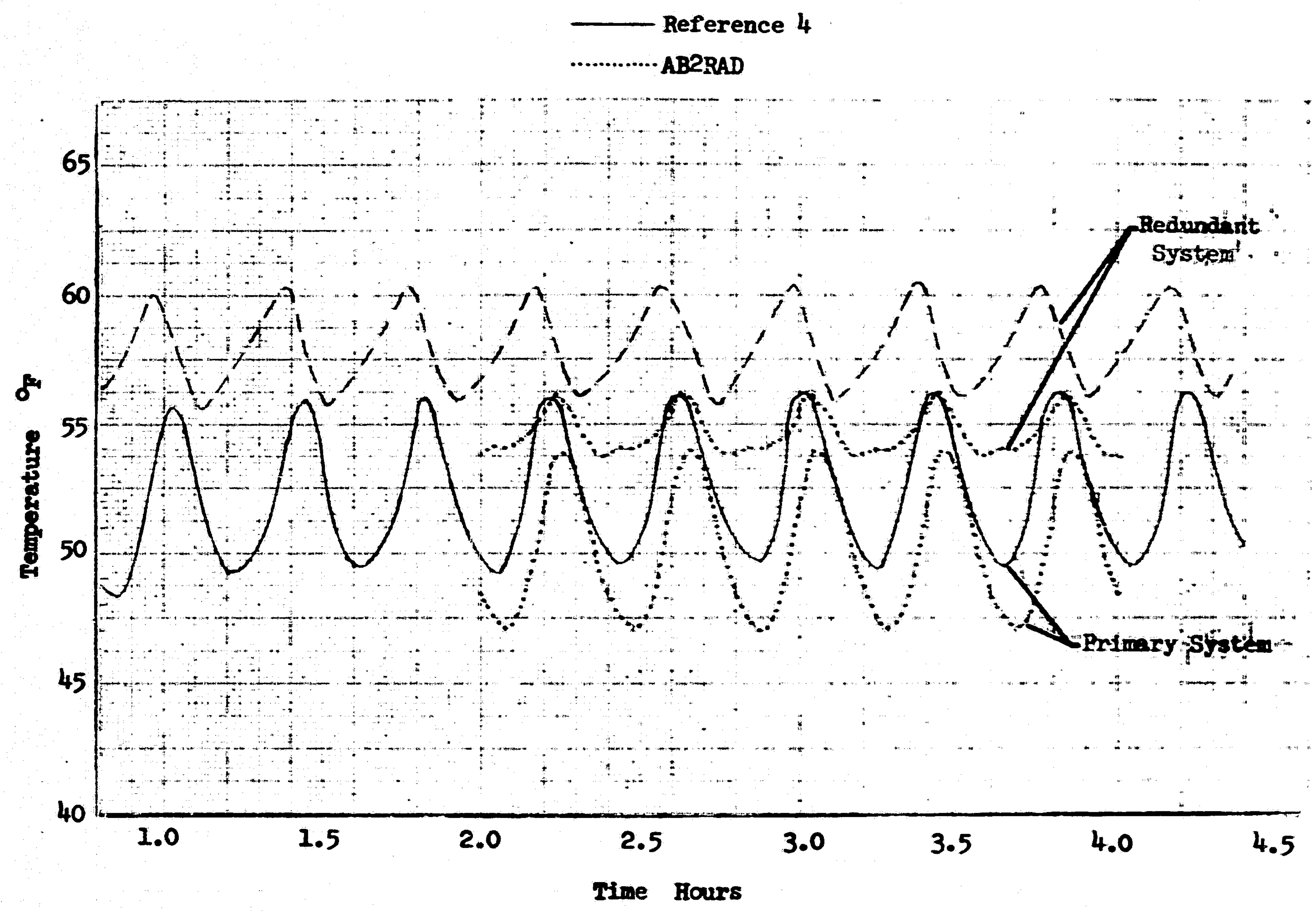


FIGURE 15 COMPARISON OF PREDICTED OUTLET TEMPERATURES IN TRANSLUNAR THERMAL CYCLE: SINGLE PANEL AND REDUNDANT SYSTEM OPERATION

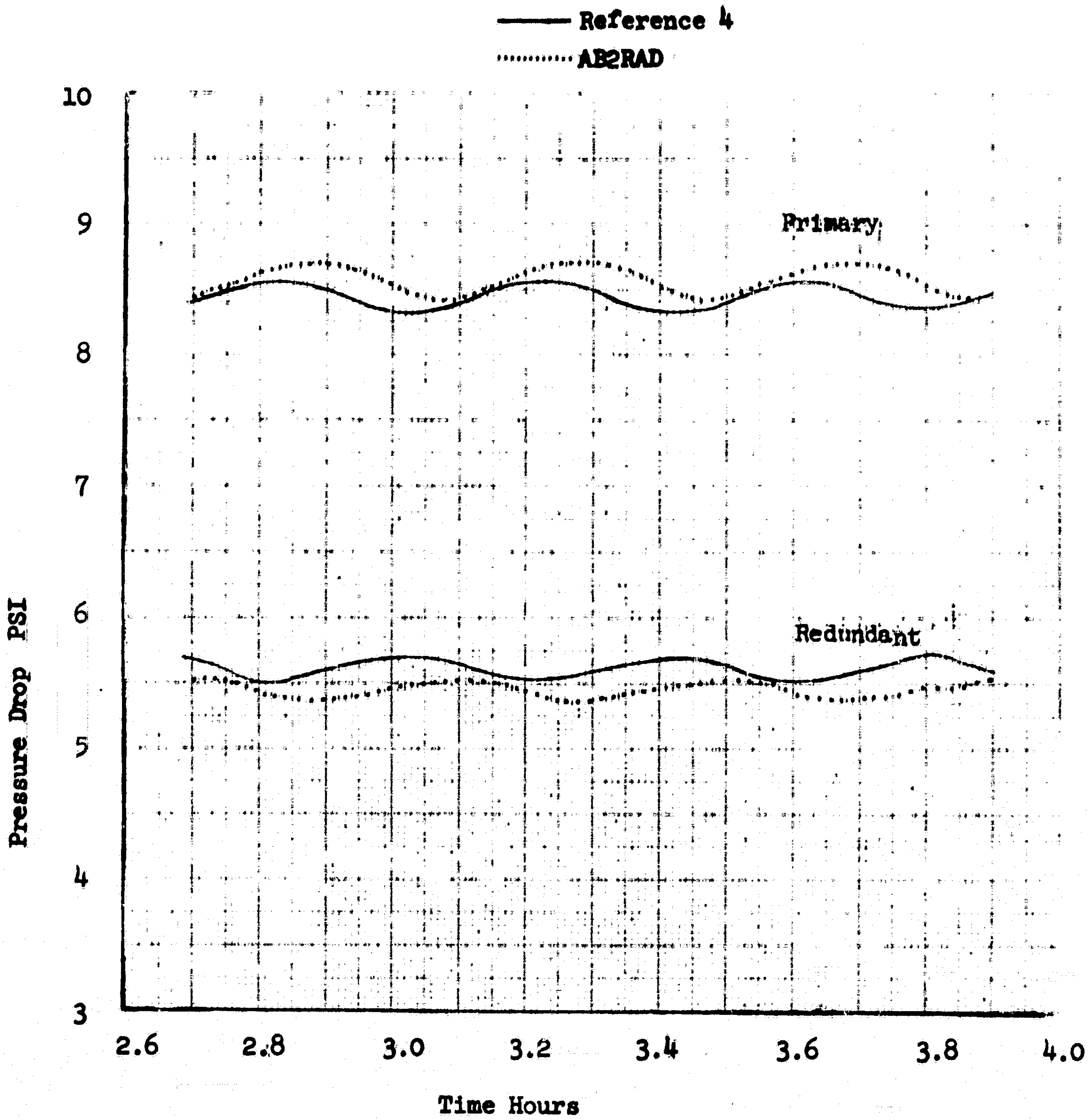


Figure 16 Comparision of Predicted Pressure Drops in Translunar Thermal Cycle; Single Panel and Redundant System Operation

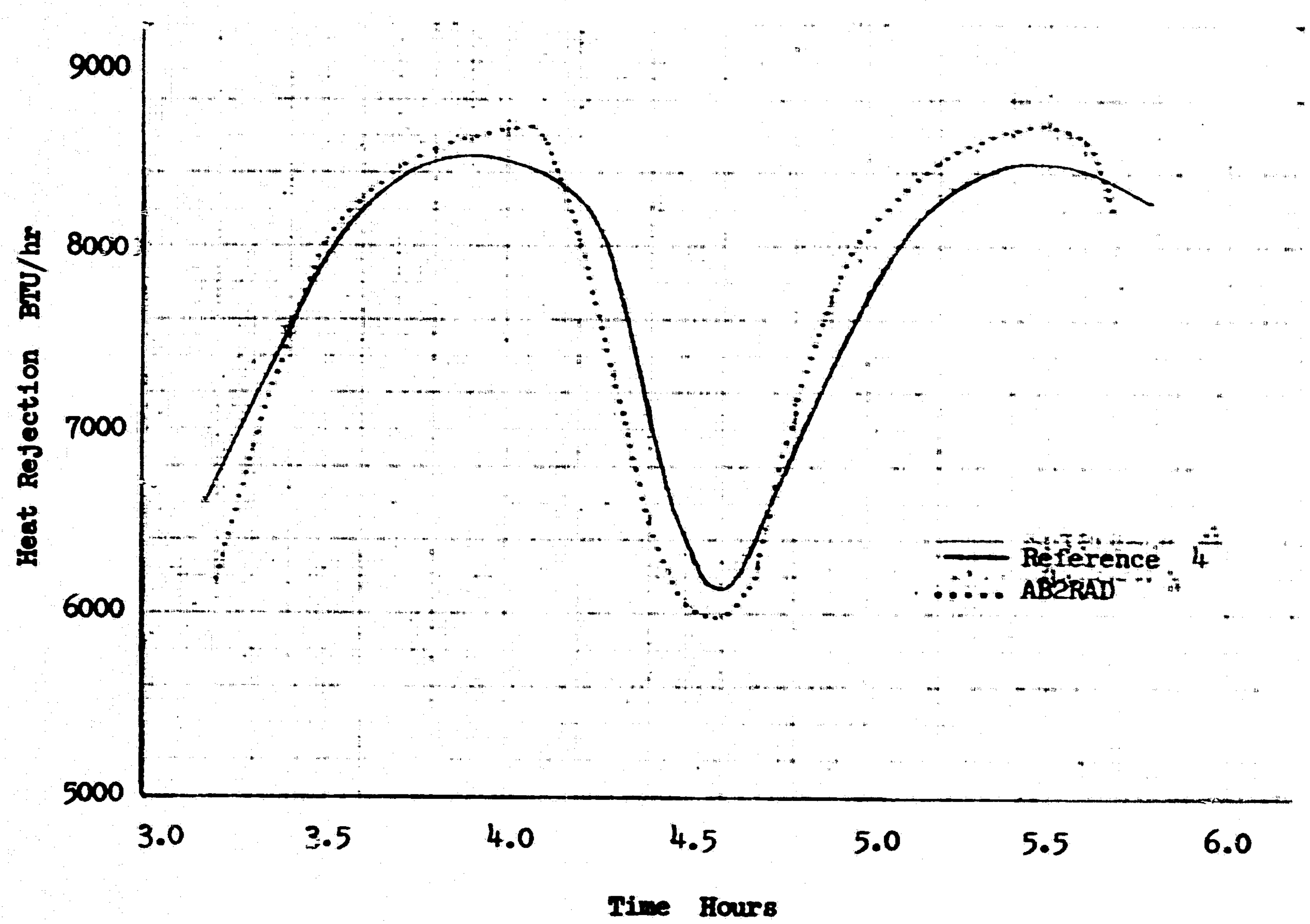


FIGURE 17 COMPARISON OF PREDICTED HEAT REJECTED IN EARTH ORBIT

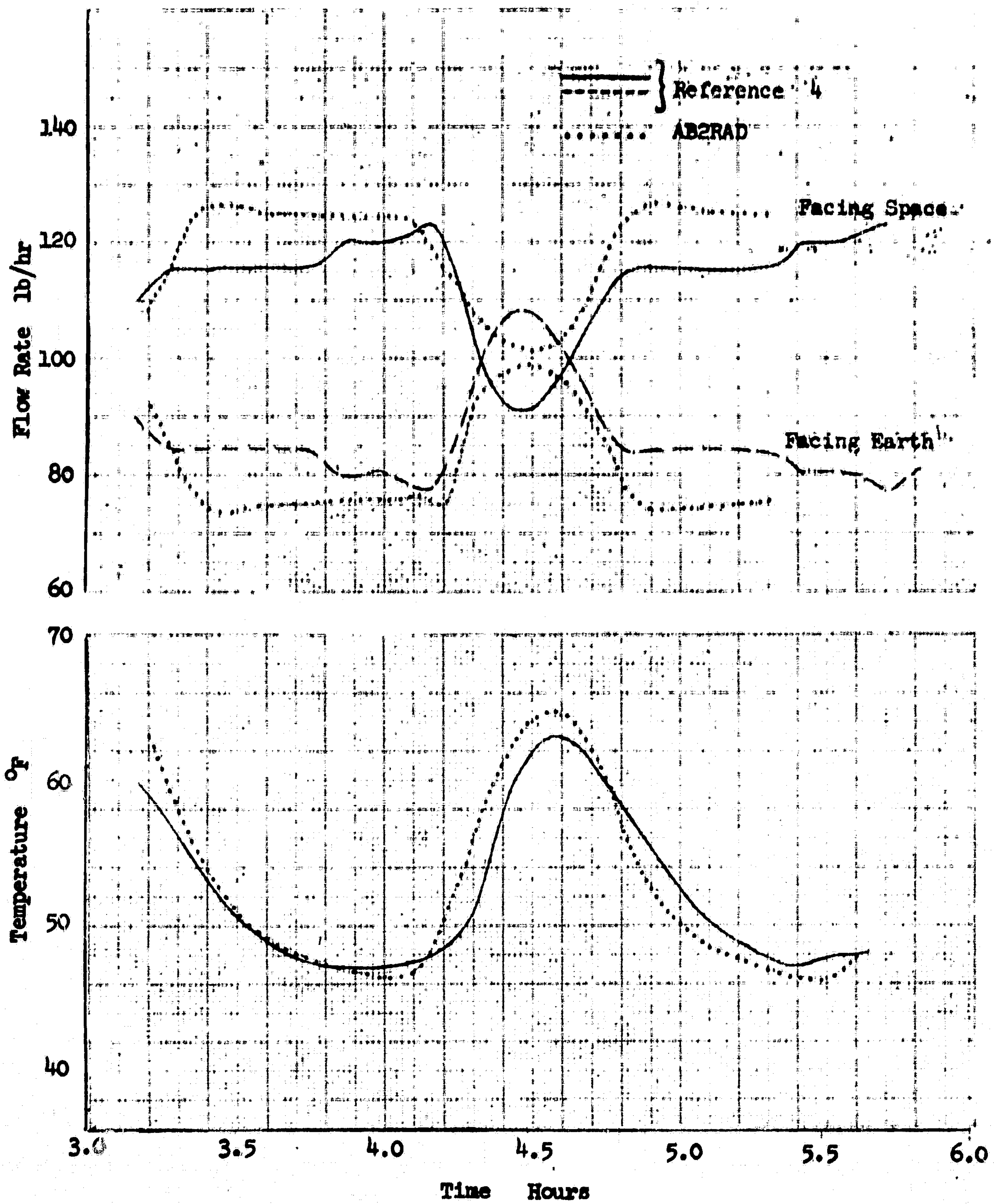


FIGURE 18 COMPARISON OF PREDICTED PANEL FLOW RATES AND OUTLET TEMPERATURE IN EARTH ORBIT

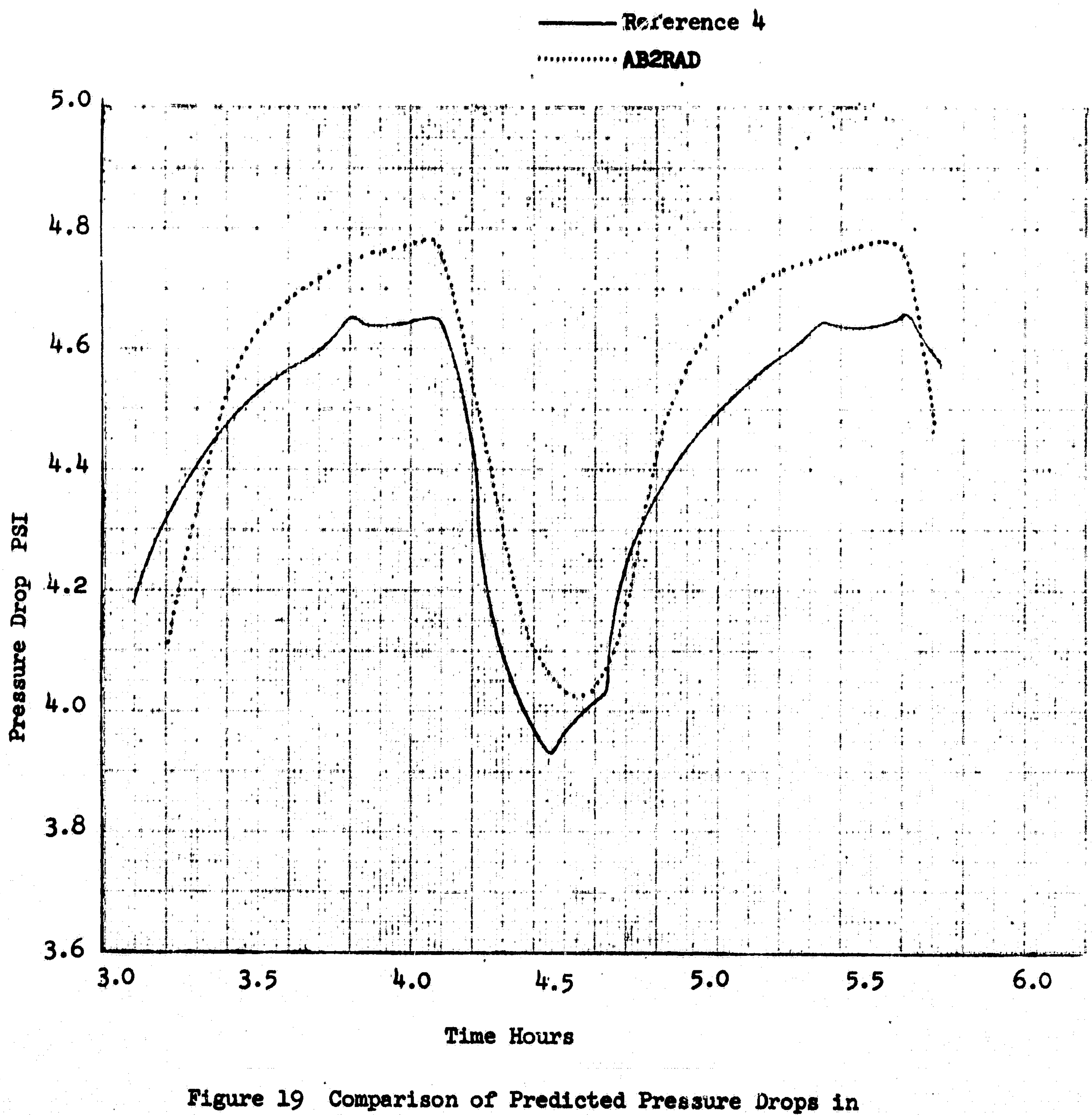


Figure 19 Comparison of Predicted Pressure Drops in Earth Orbit

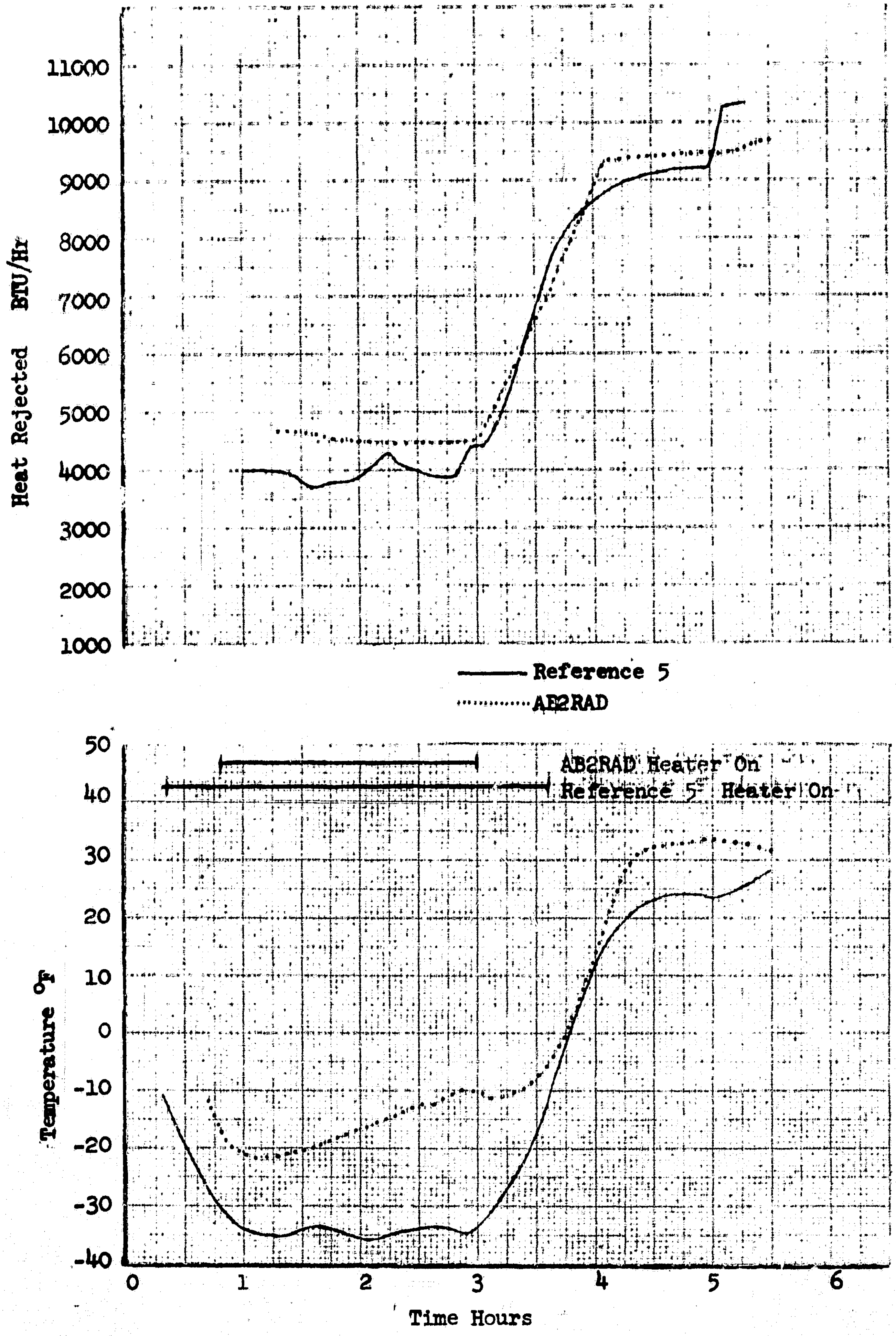


Figure 20 Comparison of Predicted Heat Rejection and Outlet Temperatures For a Deep Space Transient

Table 2 Comparison of AB2RAD and Baseline Results

Condition	Lunar Orbit Heat Load = 3470 BTU/hr	Lunar Orbit Heat Load = 8[illegible]0 BTU/hr	Lunar Orbit Heat Load 5600 BTU/hr	Translunar Heat Load 6880 BTU/hr	Earth Orbit Heat Load = 8800 BTU/hr	Deep Space Transient
Error in Maximum Heat Rejection, %	+10.4	+1.71	-11.9	+2.95	+2.49	-7.0
Error in Minimum Heat Rejection, %	-17.8	-8.05	NA	-1.18	-1.46	+15.4
Error in Average Heat Rejection, %	-3.3	-4.05	-18.8	+ .11	- .02	NA
Water Boiling Rate						
Baseline	.24 lbs/orbit	4.35 lbs/orbit	1.74 lbs/orbit	1.16 lbs/hr	2.86 lbs/orbit	0.
AB2RAD	.461 lbs/orbit	4.65 lbs/orbit	1.67 lbs/orbit	1.065 lbs/hr	2.28 lbs/orbit	0.
error	+.221	+ .30	- .07	-.095	- .58	0.
Primary System						
Error in Maximum Pressure Drop, %	-8.2	+3.66	+ .15	+1.16	+2.8	--
Error in Minimum Pressure Drop, %	-3.6	+3.58	+10.2	+1.2	+2.55	--
Error in Average Pressure Drop, %	-2.4	+2.2	+12.6	+1.42	+2.0	--
Redundant System						
Error in Maximum Pressure Drop, %	NA	NA	-8.33	-2.63	NA	NA
Error in Minimum Pressure Drop, %	NA	NA	-2.73	-3.6	NA	NA
Error in Average Pressure Drop, %	--	--	-10.73	-3.1	--	--
Low Load Heater Power Dissipation, BTU						
Baseline	789 [2]	0.0	0.0 [1]	0.0	0.0	4910.0
AB2RAD	936.35	0.0	890.3	0.0	0.0	3346.3
error	+147.35	0.0	~	0.0	0.0	-1563.7

[1] Redundant System Heater Only. Not Included in Baseline Analysis.
[2] Per Orbit

heater the AB2RAD predicts an increase in the outlet temperature; whereas, the baseline predictions show the outlet temperature being maintained at approximately -35°F during the minimum heat load conditions. The sensitivity of the AB2RAD model to the low-load heater could cause errors in the predicted heater power consumption. If the minimum heat load conditions had continued for longer than three hours, the AB2RAD would have predicted that the low-load heater would cycle on and off. As indicated by Table 2, the AB2RAD predicts 31 per cent less heater power consumption than the baseline for a 3.0 hour minimum heat load condition. The destagnation and transient to the 9275 BTU/hr heat load condition is adequately predicted by AB2RAD.

The AB2RAD predictions have been compared to detailed thermal model predictions which have been verified by predicting test results (Reference 5). Environmental conditions of deep space, solar heating, and lunar heating with the expected maximum and the minimum heat loads for the Block II ECS radiator have been considered. All active controls (bypass valve, proportioning valve, isolation valve, and low load heater) have been exercised. Both the primary and redundant systems have been operated. In conclusion, the AB2RAD has been shown to provide adequate Block II ECS radiator performance predictions for a wide variety of conditions with a minimum of computer time required. With the limitations discussed above, and summarized in Table 2, the AB2RAD can be utilized to predict the performance of the Apollo Block II ECS radiator under any combination of heat load and environment.

5.0 USER'S INSTRUCTIONS

5.1 Program Description

AB2RAD is written in Fortran V for the Univac 1108 digital computer and requires a total of 24,773 words of core storage, including the required system routines. Table 3 lists the Univac 1108, Fortran V, system subroutines which are used by AB2RAD. The square root routine (Table 3) is required regardless of the system on which the program is run. Input data comprises the majority of the storage requirements. Storage space is reserved for four incident heat tables, two inlet temperature tables and two flow rate tables. Each table is dimensioned for 1000 values of the dependent and independent variables for a total data storage requirement of 16000 words. A complete program listing is given in Appendix A. Appendix B presents a program flow chart. The major Fortran terms used in the routine are given in Appendix C.

5.2 Data Preparation

For submitting runs under the NASA Exec II Processor, the configuration of the card deck is as shown in Figure 21. If the AB2RAD source deck is submitted with the data the deck arrangement is as shown in Figure 21a. Figure 21b shows the deck configuration when the AB2RAD program is read from a magnetic tape.

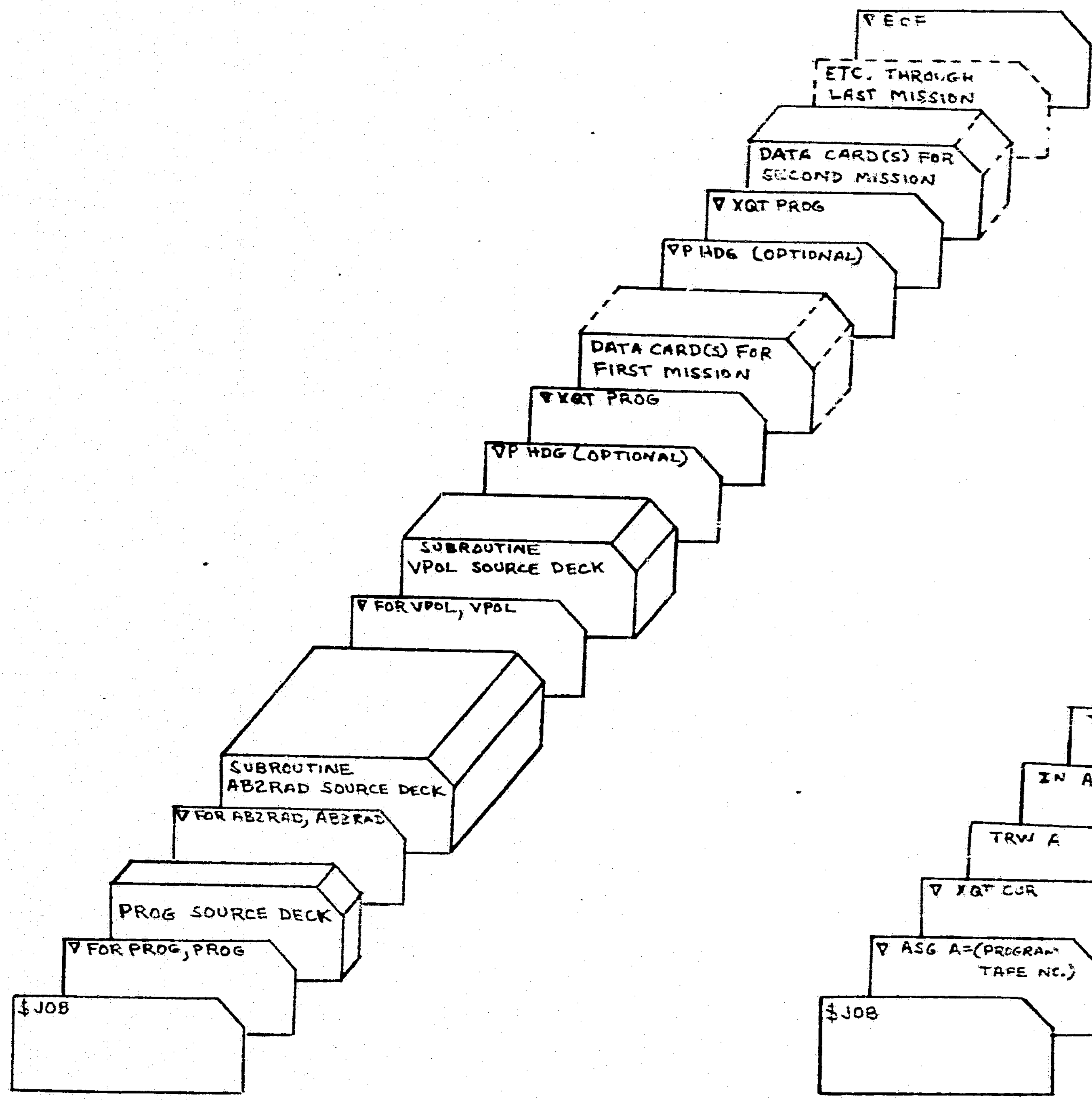
The data input consists of a mission parameter card and curve cards where required. An optional HDG control card may be used for problem identification if desired (see Figure 20). The mission parameter card specifies which heat flux data is to be used or if the heat flux data will be input, the primary and redundant loop operation code, mission time if required, print interval, inlet temperature and flow rate. The curve cards provide for tabular inputs of absorbed heat, flow rates and inlet temperatures as a function of time.

5.2.1 Mission Parameter Card

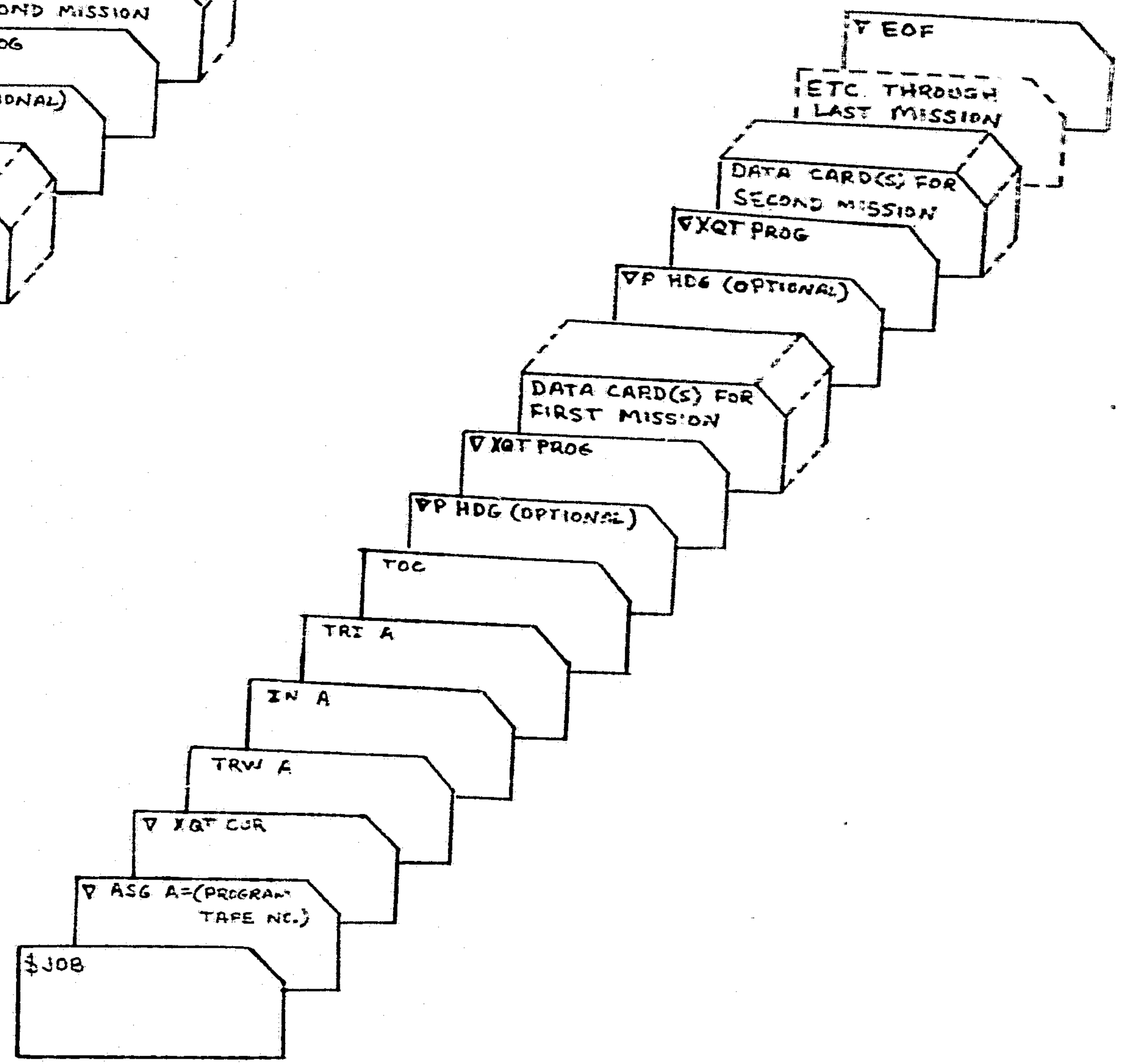
Columns	Fortran Nomenclature	Format	Description
Card 1			
1-5	MSSION	I5	Mission Code = 1, lunar-oriented broadside = 2, lunar-oriented nose down = 3, translunar broadside - 1 RPH Thermal Cycle = 4, zero incident heat (Steady state only) = 5, mission defined by time dependent curves

Table 3 System Subroutines Used

1. EXIT
2. NERR2$
3. NRDU$
4. NIO1$
5. NIO2$
6. NWDU$
7. SQRT
8. NERR3$
9. NSTOP$
10. NFTV$
11. WOTIN$
12. FPACK$
13. DEPTH
14. NERR$
15. NIOIN$
16. NINPT$
17. FLOATX
18. NEXP$X
19. NTAB$
20. CONVTX
21. NININ$



(a) Source Deck Configuration



(b) Program Tape Configuration

FIGURE 21 RUN SUBMISSION CARD DECK CONFIGURATION

Columns	Fortran Nomen-clature	Format	Description
6-8	KODE	I5	Primary System Code = 0, both primary panels on = -1, side 3,4 only on = 1, side 1,2 only on = 2, primary system off
6-10	KODSEC	I5	Redundant System Code = 0, redundant system off = 1, redundant system on
11-20	P3	F10.0	Total mission time, not required for missions 1 through 4, so may be left blank for these missions.
21-30	PERIOD	F10.0	Cyclic period for which the time dependent curves will repeat until total mission time is reached. Required only for Mission 5. May be left blank if non-cyclic curves are supplied for entire mission time. Not required for Missions 1 - 4, so may be left blank for these conditions.
31-40	PRINT	F10.0	Print interval, hrs. Must be integral multiple of calculation interval (.02 hr). For printing every iteration, any value $\leq$.02 (including zero or blank) will suffice. For Mission 4, a value of 6.0 will print only steady state values.
41-50	TINLT	F10.0	Primary system inlet fluid temperature, ^{o}F; not required for Mission 5 or if KODE = 2, so may be left blank for these conditions.
51-60	WDOTS	F10.0	Primary system total flow rate, lb/hr; not required for Mission 5 or if KODE = 2, so may be left blank for these conditions.
61-70	TINSEC	F10.0	Redundant system inlet fluid temperature, ^{o}F; not required for Mission 5 or if KODSEC = 0, so may be left blank for these conditions.
71-80	WDTSEC	F10.0	Redundant system total flow rate, lb/hr; not required for Mission 5 or if KODSEC = 0, so may be left blank for these conditions.

Card 1 constitutes the entire data set for Missions 1 through 4; for Mission 5, however, curves must be supplied as described below.

5.2.2 Curve Cards

The following curve sets (curve header card followed by curve data cards) must be supplied in the order given:

1. Absorbed heat curve for Panel 1, BTU/hr-ft^2 = f(hours)
2. Absorbed heat curve for Panel 2, BTU/hr-ft^2 = f(hours)
3. Absorbed heat curve for Panel 3, BTU/hr-ft^2 = f(hours)
4. Absorbed heat curve for Panel 4, BTU/hr-ft^2 = f(hours)
5. Primary system total flow rate, lb/hr = f(hours)
6. Primary system inlet fluid temperature, °F = f(hours)
7. Redundant system total flow rate, lb/hr = f(hours)
8. Redundant system inlet fluid temperature, °F = f(hours)

The first six curves must be supplied for all problems. If the redundant system is not used (KODSEC = 0), curves 7 and 8 must not be included. For conditions when the primary system is not operating a dummy curve 5 and 6 must be supplied. A minimum of two points must be used for each curve and the last time point must be equal to or exceed the problem mission time.

Columns	Fortran Nomen-clature	Format	Description
Card 1 (Curve Header Card)			
1-5	NPTS	I5	Number of points on curve, 2 ≤ NPTS ≤ 1000
6-72	ALPHA	11A6,A1	Title
Cards 2 through 2NPTS/7 (Curve Data Cards)			
1-10	TIME1	E10.3	Initial time point = 0.
11-20	TIME2	E10.3	Second time point, hr.
21-30	TIME3	E10.3	Third time point, hr.

Etc. through last time point, which must be equal to or greater than total mission time, P3. Then beginning in next ten-column field,

	Q, WDTTOT, or TIN	E10.3	Initial dependent variable value, BTU/hr-ft^2, lb/hr, or °F, respectively.

Etc. through last dependent variable value.

5.3 Output

During simulation of a mission, current values of heat rejection, pressure drop, flow rate, and fluid outlet temperature will be printed at times specified by the input print interval. The print interval must be an integral multiple of the calculation interval (.02 hr) or irregular print intervals will result. Upon completion of Mission 4 the steady state values of the output parameters are printed. At the end of all other missions the maximum, minimum, and average values of the output parameters are printed. For Missions 1 through 3, these will represent values encountered during the last orbit and for Mission 5, values over the entire mission including the initial conditions.

5.4 Error Diagnostics

If certain errors occur during execution of the program, diagnostic messages will be printed before execution is terminated. As an aid to error tracing, these messages are listed below with explanatory remarks.

1. INTERPOLATION IMPOSSIBLE
MERR = x TIME = x.xx
EXECUTION TERMINATED BY PROGRAMMED HALT

The problem time has exceeded the times supplied with one of the curves, the specific curve being indicated by the value of MERR as follows:

Value	Curve
1	Absorbed heat for Panel 1
2	Absorbed heat for Panel 2
3	Absorbed heat for Panel 3
4	Absorbed heat for Panel 4
5	Primary system total flow rate
6	Primary system inlet fluid temperature
7	Redundant system total flow rate
8	Redundant system inlet fluid temperature

2. THE PROBLEM COULD NOT BE SOLVED IN 500 ITERATIONS

Five hundred relaxation passes through the temperature equations failed to produce a solution accurate to within 0.002°F.

3. THE TEMPERATURE USED IN FINDING THE VISCOSITY IS GREATER THAN THE HIGHEST VALUE ON THE CURVE

Fluid temperature has become greater than 300°F at some point in the system.

4. THE TEMPERATURE USED IN FINDING THE VISCOSITY IS LESS THAN THE LOWEST TEMPERATURE ON THE CURVE

Fluid temperature has become less than -300°F at some point in the system.

5. THREE HUNDRED ITERATIONS HAVE FAILED TO PRODUCE A STEADY STATE SOLUTION

A Mission 4 problem has failed to reach steady state in 300 iterations.

6.0 LIST OF SYMBOLS

A_c	Conduction area
A_e	External area for radiation
A_f	Internal area for heat transfer
AK	Ratio of pressure drop in a tube to flow rate in that tube
B	Pressure drop constant $= \frac{2(\text{node length})(\text{Wetted Perimeter})^2}{(\text{Flow area})^3\,(\text{Fluid density})}$
c	Specific heat
D_h	Hydraulic diameter
D,E,F,	Temperature equation coefficients
G	Proportioning valve gain
H	Factor for proportioning valve pressure drop
f	Friction factor
h_f	Heat transfer coefficient
k	Thermal conductivity
K	Ratio of pressure drop to flow rate
ΔP	Pressure drop
Pr	Prandtl Number
Q	Incident heat
Re	Reynolds number
T	Temperature
t_c	Proportioning valve time constant
U	Thermal conductance
w	Weight of lump j
$\dot{w}$	Flow rate
Y	Conduction path length
X	Proportioning valve position

Z	Fraction bypassed
α	Incident heat absorptivity
ϵ	Emissivity
σ	Stefan-Boltzmann constant
μ	Dynamic viscosity
$\Delta\tau$	Calculation time increment
Θ	Iteration limit
ϕ	Overrelaxation parameter

Subscripts

i, j, k	Indices
LT	Left side
f	Fluid
fu	Upstream fluid lump
RT	Right side
s	Structure (fin)
t	Tube

Superscripts

τ	Conditions at time, τ
"	Conditions at time $\tau + \Delta\tau$

REFERENCES

1. Hixon, C. W., "Simplified Transient Computer Subroutines For Apollo Block I and Block II Environmental Control System Radiators," LTV Astronautics Report No. 00.822, 18 July 1966

2. Gaddis, J. L., "Implicit Finite-Difference Generalized Heat Transfer Program (LVVM22)," LTV Astronautics Report No. 00.809, 12 July 1966

3. Finch, H. L., et al, "Orbiting Satellite Surface Temperature Prediction and Analysis," Midwest Research Institute Project No. 2669-E (Contract No. NAS9-1059), 3 February 1964

4. Hixon, C. W., et al, "Apollo Block II Command Module Thermal Simulator," LTV Missiles and Space Division Report No. 350.2 Volume I, 28 July 1967

5. Summerhays, R. M., and Whitten, W. A., "Test Report for Qualification Test of an Apollo Block II ECS Radiator Subsystem," LTV Missiles and Space Division Report No. 332.62, 7 April 1967

APPENDIX A

PROGRAM LISTING

```
C                   ULTRA-FAST MISSION ANALYSIS ROUTINE
C                    FOR APOLLO BLOCK 2 ENVIRONMENTAL
C                         CONTROL SYSTEM RADIATORS
C
C                              DEVELOPED BY
C
C                   MISSILES AND SPACE DIVISION - TEXAS
C                       LTV AEROSPACE CORPORATION
C                  P. O. BOX 6267 - DALLAS, TEXAS   75222
C
C                                   FOR
C
C              NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
C                MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
C                        UNDER CONTRACT NAS9-6807
C
C PROG READS THE DATA AND CALLS SUBROUTINE AB2RAD WHICH DOES
C THE ACTUAL CALCULATIONS
C
    1 FORMAT(I5,I3,I2,7F10.0)
   50 READ(5,1) MSSION,KODE,KODSEC,P3,PERIOD,PRINT,TINLT,WDOTS,
     1TINSEC,WDTSEC
      CALL AB2RAD(MSSION,KODE,KODSEC,P3,PERIOD,PRINT,TINLT,WDOTS,
     1TINSEC,WDTSEC)
      GO TO 50
      END
      SUBROUTINE AB2RAD(MSSION,KODE,KODSEC,P3,PERIOD,PRINT,TINLT,
     1WDOTS,TINSEC,WDTSEC)
      DATA ON/' ON '/,OFF/' OFF'/
      DIMENSION AK(12),BMU(37),TF(32),TFIN(32),TPPF(32),TPF(32),NFCODE
     1(32),TT(32),TTIN(32),TPPT(32),TPT(32),NTCODE(32),TS(20),TSIN(20),
     2TPPS(20),TPS(20),NSCODE(20),QABS(4),Q(4000),TIME(8000),T(33),TMU
     3(33),WDOT(10),DPT(10),E(5),ALPHA(12),NPTS(8),WDTTOT(1000),TIN
     4(1000),MSTART(8),WDOTSC(1000),TINLSC(1000),H(10),F(5)
      COMMON T,TMU
  503 FORMAT(//50H THE PROBLEM COULD NOT BE SOLVED IN 500 ITERATIONS//)
      SAVE1 = PRINT
      IQUIT=0
 2508 AA1 = .034
      A2 = 32.1
      AA2 = AA1
      AA3 = 2.355
      A3A = 1.984
      A5  = .842
      AA5 = 2.55
      A5A = 2.158
      AA6 = AA5
      A7 = .087
      A8 = .0519
      A9 = 1.32E-10
      A10 = .79E-10
      A11 = .41
      A12 = .0911
      A13 = 1.39E-10
      A14 = 1.56
      A15 = .468
      A16 = 1.06
      A17 = .557
      A18 = .0792
      A19 = 1.224E-10
```

```
      A20 = 1.565
      A21 = .1091
      A22 = .0166E-8
      A23 = .719
      B1 = AA1
      B3 = A3A
      B4 = A5A
      E(1)=.000987407532
      E(2)=.002965444665
      E(3)=.0039182373
      E(4)=.004551234485
      E(5)=.004730380465
      F(1)=.000126203
      F(2)=.000126421111
      F(3)=.000139544253
      F(4)=.000156136337
      F(5)=.000178387671
      WDOTT=WDOTS
      SETPT=504.69
      DBAND=.75
      FLOWMX=1.0
      FLOWMN=.01
      RTFCTR=.0003
      RLIMIT=.0033
      POSIN = 16.5
      VLVGAN=1.155
      POSMIN=.854
      POSMAX=32.146
      FULOPN = 33.
      GFACT=30.
      PPARA=2.0
      VTOL= .001
      COUNT=0.
      SQREJ=0.
      STOUT=0.0
      SDP=0.
      TMX=0.0
      TMN=1000000.0
      TMAX=0.
      TMIN=1000000.
      DPMAX=0.0
      DPMIN=500.0
      PCMAX=0.0
      PCMIN=1000000.0
      IF(KODSEC.EQ.0) GO TO 5060
      SDP2=0.
      DPMX=0.
      DPMN=500.
      TMX2=0.
      TMN2=1000000.
      STOUT2=0.
 5060 XX1=POSIN
      XX2=XX1
      TFA21 = 529.69
      TFA23 = 529.69
      TOUTP = 529.69
      M=0
      MM=0
      MMM=0
      SUM1=0
```

```
SUM2=0
NP5=33
T( 1)=159.69
T( 2)=354.69
T( 3)=369.69
T( 4)=375.69
T( 5)=376.69
T( 6)=377.69
T( 7)=378.69
T( 8)=379.69
T( 9)=381.69
T(10)=383.69
T(11)=385.69
T(12)=387.69
T(13)=389.69
T(14)=394.69
T(15)=399.69
T(16)=409.69
T(17)=419.69
T(18)=429.69
T(19)=439.69
T(20)=449.69
T(21)=459.69
T(22)=469.69
T(23)=479.69
T(24)=489.69
T(25)=499.69
T(26)=509.69
T(27)=519.69
T(28)=529.69
T(29)=539.69
T(30)=559.69
T(31)=609.69
T(32)=659.69
T(33)=759.69
TMU( 1)=125000000.0
TMU( 2)=125000000.0
TMU( 3)=240000.0
TMU( 4)=63000.0
TMU( 5)=25000.0
TMU( 6)=11750.0
TMU( 7)=6600.0
TMU( 8)=3900.0
TMU( 9)=1850.0
TMU(10)=1420.0
TMU(11)=1190.0
TMU(12)=1000.0
TMU(13)=870.0
TMU(14)=610.0
TMU(15)=425.0
TMU(16)=245.0
TMU(17)=135.0
TMU(18)=80.0
TMU(19)=51.9
TMU(20)=34.0
TMU(21)=24.5
TMU(22)=16.5
TMU(23)=12.2
TMU(24)=9.3
TMU(25)=7.3
```

```
      TMU(26)=5.75
      TMU(27)=4.65
      TMU(28)=3.75
      TMU(29)=3.05
      TMU(30)=2.08
      TMU(31)=1.11
      TMU(32)=0.625
      TMU(33)=0.269
      GO TO (1212,1313,1414,1515,1616),MSSION
C
C
C * * * * * * * * * *     BROADSIDE      * * * * * * * * * *
C
C
 1212 MSTART(1)=1
      MSTART(2)=19
      MSTART(3)=37
      MSTART(4)=47
      PERIOD=2.0419
      P3=8.1676
      NP1=18
      NP2=36
      NP3=46
      NP4=56
      Q( 1)=284.19
      Q( 2)=275.61
      Q( 3)=267.04
      Q( 4)=217.70
      Q( 5)=142.07
      Q( 6)=8.31
      Q( 7)=8.06
      Q( 8)=31.18
      Q( 9)=1.37
      Q(10)=1.37
      Q(11)=31.18
      Q(12)=8.06
      Q(13)=8.31
      Q(14)=142.07
      Q(15)=217.70
      Q(16)=267.04
      Q(17)=275.61
      Q(18)=284.19
      Q(19)=284.19
      Q(20)=275.61
      Q(21)=267.04
      Q(22)=217.70
      Q(23)=142.07
      Q(24)=8.31
      Q(25)=8.06
      Q(26)=31.18
      Q(27)=1.37
      Q(28)=1.37
      Q(29)=31.18
      Q(30)=8.06
      Q(31)=8.31
      Q(32)=142.07
      Q(33)=217.70
      Q(34)=267.04
      Q(35)=275.61
      Q(36)=284.19
```

```
Q(37)=77.48
Q(38)=72.81
Q(39)=59.38
Q(40)=38.72
Q(41)=0.0
Q(42)=0.0
Q(43)=38.72
Q(44)=59.38
Q(45)=72.81
Q(46)=77.48
Q(47)=77.48
Q(48)=72.81
Q(49)=59.38
Q(50)=38.72
Q(51)=0.0
Q(52)=0.0
Q(53)=38.72
Q(54)=59.38
Q(55)=72.81
Q(56)=77.48
TIME( 1)=0.0
TIME( 2)=0.0567
TIME( 3)=0.1135
TIME( 4)=0.2268
TIME( 5)=0.3403
TIME( 6)=0.5105
TIME( 7)=0.5388
TIME( 8)=0.6401
TIME( 9)=0.6411
TIME(10)=1.4020
TIME(11)=1.4030
TIME(12)=1.5031
TIME(13)=1.5314
TIME(14)=1.7016
TIME(15)=1.8151
TIME(16)=1.9284
TIME(17)=1.9853
TIME(18)=2.0419
TIME(19)=0.0
TIME(20)=0.0567
TIME(21)=0.1135
TIME(22)=0.2268
TIME(23)=0.3403
TIME(24)=0.5105
TIME(25)=0.5388
TIME(26)=0.6401
TIME(27)=0.6411
TIME(28)=1.4020
TIME(29)=1.4030
TIME(30)=1.5031
TIME(31)=1.5314
TIME(32)=1.7016
TIME(33)=1.8151
TIME(34)=1.9284
TIME(35)=1.9853
TIME(36)=2.0419
TIME(37)=0.0
TIME(38)=0.1135
TIME(39)=0.2268
TIME(40)=0.3403
```

```
      TIME(41)=0.5105                                                   BLK20301
      TIME(42)=1.5314                                                   BLK20302
      TIME(43)=1.7016                                                   BLK20303
      TIME(44)=1.8151                                                   BLK20304
      TIME(45)=1.9284                                                   BLK20305
      TIME(46)=2.0419                                                   BLK20306
      TIME(47)=0.0                                                      BLK20307
      TIME(48)=0.1135                                                   BLK20308
      TIME(49)=0.2268                                                   BLK20309
      TIME(50)=0.3403                                                   BLK20310
      TIME(51)=0.5105                                                   BLK20311
      TIME(52)=1.5314                                                   BLK20312
      TIME(53)=1.7016                                                   BLK20313
      TIME(54)=1.8151                                                   BLK20314
      TIME(55)=1.9284                                                   BLK20315
      TIME(56)=2.0419                                                   BLK20316
      GO TO 1111                                                        BLK20317
C                                                                       BLK20318
C                                                                       BLK20319
C * * * * * * * * *   LUNAR DIRECT - NOSE DOWN   * * * * * * * * *      BLK20320
C                                                                       BLK20321
C                                                                       BLK20322
 1313 MSTART(1)=1                                                       BLK20323
      MSTART(2)=15                                                      BLK20324
      MSTART(3)=29                                                      BLK20325
      MSTART(4)=43                                                      BLK20326
      PERIOD=2.0419                                                     BLK20327
      P3=8.1676                                                         BLK20328
      NP1=14                                                            BLK20329
      NP2=28                                                            BLK20330
      NP3=42                                                            BLK20331
      NP4=56                                                            BLK20332
      Q( 1)=100.43                                                      BLK20333
      Q( 2)=123.63                                                      BLK20334
      Q( 3)=129.74                                                      BLK20335
      Q( 4)=131.92                                                      BLK20336
      Q( 5)=130.11                                                      BLK20337
      Q( 6)=124.30                                                      BLK20338
      Q( 7)=108.87                                                      BLK20339
      Q( 8)=77.11                                                       BLK20340
      Q( 9)=71.18                                                       BLK20341
      Q(10)=0.49                                                        BLK20342
      Q(11)=0.49                                                        BLK20343
      Q(12)=71.25                                                       BLK20344
      Q(13)=91.33                                                       BLK20345
      Q(14)=100.43                                                      BLK20346
      Q(15)=100.43                                                      BLK20347
      Q(16)=123.63                                                      BLK20348
      Q(17)=129.74                                                      BLK20349
      Q(18)=131.92                                                      BLK20350
      Q(19)=130.11                                                      BLK20351
      Q(20)=124.30                                                      BLK20352
      Q(21)=108.87                                                      BLK20353
      Q(22)=77.11                                                       BLK20354
      Q(23)=71.18                                                       BLK20355
      Q(24)=0.49                                                        BLK20356
      Q(25)=0.49                                                        BLK20357
      Q(26)=71.25                                                       BLK20358
      Q(27)=91.33                                                       BLK20359
      Q(28)=100.43                                                      BLK20360
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      Q(29)=100.43                                                      BLK20361
      Q(30)=91.33                                                       BLK20362
      Q(31)=71.25                                                       BLK20363
      Q(32)=0.49                                                        BLK20364
      Q(33)=0.49                                                        BLK20365
      Q(34)=71.18                                                       BLK20366
      Q(35)=77.11                                                       BLK20367
      Q(36)=108.87                                                      BLK20368
      Q(37)=124.30                                                      BLK20369
      Q(38)=130.11                                                      BLK20370
      Q(39)=131.92                                                      BLK20371
      Q(40)=129.74                                                      BLK20372
      Q(41)=123.63                                                      BLK20373
      Q(42)=100.43                                                      BLK20374
      Q(43)=100.43                                                      BLK20375
      Q(44)=91.33                                                       BLK20376
      Q(45)=71.25                                                       BLK20377
      Q(46)=0.49                                                        BLK20378
      Q(47)=0.49                                                        BLK20379
      Q(48)=71.18                                                       BLK20380
      Q(49)=77.11                                                       BLK20381
      Q(50)=108.87                                                      BLK20382
      Q(51)=124.30                                                      BLK20383
      Q(52)=130.11                                                      BLK20384
      Q(53)=131.92                                                      BLK20385
      Q(54)=129.74                                                      BLK20386
      Q(55)=123.63                                                      BLK20387
      Q(56)=100.43                                                      BLK20388
      TIME( 1)=0.0                                                      BLK20389
      TIME( 2)=0.1135                                                   BLK20390
      TIME( 3)=0.1702                                                   BLK20391
      TIME( 4)=0.2268                                                   BLK20392
      TIME( 5)=0.2837                                                   BLK20393
      TIME( 6)=0.3403                                                   BLK20394
      TIME( 7)=0.4253                                                   BLK20395
      TIME( 8)=0.5388                                                   BLK20396
      TIME( 9)=0.6401                                                   BLK20397
      TIME(10)=0.6411                                                   BLK20398
      TIME(11)=1.5598                                                   BLK20399
      TIME(12)=1.8151                                                   BLK20400
      TIME(13)=1.9284                                                   BLK20401
      TIME(14)=2.0419                                                   BLK20402
      TIME(15)=0.0                                                      BLK20403
      TIME(16)=0.1135                                                   BLK20404
      TIME(17)=0.1702                                                   BLK20405
      TIME(18)=0.2268                                                   BLK20406
      TIME(19)=0.2837                                                   BLK20407
      TIME(20)=0.3403                                                   BLK20408
      TIME(21)=0.4253                                                   BLK20409
      TIME(22)=0.5388                                                   BLK20410
      TIME(23)=0.6401                                                   BLK20411
      TIME(24)=0.6411                                                   BLK20412
      TIME(25)=1.5598                                                   BLK20413
      TIME(26)=1.8151                                                   BLK20414
      TIME(27)=1.9284                                                   BLK20415
      TIME(28)=2.0419                                                   BLK20416
      TIME(29)=0.0                                                      BLK20417
      TIME(30)=0.1135                                                   BLK20418
      TIME(31)=0.2268                                                   BLK20419
      TIME(32)=0.4822                                                   BLK20420
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      TIME(33)=1.4020                                                   BLK20421
      TIME(34)=1.4030                                                   BLK20422
      TIME(35)=1.5031                                                   BLK20423
      TIME(36)=1.6164                                                   BLK20424
      TIME(37)=1.7016                                                   BLK20425
      TIME(38)=1.7583                                                   BLK20426
      TIME(39)=1.8151                                                   BLK20427
      TIME(40)=1.8718                                                   BLK20428
      TIME(41)=1.9284                                                   BLK20429
      TIME(42)=2.0419                                                   BLK20430
      TIME(43)=0.0                                                      BLK20431
      TIME(44)=0.1135                                                   BLK20432
      TIME(45)=0.2260                                                   BLK20433
      TIME(46)=0.4822                                                   BLK20434
      TIME(47)=1.4020                                                   BLK20435
      TIME(48)=1.4030                                                   BLK20436
      TIME(49)=1.5031                                                   BLK20437
      TIME(50)=1.6164                                                   BLK20438
      TIME(51)=1.7016                                                   BLK20439
      TIME(52)=1.7583                                                   BLK20440
      TIME(53)=1.8151                                                   BLK20441
      TIME(54)=1.8718                                                   BLK20442
      TIME(55)=1.9284                                                   BLK20443
      TIME(56)=2.0419                                                   BLK20444
      GO TO 1111                                                        BLK20445
C                                                                       BLK20446
C * * * * * * * * * *     TRANSLUNAR     * * * * * * * *               BLK20447
C                                                                       BLK20448
C                                                                       BLK20449
 1414 MSTART(1)=1                                                       BLK20450
      MSTART(2)=14                                                      BLK20451
      MSTART(3)=27                                                      BLK20452
      MSTART(4)=40                                                      BLK20453
      PERIOD=1.0                                                        BLK20454
      P3=4.0                                                            BLK20455
      NP1=13                                                            BLK20456
      NP2=26                                                            BLK20457
      NP3=39                                                            BLK20458
      NP4=52                                                            BLK20459
      Q( 1)=76.5                                                        BLK20460
      Q( 2)=77.6                                                        BLK20461
      Q( 3)=87.0                                                        BLK20462
      Q( 4)=88.6                                                        BLK20463
      Q( 5)=87.0                                                        BLK20464
      Q( 6)=77.6                                                        BLK20465
      Q( 7)=60.6                                                        BLK20466
      Q( 8)=42.5                                                        BLK20467
      Q( 9)= 0.0                                                        BLK20468
      Q(10)= 0.0                                                        BLK20469
      Q(11)=42.5                                                        BLK20470
      Q(12)=60.6                                                        BLK20471
      Q(13)=76.5                                                        BLK20472
      Q(14)=76.5                                                        BLK20473
      Q(15)=60.6                                                        BLK20474
      Q(16)=42.5                                                        BLK20475
      Q(17)= 0.0                                                        BLK20476
      Q(18)= 0.0                                                        BLK20477
      Q(19)=42.5                                                        BLK20478
      Q(20)=60.6                                                        BLK20479
      Q(21)=77.6                                                        BLK20480
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Q(22)=87.0                                                              BLK20481
Q(23)=88.6                                                              BLK20482
Q(24)=87.0                                                              BLK20483
Q(25)=77.6                                                              BLK20484
Q(26)=76.5                                                              BLK20485
Q(27)= 0.0                                                              BLK20486
Q(28)= 0.0                                                              BLK20487
Q(29)=42.5                                                              BLK20488
Q(30)=60.6                                                              BLK20489
Q(31)=77.6                                                              BLK20490
Q(32)=87.0                                                              BLK20491
Q(33)=88.6                                                              BLK20492
Q(34)=87.0                                                              BLK20493
Q(35)=77.6                                                              BLK20494
Q(36)=60.6                                                              BLK20495
Q(37)=42.5                                                              BLK20496
Q(38)= 0.0                                                              BLK20497
Q(39)= 0.0                                                              BLK20498
Q(40)= 0.0                                                              BLK20499
Q(41)= 0.0                                                              BLK20500
Q(42)=42.5                                                              BLK20501
Q(44)=77.6                                                              BLK20502
Q(45)=87.0                                                              BLK20503
Q(46)=88.6                                                              BLK20504
Q(47)=87.0                                                              BLK20505
Q(48)=77.6                                                              BLK20506
Q(49)=60.6                                                              BLK20507
Q(50)=42.5                                                              BLK20508
Q(51)= 0.0                                                              BLK20509
Q(52)= 0.0                                                              BLK20510
TIME( 1)=0.0                                                            BLK20511
TIME( 2)=0.0078                                                         BLK20512
TIME( 3)=0.0578                                                         BLK20513
TIME( 4)=0.0856                                                         BLK20514
TIME( 5)=0.1134                                                         BLK20515
TIME( 6)=0.1638                                                         BLK20516
TIME( 7)= .219                                                          BLK20517
TIME( 8)=0.258                                                          BLK20518
TIME(9) = .333                                                          BLK20519
TIME(10)=0.8360                                                         BLK20520
TIME(11)=0.911                                                          BLK20521
TIME(12)=0.952                                                          BLK20522
TIME(13)=1.0                                                            BLK20523
TIME(14)=0.0                                                            BLK20524
TIME(15)=0.0478                                                         BLK20525
TIME(16)=0.0884                                                         BLK20526
TIME(17)=0.1660                                                         BLK20527
TIME(18)=0.666                                                          BLK20528
TIME(19) = .747                                                         BLK20529
TIME(20)=0.781                                                          BLK20530
TIME(21)=0.837                                                          BLK20531
TIME(22)=0.888                                                          BLK20532
TIME(23)=0.914                                                          BLK20533
TIME(24)=0.942                                                          BLK20534
TIME(25)=0.991                                                          BLK20535
TIME(26)=1.0                                                            BLK20536
TIME(27)=0.0                                                            BLK20537
TIME(28) = .333                                                         BLK20538
TIME(29) = .418                                                         BLK20539
TIME(30) = .459                                                         BLK20540
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```
      TIME(31)=0.507
      TIME(32)=0.557
      TIME(33)=0.586
      TIME(34)=0.613
      TIME(35)=0.664
      TIME(36)=0.719
      TIME(37)=0.758
      TIME(38)=0.835
      TIME(39)=1.0
      TIME(40)=0.0
      TIME(41)=0.1642
      TIME(42)=0.242
      TIME(43)=0.281
      TIME(44)=0.337
      TIME(45)=0.387
      TIME(46)=0.415
      TIME(47)=0.442
      TIME(48)=0.493
      TIME(49)=0.549
      TIME(50)=0.587
      TIME(51)=0.664
      TIME(52)=1.0
      GO TO 1111
C
C
C * * * * * * * * * *            ZERO             * * * * * * * * *
C
C
 1515 MSTART(1)=1
      MSTART(2)=3
      MSTART(3)=5
      MSTART(4)=7
      PERIOD=1.0
      P3=6.
      QREJ1=1000000.
      NP1=2
      NP2=4
      NP3=6
      NP4=8
      Q( 1)=0.0
      Q( 2)=0.0
      Q( 3)=0.0
      Q( 4)=0.0
      Q( 5)=0.0
      Q(6)=0.0
      Q(7)=0.0
      Q( 8)=0.0
      TIME( 1)=0.0
      TIME( 2)=1.0
      TIME( 3)=0.0
      TIME( 4)=1.0
      TIME( 5)=0.0
      TIME( 6)=1.0
      TIME( 7)=0.0
      TIME( 8)=1.0
      GO TO 1111
 1616 NEXT=1
      LAST=0
      DO 1629 I=1,8
      READ(5,1620) NPTS(I),ALPHA
```

```
 1620 FORMAT(I5,11A6,A1)
      NOPTS=NPTS(I)
      WRITE(6,1621) NPTS(I),ALPHA
 1621 FORMAT(1H0/I5,11A6,A1/)
      LAST=LAST+NPTS(I)
      GO TO (1622,1622,1622,1622,1625,1626,1630,1631), I
 1622 READ(5,1623) (TIME(II),II=NEXT,LAST),(Q(II),II=NEXT,LAST)
 1623 FORMAT(7E10.3)
      WRITE(6,1624) (TIME(II),II=NEXT,LAST),(Q(II),II=NEXT,LAST)
 1624 FORMAT(10X1P7G10.4)
      GO TO 1628
 1625 READ(5,1623) (TIME(II),II=NEXT,LAST),(WDTTOT(II),II=1,NOPTS)
      WRITE(6,1624) (TIME(II),II=NEXT,LAST),(WDTTOT(II),II=1,NOPTS)
      GO TO 1628
 1626 READ(5,1623) (TIME(II),II=NEXT,LAST),(TIN(II),II=1,NOPTS)
      WRITE(6,1624) (TIME(II),II=NEXT,LAST),(TIN(II),II=1,NOPTS)
      DO 1627 II=1,NOPTS
 1627 TIN(II)=TIN(II)+459.69
      IF (KODSEC.EQ.0) GO TO 1633
      GO TO 1628
 1630 READ(5,1623) (TIME(II),II=NEXT,LAST),(WDOTSC(II),II=1,NOPTS)
      WRITE(6,1624) (TIME(II),II=NEXT,LAST),(WDOTSC(II),II=1,NOPTS)
      GO TO 1628
 1631 READ(5,1623) (TIME(II),II=NEXT,LAST),(TINLSC(II),II=1,NOPTS)
      WRITE(6,1624) (TIME(II),II=NEXT,LAST),(TINLSC(II),II=1,NOPTS)
      DO 1632 II=1,NOPTS
 1632 TINLSC(II)=TINLSC(II)+459.69
 1628 NEXT=NEXT+NPTS(I)
 1629 CONTINUE
 1633 IF(.NOT.PERIOD.GT.0.) PERIOD=P3
      TINLT=TIN(1)
      WDOTS=WDTTOT(1)
      WDOTT=WDOTS
      MSTART(1)=1
      NP1=NPTS(1)
      MSTART(2)=NP1+1
      NP2=NP1+NPTS(2)
      MSTART(3)=NP2+1
      NP3=NP2+NPTS(3)
      MSTART(4)=NP3+1
      NP4=NP3+NPTS(4)
      MSTART(5)=NP4+1
      MW=1
      NP5B=NPTS(5)
      NP5A=NP4+NP5B
      MSTART(6)=NP5A+1
      MT=1
      NP6B=NPTS(6)
      NP6A=NP5A+NP6B
      IF(KODSEC.EQ.0) GO TO 1112
      TINSEC=TINLSC(1)
      WDTSEC=WDOTSC(1)
      MSTART(7)=NP6A+1
      MWSEC=1
      NP7=NP6A+NPTS(7)
      MSTART(8)=NP7+1
      MTSEC=1
      NP8=NP7+NPTS(7)
      GO TO 1112
 1111 TINLT=TINLT+459.69
```

```
      TINSEC=TINSEC+459.69
      TLINP = TINLT
      TLINS = TINSEC
 1112 DO 605 I=1,20
      TFIN(I)=529.69
      TTIN(I)=529.69
  605 TSIN(I)=529.69
      DO 606 I=21,32
      TFIN(I)=529.69
  606 TTIN(I)=529.69
      WDOTT1=WDOTS/2.
      WDOTT2=WDOTT1
      FLOWPC=1.
      WRITE(6,436)
  436 FORMAT('1'///16X'**------------ - -PRIMARY SYSTEM----------------**
     1**---------  ------REDUNDANT SYSTEM------------------** **TOTAL**'/
     218X'HEAT'5X'PRESSURE'4X'FLOW'5X'OUTLET'4X'INLINE'3X'HEAT'5X'PRESSU
     3RE'4X'FLOW'5X'OUTLET'6X'INLINE'6X'HEAT'/9X'TIME'3X'REJECTION'4X'DR
     4OP'6X'RATE'3X'TEMPERATURE HEATER REJECTION'4X'DROP'6X'RATE'3X'TEMP
     5ERATURE'3X'HEATER'4X'REJECTION'/107X'STAGE STAGE'/109X'1'5X'2'/)
      TAU = 0.02
      SAVE= 0.02
  425 IF(TAU-PERIOD) 431,431,426
  426 TAU=TAU-PERIOD
      GO TO (427,428,429,430,6008),MSSION
  427 MSTART(1)=1
      MSTART(2)=19
      MSTART(3)=37
      MSTART(4)=47
      GO TO 431
  428 MSTART(1)=1
      MSTART(2)=15
      MSTART(3)=29
      MSTART(4)=43
      GO TO 431
  429 MSTART(1)=1
      MSTART(2)=14
      MSTART(3)=27
      MSTART(4)=40
      GO TO 431
  430 MSTART(1)=1
      MSTART(2)=3
      MSTART(3)=5
      MSTART(4)=7
      GO TO 431
      MSTART(1)=1
      MSTART(2)=NP1+1
      MSTART(3)=NP2+1
      MSTART(4)=NP3+1
      MSTART(5)=NP4+1
      MSTART(6)=NP5A+1
      IF(KODSEC.EQ.0) GO TO 431
      MSTART(7)=NP6A+1
      MSTART(8)=NP7+1
  431 DO 35 K=1,4
      GO TO (432,433,434,435),K
  432 KK=MSTART(1)
      JJ=NP1
      GO TO 32
  433 KK=MSTART(2)
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      JJ=NP2                                                            BLK2072.
      GO TO 32                                                          BLK20722
  434 KK=MSTART(3)                                                      BLK20723
      JJ=N 3                                                            BLK20724
      GO TO 32                                                          BLK20725
  435 KK=MSTART(4)                                                      BLK20726
      JJ=NP4                                                            BLK20727
   32 DO 40 I=KK,JJ                                                     BLK20728
      J=I                                                               BLK20729
      IF(TAU-TIME(I)) 36,37,40                                          BLK20730
   40 CONTINUE                                                          BLK20731
      MERR=K                                                            BLK20732
      GO TO 2000                                                        BLK20733
   36 TEMP=TAU-TIME(J-1)                                                BLK20734
      TINT=TIME(J)-TIME(J-1)                                            BLK20735
      TEMPQ=Q(J)-Q(J-1)                                                 BLK20736
      QABS(K)=Q(J-1)+TEMP/TINT*TEMPQ                                    BLK20737
      MSTART(K)=J-1                                                     BLK20738
      GO TO 35                                                          BLK20739
   37 QABS(K)=Q(J)                                                      BLK20740
      MSTART(K)=J                                                       BLK20741
   35 CONTINUE                                                          BLK20742
      IF(MSSION .EQ. 5) GO TO 5012                                      BLK20743
      IF(KODSEC .EQ. 0) GO TO 2507                                      BLK20744
      GO TO 5013                                                        BLK20745
 5012 KK = MSTART(5)                                                    BLK20746
      DO 1650 I=KK,NP5A                                                 BLK20747
      J=I                                                               BLK20748
      IF(TAU-TIME(I)) 1651,1652,1660                                    BLK20749
 1660 MW=MW+1                                                           BLK20750
 1650 CONTINUE                                                          BLK20751
      MERR=5                                                            BLK20752
      GO TO 2000                                                        BLK20753
 1651 TEMP=TAU-TIME(J-1)                                                BLK20754
      TINT=TIME(J)-TIME(J-1)                                            BLK20755
      TEMPW=WDTTOT(MW)-WDTTOT(MW-1)                                     BLK20756
      WDOTS=WDTTOT(MW-1)+TEMP/TINT*TEMPW                                BLK20757
      MW=MW-1                                                           BLK20758
      MSTART(5)=J-1                                                     BLK20759
      GO TO 1653                                                        BLK20760
 1652 WDOTS=WDTTOT(MW)                                                  BLK20761
      MSTART(5)=J                                                       BLK20762
 1653 KK=MSTART(6)                                                      BLK20763
      DO 1654 I=KK,NP6A                                                 BLK20764
      J=I                                                               BLK20765
      IF(TAU-TIME(I)) 1655,1656,1664                                    BLK20766
 1664 MT=MT+1                                                           BLK20767
 1654 CONTINUE                                                          BLK20768
      MERR=6                                                            BLK20769
 2000 WRITE(6,2001) MERR,TAU                                            BLK20770
 2001 FORMAT(1H010X24HINTERPOLATION IMPOSSIBLE/15X5HMERR=I5/            BLK20771
     110X5HTIME=F10.2///10X40HEXECUTION TERMINATED BY PROGRAMMED HALT.) BLK20772
      CALL EXIT                                                         BLK20773
 1655 TEMP=TAU-TIME(J-1)                                                BLK20774
      TINT=TIME(J)-TIME(J-1)                                            BLK20775
      TEMPT=TIN(MT)-TIN(MT-1)                                           BLK20776
      TINLT=TIN(MT-1)+TEMP/TINT*TEMPT                                   BLK20777
      MT=MT-1                                                           BLK20778
      MSTART(6)=J-1                                                     BLK20779
      GO TO 38                                                          BLK20780
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```
 1656 TINLT=TIN(MT)
      MSTART(6)=J
   38 TLINP = TINLT
      IF(KODSEC .EQ. 0) GO TO 2507
      KK=MSTART(7)
      DO 2500 I=KK,NP7
      J=I
      IF(TAU-TIME(I)) 2501,2502,
      MWSEC=MWSEC+1
 2500 CONTINUE
      MERR=7
      GO TO 2000
 2501 TEMP=TAU-TIME(J-1)
      TINT=TIME(J)-TIME(J-1)
      TEMPWS=WDOTSC(MWSEC)-WDOTSC(MWSEC-1)
      WDTSEC=WDOTSC(MWSEC-1)+TEMP/TINT*TEMPWS
      MWSEC = MWSEC - 1
      MSTART(7)=J-1
      GO TO 2503
 2502 WDTSEC=WDOTSC(MWSEC)
      MSTART(7)=J
 2503 KK=MSTART(8)
      DO 2504 I=KK,NP8
      J=I
      IF(TAU-TIME(I)) 2505,2506,
      MTSEC=MTSEC+1
 2504 CONTINUE
      MERR=8
      GO TO 2000
 2505 TEMP=TAU-TIME(J-1)
      TINT=TIME(J)-TIME(J-1)
      TEMPTS=TINLSC(MTSEC)-TINLSC(MTSEC-1)
      TINSEC=TINLSC(MTSEC-1)+TEMP/TINT*TEMPTS
      MTSEC=MTSEC-1
      MSTART(8)=J-1
      GO TO 5015
 2506 TINSEC=TINLSC(MTSEC)
      MSTART(8)=J
 5015 TLINS = TINSEC
 5013 IF(M .EQ.1) GO TO 5002
      IF(TFIN(32) - 504.69) 5000,5000,2507
 5002 IF(TFIN(32).LT.506.69) GO TO 5003
      TINSEC=TLINS
      M=0
      MM=0
      GO TO 2507
 5000 M=1
 5003 IF(MM.EQ.1) GO TO 5004
      IF(TFIN(32).LT.503.69) GO TO 5007
 5006 TINSEC=TLINS+2130./WDTSEC
      SUM2=SUM2+30.7
      GO TO 2507
 5004 IF(TFIN(32)-505.69) 5007,5007,5006
 5007 TINSEC=TLINS+4260./WDTSEC
      SUM2=SUM2+61.4
 2507 IF(MMM .EQ. 1) GO TO 5008
      IF(TOUTP-444.69) 5009,5009,5010
 5008 IF(TOUTP.LT.449.69) GO TO 5011
      TINLT=TLINP
      MMM=0
```

```
      GO TO 5010
 5009 MMM=1
 5011 TINLT=TLINP+2130./WDOTT
      SUM1=SUM1+30.7
 5010 DO 701 I=1,32
      NFCODE(I)=0
  701 NTCODE(I)=0
      DO 94 I=1,20
   94 NSCODE(I)=0
      DO 50 I=1,10
   50 CALL VPOL(TFIN(I),BMU(I),NP5)
      CALL VPOL(TINLT,BMU(33),NP5)
      DO 51 I=1,5
   51 AK(I)=E(I)*BMU(33)+.000201*BMU(2*I-1)+F(I)    *BMU(2*I)
      DO 636 I=11,20
  636 CALL VPOL(TFIN(I),BMU(I),NP5)
      DO 637 I=6,10
  637 AK(I)=E(I-5)*BMU(33)+.000201*BMU(2*I-1)+F(I-5) *BMU(2*I)
      WDOT(1)=WDOTT1/(AK(1)/AK(2)+AK(1)/AK(3)+AK(1)/AK(4)+AK(1)/AK(5)+
     11.)
      DO 52 I=2,5
   52 WDOT(I)=WDOT(1)*AK(1)/AK(I)
      WDOT(6)=WDOTT2/(AK(6)/AK(7)+AK(6)/AK(8)+AK(6)/AK(9)+AK(6)/AK(10)+
     11.)
      DO 53 I=7,10
   53 WDOT(I)=WDOT(6)*AK(6)/AK(I)
      DO 54 I=1,10
   54 DPT(I)=AK(I)*WDOT(I)
      CALL VPOL(TFA21,BMU(34),NP5)
      CALL VPOL(TFA23,BMU(35),NP5)
      CALL VPOL(TFIN(21),BMU(21),NP5)
      CALL VPOL(TFIN(22),BMU(22),NP5)
      CALL VPOL(TFIN(23),BMU(23),NP5)
      CALL VPOL(TFIN(24),BMU(24),NP5)
      AKIL = .002675*BMU(33)
      AKIS=.001843*BMU(33)
      AKS1=.0000350*BMU(34)
      AKS2=.0000350*BMU(35)
      AKT21=.000201*BMU(21)
      AKT22=.000201*BMU(22)
      AKT23=.000201*BMU(23)
      AKT24=.000201*BMU(24)
      AK(11)=BMU(22)*.00017987
      AK(12)=BMU(24)*.00027965
      DPTS1=WDOTT1*(AKT21+AKT22+AKS1+AK(11)+AKIS)+DPT(1)
      DPTS2=WDOTT2*(AKT23+AKT24+AKS2+AK(12)+AKIL)+DPT(6)
      IF (KODSEC.EQ.0) GO TO 1634
      DPKAPS = 0.
      DO 2026 I=25,32
      CALL VPOL(TFIN(I),BMU(I),NP5)
      DPKAP = .000201*BMU(I)
      DPKAPS = DPKAPS + DPKAP
 2026 CONTINUE
      CALL VPOL (TINSEC,BMU(37),NP5)
      DPTOT = (DPKAPS+.0000254*BMU(26)+.001231*BMU(28)+.00002535*BMU(30)
     1+.00003863*BMU(32)+.003889*BMU(37))*WDTSEC
 1634 DO 1 I=1,32
         TPPF(I)=TFIN(I)
    1    TPPT(I)=TTIN(I)
      DO 91 I=1,20
```

```
91      TPPS(I)=TSIN(I)
      DO 305 ITER=1,500
      LTER=ITER
      MCODE=1
      DO 821 I=1,32
      TF(I)=TPPF(I)
  821 TT(I)=TPPT(I)
      DO 93 I=1,20
   93 TS(I)=TPPS(I)
      DO 2 I=1,32
         TPT(I)=TT(I)
    2    TPF(I)=TF(I)
      DO 92 I=1,20
   92    TPS(I)=TS(I)
C
C           FLUID LUMP TEMPERATURE EQUATIONS
C
      DO 101 I=1,9,2
      J=(I+1)/2
      IF (NFCODE(I).NE.0) GO TO 101
      TF(I) =(TFIN(I)+AA1*WDOT(J)*TINLT+AA3*TT(I))
     1 /(1.+AA3+AA1*WDOT(J))
      TPPF(I) = TF(I)
  101 CONTINUE
      DO 102 I=11,19,2
      J=(I+1)/2
      IF (NFCODE(I).NE.0) GO TO 102
      TF(I) = (TFIN(I)+AA2*WDOT(J)*TINLT+AA3*TT(I))
     1 /(1.+AA3+AA2*WDOT(J))
      TPPF(I) = TF(I)
  102 CONTINUE
      DO 103 I=2,10,2
      J=I/2
      IF (NFCODE(I).NE.0) GO TO 103
      TF(I) =(TFIN(I)+AA1*WDOT(J)*TF(I-1)+A3A*TT(I))
     1 /(1.+A3A+AA1*WDOT(J))
      TPPF(I) = TF(I)
  103 CONTINUE
      DO 104 I=12,20,2
      J=I/2
      IF(NFCODE(I).NE.0) GO TO 104
      TF(I) = (TFIN(I)+AA2*WDOT(J)*TF(I-1)+A3A*TT(I))
     1 /(1.+A3A+AA2*WDOT(J))
      TPPF(I) = TF(I)
  104 CONTINUE
      IF (NFCODE(21).NE.0) GO TO 2020
      DO 2021 I=1,5
 2021 H(I) = -83.39+.232*TF(2*I)+.000486*TF(2*I)**2
      H21=WDOT(1)*H(1)+WDOT(2)*H(2)+WDOT(3)*H(3)+WDOT(4)*H(4)+
     1 WDOT(5)*H(5)
      TFA21 = 247.43+1.879*H21/WDOTT1-.00155*H21*H21/WDOTT1/WDOTT1
      TF(21)= (TFIN(21)+AA1*WDOTT1*TFA21+A3A*TT(21))/
     1 (1. + A3A + AA1*WDOTT1)
      TPPF(21) = TF(21)
 2020 IF (NFCODE(22).NE.0) GO TO 2002
      TF(22)= (TFIN(22)+AA1*WDOTT1*TF(21)+A3A*TT(22))/
     1 (1. + A3A + AA1*WDOTT1)
      TPPF(22) = TF(22)
 2002 IF (NFCODE(23).NE.0) GO TO 2003
      DO 2004 I=6,10
```

```
2004 H(I) = -83.39+.232*TF(2*I)+.000486*TF(2*I)**2
     H23 =WDOT(6)*H(6)+WDOT(7)*H(7)+WDOT(8)*H(8)+WDOT(9)*H(9)+
    1 WDOT(10)*H(10)
     TFA23 = 247.43+1.879*H23/WDOTT2-.00155*H23*H23/WDOTT2/WDOTT2
     TF(23) = (TFIN(23)+AA2*WDOTT2*TFA23+A3A*TT(23))/
    1 (1. + A3A + AA2*WDOTT2)
     TPPF(23) = TF(23)
2003 IF (NFCODE(24).NE.0) GO TO 2005
     TF(24) = (TFIN(24)+AA2*WDOTT2*TF(23)+A3A*TT(24))/
    1 (1. + A3A + AA2*WDOTT2)
     TPPF(24) = TF(24)
2005 IF (NFCODE(25).NE.0) GO TO 2006
     TF(25) = (TFIN(25)+B1*WDTSEC*TINSEC+B3*TT(25))/(1.+B3+B1*WDTSEC)
     TPPF(25) = TF(25)
2006 DO 2007 I=26,32
     IF (NFCODE(I).NE.0) GO TO 2007
     TF(I) = (TFIN(I)+B1*WDTSEC*TF(I-1)+B3*TT(I))/(1.+B1*WDTSEC+B3)
     TPPF(I) = TF(I)
2007 CONTINUE
C
C          TUBE LUMP TEMPERATURE EQUATIONS
C
  109 IF(NTCODE( 1))111,112,111
  112 TT(1)=(TTIN(1)+A14*TF(1)+A15*TS(1)+A2*TT(26)+A7*QABS(1)-
    1 A9*TT(1)**4)/(1.+A14+A15+A2)
      TPPT( 1)=TT( 1)
  111 IF(NTCODE( 2))113,114,113
  114 TT(2)=(TTIN(2)+A16*TF(2)+A15*TS(2)+A2*TT(25) +A7*QABS(2)-
    1 A9*TT(2)**4)/(1.+A16+A15+A2)
      TPPT( 2)=TT( 2)
  113 IF(NTCODE( 3))115,116,115
  116 TT(3)=(TTIN(3)+AA5 *TF(3)+A5   *TS(3)+A5   *TS(1)+A8     *QABS(1)-
    1A10        *TT(3)**4)/(1.+AA5+2.*A5)
      TPPT( 3)=TT( 3)
  115 IF(NTCODE( 4))117,118,117
  118 TT(4)=(TTIN(4)+A5A *TF(4)+A5   *TS(2)+A5   *TS(4)+ A8     *QABS(2)-
    1A10        *TT(4)**4)/(1.+A5A+2.*A5)
      TPPT( 4)=TT( 4)
  117 IF(NTCODE( 5))119,120,119
  120 TT(5)=(TTIN(5)+AA5 *TF(5)+A5   *TS(3)+A5   *TS(5)+A8     *QABS(1)-
    1A10        *TT(5)**4)/(1.+AA5+2.*A5)
      TPPT( 5)=TT( 5)
  119 IF(NTCODE( 6))121,122,121
  122 TT(6)=(TTIN(6)+A5A *TF(6)+A5   *TS(4)+A5   *TS(6)+A8     *QABS(2)-
    1 A10       *TT(6)**4)/(1.+A5A+2.*A5)
      TPPT( 6)=TT( 6)
  121 IF(NTCODE( 7))123,124,123
  124 TT(7)=(TTIN(7)+AA5 *TF(7)+A5   *TS(5)+A5   *TS(7)+A8     *QABS(1)-
    1A10        *TT(7)**4)/(1.+AA5+2.*A5)
      TPPT( 7)=TT( 7)
  123 IF(NTCODE( 8))125,126,125
  126 TT(8)=(TTIN(8)+A5A *TF(8)+A5   *TS(6)+A5   *TS(8)+A8     *QABS(2)-
    1A10        *TT(8)**4)/(1.+A5A+2.*A5)
      TPPT( 8)=TT( 8)
  125 IF(NTCODE( 9))127,128,127
  128 TT(9)=(TTIN(9)+A14 *TF(9)+A15 *TS(7)+A7      *QABS(1)-A9*
    1TT(9)**4)/(1.+A14+A15)
      TPPT( 9)=TT( 9)
  127 IF(NTCODE(10))129,130,129
  130 TT(10)=(TTIN(10)+A16 *TF(10)+A15 *TS(8)+A7      *QABS(2)-
```

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     1A9         *TT(10)**4)/(1.+A16+A15)
      TPPT(10)=TT(10)
  129 IF(NTCODE(11))131,132,131
  132 TT(11)=(TTIN(11)+A14*TF(11)+A15*TS(9)+A2*TT(30)+A7*QABS(4)-
     1 A9*TT(11)**4)/(1.+A14+A15+A2)
      TPPT(11)=TT(11)
  131 IF(NTCODE(12))133,134,133
  134 TT(12)=(TTIN(12)+A16*TF(12)+A15*TS(10)+A2*TT(29)+A7*QABS(3)-
     1 A9*TT(12)**4)/(1.+A16+A15+A2)
      TPPT(12)=TT(12)
  133 IF(NTCODE(13))135,136,135
  136 TT(13)=(TTIN(13)+AA6 *TF(13)+A5  *TS(9)+A5  *TS(11)+A8    *QABS(4)
     1-A10          *TT(13)**4)/(1.+AA6+2.*A5)
      TPPT(13)=TT(13)
  135 IF(NTCODE(14))137,138,137
  138 TT(14)=(TTIN(14)+A5A *TF(14)+A5  *TS(10)+A5  *TS(12)+A8    *
     1QABS(3)-A10         *TT(14)**4)/(1.+A5A+2.*A5)
      TPPT(14)=TT(14)
  137 IF(NTCODE(15))139,140,139
  140 TT(15)=(TTIN(15)+AA6 *TF(15)+A5  *TS(11)+A5  *TS(13)+A8    *
     1QABS(4)-A10         *TT(15)**4)/(1.+AA6+2.*A5)
      TPPT(15)=TT(15)
  139 IF(NTCODE(16))141,142,141
  142 TT(16)=(TTIN(16)+A5A *TF(16)+A5  *TS(12)+A5  *TS(14)+A8    *
     1QABS(3)-A10         *TT(16)**4)/(1.+A5A+2.*A5)
      TPPT(16)=TT(16)
  141 IF(NTCODE(17)) 143,144,143
  144 TT(17)=(TTIN(17)+AA6 *TF(17)+A5  *TS(13)+A5  *TS(15)+A8    *
     1QABS(4)-A10         *TT(17)**4)/(1.+AA6+2.*A5)
      TPPT(17)=TT(17)
  143 IF(NTCODE(18)) 145,146,145
  146 TT(18)=(TTIN(18)+A5A *TF(18)+A5  *TS(14)+A5  *TS(16)+A8    *
     1QABS(3)-A10         *TT(18)**4)/(1.+A5A+2.*A5)
      TPPT(18)=TT(18)
  145 IF(NTCODF(19)) 147,148,147
  148 TT(19)=(TTIN(19)+A14 *TF(19)+A15 *TS(15)+A7      *QABS(4)-
     1A9         *TT(19)**4)/(1.+A14+A15)
      TPPT(19)=TT(19)
  147 IF(NTCODE(20)) 149,150,149
  150 TT(20)=(TTIN(20)+A16 *TF(20)+A15 *TS(16)+A7      *QABS(3)-
     1A9   *        TT(20)**4)/(1.+A16+A15)
      TPPT(20)=TT(20)
  149 IF(NTCODE(21).NE.0) GO TO 2008
      TT(21)=(TTIN(21)+A5A*TF(21)+A20*TS(17)+A2*TT(28)+A8*QABS(2)-
     1 A10*TT(21)**4)/(1.+A5A+A20+A2)
      TPPT(21) = TT(21)
 2008 IF (NTCODE(22).NE.0) GO TO 2009
      TT(22)=(TTIN(22)+A5A*TF(22)+A20*TS(18)+A2*TT(27)+A8*QABS(1)-
     1 A10*TT(22)**4)/(1.+A5A+A20+A2)
      TPPT(22) = TT(22)
 2009 IF (NTCODE(23).NE.0) GO TO 2010
      TT(23)=(TTIN(23)+A5A*TF(23)+A20*TS(19)+A2*TT(32)+A8*QABS(3)-
     1 A10*TT(23)**4)/(1.+A5A+A20+A2)
      TPPT(23) = TT(23)
 2010 IF (NTCODE(24).NE.0) GO TO 2011
      TT(24)=(TTIN(24)+A5A*TF(24)+A20*TS(20)+A2*TT(31)+A8*QABS(4)-
     1 A10*TT(24)**4)/(1.+A5A+A20+A2)
      TPPT(24) = TT(24)
 2011 IF (NTCODE(25).NE.0) GO TO 2012
      TT(25) = (TTIN(25)+B4*TF(25)+A2*TT(2))/(1.+B4+A2)
```

```
      TPPT(25) = TT(25)
 2012 IF (NTCODE(26).NE.0) GO TO 2013
      TT(26) = (TTIN(26)+B4*TF(26)+A2*TT(1))/(1.+B4+A2)
      TPPT(26) = TT(26)
 2013 IF (NTCODE(27).NE.0) GO TO 2014
      TT(27) = (TTIN(27)+B4*TF(27)+A2*TT(22)+A20*TS(18)+A8*QABS(1)-
     1 A10*TT(27)**4)/(1.+B4+A2+A20)
      TPPT(27) = TT(27)
 2014 IF (NTCODE(28).NE.0) GO TO 2015
      TT(28) = (TTIN(28)+A5A*TF(28)+A2*TT(21)+A20*TS(17)+A8*QABS(2)-
     1 A10*TT(28)**4)/(1.+A5A+A2+A20)
      TPPT(28) = TT(28)
 2015 IF (NTCODE(29).NE.0) GO TO 2016
      TT(29) = (TTIN(29)+B4*TF(29)+A2*TT(12))/(1.+B4+A2)
      TPPT(29) = TT(29)
 2016 IF (NTCODE(30).NE.0) GO TO 2017
      TT(30) = (TTIN(30)+B4*TF(30)+A2*TT(11))/(1.+B4+A2)
      TPPT(30) = TT(30)
 2017 IF (NTCODE(31).NE.0) GO TO 2018
      TT(31) = (TTIN(31)+B4*TF(31)+A2*TT(24)+A20*TS(20)+A8*QABS(4)-
     1 A10*TT(31)**4)/(1.+B4+A2+A20)
      TPPT(31) = TT(31)
 2018 IF(NTCODE(32).NE.0) GO TO 2019
      TT(32)=(TTIN(32)+B4*TF(32)+A2*TT(23)+A20*TS(19)+A8*QABS(3)-
     1 A10*TT(32)**4)/(1.+B4+A2+A20)
      TPPT(32) = TT(32)
C
C          STRUCTURAL LUMP TEMPERATURE EQUATIONS
C
 2019 DO 155 I=3,7,2
      IF(NSCODE(I))  155,156,155
  156 TS(I)=(TSIN(I)+A11   *TT(I)+A11   *TT(I+2)+A12 *QABS(1)-A13*
     1TS(I)**4)/(1.+2.*A11)
      TPPS(I)=TS(I)
  155 CONTINUE
      DO 255 I=11,15,2
      IF(NSCODE(I)) 255,256,255
  256 TS(I)=(TSIN(I)+A11   *TT(I+2)+A11   *TT(I+4)+A12 *QABS(4)-
     1   A13    *TS(I)**4)/(1.+2.*A11)
      TPPS(I)=TS(I)
  255 CONTINUE
      DO 157 I=4,8,2
      IF(NSCODE(I)) 157,158,157
  158 TS(I)=(TSIN(I)+A11   *TT(I)+A11   *TT(I+2)+A12 *QABS(2)-A13*
     1TS(I)**4)/(1.+2.*A11)
      TPPS(I)=TS(I)
  157 CONTINUE
      DO 257 I=12,16,2
      IF(NSCODE(I)) 257,258,257
  258 TS(I)=(TSIN(I)+A11   *TT(I+2)+A11   *TT(I+4)+A12 *QABS(3)-
     1A13          *TS(I)**4)/(1.+2.*A11)
      TPPS(I)=TS(I)
  257 CONTINUE
      DO 356 I=1,2
      IF (NSCODE(I)) 356,355,356
  355 TS(I)=(TSIN(I)+A17*TT(I)+A17*TT(I+2)+A18*QABS(I)-A19*TS(I)**4)
     1/(1.+2.*A17)
      TPPS(I)=TS(I)
  356 CONTINUE
      IF (NSCODE(9).NE.0) GO TO 357
```

```
      TS(9)=(TSIN(9)+A17*TT(11)+A17*TT(13)+A18*QABS(4)-A19*TS(9)**4)
     1/(1.+2.*A17)
      TPPS(9)=TS(9)
  357 IF (NSCODE(10).NE.0) GO TO 358
      TS(10)=(TSIN(10)+A17*TT(12)+A17*TT(14)+A18*QABS(3)-A19*TS(10)**4)
     1/(1.+2.*A17)
      TPPS(10)=TS(10)
  358 CONTINUE
      IF (NSCODE(17).NE.0) GO TO 2022
      TS(17) = (TSIN(17)+A23*TT(21)+A23*TT(28)+A21*QABS(2)-
     1 A22*TS(17)**4)/(1.+2.*A23)
      TPPS(17) = TS(17)
 2022 IF (NSCODE(18).NE.0) GO TO 2023
      TS(18) = (TSIN(18)+A23*TT(22)+A23*TT(27)+A21*QABS(1)-
     1 A22*TS(18)**4)/(1.+2.*A23)
      Q(10)=0.49
      TPPS(18) = TS(18)
 2023 IF (NSCODE(19).NE.0) GO TO 2024
      TS(19) = (TSIN(19)+A23*TT(23)+A23*TT(32)+A21*QABS(3)-
     1 A22*TS(19)**4)/(1.+2.*A23)
      TPPS(19) = TS(19)
 2024 IF (NSCODE(20).NE.0) GO TO 2025
      TS(20) = (TSIN(20)+A23*TT(24)+A23*TT(31)+A21*QABS(4)-
     1 A22*TS(20)**4)/(1.+2.*A23)
      TPPS(20) = TS(20)
 2025 CONTINUE
      DO 820 I=1,32
      TPPF(I)=TPF(I)+1.3*(TPPF(I)-TPF(I))
  820 TPPT(I)=TPT(I)+1.3*(TPPT(I)-TPT(I))
      DO 95 I=1,20
   95 TPPS(I)=TPS(I)+1.3*(TPPS(I)-TPS(I))
      DO 14 I=1,32
      IF(NFCODE(I).NE.0) GO TO 1300
      IF(ABS(TPPF(I)-TPF(I))-.1) 20,20,21
   20 NFCODE(I)=ITER
      GO TO 22
   21 NFCODE(I)=0
      MCODE=0
 1300 IF(NTCODE(I).NE.0) GO TO 14
   22 IF(ABS(TPPT(I)-TPT(I))-.1) 23,23,24
   23 NTCODE(I)=ITER
      GO TO 14
   24 NTCODE(I)=0
      MCODE=0
   14    CONTINUE
      DO 96 I=1,20
 1301 IF(NSCODE(I).NE.0) GO TO 96
      IF(ABS(TPPS(I)-TPS(I))-.1) 26,26,27
   26 NSCODE(I)=ITER
      GO TO 96
   27 NSCODE(I)=0
      MCODE=0
   96 CONTINUE
      IF (MCODE.EQ.0) GO TO 305
      DO 306 I=1,20
      IF (NFCODE(I).NE.ITER) GO TO 308
      IF (NTCODE(I).NE.ITER) GO TO 308
      IF (NSCODE(I).NE.ITER) GO TO 308
  306 CONTINUE
      DO 307 I=1,32
```

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      IF (NFCODE(I).NE.ITER) GO TO 308
      IF (NFCODE(I).NE.ITFR) GO TO 308
  307 CONTINUE
      GO TO 28
  308 DO 309 I=1,20
      NFCODE(I)=0
      NTCODE(I)=0
      NSCODE(I)=0
  309 CONTINUE
      DO 310 I=21,32
      NFCODE(I)=0
      NTCODE(I)=0
  310 CONTINUE
  305 CONTINUE
      WRITE(6,503)
      GO TO 399
   28 IF (KODSEC.EQ.0) GO TO 1635
      HIN=-83.39+.232*TLINS+.000486*TLINS**2
      HOUT= -83.39+.232*TF(32)+.000486*TF(32)**2
      QRJTSC = WDTSEC * (HIN - HOUT )
 1635 H22 = -83.39+.232*TF(22)+.000486*TF(22)**2
      H24 = -83.39+.232*TF(24)+.000486*TF(24)**2
      HINLT=-83.39+.232*TLINP+.000486*TLINP**2
      HPRI = (WDOTT1*H22 + WDOTT2*H24)/WDOTT
      QRJT = WDOTT * (HINLT - HPRI)
      TOUT = 247.43+1.879*HPRI-.00155*HPRI*HPRI
      HMIX = (WDOTT*HPRI + (WDOTS-WDOTT)*HINLT)/WDOTS
      TOUTP=TOUT
      TMIX = 247.43+1.879*HMIX-.00155*HMIX*HMIX
      CALL VPOL (TOUT,BMU(36),NP5)
      RATE1=WDOTT1
      RATE2=WDOTT2
  399 CONTINUE
      DO 66 I=1,32
      TFIN(I)=TPPF(I)
   66 TTIN(I)=TPPT(I)
      DO  98 I=1,20
   98 TSIN(I)=TPPS(I)
      TOUTSC = TFIN(32)
      SLTEMP = TMIX
      DELTAT=ABS(SLTEMP-SETPT)-DBAND
      ARG2=SLTEMP-SETPT
      IF(DELTAT)452,452,453
  453 DELTAT=SIGN(DELTAT,ARG2)
      DELTAP=RTFCTR*DELTAT
      IF(ABS(DELTAP)-RLIMIT)454,454,455
  455 DELTAP=SIGN(RLIMIT,ARG2)
  454 FLOWPC=FLOWPC+DELTAP*3600.*.02
      IF(FLOWPC-FLOWMX)456,452,457
  457 FLOWPC=FLOWMX
      GO TO 452
  456 IF(FLOWPC-FLOWMN)458,452,452
  458 FLOWPC=FLOWMN
  452 WDOTT=WDOTS*FLOWPC
      IF(KODE) 732,,731
      DTEMP=TF(22)-TF(24)
      DX=          (POSIN-XX1+VLVGAN*DTEMP)
      XX1=XX1+DX
      IF(XX1-POSMIN) 81,82,82
   81 XX1=POSMIN
```

```
      GO TO 84
   82 IF(XX1-POSMAX) 84,84,83
   83 XX1=POSMAX
   84 XX2=FULOPN-XX1
      BB=DPTS2/WDOTT2+DPTS1/WDOTT1+PPARA*(WDOTT/(GFACT*XX2**2))
      CC=DPTS1/WDOTT1*WDOTT+(WDOTT/XX2)**2/GFACT
      AA=(1./XX2**2-1./XX1**2)/GFACT
      IF(ABS(XX1-XX2)-VTOL) 85,85,86
   85 WDOTT2=CC/BB
      GO TO 87
   86 WDOTT2=( BB-SQRT(BB**2-4.*AA*CC))/2./AA
   87 WDOTT1=WDOTT-WDOTT2
      FLOW=WDOTT1
      GO TO 2510
  731 IF (KODE.EQ.2) GO TO 733
      WDOTT1=WDOTT
      WDOTT2=0.
      FLOW=WDOTT1
      GO TO 2510
  733 WDOTT1=0.
      WDOTT2=0.
      FLOW=0.
      GO TO 2510
  732 WDOTT1=0.
      WDOTT2=WDOTT
      FLOW=WDOTT2
 2510 IF(DPTS1.LT.DPTS2) DPTS1=DPTS2
      DPPRNT=DPTS1+(.005912*BMU(33)+.00079542*BMU(36))*WDOTT
      TOTREJ=QRJT+QRJTSC
      IF(MSSION.EQ.4.OR.(MSSION.LT.4.AND.SAVE+PERIOD.LT.P3)) GO TO 940
  914 COUNT=COUNT+1.
      SDP=SDP+DPPRNT
      STOUT=STOUT+TOUT
      SQREJ=SQREJ+TOTREJ
      IF(TOTREJ.GT.TMAX) TMAX=TOTREJ
      IF(TOTREJ.LT.TMIN) TMIN=TOTREJ
      IF(TOUT.GT.TMX) TMX=TOUT
      IF(TOUT.LT.TMN) TMN=TOUT
      TEMP=1.-FLOWPC
      IF(TEMP.GT.PCMAX) PCMAX=TEMP
      IF(TEMP.LT.PCMIN) PCMIN=TEMP
      IF(DPPRNT.GT.DPMAX) DPMAX=DPPRNT
      IF(DPPRNT.LT.DPMIN) DPMIN=DPPRNT
      IF(KODSEC.EQ.0) GO TO 940
      SDP2=SDP2+DPTOT
      STOUT2=STOUT2+TOUTSC
      IF(TOUTSC.GT.TMX2) TMX2=TOUTSC
      IF(TOUTSC.LT.TMN2) TMN2=TOUTSC
      IF(DPTOT.GT.DPMX) DPMX=DPTOT
      IF(DPTOT.LT.DPMN) DPMN=DPTOT
  940 ITEST=0
      IF(SAVE1 .GT. SAVE+.001) GO TO 918
      SAVE1=SAVE1+PRINT
  788 TOUT=TOUT-459.69
      TOUTSC = TOUTSC - 459.69
      TF(22)=TF(22)-459.69
      TF(24)=TF(24)-459.69
      ITEST=1
      IF(MMM .EQ. 0) GO TO 5051
      PRHTR=ON
```

```
      GO TO 5052
 5051 PRHTR=OFF
 5052 IF(M.EQ.0) GO TO 5053
      SCHTR1=ON
      IF(MM.EQ.0) GO TO 5054
      SCHTR2=ON
      GO TO 5055
 5053 SCHTR1=OFF
 5054 SCHTR2=OFF
 5055 WRITE(6,1670) SAVE,QRJT,DPPRNT,WDOTS,TOUT,PRHTR,QRJTSC,DPTOT,
     1              WDTSEC,TOUTSC,SCHTR1,SCHTR2,TOTREJ
 1670 FORMAT(7X1PG9.3,G11.5,G10.5,G11.5,G10.4,A4,G14.5,G10.5,G11.5,
     1       G10.4,A4,2XA4,G14.5)
      WRITE(6,2600) RATE1,TF(22),RATE2,TF(24)
 2600 FORMAT(27X'SIDE 1,2  '1PG11.5,G10.4/27X'SIDE 3,4  'G11.5,G10.4/)
      IF(IQUIT .EQ. 0 .AND. MSSION .EQ. 4) GO TO 787
      IF(MSSION .EQ. 4) RETURN
      IF(IQUIT .EQ. 1) GO TO 789
      GO TO 920
  918 IF(MSSION.NE.4) GO TO 920
  787 IF(ABS(TOTREJ-QREJ1) .LT. .5) GO TO 790
      QREJ1=TOTREJ
      GO TO 920
  790 WRITE(6,784)
  784 FORMAT(15X'STEADY STATE ATTAINED.'//)
      GO TO 791
  920 IF(.NOT. SAVE .LT. P3 - .01) GO TO 9001
      SAVE = SAVE + .02
      TAU=TAU+0.02
      GO TO 425
 9001 IF(MSSION .NE. 4) GO TO 791
      WRITE(6,1097)
 1097 FORMAT(15X'THREE HUNDRED ITERATIONS HAVE FAILED TO PRODUCE A STEAD
     1Y STATE SOLUTION.'//15X'LAST VALUES OBTAINED'/)
  791 IQUIT=1
      IF(MSSION .NE. 4) GO TO 786
      IF(ITEST .EQ. 1) GO TO 5055
      GO TO 788
  786 IF(ITEST .EQ. 0) GO TO 788
  789 IF(KODSEC.EQ.0) GO TO 400
      TAVG2=STOUT2/COUNT
      TMX2=TMX2-459.69
      TMN2=TMN2-459.69
      TAVG2=TAVG2-459.69
      DPAVG2=SDP2/COUNT
  400 HAVG=SQREJ/COUNT
      DPAVG=SDP/COUNT
      TAVG=STOUT/COUNT
      TMX=TMX-459.69
      TMN=TMN-459.69
      TAVG=TAVG-459.69
 5061 PCMAX=100.*PCMAX
      PCMIN=100.*PCMIN
      WRITE(6,6001)
 6001 FORMAT('1'52X'MAXIMUM'5X'MINIMUM'5X'AVERAGE'/)
      WRITE(6,6002) TMAX,TMIN,HAVG
 6002 FORMAT('0'9X'TOTAL HEAT REJECTION RATE, BTU/HR'8X1P3G12.5/)
      WRITE(6,6003) DPMAX,DPMIN,DPAVG,DPMX,DPMN,DPAVG2
 6003 FORMAT('0'9X'PRESSURE DROP, PSI'/15X'PRIMARY SYSTEM'22X1P3G12.5/
     1       15X'REDUNDANT SYSTEM'20X3G12.5/)
```

```
      WRITE(6,6004) TMX,TMN,TAVG,TMX2,TMN2,TAVG2
 6004 FORMAT('0'9X'OUTLET TEMPERATURE, DEG. F'/15X'PRIMARY SYSTEM'22X
     1        P3G12.4/15X'REDUNDANT SYSTEM'20X3G12.4/)
      WRITE(6,6005) PCMAX,PCMIN
 6005 FORMAT('0'9X'PRIMARY SYSTEM BYPASS, PERCENT'11X1P2G12.5/)
      WRITE(6,6006) SUM1,SUM2
 6006 FORMAT('0'9X'TOTAL INLINE HEATER POWER DISSIPATION, BTU'/15X
     1        'PRIMARY SYSTEM'22X1PG12.5/15X'REDUNDANT SYSTEM'20XG12.5/)
      RETURN
      END
      SUBROUTINE VPOL(TVIS,BMU,NP3)
C     THIS SUBROUTINE FIND A FLUID VISCOSITY FOR A GIVEN TEMPERATURE
C          FROM A CURVE OF TEMPERATURE VS. VISCOSITY
      DIMENSION T(33),TMU(33)
      COMMON T, TMU
      J=1
      IF(TVIS-T(1)) 6,4,7
    7 IF(TVIS-T(NP3)) 1,9,8
    1 DO 2 I=2,NP3
      J=I
      IF(TVIS-T(I))3,4,2
    2 CONTINUE
    3 TEMP=TVIS-T(J-1)
      TINT=T(J)-T(J-1)
      TEMPMU=TMU(J)-TMU(J-1)
      BMU=TMU(J-1)+(TEMP/TINT)*TEMPMU
      RETURN
    4 BMU=TMU(J)
      RETURN
    6 WRITE(6,200)
  200 FORMAT(////99H    THE TEMPERATURE USED IN FINDING THE VISCOSITY IS
     1 LESS THAN THE LOWEST TEMPERATURE ON THE CURVE./////)
      CALL EXIT
    8 WRITE(6,201)
  201 FORMAT(//// 97H    THE TEMPERATURE USED IN FINDING THE VISCOSITY I
     1S GREATER THAN THE HIGHEST VALUE ON THE CURVE./////)
      CALL EXIT
    9 BMU=TMU(NP3)
      RETURN
      END
 01420
```

APPENDIX B

PROGRAM FLOW CHART

ULTRA-FAST MISSION ANALYSIS ROUTINE
FOR APOLLO BLOCK 2 ENVIRONMENTAL
CONTROL SYSTEM RADIATORS

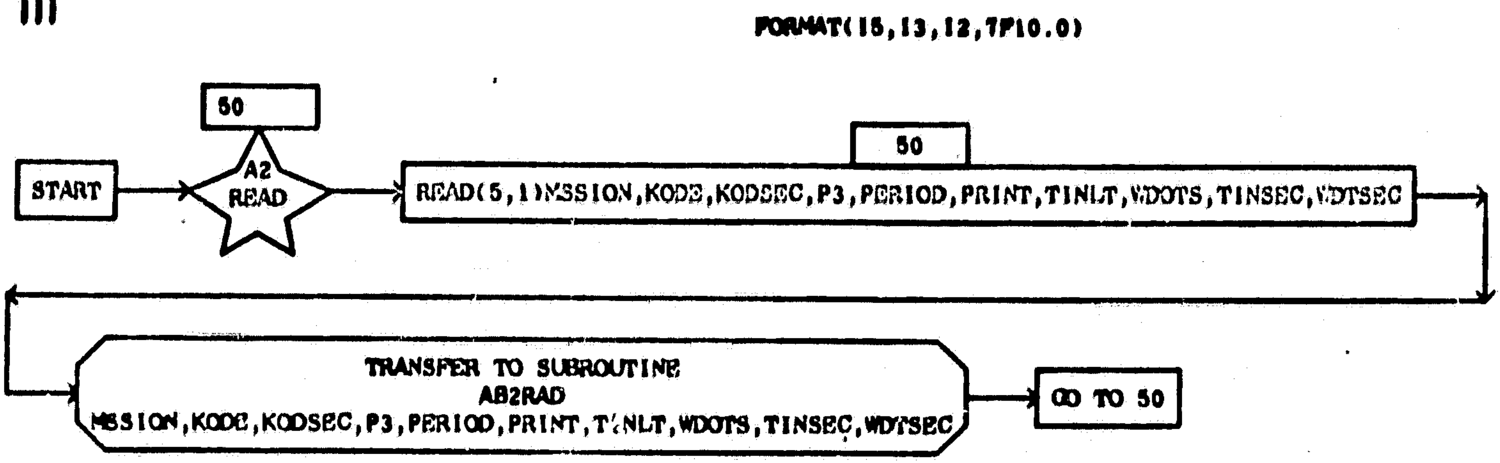
DEVELOPED BY

MISSILES AND SPACE DIVISION - TEXAS
LTV AEROSPACE CORPORATION
P. O. BOX 6267 - DALLAS, TEXAS 75222

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
UNDER CONTRACT NAS9-6807

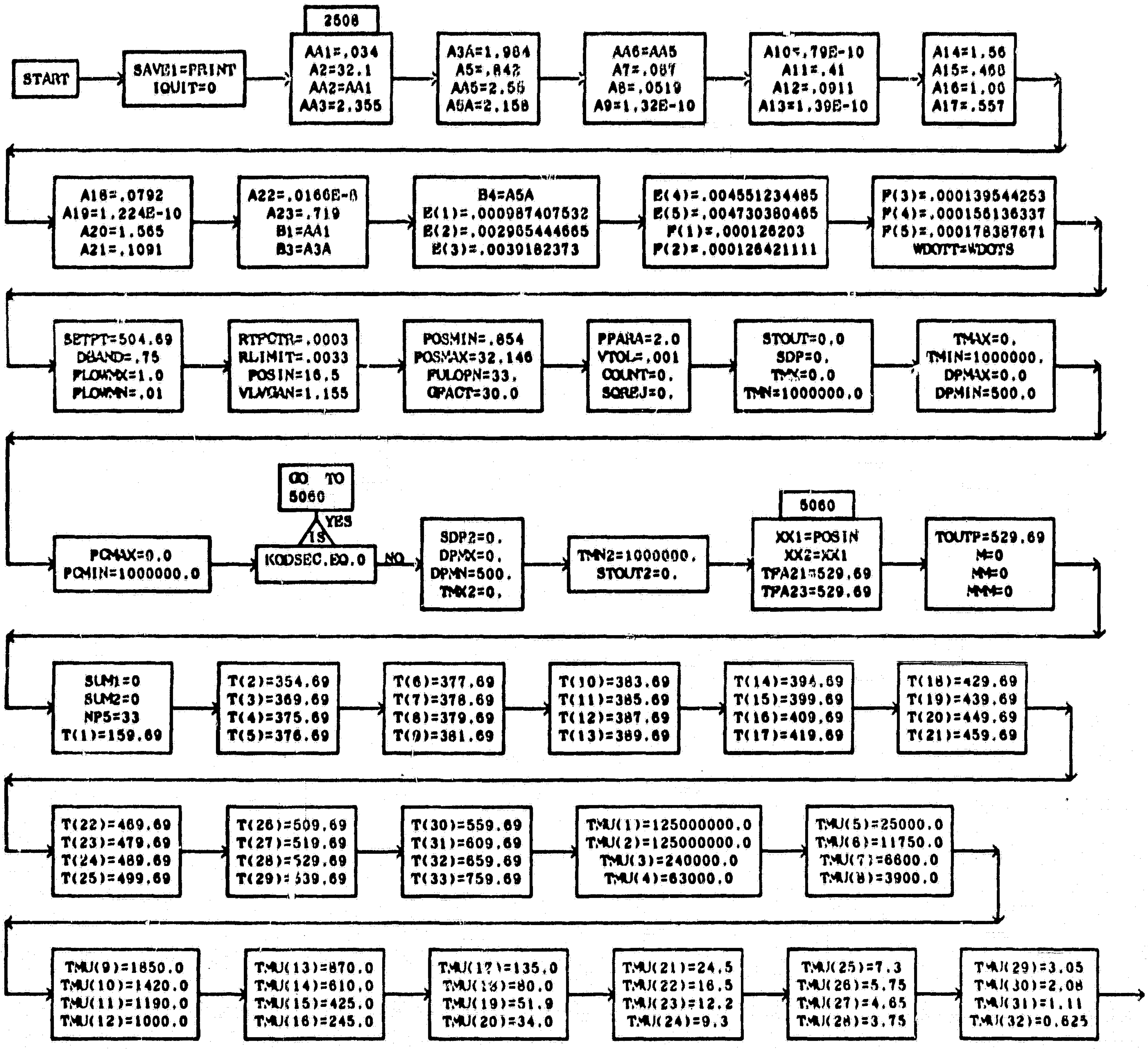
PROG READS THE DATA AND CALLS SUBROUTINE AB2RAD WHICH DOES
THE ACTUAL CALCULATIONS

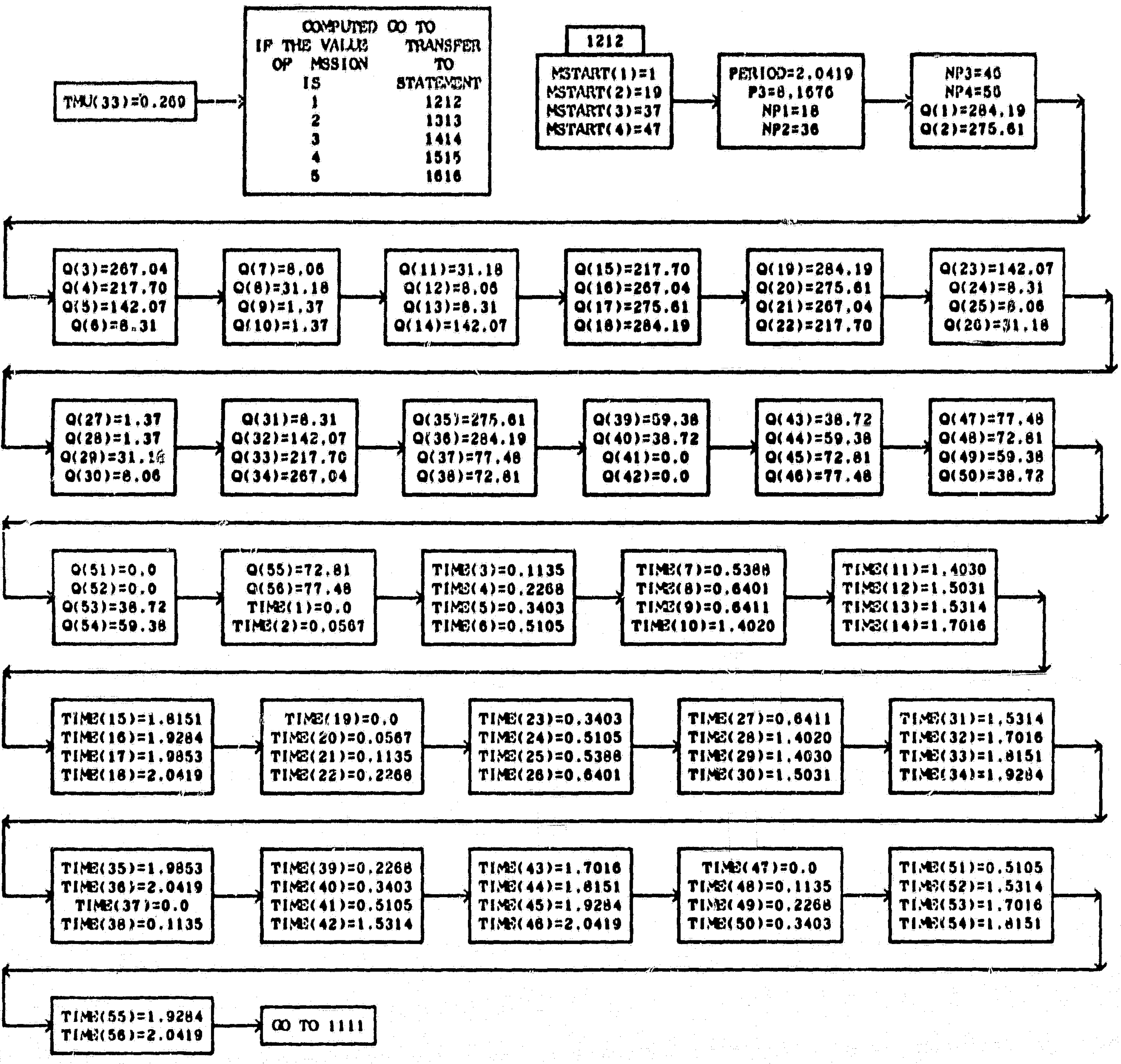

FORMAT(I5,I3,I2,7F10.0)
50
START
A2
READ
50
READ(5,1)MSSION,KODE,KODSEC,P3,PERIOD,PRINT,TINLT,WDOTS,TINSEC,WDTSEC
TRANSFER TO SUBROUTINE
AB2RAD
MSSION,KODE,KODSEC,P3,PERIOD,PRINT,TINLT,WDOTS,TINSEC,WDTSEC
GO TO 50

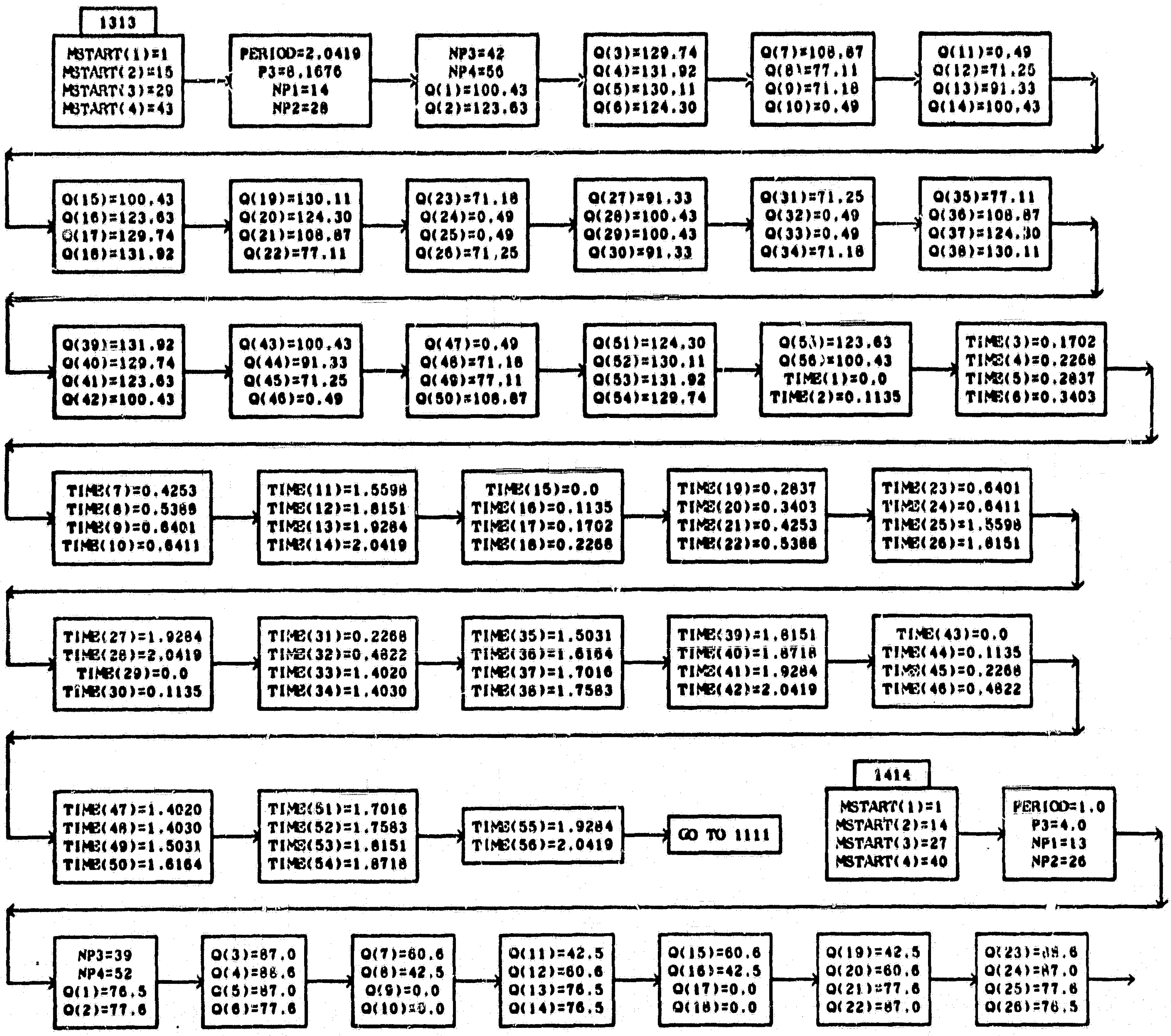
DIMENSIONED VARIABLES

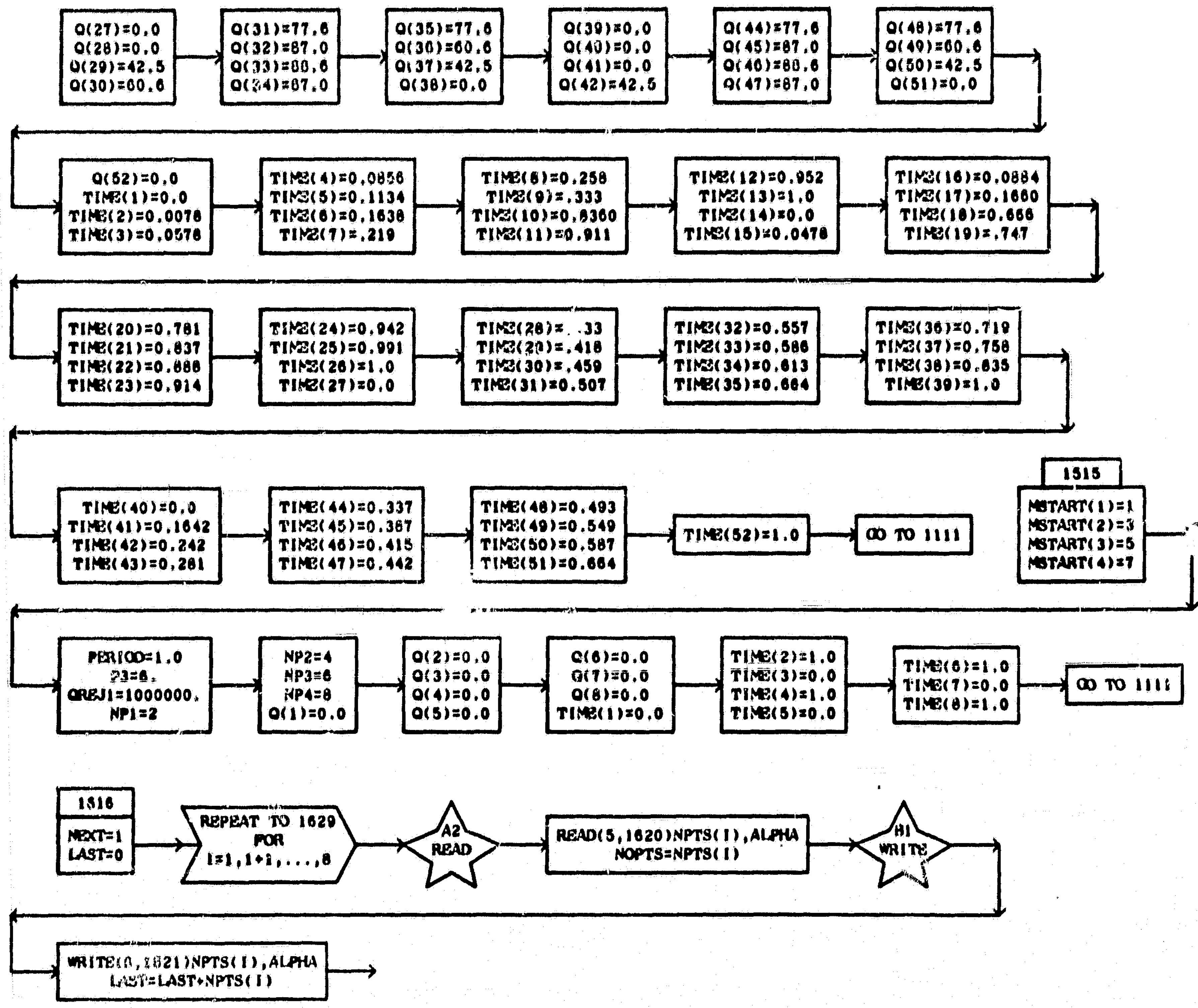
SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES
AK	12	BMU	37	TP	32	TPIN	32	TPPF	32
TPF	32	NPCODE	32	TT	32	TTIN	32	TPPT	32
TPT	32	NTCODE	32	TS	20	TSIN	20	TPPS	20
TPS	20	NSCODE	20	QABS	4	Q	4000	TIME	6000
T	33	TMU	33	WDOT	10	DPT	10	E	5
ALPHA	12	NPTS	8	WDTTOT	1000	TIN	1000	MSTART	6
WDOTSC	1000	TINLSC	100	H	10	F	5		

SUBROUTINE AB2RAD (MSSION,KODE,KODSEC,P3,PERIOD,PRINT,TINLT,

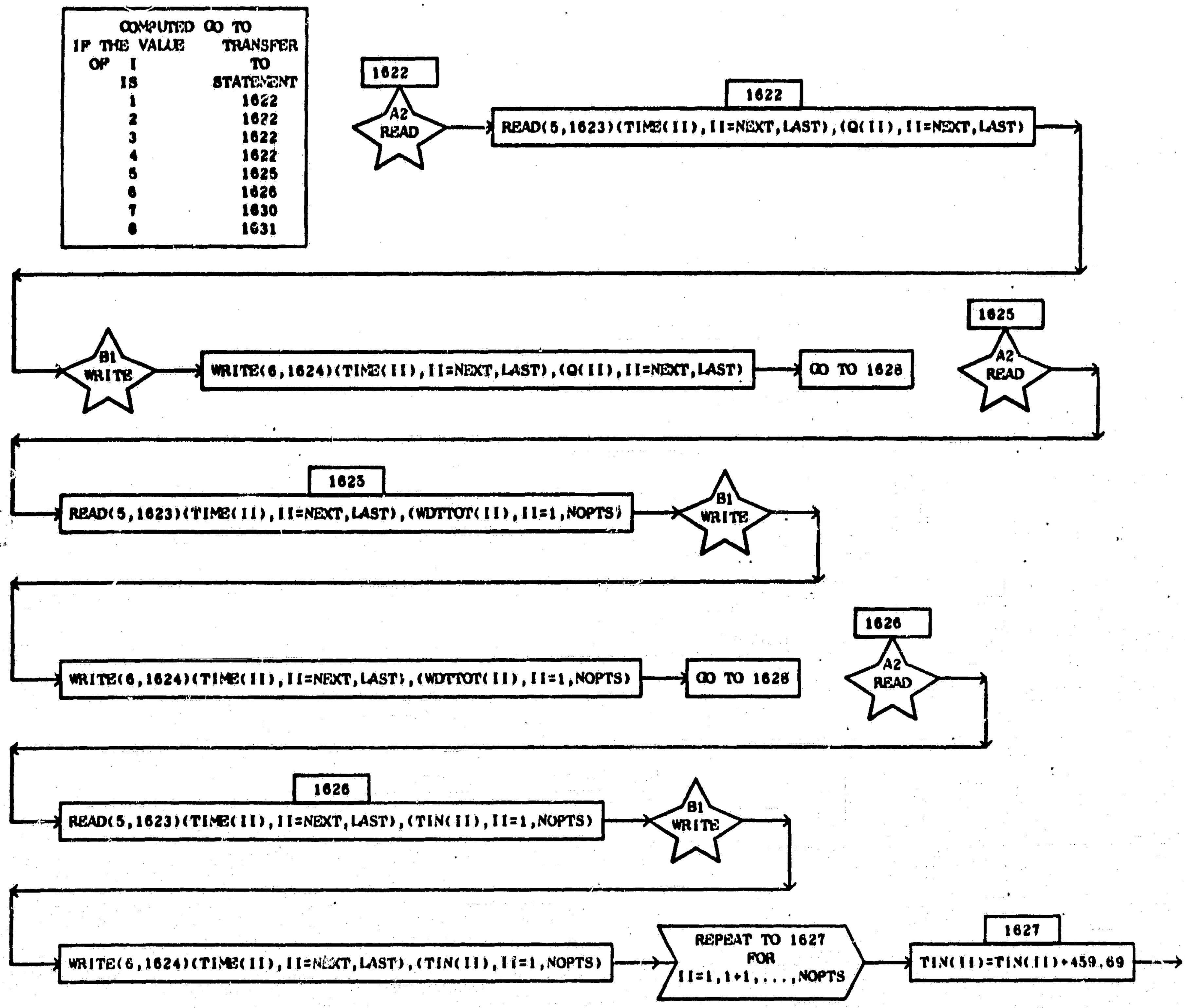


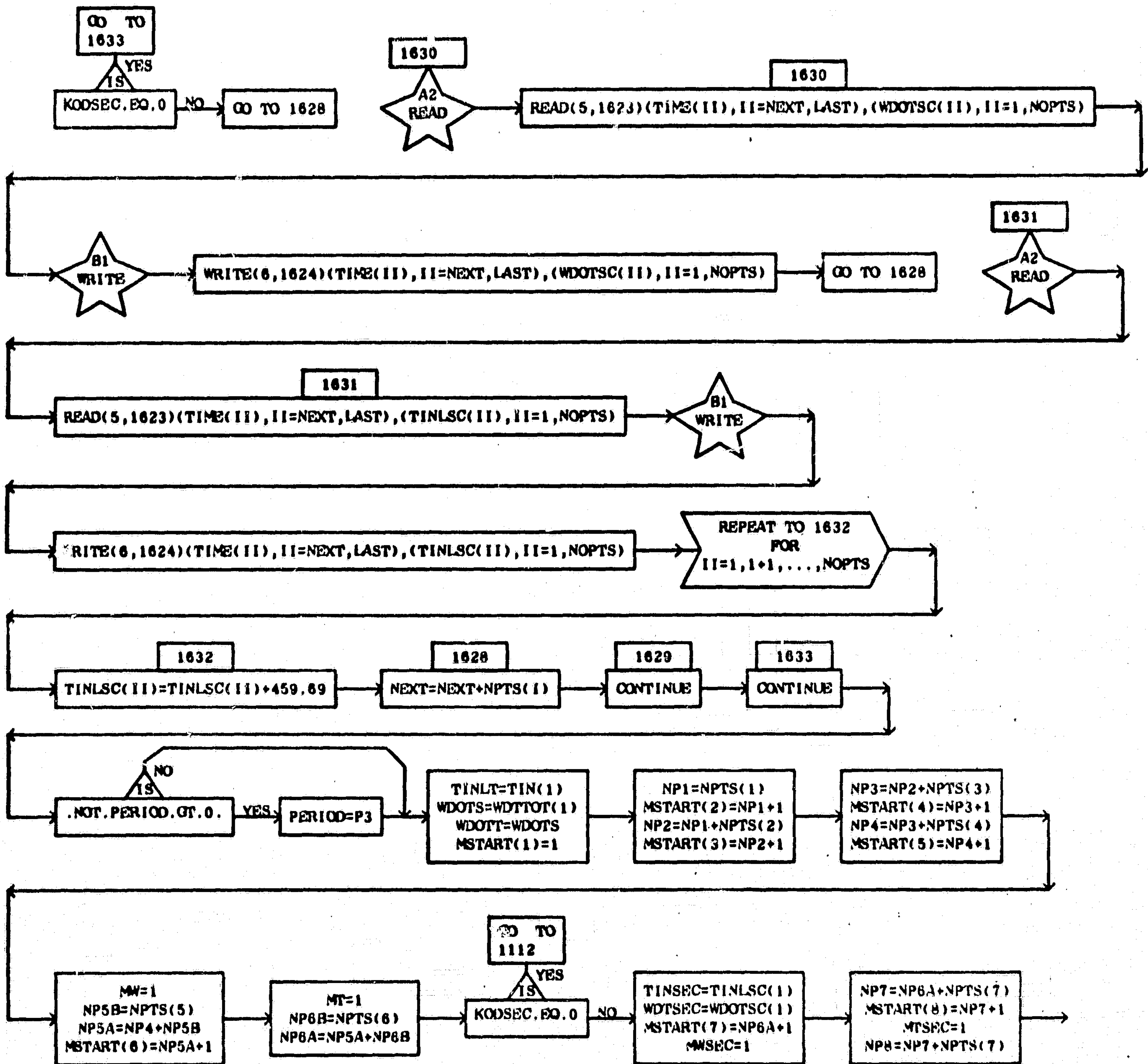

TMU(33)=0.260
COMPUTED GO TO
IF THE VALUE OF MSSION IS / TRANSFER TO STATEMENT
1 1212
2 1313
3 1414
4 1515
5 1616
1212
MSTART(1)=1
MSTART(2)=19
MSTART(3)=37
MSTART(4)=47
PERIOD=2.0419
P3=8.1676
NP1=18
NP2=36
NP3=40
NP4=50
Q(1)=284.19
Q(2)=275.61
Q(3)=267.04
Q(4)=217.70
Q(5)=142.07
Q(6)=8.31
Q(7)=8.06
Q(8)=31.18
Q(9)=1.37
Q(10)=1.37
Q(11)=31.18
Q(12)=8.06
Q(13)=8.31
Q(14)=142.07
Q(15)=217.70
Q(16)=267.04
Q(17)=275.61
Q(18)=284.19
Q(19)=284.19
Q(20)=275.61
Q(21)=267.04
Q(22)=217.70
Q(23)=142.07
Q(24)=8.31
Q(25)=8.06
Q(26)=31.18
Q(27)=1.37
Q(28)=1.37
Q(29)=31.18
Q(30)=8.06
Q(31)=8.31
Q(32)=142.07
Q(33)=217.70
Q(34)=267.04
Q(35)=275.61
Q(36)=284.19
Q(37)=77.48
Q(38)=72.81
Q(39)=59.38
Q(40)=38.72
Q(41)=0.0
Q(42)=0.0
Q(43)=38.72
Q(44)=59.38
Q(45)=72.81
Q(46)=77.48
Q(47)=77.48
Q(48)=72.81
Q(49)=59.38
Q(50)=38.72
Q(51)=0.0
Q(52)=0.0
Q(53)=38.72
Q(54)=59.38
Q(55)=72.81
Q(56)=77.48
TIME(1)=0.0
TIME(2)=0.0567
TIME(3)=0.1135
TIME(4)=0.2268
TIME(5)=0.3403
TIME(6)=0.5105
TIME(7)=0.5388
TIME(8)=0.6401
TIME(9)=0.6411
TIME(10)=1.4020
TIME(11)=1.4030
TIME(12)=1.5031
TIME(13)=1.5314
TIME(14)=1.7016
TIME(15)=1.8151
TIME(16)=1.9284
TIME(17)=1.9853
TIME(18)=2.0419
TIME(19)=0.0
TIME(20)=0.0567
TIME(21)=0.1135
TIME(22)=0.2268
TIME(23)=0.3403
TIME(24)=0.5105
TIME(25)=0.5388
TIME(26)=0.6401
TIME(27)=0.6411
TIME(28)=1.4020
TIME(29)=1.4030
TIME(30)=1.5031
TIME(31)=1.5314
TIME(32)=1.7016
TIME(33)=1.8151
TIME(34)=1.9284
TIME(35)=1.9853
TIME(36)=2.0419
TIME(37)=0.0
TIME(38)=0.1135
TIME(39)=0.2268
TIME(40)=0.3403
TIME(41)=0.5105
TIME(42)=1.5314
TIME(43)=1.7016
TIME(44)=1.8151
TIME(45)=1.9284
TIME(46)=2.0419
TIME(47)=0.0
TIME(48)=0.1135
TIME(49)=0.2268
TIME(50)=0.3403
TIME(51)=0.5105
TIME(52)=1.5314
TIME(53)=1.7016
TIME(54)=1.8151
TIME(55)=1.9284
TIME(56)=2.0419
GO TO 1111

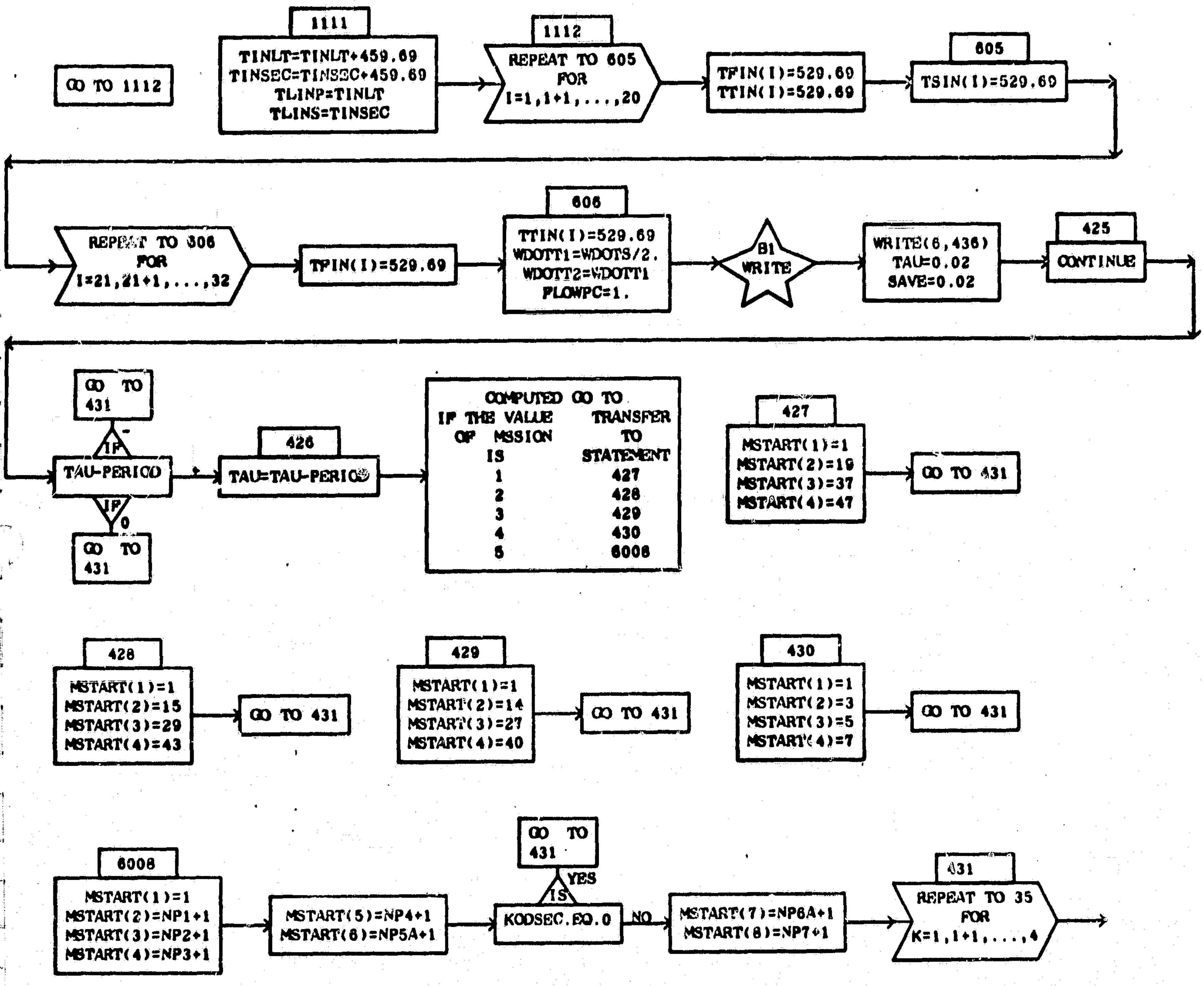

1313
MSTART(1)=1
MSTART(2)=15
MSTART(3)=29
MSTART(4)=43
PERIOD=2.0419
P3=8.1676
NP1=14
NP2=28
NP3=42
NP4=56
Q(1)=100.43
Q(2)=123.63
Q(3)=129.74
Q(4)=131.92
Q(5)=130.11
Q(6)=124.30
Q(7)=108.87
Q(8)=77.11
Q(9)=71.18
Q(10)=0.49
Q(11)=0.49
Q(12)=71.25
Q(13)=91.33
Q(14)=100.43
Q(15)=100.43
Q(16)=123.63
Q(17)=129.74
Q(18)=131.92
Q(19)=130.11
Q(20)=124.30
Q(21)=108.87
Q(22)=77.11
Q(23)=71.18
Q(24)=0.49
Q(25)=0.49
Q(26)=71.25
Q(27)=91.33
Q(28)=100.43
Q(29)=100.43
Q(30)=91.33
Q(31)=71.25
Q(32)=0.49
Q(33)=0.49
Q(34)=71.18
Q(35)=77.11
Q(36)=108.87
Q(37)=124.30
Q(38)=130.11
Q(39)=131.92
Q(40)=129.74
Q(41)=123.63
Q(42)=100.43
Q(43)=100.43
Q(44)=91.33
Q(45)=71.25
Q(46)=0.49
Q(47)=0.49
Q(48)=71.18
Q(49)=77.11
Q(50)=108.87
Q(51)=124.30
Q(52)=130.11
Q(53)=131.92
Q(54)=129.74
Q(55)=123.63
Q(56)=100.43
TIME(1)=0.0
TIME(2)=0.1135
TIME(3)=0.1702
TIME(4)=0.2268
TIME(5)=0.2837
TIME(6)=0.3403
TIME(7)=0.4253
TIME(8)=0.5388
TIME(9)=0.6401
TIME(10)=0.6411
TIME(11)=1.5598
TIME(12)=1.8151
TIME(13)=1.9284
TIME(14)=2.0419
TIME(15)=0.0
TIME(16)=0.1135
TIME(17)=0.1702
TIME(18)=0.2268
TIME(19)=0.2837
TIME(20)=0.3403
TIME(21)=0.4253
TIME(22)=0.5388
TIME(23)=0.6401
TIME(24)=0.6411
TIME(25)=1.5598
TIME(26)=1.8151
TIME(27)=1.9284
TIME(28)=2.0419
TIME(29)=0.0
TIME(30)=0.1135
TIME(31)=0.2268
TIME(32)=0.4822
TIME(33)=1.4020
TIME(34)=1.4030
TIME(35)=1.5031
TIME(36)=1.6164
TIME(37)=1.7016
TIME(38)=1.7583
TIME(39)=1.8151
TIME(40)=1.8718
TIME(41)=1.9284
TIME(42)=2.0419
TIME(43)=0.0
TIME(44)=0.1135
TIME(45)=0.2268
TIME(46)=0.4822
TIME(47)=1.4020
TIME(48)=1.4030
TIME(49)=1.5031
TIME(50)=1.6164
TIME(51)=1.7016
TIME(52)=1.7583
TIME(53)=1.8151
TIME(54)=1.8718
TIME(55)=1.9284
TIME(56)=2.0419
GO TO 1111
1414
MSTART(1)=1
MSTART(2)=14
MSTART(3)=27
MSTART(4)=40
PERIOD=1.0
P3=4.0
NP1=13
NP2=26
NP3=39
NP4=52
Q(1)=76.5
Q(2)=77.6
Q(3)=87.0
Q(4)=88.6
Q(5)=87.0
Q(6)=77.6
Q(7)=60.6
Q(8)=42.5
Q(9)=0.0
Q(10)=0.0
Q(11)=42.5
Q(12)=60.6
Q(13)=76.5
Q(14)=76.5
Q(15)=60.6
Q(16)=42.5
Q(17)=0.0
Q(18)=0.0
Q(19)=42.5
Q(20)=60.6
Q(21)=77.6
Q(22)=87.0
Q(23)=88.6
Q(24)=87.0
Q(25)=77.6
Q(26)=76.5

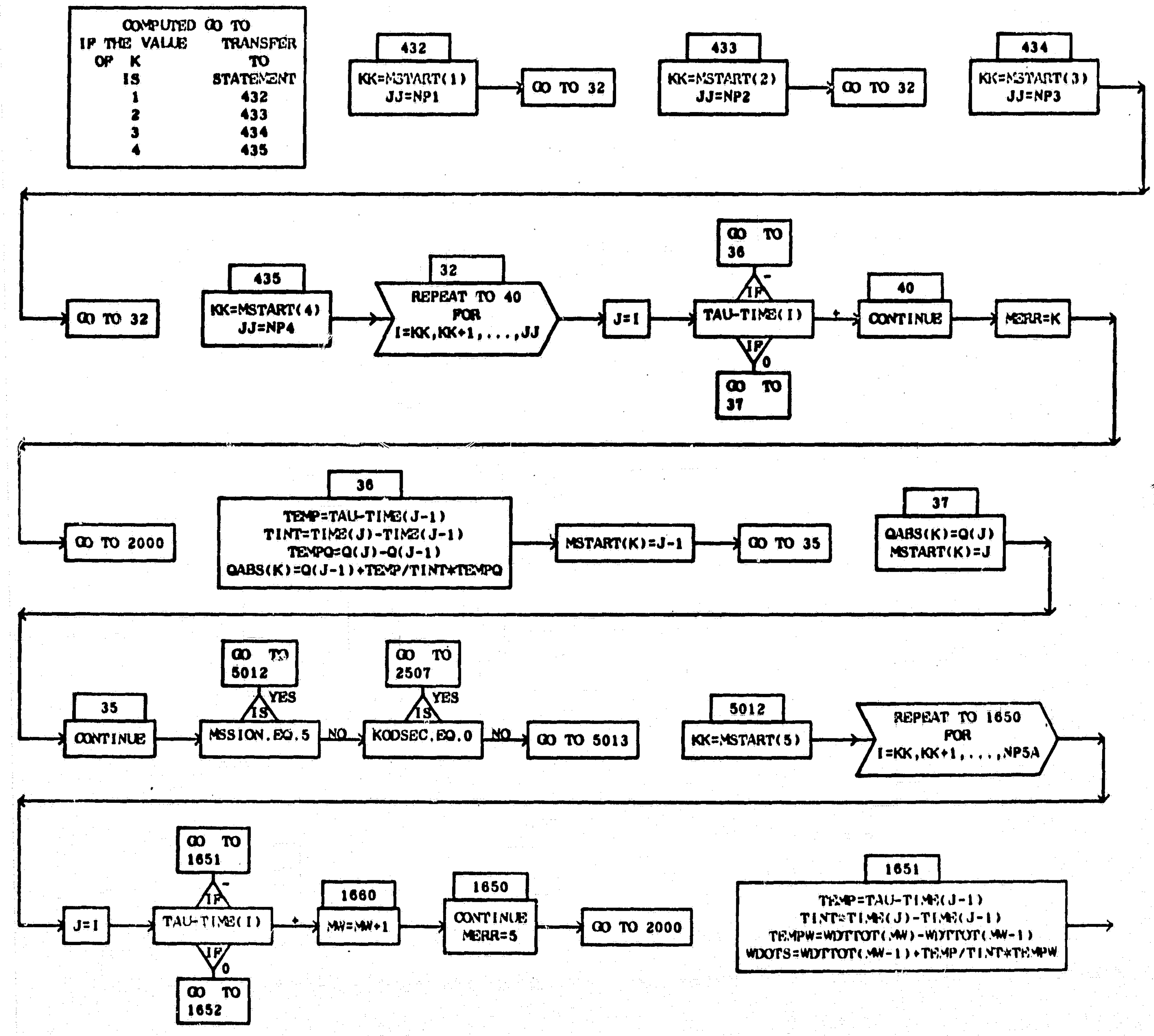


Q(27)=0.0
Q(28)=0.0
Q(29)=42.5
Q(30)=60.6
Q(31)=77.6
Q(32)=87.0
Q(33)=88.6
Q(34)=87.0
Q(35)=77.6
Q(36)=60.6
Q(37)=42.5
Q(38)=0.0
Q(39)=0.0
Q(40)=0.0
Q(41)=0.0
Q(42)=42.5
Q(44)=77.6
Q(45)=87.0
Q(46)=88.6
Q(47)=87.0
Q(48)=77.6
Q(49)=60.6
Q(50)=42.5
Q(51)=0.0
Q(52)=0.0
TIME(1)=0.0
TIME(2)=0.0078
TIME(3)=0.0578
TIME(4)=0.0856
TIME(5)=0.1134
TIME(6)=0.1638
TIME(7)=.219
TIME(8)=0.258
TIME(9)=.333
TIME(10)=0.8360
TIME(11)=0.911
TIME(12)=0.952
TIME(13)=1.0
TIME(14)=0.0
TIME(15)=0.0478
TIME(16)=0.0884
TIME(17)=0.1660
TIME(18)=0.666
TIME(19)=.747
TIME(20)=0.781
TIME(21)=0.837
TIME(22)=0.886
TIME(23)=0.914
TIME(24)=0.942
TIME(25)=0.991
TIME(26)=1.0
TIME(27)=0.0
TIME(28)=.33
TIME(29)=.418
TIME(30)=.459
TIME(31)=0.507
TIME(32)=0.557
TIME(33)=0.586
TIME(34)=0.613
TIME(35)=0.664
TIME(36)=0.719
TIME(37)=0.758
TIME(38)=0.835
TIME(39)=1.0
TIME(40)=0.0
TIME(41)=0.1642
TIME(42)=0.242
TIME(43)=0.281
TIME(44)=0.337
TIME(45)=0.387
TIME(46)=0.415
TIME(47)=0.442
TIME(48)=0.493
TIME(49)=0.549
TIME(50)=0.587
TIME(51)=0.664
TIME(52)=1.0
GO TO 1111
1515
MSTART(1)=1
MSTART(2)=3
MSTART(3)=5
MSTART(4)=7
PERIOD=1.0
P3=6.
QREJ1=1000000.
NP1=2
NP2=4
NP3=6
NP4=8
Q(1)=0.0
Q(2)=0.0
Q(3)=0.0
Q(4)=0.0
Q(5)=0.0
Q(6)=0.0
Q(7)=0.0
Q(8)=0.0
TIME(1)=0.0
TIME(2)=1.0
TIME(3)=0.0
TIME(4)=1.0
TIME(5)=0.0
TIME(6)=1.0
TIME(7)=0.0
TIME(8)=1.0
GO TO 1111
1516
NEXT=1
LAST=0
REPEAT TO 1629
FOR
I=1,I+1,...,8
A2
READ
READ(5,1620)NPTS(I),ALPHA
NOPTS=NPTS(I)
H1
WRITE
WRITE(6,1621)NPTS(I),ALPHA
LAST=LAST+NPTS(I)

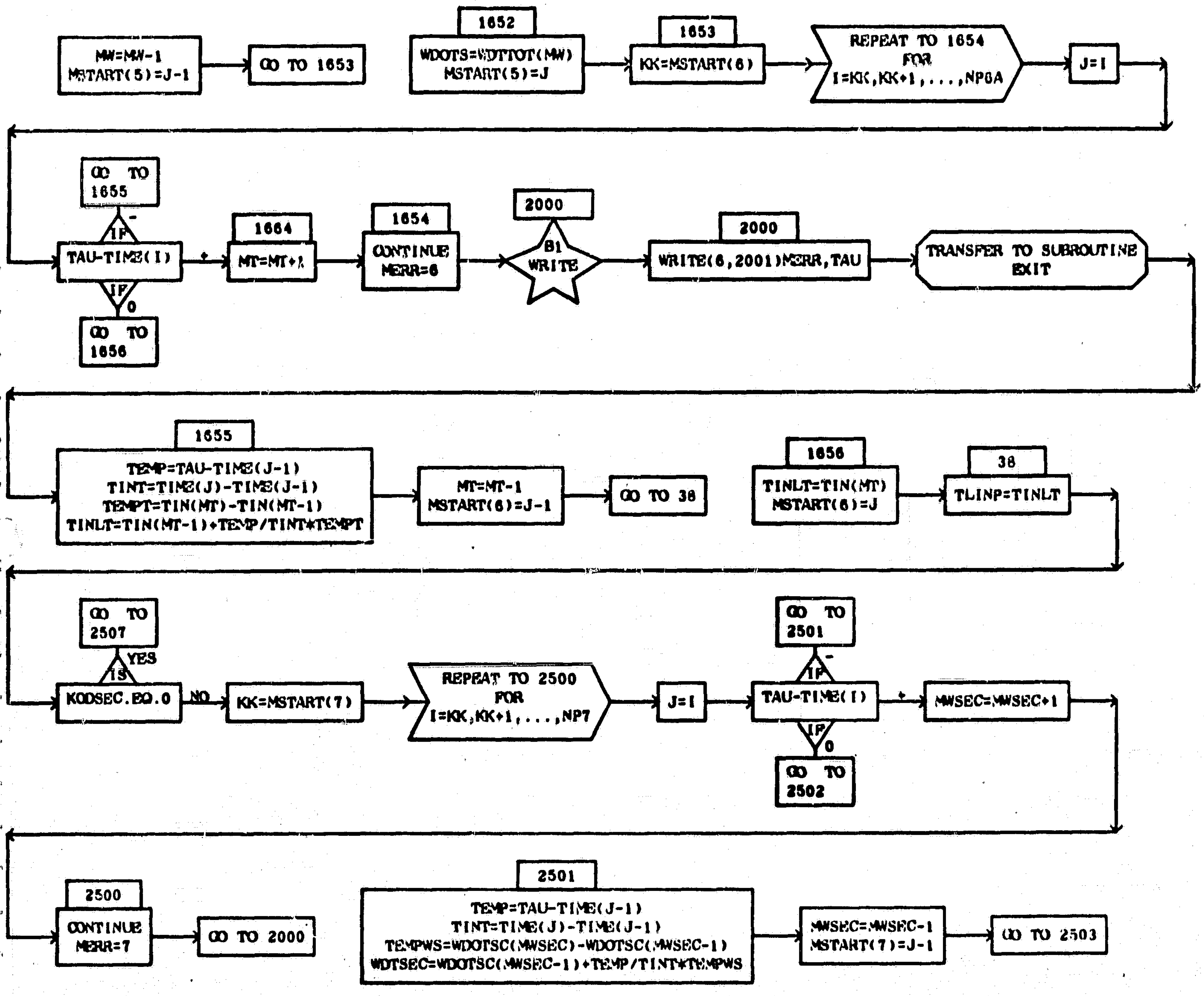

COMPUTED GO TO
IF THE VALUE OF I IS / TRANSFER TO STATEMENT
1 1622
2 1622
3 1622
4 1622
5 1625
6 1626
7 1630
8 1631
1622
A2 READ
1622
READ(5,1623)(TIME(II),II=NEXT,LAST),(Q(II),II=NEXT,LAST)
B1 WRITE
WRITE(6,1624)(TIME(II),II=NEXT,LAST),(Q(II),II=NEXT,LAST)
GO TO 1628
1625
A2 READ
1625
READ(5,1623)(TIME(II),II=NEXT,LAST),(WDTTOT(II),II=1,NOPTS)
B1 WRITE
WRITE(6,1624)(TIME(II),II=NEXT,LAST),(WDTTOT(II),II=1,NOPTS)
GO TO 1628
1626
A2 READ
1626
READ(5,1623)(TIME(II),II=NEXT,LAST),(TIN(II),II=1,NOPTS)
B1 WRITE
WRITE(6,1624)(TIME(II),II=NEXT,LAST),(TIN(II),II=1,NOPTS)
REPEAT TO 1627 FOR II=1,1+1,...,NOPTS
1627
TIN(II)=TIN(II)+459.69


GO TO 1633
YES
IS
KODSEC.EQ.0
NO
GO TO 1628
1630
A2 READ
1630
READ(5,1623)(TIME(II),II=NEXT,LAST),(WDOTSC(II),II=1,NOPTS)
B1 WRITE
WRITE(6,1624)(TIME(II),II=NEXT,LAST),(WDOTSC(II),II=1,NOPTS)
GO TO 1628
1631
A2 READ
1631
READ(5,1623)(TIME(II),II=NEXT,LAST),(TINLSC(II),II=1,NOPTS)
B1 WRITE
WRITE(6,1624)(TIME(II),II=NEXT,LAST),(TINLSC(II),II=1,NOPTS)
REPEAT TO 1632 FOR II=1,1+1,...,NOPTS
1632
TINLSC(II)=TINLSC(II)+459.69
1628
NEXT=NEXT+NPTS(I)
1629
CONTINUE
1633
CONTINUE
NO
IS
.NOT.PERIOD.GT.0.
YES
PERIOD=P3
TINLT=TIN(1)
WDOTS=WDTTOT(1)
WDOTT=WDOTS
MSTART(1)=1
NP1=NPTS(1)
MSTART(2)=NP1+1
NP2=NP1+NPTS(2)
MSTART(3)=NP2+1
NP3=NP2+NPTS(3)
MSTART(4)=NP3+1
NP4=NP3+NPTS(4)
MSTART(5)=NP4+1
MW=1
NP5B=NPTS(5)
NP5A=NP4+NP5B
MSTART(6)=NP5A+1
MT=1
NP6B=NPTS(6)
NP6A=NP5A+NP6B
GO TO 1112
YES
IS
KODSEC.EQ.0
NO
TINSEC=TINLSC(1)
WDTSEC=WDOTSC(1)
MSTART(7)=NP6A+1
MWSEC=1
NP7=NP6A+NPTS(7)
MSTART(8)=NP7+1
MTSEC=1
NP8=NP7+NPTS(7)

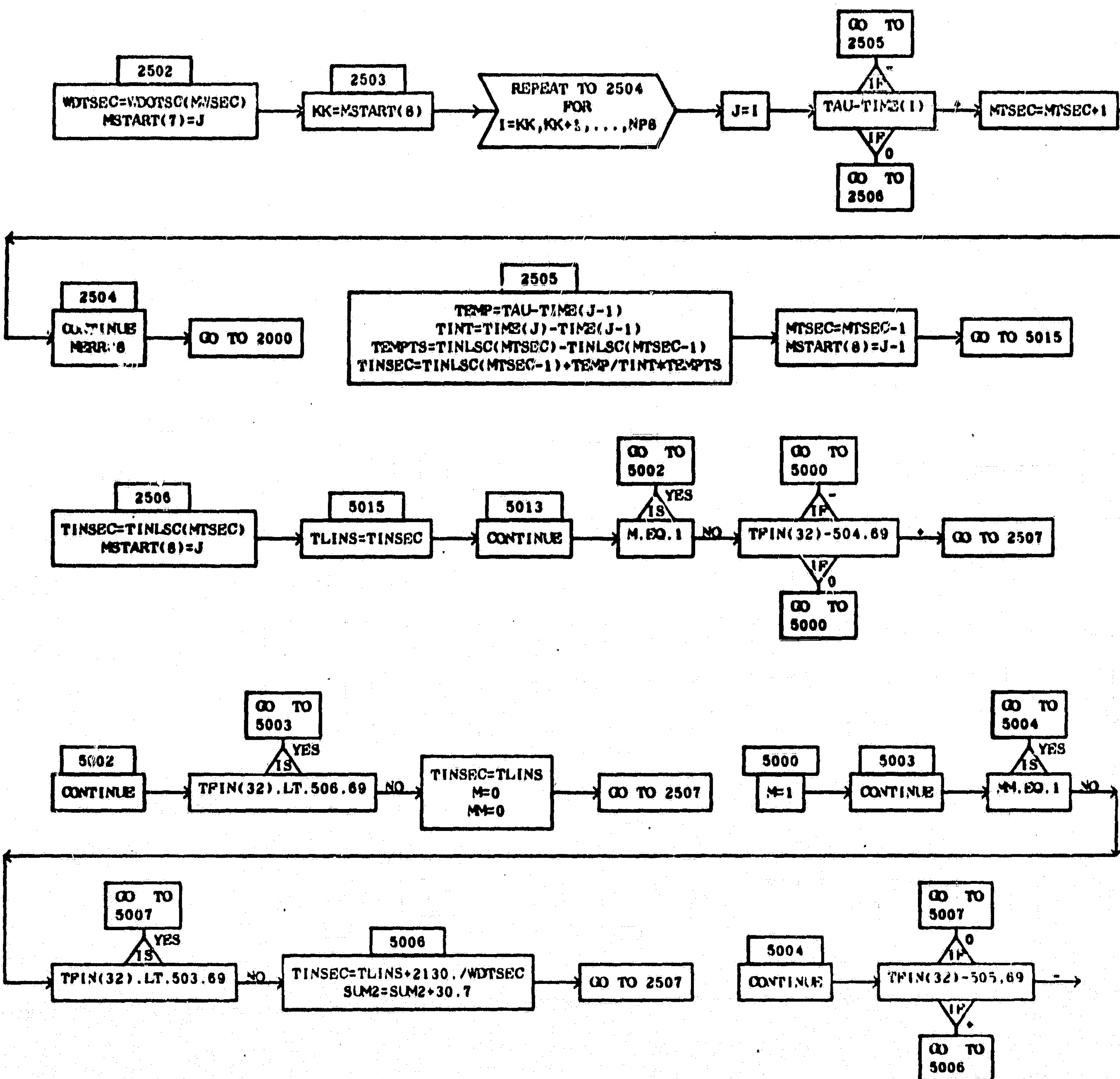

GO TO 1112
1111
TINLT=TINLT+459.69
TINSEC=TINSEC+459.69
TLINP=TINLT
TLINS=TINSEC
1112
REPEAT TO 605
FOR
I=1,I+1,...,20
TFIN(I)=529.69
TTIN(I)=529.69
605
TSIN(I)=529.69
REPEAT TO 606
FOR
I=21,21+1,...,32
TFIN(I)=529.69
606
TTIN(I)=529.69
WDOTT1=WDOTS/2.
WDOTT2=WDOTT1
FLOWPC=1.
B1
WRITE
WRITE(6,436)
TAU=0.02
SAVE=0.02
425
CONTINUE
GO TO
431
IF
TAU-PERIOD
IF
0
GO TO
431
426
TAU=TAU-PERIOD
COMPUTED GO TO
IF THE VALUE OF MISSION IS
TRANSFER TO STATEMENT
1 427
2 428
3 429
4 430
5 6006
427
MSTART(1)=1
MSTART(2)=19
MSTART(3)=37
MSTART(4)=47
GO TO 431
428
MSTART(1)=1
MSTART(2)=15
MSTART(3)=29
MSTART(4)=43
GO TO 431
429
MSTART(1)=1
MSTART(2)=14
MSTART(3)=27
MSTART(4)=40
GO TO 431
430
MSTART(1)=1
MSTART(2)=3
MSTART(3)=5
MSTART(4)=7
GO TO 431
6006
MSTART(1)=1
MSTART(2)=NP1+1
MSTART(3)=NP2+1
MSTART(4)=NP3+1
MSTART(5)=NP4+1
MSTART(6)=NP5A+1
GO TO
431
YES
IS
KODSEC.EQ.0
NO
MSTART(7)=NP6A+1
MSTART(8)=NP7+1
431
REPEAT TO 35
FOR
K=1,1+1,...,4

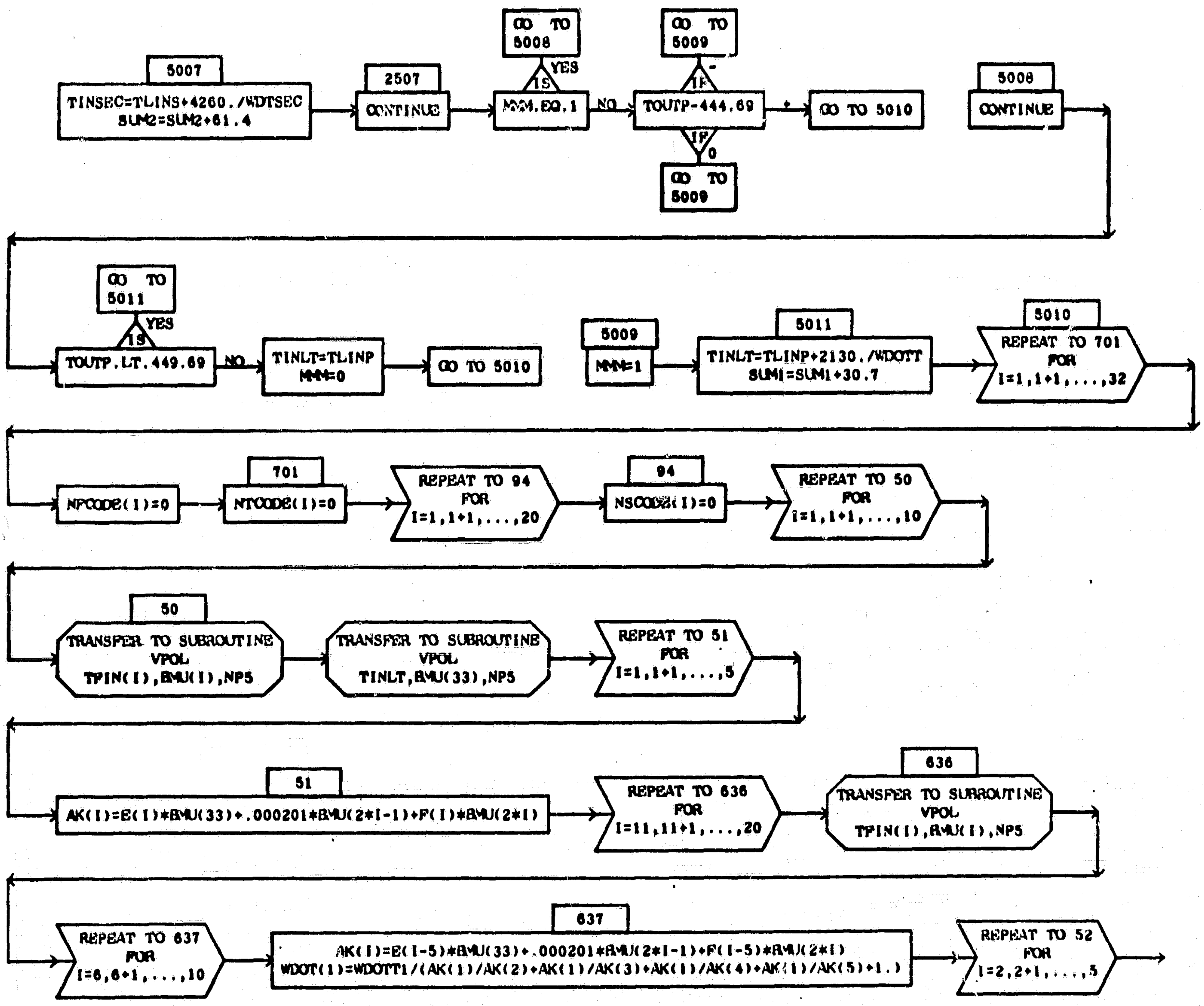


COMPUTED GO TO
IF THE VALUE OF K IS 1 2 3 4
TRANSFER TO STATEMENT 432 433 434 435
432
KK=MSTART(1) JJ=NP1
GO TO 32
433
KK=MSTART(2) JJ=NP2
GO TO 32
434
KK=MSTART(3) JJ=NP3
GO TO 32
435
KK=MSTART(4) JJ=NP4
32
REPEAT TO 40 FOR I=KK,KK+1,...,JJ
J=I
TAU-TIME(I)
IF -
GO TO 36
IF 0
GO TO 37
+
40
CONTINUE
MERR=K
GO TO 2000
36
TEMP=TAU-TIME(J-1)
TINT=TIME(J)-TIME(J-1)
TEMPQ=Q(J)-Q(J-1)
QABS(K)=Q(J-1)+TEMP/TINT*TEMPQ
MSTART(K)=J-1
GO TO 35
37
QABS(K)=Q(J)
MSTART(K)=J
35
CONTINUE
IS MSSION.EQ.5
YES
GO TO 5012
NO
IS KODSEC.EQ.0
YES
GO TO 2507
NO
GO TO 5013
5012
KK=MSTART(5)
REPEAT TO 1650 FOR I=KK,KK+1,...,NP5A
J=I
TAU-TIME(I)
IF -
GO TO 1651
IF 0
GO TO 1652
+
1660
MW=MW+1
1650
CONTINUE MERR=5
GO TO 2000
1651
TEMP=TAU-TIME(J-1)
TINT=TIME(J)-TIME(J-1)
TEMPW=WDTTOT(MW)-WDTTOT(MW-1)
WDOTS=WDTTOT(MW-1)+TEMP/TINT*TEMPW

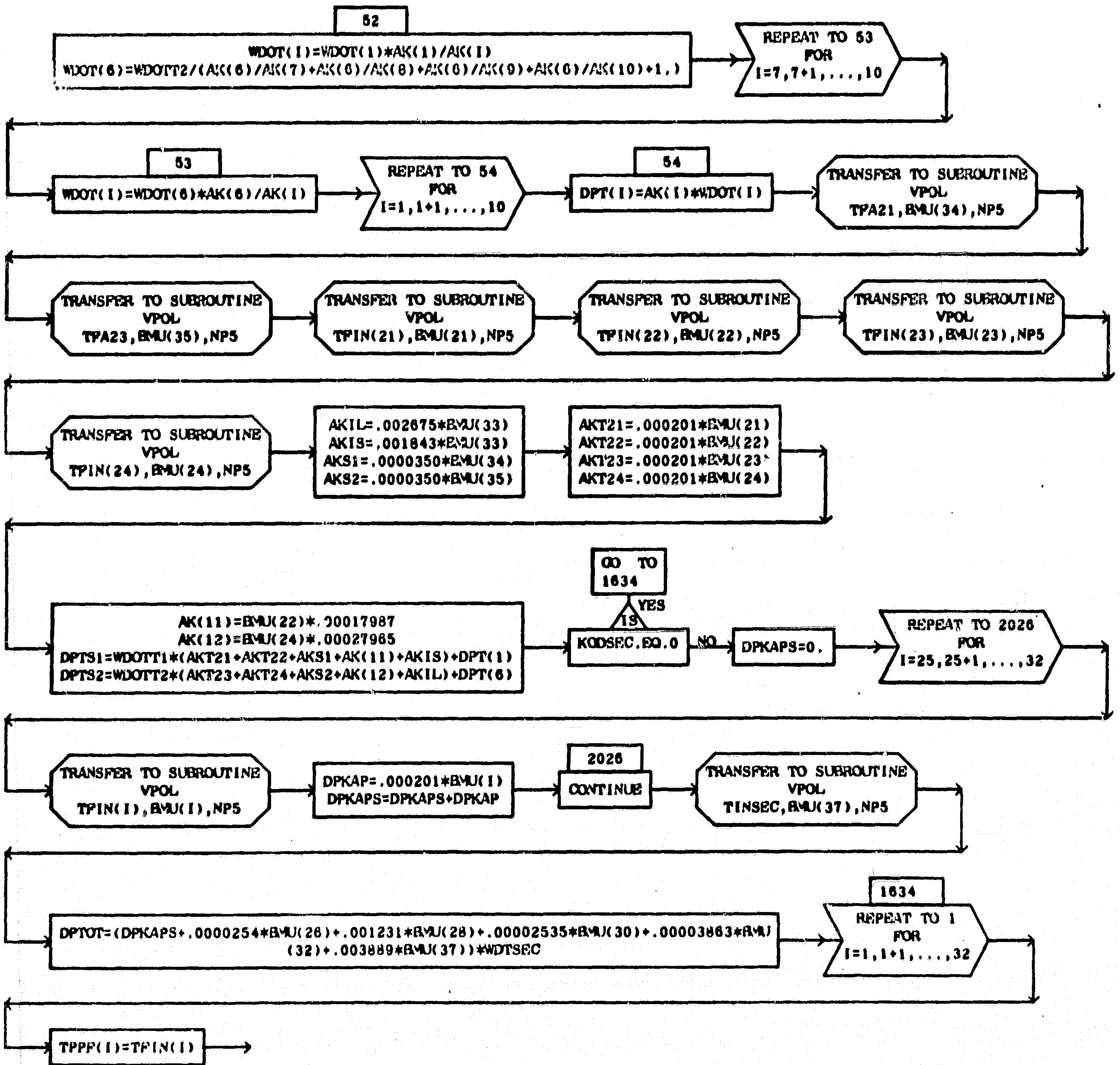


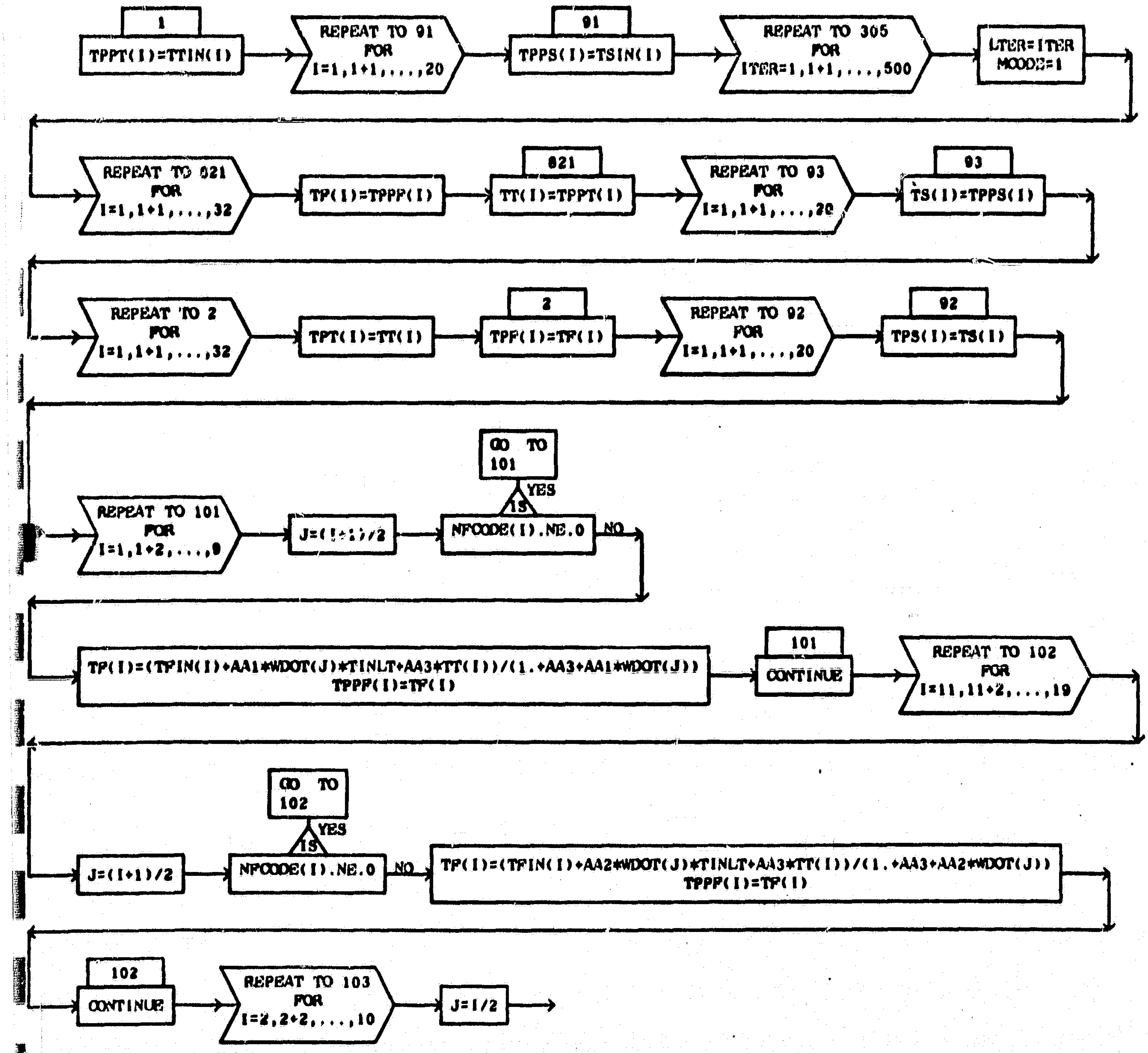
MW=MW-1
MSTART(5)=J-1
GO TO 1653
1652
WDOTS=WDTTOT(MW)
MSTART(5)=J
1653
KK=MSTART(6)
REPEAT TO 1654
FOR
I=KK,KK+1,...,NPGA
J=I
GO TO
1655
IF
TAU-TIME(I)
IF
GO TO
1656
1664
MT=MT+1
1654
CONTINUE
MERR=6
2000
B1
WRITE
2000
WRITE(6,2001)MERR,TAU
TRANSFER TO SUBROUTINE
EXIT
1655
TEMP=TAU-TIME(J-1)
TINT=TIME(J)-TIME(J-1)
TEMPT=TIN(MT)-TIN(MT-1)
TINLT=TIN(MT-1)+TEMP/TINT*TEMPT
MT=MT-1
MSTART(6)=J-1
GO TO 38
1656
TINLT=TIN(MT)
MSTART(6)=J
38
TLINP=TINLT
GO TO
2507
YES
IS
KODSEC.EQ.0
NO
KK=MSTART(7)
REPEAT TO 2500
FOR
I=KK,KK+1,...,NP7
J=I
GO TO
2501
IF
TAU-TIME(I)
IF
GO TO
2502
MWSEC=MWSEC+1
2500
CONTINUE
MERR=7
GO TO 2000
2501
TEMP=TAU-TIME(J-1)
TINT=TIME(J)-TIME(J-1)
TEMPWS=WDOTSC(MWSEC)-WDOTSC(MWSEC-1)
WDTSEC=WDOTSC(MWSEC-1)+TEMP/TINT*TEMPWS
MWSEC=MWSEC-1
MSTART(7)=J-1
GO TO 2503

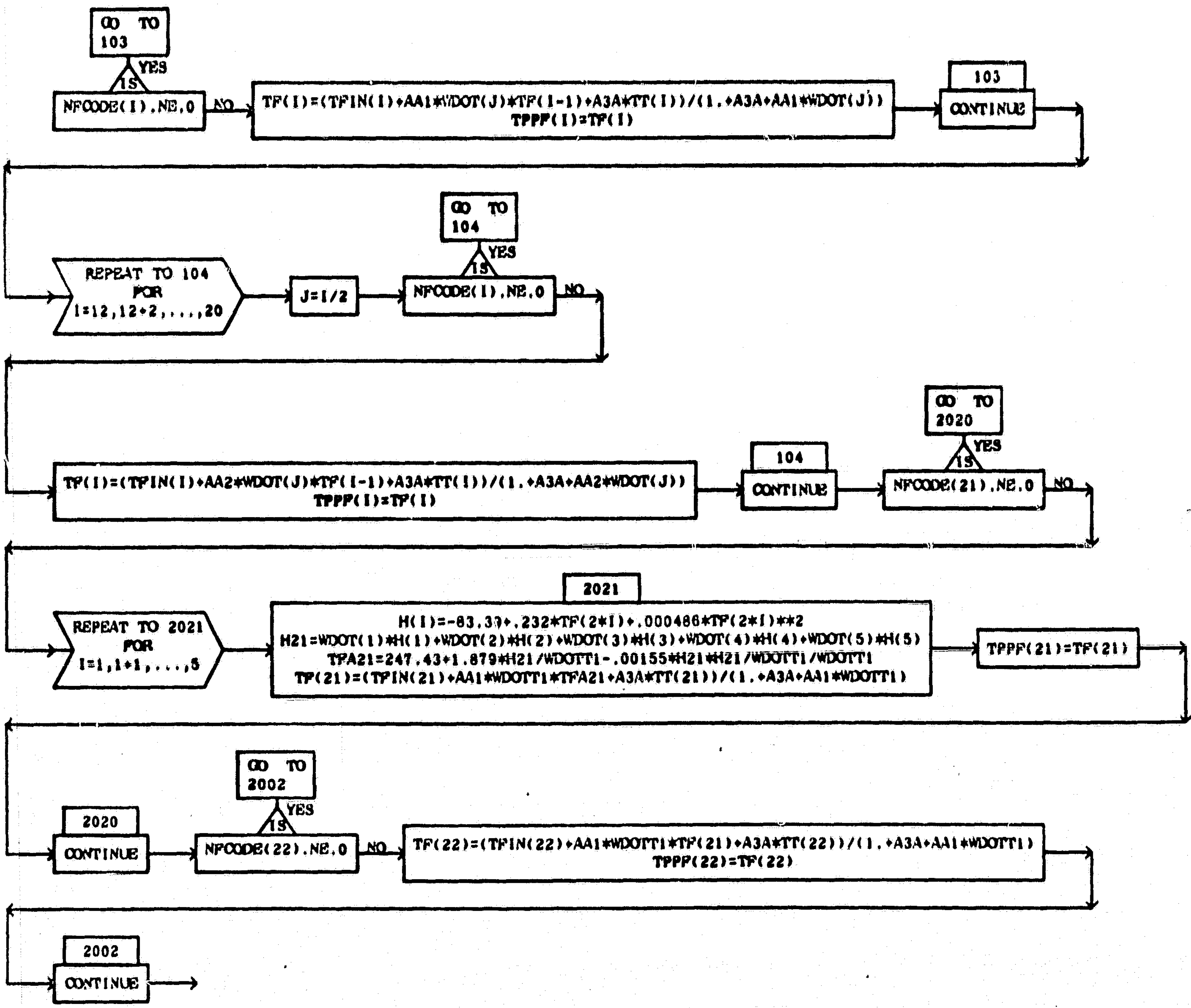

2502
WDTSEC=WDOTSC(MTSEC)
MSTART(7)=J
2503
KK=MSTART(8)
REPEAT TO 2504
FOR
I=KK,KK+1,...,NP8
J=1
GO TO 2505
IF
TAU-TIME(I)
IF
0
GO TO 2506
MTSEC=MTSEC+1
2504
CONTINUE
MERR=8
GO TO 2000
2505
TEMP=TAU-TIME(J-1)
TINT=TIME(J)-TIME(J-1)
TEMPTS=TINLSC(MTSEC)-TINLSC(MTSEC-1)
TINSEC=TINLSC(MTSEC-1)+TEMP/TINT*TEMPTS
MTSEC=MTSEC-1
MSTART(8)=J-1
GO TO 5015
2506
TINSEC=TINLSC(MTSEC)
MSTART(8)=J
5015
TLINS=TINSEC
5013
CONTINUE
GO TO 5002
YES
IS
M.EQ.1
NO
GO TO 5000
-
IF
TPIN(32)-504.69
+
GO TO 2507
IF
0
GO TO 5000
5002
CONTINUE
GO TO 5003
YES
IS
TPIN(32).LT.506.69
NO
TINSEC=TLINS
M=0
MM=0
GO TO 2507
5000
M=1
5003
CONTINUE
GO TO 5004
YES
IS
MM.EQ.1
NO
GO TO 5007
YES
IS
TPIN(32).LT.503.69
NO
5006
TINSEC=TLINS+2130./WDTSEC
SUM2=SUM2+30.7
GO TO 2507
5004
CONTINUE
GO TO 5007
0
IF
TPIN(32)-505.69
-
IF
+
GO TO 5006

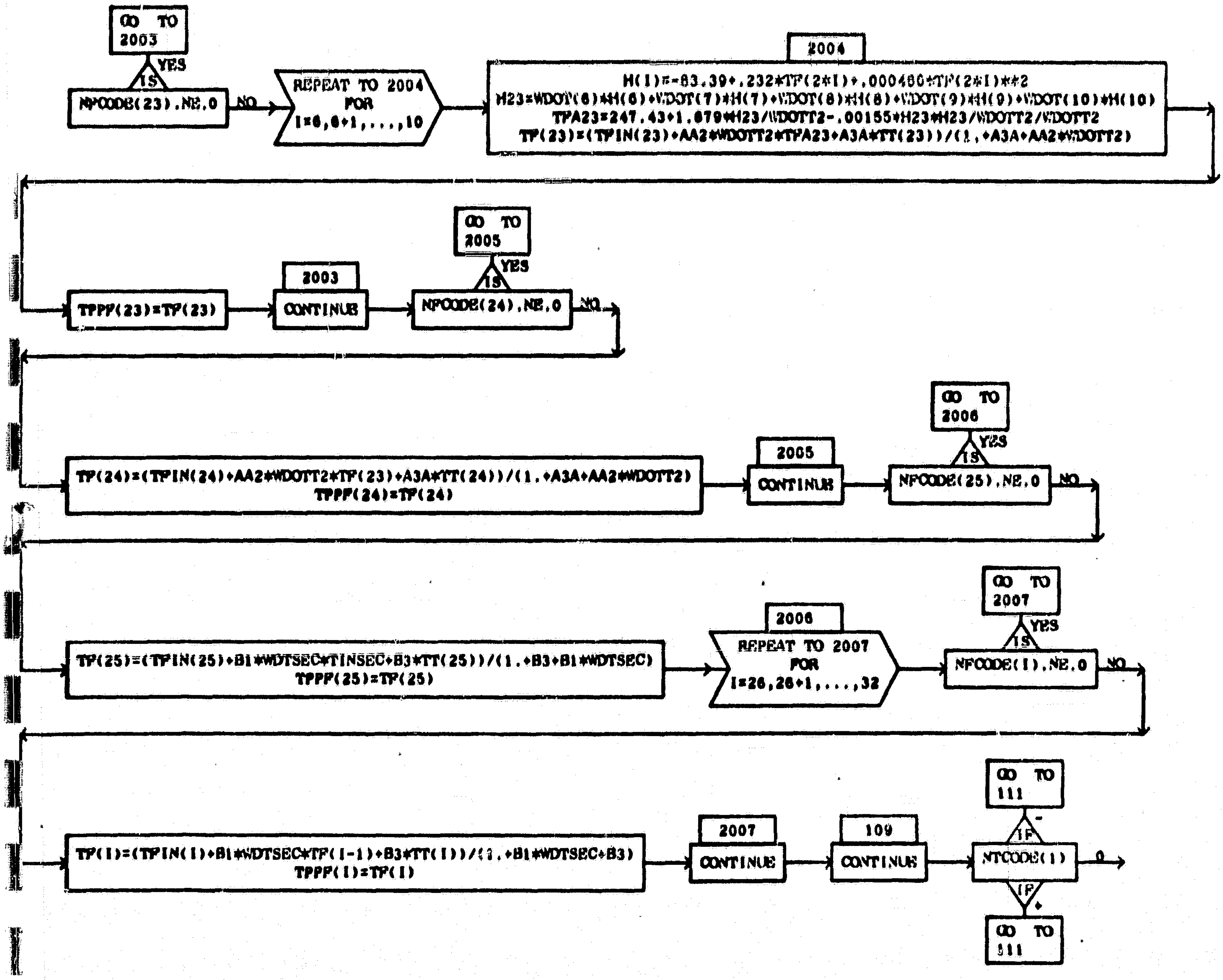


5007
TINSEC=TLINS+4260./WDTSEC
SUM2=SUM2+61.4
2507
CONTINUE
GO TO 5008
YES
IS
MMM.EQ.1
NO
GO TO 5009
-
IF
TOUTP-444.69
+
GO TO 5010
IF
0
GO TO 5009
5008
CONTINUE
GO TO 5011
YES
IS
TOUTP.LT.449.69
NO
TINLT=TLINP
MMM=0
GO TO 5010
5009
MMM=1
5011
TINLT=TLINP+2130./WDOTT
SUM1=SUM1+30.7
5010
REPEAT TO 701
FOR
I=1,1+1,...,32
NPCODE(I)=0
701
NTCODE(I)=0
REPEAT TO 94
FOR
I=1,1+1,...,20
94
NSCODE(I)=0
REPEAT TO 50
FOR
I=1,1+1,...,10
50
TRANSFER TO SUBROUTINE
VPOL
TPIN(I),BMU(I),NP5
TRANSFER TO SUBROUTINE
VPOL
TINLT,BMU(33),NP5
REPEAT TO 51
FOR
I=1,1+1,...,5
51
AK(I)=E(I)*BMU(33)+.000201*BMU(2*I-1)+F(I)*BMU(2*I)
REPEAT TO 636
FOR
I=11,11+1,...,20
636
TRANSFER TO SUBROUTINE
VPOL
TPIN(I),BMU(I),NP5
REPEAT TO 637
FOR
I=6,6+1,...,10
637
AK(I)=E(I-5)*BMU(33)+.000201*BMU(2*I-1)+F(I-5)*BMU(2*I)
WDOT(I)=WDOTT1/(AK(I)/AK(2)+AK(I)/AK(3)+AK(I)/AK(4)+AK(I)/AK(5)+1.)
REPEAT TO 52
FOR
I=2,2+1,...,5

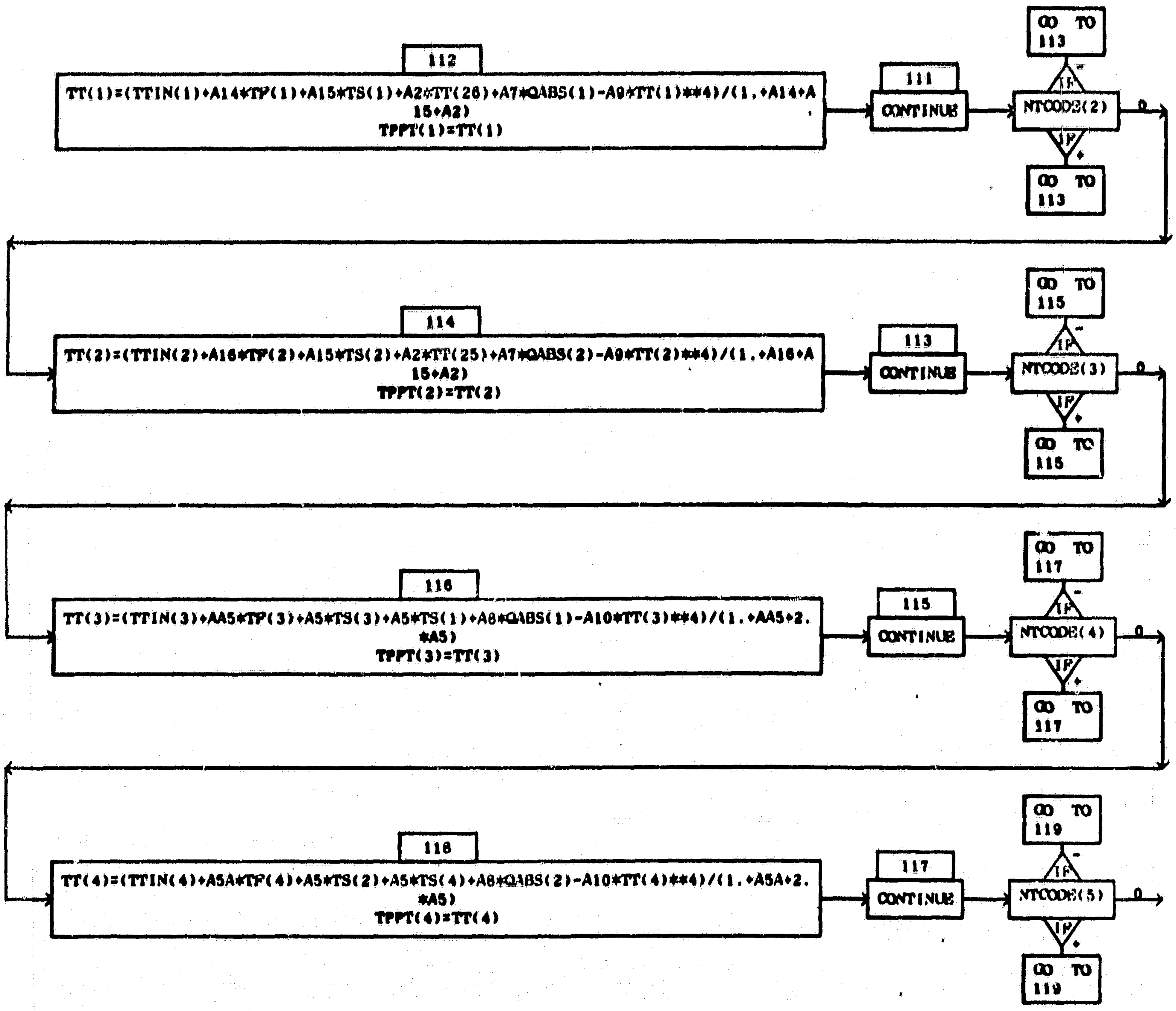

52
WDOT(I)=WDOT(1)*AK(1)/AK(I)
WDOT(6)=WDOTT2/(AK(6)/AK(7)+AK(6)/AK(8)+AK(6)/AK(9)+AK(6)/AK(10)+1.)
REPEAT TO 53 FOR I=7,7+1,...,10
53
WDOT(I)=WDOT(6)*AK(6)/AK(I)
REPEAT TO 54 FOR I=1,1+1,...,10
54
DPT(I)=AK(I)*WDOT(I)
TRANSFER TO SUBROUTINE VPOL TPA21,BMU(34),NP5
TRANSFER TO SUBROUTINE VPOL TPA23,BMU(35),NP5
TRANSFER TO SUBROUTINE VPOL TPIN(21),BMU(21),NP5
TRANSFER TO SUBROUTINE VPOL TPIN(22),BMU(22),NP5
TRANSFER TO SUBROUTINE VPOL TPIN(23),BMU(23),NP5
TRANSFER TO SUBROUTINE VPOL TPIN(24),BMU(24),NP5
AKIL=.002675*BMU(33)
AKIS=.001843*BMU(33)
AKS1=.0000350*BMU(34)
AKS2=.0000350*BMU(35)
AKT21=.000201*BMU(21)
AKT22=.000201*BMU(22)
AKT23=.000201*BMU(23)
AKT24=.000201*BMU(24)
AK(11)=BMU(22)*.00017987
AK(12)=BMU(24)*.00027965
DPTS1=WDOTT1*(AKT21+AKT22+AKS1+AK(11)+AKIS)+DPT(1)
DPTS2=WDOTT2*(AKT23+AKT24+AKS2+AK(12)+AKIL)+DPT(6)
GO TO 1634
YES
IS
KODSEC.EQ.0
NO
DPKAPS=0.
REPEAT TO 2026 FOR I=25,25+1,...,32
TRANSFER TO SUBROUTINE VPOL TPIN(I),BMU(I),NP5
DPKAP=.000201*BMU(I)
DPKAPS=DPKAPS+DPKAP
2026
CONTINUE
TRANSFER TO SUBROUTINE VPOL TINSEC,BMU(37),NP5
DPTOT=(DPKAPS+.0000254*BMU(26)+.001231*BMU(28)+.00002535*BMU(30)+.00003863*BMU(32)+.003889*BMU(37))*WDTSEC
1634
REPEAT TO 1 FOR I=1,1+1,...,32
TPPF(I)=TPIN(I)

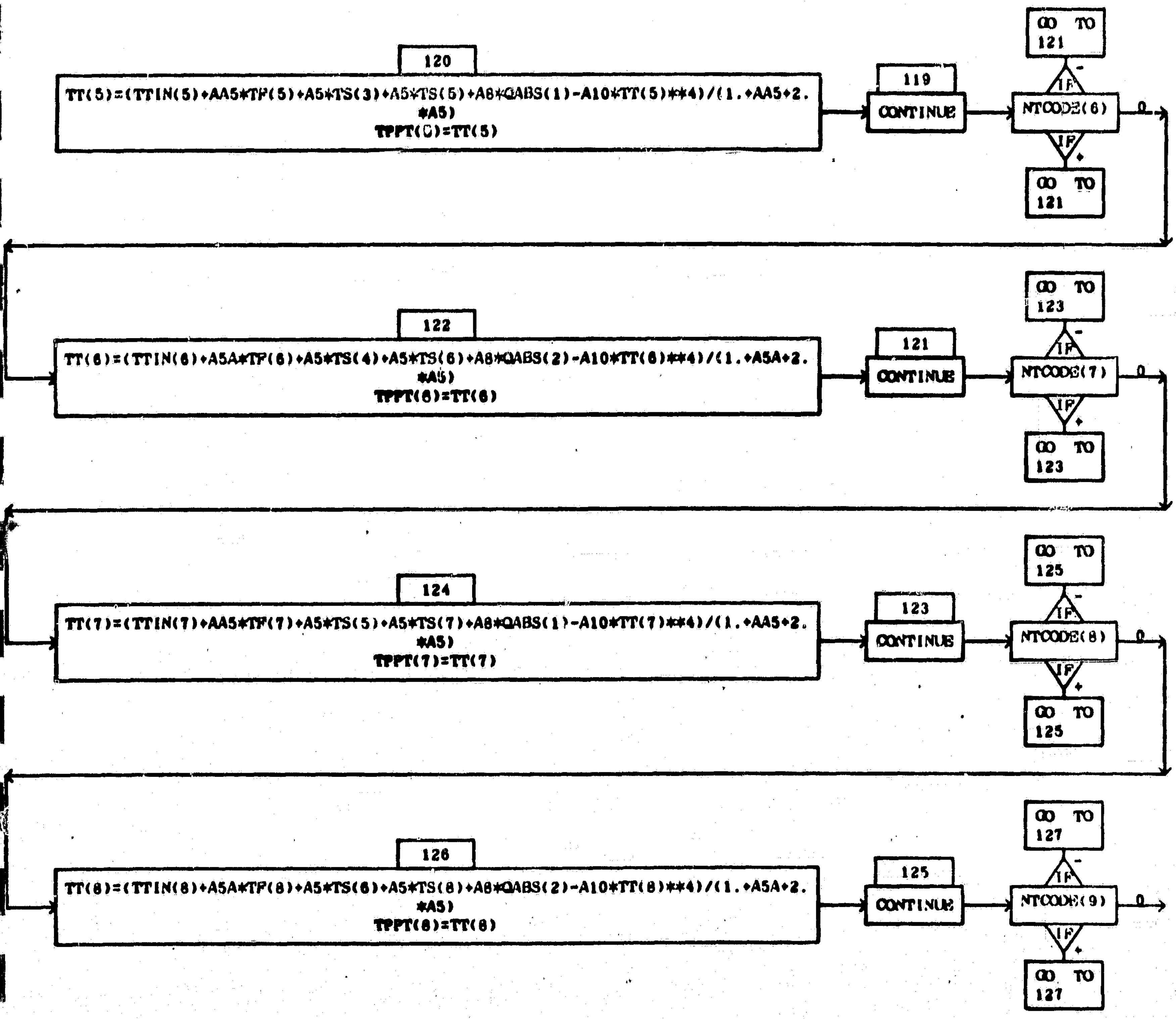

1
TPPT(I)=TTIN(I)
REPEAT TO 91 FOR I=1,1+1,...,20
91
TPPS(I)=TSIN(I)
REPEAT TO 305 FOR ITER=1,1+1,...,500
LTER=ITER
MOODE=1
REPEAT TO 821 FOR I=1,1+1,...,32
TP(I)=TPPP(I)
821
TT(I)=TPPT(I)
REPEAT TO 93 FOR I=1,1+1,...,20
93
TS(I)=TPPS(I)
REPEAT TO 2 FOR I=1,1+1,...,32
TPT(I)=TT(I)
2
TPP(I)=TP(I)
REPEAT TO 92 FOR I=1,1+1,...,20
92
TPS(I)=TS(I)
GO TO 101
YES
IS
REPEAT TO 101 FOR I=1,1+2,...,9
NFCODE(I).NE.0
NO
TP(I)=(TPIN(I)+AA1*WDOT(J)*TINLT+AA3*TT(I))/(1.+AA3+AA1*WDOT(J))
TPPP(I)=TP(I)
101
CONTINUE
REPEAT TO 102 FOR I=11,11+2,...,19
GO TO 102
YES
IS
J=(I+1)/2
NFCODE(I).NE.0
NO
TP(I)=(TPIN(I)+AA2*WDOT(J)*TINLT+AA3*TT(I))/(1.+AA3+AA2*WDOT(J))
TPPP(I)=TP(I)
102
CONTINUE
REPEAT TO 103 FOR I=2,2+2,...,10
J=I/2

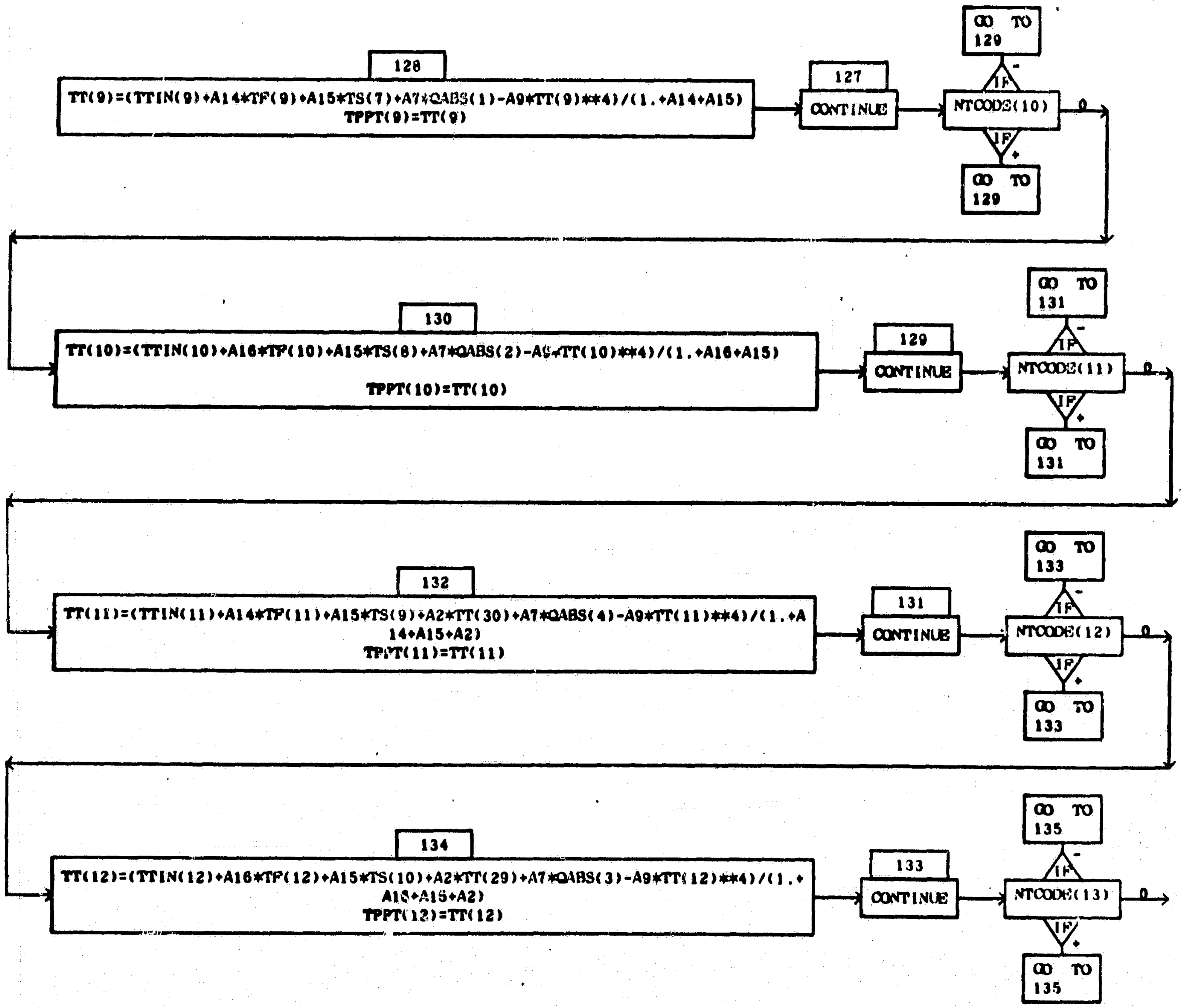

GO TO 103
YES
IS
NFCODE(I).NE.0
NO
TF(I)=(TFIN(I)+AA1*WDOT(J)*TF(I-1)+A3A*TT(I))/(1.+A3A+AA1*WDOT(J))
TPPF(I)=TF(I)
103
CONTINUE
REPEAT TO 104
FOR
I=12,12+2,...,20
J=I/2
GO TO 104
YES
IS
NFCODE(I).NE.0
NO
TF(I)=(TFIN(I)+AA2*WDOT(J)*TF(I-1)+A3A*TT(I))/(1.+A3A+AA2*WDOT(J))
TPPF(I)=TF(I)
104
CONTINUE
GO TO 2020
YES
IS
NFCODE(21).NE.0
NO
REPEAT TO 2021
FOR
I=1,1+1,...,5
2021
H(I)=-83.39+.232*TF(2*I)+.000486*TF(2*I)**2
H21=WDOT(1)*H(1)+WDOT(2)*H(2)+WDOT(3)*H(3)+WDOT(4)*H(4)+WDOT(5)*H(5)
TFA21=247.43+1.879*H21/WDOTT1-.00155*H21*H21/WDOTT1/WDOTT1
TF(21)=(TFIN(21)+AA1*WDOTT1*TFA21+A3A*TT(21))/(1.+A3A+AA1*WDOTT1)
TPPF(21)=TF(21)
2020
CONTINUE
GO TO 2002
YES
IS
NFCODE(22).NE.0
NO
TF(22)=(TFIN(22)+AA1*WDOTT1*TF(21)+A3A*TT(22))/(1.+A3A+AA1*WDOTT1)
TPPF(22)=TF(22)
2002
CONTINUE

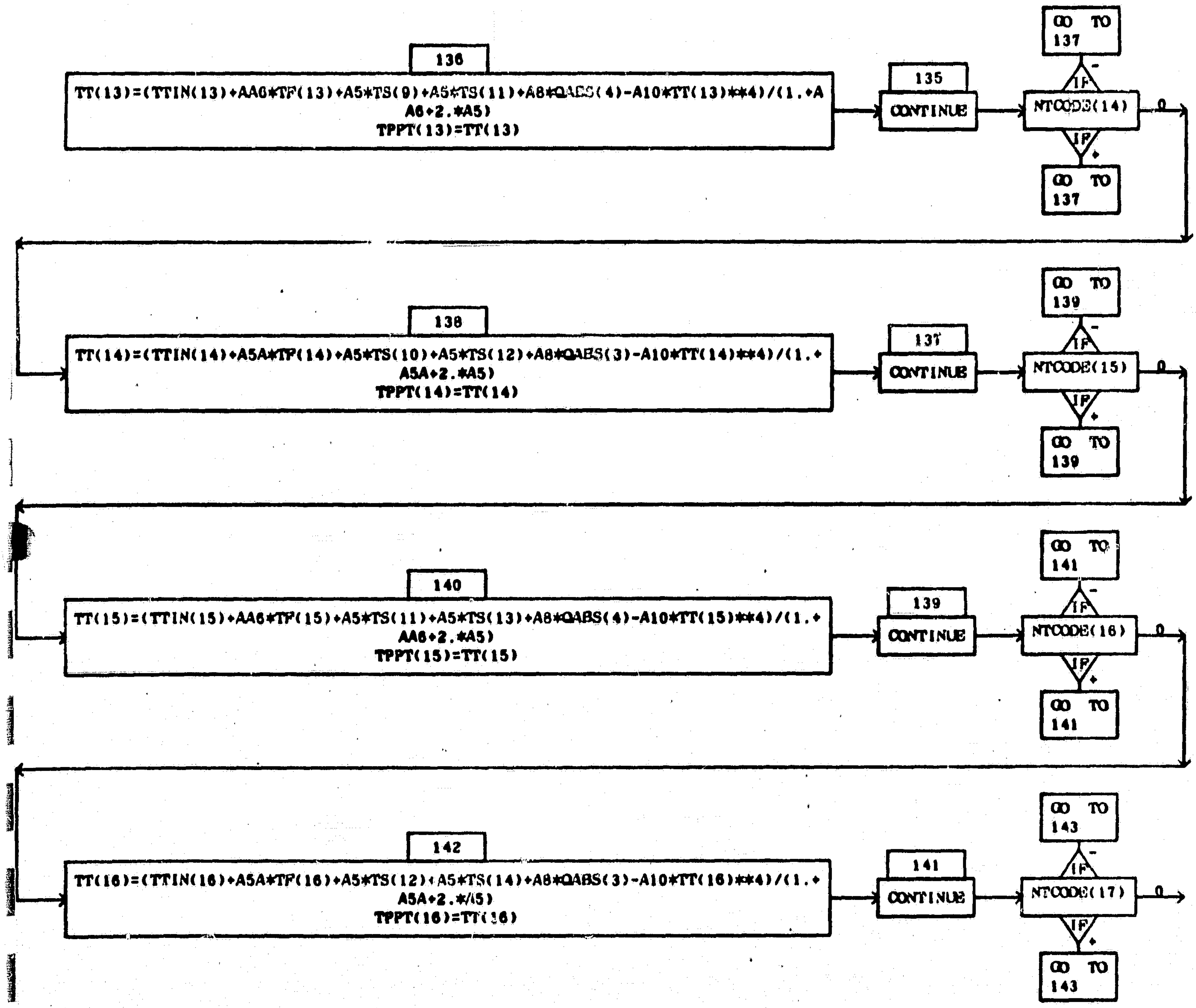


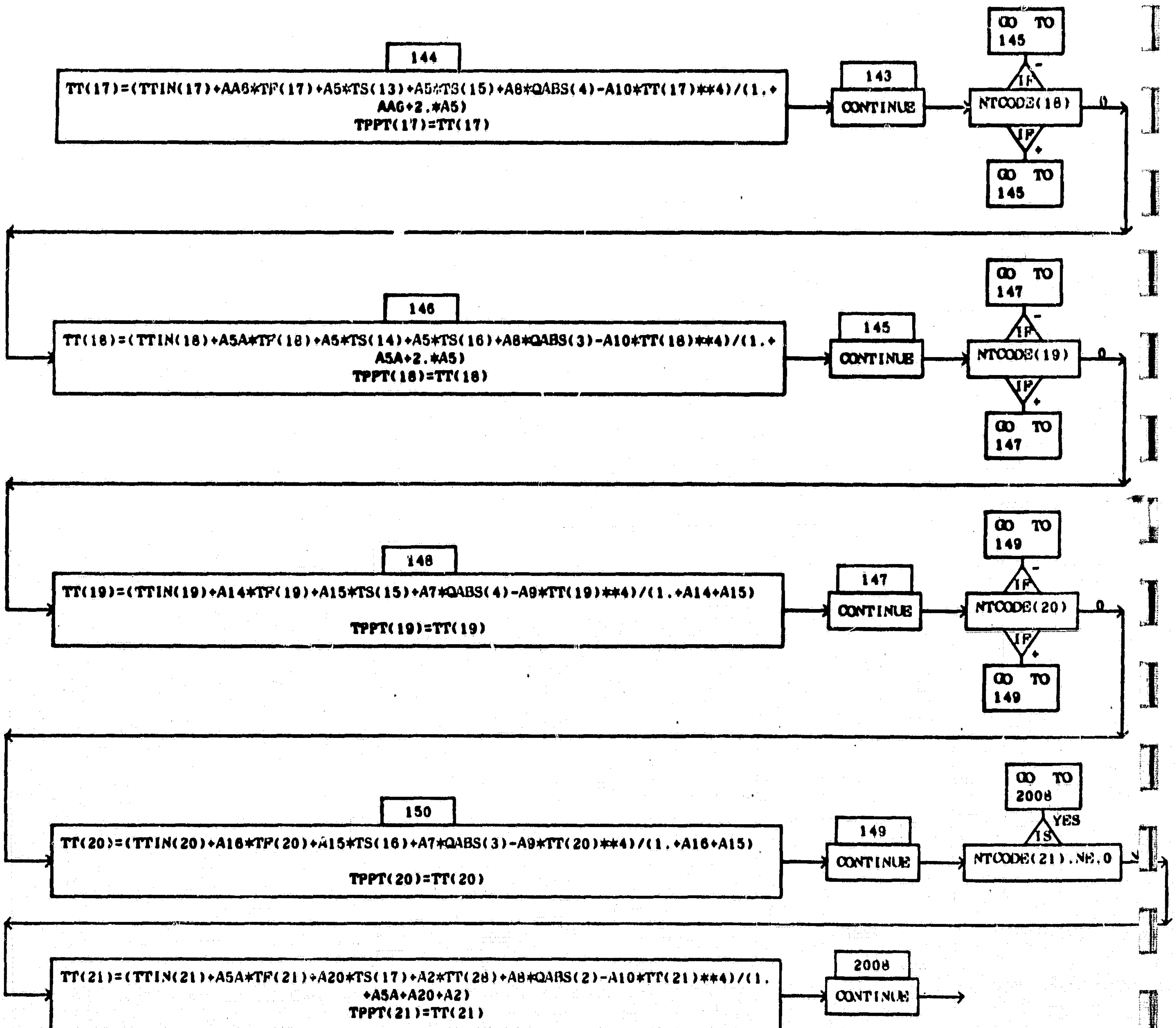
GO TO 2003
YES
IS
NFCODE(23).NE.0
NO
REPEAT TO 2004 FOR I=6,6+1,...,10
2004
H(I)=-83.39+.232*TF(2*I)+.000480*TF(2*I)**2
H23=WDOT(6)*H(6)+WDOT(7)*H(7)+WDOT(8)*H(8)+WDOT(9)*H(9)+WDOT(10)*H(10)
TPA23=247.43+1.679*H23/WDOTT2-.00155*H23*H23/WDOTT2/WDOTT2
TP(23)=(TPIN(23)+AA2*WDOTT2*TPA23+A3A*TT(23))/(1.+A3A+AA2*WDOTT2)
TPPF(23)=TP(23)
2003
CONTINUE
GO TO 2005
YES
IS
NFCODE(24).NE.0
NO
TP(24)=(TPIN(24)+AA2*WDOTT2*TP(23)+A3A*TT(24))/(1.+A3A+AA2*WDOTT2)
TPPF(24)=TP(24)
2005
CONTINUE
GO TO 2006
YES
IS
NFCODE(25).NE.0
NO
TP(25)=(TPIN(25)+B1*WDTSEC*TINSEC+B3*TT(25))/(1.+B3+B1*WDTSEC)
TPPF(25)=TP(25)
2006
REPEAT TO 2007 FOR I=26,26+1,...,32
GO TO 2007
YES
IS
NFCODE(I).NE.0
NO
TP(I)=(TPIN(I)+B1*WDTSEC*TP(I-1)+B3*TT(I))/(1.+B1*WDTSEC+B3)
TPPF(I)=TP(I)
2007
CONTINUE
109
CONTINUE
GO TO 111
-
IF
NTCODE(I)
0
IF
+
GO TO 111

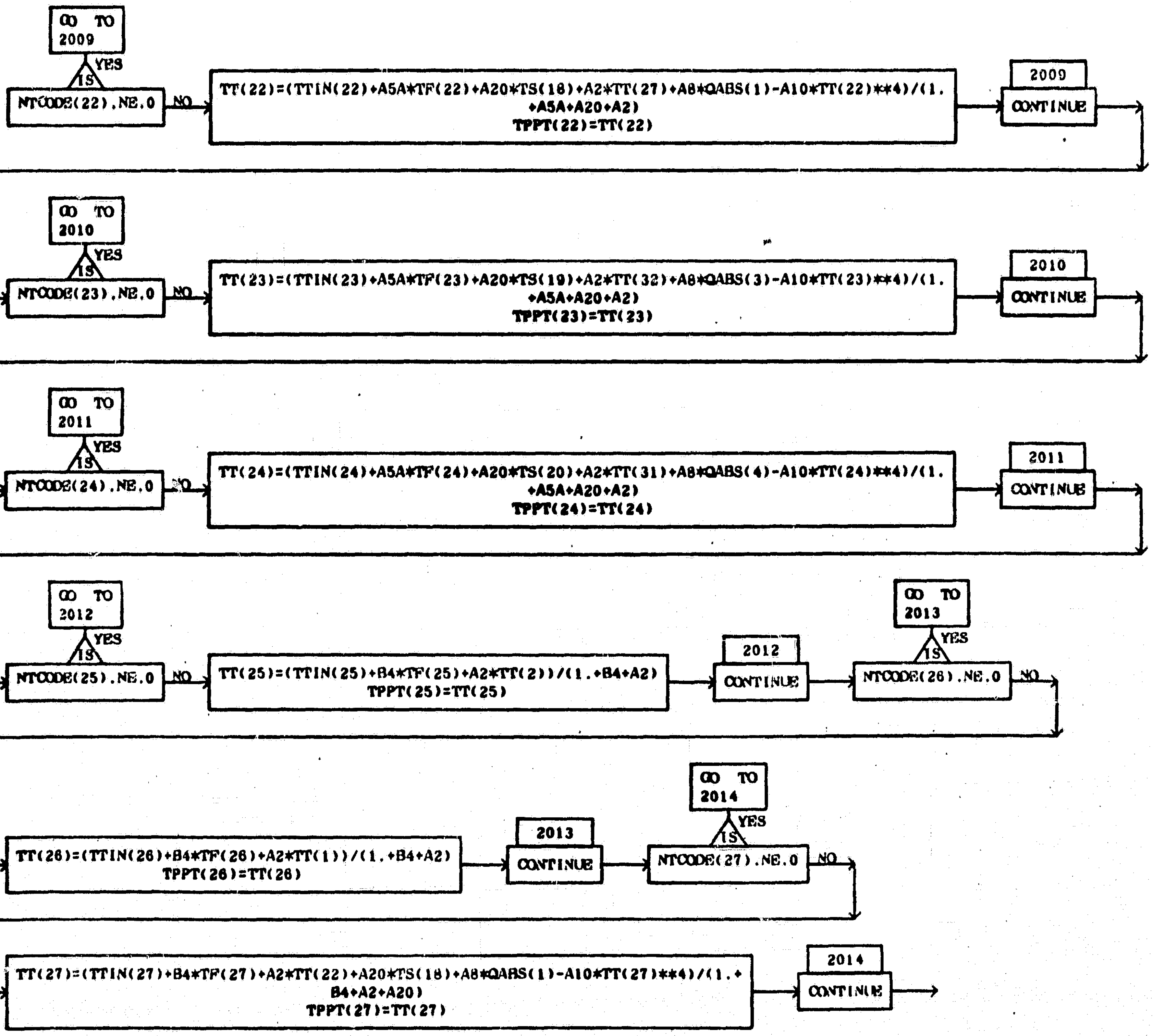

112
TT(1)=(TTIN(1)+A14*TF(1)+A15*TS(1)+A2*TT(26)+A7*QABS(1)-A9*TT(1)**4)/(1.+A14+A15+A2)
TFPT(1)=TT(1)
111
CONTINUE
NTCODE(2)
IF
GO TO 113
-
+
0
GO TO 113
114
TT(2)=(TTIN(2)+A16*TF(2)+A15*TS(2)+A2*TT(25)+A7*QABS(2)-A9*TT(2)**4)/(1.+A16+A15+A2)
TFPT(2)=TT(2)
113
CONTINUE
NTCODE(3)
GO TO 115
GO TO 115
116
TT(3)=(TTIN(3)+AA5*TF(3)+A5*TS(3)+A5*TS(1)+A8*QABS(1)-A10*TT(3)**4)/(1.+AA5+2.*A5)
TFPT(3)=TT(3)
115
CONTINUE
NTCODE(4)
GO TO 117
GO TO 117
118
TT(4)=(TTIN(4)+A5A*TF(4)+A5*TS(2)+A5*TS(4)+A8*QABS(2)-A10*TT(4)**4)/(1.+A5A+2.*A5)
TFPT(4)=TT(4)
117
CONTINUE
NTCODE(5)
GO TO 119
GO TO 119

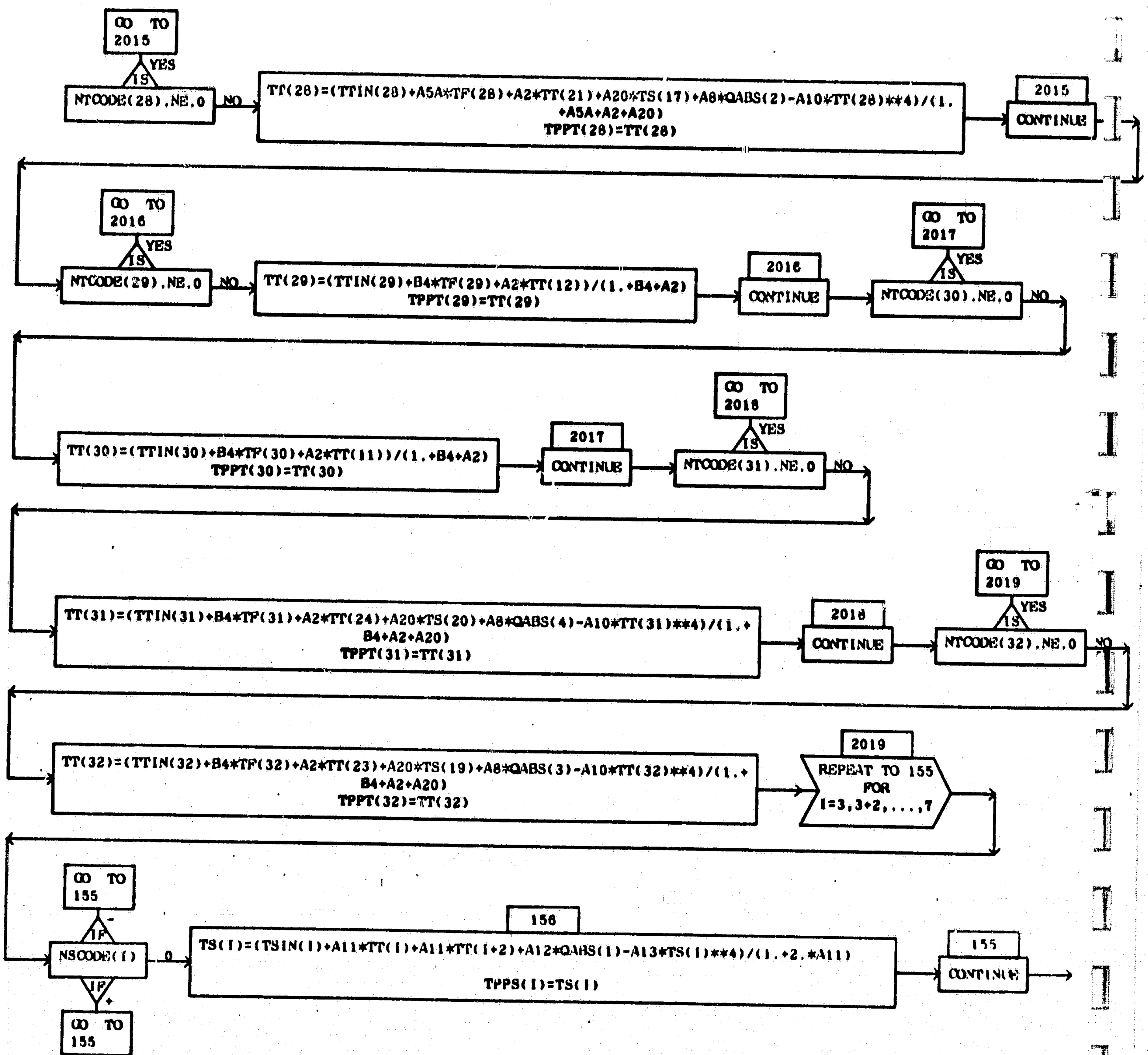

120
TT(5)=(TTIN(5)+AA5*TF(5)+A5*TS(3)+A5*TS(5)+A8*QABS(1)-A10*TT(5)**4)/(1.+AA5+2.
*A5)
TPPT(5)=TT(5)
119
CONTINUE
NTCODE(6)
IF
-
+
0
GO TO
121
GO TO
121
122
TT(6)=(TTIN(6)+A5A*TF(6)+A5*TS(4)+A5*TS(6)+A8*QABS(2)-A10*TT(6)**4)/(1.+A5A+2.
*A5)
TPPT(6)=TT(6)
121
CONTINUE
NTCODE(7)
GO TO
123
GO TO
123
124
TT(7)=(TTIN(7)+AA5*TF(7)+A5*TS(5)+A5*TS(7)+A8*QABS(1)-A10*TT(7)**4)/(1.+AA5+2.
*A5)
TPPT(7)=TT(7)
123
CONTINUE
NTCODE(8)
GO TO
125
GO TO
125
126
TT(8)=(TTIN(8)+A5A*TF(8)+A5*TS(6)+A5*TS(8)+A8*QABS(2)-A10*TT(8)**4)/(1.+A5A+2.
*A5)
TPPT(8)=TT(8)
125
CONTINUE
NTCODE(9)
GO TO
127
GO TO
127

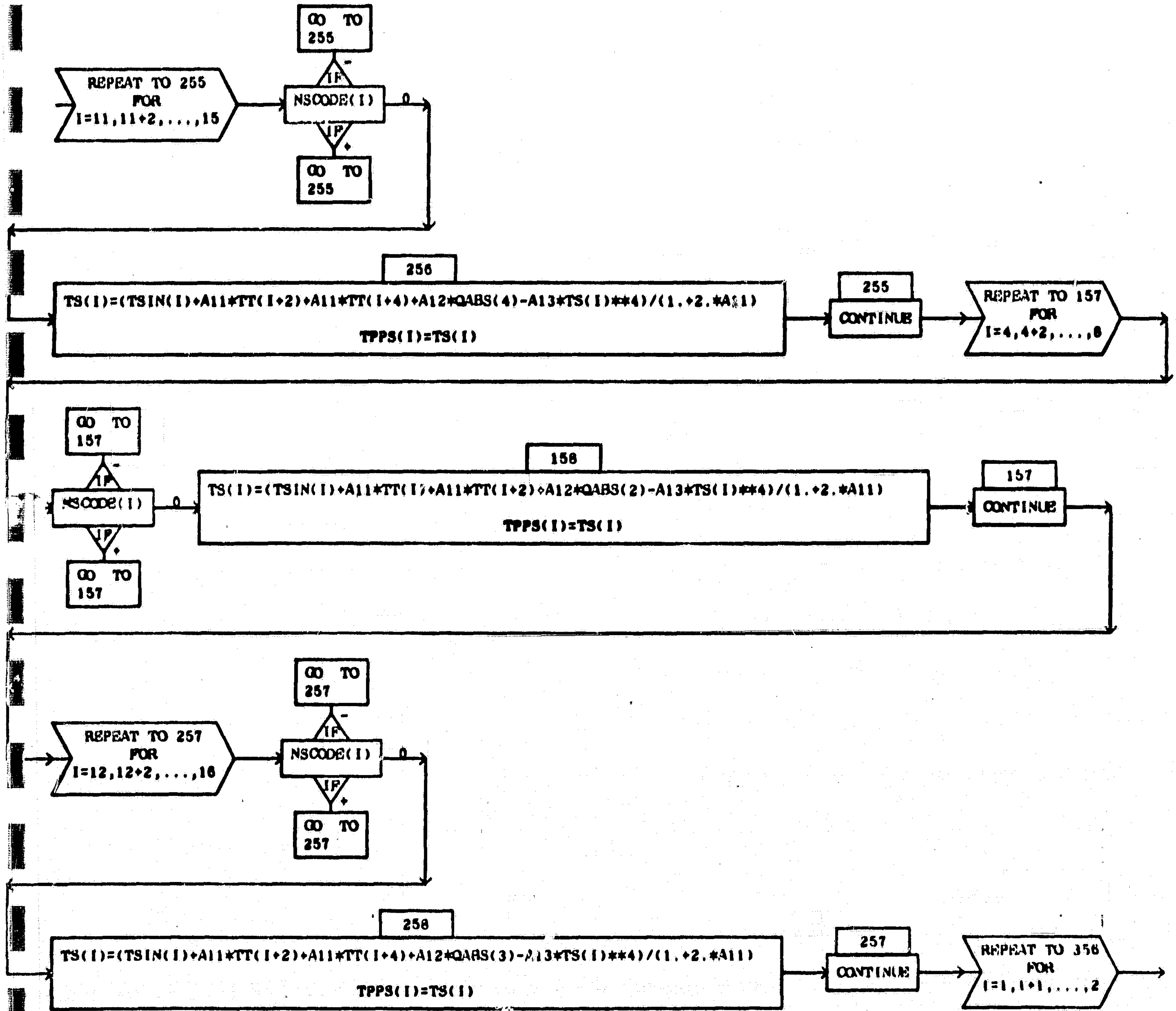

128
TT(9)=(TTIN(9)+A14*TF(9)+A15*TS(7)+A7*QABS(1)-A9*TT(9)**4)/(1.+A14+A15)
TPPT(9)=TT(9)
127
CONTINUE
NTCODE(10)
IF
-
+
0
GO TO
129
GO TO
129
130
TT(10)=(TTIN(10)+A16*TF(10)+A15*TS(8)+A7*QABS(2)-A9*TT(10)**4)/(1.+A16+A15)
TPPT(10)=TT(10)
129
CONTINUE
NTCODE(11)
GO TO
131
GO TO
131
132
TT(11)=(TTIN(11)+A14*TF(11)+A15*TS(9)+A2*TT(30)+A7*QABS(4)-A9*TT(11)**4)/(1.+A
14+A15+A2)
TPPT(11)=TT(11)
131
CONTINUE
NTCODE(12)
GO TO
133
GO TO
133
134
TT(12)=(TTIN(12)+A16*TF(12)+A15*TS(10)+A2*TT(29)+A7*QABS(3)-A9*TT(12)**4)/(1.+
A16+A15+A2)
TPPT(12)=TT(12)
133
CONTINUE
NTCODE(13)
GO TO
135
GO TO
135

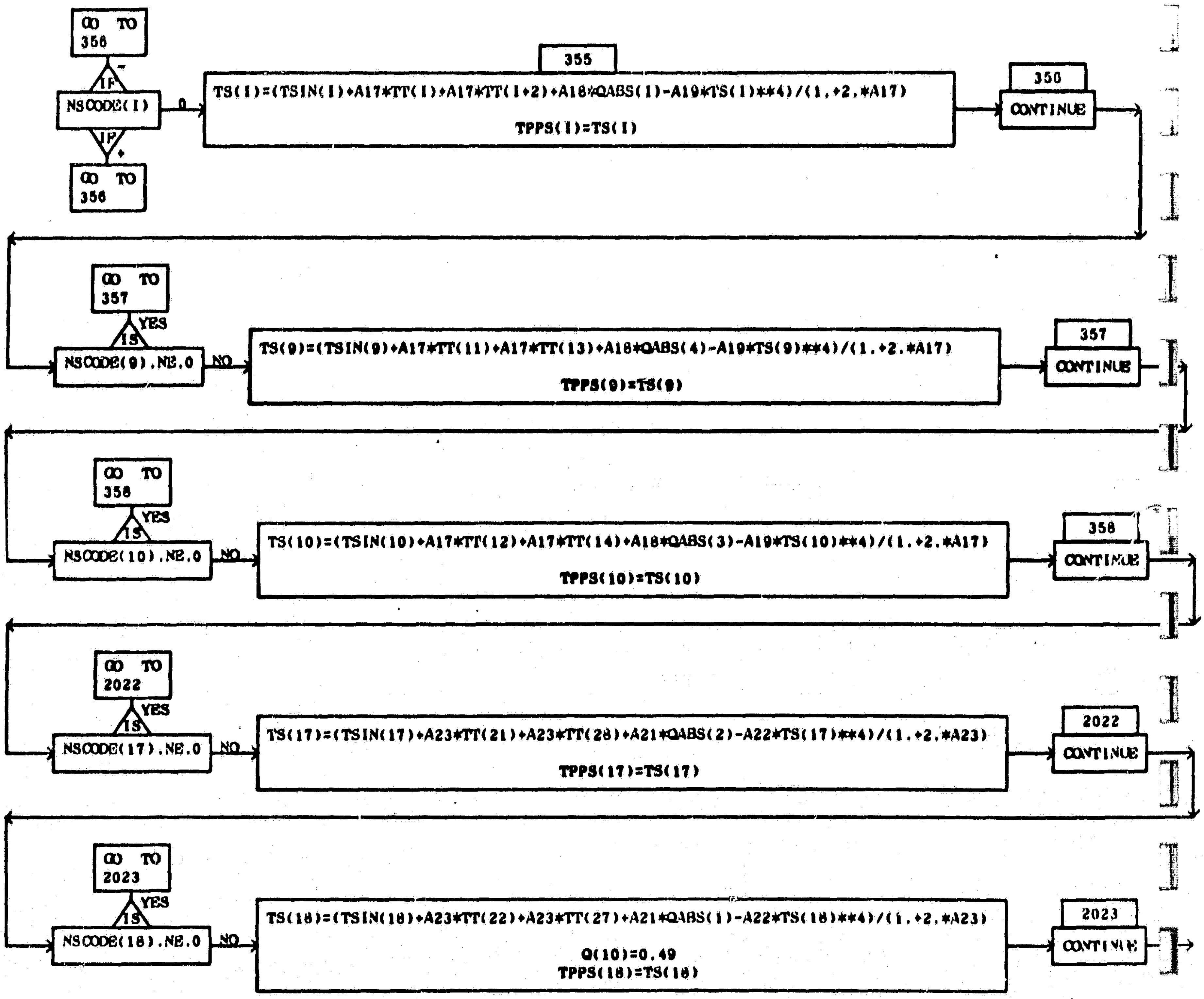

136
TT(13)=(TTIN(13)+AA6*TF(13)+A5*TS(9)+A5*TS(11)+A8*QABS(4)-A10*TT(13)**4)/(1.+A
A6+2.*A5)
TPPT(13)=TT(13)
135
CONTINUE
NTCODE(14)
IF
GO TO 137
GO TO 137
0
138
TT(14)=(TTIN(14)+A5A*TF(14)+A5*TS(10)+A5*TS(12)+A8*QABS(3)-A10*TT(14)**4)/(1.+
A5A+2.*A5)
TPPT(14)=TT(14)
137
CONTINUE
NTCODE(15)
GO TO 139
GO TO 139
140
TT(15)=(TTIN(15)+AA6*TF(15)+A5*TS(11)+A5*TS(13)+A8*QABS(4)-A10*TT(15)**4)/(1.+
AA6+2.*A5)
TPPT(15)=TT(15)
139
CONTINUE
NTCODE(16)
GO TO 141
GO TO 141
142
TT(16)=(TTIN(16)+A5A*TF(16)+A5*TS(12)+A5*TS(14)+A8*QABS(3)-A10*TT(16)**4)/(1.+
A5A+2.*A5)
TPPT(16)=TT(16)
141
CONTINUE
NTCODE(17)
GO TO 143
GO TO 143

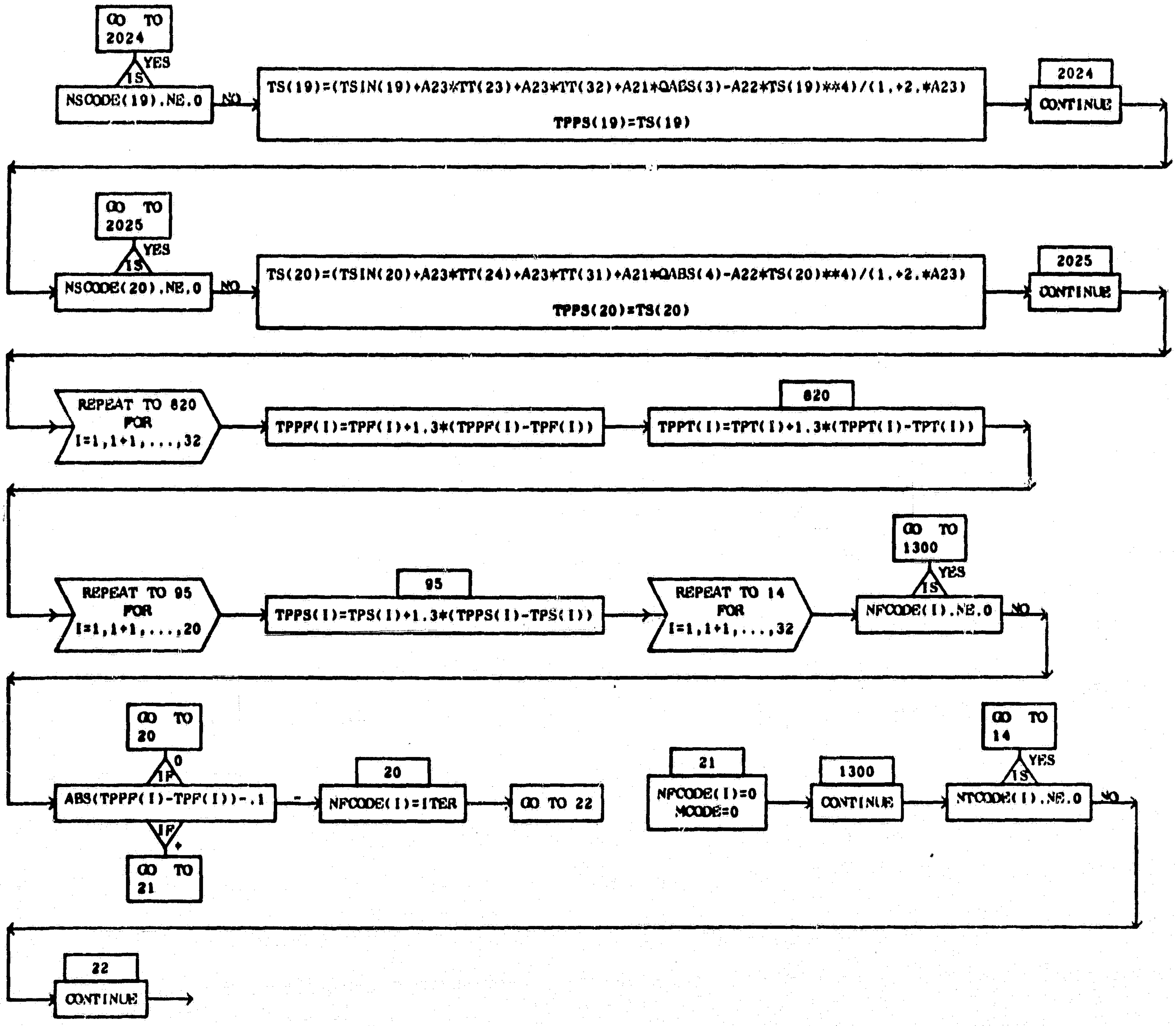

144
TT(17)=(TTIN(17)+AA6*TF(17)+A5*TS(13)+A5*TS(15)+A8*QABS(4)-A10*TT(17)**4)/(1.+AA6+2.*A5)
TPPT(17)=TT(17)
143
CONTINUE
IF
NTCODE(18)
GO TO 145
GO TO 145
146
TT(18)=(TTIN(18)+A5A*TF(18)+A5*TS(14)+A5*TS(16)+A8*QABS(3)-A10*TT(18)**4)/(1.+A5A+2.*A5)
TPPT(18)=TT(18)
145
CONTINUE
IF
NTCODE(19)
GO TO 147
GO TO 147
148
TT(19)=(TTIN(19)+A14*TF(19)+A15*TS(15)+A7*QABS(4)-A9*TT(19)**4)/(1.+A14+A15)
TPPT(19)=TT(19)
147
CONTINUE
IF
NTCODE(20)
GO TO 149
GO TO 149
150
TT(20)=(TTIN(20)+A16*TF(20)+A15*TS(16)+A7*QABS(3)-A9*TT(20)**4)/(1.+A16+A15)
TPPT(20)=TT(20)
149
CONTINUE
IS
NTCODE(21).NE.0
YES
GO TO 2008
TT(21)=(TTIN(21)+A5A*TF(21)+A20*TS(17)+A2*TT(28)+A8*QABS(2)-A10*TT(21)**4)/(1.+A5A+A20+A2)
TPPT(21)=TT(21)
2008
CONTINUE


GO TO 2009
YES
IS
NTCODE(22).NE.0
NO
TT(22)=(TTIN(22)+A5A*TF(22)+A20*TS(18)+A2*TT(27)+A8*QABS(1)-A10*TT(22)**4)/(1.
+A5A+A20+A2)
TPPT(22)=TT(22)
2009
CONTINUE
GO TO 2010
YES
IS
NTCODE(23).NE.0
NO
TT(23)=(TTIN(23)+A5A*TF(23)+A20*TS(19)+A2*TT(32)+A8*QABS(3)-A10*TT(23)**4)/(1.
+A5A+A20+A2)
TPPT(23)=TT(23)
2010
CONTINUE
GO TO 2011
YES
IS
NTCODE(24).NE.0
NO
TT(24)=(TTIN(24)+A5A*TF(24)+A20*TS(20)+A2*TT(31)+A8*QABS(4)-A10*TT(24)**4)/(1.
+A5A+A20+A2)
TPPT(24)=TT(24)
2011
CONTINUE
GO TO 2012
YES
IS
NTCODE(25).NE.0
NO
TT(25)=(TTIN(25)+B4*TF(25)+A2*TT(2))/(1.+B4+A2)
TPPT(25)=TT(25)
2012
CONTINUE
GO TO 2013
YES
IS
NTCODE(26).NE.0
NO
TT(26)=(TTIN(26)+B4*TF(26)+A2*TT(1))/(1.+B4+A2)
TPPT(26)=TT(26)
2013
CONTINUE
GO TO 2014
YES
IS
NTCODE(27).NE.0
NO
TT(27)=(TTIN(27)+B4*TF(27)+A2*TT(22)+A20*TS(18)+A8*QABS(1)-A10*TT(27)**4)/(1.+
B4+A2+A20)
TPPT(27)=TT(27)
2014
CONTINUE

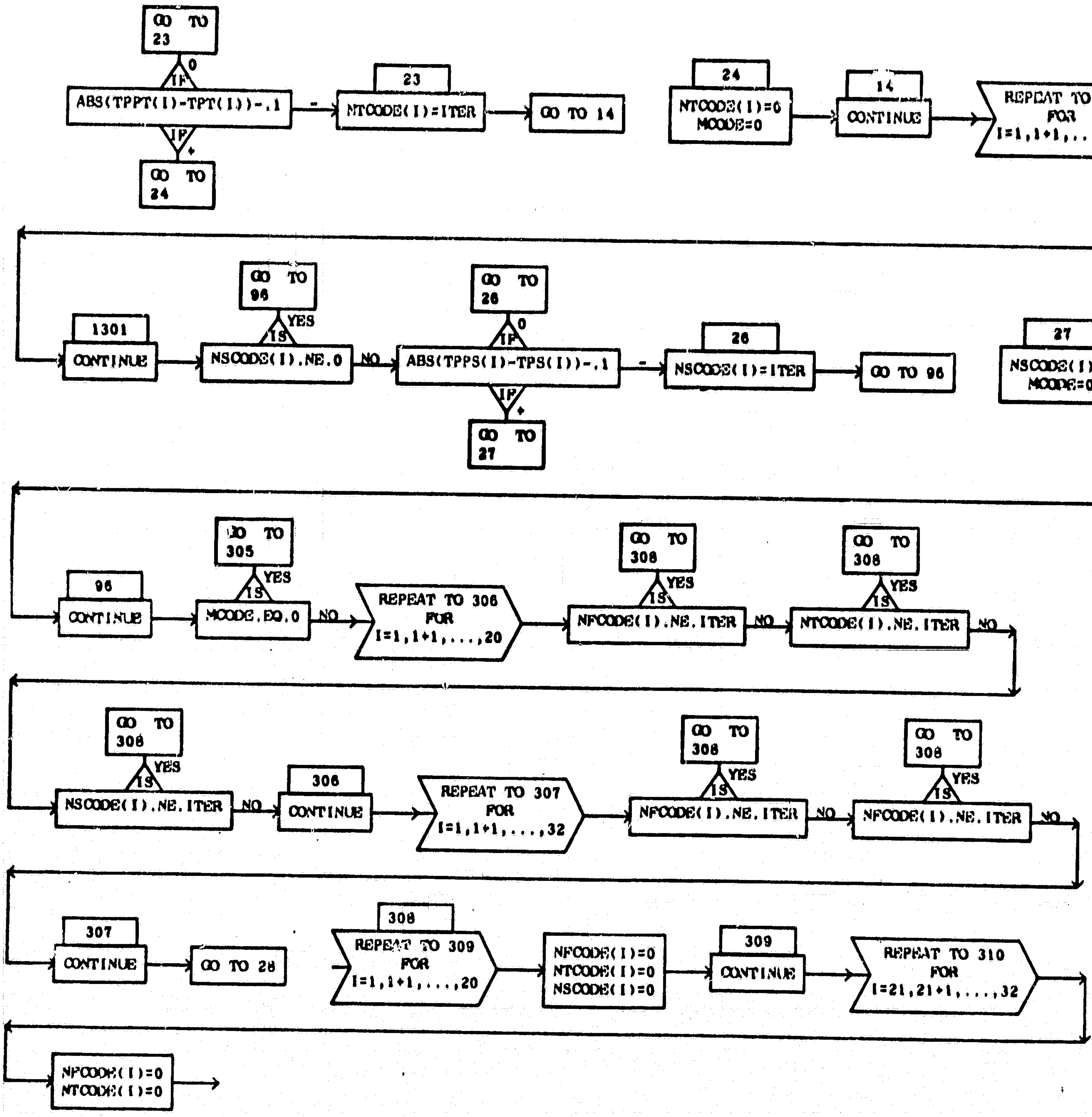

GO TO 2015
YES
IS
NTCODE(28).NE.0
NO
TT(28)=(TTIN(28)+A5A*TF(28)+A2*TT(21)+A20*TS(17)+A8*QABS(2)-A10*TT(28)**4)/(1.
+A5A+A2+A20)
TPPT(28)=TT(28)
2015
CONTINUE
GO TO 2016
YES
IS
NTCODE(29).NE.0
NO
TT(29)=(TTIN(29)+B4*TF(29)+A2*TT(12))/(1.+B4+A2)
TPPT(29)=TT(29)
2016
CONTINUE
GO TO 2017
YES
IS
NTCODE(30).NE.0
NO
TT(30)=(TTIN(30)+B4*TF(30)+A2*TT(11))/(1.+B4+A2)
TPPT(30)=TT(30)
2017
CONTINUE
GO TO 2018
YES
IS
NTCODE(31).NE.0
NO
TT(31)=(TTIN(31)+B4*TF(31)+A2*TT(24)+A20*TS(20)+A8*QABS(4)-A10*TT(31)**4)/(1.+
B4+A2+A20)
TPPT(31)=TT(31)
2018
CONTINUE
GO TO 2019
YES
IS
NTCODE(32).NE.0
NO
TT(32)=(TTIN(32)+B4*TF(32)+A2*TT(23)+A20*TS(19)+A8*QABS(3)-A10*TT(32)**4)/(1.+
B4+A2+A20)
TPPT(32)=TT(32)
2019
REPEAT TO 155
FOR
I=3,3+2,...,7
GO TO 155
-
IF
NSCODE(I)
0
IF
+
GO TO 155
156
TS(I)=(TSIN(I)+A11*TT(I)+A11*TT(I+2)+A12*QABS(I)-A13*TS(I)**4)/(1.+2.*A11)
TPPS(I)=TS(I)
155
CONTINUE


GO TO 255
REPEAT TO 255 FOR I=11,11+2,...,15
IF
NSCODE(I)
0
IF
-
+
GO TO 255
256
TS(I)=(TSIN(I)+A11*TT(I+2)+A11*TT(I+4)+A12*QABS(4)-A13*TS(I)**4)/(1.+2.*A11)
TPPS(I)=TS(I)
255
CONTINUE
REPEAT TO 157 FOR I=4,4+2,...,8
GO TO 157
NSCODE(I)
0
GO TO 157
158
TS(I)=(TSIN(I)+A11*TT(I)+A11*TT(I+2)+A12*QABS(2)-A13*TS(I)**4)/(1.+2.*A11)
TPPS(I)=TS(I)
157
CONTINUE
GO TO 257
REPEAT TO 257 FOR I=12,12+2,...,16
NSCODE(I)
0
GO TO 257
258
TS(I)=(TSIN(I)+A11*TT(I+2)+A11*TT(I+4)+A12*QABS(3)-A13*TS(I)**4)/(1.+2.*A11)
TPPS(I)=TS(I)
257
CONTINUE
REPEAT TO 358 FOR I=1,1+1,...,2

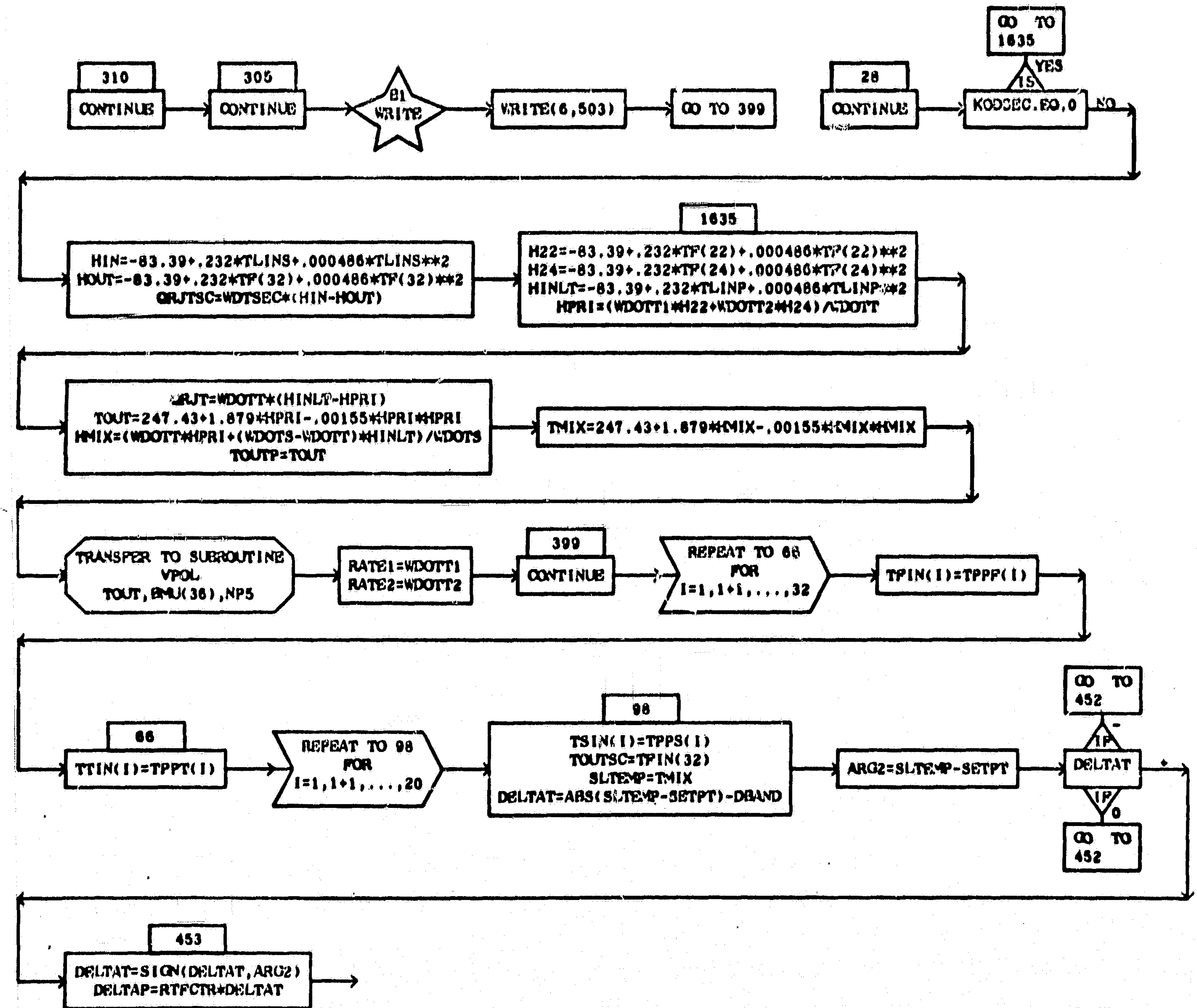

GO TO 356
IF
NSCODE(I)
IF
GO TO 356
0
355
TS(I)=(TSIN(I)+A17*TT(I)+A17*TT(I+2)+A18*QABS(I)-A19*TS(I)**4)/(1.+2.*A17)
TPPS(I)=TS(I)
356
CONTINUE
GO TO 357
YES
IS
NSCODE(9).NE.0
NO
TS(9)=(TSIN(9)+A17*TT(11)+A17*TT(13)+A18*QABS(4)-A19*TS(9)**4)/(1.+2.*A17)
TPPS(9)=TS(9)
357
CONTINUE
GO TO 358
YES
IS
NSCODE(10).NE.0
NO
TS(10)=(TSIN(10)+A17*TT(12)+A17*TT(14)+A18*QABS(3)-A19*TS(10)**4)/(1.+2.*A17)
TPPS(10)=TS(10)
358
CONTINUE
GO TO 2022
YES
IS
NSCODE(17).NE.0
NO
TS(17)=(TSIN(17)+A23*TT(21)+A23*TT(28)+A21*QABS(2)-A22*TS(17)**4)/(1.+2.*A23)
TPPS(17)=TS(17)
2022
CONTINUE
GO TO 2023
YES
IS
NSCODE(18).NE.0
NO
TS(18)=(TSIN(18)+A23*TT(22)+A23*TT(27)+A21*QABS(1)-A22*TS(18)**4)/(1.+2.*A23)
Q(10)=0.49
TPPS(18)=TS(18)
2023
CONTINUE

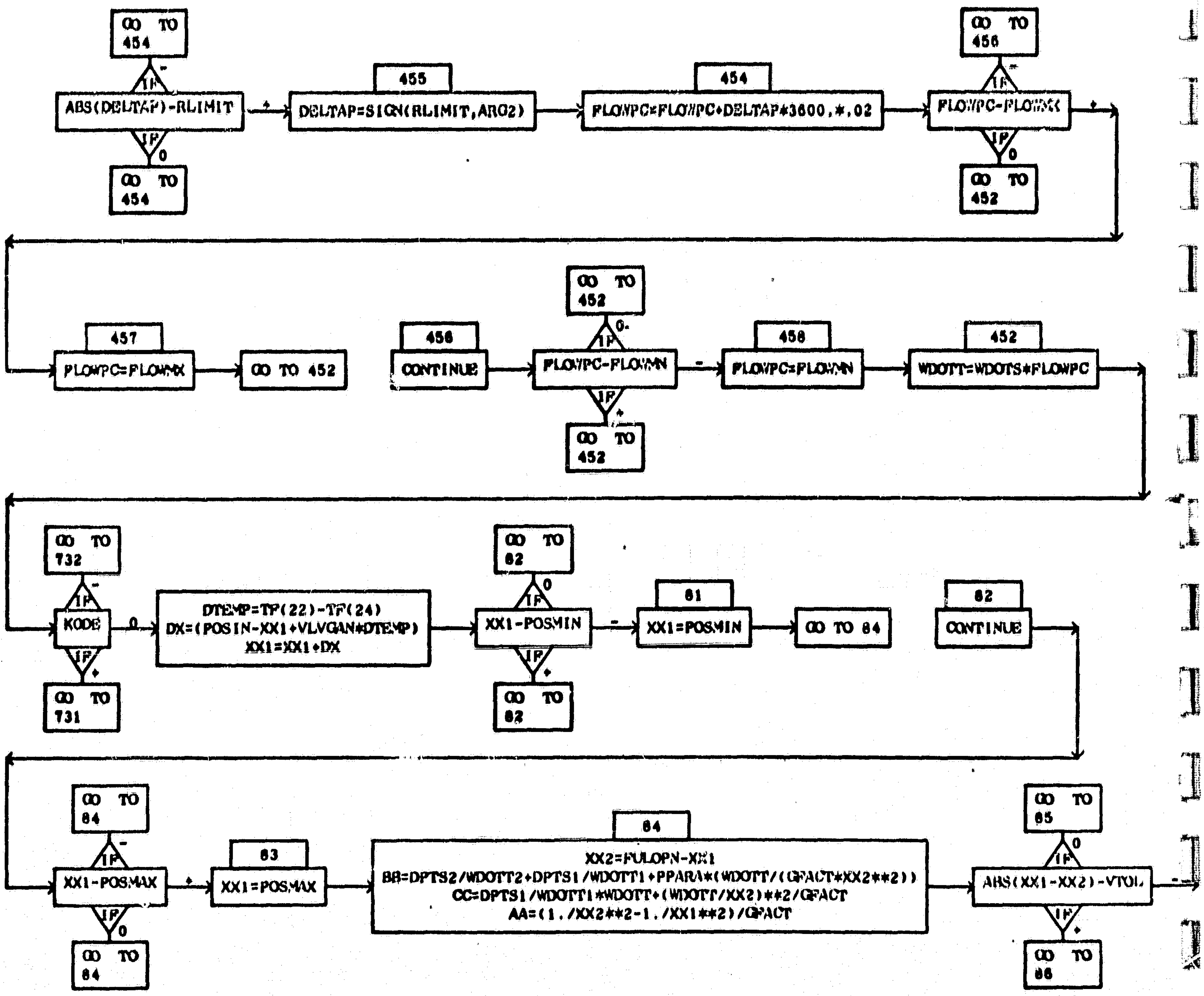


GO TO 2024
YES
IS
NSCODE(19).NE.0
NO
TS(19)=(TSIN(19)+A23*TT(23)+A23*TT(32)+A21*QABS(3)-A22*TS(19)**4)/(1.+2.*A23)
TPPS(19)=TS(19)
2024
CONTINUE
GO TO 2025
YES
IS
NSCODE(20).NE.0
NO
TS(20)=(TSIN(20)+A23*TT(24)+A23*TT(31)+A21*QABS(4)-A22*TS(20)**4)/(1.+2.*A23)
TPPS(20)=TS(20)
2025
CONTINUE
REPEAT TO 820 FOR I=1,1+1,...,32
TPPF(I)=TPF(I)+1.3*(TPPF(I)-TPF(I))
820
TPPT(I)=TPT(I)+1.3*(TPPT(I)-TPT(I))
REPEAT TO 95 FOR I=1,1+1,...,20
95
TPPS(I)=TPS(I)+1.3*(TPPS(I)-TPS(I))
REPEAT TO 14 FOR I=1,1+1,...,32
GO TO 1300
YES
IS
NFCODE(I).NE.0
NO
GO TO 20
IF 0
ABS(TPPF(I)-TPF(I))-.1
IF +
GO TO 21
-
20
NFCODE(I)=ITER
GO TO 22
21
NFCODE(I)=0
MCODE=0
1300
CONTINUE
GO TO 14
YES
IS
NTCODE(I).NE.0
NO
22
CONTINUE

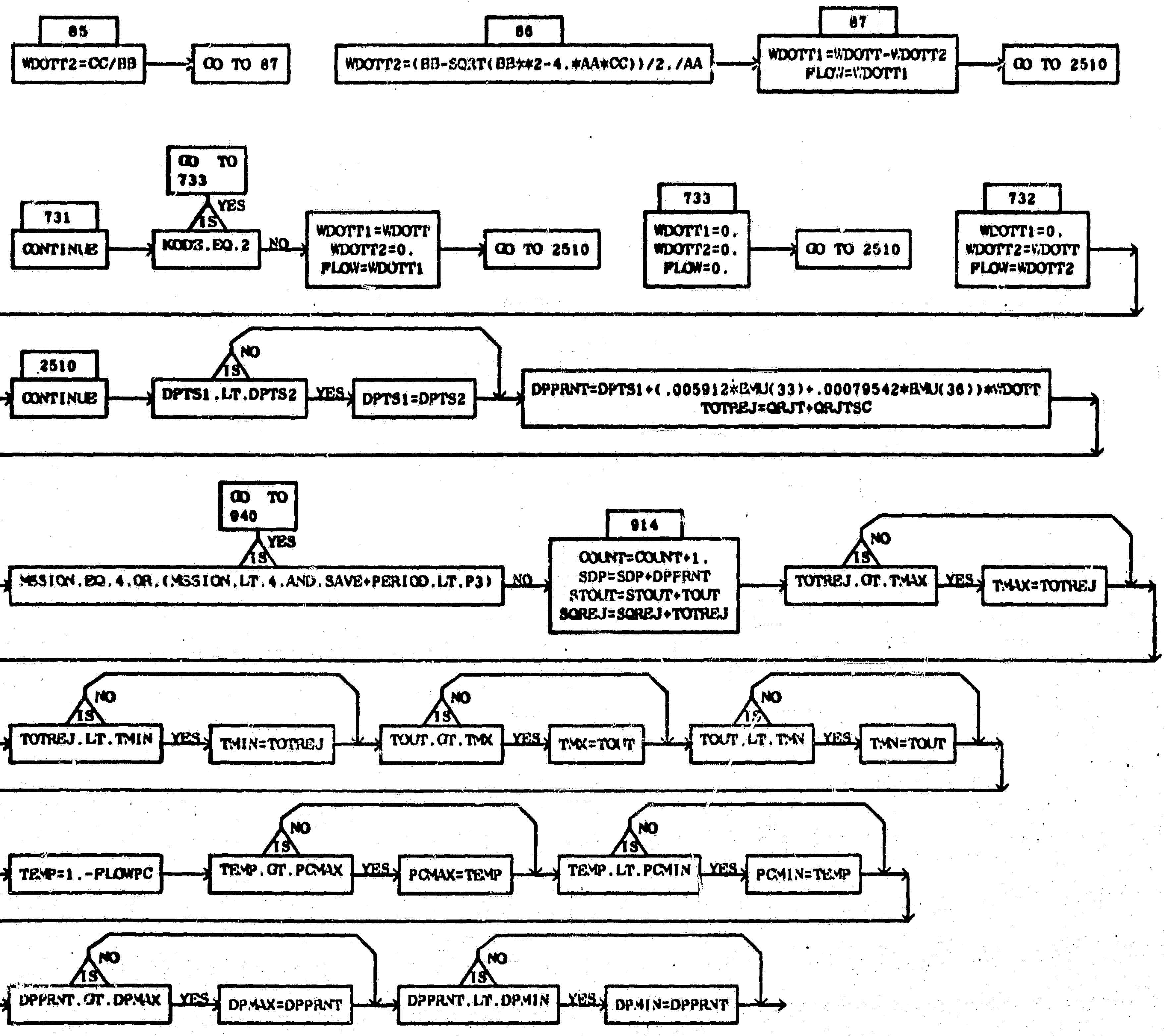


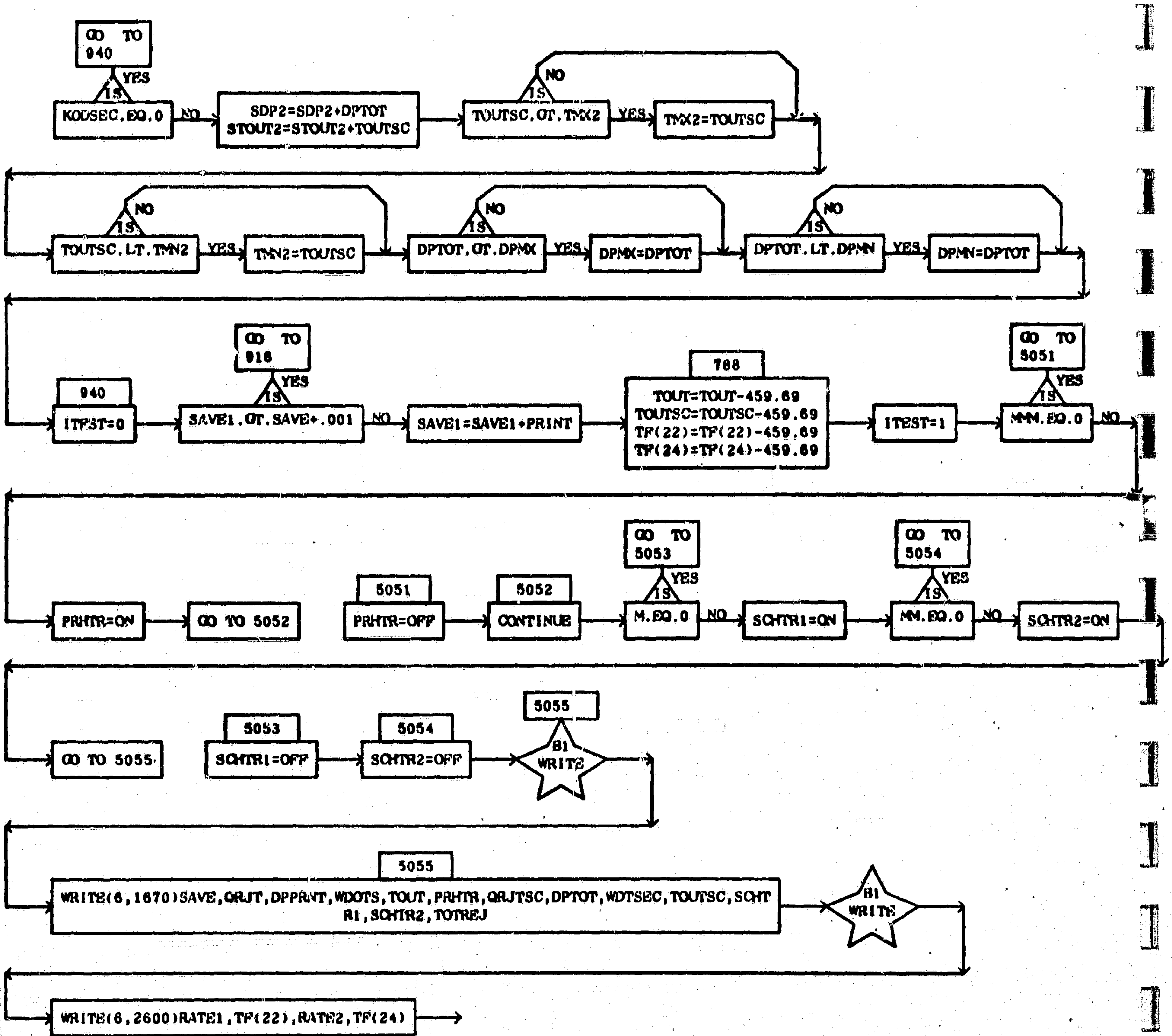
GO TO 23
ABS(TPPT(I)-TPT(I))-.1
GO TO 24
23
NTCODE(I)=ITER
GO TO 14
24
NTCODE(I)=0
MCODE=0
14
CONTINUE
REPEAT TO 96 FOR I=1,1+1,...,20
1301
CONTINUE
GO TO 96
NSCODE(I).NE.0
GO TO 26
ABS(TPPS(I)-TPS(I))-.1
GO TO 27
26
NSCODE(I)=ITER
GO TO 96
27
NSCODE(I)=0
MCODE=0
96
CONTINUE
GO TO 305
MCODE.EQ.0
REPEAT TO 306 FOR I=1,1+1,...,20
GO TO 308
NFCODE(I).NE.ITER
GO TO 308
NTCODE(I).NE.ITER
GO TO 308
NSCODE(I).NE.ITER
306
CONTINUE
REPEAT TO 307 FOR I=1,1+1,...,32
GO TO 308
NFCODE(I).NE.ITER
GO TO 308
NFCODE(I).NE.ITER
307
CONTINUE
GO TO 28
308
REPEAT TO 309 FOR I=1,1+1,...,20
NFCODE(I)=0
NTCODE(I)=0
NSCODE(I)=0
309
CONTINUE
REPEAT TO 310 FOR I=21,21+1,...,32
NFCODE(I)=0
NTCODE(I)=0

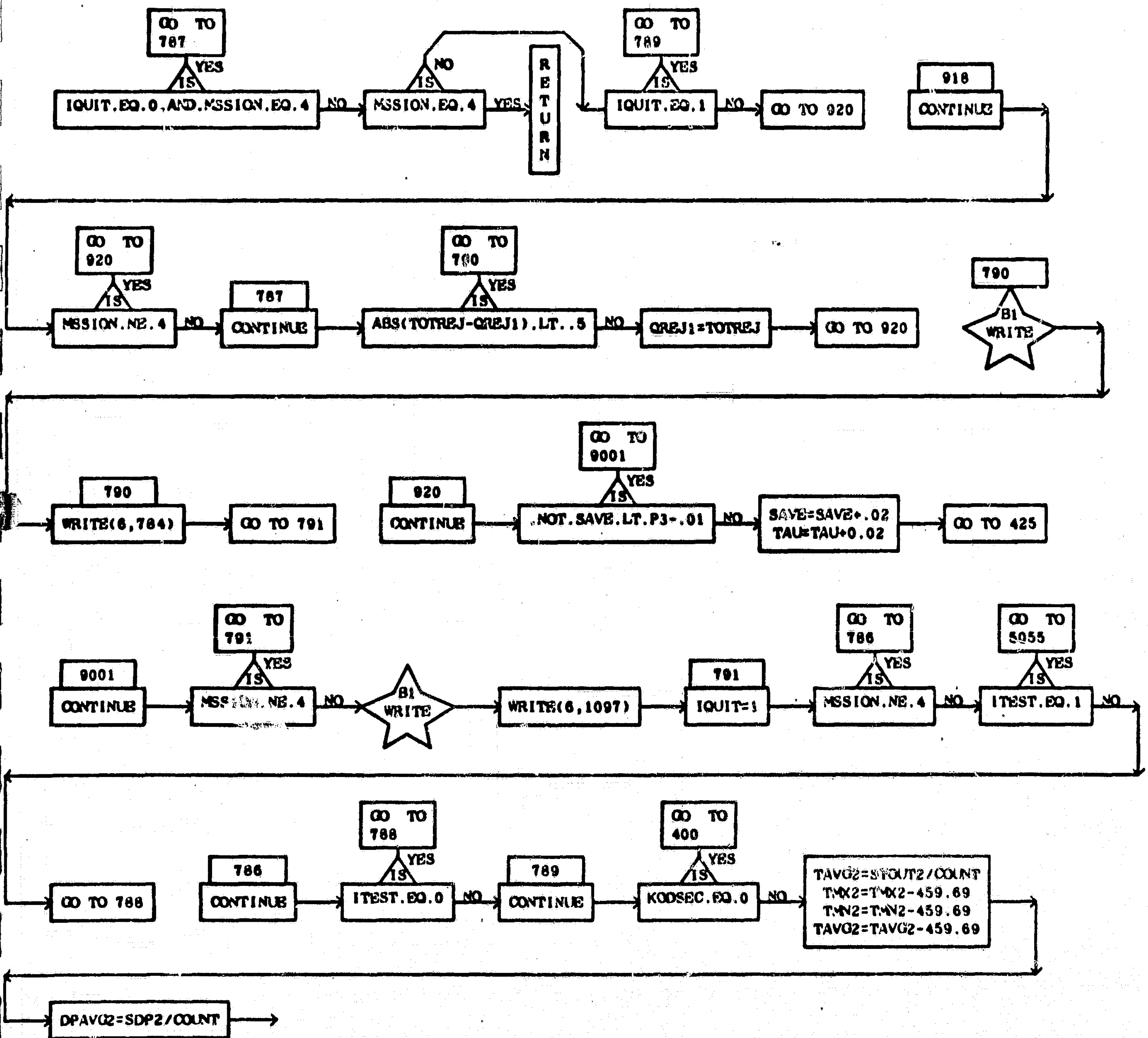

GO TO 1635
YES
IS
310
CONTINUE
305
CONTINUE
81 WRITE
WRITE(6,503)
GO TO 399
28
CONTINUE
KODSEC.EQ.0
NO
HIN=-83.39+.232*TLINS+.000486*TLINS**2
HOUT=-83.39+.232*TF(32)+.000486*TF(32)**2
QRJTSC=WDTSEC*(HIN-HOUT)
1635
H22=-83.39+.232*TF(22)+.000486*TF(22)**2
H24=-83.39+.232*TF(24)+.000486*TF(24)**2
HINLT=-83.39+.232*TLINP+.000486*TLINP**2
HPRI=(WDOTT1*H22+WDOTT2*H24)/WDOTT
QRJT=WDOTT*(HINLT-HPRI)
TOUT=247.43+1.879*HPRI-.00155*HPRI*HPRI
HMIX=(WDOTT*HPRI+(WDOTS-WDOTT)*HINLT)/WDOTS
TOUTP=TOUT
TMIX=247.43+1.879*HMIX-.00155*HMIX*HMIX
TRANSFER TO SUBROUTINE VPOL
TOUT,EMU(36),NP5
RATE1=WDOTT1
RATE2=WDOTT2
399
CONTINUE
REPEAT TO 66 FOR I=1,1+1,...,32
TFIN(I)=TPPF(I)
66
TTIN(I)=TPPT(I)
REPEAT TO 98 FOR I=1,1+1,...,20
98
TSIN(I)=TPPS(I)
TOUTSC=TFIN(32)
SLTEMP=TMIX
DELTAT=ABS(SLTEMP-SETPT)-DBAND
ARG2=SLTEMP-SETPT
GO TO 452
-
IF
DELTAT
IF
0
GO TO 452
+
453
DELTAT=SIGN(DELTAT,ARG2)
DELTAP=RTFCTR*DELTAT

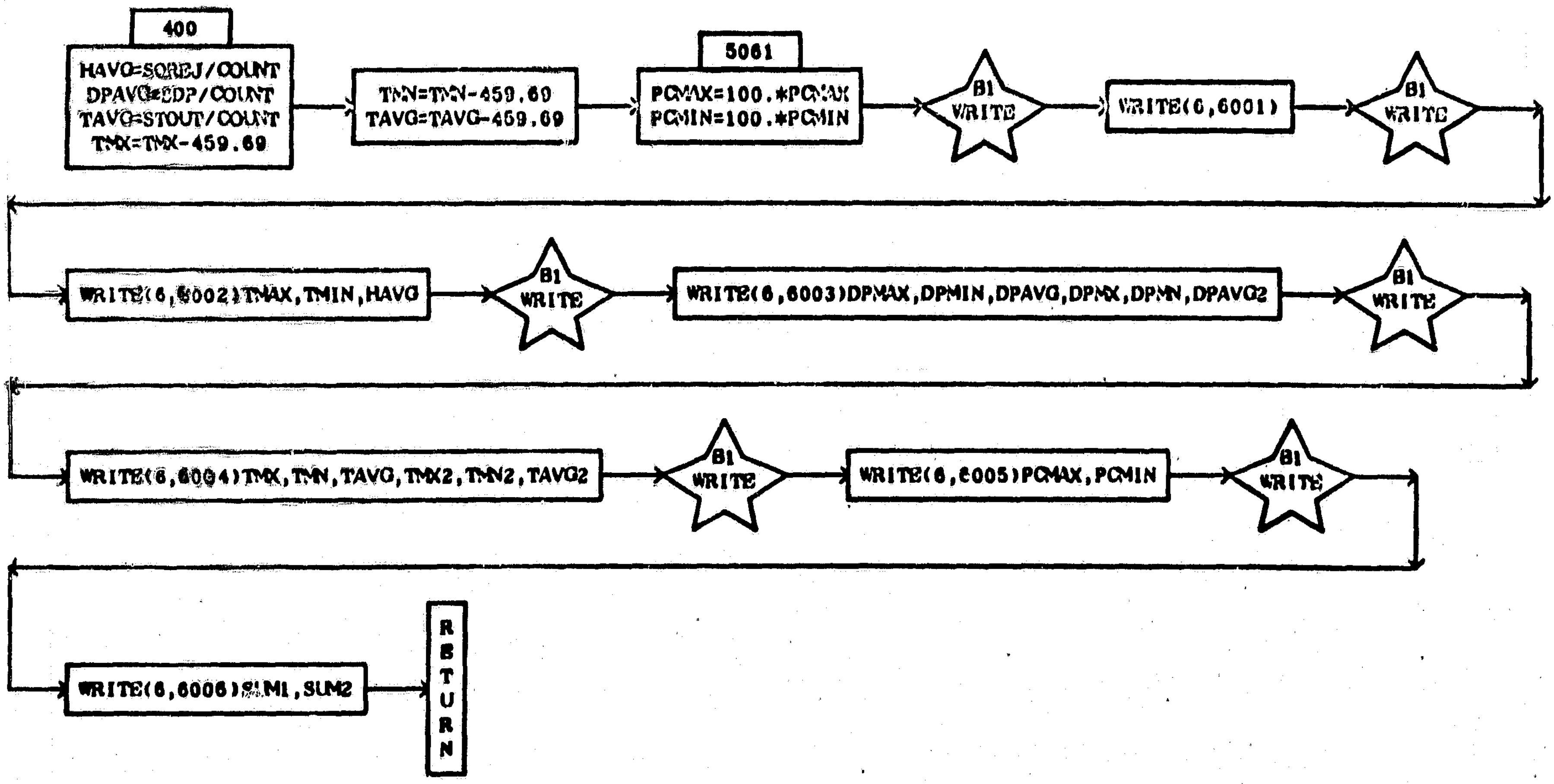


GO TO 454
ABS(DELTAP)-RLIMIT
IF
GO TO 454
455
DELTAP=SIGN(RLIMIT,ARG2)
454
FLOWPC=FLOWPC+DELTAP*3600.*.02
GO TO 456
FLOWPC-FLOWMX
GO TO 452
457
FLOWPC=FLOWMX
GO TO 452
456
CONTINUE
GO TO 452
FLOWPC-FLOWMN
GO TO 452
458
FLOWPC=FLOWMN
452
WDOTT=WDOTS*FLOWPC
GO TO 732
KODE
GO TO 731
DTEMP=TF(22)-TF(24)
DX=(POSIN-XX1+VLVGAN*DTEMP)
XX1=XX1+DX
GO TO 82
XX1-POSMIN
GO TO 82
81
XX1=POSMIN
GO TO 84
82
CONTINUE
GO TO 84
XX1-POSMAX
GO TO 84
83
XX1=POSMAX
84
XX2=FULOPN-XX1
BB=DPTS2/WDOTT2+DPTS1/WDOTT1+PPARA*(WDOTT/(GFACT*XX2**2))
CC=DPTS1/WDOTT1*WDOTT+(WDOTT/XX2)**2/GFACT
AA=(1./XX2**2-1./XX1**2)/GFACT
GO TO 85
ABS(XX1-XX2)-VTOL
GO TO 86


85
WDOTT2=CC/BB
GO TO 87
86
WDOTT2=(BB-SQRT(BB**2-4.*AA*CC))/2./AA
87
WDOTT1=WDOTT-WDOTT2
FLOW=WDOTT1
GO TO 2510
GO TO 733
YES
IS
731
CONTINUE
KODE.EQ.2
NO
WDOTT1=WDOTT
WDOTT2=0.
FLOW=WDOTT1
GO TO 2510
733
WDOTT1=0.
WDOTT2=0.
FLOW=0.
GO TO 2510
732
WDOTT1=0.
WDOTT2=WDOTT
FLOW=WDOTT2
2510
CONTINUE
NO
IS
DPTS1.LT.DPTS2
YES
DPTS1=DPTS2
DPPRNT=DPTS1+(.005912*EMU(33)+.00079542*EMU(36))*WDOTT
TOTREJ=QRJT+QRJTSC
GO TO 940
YES
IS
MISSION.EQ.4.OR.(MISSION.LT.4.AND.SAVE+PERIOD.LT.P3)
NO
914
COUNT=COUNT+1.
SDP=SDP+DPPRNT
STOUT=STOUT+TOUT
SQREJ=SQREJ+TOTREJ
NO
IS
TOTREJ.GT.TMAX
YES
TMAX=TOTREJ
TOTREJ.LT.TMIN
TMIN=TOTREJ
TOUT.GT.TMX
TMX=TOUT
TOUT.LT.TMN
TMN=TOUT
TEMP=1.-FLOWPC
TEMP.GT.PCMAX
PCMAX=TEMP
TEMP.LT.PCMIN
PCMIN=TEMP
DPPRNT.GT.DPMAX
DPMAX=DPPRNT
DPPRNT.LT.DPMIN
DPMIN=DPPRNT


GO TO 940
YES
IS
KODSEC.EQ.0
NO
SDP2=SDP2+DPTOT
STOUT2=STOUT2+TOUTSC
NO
IS
TOUTSC.GT.TMX2
YES
TMX2=TOUTSC
NO
IS
TOUTSC.LT.TMN2
YES
TMN2=TOUTSC
NO
IS
DPTOT.GT.DPMX
YES
DPMX=DPTOT
NO
IS
DPTOT.LT.DPMN
YES
DPMN=DPTOT
940
ITEST=0
GO TO 916
YES
IS
SAVE1.GT.SAVE+.001
NO
SAVE1=SAVE1+PRINT
788
TOUT=TOUT-459.69
TOUTSC=TOUTSC-459.69
TF(22)=TF(22)-459.69
TF(24)=TF(24)-459.69
ITEST=1
GO TO 5051
YES
IS
MMM.EQ.0
NO
PRHTR=ON
GO TO 5052
5051
PRHTR=OFF
5052
CONTINUE
GO TO 5053
YES
IS
M.EQ.0
NO
SCHTR1=ON
GO TO 5054
YES
IS
MM.EQ.0
NO
SCHTR2=ON
GO TO 5055
5053
SCHTR1=OFF
5054
SCHTR2=OFF
5055
B1
WRITE
5055
WRITE(6,1670)SAVE,QRJT,DPPRNT,WDOTS,TOUT,PRHTR,QRJTSC,DPTOT,WDTSEC,TOUTSC,SCHT
R1,SCHTR2,TOTREJ
B1
WRITE
WRITE(6,2600)RATE1,TF(22),RATE2,TF(24)

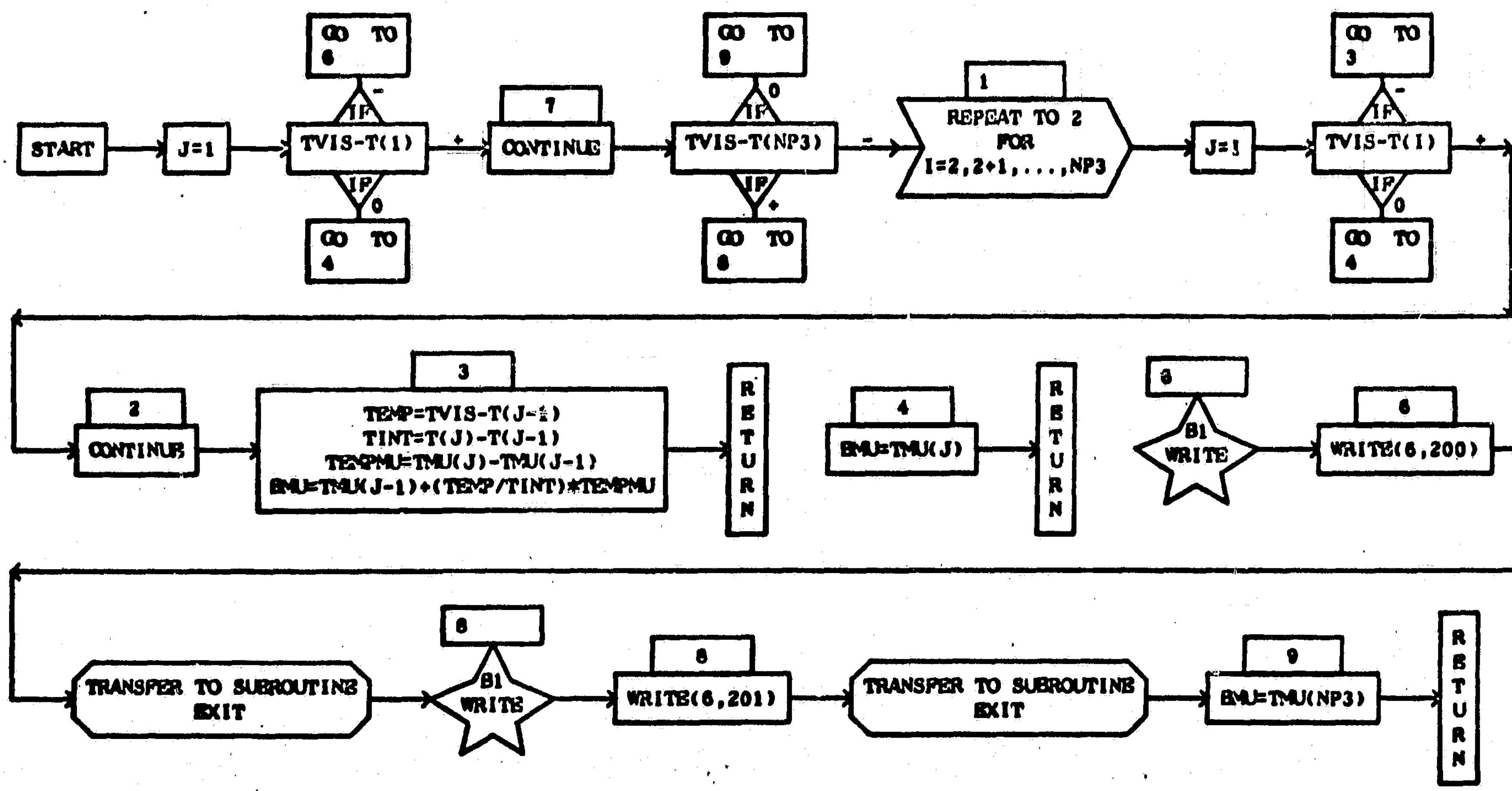

GO TO 787
IQUIT.EQ.0.AND.MSSION.EQ.4
MSSION.EQ.4
RETURN
GO TO 789
IQUIT.EQ.1
GO TO 920
918
CONTINUE
GO TO 920
MSSION.NE.4
787
CONTINUE
ABS(TOTREJ-QREJ1).LT..5
QREJ1=TOTREJ
GO TO 920
790
B1 WRITE
790
WRITE(6,784)
GO TO 791
920
CONTINUE
GO TO 9001
.NOT.SAVE.LT.P3-.01
SAVE=SAVE+.02
TAU=TAU+0.02
GO TO 425
9001
CONTINUE
GO TO 791
MSSION.NE.4
B1 WRITE
WRITE(6,1097)
791
IQUIT=1
GO TO 786
MSSION.NE.4
GO TO 5055
ITEST.EQ.1
GO TO 788
786
CONTINUE
GO TO 788
ITEST.EQ.0
789
CONTINUE
GO TO 400
KODSEC.EQ.0
TMX2=TMX2-459.69
TMN2=TMN2-459.69
TAVG2=TAVG2-459.69
DPAVG2=SDP2/COUNT
IS
YES
NO


400
HAVG=SQREJ/COUNT
DPAVG=SDP/COUNT
TAVG=STOUT/COUNT
TMX=TMX-459.69
TMN=TMN-459.69
TAVG=TAVG-459.69
5061
PCMAX=100.*PCMAX
PCMIN=100.*PCMIN
B1 WRITE
WRITE(6,6001)
B1 WRITE
WRITE(6,6002)TMAX,TMIN,HAVG
B1 WRITE
WRITE(6,6003)DPMAX,DPMIN,DPAVG,DPMX,DPMN,DPAVG2
B1 WRITE
WRITE(6,6004)TMX,TMN,TAVG,TMX2,TMN2,TAVG2
B1 WRITE
WRITE(6,6005)PCMAX,PCMIN
B1 WRITE
WRITE(6,6006)SUM1,SUM2
RETURN

D I M E N S I O N E D   V A R I A B L E S

SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES
T	33	TMU	33						

SUBROUTINE VPOL(TVIS,BMU,NP3)



APPENDIX C

DICTIONARY OF FORTRAN TERMS

AA	Squared coefficient in quadratic equation used to solve proportioning valve flow distribution
AA1	Upstream fluid temperature coefficient, fluid nodes 1, 3, 5, 7 and 9
AA2	Upstream fluid temperature coefficient; fluid nodes 11, 13, 15, 17 and 19
AA3	Fluid to tube convection temperature coefficient, fluid nodes 1, 3, 5, 7 and 9
AA5	Tube to fluid convection temperature coefficient; tube nodes 3, 5, 7, 21 and 22
AA6	Tube to fluid convection temperature coefficient; tube nodes 13, 15 and 17
AK	Pressure drop divided by flow; $\Delta P/\dot{w}$
AKIL	Pressure drop from proportioning valve to panel 3-4 inlet manifold divided by flow rate
AKIS	Pressure drop from proportioning valve to panel 1-2 inlet manifold divided by flow rate
AKS1	Pressure drop from selective stagnation panel 1-2 outlet manifold to series panel divided by flow rate
AKS2	Pressure drop from selective stagnation panel 3-4 outlet manifold to series panel divided by flow rate
AKT21	Pressure drop in fluid node 21 divided by flow rate
AKT22	Pressure drop in fluid node 22 divided by flow rate
AKT23	Pressure drop in fluid node 23 divided by flow rate
AKT24	Pressure drop in fluid node 24 divided by flow rate
ALPHA	Curve title
ARG2	Difference between radiator mixed outlet temperature and bypass valve set point
A10	Radiation temperature coefficient; tube nodes 3 through 8, 13 through 18 and 21 through 32
A11	Structure to tube conductance temperature coefficient; structure nodes 3 through 8 and 11 through 16

A12	Absorbed heat coefficient; structure nodes 3 through 8 and 11 through 16
A13	Radiation temperature coefficient; structure nodes 3 through 8 and 11 through 16
A14	Tube to fluid convection temperature coefficient; tube nodes 1, 9, 11 and 19
A15	Tube to structure conductance temperature coefficient; tube nodes 1, 2, 9, 10, 11, 12, 19 and 20
A16	Tube to fluid convection temperature coefficient; tube nodes 2, 10, 12 and 20
A17	Structure to tube conductance temperature coefficient; structure nodes 1, 2, 9 and 10
A18	Absorbed heat coefficient; structure nodes 1, 2, 9 and 10
A19	Radiation temperature coefficient; structure nodes 1, 2, 9 and 10
A2	Tube to tube conduction temperature coefficient; tube nodes 1, 2, 11, 12 and 21 through 32
A20	Tube to structure conduction temperature coefficient; tube nodes 21 through 24, 27, 28, 31 and 32
A21	Absorbed heat coefficient; structure nodes 17 through 20
A22	Radiation temperature coefficient; structure nodes 17 through 20
A23	Structure to tube conduction temperature coefficient; structure nodes 17, 18, 19 and 20
A3A	Upstream fluid temperature coefficient, fluid nodes 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20
A5	Tube to structure conductance temperature coefficient, tube nodes 3, 4, 5, 6, 7, 8, 13, 14, 15, 16, 17 and 18
A5A	Tube to fluid convection temperature coefficient; tube nodes 4, 6, 8, 14, 16, 18, 21, 22, 23 and 24
A7	Absorbed heat coefficient; tube nodes 1, 2, 9, 10, 11, 12, 19 and 20
A8	Absorbed heat coefficient; tube nodes 3 through 8, 13 through 18 and 21 through 32

A9	Radiation temperature coefficient; tube nodes 1, 2, 9, 10, 11, 12, 19 and 20
BB	Linear coefficient in quadratic equation used to solve proportioning valve flow distribution
BMU	Radiator fluid viscosity
B1	Upstream fluid temperature coefficient; fluid nodes 25 through 32
B3	Fluid to tube convection temperature coefficient; fluid nodes 25 through 32
B4	Tube to fluid convection temperature coefficient; tube nodes 25, 26, 27, 29, 30, 31 and 32
CC	Constant in quadratic equation used to solve proportioning valve flow distribution
COUNT	Number of calculation intervals
DBAND	Bypass valve deadband
DELTA	Difference between maximum and minimum heat rejection
DELTAP	Bypass valve movement rate
DELTAT	Temperature difference used in calculating bypass valve movement rate
DPKAP	Pressure drop divided by flow rate for secondary system nodes
DPKAPS	Sum of pressure drop divided by flow rate for secondary system nodes
DPPRNT	Total primary system pressure drop
DPT	Pressure drop in individual tubes on the selective stagnation panels
DPTOT	Secondary system total pressure drop
DPTS1	Pressure drop for panel 1-2 loop from proportioning valve to bypass line mix junction
DPTS2	Pressure drop for panel 3-4 loop from proportioning valve to bypass line mix junction
DTEMP	Difference in panel outlet temperatures used to determine proportioning valve position

DX	Change in proportioning valve position
E	Pressure drop coefficient for inlet end of selective stagnation panels
F	Pressure drop coefficient for outlet end of selective stagnation panels
FLOW	Flow rate used in calculating total primary system pressure drop
FLOWMN	Minimum fraction of total flow through the radiator
FLOWMX	Maximum fraction of total flow through the radiator
FLOWPC	Fraction total flow through the radiator as determined by the bypass valve
FULOPN	Proportioning valve maximum possible position from the left
GFACT	Proportioning valve geometry factor
H	Fluid enthapy
HIN	Fluid enthalpy for redundant system inlet
HINLT	Fluid enthalpy for primary system inlet
HMIX	Fluid enthalpy downstream of primary system bypass valve
HOUT	Fluid enthalpy for redundant system outlet
HPRI	Fluid enthalpy upstream of primary system bypass valve
H21	Fluid enthalpy out of selective stagnation panel 1-2
H22	Fluid enthalpy out of series panel 1-2
H23	Fluid entahlpy out of selective stagnation panel 3-4
H24	Fluid enthalpy out of series panel 3-4
ITER	Iteration counter
LAST	Used for curve read in; indicates location of last variable
LTER	Iteration counter
M	On/off code for first stage redundant system inline heater
MCODE	Code which indicates whether or not further iterations are required

MERR	Error code which indicates which curve limits were exceeded
MM	On/off code for second stage redundant system inline heater
MMM	On/off code for primary system inline heater
MSTART	Address of first time point on each curve to be considered during an iteration
MT	Address of first dependent variable on primary system inlet temperature curve to be considered during an iteration
MTSEC	Address of first dependent variable on secondary system inlet temperature curve to be considered during an iteration
MW	Address of first dependent variable on primary system flow rate curve to be considered during an iteration
MWSEC	Address of first dependent variable on secondary system flow rate curve
NEXT	Used for curve read in; indicates location of first variable
NFCODE	Fluid lump code for suspending temperature iteration
NOPTS	Number of points on flow rate and inlet temperature curves
NPTS	Number of points on time dependent curves
NP1	Address of last time point for absorbed heat curve for panel 1
NP2	Address of last time point for absorbed heat curve for panel 2
NP3	Address of last time point for absorbed heat curve for panel 3
NP4	Address of last time point for absorbed heat curve for panel 4
NP5	Number of points on viscosity versus temperature curve
NP5A	Address of last time point for primary system flow rate curve
NP5B	Number of points on primary system flow rate curve
NP6A	Address of last time point for primary system inlet temperature curve
NP6B	Number of points on primary system inlet temperature curve
NP7	Address of last time point for secondary system flow rate curve

NP8	Address of last time point for secondary system inlet temperature curve
NSCODE	Structure lump code for suspending temperature iteration
NTCODE	Tube lump code for suspending temperature iteration
PCBYPS	Flow rate through bypass line
PERIOD	Total mission time
POSIN	Initial proportioning valve position from left
POSMAX	Proportioning valve maximum allowable position from left
POSMIN	Proportioning valve minimum allowable position from left
PPARA	Panel parameter used in proportioning valve calculations
Q	Dependent values for absorbed heat curves
QABS	Absorbed heat for each panel
QRJT	Primary system heat rejection rate
QRJTSC	Redundant system heat rejection rate
RATE1	Flow rate in panel 1-2
RATE2	Flow rate in panel 3-4
RLIMIT	Bypass valve rate limit, fraction bypass per time interval
RTFCTR	Bypass valve rate factor, fraction bypass per time interval per °F
SAVE	Mission time
SAVE1	Print interval indicator
SDP	Sum of system pressure drop
SETPT	Bypass valve control point temperature
SLTEMP	Temperature downstream of bypass valve
SQREJ	Sum of total heat rejection
STOUT	Sum of radiator outlet temperatures
SUM1	Total primary system inline heater heat output

SUM2	Total redundant system inline heater heat output
T	Independent variable for viscosity curve
TAU	Mission time
TEMP	Difference in mission time and time on time-dependent curves used for interpolation
TEMPQ	Difference in adjacent absorbed heat values on absorbed heat curve; used for interpolation
TEMPT	Difference in adjacent inlet temperatures values on primary inlet temperature curve; used for interpolation
TEMPTS	Difference in adjacent inlet temperature values on secondary inlet temperature curve; used for interpolation
TEMPW	Difference in adjacent flow rate values on primary flow rate curve, used for interpolation
TEMPWS	Difference in adjacent flow rate values on secondary flow rate curve; used for interpolation
TF	Fluid lump temperatures
TFA21	Inlet temperature for panel 1-2 series panel
TFA23	Inlet temperature for panel 3-4 series panel
TFIN	Fluid lump temperatures calculated last iteration
TIME	Independent variable for time-dependent curves
TIN	Dependent values for primary system inlet temperature curve
TINLSC	Dependent values for secondary system inlet temperature curve
TINT	Difference in adjacent time values on time dependent curve; used for interpolation
TMIX	Temperature downstream of bypass valve
TMU	Dependent variable for viscosity curve
TOTREJ	Total heat rejection rate for both primary and secondary systems
TOUT	Primary system outlet temperature
TOUTSC	Redundant system outlet temperature

TPF	Used for checking fluid lump temperatures
TPPF	Fluid lump temperatures calculated this iteration
TPPS	Structure lump temperatures calculated this iteration
TPPT	Tube lump temperatures calculated this iteration
TPS	Used for checking structure lump temperatures
TPT	Used for checking tube lump temperatures
TS	Structure lump temperatures
TSIN	Structure lump temperatures calculated last iteration
TT	Tube lump temperatures
TTIME	Time for mission 4
TTIN	Tube lump temperatures calculated last iteration
VLVGAN	Proportioning valve gain
VTOL	Proportioning valve null position tolerance
WDOT	Flow rate in a tube
WDOTSC	Dependent values for secondary system flow rate curve
WDOTT	Primary system flow through radiator panels
WDOTT1	Primary system flow rate to panel 1-2
WDOTT2	Primary system flow rate to panel 3-4
WDTTOT	Dependent values for primary system flow rate curve
XX1	Proportioning valve position from left
XX2	Proportioning valve position from right

THIS FORM MUST BE COMPLETED BY TYPEWRITER

01 4	01 7 PROGRAM NO	COMPUTER PROGRAM ABSTRACT	01 14 DATE
			30 Sept. 1968

01 20 TITLE OF PROGRAM (61 CHARACTERS MAXIMUM)	PARENT PROGRAM 02 14 CATEGORY	02 15 SITE	02 18 PROGRAM NO
LTV-APOLLO II ECS Radiator Analysis			

02 26 CATEGORY	02 27 LANGUAGE NO. 1	02 32 LANGUAGE NO. 2	02 37 KEY WORDS (3 MAXIMUM, SEPARATED BY COMMAS)
F	FOR5		Radiator, Temperature, Fluid Flow

WHO TO CONTACT ABOUT THE PROGRAM

05 14 CONTACT	05 28 SITE	05 31 ORGN CODE	05 39 PROJECT NO	05 45 NASA CENTER	05 48 STATUS	05 49
D. W. Morris	MSC	EC 34	3475		☐ A. UNDER DEVELOPMENT ☐ B. OPERATIONAL ☒ C. COMPLETED	☒ A. THIS PROGRAM IS NOT FOR SHARING

DATES 05 50 INITIATED	DATES 05 54 COMPLETED	05 58 REVISION CODE	TIME AND COST FOR DEVELOPMENT 05 59 MANMONTHS	05 64 MACHINE HOURS	05 69 COMPUTER TYPE	05 74 TOTAL COST (DOLLARS)
0167	0568	☐ A REVISION ☐ B CANCELLATION	2.5	5.0	1108	6000

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CARD NUMBER COLUMN 14

ABSTRACT

This computer routine provides for rapid performance predictions of the Apollo Block II ECS radiator. Specific equations for a simplified thermal model of the radiators are written directly in the program. The temperature equations for each node in the thermal model are solved by an implicit finite difference method. A characterization of the flow proportioning valve, bypass valve, and low load heater are included in the routine. Provisions are also included for single panel and redundant system operation.

Two lunar orbital and a translunar thermal cycle radiator environments are contained in the routine. Time dependent values may also be input for any radiator environment, inlet temperature and flow rate. The routine outputs radiator heat rejection, pressure drop, low load heater on/off operation, flow rate, and outlet fluid temperature at times specified by the user. Following completion of the problem, maximum, minimum and average values for heat rejection, pressure drop and fluid outlet temperature and total heat dissipated by the low load heater are also output.

Computer time required to analyze a 4.08 hour lunar orbit mission (two orbits) with a calculation and print interval of .02 hours is 53 seconds on the Univac 1108 computer. This represents a routine run speed of better than 250 times real time.

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