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TURBINE ENGINE CONTROL SYNTHESIS. VOLUME II. SIMULATION AND CONTROLLER SOFTWARE

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NOTICE

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This report has been reviewed by the Information Office, (ASD/OIP) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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The objective was to determine whether optimal control synthesis methods provide superior means for designing jet engine controllers. The methods design controllers with more capability and/or can be exploited to provide less expensive hardware. For newer kinds of engines the cost to design should be less than for presently used methods. Volume I summarizes optimal control design methodology. A paper design of a command and disturbance controller shows that good power lever command response can be achieved; the same controller is designed to be insensitive to inlet duct buzz.

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20. Abstract (Continued)

A command controller is synthesized and wind tunnel tested. This controller is a good approximation to time optimal with surge-stall, TT4, and flameout constraints. Small-amplitude control responses are precise. There is strong stability. Volume II contains three Appendices. Appendix A contains the details of engine math models. The software for the wind tunnel controller is presented in Appendix B. Appendix C contains a derivation of rate model following. Volume III presents results of frequency response tests of a J85-13 engine operating in the APL wind tunnel. The data are reduced and models identified.

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COMPONENT MODEL SOFTWARE

Software models of the J85 engine are presented in this appendix. Two computer programs are discussed:

- Linearization
- Nonlinear engine simulation

Fortran listings of the two programs are presented in Tables A-1* and A-2. Both programs were written for the SDS-9300 computer.

The linearization program, discussed in the first part of this appendix, was used to generate linear engine models for the synthesis of linear optimal controllers reported in Section IV of Volume I.

The nonlinear engine simulation package is discussed in the second half of this appendix. This computer program is basically a Fortran version of the J85 NASA component model of Reference A-1.

LINEARIZATION PROGRAM

The function of this program is to generate linear models of the J85 engine. A Fortran listing of the program is presented in Table A-2 and discussed in the following paragraphs.

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* For the convenience of the reader, all figures and tables are provided at the end of each appendix.

The discussion is divided into four sections which correspond with the main parts of the program:

- Trim point calculation
- Engine dynamics
- Linearization
- Input data

Trim point calculations are discussed in the first subsection, labeled Trim Routine, where steady-state set points for the engine are computed. This section of the program calculates the fuel flow required to maintain the nominal operating condition specified by the input parameters. Trim values of engine responses are also calculated in this subsection.

Engine dynamics are discussed in the next subsection. A nonlinear dynamic model of the engine is contained in a subroutine called DYNAMIC. The model is a reduced order-version of the NASA component model of Reference A-1. All gas dynamics have been removed from the model so that it contains only two states, spool speed and engine case temperature.

The linearization procedure is presented in the third subsection of this appendix, under Linearization Routine. Engine dynamics are linearized about a steady-state trim point.

Input data are discussed in the last subsection. Two sets of data are required to run the program. One set defines the nominal operating conditions, i.e., steady-state spool speed, geometry control positions, compressor inlet pressure, and rotor torque load. The other set contains steady-state engine component data, i.e., compressor stage data and turbine map data.

Computations in the linearization program proceed in the following order. First, engine component data are read in. Then input parameters defining the nominal operating condition are read. Next a steady-state trim point corresponding to the input parameters is computed. Finally, a linear model of the engine is obtained by linearizing the nonlinear engine dynamics about the trim point.

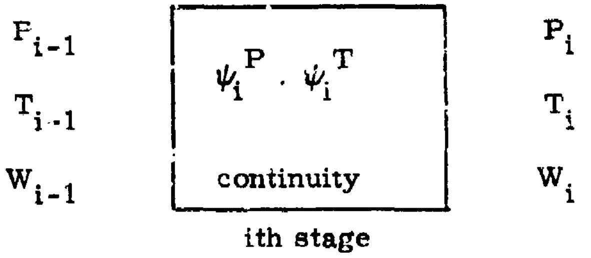
Trim Routine

This section of the program generates steady-state trim solutions of the engine dynamic equations. Inputs to the routine include steady-state spool speed (N), geometry control position (IGV, BLD, A_8), compressor inlet pressure and temperature (P_o, T_o), exhaust nozzle discharge pressure (P_8), and external rotor torque load (SPLC). Given this set of inputs, the program iteratively computes a steady-state operating point. The computational procedure is summarized in the next paragraph.

First, steady-state values of the eight input parameters, N, A_8, IGV, BLD, P_o, T_o, P_8, and SPLC, are read in. Then initial guesses for fuel flow (WF), burner temperature (TB), turbine discharge pressure (PT), and inlet airflow (W_o) are made. Steady-state values of these four parameters are iteratively computed in four nested iteration loops. Steady-state values of all of the other engine variables are computed closed form.

Computations in the routine proceed in a manner analogous to the path followed by a particle of air entering the inlet; i.e., the compressor section is trimmed first, followed by the burner, the turbine, and finally the nozzle section.

The compressor is modeled by the stage stacking technique. Each stage is individually represented by a pair of experimental functions (ψ^P, ψ^T) which are used to compute the pressure rise and temperature rise across the stage. Airflow through the stage is computed from the steady-state continuity relation.



$$
\begin{aligned}
T_i &= T_{i-1} + f_1 \left[\psi_i^T , N\right] \\
P_i &= P_{i-1} \cdot f_2 \left[\psi_i^P , N, T_{i-1}\right] \qquad \text{(A-1)} \\
W_i &= W_{i-1}
\end{aligned}
$$

The stages are interconnected, or stacked, to form the compressor model where the discharge conditions of one stage are the inlet conditions of the following stage. Compressor bleed (BLD) and inlet guide vane (IGV) effects are included in the appropriate stages.

Thus, steady-state values of all the compressor variables can be computed closed form from a knowledge of the input parameters, N, IGV, BLD, P_o, T_o, and W_o. All of these inputs are specified, except for inlet airflow (W_o). This variable is computed iteratively in the outer iteration loop.

Burner performance is represented by three experimental relations, pressure drop across the burner (Δ PB), burner enthalpy (HB), and burner efficiency (η_B), together with the steady-state continuity relation. The pressure drop across the combustor is a function of compressor discharge pressure (PCD), burner inlet airflow (WB), compressor discharge temperature (TCD) and burner temperature (TB).

$$\Delta PB = f_1 [PCD, WB, TCD, TB] \quad (A-2)$$

Burner enthalpy is computed from a real gas experimental relationship which is a function of burner temperature (TB), burner airflow (WB) and fuel flow (WF).

$$HB = f_2 [TB, WB, WF] \quad (A-3)$$

Combustor efficiency is defined as the portion of the heat of combustion that is available for a gas temperature rise. It is computed from an experimental correlation of the form

$$\eta_B = f_3 [PB \cdot \Delta TB] \quad (A-4)$$

where

$$PB = PCD + \Delta PB$$

$$\Delta TB = TB - TCD$$

These three functions, f_1, f_2, and f_3, are functions of the three burner variables, WB, TB, and WF. One of these parameters, WB, is computed closed form (from the continuity relation), as

$$WB = WCD - WTC \quad (A-5)$$

where WTC is airflow which is bled from the compressor to cool the turbine.

The other two parameters, TB and WF, are computed iteratively in the inner two iteration loops.

The turbine is modeled by two performance maps, together with the steady-state continuity relation. Turbine enthalpy drop (ΔHT) and turbine airflow (WT) are represented as functions of burner temperature (TB), burner pressure (PB), spool speed (N), and turbine pressure ratio (PR_T).

$$\begin{aligned} HT &= f_1\,[N,\ TB,\ PR_T] \\ WT &= f_2\,[N,\ TB,\ PB,\ PR_T] \end{aligned} \qquad \text{(A-6)}$$

These functions cannot be evaluated until the variable PR_T is computed. Although WT is established by the continuity relation

$$WT = WB + WF \qquad \text{(A-7)}$$

PR_T cannot be obtained closed form because the second function, f_2, cannot be inverted to solve for PR_T. Thus, PR_T is calculated in the third iteration loop.

The exhaust nozzle is represented as a variable area flow passage capable of choking. The mathematical relation is

$$\frac{WN\sqrt{TT}}{PT} = KNA8 \cdot A_8 \cdot f\left[\frac{P_8}{PT}\right] \qquad \text{(A-8)}$$

where

$$f\left[\frac{P_8}{PT}\right] = \left(\frac{P_8}{PT}\right)^{\frac{1}{\gamma}} \sqrt{1 - \frac{P_8}{PT}}^{\,\frac{\gamma-1}{\gamma}}$$

This expression is used to compute the nozzle airflow (WN).

Compressor inlet airflow (W_o) is systematically changed in the outer iteration loop until the nozzle airflow computed from the above relation agrees with nozzle airflow computed from the steady-state continuity relation

$$WN = WT + WTC \qquad \text{(A-9)}$$

Details of the trim routine are presented in the flowchart of Figure A-1.

First, the input variables N, A_8, IGV, BLD, P_o, T_o, P_8, and SPLC are read in. The last variable, SPLC, is a fictitious external torque load applied to the rotor shaft. If this variable is set to zero, the routine will identify a steady-state operating point on the engine equilibrium line. Nonzero values of SPLC cause the routine to identify quasi-steady-state operating points off of the equilibrium line. Quasi-steady state means that both N = constant and $\dot{N}$ = constant; the nonzero $\dot{N}$ is balanced by the external torque lead SPLC.

Then, initial guesses of fuel-to-air-ratio in the burner (FAB), burner temperature (TB), and inlet airflow (W_o) are made. The parameter FAB is defined as

$$\mathrm{FAB} \triangleq \mathrm{WF/WB} \tag{A-10}$$

Thus, guessing a value of FAB is equivalent to guessing fuel flow.

Next, the integer variables which count the number of iterations are initialized to zero. The variables are defined as:

ITER1 -- number of iterations of the W_o loop
ITER2 -- number of iterations of the PT loop
ITER3 -- number of iterations of the TB loop

A counter is not assigned to the inner loop, the WF iteration. The variable III is a switch which is maintained as zero during the iteration process and set equal to one when all loops have converged.

In the next section of the program steady-state compressor variables are computed. Individual calculations are made for each compressor stage; the outlet conditions of one stage are inlet conditions of the next stage.

First, the pressure at the outlet of the inlet guide vanes is computed from the equation

$$P_{IGV} = P_o \cdot PR_{IGV} - 0.005\ P_o \tag{A-11}$$

where the IGV pressure ratio (PR_{IGV}) is calculated as a function of spool speed.

$$PR_{IGV} = PR_{IGV}\,[N]$$

Temperature and airflow, which are constant across the inlet guide vanes, are computed as

$$\begin{aligned} T_{IGV} &= T_o \\ W_{IGV} &= W_o \end{aligned} \tag{A-12}$$

The outlet conditions of the inlet guide vanes are the inlet conditions of the first compressor stage. Airflow in the first compressor stage is computed from the continuity equation

$$WC_1 = W_{IGV} \tag{A-13}$$

This airflow, together with T_{IGV} and P_{IGV}, are used to compute the axial component of velocity in the stage:

$$v_{z_1} = v\,[WC_1,\ T_{IGV},\ P_{IGV}] \tag{A-14}$$

which in turn is used to compute the flow coefficient

$$\phi_1 = K_{\phi 1} \cdot v_{z_1}/N \tag{A-15}$$

The constant $K_{\phi 1}$ in this expression is a function of the geometry of the stage. Next, pressure rise and temperature rise coefficients are determined from ϕ_1.

$$\begin{aligned} \psi_1^P &= \psi_1^P [\phi_1, IGV] \\ \psi_1^T &= \psi_1^T [\phi_1, IGV] \end{aligned} \qquad \text{(A-16)}$$

Note the effect of inlet guide vane position is included in the first-stage coefficients. Finally, the pressure and temperature at the outlet of the stage are computed.

$$\begin{aligned} BC_1 &= P_{IGV} \cdot \left(1 + \psi_1^P \cdot K_{\psi_1} \cdot N^2 / T_{IGV}\right)^{\frac{\gamma}{\gamma-1}} \\ TC_1 &= T_{IGV} + K_{\psi_1} \cdot N^2 \cdot \psi_1^T \end{aligned} \qquad \text{(A-17)}$$

The constant K_{ψ_1} in these expressions is also a function of the geometry of the first stage.

Pressure, temperature, and airflow in the other compressor stages are computed in the same manner as the first-stage data. Calculations for the second and third stages are shown explicitly in the Figure A-1 flowchart.

Compressor bleed effects are included in the third, fourth, and fifth compressor stages. Bleed airflow in the third stage (WBL_3) is computed from the relation

$$WBL_3 = KBLD_3 \cdot BLD \cdot PC_3 / \quad TC_3 \qquad \text{(A-18)}$$

where

$KBLD_3$ is the bleed flow coefficient
BLD is the bleed area
PC_3 is the third-stage discharge pressure
TC_3 is the third-stage discharge temperature

The third-stage bleed airflow is subtracted from the third-stage inlet airflow (WC_3) to determine the inlet airflow to the fourth stage (WC_4)

$$WC_4 = WC_3 - WBL_3 \qquad (A\text{-}19)$$

Bleed effects in the fourth and fifth stages are evaluated in the same way.

Compressor discharge relations are evaluated at the end of the compressor simulation section. The pressure, temperature, and airflow at the compressor discharge are the values at the outlet guide vanes.

$$\begin{aligned} PCD &= P_{OGV} \\ TCD &= T_{OGV} \qquad (A\text{-}20) \\ WCD &= W_{OGV} \end{aligned}$$

Compressor discharge enthalpy (HCD) is evaluated as a function of TCD from a real gas model,

$$HCD = HCD\,[TCD] \qquad (A\text{-}21)$$

Finally, the net change in airflow times enthalpy across the compressor is evaluated.

$$\begin{aligned} \Delta(WH)_{CD} = {} & WCD \cdot HCD + c_p(WBL_3 \cdot TC_3 + WBL_4 \cdot TC_4 + WBL_5 \cdot TC_5) \\ & - c_p \cdot W_o \cdot T_o + SPLC \end{aligned} \qquad (A\text{-}22)$$

This change is proportional to the compressor torque load on the rotor shaft.

Next, steady-state airflow into the burner (WB) is evaluated as

$$WB = WCD - WTC \qquad (A\text{-}23)$$

where WTC is airflow which is extracted from the compressor discharge to cool the turbine.

Then a test is made to determine if ITER1 equals one. If ITER1 = 1, indicating that this is the first pass through the W_o iteration loop, an initial value is assigned to turbine discharge pressure (PT).

$$PT = 0.35\ PCD \tag{A-24}$$

If ITER1 > 1, the routine goes directly to step 2 since a value for PT has already been calculated in this case.

Turbine inlet airflow is then computed from the steady-state continuity relation

$$WT_{OLD} = WB\ (1 + FAB) \tag{A-25}$$

This is the sum of burner inlet airflow and fuel flow.

Next, the three experimental relations which model burner performance are evaluated. First, the pressure drop across the burner is computed

$$\Delta PB = \frac{KB \cdot WB^2}{PCD}\ (0.771\ TCD - 0.35\ TB) \tag{A-26}$$

where KB is a constant. Pressure losses due to both fluid friction and momentum changes from the addition of heat are included in this expression.

The pressure at the burner discharge (PB) is

$$PB = PCD - \Delta PB \tag{A-27}$$

Next, burner efficiency η_B is evaluated as a function of the parameter PBDTB where

$$PBDTB \overset{\Delta}{=} PB\ (TB - TCD) \tag{A-28}$$

Burner efficiency is defined as the portion of the heat of combustion that is available for a gas temperature rise. Finally, burner enthalpy (HB) is determined from the real-gas functional relationship

$$HB = HB\,[FAB,\ TB] \tag{A-29}$$

The Figure A-1 flow chart shows that turbine enthalpy drop (ΔHT) is actually calculated between the computation of burner efficiency and burner enthalpy. Turbine enthalpy drop is determined from experimental turbine data, i.e., from $\frac{\Delta HT}{N\sqrt{TB}}$, $\frac{PT}{PB}$, and $\frac{N}{\sqrt{TB}}$. Thus the enthalpy drop is

$$\Delta HT = \frac{\Delta HT}{N\sqrt{TB}} \cdot N \cdot \sqrt{TB} \tag{A-30}$$

At this point in the routine, sufficient data are available to recalculate turbine inlet airflow from the heat equation as applied to the burner. The heat equation specifies that under steady flow conditions

$$\Sigma\dot{Q}_{BURNER} = \Sigma(WH)_{BURNER} = 0$$

The amount of heat which enters the burner must equal the heat which exits from the burner. In terms of the parameters previously identified

$$(WH)_{in} = (WH)_{out}$$

or (A-31)

$$WB \cdot HCD + W_f \cdot h_{FUEL} \cdot \eta_E = (WB+W_f) \cdot HB$$

This equation is solved for the term (WB + WF) which is the burner discharge flow. The result is

$$WT_1 = \frac{WB\,(h_{FUEL} \cdot \eta_B - HCD)}{(h_{FUEL} \cdot \eta_B - HB)} \tag{A-32}$$

where $WT_1 = (WB + W_f)$ is the burner discharge or turbine inlet airflow. Note that fuel flow does not appear explicitly in this equation, but rather as the difference $WT_1 - WB$.

Next, the difference between turbine inlet airflow as determined from the heat equation (WT_1) and as determined from the continuity relation (WT_{OLD}) is computed. The result is termed turbine airflow error, WT_{ERROR}.

$$WT_{ERROR} \triangleq |WT_1 - WT_{OLD}| \qquad \text{(A-33)}$$

The magnitude of this error is the convergence criterion for the fuel flow iteration loop. If $|WT_{ERROR}| \leq 0.0005$, the iteration loop is converged. If $|WT_{ERROR}| > 0.0005$, fuel flow is updated according to the following scheme:

$$\begin{aligned} WT_{OLD} &= 1/2\,(WT_{OLD} + WT_1) \\ WF &= WT_{OLD} - WB \qquad \text{(A-34)} \\ FAB &= WT/WB \end{aligned}$$

and the routine is returned to step 4. The fuel flow iteration continues until the criterion $|WT_{ERROR}| \leq 0.0005$ is satisfied.

After the fuel flow iteration converges, the airflow out of the turbine is computed. This airflow is called the nozzle airflow, WN.

$$WN = WT_1 + WTC \qquad \text{(A-35)}$$

It is assumed that the cooling airflow, WTC, is added back into the flow at the turbine discharge.

Next, turbine enthalpy is computed from the equation

$$HT = \frac{WT_1(HB - \Delta HT) + WTC \cdot HCD}{WN} \qquad \text{(A-36)}$$

Then the steady-state rotor torque relation,

$$\dot{N} = \Sigma_{TORQUE} = 0$$

is used to recalculate burner enthalpy. The airflow-enthalpy change across the compressor is subtracted from the airflow-enthalpy change across the turbine to determine the net rotor torque.

$$\Sigma_{TORQUE} = \Delta(WH)_{TURBINE} - \Delta(SH)_{COMPRESSOR} = 0$$

This equation is solved for a new estimate of burner enthalpy, called HB_R.

$$HB_R = \frac{\Delta(WH)_{CD} + WN \cdot HT - WTC \cdot HCD}{WT_1} \qquad \text{(A-37)}$$

The difference between burner enthalpy as calculated from the above equation (HB_R) and burner enthalpy as previously determined from the real gas model (HB) is termed burner temperature error.

$$TB_{ERROR} \overset{\Delta}{=} HB_R - HB \qquad \text{(A-38)}$$

A non-zero value of TB_{ERROR} indicates that the burner temperature estimate, TB, is inaccurate. The magnitude of this error is the convergence criterion for the TB iteration loop. If $|TB_{ERROR}| \leq 0.0005$ the iteration is converged; if $|TB_{ERROR}| > 0.0005$ the estimate of burner temperature, TB, is updated and the routine returns to step 3.

The change in TB depends on the algebraic sign of TB_{ERROR}. If HB_R is greater than HB, TB is increased. If HB_R is less than HB, TB is decreased. The magnitude of the change in TB, called ΔTB, is regulated in the routine such that if the algebraic sign of TB_{ERROR} changes in successive iterations, the step size is halved. This procedure guarantees convergence.

Flow conditions in the exhaust nozzle are computed after the TB iteration is converged. First, the nozzle pressure ratio (PR_N) is evaluated

$$PR_N = \frac{P_8}{PT} \tag{A-39}$$

where P_8 is discharge pressure at the nozzle exit.

The flow condition in the nozzle is determined by the magnitude of PR_N. If $PR_N > 1$, ambient pressure is greater than nozzle pressure and thus zero flow is assumed. If $PR_N < 0.528$, the nozzle is choked and if $0.528 < PR_N < 1$, the nozzle is unchoked. A nozzle coefficient is assigned depending on the flow condition.

$$\begin{aligned} K_{NOZ} &= 0 \quad \text{if } PR_N > 1, \quad \text{zero flow} \\ K_{NOZ} &= 0.2588 \quad \text{if } PR_N > 0.528, \quad \text{choked flow} \\ K_{NOZ} &= \left(\frac{P_8}{PT}\right)^{\frac{1}{\gamma}} \sqrt{1 - \left(\frac{P_8}{PT}\right)^{\frac{\gamma-1}{\gamma}}} \quad \text{if } 0.528 < PR_N < 1, \text{ unchoked flow} \end{aligned} \tag{A-40}$$

Next, turbine airflow is recalculated from experimental turbine data which is a correlation of the three parameters $\frac{WT \cdot TB}{N \cdot PB}$, $\frac{PT}{PB}$, $\frac{N}{TB}$. Turbine airflow computed from this data is

$$WT_2 = \left(\frac{WT \cdot TB}{N \cdot PB}\right) \cdot \frac{N \cdot PB}{TB} \tag{A-41}$$

The symbol WT_2 is used to differentiate this airflow from the two expressions for turbine airflow previously obtained, WT_{OLD} and WT_1.

The difference between WT_2 and WT_1 is then computed.

$$PT_{ERROR} \overset{\Delta}{=} WT_2 - WT_1 \tag{A-42}$$

This error is called turbine pressure error because a mismatch between WT_2 and WT_1 indicates that turbine pressure is not correct. The magnitude of this error determines if the iteration on PT is converged. If $|PT_{ERROR}| \leq 0.0005$, the iteration is converged. If $|PT_{ERROR}| > 0.0005$ the estimate of PT is updated and the routine returned to step 2 for another iteration.

The algebraic sign of PT_{ERROR} determines how the value of PT is adjusted. If PT_{ERROR} is positive, the value of PT is increased; and if PT_{ERROR} is negative, PT is decreased. Mechanization of the PT iteration is identical to the TB iteration (refer to Figure A-1 flow chart).

Following the convergence of the PT iteration, the turbine temperature (TT) is evaluated as a function of turbine enthalpy (HT) and fuel-to-air ratio in the turbine (FAT). Turbine temperature is then used to recompute nozzle airflow from the isentropic relation

$$WN_X = \frac{KNA8 \cdot K_{NOZ} \cdot PT \cdot A_8}{\sqrt{TT}} \tag{A-43}$$

The constant KNA8 is a contraction coefficient which is a function of spool speed. The subscript X on WN is used in this expression to differentiate between the nozzle airflow computed here and the nozzle airflow previously computed from the continuity relation, WN.

The difference between WN_X and WN is then computed

$$W_{ERROR} \overset{\Delta}{=} WN_X - WN \tag{A-44}$$

This error is a measure of the accuracy achieved by the outer loop iteration for inlet airflow, W_o. If $|W_{ERROR}| \leq 0.0005$, the iteration is sufficiently converged. If $|W_{ERROR}| > 0.0005$, the value of W_o is updated and the routine returns to step 1. Inlet airflow, W_o, is increased if W_{ERROR} is positive and decreased if W_{ERROR} is negative. The logic associated with this iteration loop is identical to the logic used in the TB and PT iterations.

Logic for the trim completion switch III is also found in this section of the routine. The switch controls printout of results obtained from intermediate steps in the program. Until all four iteration loops have converged to within the specified tolerances, the value of III is zero. Once the loops have all converged, III is set equal to one and the routine is sent back to the beginning, station 1. Values of the parameters of interest are then printed out during this final pass through the iteration loops.

Dynamic Subroutine

This section of the program computes derivatives with respect to time of spool speed (N) and case temperature (TM) given the following set of initial conditions: compressor inlet pressure and temperature ($P_o T_o$), nozzle discharge pressure (P_8), current spool speed (N), current case temperature (TM), fuel flow (W_f), and geometry control positions (A_8, IGV, BLD).

The structure of this routine closely parallels that of the TRIM routine. Computations begin at the engine inlet and proceed through the engine to the exhaust nozzle. Parameters associated with the compressor section are evaluated first, followed in order by burner, turbine and finally exhaust nozzle parameters.

Initial conditions are specified by the nine input parameters, P_o, T_o, P_8, N, TM, W_f, A_8, IGV, and BLD. Initial estimates of turbine pressure (PT), inlet airflow (W_o), and burner efficiency (η_B) are also required. Actual values of these three parameters, PT, W_o and η_B, are computed iteratively in the subroutines.

The compressor is modeled by the same set of mathematical relations which are included in the TRIM routine. Inputs to the compressor section include spool speed, inlet parameters W_o, P_o, and T_o, and compressor geometry control positions IGV and BLD. Steady-state pressure and temperature rise maps are used to compute individual stage parameters. The stages are stacked to form the compressor model; i.e., the discharge conditions of one stage are the inlet conditions of the next stage. Flow conditions at the compressor discharge are defined in terms of pressure (PCD), temperature (TCD), airflow (WCD), and enthalpy (HCD).

Steady-state burner performance is modeled by the same three experimental relations which are included in the TRIM routine. Two of these relations are used to compute burner temperature (TEB) and burner pressure (PB). The third relation is used in an iteration loop to determine burner efficiency (η_B).

Thermal capacitance effects are included at the end of the burner section. The rate of change of temperature of the engine case metal is calculated from the equation

$$\dot{T}_M = K_{TM}\,(TEB - TM) \qquad (A\text{-}45)$$

where TM is the average temperature of the metal and K_{TM} is a constant of proportionality (a function of thermal conductivity and geometric measurements). The temperature of the gas discharged from the burner (TB) is computed from

$$TB = TEB - K_{TB} \cdot \dot{TM} \qquad (A\text{-}46)$$

where K_{TB} is a constant similar to K_{TM}. Note that in thermal equilibrium these equations reduce to

$$TEB = TM = TB$$

Turbine and exhaust nozzle performance are also modeled by the steady-state relations which are included in the TRIM routine. These functions relate nozzle airflow (WN), turbine temperature (TT), turbine enthalpy drop ΔHT), and turbine airflow (WT) with spool speed, burner discharge pressure and temperature (TB and PB), nozzle area (A_8), and ambient nozzle pressure (P_8).

Rotor dynamics are considered at the end of the nozzle section. Angular acceleration of the rotor shaft is computed as a function of enthalpy change,

$$\dot{N} = \frac{K_N \cdot [\Delta(WH)_T - \Delta(WH)_{CD}]}{N} \tag{A-47}$$

where $\Delta(WH)_T$ is the airflow · enthalpy change across the turbine, and $\Delta(WH)_{CD}$ is the airflow · enthalpy change across the compressor. K_N is a constant relating rotor speed in radians per second to rotor speed in revolutions per minute.

Inlet airflow (W_o) and turbine discharge pressure (PT) are computed iteratively in the last section of the program. A gradient search procedure, Newton's method, is used to find W_o and PT since they cannot be obtained directly from the model equations.

A flow chart of the DYNAMIC subroutine is presented in Figure A-2. Details of the procedure are discussed in the following paragraphs.

First, the initial conditions P_o, T_o, P_8, N, TM, W_f, A_8, IGV and BLD and initial estimates W_o, PT, and η_E are read in. These variables are obtained either directly from the TRIM routine or from a previous call to this subroutine.

Then the iteration loop counters are initialized. Both ITER1 and ITER2 are set to zero. ITER2 counts the number of outer loop iterations and ITER1 is a loop counter within the gradient search procedure.

Compressor variables are computed in the next section of the program. The compressor model included in this subroutine is identical to the model included in the TRIM routine.

Inputs to the compressor section include inlet conditions W_o, P_o, and T_o and compressor geometry control positions IGV and BLD. Discharge airflow, WCD, pressure, PCD, temperature, TCD, and enthalpy, HCD, are evaluated in the model. Details of the compressor simulation are shown in the Figure A-2 flow chart and discussed in the TRIM routine documentation.

Next burner inlet airflow is computed from the continuity relation

$$WB = WCD - WTC \qquad \text{(A-48)}$$

where WTC is the airflow which is extracted from the compressor discharge airflow to cool the turbine vanes. The fuel-to-air ratio in the burner is also evaluated,

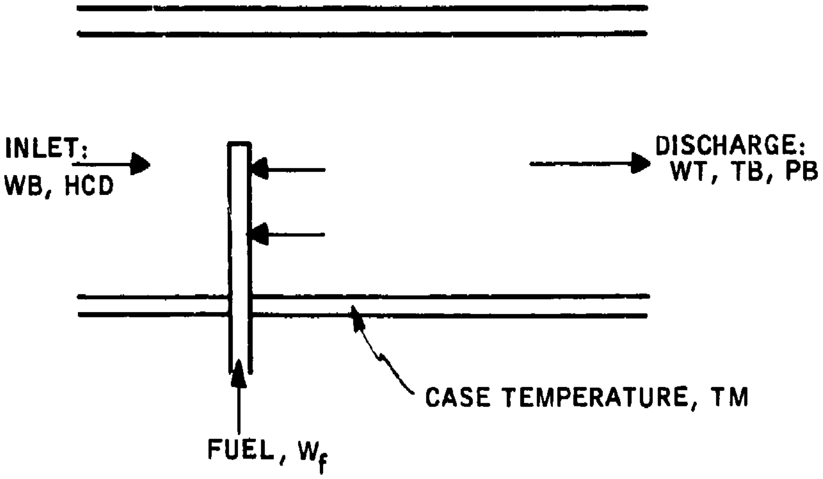
$$FAB = W_f/WB \qquad \text{(A-49)}$$

Burner enthalpy is calculated from the heat equation.

$$HB = HCD + h_{FUEL} \cdot \eta_{B_0} \cdot FAB \qquad \text{(A-50)}$$

The term $h_{FUEL} \cdot \eta_{B_0} \cdot FAB$ is the enthalpy increase due to burning of the fuel. The current value of burner efficiency, η_B, is also stored as the variable η_{B_0} in this step.

The time derivative of burner case temperature, $\dot{TM}$, is determined in the next step from the thermal capacitance model:



First, the combustion temperature of the gas is computed as a function of FAB and HB,

$$TEB = TEB\,[FAB,\ HB] \qquad \text{(A-51)}$$

Then the rate of change of case temperature, $\dot{TM}$, is computed from the heat transfer relation, Equation (A-45):

$$\dot{TM} = K_{TM} \cdot (TEB - TM)$$

The constant K_{TM} is a function of the thermal properties of the case material and the term (TEB - TM) is the temperature gradient at the gas-metal interface. Finally, the temperature of the gas discharged from the burner is computed from Equation (A-46):

$$TB = TEB - K_{TB} \cdot \dot{TM}$$

K_{TB} is a constant in this equation. Note that if the burner is not in thermal equilibrium, i.e., TM $\neq$ TEB, the temperature of the gas discharged from the burner, TB, will not equal the combustion temperature, TEB.

Burner pressure is calculated in the next step.

$$PB = PCD - \frac{K_B \cdot WB^2}{PCD} (0.771\ TCD - 0.085\ TB) \qquad (A\text{-}52)$$

This relation was also used to calculate burner pressure in the TRIM routine.

Then the value of burner efficiency is recalculated from the experimental data relating efficiency to the variables PB, TB and TCD.

$$\eta_B = \eta_B\ [PB\ (TB - TCD)] \qquad (A\text{-}53)$$

The updated value η_B is compared with the previous value η_{B_o} to determine if the burner simulation is converged. If the error $|\eta_B - \eta_{B_o}|$ is less than E-10, the routine proceeds to the turbine simulation. If $|\eta_B - \eta_{B_o}|$ is greater than E-10, η_{B_o} is replaced by η_B and the routine returns to step 2.

The first parameter calculated in the turbine section is turbine inlet airflow, WT. It is computed from the continuity relation

$$WT = WB + WF \qquad (A\text{-}54)$$

Fuel-to-air ratio in the turbine is also computed at this time.

$$FAT = WF/(WT + WTC) \qquad (A\text{-}55)$$

Note that the turbine cooling airflow, WTC, has been added to turbine inlet airflow in this equation.

Next, turbine inlet airflow is recalculated from the experimental data relating airflow with turbine pressure ratio, burner temperature, and spool speed.

$$WT_{CAL} = \frac{N \cdot PB}{TB} \cdot \left(\frac{WT \cdot TB}{N \cdot PB} \left[\frac{PT}{PB}, \frac{N}{\sqrt{TB}} \right] \right) \qquad \text{(A-56)}$$

The subscript CAL is attached to this airflow to differentiate between it and turbine airflow computed from the continuity relation.

The difference between WT_{CAL} and WT is then taken.

$$PT_{ERROR} = WT_{CAL} - WT \qquad \text{(A-57)}$$

The variable name PT_{ERROR} is assigned to this difference because it represents an error in the estimation of turbine discharge pressure, PT. This error is used in the gradient search portion of the program to obtain a better estimate of PT.

Nozzle airflow, WN, is computed from the continuity relation in the next step,

$$WN = WT + WTC \qquad \text{(A-58)}$$

This parameter is used to evaluate turbine enthalpy, HT, from the heat equation,

$$HT = \frac{WT(HB - \Delta HT) + WTC \cdot HCD}{WN} \qquad \text{(A-59)}$$

where turbine enthalpy drop, ΔHT, is obtained from the experimental relation

$$\Delta HT = N \cdot \sqrt{TB} \cdot \frac{\Delta HT}{N\sqrt{TB}} \quad \frac{PT}{PB}, \frac{N}{\sqrt{TB}} \qquad \text{(A-60)}$$

Turbine temperature is then computed from the real gas relation

$$TT = TT\,[FAT,\ HT] \tag{A-61}$$

Airflow in the exhaust nozzle is computed in the next subsection. First, the pressure ratio across the nozzle opening is computed,

$$PR_N \triangleq \frac{P_8}{PT} \tag{A-62}$$

The value of this coefficient determines if the nozzle is choked, unchoked or operating under conditions of reversed flow. This information is conveyed to the nozzle airflow equation through the coefficient K_{NOZ}.

$$\begin{aligned} K_{NOZ} &= 0 \qquad \text{if } PR_N > 1, \qquad \text{reversed flow} \\ K_{NOZ} &= 0.2588 \qquad \text{if } PR_N < 0.528, \qquad \text{choked flow} \\ K_{NOZ} &= \left(\frac{P_8}{PT}\right)^{\frac{1}{\gamma}} \sqrt{1-\left(\frac{P_8}{PT}\right)^{\frac{\gamma-1}{\gamma}}} \quad \text{if } 0.528 < PR_N < 1, \text{ normal flow} \end{aligned} \tag{A-63}$$

Reversed flow is not allowed in the simulation. If $PR_N > 1$, nozzle airflow is set to zero by assigning $K_{NOZ} = 0$.

After the nozzle coefficient is computed, nozzle airflow is recalculated from the isentropic relation

$$WN_{CAL} = \frac{KNA8 \cdot K_{NOZ} \cdot PT \cdot A_8}{TT} \tag{A-64}$$

This expression is also used in the TRIM routine. The subscript CAL is used to differentiate between nozzle airflow computed from the continuity relation, WN, and airflow computed from this expression, WN_{CAL}.

Next, the difference between WN_{CAL} and WN is calculated

$$W_{ERROR} = WN_{CAL} - WN \tag{A-65}$$

The name W_{ERROR} is assigned to this difference since it represents the error in the estimation of inlet airflow, W_o. This error, together with PT_{ERROR}, is used in the gradient search procedure to obtain better estimates of the parameters W_o and PT.

Rotor acceleration, $\dot{N}$, is computed next from the conservation of angular momentum.

$$\dot{N} = \frac{K_N \cdot [\Delta(WH)_T - \Delta(WH)_{CD}]}{N} \tag{A-66}$$

The symbols $\Delta(WH)_T$ and $\Delta(WH)_{CD}$ represent the airflow · enthalpy changes across the turbine and the compressor respectively. They are defined as

$$\Delta(WH)_T = WT \cdot \Delta HT$$

$$\Delta(WH)_{CD} = HCD \cdot WCD - c_p \cdot T_o \cdot W_o \tag{A-67}$$

$$+ c_p (WBL_3 \cdot TC_3 + WBL_4 \cdot TC_4 + WBL_5 \cdot TC_5)$$

Finally, the errors PT_{ERROR} and W_{ERROR} are interrogated to determine if the outer iteration loop on the parameters PT and W_o is converged. If the magnitudes of both errors are less than the maximum allowable error, e, the iteration is converged and the subroutine returns to the main program. If the test is not passed, new estimates of the parameters PT and W_o are computed by Newton's method and the subroutine starts over at step 1.

In Newton's method the k+1 gradient step is

$$\underline{Z}^{k+1} = \underline{Z}^{k} - (\nabla h_{[\underline{Z}^k]})^{-1} \cdot \underline{h}_{[\underline{Z}^k]} \tag{A-68}$$

where $\underline{Z}$ is the vector of unknowns and $\underline{h}$ is the vector of errors. Thus the k+1 estimate of $\underline{Z}$ is computed from the kth estimate of $\underline{Z}$, the value of the error function $\underline{h}$ evaluated at $\underline{Z}^k$, and the gradient of the error function ∇h evaluated at $\underline{Z}^k$. In terms of the parameters PT, W_o, PT_{ERROR} and W_{ERROR} the vectors $\underline{Z}$, $\underline{h}$ and ∇h are

$$\underline{Z}^T \triangleq \{PT, W_o\}$$

$$\underline{h}^T \triangleq \{PT_{ERROR}, W_{ERROR}\}$$

$$\nabla h \triangleq \begin{bmatrix} \dfrac{\partial PT_{ERROR}}{\partial PT} & \dfrac{\partial PT_{ERROR}}{\partial W_o} \\ \dfrac{\partial W_{ERROR}}{\partial PT} & \dfrac{\partial W_{ERROR}}{\partial W_o} \end{bmatrix} \tag{A-69}$$

Since the partial derivatives in ∇h cannot be computed analytically, they are approximated by finite difference equations in the computer program. For example,

$$\frac{\partial PT_{ERROR}}{\partial PT} = \frac{PT_{ERROR}[PT + \Delta PT, W_o] - PT_{ERROR}[PT - \Delta PT, W_o]}{2\,\Delta PT} \tag{A-70}$$

Thus, both positive and negative perturbations in the unknown variable PT are considered. Similar expressions could be written for the other partial derivatives.

The gradient calculation consists of five intermediate steps. In the first step, the errors in the h vector are evaluated, PT_{ERROR} and W_{ERROR}. The partial derivatives with respect to PT, $\partial PT_{ERROR}/\partial PT$ and $\partial W_{ERROR}/\partial W_o$, are computed in the second and third steps. These calculations require two steps because both positive and negative perturbations in PT are considered. The other two partial derivatives, $\partial PT_{ERROR}/\partial W_o$ and $\partial W_{ERROR}/\partial W_o$, are evaluated in the final two steps. New estimates of PT and W_o are also obtained in the last step from the equation

$$\begin{bmatrix} PT_S \\ W_{o_S} \end{bmatrix} = \begin{bmatrix} PT \\ W_o \end{bmatrix} + \begin{bmatrix} \frac{\partial PT_{ERROR}}{\partial PT} & \frac{\partial PT_{ERROR}}{\partial W_o} \\ \frac{\partial W_{ERROR}}{\partial PT} & \frac{\partial W_{ERROR}}{\partial W_o} \end{bmatrix}^{-1} \begin{bmatrix} PT_{ERROR} \\ W_{ERROR} \end{bmatrix} \tag{A-71}$$

where the subscript S is used to denote the updated values.

The actual calculations performed in the subroutine are presented in the Figure A-2 flow chart beginning with the computation

ITER1 = ITER1+1

Logic which differentiates between the five steps of the gradient procedure is provided through this variable.

In the first step (ITER1=1), nominal values of the errors PT_{ERROR} and W_{ERROR} are stored under the names F and G. Then the nominal value of PT is increased by the amount ΔPT and the routine is sent back to location number 1.

In the second step (ITER1=2), new values of the errors PT_{ERROR} and W_{ERROR} evaluated for a positive perturbation in PT are stored as FX_+ and GX_+. Then the current value of PT is decreased by the amount $2\Delta PT$ and the routine is sent back to location 1. This is equivalent to decreasing the nominal value of PT by ΔPT.

New values of the errors PT_{ERROR} and W_{ERROR} evaluated for a negative perturbation in PT are stored as FX_- and GX_- in the third step (ITER1=3). The partial derivatives with respect to PT are evaluated from the finite difference approximations,

$$\frac{\partial PT_{ERROR}}{\partial PT} \triangleq FX = \frac{(FX_+ - FX_-)}{2\Delta PT}$$

$$\frac{W_{ERROR}}{PT} \triangleq GX = \frac{(GX_+ - GX_-)}{2\Delta PT} \qquad \text{(A-72)}$$

Then PT is returned to its nominal value by adding ΔPT to the current value, and the nominal value of W_o is increased by ΔW_o. Finally, the routine is sent to location 1.

Partial derivatives with respect to W_o are evaluated in steps four and five in the same manner as derivatives with respect to PT were obtained in steps two and three. The resulting finite difference approximations are

$$\frac{\partial PT_{ERROR}}{\partial W_o} \triangleq FY = \frac{(FY_+ - FY_-)}{2\Delta W_o}$$

$$\frac{\partial W_{ERROR}}{\partial W_o} \triangleq GY = \frac{(GY_+ - GY_-)}{2\Delta W_o} \qquad \text{(A-73)}$$

These partial derivatives, together with the nominal errors F and G, are then used to compute the incremental gradient step defined by

$$\Delta PT_S = \frac{(-F \cdot GY + G \cdot FY)}{D}$$

$$\Delta W_{O_S} = \frac{(-G \cdot FX + F \cdot GX)}{D} \qquad \text{(A-74)}$$

where ΔPT_S is the incremental change in PT and ΔW_{OS} is the incremental change in W_O. The symbol D represents the determinant of the partial derivative matrix

$$D = FX \cdot GY - GX \cdot FY \qquad \text{(A-75)}$$

Before the gradient step defined by the increments ΔPT_S and ΔW_{OS} is taken, the magnitude of the increments is tested and reduced, if necessary. First the magnitude of ΔPT_S is tested.

$$|\Delta PT_S| < 2\Delta PT$$

If this test is failed, the magnitudes of both ΔPT_S and ΔW_{OS} are reduced by the ratio, $2\Delta PT/|\Delta PT_S|$.

This adjustment reduces only the magnitude of the gradient step; the gradient direction is preserved. If $|\Delta PT_S|$ is smaller than $2\Delta PT$, this adjustment is bypassed.

The magnitude of ΔW_{OS} is also tested in a similar manner. If $|\Delta W_{OS}|$ is greater than $2\Delta W_O$, the gradient step is further reduced by the ratio, $2\Delta W_O/|\Delta W_{OS}|$. If $|\Delta W_{OS}|$ is smaller than $2\Delta W_O$, this magnitude adjustment is bypassed.

Finally, the current values of PT and W_o are updated,

$$\begin{aligned} PT &= PT + \Delta PT_S \\ W_o &= W_o + \Delta W_{o_S} \end{aligned} \tag{A-76}$$

the counter ITER1 is reinitialized, and the routine is started anew from location number 1.

Linearizer

This section of the program extracts linear models from the nonlinear engine model. Inputs to the program include steady-state spool speed (N), steady-state engine case temperature (TM), fuel flow (W_f), geometry control positions (A_8, IGV, BLD), inlet pressure and temperature (P_o, T_o), exhaust nozzle discharge pressure (P_8), and perturbation step size (DPERT). The nonlinear engine model is linearized about the equilibrium operating point defined by the first nine input parameters. The tenth input parameter (DPERT) determines the magnitude of the perturbations considered in constructing the linear model.

The linear models obtained are of the form

$$\begin{aligned} \Delta\dot{x} &= F\Delta x + G1\Delta u + G2\Delta\eta \\ \Delta r &= H\Delta x + D1\ \Delta u + D2\ \Delta\eta \end{aligned} \tag{A-77}$$

where x is the state vector, u is the control vector, η is the disturbance vector, r is the response vector and F, G1, G2, H, D1, D2 are coefficient matricies. The Δ symbol is used in these equations to emphasize the fact that the linear models represent perturbations from equilibrium operating conditions.

Engine variables included in the x, u, η, or r vectors are:

$$
\begin{aligned}
x &= \text{N (spool speed)} \\
&\quad \text{TM (engine case temperature)} \\
u &= \text{WF (fuel flow)} \\
&\quad \text{IGV (inlet guide vane angle)} \\
&\quad A_8 \text{ (exhaust area)} \\
&\quad \text{BLD (compressor bleed position)} \\
\eta &= P_c \text{ (inlet pressure)} \\
&\quad T_o \text{ (inlet temperature)} \\
&\quad P_8 \text{ (exhaust nozzle discharge pressure)} \\
r &= \text{PCD (compressor discharge pressure)} \\
&\quad \text{PT (turbine discharge pressure)} \\
&\quad \text{TB (burner temperature)} \\
&\quad \text{TT (turbine discharge temperature)}
\end{aligned}
\tag{A-78}
$$

It should be noted that additional variables can be added to the response vector by the user, if desired. The x, u, and η vectors cannot be enlarged as they already contain all the states, controls, and disturbances which are included in the nonlinear engine model.

Coefficients in the matrices F, G1, G2, H, D1 and D2 are computed in the program by a procedure based on the linearization method described in Reference A-2. Briefly, the procedure consists of expanding the nonlinear engine model represented by the nonlinear matrix functions f and h,

$$
\begin{aligned}
\dot{x} &= f(x,u,\eta) \\
r &= h(x,u,\eta)
\end{aligned}
\tag{A-79}
$$

in a Taylor series about the equilibrium operating point defined by the steady-state input parameters N, TM, WF, A_8, IGV, BLD, P_o, T_o and P_8. This equilibrium point is denoted as (x_o, u_o, η_o). Note that substitution of these variables, x_o, u_o, and η_o, into the nonlinear system equations gives

$$\begin{aligned} f(x_o, u_o, \eta_o) &= \dot{x}_o = 0 \\ h(x_o, u_o, \eta_o) &= r_o \end{aligned} \tag{A-80}$$

The result of the Taylor series expansion is

$$\begin{aligned} f(x, u, \eta_o) - f(x_o, u_o, \eta_o) &= \frac{\partial f}{\partial x}(x_o, u_o, \eta_o)\Delta x + \frac{\partial f}{\partial u}(x_o, u_o, \eta_o)\Delta u \\ &\quad + \frac{\partial f}{\partial \eta}(x_o, u_o, \eta_o)\Delta \eta \\ h(x, u, \eta_o) - h(x_o, u_o, \eta_o) &= \frac{\partial h}{\partial x}(x_o, u_o, \eta_o)\Delta x + \frac{\partial h}{\partial u}(x_o, u_o, \eta_o)\Delta u \\ &\quad + \frac{\partial h}{\partial \eta}(x_o, u_o, \eta_o)\Delta \eta \end{aligned} \tag{A-81}$$

which is equivalent to the linear representation of Equations (A-77) if the following definitions are made.

$$\begin{aligned} \Delta\dot{x} &\triangleq \dot{x} - \dot{x}_o = f(x, u, \eta) - f(x_o, u_o, \eta_o) \\ \Delta r &\triangleq r - r_o = h(x, u, \eta) - h(x_o, u_o, \eta_o) \\ F &\triangleq \frac{\partial f}{\partial x}(x_o, u_o, \eta_o) \\ G1 &\triangleq \frac{\partial f}{\partial u}(x_o, u_o, \eta_o) \\ G2 &\triangleq \frac{\partial f}{\partial \eta}(x_o, u_o, \eta_o) \end{aligned} \tag{A-82}$$

$$
\begin{aligned}
H &\triangleq \frac{\partial h}{\partial x}(x_o, u_o, \eta_o) \\
D1 &\triangleq \frac{\partial h}{\partial u}(x_o, u_o, \eta_o) \\
D2 &\triangleq \frac{\partial h}{\partial \eta}(x_o, u_o, \eta_o)
\end{aligned}
\qquad \text{(A-82)}
$$

Thus the coefficient matricies are actually matricies of partial derivatives evaluated at the equilibrium point. For example, the F matrix is

$$
F = \begin{bmatrix}
\frac{\partial f_1}{\partial x_1}(x_o, u_o, \eta_o) & \frac{\partial f_1}{\partial x_2}(x_o, u_o, \eta_o) \ldots & \frac{\partial f_1}{\partial x_\eta}(x_o, u_o, \eta_o) \\
\frac{\partial f_2}{\partial x_1}(x_o, u_o, \eta_o) & \frac{\partial f_2}{\partial x_2}(x_o, u_o, \eta_o) \ldots & \frac{\partial f_2}{\partial x_\eta}(x_o, u_o, \eta_o) \\
\vdots & & \\
\frac{\partial f_\eta}{\partial x_1}(x_o, u_o, \eta_o) & \frac{\partial f_\eta}{\partial x_2}(x_o, u_o, \eta_o) \ldots & \frac{\partial f_\eta}{\partial x_\eta}(x_o, u_o, \eta_o)
\end{bmatrix}
\qquad \text{(A-83)}
$$

where n is the dimension of the state vector, x.

Written in terms of engine variables, this matrix is

$$
F = \begin{bmatrix}
\frac{\partial \dot{N}}{\partial N}(x_o, u_o, \eta_o) & \frac{\partial \dot{N}}{\partial TM}(x_o, u_o, \eta_o) \\
\frac{\partial \dot{TM}}{\partial N}(x_o, u_o, \eta_o) & \frac{\partial \dot{TM}}{\partial TM}(x_o, u_o, \eta_o)
\end{bmatrix}
\qquad \text{(A-84)}
$$

Similar expressions could be written for the other coefficient matrices.

Since the partial derivatives in these matrices cannot be evaluated analytically, they are computed from finite difference approximations in the computer program. The method is illustrated below for the (1, 1) element in the F matrix.

$$\frac{\partial f_1}{\partial x_1}(x_o, u_o, \eta_o) = \frac{f_1(x_{1_o} + \Delta x_1, x_{2o}, \ldots x_{\eta_o}, u_o, \eta_o) - f_1(x_{1_o} - \Delta x_1, x_{20}, \ldots x_{\eta_o}, u_o, \eta_o)}{2\Delta x_1} \tag{A-85}$$

Thus the procedure involves evaluating the nonlinear-dependent function [$f_1(x, u, \eta)$ in the example] for small perturbations in the independent variable (ΔX_1) about the equilibrium point (x_o, u_o, η_o). Both positive and negative perturbations in the independent variable are considered. The results are averaged to compute the final answer.

In the notation used in the computer program, the partial derivatives associated with the coefficient matrices are denoted as

$$\frac{\partial DX_i}{\partial X_j} = \frac{DX2_i - DX1_i}{2\Delta X_j} \tag{A-86}$$

where

$$DX^T = (\dot{N}, \dot{T}M, PCD, PT, TB, TT)$$

$$X^T = (N, TM, WF, IGV, A_8, BLD, P_o, T_o, P_8)$$

Thus the engine variables associated with the nonlinear functions f and h (i.e., time derivatives of the states and responses) are lumped together in the DX vector. The independent variables (i.e., states, controls, and disturbances) are lumped together in the X vector. The symbol DX2 is used in these equations to denote the DX vector evaluated for a positive perturbation in X_j. Similarly, DX1 denotes the DX vector evaluated for a negative perturbation in X_j.

computations in the program proceed in the following order. First, all the derivatives with respect to X_1 are computed,

$$\frac{\partial DX_i}{\partial X_1} \quad i = 1, 2, \ldots NXR$$

where NXR is the dimension of the DX vector. Then all the derivatives with respect to X_2 are computed,

$$\frac{\partial DX_i}{\partial X_2} \quad i = 1, 2, \ldots NXR$$

This procedure continues until all the derivatives have been computed. The last set evaluated is

$$\frac{\partial DX_i}{\partial X_{NXUE}} \quad i = 1, 2, \ldots NXR$$

where NXUE is the dimension of the X vector.

A flowchart of the linearization program is presented in Figure A-3. This flowchart corresponds to the portion of the fortran listing beginning at statement number 511 in the main program (see listing in Table A-2).

First the parameters N, TM, W_f, IGV, A_8, BLD, P_0, T_c and P_8 specifying the operating point are input. These variables are obtained from the TRIM section of the main program.

Then the perturbation step size DPERT is read in. The units on DPERT are percent.

Next the integer variable J which corresponds to the subscript j in Equation (A-86) is initialized. It is set to zero.

Then nominal values of the variables in the DX vector are computed in subroutine DYNAMIC. The nominal values obtained are stored in the vector DXN.

In the next step the value of J is increased by one. This means that the partial derivatives with respect to X_1 are to be computed first.

Values of the variables in the DX vector are recalculated for a negative perturbation in X_j, in the following steps. However, before the actual calculations are made, the variable X_j is tested to determine if it is zero. A zero value of X_j implies that a negative perturbation step in X_j cannot be taken, since all of the variables in the X vector must always be positive. Thus if $X_j = 0$, the calculations for a negative perturbation in X_j are bypassed. This condition will be discussed later.

If X_j is nonzero, a negative perturbation in X_j is computed from the relation,

$$\begin{aligned} PERT &= X_j \cdot DPERT \\ X_j &= X_j - PERT \end{aligned} \qquad (A\text{-}87)$$

Then new values of the variables in the DX vector are calculated in subroutine DYNAMIC. The new values are stored in the vector DX1 and the vector DX is reloaded with the nominal values stored in DXN. Finally, the independent variable X_j is restored to its nominal value by adding PERT back on X_j.

$$X_j = X_j + PERT$$

At this point the values of variables in the DX vector have been computed for a negative perturbation in X_j. In the next steps the variables in the DX vector are recomputed for a positive perturbation in X_j. However, before these calculations can be made, the value of X_j is again tested. This time X_j is tested to determine if its value is close to one, i.e., if $|X_j-1|$ is less than PERT.

The condition $X_j = 1$ is important because two of the independent variables, IGV and BLD, are scaled to be in the range 0 - 1.0. Thus if X_j corresponds to one of these variables (J = 4 or 6) and X_j is one, then a positive perturbation in X_j cannot be computed since it would give $X_j > 1$. In this case the calculations for a positive perturbation in X_j are bypassed. It should be noted that this test does not affect the other independent variables since they are always much greater than one. The calculations performed if $|X_j - 1|$ is less than PERT will be discussed later.

If $|X_j - 1|$ is greater than PERT, then a positive perturbation in X_j is calculated,

$$X_j = X_j + PERT$$

Values of the variables in the DX vector are recomputed in subroutine DYNAMIC. The results are stored in DX2 and the vector DX is reloaded with nominal values stored in DXN. Finally, X_j is restored to its nominal value by subtracting PERT from X_j.

$$X_j = X_j - PERT$$

At this point if both the tests on X_j,

$$X_j = 0 \quad \text{and} \quad |X_j - 1| < PERT$$

were failed, the values of the variables in the DX vector for a negative perturbation in X_j are stored in DX1 and the values of the variables for a positive perturbation in X_j are stored in DX2. In this case the values of the partial derivatives with respect to X_j are computed from the finite difference equation,

$$\frac{\partial DX_i}{\partial X_j} = \frac{DX2_i - DX1_i}{2\ PERT} \qquad i = 1,\ 2,\ \ldots\ NXR \qquad \text{(A-88)}$$

However, if either of the tests on X_j were passed, then the partial derivatives must be calculated from a different equation because only one of the vectors DX1 or DX2 can be computed.

First consider the case $X_j=0$. In this case only positive perturbations in X_j can be computed. Thus in the calculations beginning at station 3, first a positive perturbation in X_j is computed from

$$PERT = DPERT$$

$$X_j = X_j + PERT$$

(Note that a perturbation in X_j cannot be computed from $PERT = X_j \cdot DPERT$ because $X_j=0$.) Then the values of the variables in the DX vector are computed and stored in DX2. Next, X_j is restored to its nominal value

$$X_j = X_j - PERT$$

and finally the partial derivatives with respect to X_j are computed from the one-sided finite difference equation

$$\frac{\partial DX_i}{\partial X_j} = \frac{DX2_i - DXN_i}{PERT} \qquad i=1,\ 2,\ \ldots\ NXR \qquad \text{(A-89)}$$

Similarly, in the case $|X_j - 1| < \text{PERT}$ (corresponding to station 4) the partial derivatives are calculated from the one-sided finite difference equation

$$\frac{\partial DX_i}{\partial X_j} = \frac{DXN_i - DX1_i}{PERT} \qquad i=1,2,\ldots NXR \tag{A-90}$$

since values of DX2 cannot be obtained.

After the partial derivatives with respect to X_j have been calculated, control of the routine is transferred to station 2. The variable J is tested to determine if all the partial derivatives have been computed (J=NXUE). If J is less than NXUE the routine returns to station 1 to compute the partial derivatives with respect to X_{j+1}. If J=NXUE, the linearization procedure is finished.

Input Data

The input data required to run the linearization program are described in this subsection. Two groups of data are necessary, the program control group and the component description group.

The program control group includes parameters which define the nominal operating condition for the engine and parameters which control the linearization procedure. This information is input on the four data cards identified below, cards A-E.

Card A

(1) ERROR	This parameter determines the accuracy of the iterations in subroutine DYNAMIC

Card B

(1)	NX	Dimension of the state vector
(2)	NU	Dimension of the control vector
(3)	NE	Dimension of the disturbance vector
(4)	NR	Dimension of the response vector
(5)	DPERT	Perturbation step size used in the LINEARIZATION routine

Card C

(1)	N	Nominal value of spool speed
(2)	WINGS	Initial guess for inlet airflow in the TRIM routine
(3)	SPLC	Rotor torque load
(4)	IGV	Inlet guide vane position
(5)	BLD	Compressor bleed position

Card D

(1)	P_0	Compressor inlet pressure
(2)	T_0	Compressor inlet temperature

The component description group consists of tabulated experimental data which models the steady-state operating characteristics of the engine components. This data is stored on magnetic tape and read into dummy arrays at the beginning of the program. Two function subroutines, FUN1 and FUN2, are used in the program to interpolate between the data points.

The experimental functions contained in this data group are presented in Tables A-3a through A-3x and identified below.

Table Number	Function ID	Experimental Function
A-3a	F11	$ABLB = f(BVOB)$
A-3b	F12	$IGVPR = F(N/N_{max})$
A-3c	F13	$OGVPR = f(N/N_{max})$
A-3d	F15	$\psi_2{}^P = f(\phi_2)$
A-3e	F16	$\psi_2{}^T = f(\phi_2)$
A-3f	F17	$\psi_3{}^P = f(\phi_3)$
A-3g	F18	$\psi_3{}^T = f(\phi_3)$
A-3h	F19	$\psi_4{}^P = f(\phi_4)$
A-3i	F110	$\psi_4{}^T = f(\phi_4)$
A-3j	F111	$\psi_5{}^P = f(\phi_5)$
A-3k	F112	$\psi_3{}^T = f(\phi_5)$
A-3l	F113	$\psi_6{}^P = f(\phi_6)$
A-3m	F114	$\psi_6{}^T = f(\phi_6)$
A-3n	F115	$\psi_7{}^P = f(\phi_7)$
A-3o	F116	$\psi_7{}^T = f(\phi_7)$
A-3p	F117	$\psi_8{}^P = f(\phi_8)$
A-3q	F118	$\psi_8{}^T = f(\phi_8)$
A-3r	F119	$\eta_B = f[PB \cdot (TB-TCD)]$
A-3s	F120	$KWB = f(N/N_{max})$
A-3t	F1	$BVOB = f(N/N_{max}, T_o)$

Table Number	Function ID	Experimental Function
A-3u	F2	$\psi_2^P = f(\phi_2, \mathrm{IGV})$
A-3v	F3	$\frac{WT \cdot TB}{N \cdot PB} = f(\frac{PT}{PB}, \frac{N}{\sqrt{TB}})$
A-3w	F4	$\frac{\Delta HT}{N \sqrt{TB}} = f(\frac{PT}{PB}, \frac{N}{\sqrt{TB}})$
A-3x	F5	$\psi_2^T = f(\phi_2, \mathrm{IGV})$

Nominal schedules for the two compressor geometry controls are contained in functions F1 and F11. F1 gives the nominal setting for the IGV (BVOB) as a function of spool speed and compressor inlet temperature. F11 gives the nominal setting for the BLD (ABLB) as a function of BVOB. These actuator schedules were obtained from the NASA component model (Reference A-1). They were not used in the linearization program. Nominal settings for the IGV and BLD are read in on card C of the program control group.

Functions F12 and F13 are correlations of inlet guide vane pressure ratio and outlet guide vane pressure ratio with spool speed.

Pressure and temperature rise coefficients for compressor stages 2 through 8 are contained in functions F15 - F118. These coefficients are functions of a single variable, the flow coefficient ϕ_i.

Pressure and temperature rise coefficients for the first compressor stage are given by functions F2 and F5.

The coefficients for this stage are functions of both flow coefficient ϕ_1 and inlet guide vane position.

Burner efficiency is presented as a function of the parameter PB · (TB-TCD) in F119 where PB is burner pressure, TB is burner temperature, and TCD is compressor discharge temperature.

The constant KWB is determined as a function of spool speed in F120. This constant is used to determine the pressure loss in the burner.

The function F3 and F4 contain steady-state turbine performance data. The parameter WT · TB/N · PB where WT is turbine airflow is given as a function of turbine pressure ratio and the parameter $N/\sqrt{TB}$ in F3. Turbine enthalpy drop ΔHT divided by $N \cdot \sqrt{TB}$ is given as a function of the same two parameters, PT/PB and $N/\sqrt{TB}$, in F4.

NONLINEAR ENGINE SIMULATION

The nonlinear engine simulation program is discussed in this subsection. This program is a fortran version of the NASA component model of Reference A-1. A Fortran listing of the program is presented in Table A-1. A listing of the reduced-order component model is presented in Table A-2.

The function of this program is to simulate the transient response of the engine to changes in full flow, exhaust area, inlet guide vane position and compressor bleed position.

A flowchart of the program is presented in Figure A-4. Computations performed in the program are summarized in the following paragraphs. A detailed description of the software is contained in Reference A-1 and in Section II, Volume I of this report.

First, nominal values of spool speed (N), geometry control positions (A_8, IGV, BLD), compressor inlet pressure and temperature (P_o, T_o), nozzle discharge pressure (P_8) and rotor torque load (SPLC) are read in. These parameters define the nominal operating condition for the engine.

A steady-state trim point corresponding to these nominal input parameters is computed next. The fuel flow required to maintain nominal spool speed is calculated in addition to initial values of all the engine states X(o) and responses r(o). It should be noted that the section of the program which performs these calculations is identical to the TRIM routine included in the linearization program. A detailed discussion of the TRIM routine is included in the documentation of the linearization program.

Next the control positions u(T) defining the transient to be simulated are read in. The u vector includes fuel flow, exhaust area, inlet guide vane position and compressor bleed position.

The time increment ΔT and simulation stop time FINTIME are defined in the following step. Then time is initialized and the time corresponding to the first integration step is computed.

$$T = T + \Delta T$$

Engine dynamics are computed in the next two steps from the nonlinear engine model contained in subroutine DYNAMIC. This nonlinear model is described in detail in Section II, Volume I of this report. Time derivatives of the engine states are computed from the nonlinear function f,

$$\dot{x}(T) = f[x(T), r(T), u(T)]$$

and updated values of the responses are computed from the nonlinear function h

$$r(T + \Delta T) = h[x(T), r(T), u(T)]$$

The derivatives are then integrated with a four point Runge Kutta integration routine to determine the value of the states at time T + ΔT.

$$x(T + \Delta T) = x(T) + \int_{T}^{T+\Delta T} \dot{x}(T)dT$$

In the final step in the program, the current value of time is compared with the stop time. If $T \geq$ FINTIME, the program exits from the integration loop. If $T <$ FINTIME, the routine returns to station 1 for an additional integration step.

Table A-1. Nonlinear Engine Simulation Program

```
AFORTRAN LS,C0                                                            A=00
      DIMENSION IGV(42),A(20),PV(20),TV(20),YY1(14),XX1(17),ZZ1(196)
      DIMENSION L(20),V(20),KGAL(20),KVOL(20),KNR(8),RAD(8),KRAD(8)
      DIMENSION KA(30)
      DIMENSION TWV(20),WD(20),WV(20),KBLD(8),DPRB(14)
      COMMON/TDATA/TIME,DT,ISTEP,NICOT
      COMMON/DATA/X(39),U(3),ETA(3),DXN(40),DX(40),DXT(40),CLM(40),
     1KVOLIG,KGALIG,KVOLOG,KGALOG,RTHO,ABL,KOGV,WTC,KVOLCD,KGALCD,TB,KWB
     2,KGALB,KVOLB,HT,TT,PT,K4,K2,WT,HCD,PO,WN,KNA8,KSPEED,KFIGV,K3,IGVP
     3R,TVO
      REAL ICTWVO,ICWVO
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVOL
      REAL KVOLOG,KGALOG,KVOLCD,KGALCD,KGALB,KWB,KVOLB,KVOLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KOGV,KNA8,NRTTB,ICPVO,ICWDO,ICWD1,ICWV1
      REAL ICTWV1,ICWD2,ICWV2,ICTWV2,ICWD3,ICWV3,ICTWV3,ICWD4,ICWV4
      REAL ICTWV4,ICWD5,ICWV5,ICTWV5,ICWD6,ICWV6,ICTWV6,ICWD7,ICWV7
      REAL ICTWV7,ICWD8,ICWV8,ICTWV8,ICTWOG,ICWOGV,ICWDOG,ICTWCD,ICWCD
      REAL ICWDCD,ICWB,ICPB,ICHB,ICRT,ICRHT,ICWFQP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMD,ITER,IMPL,INTGRL,KIC
      REAL KA8,ICWDOG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVOLIG
      EQUIVALENCE (ICWDO,WDO,X(1 )),(ICWVO,WVO,X(2 )),(ICTWVO,TWVO,X(3 )
     1           ),(ICWD1,WD1,X(4 )),(ICWV1,WV1,X(5 )),(ICTWV1,TWV1,X(6 )
     2           ),(ICWD2,WD2,X(7 )),(ICWV2,WV2,X(8 )),(ICTWV2,TWV2,X(9 )
     3           ),(ICWD3,WD3,X(10)),(ICWV3,WV3,X(11)),(ICTWV3,TWV3,X(12)
     4           ),(ICWD4,WD4,X(13)),(ICWV4,WV4,X(14)),(ICTWV4,TWV4,X(15)
     5           ),(ICWD5,WD5,X(16)),(ICWV5,WV5,X(17)),(ICTWV5,TWV5,X(18)
     6           ),(ICWD6,WD6,X(19)),(ICWV6,WV6,X(20)),(ICTWV6,TWV6,X(21)
     7           ),(ICWD7,WD7,X(22)),(ICWV7,WV7,X(23)),(ICTWV7,TWV7,X(24)
     8           ),(ICWD8,WD8,X(25)),(ICWV8,WV8,X(26)),(ICTWV8,TWV8,X(27)
     9      ),(ICWDOG,WDOG,X(28)),(ICWOGV,WOGV,X(29)),(ICTWOG,TWOG,X(30))
     A       ,(ICWDCD,WDCD,X(31)),(ICWCD,WCD,X(32)),(ICTWCD,TWCD,X(33))
     B                         ,(ICWB,WB,X(34)),(ICPB,PB,X(35))
     C       ,(ICHB,HB,X(36)),(ICRHT,RHT,X(37)),(ICRT,RT,X(38))
     D       ,(ICN,N,X(39)),(WF,U(1)),(BVO,U(2)),(A8,U(3)),(P2,ETA(1))
     E       ,(T2,ETA(2)),(P8,ETA(3))
      EQUIVALENCE (WDODT  ,DX(1 )),(WVODT  ,DX(2 )),(TWVODT ,DX(3 )),
     1             (WD1DT  ,DX(4 )),(WV1DT  ,DX(5 )),(TWV1DT ,DX(6 )),
     2             (WD2DT  ,DX(7 )),(WV2DT  ,DX(8 )),(TWV2DT ,DX(9 )),
     3             (WD3DT  ,DX(10)),(WV3DT  ,DX(11)),(TWV3DT ,DX(12)),
     4             (WD4DT  ,DX(13)),(WV4DT  ,DX(14)),(TWV4DT ,DX(15)),
     5             (WD5DT  ,DX(16)),(WV5DT  ,DX(17)),(TWV5DT ,DX(18)),
     6             (WD6DT  ,DX(19)),(WV6DT  ,DX(20)),(TWV6DT ,DX(21)),
     7             (WD7DT  ,DX(22)),(WV7DT  ,DX(23)),(TWV7DT ,DX(24)),
     8             (WD8DT  ,DX(25)),(WV8DT  ,DX(26)),(TWV8DT ,DX(27)),
     9             (WDOGDT ,DX(28)),(WOGVDT ,DX(29)),(TWOGDT ,DX(30)),
     A             (WDCDDT ,DX(31)),(WCDDT  ,DX(32)),(TWCDDT ,DX(33)),
     B                               (WBDT   ,DX(34)),(PBDT   ,DX(35)),
     C             (HBDT   ,DX(37)),(RHTDT  ,DX(38)),(RTDT   ,DX(39)),
     D             (NDT    ,DX(39))
      REWIND 3
 8099 CONTINUE
      RND1=0.
      RND2=0.
      READ(5,8030)NX,NU,NE,DPERT
 8030 FORMAT(3I2,G12.5)
      REWIND 7
      DATA (DPRB(I),I=1,14)/.60,7.26E-4,.70,7.07E-4,.80,6.98E-4,.85,6.9[illegible]
     1-4,.90,6.96E-4,.97,6.96E-4,1.0,7.38E-4/
      DATA (KBLD(I),I=1,8)/2*0.,1.1025,1.0572,1.0411,3*0./
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      DATA (KGAL(I),I=1,8)/25542.,27942.,27247.,26407.,24084.,21872.,221
     155.,22439./
      DATA (KVAL(I),I=1,8)/1.9107,3.3711,4.9797,7.0839,9.3047,11.2953,13
     1.7727,15.1219/
      DATA (TV(I),I=1,20)/5*1600.,15*518.7/
      DATA (TWV(I),I=1,20)/20*10./
      DATA (WC(I),I=1,20)/20*30./
      DATA (WV(I),I=1,20)/20*.01/
      READ(7)(IGV(I),I=1,18)
      F11 =FN1SET(1,IGV   ,9,1,1)
      READ(7)(IGV(I),I=1,38)
      F14 =FN1SET(4,IGV ,19,4,5)
      READ(7)(IGV(I),I=1,20)
      F12 =FN1SET(2,IGV,10,2,2)
      READ(7)(IGV(I),I=1,18)
      F13 =FN1SET(3,IGV,9, 3,3)
      READ(7)(IGV(I),I=1,40)
      F15 =FN1SET(5,IGV   ,20,6,7)
      READ(7)(IGV(I),I=1,42)
      READ(5,877)(IGV(I),I=1,42)
  877 FORMAT(10F8.4)
      F16 =FN1SET(6,IGV ,21,8,9)
      READ(7)(IGV(I),I=1,34)
      F17 =FN1SET(7,IGV   ,17,10,11)
      READ(7)(IGV(I),I=1,38)
      READ(5,877)(IGV(I),I=1,38)
      F18 =FN1SET(8,IGV ,19,12,13)
      READ(7)(IGV(I),I=1,36)
      F19 =FN1SET(9,IGV   ,18,14,15)
      READ(7)(IGV(I),I=1,36)
      IGV(3)=.53
      READ(5,877)(IGV(I),I=1,40)
      F110=FN1SET(10,IGV,20,16,17)
      READ(7)(IGV(I),I=1,32)
      F111=FN1SET(11,IGV   ,16,18,19)
      READ(7)(IGV(I),I=1,32)
      READ(5,877)(IGV(I),I=1,36)
      F112=FN1SET(12,IGV,18,20,21)
      READ(7)(IGV(I),I=1,26)
      F113=FN1SET(13,IGV   ,13,22,23)
      READ(7)(IGV(I),I=1,26)
      READ(5,877)(IGV(I),I=1,26)
      F114=FN1SET(14,IGV ,13,24,25)
      READ(7)(IGV(I),I=1,30)
      F115=FN1SET(15,IGV   ,15,26,27)
      READ(7)(IGV(I),I=1,24)
      READ(5,877)(IGV(I),I=1,26)
      F116=FN1SET(16,IGV,13,28,29)
      READ(7)(IGV(I),I=1,30)
      F117=FN1SET(17,IGV   ,15,30,31)
      READ(7)(IGV(I),I=1,32)
      READ(5,877)(IGV(I),I=1,32)
      F118=FN1SET(18,IGV ,16,32,33)
      READ(7)(IGV(I),I=1,28)
      F119=FN1SET(19,IGV ,14,34,35)
      READ(7)(IGV(I),I=1,26)
      F120=FN1SET(20,DPRB,7,36,37)
      READ(7)(IGV(I),I=1,40)
      F121=FN1SET(21,IGV    ,20,38,39)
        READ(7)(A(I),I=1,20)
        READ(7)(L(I),I=1,20)
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      READ(7)(V(I),I=1,20)
      READ(7)(IGV (I),I=1,20)
      READ(7)(IGV (I),I=1,20)
      READ(7)(RAD(I),I=1,8)
      READ(7)(KRAD(I),I=1,8)
      READ(7)(FV(I),I=1,20)
      READ(7)(IGV(I),I=1,20)
      READ(7)(YY1(I),I=1,5)
      READ(7)(XX1(I),I=1,13)
      READ(7)(ZZ1(I),I=1,65)
     F1= FN2SET(1,XX1,YY1,ZZ1,13,5,1,2)
      READ(7)(KA(I),I=1,30)
      READ(7)(YY1(I),I=1,4)
      READ(7)(XX1(I),I=1,17)
      READ(7)(ZZ1(I),I=1,68)
     F2 = FN2SET(2,XX1,YY1,ZZ1,17,4,3,4)
      READ(7)(YY1(I),I=1,14)
      READ(7)(XX1(I),I=1,14)
      READ(7)(ZZ1(I),I=1,196)
      DO 9773 I=1,43
      IJ=196-I
      JJ=IJ+1
 9773 ZZ1(JJ)=ZZ1(IJ)
      ZZ1(148)=.0545
      WRITE(9,1602)
      WRITE(9,1601)(YY1(I),I=1,14)
      WRITE(9,1603)
      WRITE(9,1601)(XX1(I),I=1,14)
      WRITE(9,1603)
      WRITE(9,1601)(ZZ1(I),I=1,196)
      WRITE(9,1602)
      F3 = FN2SET(3,XX1,YY1,ZZ1,14,14,5,6)
       READ(7)(YY1(I),I=1,14)
       READ(7)(XX1(I),I=1,14)
       READ(7)(ZZ1(I),I=1,196)
 1601 FORMAT(13F9.4)
 1602 FORMAT(1H1)
 1603 FORMAT(//)
      ZZ1(94)=.0991
      F4 = FN2SET(4,XX1,YY1,ZZ1,14,14,7,8)
      READ(5,877)(YY1(I),I=1,4)
      READ(5,877)(XX1(I),I=1,17)
      READ(5,877)(ZZ1(I),I=1,68)
      F5=FN2SET(5,XX1,YY1,ZZ1,17,4,9,10)
C
C SET PARAMETERS
C
      KAR=0
      NSSP=1
      TIGS=1700.
      READ(5,8066)NRAT,AB,TBGS,WINGS,FABGS,SPLC
 8066 FORMAT(6G12.5)
      WRITE(9,8066)NRAT,AB,TBGS,WINGS,FABGS,SPLC
      P2=14.7
      T2=518.7
      WDEL=.1
      K1 = 3.14159/360.
      K2=7.*32.17*53.35/(K1*K1)
      K3=SQRT(518.7)
      K4=(53.35*12.)/17600.
      KBALIG=51.37.
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      KVØLIG=3.31
      KGALØG = 22430.
      KVØLØG = 15.11
      KGALCD = 6730.
      KVØLCD = 1.981
      KGALR = 5470.
      KVØLR = 2.649
      KNB = .0004445
      KVØLT = 14.15
      KSPEED = 138400.
      ICN=NRAT*16500.
      P0=P2
      P8=P2
      TV0 = T2
      RTH0 = SQRT(TV0/518.7)
      NC1 = ICN/RTH0
      NC1N = NC1/16500.
      BV8 = FUN2(1,NC1N,TV0,1)
      ABL=FUN1(1,BV8,1)
      IGVPR=FUN1(2,NC1N,2)
      BGVPR=FUN1(3,NC1N,3)
      TV(10) = T2
      III=0
      ITER1=0
      ITER2=0
      ITER3=0
      DØ 60 K=1,NSSP
      FAB=FABGS
      TB=TBGS
      WIN=WINGS
      DWINX=.1
      PV(10) = P2*IGVPR - .005*P2
   39 CØNTINUE
      WD(10)=WIN-FLØAT(K-1)*WDEL
      ITER1=ITER1+1
      KFIGV=KGALIG*(P2-PV(10))/(WD(10)*WD(10))
      WBL=0.
      WBLTBL=0.
      IF(SENSE SWITCH 3)8073,8074
 8074 CØNTINUE
      IF(III.NE.1) GØTØ 5901
 8073 CØNTINUE
      J = 0
      WRITE(6,50) ICN,ABL,BV8,IGVPR,BGVPR
      WRITE(6,51)
      WRITE(6,52) J,PV(10),TV(10),WD(10)
 5901 CØNTINUE
      DØ 20 I=11,18
      J = I-10
      DELX = PV(I-1)/14.7
      RTHX = SQRT(TV(I-1)/518.7)
      NCX = ICN/RTHX
      WD(I)=WD(I-1)-WBL
      FPX=WD(I)*RTHX/(DELX*A(I))
      VZTX=KA(J)+FPX*(KA(J+10)+FPX*KA(J+20))
      KRAD(J) = K1*RAD(J)
      PHIX = VZTX/(KRAD(J)*NCX)
      GØ TØ (1,2,3,4,5,6,7,8),J
    1 CØNTINUE
      PSIPX = FUN2(2,PHIX,BV8,3)
      PSITX=FUN2(5,PHIX,BV8,9)
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      GØTØ 10
    2 CØNTINUE
      PSIPX=FUN1(5,PHIX,6)
      PSITX=FUN1(6 ,PHIX,8 )
      GØTØ 10
    3 CØNTINUE
      PSIPX=FUN1(7,PHIX,10)
      PSITX=FUN1(8 ,PHIX,12)
      GØTØ 10
    4 CØNTINUE
      PSIPX=FUN1(9,PHIX,14)
      PSITX=FUN1(10,PHIX,16)
      GØTØ 10
    5 CØNTINUE
      PSIPX=FUN1(11,PHIX,18)
      PSITX=FUN1(12,PHIX,20)
      GØTØ 10
    6 CØNTINUE
      PSIPX=FUN1(13,PHIX,22)
      PSITX=FUN1(14,PHIX,24)
      GØTØ 10
    7 CØNTINUE
      PSIPX=FUN1(15,PHIX,26)
      PSITX=FUN1(16,PHIX,28)
      GØTØ 10
    8 CØNTINUE
      PSIPX=FUN1(17,PHIX,30)
      PSITX=FUN1(18,PHIX,32)
   10 CØNTINUE
      KNR(J)=(ICN*RAD(J))**2/K2
      PV(I) = PV(I-1)*(1.+PSIPX*KNR(J)/TV(I-1))**3.5
      TV(I) = TV(I-1)+KNR(J)*PSITX
      TWV(I)=PV(I)/KVØL(J)
      WV(I)=TWV(I)/TV(I)
      PR = PV(I)/PV(I-1)
      WBL=KBLD(J)*ABL*PV(I)/SQRT(TV(I))
      IF(J.EQ.3) WBL3=WBL
      IF(J.EQ.4) WBL4=WBL
      IF(J.EQ.5) WBL5=WBL
      WBLTBL=WBLTBL+WBL*TV(I)
      IF(SENSE SWITCH 3)8075,8076
 8076 CØNTINUE
      IF(III.NE.1) GØTØ 5902
 8075 CØNTINUE
      WRITE(6,52)J,PV(I),TV(I),WD(I),WBL,PSITX,VZTX,PHIX,PSIPX,PR
 5902 CØNTINUE
   20 CØNTINUE
      J = 19
      PØGV = PV(18)*ØGVPR
      TØGV = TV(18)
      WØGV=WD(18)
      KØGV = KGALØG*(PV(18)-PØGV)/WØGV**2
      TWØG = PØGV/KVØLØG
      WØØG = TWØG/TØGV
      PR23=PØGV/P2
      TR23=TØGV/T2
      EFF23=(PR23**.285-1.)/(TR23-1.)
      IF(SENSE SWITCH 3)8077,8078
 8078 CØNTINUE
      IF(III.NE.1) GØTØ 5903
 8077 CØNTINUE
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      WRITE(6,53)
      WRITE(6,52)J,POGV,TOGV,WOGV,WBLTBL,EFF23,PR23,TR23
 5903 CONTINUE
      J = 11
      PCD = POGV
      TCD=TOGV
      CALL PROCOM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
      WCD =WOGV
      TWCD = FCL/KVOLCD
      WDCD = TWCD/TCD
      WTC=.033*WD(10)
      DLWHC=HCD*WCD+.24*(WBLTBL-WD(10)*TV(10))+SPLC
      KNAB =FUN1(21,ICN,38)*.975
      IF(SENSE SWITCH 3)8170,8171
 8171 CONTINUE
      IF(III.NE.1) GOTO 5904
 8170 CONTINUE
      WRITE(6,54)
      WRITE(6,52)J,PCD,TCD,WCD,WTC,DLWHC,KNAB
 5904 CONTINUE
      J=12
      KWB=FUN1(20,NRAT,36)
      WB=WCD-WTC
      IF(ITER1.EQ.1) PT=.35*PCD
      DPTX=1.
  220 CONTINUE
      ITER2=ITER2+1
      DTBX=25.
      WTOLD=(1.+FAB)*WB
  221 NRTTB=ICN/SQRT(TB)
      ITER3=ITER3+1
      DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
      PB = PCD-DELPB
      PBDLTB = PB*(TB-TCD)
      ETAB =FUN1(19,PBDLTB,34)
      PTPB = PT/PB
      DHTNTB = FUN2(4,PTPB,NRTTB,7)
      DHT=DHTNTB*ICN/1000.*SQRT(TB)
  222 CALL PROCOM(FAB,TB,CPB,GMB,GMBX,HB,IFA)
      IF(SENSE SWITCH 4)8098,8091
 8091 CONTINUE
      WT1=WB*(18650.*ETAB-HCD)/(18650.*ETAB-HB)
      IF(IFA.GT.0) GOTO 8071
      WTERR=ABS(WT1-WTOLD)
      IF(WTERR.GT..0005) GOTO 223
 8072 CONTINUE
      WF=WT1-WB
      FAB=WF/WB
      WN=WT1+WTC
      GOTO 224
 8071 IF(WT1.LT.WB) WT1=WB
      IF(WT1.GT.(WB*1.067623)) WT1=1.067623*WB
      WTOLD=WT1
      GOTO 8072
  223 WTOLD=(WT1+WTOLD)*.5
      WF=WTOLD-WB
      FAB=WF/WB
      GOTO 222
  224 CONTINUE
      HT=WT1/WN*(HB-DHT)+WTC/WN*HCD
      HBR=(DLWHC+WN*HT-HCD*WTC)/WT1
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      TBERR=HBR-HB
      IF(TBERR.GT..0005) GOTO 225
      IF(TBERR.LT.-.0005) GOTO 228
      GOTO 229
  225 IF(DTBX)226,226,227
  226 DTBX=-DTBX*.5
  227 TB=TB+DTBX
      GOTO 221
  228 IF(DTBX)227,227,226
  229 CONTINUE
      POPT=PO/PT
      IF(POPT-.528)233,233,230
  230 IF(POPT-1.)232,231,231
  231 WNTKNP=0.
      GOTO 234
  232 WNTKNP= POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
      GOTO 234
  233 WNTKNP=.2588
  234 CONTINUE
      WTTNPB=FUN2(3,PTPB,NRTTB,5)
      WT2=WTTNPB*PB/TB*ICN
      PTERR=WT2-WT1
  240 IF(PTERR.GT..0005) GOTO 241
      IF(PTERR.LT.-.0005) GOTO 245
      GOTO 250
  241 IF(DPTX)242,242,243
  242 DPTX=-DPTX*.5
  243 PT=PT+DPTX
      GOTO 220
  245 IF(DPTX)243,243,242
  250 CONTINUE
      FAT=WF/WN
      TT=TFNH(1,FAT,HT,TV)
      IF(SENSE SWITCH 4)8098,8092
 8092 CONTINUE
      WNX=(KNAB*PT*WNTKNP*AB)/SQRT(TT)
      WNERR=WNX-WN
      IF(III.EQ.1) GOTO 60
      IF(WNERR.GT..005) GOTO 5951
      IF(WNERR.LT.-.005) GOTO 5955
      III=1
      GOTO 99
 5951 IF(DWINX)5952,5952,5953
 5952 DWINX=-DWINX*.5
 5953 WIN=WIN+DWINX
      GOTO 99
 5955 IF(DWINX)5953,5953,5952
   60 CONTINUE
      DLWHT=HB*WT1+HCD*WTC-HT*WN
      WFM = 3600.*WF
      WRITE(6,56)
      WRITE(6,52) J,FB,TB,WB,ETAB,HB,PTPB,NRTTB,DHTNTB,WTTNPB
      J = 13
      WRITE(6,57)
      WRITE(6,52)J,PT,TT,WT1,WF,HT,DLWHT,WN,WNTKNP,AB
      WRITE(6,2108)ITER1,ITER2,ITER3
 2108 FORMAT(1H0,5X,8HITER1 = I5,5X,8HITER2 = I5,5X,8HITER3 = I5)
   50 FORMAT(1H1/4X,4HN = ,F8.2,4X,6HABL = ,F8.4,4X,6HBV0 = ,F8.4,4X,
     *8HIGVPR = ,F8.4,4X,8HOGVPR = ,F8.4)
   51 FORMAT(1H0,3X,1HJ,5X,5HPV(I),9X,5HTV(I),9X,5HWD(J),8X,6HWBL(J),8X
     *6HPSIT J,8X,6HVZT(J),8X,6HPHI(J),7X,7HPSIP(J),9X,5HPR(J))
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
   52 FØRMAT(1H0,I4,9G14.5)
   53 FØRMAT(1H0,3X,1HJ,6X,4HPØGV,10X,4HTØGV,10X,4HWØGV,8X,6HWBLTBL,9X,5
     1HEFF23,10X,4HPR23,10X,4HTR23)
   54 FØRMAT(1H0,3X,1HJ,7X,3HPCD,11X,3HTCD,11X,3HWCD,11X,3HWTC,9X,5HDLWH
     1C,10X,4HKNAB)
   56 FØRMAT(1H0,3X,1HJ,8X,2HPB,12X,2HTB,12X,2HWB,10X,4HETAB,12X,2HHB,
     110X,4HPTPB,9X,5HNRTTB,8X,6HDHTNTB,8X,6HWTTNPB)
   57 FØRMAT(1H0,3X,1HJ,8X,2HPT,12X,2HTT,12X,2HWT,12X,2HWF,12X,2HHT,9X,5
     1HDLWHT,12X,2HWN,8X,6HWNTKNP,12X,2HAB)
      ICPVO = PV(10)
       ICWDO=WD(10)
       ICWD1=WD(11)
      ICWV1=WV(11)
      ICTWV1=TWV(11)
       ICWD2=WD(12)
      ICWV2=WV(12)
      ICTWV2=TWV(12)
       ICWD3=WD(13)
      ICWV3=WV(13)
      ICTWV3=TWV(13)
       ICWD4=WD(14)
      ICWV4=WV(14)
      ICTWV4=TWV(14)
       ICWD5=WD(15)
      ICWV5=WV(15)
      ICTWV5=TWV(15)
       ICWD6=WD(16)
      ICWV6=WV(16)
      ICTWV6=TWV(16)
       ICWD7=WD(17)
      ICWV7=WV(17)
      ICTWV7=TWV(17)
       ICWD8=WD(18)
      ICWV8=WV(18)
      ICTWV8=TWV(18)
      ICTWØG = TWØG
      ICWØGV = WØGV
      ICWDØG = WDØG
      ICTWCD = TWCD
      ICWCD = WCD
      ICWDCD = WDCD
      ICWB = WB
      ICPB  = PB
      ICHB = HB
      ICRT =PT/K4/TT
      ICRHT = HT*ICRT
      ICTWVO = ICPVO/KVØLIG
      ICWVO = ICTWVO/TVO
      DØ 298 I=1,8
      II=I+10
      KGAL(II)=KGAL(I)
  298 KVØL(II)=KVØL(I)
      READ(5,9011)(DX(I),I=1,NX)
 9011 FØRMAT(8E10.4)
      IF(DX(1).NE.0.) GØTØ 9701
      CCC=0.
      GØTØ 9702
 9701 CØNTINUE
      DØ 9012 I=1,NX
 9012 DX(I)=2.*DX(I)
      CCC=.01*X(1)/DX(1)
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
 9702 CONTINUE
      DO 9013 I=1,NX
      DX(I)=DX(I)*CCC
 9013 X(I)=X(I)+DX(I)
      WRITE(3)(X(I),I=1,NX)
      READ(5,9014)DELT,FINTIME,PRDEL,OUTDEL
 9014 FORMAT(4G12.5)
      DT=DELT
      TIME=0.
      DTH=DELT*.5
      NXUE=NX+NU+NE
      SIGN=1.
      WRITE(9,8061)
      WRITE(9,8060)(X(I),I=1,NX)
 8060 FORMAT(E20.8)
 8061 FORMAT(1H1)
 3333 CONTINUE
      ISTEP=0
      NICOT=0
      CALL DYNAM(A,PV,TV,KGAL,KVOL,KNR,RAD,KRAD,KA,T,V,WD,HV,KBLD,DPRR)
      TIME=TIME+DELT
      IF(ABS(TIME-PRDEL).GT..000001) GOTO 3333
      PRDEL=PRDEL+OUTDEL
      WRITE(3)(X(I),I=1,NX)
      IF(ABS(TIME-FINTIME).GT..000001) GOTO 3333
 8098 CONTINUE
      PAUSE
      GOTO 8099
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTIØN INTGRL(IC,DXDT)
      CØMMØN/TDATA/TIME,DT,ISTEP,NICØT
      DIMENSIØN G(40,4),XK(40)
      REAL IC,INTGRL
      IF(ISTEP.NE.0) GØTØ 2
      IF(NICØT.NE.0) GØTØ 1
      NI=39
    1 NICØT=NICØT+1
      G(NICØT,1)=DT*DXDT
      XK(NICØT)=IC
      INTGRL=XK(NICØT)+.5*G(NICØT,1)
      IF(NICØT.EQ.NI) ISTEP=1
      RETURN
    2 NICØT=NICØT+1
      GØTØ(3,4,5),ISTEP
    3 G(NICØT,2)=DT*DXDT
      INTGRL=XK(NICØT)+.5*G(NICØT,2)
      IF(NICØT.EQ.NI) ISTEP=2
      RETURN
    4 G(NICØT,3)=DT*DXDT
      INTGRL=XK(NICØT)+G(NICØT,3)
      IF(NICØT.EQ.NI) ISTEP=3
      RETURN
    5 G(NICØT,4)=DT*DXDT
      INTGRL=XK(NICØT)+(G(NICØT,1)+2.*G(NICØT,2)+2.*G(NICØT,3)+G(NICØT,4
     1))/6.
      IF(NICØT.EQ.NI) ISTEP=4
      RETURN
      END
```

```
      FUNCTIØN TFNH(NX,FAX,HX,TV)
      DIMENSIØN TV(20)
      DTX=50.
      TX=TV(NX)
   51 CALL PRØCØM(FAX,TX,CPX,GMX,GMXX,HX1,IFA)
      IF(IFA.GT.1) GØTØ 70
      TXERR=HX-HX1
      IF(TXERR.GT..001) GØTØ 52
      IF(TXERR.LT.-.001) GØTØ 55
      GØTØ 60
   52 IF(DTX)53,53,54
   53 DTX=-DTX*.5
   54 TX=TX+DTX
      GØTØ 51
   55 IF(DTX)54,54,53
   60 CØNTINUE
   70 CØNTINUE
      TFNH=TX
      TV(NX)=TX
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      SUBRØUTINE PRØCØM(FARX,TEX,CP,GM,GMX,H,IFA)
      IFA=0
      IF(FARX.GT.0.) GØTØ 2
      FARX=0.
      IFA=1
      GØTØ 3
    2 IF(FARX.LT..067623) GØTØ 3
      FARX=.067623
      IFA=1
    3 IF(TEX-1500.) 20,10,5
    5 IF(TEX.LT.4000.) GØTØ 7
      TEX=4000.
      IF(IFA.EQ.1) GØTØ 50
      IFA=2
      GØTØ 16
   50 IFA=3
      GØTØ 16
    7 IF(TEX-2300.) 9,14,8
    8 IF(TEX-2500.) 14,16,16
    9 IF(TEX-2000.) 10,12,12
   10 CPA = .2644+2.6E-5*(TEX-1500.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
      GØ TØ 40
   12 CPA = .27738+1.82E-5*(TEX-2000.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
      GØ TØ 40
   14 CPA = .27738+1.82E-5*(TEX-2000.)
      HA = (.25987+5.36E-6*TEX)*TEX-37.404
      GØ TØ 40
   16 CPA = .2865+1.17E-5*(TEX-2500.)
      HA = (.25987+5.36E-6*TEX)*TEX-37.404
      GØ TØ 40
   20 IF(TEX.GT.300.) GØTØ 21
      TEX=300.
      IF(IFA.EQ.1) GØTØ 51
      IFA=2
      GØTØ 24
   51 IFA=3
      GØTØ 24
   21 IF(TEX-900.) 23,28,22
   22 IF(TEX-1200.) 26,30,30
   23 IF(TEX-700.) 24,26,26
   24 CPA = .2392+1.1E-5*(TEX-500.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GØ TØ 40
   26 CPA = .2414+2.4E-5*(TEX-700.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GØ TØ 40
   28 CPA = .2458+3.1E-5*(TEX-900.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GØ TØ 40
   30 CPA = .2458+3.1E-5*(TEX-900.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
   40 CPF = .9333-(5.87E-5+3.27E-8*(3500.-TEX))*(3500.-TEX)
      HF = (.50699+6.180E-5*TEX)*TEX-132.20
      CP = (CPA+FARX*CPF)/(1.+FARX)
      H = (HA+FARX*HF)/(1.+FARX)
      AMW = 28.97-.946186*FARX
      REX = 1.98637/AMW
      GM = CP/(CP-REX)
      GMX = (GM-1.)/GM
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      SUBROUTINE DYNAM(A,PV,TV,KGAL,KVOL,KNR,RAD,KRAD,KA,THV,WD,WV,KBLD,
     1DPRB)
      DIMENSION A(20),PV(20),TV(20),KGAL(20),KVOL(20),KNR(8),RAD(8)
      DIMENSION KRAD(8),KA(30),THV(20),WD(20),WV(20),KBLD(3),DPRB(14)
      COMMON/TDATA/TIME,DT,ISTEP,NICOT
      COMMON/DATA/X(39),U(3),ETA(3),DXN(40),DX(40),DX1(40),CLM(40),
     1KVOLIG,KGALIG,KVOLOG,KGALOG,RTHO,ABL,KBGV,WTC,KVOLCD,KGALCD,TB,KWB
     2,KGALB,KVOLB,HT,TT,PT,K4,K2,WT,HCD,PO,WN,KNAB,KSPEED,KFIGV,K3,IGVP
     3R,TVO
      REAL ICTWVO,ICWVO
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVOL
      REAL KVOLOG,KGALOG,KVOLCD,KGALCD,KGALB,KWB,KVOLB,KVOLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KBGV,KNAB,NRTTB,ICPVO,ICWDO,ICWD1,ICWV1
      REAL ICTWV1,ICWD2,ICWV2,ICTWV2,ICWD3,ICWV3,ICTWV3,ICWD4,ICWV4
      REAL ICTWV4,ICWD5,ICWV5,ICTWV5,ICWD6,ICWV6,ICTWV6,ICWD7,ICWV7
      REAL ICTWV7,ICWD8,ICWV8,ICTWV8,ICTWBG,ICWBGV,ICWDBG,ICTWCD,ICWCD
      REAL ICWDCD,ICWB,ICPB,ICHB,ICRT,ICRHT,ICWFBP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMO,ITER,IMPL,INTGRL,KIC
      REAL KA8,ICWDBG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVOLIG
      EQUIVALENCE (ICWD0,WD0,X(1 )),(ICWV0,WV0,X(2 )),(ICTWV0,TWV0,X(3 )
     1            ),(ICWD1,WD1,X(4 )),(ICWV1,WV1,X(5 )),(ICTWV1,TWV1,X(6 )
     2            ),(ICWD2,WD2,X(7 )),(ICWV2,WV2,X(8 )),(ICTWV2,TWV2,X(9 )
     3            ),(ICWD3,WD3,X(10)),(ICWV3,WV3,X(11)),(ICTWV3,TWV3,X(12)
     4            ),(ICWD4,WD4,X(13)),(ICWV4,WV4,X(14)),(ICTWV4,TWV4,X(15)
     5            ),(ICWD5,WD5,X(16)),(ICWV5,WV5,X(17)),(ICTWV5,TWV5,X(18)
     6            ),(ICWD6,WD6,X(19)),(ICWV6,WV6,X(20)),(ICTWV6,TWV6,X(21)
     7            ),(ICWD7,WD7,X(22)),(ICWV7,WV7,X(23)),(ICTWV7,TWV7,X(24)
     8            ),(ICWD8,WD8,X(25)),(ICWV8,WV8,X(26)),(ICTWV8,TWV8,X(27)
     9      ),(ICWDBG,WDBG,X(28)),(ICWBGV,WBGV,X(29)),(ICTWBG,TWBG,X(30))
     A      ,(ICWDCD,WDCD,X(31)),(ICWCD,WCD,X(32)),(ICTWCD,TWCD,X(33))
     B                       ,(ICWB,WB,X(34)),(ICPB,PB,X(35))
     C      ,(ICHB,HB,X(36)),(ICRHT,RHT,X(37)),(ICRT,RT,X(38))
     D      ,(ICN,N,X(39)),(WF,U(1)),(BV0,U(2)),(A8,U(3)),(P2,ETA(1))
     E      ,(T2,ETA(2)),(P8,ETA(3))
      EQUIVALENCE (WD0DT   ,DX(1 )),(WV0DT   ,DX(2 )),(THV0DT  ,DX(3 )),
     1            (WD1DT   ,DX(4 )),(WV1DT   ,DX(5 )),(THV1DT  ,DX(6 )),
     2            (WD2DT   ,DX(7 )),(WV2DT   ,DX(8 )),(THV2DT  ,DX(9 )),
     3            (WD3DT   ,DX(10)),(WV3DT   ,DX(11)),(THV3DT  ,DX(12)),
     4            (WD4DT   ,DX(13)),(WV4DT   ,DX(14)),(THV4DT  ,DX(15)),
     5            (WD5DT   ,DX(16)),(WV5DT   ,DX(17)),(THV5DT  ,DX(18)),
     6            (WD6DT   ,DX(19)),(WV6DT   ,DX(20)),(THV6DT  ,DX(21)),
     7            (WD7DT   ,DX(22)),(WV7DT   ,DX(23)),(THV7DT  ,DX(24)),
     8            (WD8DT   ,DX(25)),(WV8DT   ,DX(26)),(THV8DT  ,DX(27)),
     9            (WD0BDT  ,DX(28)),(WBGVDT  ,DX(29)),(TW0BDT  ,DX(30)),
     A            (WDCDDT  ,DX(31)),(WCDDT   ,DX(32)),(TWCDDT  ,DX(33)),
     B                              (WBDT    ,DX(34)),(PBDT    ,DX(35)),
     C            (HBDT    ,DX(36)),(RHTDT   ,DX(37)),(RTDT    ,DX(38)),
     D            (NDT     ,DX(39))
  999 CONTINUE
      TVO = TWVO/WVO
      RTHO=SQRT(TVO/518.7)
      ABL=FUN1(1,BV0,1)
      DO 299 I=1,8
  299 KNR(I)=(N*RAD(I))**2/K2
C
C DYNAMICS
C
C  INLET AND STAGE ONE
C
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      NC1 = N/RTH0
      NC1N = NC1/16500
      IGVPR=FUN1(1,NC1N,2)
      PD0 = P2+IGVPR*.005*P2
      TD0 = T2
      PV0 =KVOL(10) *TWV0
      WD0DT = KGAL(10) *(PD0-PV0)
      WV0DT = WD0 - WD1
      TWV0DT = 1.4*(TD0*WD0-TV0*WD1)
      PV1=KVOL(11)*TWV1
      DEL0 = PV0/14.7
      FP1 = WD1*RTH0/(DEL0*A(11))
      VZT1 = KA(1) + KA(11)*FP1 + KA(21)*FP1*FP1
      PHI1 = VZT1/(KRAD(1)*NC1)
      PSIP1 = FUN2(2,PHI1,BV0,4)
      PSIT1=FUN2(5,PHI1,BV0,10)
      PD1= PV0*(1.+PSIP1*KNR(1)/TV0)**3.5
      WD1DT=KGAL(11)*(PD1-PV1)
      WV1DT=WD1-WD2
      TV1 = TWV1/WV1
      TD1 = TV0+KNR(1)*PSIT1
      TWV1DT=1.4*(TD1*WD1-TV1*WD2)
C
C  STAGE TWO
C
      PV2 = KVOL(12)*TWV2
      RTH1 = SQRT(TV1/518.7)
      NC2 = N/RTH1
      DEL1 = PV1/14.7
      FP2 = WD2*RTH1/(DEL1*A(12))
      VZT2 = KA(2) + KA(12)*FP2 + KA(22)*FP2*FP2
      PHI2 = VZT2/(KRAD(2)*NC2)
      PSIP2=FUN1(5,PHI2,7)
      PD2 = PV1*(1.+PSIP2*KNR(2)/TV1)**3.5
      WD2DT=KGAL(12)*(PD2-PV2)
      WV2DT=WD2-WD3
      TV2 = TWV2/WV2
      PSIT2=FUN1(6,PHI2,9 )
      TD2 = TV1+KNR(2)*PSIT2
      TWV2DT=1.4*(TD2*WD2-TV2*WD3)
C
C  STAGE THREE
C
      PV3 = KVOL(13)*TWV3
      RTH2 = SQRT(TV2/518.7)
      NC3 =N/RTH2
      DEL2 = PV2/14.7
      FP3 = WD3*RTH2/(DEL2*A(13))
      VZT3 = KA(3) + KA(13)*FP3 + KA(23)*FP3*FP3
      PHI3 = VZT3/(KRAD(3)*NC3)
      PSIP3=FUN1(7,PHI3,11)
      PD3 = PV2*(1.+PSIP3*KNR(3)/TV2)**3.5
      WD3DT=KGAL(13)*(PD3-PV3)
      TV3 = TWV3/WV3
      RTH3 = SQRT(TV3/518.7)
      WBL3 =KBLD(3)*ABL*PV3/(K3*RTH3)
      WV3DT=WD3-WD4-WBL3
      PSIT3=FUN1(8,PHI3,13)
      TD3 = TV2+KNR(3)*PSIT3
      TWV3DT=1.4*(TD3*WD3-TV3*(WD4+WBL3))
C
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
C     STAGE FOUR
C
      PV4 = KVBL(14)*TWV4
      NC4 = N/RTH3
      DEL3 = PV3/14.7
      FP4 = WD4*RTH3/(DEL3*A(14))
      VZT4 = KA(4) + KA(14)*FP4 + KA(24)*FP4*FP4
      PHI4 = VZT4/(KRAD(4)*NC4)
      PSIP4=FUN1(9 ,PHI4,15)
      PD4 = PV3*(1.+PSIP4*KNR(4)/TV3)**3.5
      WD4DT=KGAL(14)*(PD4-PV4)
      TV4 = TWV4/WV4
      RTH4 = SQRT(TV4/518.7)
      WBL4 =KBLD(4)*ABL*PV4/(K3*RTH4)
      WV4DT=WD4-WD5-WBL4
      PSIT4=FUN1(10,PHI4,17)
      TD4 = TV3+KNR(4)*PSIT4
      TWV4DT=1.4*(TD4*WD4-TV4*(WD5+WBL4))
C
C     STAGE FIVE
C
      PV5 = KVBL(15)*TWV5
      NC5 = N/RTH4
      DEL4 = PV4/14.7
      FP5 = WD5*RTH4/(DEL4*A(15))
      VZT5 = KA(5) + KA(15)*FP5 + KA(25)*FP5*FP5
      PHI5 = VZT5/(KRAD(5)*NC5)
      PSIP5=FUN1(11,PHI5,19)
      PD5 = PV4*(1.+PSIP5*KNR(5)/TV4)**3.5
      WD5DT=KGAL(15)*(PD5-PV5)
      TV5 = TWV5/WV5
      RTH5 = SQRT(TV5/518.7)
      WBL5 =KBLD(5)*ABL*PV5/(K3*RTH5)
      WV5DT=WD5-WD6-WBL5
      PSIT5=FUN1(12,PHI5,21)
      TD5 = TV4+KNR(5)*PSIT5
      TWV5DT=1.4*(TD5*WD5-TV5*(WD6+WBL5))
C
C     STAGE SIX
C
      PV6 = KVBL(16)*TWV6
      NC6 = N/RTH5
      DEL5 = PV5/14.7
      FP6 = WD6*RTH5/(DEL5*A(16))
      VZT6 = KA(6) + KA(16)*FP6 + KA(26)*FP6*FP6
      PHI6 = VZT6/(KRAD(6)*NC6)
      PSIP6=FUN1(13,PHI6,23)
      PD6 = PV5*(1.+PSIP6*KNR(6)/TV5)**3.5
      WD6DT=KGAL(16)*(PD6-PV6)
      WV6DT=WD6-WD7
      TV6 = TWV6/WV6
      PSIT6=FUN1(14,PHI6,25)
      TD6 = TV5+KNR(6)*PSIT6
      TWV6DT=1.4*(TD6*WD6-TV6*WD7)
C
C     STAGE SEVEN
C
      PV7 = KVBL(17)*TWV7
      RTH6 = SQRT(TV6/518.7)
      NC7 = N/RTH6
      DEL6 = PV6/14.7
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FP7 = WD7*RTH6/(DEL6*A(17))
      VZT7 = KA(7) + KA(17)*FP7 + KA(27)*FP7*FP7
      PHI7 = VZT7/(KRAD(7)*NC7)
      PSIP7=FUN1(15,PHI7,27)
      PD7 = PV6*(1.+PSIP7*KNR(7)/TV6)**3.5
      WD7DT=KGAL(17)*(PD7-PV7)
      WV7DT=WD7-WD8
      TV7 = TWV7/WV7
      PSIT7=FUN1(16,PHI7,29)
      TD7 = TV6+KNR(7)*PSIT7
      TWV7DT=1.4*(TD7*WD7-TV7*WD8)
C
C  STAGE EIGHT
C
      PV8 = KVOL(18)*TWV8
      RTH7 = SQRT(TV7/518.7)
      NC8 = N/RTH7
      DEL7 = PV7/14.7
      FP8 = WD8*RTH7/(DEL7*A(18))
      VZT8 = KA(8) + KA(18)*FP8 + KA(28)*FP8*FP8
      PHI8 = VZT8/(KRAD(8)*NC8)
      PSIP8=FUN1(17,PHI8,31)
      PD8 = PV7*(1.+PSIP8*KNR(8)/TV7)**3.5
      WD8DT=KGAL(18)*(PD8-PV8)
      WV8DT=WD8-WOGV
      TV8 = TWV8/WV8
      PSIT8=FUN1(18,PHI8,33)
      TD8 = TV7+KNR(8)*PSIT8
      TWV8DT=1.4*(TD8*WD8-TV8*WOGV)
C
C  OUTLET GUIDE VANES
C
      TOGV = TWOG/WDOG
      TWOGDT=1.4*(TV8*WOGV-TOGV*WCD)
      POGV = KVOLOG*TWOG
      WOGVDT=KGALOG*(PV8-POGV)-KOGV*WOGV*WOGV
      WDOGDT=WOGV-WCD
C
C  COMPRESSOR DISCHARGE
C
      WTC = .033*WCD
      TCD = TWCD/WDCD
      TWCDDT=(TOGV*WCD-TCD*(WB+WTC))*1.4
      PCD = KVOLCD*TWCD
      WCDDT=KGALCD*(POGV-PCD)
      WDCDDT=WCD-WB-WTC
C
C  BURNER
C
      FAB=WF/WB
      TB=TFNH(2,FAB,HF,TV)
      DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
      WBDT = KGALB*(PCD-PB-DELPB)
      NRTTB = N/SQRT(TB)
      HT = RHT/WT
      FAT=WF/(WB+WF+WTC)
      TT=TFNH(3,FAT,HT,TV)
      PT = K4*RT*TT
      PTPB = PT/PB
      WTTNPB = FUN2(3,PTPB,NRTTB,6)
      WT = WTTNPB*N*PB/TB
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      PBDLTB=PB*(TB-TCD)
      ETAB=FUN1(19,PBDLTB,35)
      CALL PROCOM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
      PBDT=KVBLB*(HCD*WB+18650.*ETAB*WF-WT*HB)
      HBDT = HB/PB*(PBDT-KVBLB/1.4*HB*(WB+WF-WT))
      POPT=P6/PT
      WNTKNP=HBKEY(POPT)
      WN = WNTKNP*A8*KNA8*PT/SQRT(TT)
      DHTNTB = FUN2(4,PTPB,NRTTB,8)
      DHT=N/1000.*DHTNTB*SQRT(TB)
      RHTDT=(HB*WT+HCD*WTC-DHT*WT- T*WN)/1.53
      RTDT = (WT+WTC-WN)/1.53
      WBLTBL = WBL3*TV3+WBL4*TV4+WBL5*TV5
      DLWHC=HCD*WCD+.24*(WBLTBL-TVO*WDO)
      DLWHT=HB*WT+HCD*WTC-HT*WN
      NDT=KSPEED/N*(DLWHT-DLWHC)
      WDO = INTGRL(ICWDO,WDODT)
      WVO = INTGRL(ICWVO,WVODT)
      TWVO=INTGRL(ICTWVO,TWVODT)
      WD1=INTGRL(ICWD1,WD1DT)
      WV1=INTGRL(ICWV1,WV1DT)
      TWV1=INTGRL(ICTWV1,TWV1DT)
      WD2=INTGRL(ICWD2,WD2DT)
      WV2=INTGRL(ICWV2,WV2DT)
      TWV2=INTGRL(ICTWV2,TWV2DT)
      WD3=INTGRL(ICWD3,WD3DT)
      WV3=INTGRL(ICWV3,WV3DT)
      TWV3=INTGRL(ICTWV3,TWV3DT)
      WD4=INTGRL(ICWD4,WD4DT)
      WV4=INTGRL(ICWV4,WV4DT)
      TWV4=INTGRL(ICTWV4,TWV4DT)
      WD5=INTGRL(ICWD5,WD5DT)
      WV5=INTGRL(ICWV5,WV5DT)
      TWV5=INTGRL(ICTWV5,TWV5DT)
      WD6=INTGRL(ICWD6,WD6DT)
      WV6=INTGRL(ICWV6,WV6DT)
      TWV6=INTGRL(ICTWV6,TWV6DT)
      WD7=INTGRL(ICWD7,WD7DT)
      WV7=INTGRL(ICWV7,WV7DT)
      TWV7=INTGRL(ICTWV7,TWV7DT)
      WD8=INTGRL(ICWD8,WD8DT)
      WV8=INTGRL(ICWV8,WV8DT)
      TWV8=INTGRL(ICTWV8,TWV8DT)
      TWAG=INTGRL(ICTWAG,TWAGDT)
      WBGV=INTGRL(ICWBGV,WBGVDT)
      WDBG=INTGRL(ICWDBG,WDBGDT)
      TWCD=INTGRL(ICTWCD,TWCDDT)
      WCD=INTGRL(ICWCD,WCDDT)
      WDCD=INTGRL(ICWDCD,WDCDDT)
      WB = INTGRL(ICWB,WBDT)
      PB = INTGRL(ICPB,PBDT)
      HB = INTGRL(ICHB,HBDT)
      RHT = INTGRL(ICRHT,RHTDT)
      RT = INTGRL(ICRT,RTDT)
      N = INTGRL(ICN,NDT)
      NICNT=0
      GOTO(999,999,999,998),ISTEP
  998 CONTINUE
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTIØN HØKEY(PØPT)
      IF(PØPT.GE.1.) GØTØ 1
      IF(PØPT.GE..53) HØKEY=PØPT**(1./1.4)*SQRT(1.-PØPT**(.4/1.4))
      IF(PØPT.GE.0..AND.PØPT.LE..53) HØKEY=.2588
      RETURN
    1 HØKEY=0.
      RETURN
      END
```

```
      FUNCTIØN FN1SET(N,ZX,NP,N1,N2)
      CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),[illegible](17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      CØMMØN        X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
      DIMENSIØN ZX(1)
      MX(N) = NP
      DØ 10 J=1,NP
      K=2*J
      X1(J,N) = ZX(K-1)
   10 Z1(J,N) = ZX(K)
      FN1SET = 1.
      DØ 30 NR=N1,N2
      KK(NR) = 2
      XDIF(NR) = X1(2,N)-X1(1,N)
      ZPT(NR) = Z1(1,N)
      SLP(NR) =(Z1(2,N)-Z1(1,N))/XDIF(NR)
   30 CØNTINUE
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTIØN FUN1(N,XIN,NR)
      CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      CØMMØN        X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
C
      IØLD = KK(NR)
      NXP = MX(N)
      IF(XIN-X1(IØLD,N)) 105,105,120
  105 IF(XIN-X1(IØLD-1,N)) 140,140,110
  110 I = IØLD
      GØ TØ 250
C     CØUNT UP
  120 IF(XIN-X1(NXP,N)) 125,180,300
  125 NF = IØLD + 1
      DØ 130 I = NF,NXP
      IF(XIN-X1(I,N)) 200,200,130
  130 CØNTINUE
      GØ TØ 200
C     CØUNT DØWN
  140 IF(XIN-X1(1,N)) 300, 190,145
  145 NL = IØLD - 2
      DØ 150 K = 1,NL
      I = IØLD - K
      IF(XIN-X1(I-1,N)) 150,150, 200
  150 CØNTINUE
      GØ TØ 200
  180 I = NXP
      GØ TØ 200
  190 I = 2
  200 XDIF(NR) = X1(I,N)-X1(I-1,N)
      ZPT(NR) = Z1(I-1,N)
      SLP(NR) =(Z1(I,N)-ZPT(NR))/XDIF(NR)
  250 XINC = XIN-X1(I-1,N)
      FUN1 = ZPT(NR)+XINC*SLP(NR)
      KK(NR) = I
      RETURN
  300 CØNTINUE
      IF(XIN.LT.X1(1,N))FUN1=Z1(1,N)
      IF(XIN.GT.X1(NXP,N))FUN1=Z1(NXP,N)
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTION FN2SET(N,X,Y,Z,NXP,NYP,N1,N2)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      COMMON        X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
      DIMENSION X( 1),Y(1),Z(1)
   10 NX(N) = NXP
      NY(N) = NYP
      DO 15 J=1,NYP
      YY(J,N) = Y(J)
      DO 15 I=1,NXP
      K = I+(J-1)*NXP
   15 ZZZ(I,J,N) = Z(K)
      DO 20 I=1,NXP
   20 XX(I,N) = X(I)
      FN2SET = 1.0
      DO 30 NR=N1,N2
      II(NR) = 2
      JJ(NR) = 2
      XDEL = XX(2,N)-XX(1,N)
      YDEL(NR) = YY(2,N)-YY(1,N)
      ZPT1(NR) = ZZZ(1,1,N)
      ZPT2(NR) = ZZZ(1,2,N)
      SLP1(NR) = (ZZZ(2,1,N)-ZPT1(NR))/XDEL
      SLP2(NR) = (ZZZ(2,2,N)-ZPT2(NR))/XDEL
   30 CONTINUE
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Concluded)

```
      FUNCTIØN FUN2(N,XIN,YIN,NR)
      CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      CØMMØN         X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
C     TEST FØR X IN PREVIØUS INTERVAL
      NXP = NX(N)
      IØLD = II(NR)
      IF(XIN - XX(IØLD,N)) 105,105,120
  105 IF(XIN - XX(IØLD-1,N)) 140,140,110
  110 I = IØLD
      GØ TØ 200
C     CØUNT UP
  120 IF(XIN - XX(NXP,N))  125,180,180
  125 NF = IØLD + 1
      DØ 130 I = NF,NXP
      IF(XIN - XX(I,N))200,200,130
  130 CØNTINUE
      GØ TØ 200
C     CØUNT DØWN
  140 IF(XIN-XX(1,N)) 190,190,145
  145 NL = IØLD -2
      DØ 150K = 1,NL
      I = IØLD - K
      IF(XIN-XX(I-1,N))150,150,200
  150 CØNTINUE
      GØTØ 200
  180 I=NXP
      XIN=XX(NXP,N)
      GØ TØ 200
  190 I = 2
      XIN=XX(1,N)
C     TEST FØR Y IN PREVIØUS INTERVAL
  200 NYP = NY(N)
      JØLD = JJ(NR)
      IF(YIN - YY(JØLD,N)) 205, 205, 220
  205 IF(YIN - YY(JØLD-1,N)) 240,240,210
  210 J = JØLD
      IF(I-IØLD) 300,400,300
C     CØUNT UP
  220 IF(YIN - YY(NYP,N)) 225, 280,280
  225 NF = JØLD + 1
      DØ 230 J = NF,NYP
      IF(YIN - YY(J,N)) 300,300,230
  230 CØNTINUE
      GØ TØ 300
C     CØUNT DØWN
  240 IF(YIN - YY(1,N))290,290,245
  245 NL = JØLD - 2
      DØ 250 K = 1,NL
      J = JØLD - K
      IF(YIN -YY(J-1,N)) 250,250,300
  250 CØNTINUE
      GØ TØ 300
  280 J = NYP
      YIN=YY(NYP,N)
      GØ TØ 300
  290 J = 2
      YIN=YY(1,N)
C     CØMPUTE Z(Y) INTERCEPTS AND SLØPES
  300 XDEL = XX(I,N)-XX(I-1,N)
      YDEL(NR) = YY(J,N)-YY(J-1,N)
      ZPT1(NR) = ZZZ(I-1,J-1,N)
      ZPT2(NR) = ZZZ(I-1,J,N)
      SLP1(NR) = (ZZZ(I,J-1,N)-ZPT1(NR))/XDEL
      SLP2(NR) = (ZZZ(I,J,N)-ZPT2(NR))/XDEL
C     INTERPØLATE FØR ANSWER
  400 II(NR) = I
      JJ(NR) = J
      XINC = XIN-XX(I-1,N)
      P1ZZ = ZPT1(NR)+XINC*SLP1(NR)
      P2ZZ = ZPT2(NR)+XINC*SLP2(NR)
      YFRAC = (YIN-YY(J-1,N))/YDEL(NR)
      FUN2 = P1ZZ + YFRAC*(P2ZZ-P1ZZ)
      RETURN
      END
```

Table A-2. Reduced-Order Component Model

```
      DIMENSION IGV(42),A(20),PV(20),TV(20),YY1(14),XX1(17),ZZ1(196)
      DIMENSION L(20),V(20),KGAL(20),KVOL(20),KNR(8),RAD(8),KRAD(8)
      DIMENSION KA(30)
      DIMENSION TWV(20),WD(20),WV(20),KBLD(8),DPRB(14)
      COMMON/TDATA/TIME,DTH
      COMMON/DATA/X( 2),U(4),ETA(3),DXN( 6),DX( 6),DX1( 6),CLM( 6),KVOLI
     1G,      RTHO,     KVOLOG,KGALOG,KOGV,WTC,KVOLCD,KGALCD,    KWB,KGALB,
     2HT,       K4,K2,WT,HCD,KVOLB,PO,WN,KNAB,KSPEED,KGALIG,KFIGV,K3,
     3WBL3,WBL4,WBL5,WCD,WDCD,TWCD,ETAB,DHT
     4,TCD,     WB,HB,PB,ERROR
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVOL
      REAL KVOLOG,KGALOG,KVOLCD,KGALCD,KGALB,KWB,KVOLB,KVOLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KOGV,KNAB,NRTTB,ICPVO,ICWDO,ICWD1,ICWV1
      REAL ICTWV1,ICWD2,ICWV2,ICTWV2,ICWD3,ICWV3,ICTWV3,ICWD4,ICWV4
      REAL ICTWV4,ICWD5,ICWV5,ICTWV5,ICWD6,ICWV6,ICTWV6,ICWD7,ICWV7
      REAL ICTWV7,ICWD8,ICWV8,ICTWV8,ICTWOG,ICWOGV,ICWDOG,ICTWCD,ICWCD
      REAL ICWDCD,ICWS,ICPB,ICHB,ICRT,ICRHT,ICWFOP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMD,ITER,IMPL,INTGRL,KIC
      REAL KAB,ICWDOG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVOLIG
      EQUIVALENCE(ICN,N,X(1))
      EQUIVALENCE
     2              (NDT,DX( 1)),(WF,U(1)),(BVO,U(2)),(A8,U(3)),(P2,ETA(1
     3)),(TVO,T2,ETA(2)),(P8,ETA(3)),(U(4),ABL)
      EQUIVALENCE (TMIC,TM,X(2)),(TMDT,DX(2))
      EQUIVALENCE (PCD,DX(3)),(PT,DX(4)),(TB,DX(5)),(TT,DX(6))
      REWIND 3
 8099 CONTINUE
      READ(5,6306) ERROR
      IF(ERROR.EQ.0.0) GO TO 8098
 6306 FORMAT(G12.5)
      READ(5,8030) NX,NU,NE,NR,DPERT
 8030 FORMAT(4I2,G12.5)
      REWIND 7
      DATA (DPRB(I),I=1,14)/.60,7.26E-4,.70,7.07E-4,.80,6.98E-4,.85,6.9E
     1-4,.90,6.96E-4,.97,6.96E-4,1.0,7.38E-4/
      DATA (KBLD(I),I=1,8)/2*0.,1.1025,1.0572,1.0411,3*0./
      DATA (KGAL(I),I=1,8)/25542.,27942.,27247.,26407.,24084.,21872.,221
     156.,22439./
      DATA (KVOL(I),I=1,8)/1.9107,3.3711,4.9797,7.0830,9.3087,11.2953,13
     1.7727,15.1219/
      DATA (TV(I),I=1,20)/5*1600.,15*518.7/
      DATA (TWV(I),I=1,20)/20*10./
      DATA (WD(I),I=1,20)/20*30./
      DATA (WV(I),I=1,20)/20*.01/
      READ(7)(IGV(I),I=1,18)
      F11 =FN1SET(1,IGV   ,9,1,1)
      READ(7)(IGV(I),I=1,38)
      F14 =FN1SET(4,IGV ,19,4,5)
      READ(7)(IGV(I),I=1,20)
      F12 =FN1SET(2,IGV,10,2,2)
      READ(7)(IGV(I),I=1,18)
      F13 =FN1SET(3,IGV,9, 3,3)
      READ(7)(IGV(I),I=1,40)
      F15 =FN1SET(5,IGV  ,20,6,7)
      READ(7)(IGV(I),I=1,42)
      F16 =FN1SET(6,IGV ,21,8,9)
      READ(7)(IGV(I),I=1,34)
      F17 =FN1SET(7,IGV  ,17,10,11)
      READ(7)(IGV(I),I=1,38)
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000074           F18 =FN1SET(8,IGV ,19,12,13)
00000075           READ(7)(IGV(I),I=1,36)
00000076           F19 =FN1SET(9,IGV  ,18,14,15)
00000077           READ(7)(IGV(I),I=1,40)
00000100           F110=FN1SET(10,IGV,20,16,17)
00000101           READ(7)(IGV(I),I=1,32)
00000102           F111=FN1SET(11,IGV  ,16,18,19)
00000103           READ(7)(IGV(I),I=1,36)
00000104           F112=FN1SET(12,IGV,18,20,21)
00000105           READ(7)(IGV(I),I=1,26)
00000106           F113=FN1SET(13,IGV  ,13,22,23)
00000107           READ(7)(IGV(I),I=1,26)
00000110           F114=FN1SET(14,IGV ,13,24,25)
00000111           READ(7)(IGV(I),I=1,30)
00000112           F115=FN1SET(15,IGV  ,15,26,27)
00000113           READ(7)(IGV(I),I=1,26)
00000114           F116=FN1SET(16,IGV,13,28,29)
00000115           READ(7)(IGV(I),I=1,30)
00000116           F117=FN1SET(17,IGV  ,15,30,31)
00000117           READ(7)(IGV(I),I=1,32)
00000120           F118=FN1SET(18,IGV ,16,32,33)
00000121           READ(7)(IGV(I),I=1,28)
00000122           F119=FN1SET(19,IGV ,14,34,35)
00000123           F120=FN1SET(20,DPRB,7,36,37)
00000124           READ(7)(IGV(I),I=1,40)
00000125           IGV(6)=1.39
00000126           IGV(8)=1.395
00000127           DO 6301 I=9,39,2
00000130           II=I+1
00000131           XSQ=IGV(I)*IGV(I)
00000132           FBFX=XSQ*1.031964679E-8-IGV(I)*1.735330756E-4+2.129761925
00000133      6301 IGV(II)=FBFX
00000134           F121=FN1SET(21,IGV   ,20,38,39)
00000135            READ(7)(A(I),I=1,20)
00000136            READ(7)(L(I),I=1,20)
00000137            READ(7)(V(I),I=1,20)
00000140            READ(7)(IGV (I),I=1,20)
00000141            READ(7)(IGV (I),I=1,20)
00000142            READ(7)(RAD(I),I=1,8)
00000143            READ(7)(KRAD(I),I=1,8)
00000144            READ(7)(PV(I),I=1,20)
00000145            READ(7)(IGV(I),I=1,20)
00000146            READ(7)(YY1(I),I=1,5)
00000147            READ(7)(XX1(I),I=1,13)
00000150            READ(7)(ZZ1(I),I=1,65)
00000151           F1= FN2SET(1,XX1,YY1,ZZ1,13,5,1,2)
00000152            READ(7)(KA(I),I=1,30)
00000153            READ(7)(YY1(I),I=1,4)
00000154            READ(7)(XX1(I),I=1,17)
00000155            READ(7)(ZZ1(I),I=1,68)
00000156           F2 = FN2SET(2,XX1,YY1,ZZ1,17,4,3,4)
00000157            READ(7)(YY1(I),I=1,14)
00000160            READ(7)(XX1(I),I=1,14)
00000161            READ(7)(ZZ1(I),I=1,196)
00000162           F3 = FN2SET(3,XX1,YY1,ZZ1,14,14,5,6)
00000163            READ(7)(YY1(I),I=1,14)
00000164            READ(7)(XX1(I),I=1,14)
00000165            READ(7)(ZZ1(I),I=1,196)
00000166           F4 = FN2SET(4,XX1,YY1,ZZ1,14,14,7,8)
00000167           READ(7)     (YY1(I),I=1,4)
00000170           READ(7)     (XX1(I),I=1,17)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      READ(7)      (ZZ1(I),I=1,68)
      F5=FN2SET(5,XX1,YY1,ZZ1,17,4,9,10)
C
C SET PAFAMETERS
C
      KAB=0
      NSSP=1
      TTGS=1700.
      READ(5,8066)NRAT,WINGS,SPLC,BV0,ABL
      WRITE(9,8066) ERRØR
      WRITE(9,8030) NX,NU,NE,NR,DPERT
      WRITE(9,8066)NRAT,WINGS,SPLC,BV0,ABL
      READ(5,9903) P2,T2
 9903 FØRMAT(2G12.5)
      WRITE(9,9903) P2,T2
 8066 FØRMAT(6G12.5)
      AB=ABFN(NRAT)
      AJ=AB
      TBGS=2100.
      FABGS=.02
      T2=518.7
      WDEL=.1
      DTH=DELT*.5
      TIME=0.
      K1 = 3.14159/360.
      K2=7.*32.17*53.35/(K1*K1)
      K3=SQRT(518.7)
      K4=(53.35*12.)/17600.
      KGALIG=51837.
      KVØLIG=3.31
      KGALAG = 22430.
      KVØLAG = 15.10
      KGALCD = 8730.
      KVØLCD = 1.981
      KGALB=54.7
      KVØLB = 2.659
      KWB = .0004445
      KVØLT = 14.15
      KSPEED = 138400.
      ICN=NRAT*16500.
      P0=P2
      P8=P0
      TV0 = T2
      RTH0 = SQRT(TV0/518.7)
      NC1 = ICN/RTH0
      NC1N = NC1/16500.
      BVØB=FUN2(1,NC1N,TV0,1)
      ABLB=FUN1(1,BVØB,1)
      IGVPR=FUN1(2,NC1N,2)
      BGVPR=FUN1(3,NC1N,3)
      TV(10) = T2
      III=0
      ITER1=0
      ITER2=0
      ITER3=0
      DØ 60 K=1,NSSP
      FAB=FABGS
      TB=TBGS
      WIN=WINGS
      DWINX=.01
      PV(10) = P2*IGVPR - .005*P2
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000266       99 CONTINUE
00000267          WD(10)=WIN-FLOAT(K-1)*WDEL
00000270          ITER1=ITER1+1
00000271          KFIGV=KGALIG*(P2-PV(10))/(WD(10)*WD(10))
00000272          WBL=0.
00000273          WBLTBL=0.
00000274          IF(SENSE SWITCH 3)8073,8074
00000275     8074 CONTINUE
00000276          IF(III.NE.1) GOTO 5901
00000277     8073 CONTINUE
00000300          J = 0
00000301          WRITE(6,50) ICN,ABL,BVB,IGVPR,RGVPR
00000302          WRITE(6,51)
00000303          WRITE(6,52) J,PV(10),TV(10),WD(10)
00000304     5901 CONTINUE
00000305          DO 20 I=11,18
00000306          J = I-10
00000307          DELX = PV(I-1)/14.7
00000310          RTHX = SQRT(TV(I-1)/518.7)
00000311          NCX = ICN/RTHX
00000312          WD(I)=WD(I-1)-WBL
00000313          FPX=WD(I)*RTHX/(DELX*A(I))
00000314          VZTX=KA(J)+FPX*(KA(J+10)+FPX*KA(J+20))
00000315          KRAD(J) = K1*RAD(J)
00000316          PHIX = VZTY/(KRAD(J)*NCX)
00000317          GO TO (1,2,3,4,5,6,7,8),J
00000320        1 CONTINUE
00000321          PSIPX = FUN2(2,PHIX,BVB,3)
00000322          PSITX=FUN2(5,PHIX,BVB,9)
00000323          GOTO 10
00000324        2 CONTINUE
00000325          PSIPX=FUN1(5,PHIX,6)
00000326          PSITX=FUN1(6 ,PHIX,8 )
00000327          GOTO 10
00000330        3 CONTINUE
00000331          PSIPX=FUN1(7,PHIX,10)
00000332          PSITX=FUN1(8 ,PHIX,12)
00000333          GOTO 10
00000334        4 CONTINUE
00000335          PSIPX=FUN1(9,PHIX,14)
00000336          PSITX=FUN1(10,PHIX,16)
00000337          GOTO 10
00000340        5 CONTINUE
00000341          PSIPX=FUN1(11,PHIX,18)
00000342          PSITX=FUN1(12,PHIX,20)
00000343          GOTO 10
00000344        6 CONTINUE
00000345          PSIPX=FUN1(13,PHIX,22)
00000346          PSITX=FUN1(14,PHIX,24)
00000347          GOTO 10
00000350        7 CONTINUE
00000351          PSIPX=FUN1(15,PHIX,26)
00000352          PSITX=FUN1(16,PHIX,28)
00000353          GOTO 10
00000354        8 CONTINUE
00000355          PSIPX=FUN1(17,PHIX,30)
00000356          PSITX=FUN1(18,PHIX,32)
00000357       10 CONTINUE
00000360          KNR(J)=(ICN*RAD(J))**2/K2
00000361          PV(I) = PV(I-1)*(1.+PSIPX*KNR(J)/TV(I-1))**3.5
00000362          TV(I) = TV(I-1)+KNR(J)*PSITX
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000363            TWV(I)=PV(I)/KVØL(J)
00000364            WV(I)=TWV(I)/TV(I)
00000365            PR = PV(I)/PV(I-1)
00000366            WBL=KBLD(J)*ABL*PV(I)/SQRT(TV(I))
00000367            IF(J.EQ.3) WBL3=WBL
00000370            IF(J.EQ.4) WBL4=WBL
00000371            IF(J.EQ.5) WBL5=WBL
00000372            WBLTBL=WBLTBL+WBL*TV(I)
00000373            IF(SENSE SWITCH 3)8075,8076
00000374       8076 CØNTINUE
00000375            IF(III.NE.1) GØTØ 5902
00000376       8075 CØNTINUE
00000377            WRITE(9,52)J,PV(I),TV(I),WD(I),WBL,PSITX,V7TX,PHIX,PSIPX,PR
00000400       5902 CØNTINUE
00000401         20 CØNTINUE
00000402            J = 10
00000403            PØGV = PV(18)*ØGVPR
00000404            TØGV = TV(18)
00000405            WØGV=WD(18)
00000406            KØGV = KGALØG*(PV(18)-PØGV)/WØGV**2
00000407            TWØG = PØGV/KVØLØG
00000410            WDØG = TWØG/TØGV
00000411            PR23=PØGV/P2
00000412            TR23=TØGV/T2
00000413            EFF23=(PR23**.285-1.)/(TR23-1.)
00000414            IF(SENSE SWITCH 3)8077,8078
00000415       8078 CØNTINUE
00000416            IF(III.NE.1) GØTØ 5903
00000417       8077 CØNTINUE
00000420            WRITE(6,53)
00000421            WRITE(6,52)J,PØGV,TØGV,WØGV,WBLTBL,EFF23,PR23,TR23
00000422       5903 CØNTINUE
00000423            J = 11
00000424            PCD = PØGV
00000425            TCD=TØGV
00000426            CALL PRØCØM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
00000427            WCD =WØGV
00000430            TWCD = PCD/KVØLCD
00000431            WDCD = TWCD/TCD
00000432            WTC=.033*WD(10)
00000433            DLWHC=HCD*WCD+.24*(WBLTBL-WD(10)*TV(10))+SPLC
00000434            KNA8=5.0405-.0429772*A8+.000126664*A8**2
00000435            IF(SENSE SWITCH 3)8170,8171
00000436       8171 CØNTINUE
00000437            IF(III.NE.1) GØTØ 5904
00000440       8170 CØNTINUE
00000441            WRITE(6,54)
00000442            WRITE(6,52)J,PCD,TCD,WCD,WTC,DLWHC,KNA8
00000443       5904 CØNTINUE
00000444            J=12
00000445            KWB=FUN1(20,NRAT,36)
00000446            WB=WCD-WTC
00000447            IF(ITER1.EQ.1) PT=.35*PCD
00000450            DPTX=1.
00000451        220 CØNTINUE
00000452            ITER2=ITER2+1
00000453            DTBX=25.
00000454            WTØLD=(1.+FAB)*WB
00000455        221 NRTTB=ICN/SQRT(TB)
00000456            ITER3=ITER3+1
00000457            DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000460         PB = PCD-DELPB
00000461         PBDLTB = PB*(TB-TCD)
00000462         ETAB =FUN1(19,PBDLTB,34)
00000463         PTPB = PT/PB
00000464         DHTNTB = FUN2(4,PTPB,NRTTB,7)
00000465         DHT=DHTNTB*ICN/1000.*SQRT(TB)
00000466     222 CALL PROCOM(FAB,TB,CPB,GMB,GMBX,HB,IFA)
00000467         IF(SENSE SWITCH 4)8098,8091
00000470    8091 CONTINUE
00000471         WT1=WB*(18650.*ETAB-HCD)/(18650.*ETAB-HB)
00000472         IF(IFA.GT.0) GOTO 8071
00000473         WTERR=ABS(WT1-WTOLD)
00000474         IF(WTERR.GT..0005) GOTO 223
00000475    8072 CONTINUE
00000476         WF=WT1-WB
00000477         FAB=WF/WB
00000500         WN=WT1+WTC
00000501         GOTO 224
00000502    8071 IF(WT1.LT.WB) WT1=WB
00000503         IF(WT1.GT.(WB*1.067623)) WT1=1.067623*WB
00000504         WTOLD=WT1
00000505         GOTO 8072
00000506     223 WTOLD=(WT1+WTOLD)*.5
00000507         WF=WTOLD-WB
00000510         FAB=WF/WB
00000511         GOTO 222
00000512     224 CONTINUE
00000513         HT=WT1/WN*(HB-DHT)+WTC/WN*HCD
00000514         HBR=(DLWHC+WN*HT-HCD*WTC)/WT1
00000515         TBERR=HBR-HB
00000516         IF(TBERR.GT..0005) GOTO 225
00000517         IF(TBERR.LT.-.0005) GOTO 228
00000520         GOTO 229
00000521     225 IF(DTBX)226,226,227
00000522     226 DTBX=-DTBX*.5
00000523     227 TB=TB+DTBX
00000524         GOTO 221
00000525     228 IF(DTBX)227,227,226
00000526     229 CONTINUE
00000527         POPT=PO/PT
00000530         IF(POPT-.528)233,233,230
00000531     230 IF(POPT-1.)232,231,231
00000532     231 WNTKNP=0.
00000533         GOTO 234
00000534     232 WNTKNP= POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
00000535         GOTO 234
00000536     233 WNTKNP=.2588
00000537     234 CONTINUE
00000540         WTTNPB=FUN2(3,PTPB,NRTTB,5)
00000541         WT2=WTTNPB*PB/TB*ICN
00000542         PTERR=WT2-WT1
00000543     240 IF(PTERR.GT..0005) GOTO 241
00000544         IF(PTERR.LT.-.0005) GOTO 245
00000545         GOTO 250
00000546     241 IF(DPTX)242,242,243
00000547     242 DPTX=-DPTX*.5
00000550     243 PT=PT+DPTX
00000551         GOTO 220
00000552     245 IF(DPTX)243,243,242
00000553     250 CONTINUE
00000554         FAT=WF/WN
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000555           TT=TFNH(1,FAT,WT,TV)
00000556           IF(SENSE SWITCH 4)8098,8092
00000557     8092  CONTINUE
00000560           WNX=(KNAB*PT*WNTKNP*AB)/SQRT(TT)
00000561           WNERR=WNX-WN
00000562           IF(III.EQ.1) GOTO 60
00000563           IF(WNERR.GT..005) GOTO 5951
00000564           IF(WNERR.LT.-.005) GOTO 5955
00000565           III=1
00000566           GOTO 99
00000567     5951  IF(DWINX)5952,5952,5953
00000570     5952  DWINX=-DWINX*.5
00000571     5953  WIN=WIN+DWINX
00000572           GOTO 99
00000573     5955  IF(DWINX)5953,5953,5952
00000574       60  CONTINUE
00000575           DLWHT=HB*WT1+HCD*WTC-HT*WN
00000576           WFM = 3600.*WF
00000577           WRITE(6,56)
00000600           WRITE(6,52) J,PB,TB,WB,ETAB,HB,PTPB,WRTTB,DHTNTB,WTTNPB
00000601           J = 13
00000602           WRITE(6,57)
00000603           WRITE(6,52)J,PT,TT,WT1,WF,HT,DLWHT,WN,WNTKNP,AB
00000604           ACD=50.7334498
00000605           CFMCD=WCD*SQRT(53.3*TCD/(1.4*32.2))/(PCD*ACD)
00000606           FMCD=RNFM(CFMCD)
00000607           CFMN=WN*SQRT(53.3*TT/(1.4*32.2))/(PT*AJ)
00000610           FMN=RNFM(CFMN)
00000611           FMNS=FMN*FMN
00000612           AAA=1.+.2*FMNS
00000613           AAA=AAA**3.5
00000614           AAA=1./AAA
00000615           AAA=(1.4*FMNS+1.)*AAA
00000616           THRUST=(PT*AAA-P2)*AJ
00000617           SPFC=WFM/THRUST
00000620           WRITE(9,6791)FMCD,FMN,WFM,THRUST,SPFC
00000621     6791  FORMAT(1H0,2X,5H MCD=G13.5,4H MN=G13.5,5H WFM=G13.5,8H THRUST=G13.
00000622          15,6H SPFC=G13.5)
00000623           PCDP2=PCD/P2
00000624           WRITE(9,6792)PCDP2
00000625     6792  FORMAT(1H0,7H P3/P2=G13.5)
00000626           WRITE(6,2108)ITER1,ITER2,ITER3
00000627     2108  FORMAT(1H0,5X,8HITER1 = I5,5X,8HITER2 = I5,5X,8HITER3 = I5)
00000630       50  FORMAT(1H1/4X,4HN = ,F8.2,4X,6HABL = ,F8.4,4X,6HBVO = ,F8.4,4X,
00000631          *8HIGVPR = ,F8.4,4X,8HOGVPR = ,F8.4)
00000632       52  FORMAT(1H0,I3,9G13.5)
00000633       51  FORMAT(1H0,2X,1HJ,4X,5HPV(J),8X,5HTV(J),8X,5HWD(J),7X,6HWBL(J),7X,
00000634          18HPSITX(J),6X,7HVZTX(J),6X,7HPHIX(J),6X,8HPSIPX(J),5X,5HPR(J))
00000635       53  FORMAT(1H0,3X,1HJ,6X,4HPOGV,10X,4HTOGV,10X,4HWOGV,8X,6HWBLTBL,9X,5
00000636          1HEFF23,10X,4HPR23,10X,4HTR23)
00000637       54  FORMAT(1H0,3X,1HJ,7X,3HPCD,11X,3HTCD,11X,3HWCD,11X,3HWTC,9X,5HDLWH
00000640          1C,10X,4HKNAB)
00000641       56  FORMAT(1H0,3X,1HJ,8X,2HPB,12X,2HTB,12X,2HWB,10X,4HETAB,12X,2HHB,
00000642          110X,4HPTPB,9X,5HNRTTB,8X,6HDHTNTB,8X,6HWTTNPB)
00000643       57  FORMAT(1H0,3X,1HJ,8X,2HPT,12X,2HTT,12X,2HWT,12X,2HWF,12X,2HHT,9X,5
00000644          1HDLWHT,12X,2HWN,8X,6HWNTKNP,12X,2HAB)
00000645           ICPV0 = PV(10)
00000646            ICWD0=WD(10)
00000647            ICWD1=WD(11)
00000650           ICWV1=WV(11)
00000651           ICTWV1=TWV(11)
```

Table A-2. Reduced-Order Component Model (Continued)

```
427   00000652          ICWD2=WD(12)
428   00000653         ICWV2=WV(12)
429   00000654         ICTWV2=TWV(12)
430   00000655          ICWD3=WD(13)
431   00000656         ICWV3=WV(13)
432   00000657         ICTWV3=TWV(13)
433   00000660          ICWD4=WD(14)
434   00000661         ICWV4=WV(14)
435   00000662         ICTWV4=TWV(14)
436   00000663          ICWD5=WD(15)
437   00000664         ICWV5=WV(15)
438   00000665         ICTWV5=TWV(15)
439   00000666          ICWD6=WD(16)
440   00000667         ICWV6=WV(16)
441   00000670         ICTWV6=TWV(16)
442   00000671          ICWD7=WD(17)
443   00000672         ICWV7=WV(17)
444   00000673         ICTWV7=TWV(17)
445   00000674          ICWD8=WD(18)
446   00000675         ICWV8=WV(18)
447   00000676         ICTWV8=TWV(18)
448   00000677         ICTWBG = TWBG
449   00000700         ICWBGV = WBGV
450   00000701         ICWDBG = WDBG
451   00000702         ICTWCD = TWCD
452   00000703         ICWCD = WCD
453   00000704         ICWDCD = WDCD
454   00000705         ICWB = WB
455   00000706         ICPB  = PB
456   00000707         ICHB = HB
457   00000710         ICRT =PT/K4/TT
458   00000711         ICRHT = HT*ICRT
459   00000712         DO 298 I=1,8
460   00000713         II=I+10
461   00000714         KGAL(II)=KGAL(I)
462   00000715     298 KVOL(II)=KVOL(I)
463   00000716         TMIC=TB
464   00000717         TBSS=TB
465   00000720         TM=TB
466   00000721    3333 CONTINUE
467   00000722         NXUE=NX+NU+NE
468   00000723         NX1=NX+1
469   00000724         NXR=NX+NR
470   00000725         SIGN=1.
471   00000726         WRITE(9,8061)
472   00000727         WRITE(9,8060)(X(I),I=1,NX)
473   00000730    8060 FORMAT(E20.8)
474   00000731    8061 FORMAT(1H1)
475   00000732         WT=WT1
476   00000733         CALL DYNAM(A,PV,TV,KGAL,KVOL,KNR,RAD,KRAD,KA,TWV,WD,WV,KBLD,DPRB,1
477   00000734        1)
478   00000735         WB    =WBL3
479   00000736         WBL-  =WBL4
480   00000737         WBL5S=WBL5
481   00000740         WTS=WT
482   00000741         WTCS=WTC
483   00000742         WRITE(9,8061)
484   00000743         WRITE(9,9000)
485   00000744    9000 FORMAT(////,5X,41HSTEADY STATE DATA FROM SUBROUTINE DYNAMIC,///)
486   00000745         WRITE(9,9001)
487   00000746    9001 FORMAT(8X,1HN,14X,2HWF,13X,2HAB,13X,3HBVB,12X,3HABL)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      WRITE(9,9010) N,WF,AB,BV3,ABL
      WRITE(9,9002)
 9002 FØRMAT(//,6X,4HWBL3,11X,4HWBL4,11X,4HWBL5)
      WRITE(9,9010) WBL3,WBL4,WBL5
      WRITE(9,9003)
 9003 FØRMAT(//,7X,3HWCD,12X,3HTCD,12X,3HPCD,12X,3HHCD)
      WRITE(9,9010) WCD,TCD,PCD,HCD
      WRITE(9,9004)
 9004 FØRMAT(//,7X,2HWB,13X,2HTB,13X,2HPB,13X,2HHB,13X,3HKWB,11X,4HETAB)
      WRITE(9,9010) WB,TB,PB,HB,KWB,ETAB
      WRITE(9,9005)
 9005 FØRMAT(//,7X,2HWT,13X,2HTT,13X,2HPT,13X,2HHT)
      WRITE(9,9010) WT,TT,PT,HT
      WRITE(9,9006)
 9006 FØRMAT(//,7X,2HWN,12X,4HKNAB,12X,3HNDT,11X,4HTMDT,12X,2HTM)
      WRITE(9,9010) WN,KNAB,NDT,TMDT,TM
 9010 FØRMAT(2X,E12.5,7(2X,E12.5))
      WRITE(9,8061)
      WRITE(9,8060)(DX(I),I=1,NX)
      WRITE(9,8061)
      WRITE(9,8060) (DX(I),I=NX1,NXR)
      DØ 8031 I=1,NXR
 8031 DXN(I)=DX(I)
C ØNE
C TWØ
      DØ 8040 J=1,NXE
 8032 SIGN=-1.*SIGN
      IF(X(J).NE.0.) GØTØ 3703
      IF(SIGN.LT.0.) GØTØ 8032
      PERT=DPERT
      GØTØ 3704
 3703 CØNTINUE
      PERT=SIGN*X(J)*DPERT
 3704 CØNTINUE
      X(J)=X(J)+PERT
      CALL DYNAM(A,PV,TV,KGAL,KVBL,KKR,RAD,KRAD,KA,TWV,WD,WV,KBLD,DPRB,2
     1)
      WBL3=WBL3S
      WBL4=WBL4S
      WBL5=WBL5S
      WT=WTS
      WTC=WTCS
      X(J)=X(J)-PERT
      IF(X(J).EQ.0.) GØTØ 3705
      IF(SIGN)8033,8034,8035
 8033 CØNTINUE
      IF(SIGN.LT.0..AND.ABS(X(J)-1.0).LT.ABS(PERT)) GØ TØ 3701
      DØ 8034 I=1,NXR
      DX1(I)=DX(I)
C THREE
C FØUR
 8034 DX(I)=DXN(I)
      GØ TØ 8032
 3701 CØNTINUE
      SIGN=-1.*SIGN
      DØ 3707 I=1,NXR
      DX1(I)=DX(I)
 3707 X(I)=DXN(I)
      PERT=-PERT
      GØTØ 8035
 3705 CØNTINUE
```

Table A-2. Reduced-Order Component Model (Continued)

```
      DO 3702 I=1,NXR
 3702 DX1(I)=DXN(I)
      PERT=-.5*PERT
C FIVE
C SIX
      GOTO 8035
 8035 CONTINUE
 3074 FORMAT(1H1/7X,8H COLUMN I3/)
      DO 8036 I=1,NXR
      CLM(I)=(DX(I)-DX1(I))/(2.*ABS(PERT))
 3076 FORMAT(I3,4E20.10)
 8036 DX(I)=DXN(I)
      WRITE(3) (CLM(I),I=1,NX)
      WRITE(3) (CLM(I),I=NX1,NXR)
 8040 CONTINUE
      GOTO 8099
 8099 CONTINUE
      PAUSE
      GOTO 8099
      END
```

```
      FUNCTION   INTGRL(IC,DXDT)
      COMMON/TDATA/TIME,DTH
      DIMENSION DN1(50)
      REAL IC,INTGRL
      INTGRL=IC
      RETURN
      END
```

```
      FUNCTION IDX(I,J,N,NX,NY)
      DIMENSION NX(5),NY(5)
      KSUM=0
      IF(N.EQ.1) GOTO 1
      NN=N-1
      DO 2 L=1,NN
    2 KSUM=KSUM+NX(L)*NY(L)
    1 CONTINUE
      IDX=KSUM+I+(J-1)*NX(N)
      RETURN
      END
```

```
      FUNCTION ABFN(NRAT)
      REAL NRAT
      IF(NRAT.GT..85) GOTO 1
      ABFN=162.01
      RETURN
    1 A=70.51/.15+91.5
      B=-70.51/.15
      ABFN=A+B*NRAT
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000000          FUNCTIØN FN1SET(N,ZX,NP,N1,N2)
00000001          CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
00000002         10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
00000003          CØMMØN X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
00000004          DIMENSIØN ZX(1)
00000005          MX(N) = NP
00000006          DØ 10 J=1,NP
00000007          K=2*J
00000010          X1(J,N) = ZX(K-1)
00000011       10 Z1(J,N) = ZX(K)
00000012          FN1SET = 1.0
00000013          DØ 30 NR=N1,N2
00000014          KK(NR) = 2
00000015          XDIF(NR) = X1(2,N)-X1(1,N)
00000016          ZPT(NR) = Z1(1,N)
00000017          SLP(NR) =(Z1(2,N)-Z1(1,N))/XDIF(NR)
00000020       30 CØNTINUE
00000021          RETURN
00000022          END
```

```
00000000          FUNCTIØN FN2SET(N,X,Y,Z,NXP,NYP,N1,N2)
00000001          CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
00000002         10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
00000003          CØMMØN X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
00000004          DIMENSIØN X( 1),Y(1),Z(1)
00000005       10 NX(N) = NXP
00000006          NY(N) = NYP
00000007          DØ 15 J=1,NYP
00000010          YY(J,N) = Y(J)
00000011          DØ 15 I=1,NXP
00000012          K = I+(J-1)*NXP
00000013          LL=IDX(I,J,N,NX,NY)
00000014       15 ZZZ(LL)=Z(K)
00000015          DØ 20 I=1,NXP
00000016       20 XX(I,N) = X(I)
00000017          FN2SET = 1.0
00000020          DØ 30 NR=N1,N2
00000021          II(NR) = 2
00000022          JJ(NR) = 2
00000023          XDEL = XX(2,N)-XX(1,N)
00000024          YDEL(NR) = YY(2,N)-YY(1,N)
00000025          LL=IDX(1,1,N,NX,NY)
00000026          ZPT1(NR)=ZZZ(LL)
00000027          LL=IDX(1,2,N,NX,NY)
00000030          ZPT2(NR)=ZZZ(LL)
00000031          LL=IDX(2,1,N,NX,NY)
00000032          SLP1(NR)=(ZZZ(LL)-ZPT1(NR))/XDEL
00000033          LL=IDX(2,2,N,NX,NY)
00000034          SLP2(NR)=(ZZZ(LL)-ZPT2(NR))/XDEL
00000035       30 CØNTINUE
00000036          RETURN
00000037          END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTIØN RNFM(C)
      XK=C
      IF(C.LT..58) GØTØ 1
      RNFM=1.
      RETURN
    1 XKS=XK*XK
      A=(1.+.2*XKS)
      AS=A*A
      AC=AS*A
      UP=C*AC-XK
      DN=1.2*C*XK*AS-1.
      XKP1=XK-(UP/DN)
      RAT=ABS(XKP1/XK)
      RAT=ABS(RAT-1.)
      IF(RAT.GT..001) GØTØ 10
      RNFM=XKP1
      RETURN
   10 XK=XKP1
      GØTØ 1
      END
```

```
      FUNCTIØN TENH(NX,FAX,HX,TV)
      DIMENSIØN TV(20)
      DTX=50.
      TX=TV(NX)
   51 CALL PRØCØM(FAX,TX,CPX,GMX,GMXX,HX1,IFA)
      IF(IFA.GT.1) GØTØ 70
      TXERR=HX-HX1
      IF(TXERR.GT..001) GØTØ 52
      IF(TXERR.LT.-.001) GØTØ 55
      GØTØ 60
   52 IF(DTX)53,53,54
   53 DTX=-DTX*.5
   54 TX=TX+DTX
      GØTØ 51
   55 IF(DTX)54,54,53
   60 CØNTINUE
   70 CØNTINUE
      TENH=TX
      TV(NX)=TX
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000000          SUBROUTINE PROCPM(FARX,TEX,CP,GM,GMX,H,IFA)
00000001          IFA=0
00000002          IF(FARX.GT.0.) GOTO 2
00000003          FARX=0.
00000004          IFA=1
00000005          GOTO 3
00000006        2 IF(FARX.LT..067623) GOTO 3
00000007          FARX=.067623
00000010          IFA=1
00000011        3 IF(TEX-1500.) 20,10,5
00000012       10 IF(TEX.LT.4000.) GOTO 7
00000013          TEX=4000.
00000014          IF(IFA.EQ.1) GOTO 50
00000015          IFA=2
00000016          GOTO 16
00000017        5 IFA=3
00000020          GOTO 16
00000021        7 IF(TEX-2300.) 9,14,8
00000022        8 IF(TEX-2500.) 14,16,16
00000023        9 IF(TEX-2000.) 10,12,12
00000024       10 CPA = .2644+2.6E-5*(TEX-1500.)
00000025          HA = (.22519+1.292E-5*TEX)*TEX+2.3733
00000026          GO TO 40
00000027       12 CPA = .27738+1.82E-5*(TEX-2000.)
00000030          HA = (.22519+1.292E-5*TEX)*TEX+2.3733
00000031          GO TO 40
00000032       14 CPA = .27738+1.82E-5*(TEX-2000.)
00000033          HA = (.25987+5.36E-6*TEX)*TEX-17.404
00000034          GO TO 40
00000035       16 CPA = .2865+1.17E-5*(TEX-2500.)
00000036          HA = (.25987+5.36E-6*TEX)*TEX-17.404
00000037          GO TO 40
00000040       20 IF(TEX.GT.300.) GOTO 21
00000041          TEX=300.
00000042          IF(IFA.EQ.1) GOTO 51
00000043          IFA=2
00000044          GOTO 24
00000045       51 IFA=4
00000046          GOTO 24
00000047       21 IF(TEX-900.) 23,28,22
00000050       22 IF(TEX-1200.) 28,30,30
00000051       23 IF(TEX-700.) 24,26,26
00000052       24 CPA = .2392+1.1E-5*(TEX-500.)
00000053          HA = (.22623+1.126E-5*TEX)*TEX+3.5214
00000054          GO TO 40
00000055       26 CPA = .2414+2.4E-5*(TEX-700.)
00000056          HA = (.22623+1.126E-5*TEX)*TEX+3.5214
00000057          GO TO 40
00000060       28 CPA = .2458+3.1E-5*(TEX-900.)
00000061          HA = (.22623+1.126E-5*TEX)*TEX+3.5214
00000062          GO TO 40
00000063       30 CPA = .2458+3.1E-5*(TEX-900.)
00000064          HA = (.22579+1.292E-5*TEX)*TEX+2.3733
00000065       40 CPF = .9333-(5.87E-5+3.27E-8*(3500.-TEX))*(3500.-TEX)
00000066          HF = (.50899+6.180E-5*TEX)*TEX-132.20
00000067          CP = (CPA+FARX*CPF)/(1.+FARX)
00000070          H = (HA+FARX*HF)/(1.+FARX)
00000071          AMW = 28.97-.946186*FARX
00000072          REX = 1.98637/AMW
00000073          GM = CP/(CP-REX)
00000074          GMX = (GM-1.)/GM
00000075          RETURN
00000076          END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTIØN FUN1(N,XIN,NR)
      CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
     10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
      CØMMØN X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
C
      IØLD = KK(NR)
      NXP = MX(N)
      IF(XIN-X1(IØLD,N)) 105,105,120
  105 IF(XIN-X1(IØLD-1,N)) 140,140,110
  110 I = IØLD
      GØ TØ 250
C     CØUNT UP
  120 IF(XIN-X1(NXP,N)) 125,180,300
  125 NF = IØLD + 1
      DØ 130 I = NF,NXP
      IF(XIN-X1(I,N)) 200,200,130
  130 CØNTINUE
      GØ TØ 200
C     CØUNT DØWN
  140 IF(XIN-X1(1,N)) 300, 190,145
  145 NL = IØLD - 2
      DØ 150 K = 1,NL
      I = IØLD - K
      IF(XIN-X1(I-1,N)) 150,150, 200
  150 CØNTINUE
      GØ TØ 200
  180 I = NXP
      GØ TØ 200
  190 I = 2
  200 XDIF(NR) = X1(I,N)-X1(I-1,N)
      ZPT(NR) = Z1(I-1,N)
      SLP(NR) =(Z1(I,N)-ZPT(NR))/XDIF(NR)
  250 XINC = XIN-X1(I-1,N)
      FUN1 = ZPT(NR)+XINC*SLP(NR)
      KK(NR) = I
      RETURN
  300 CØNTINUE
      IF(XIN.LT.X1(1,N))FUN1=Z1(1,N)
      IF(XIN.GT.X1(NXP,N))FUN1=Z1(NXP,N)
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTIØN FUN2(N,XIN,YIN,NR)
      CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
     10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
      CØMMØN X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
C     TEST FØR X IN PREVIØUS INTERVAL
      NXP = NX(N)
      IØLD = II(NR)
      IF(XIN - XX(IØLD,N)) 105,105,120
  105 IF(XIN - XX(IØLD-1,N)) 140,140,110
  110 I = IØLD
      GØ TØ 200
C     CØUNT UP
  120 IF(XIN - XX(NXP,N))  125,180,180
  125 NF = IØLD + 1
      DØ 130 I = NF,NXP
      IF(XIN - XX(I,N))200,200,130
  130 CØNTINUE
      GØ TØ 200
C     CØUNT DØWN
  140 IF(XIN-XX(1,N)) 190,190,145
  145 NL = IØLD -2
      DØ 150K = 1,NL
      I = IØLD - K
      IF(XIN-XX(I-1,N))150,150,200
  150 CØNTINUE
      GØTØ 200
  180 I=NXP
      XIN=XX(NXP,N)
      GØ TØ 200
  190 I = 2
      XIN=XX(1,N)
C     TEST FØR Y IN PREVIØUS INTERVAL
  200 NYP = NY(N)
      JØLD = JJ(NR)
      IF(YIN - YY(JØLD,N)) 205, 205, 220
  205 IF(YIN - YY(JØLD-1,N)) 240,240,210
  210 J = JØLD
      IF(I-IØLD) 300,400,300
C     CØUNT UP
  220 IF(YIN - YY(NYP,N)) 225, 280,280
  225 NF = JØLD + 1
      DØ 230 J = NF,NYP
      IF(YIN - YY(J,N)) 300,300,230
  230 CØNTINUE
      GØ TØ 300
C     CØUNT DØWN
  240 IF(YIN - YY(1,N))290, 290,245
  245 NL = JØLD - 2
      DØ 250 K = 1,NL
      J = JØLD - K
      IF(YIN -YY(J-1,N)) 250,250,300
  250 CØNTINUE
      GØ TØ 300
  280 J = NYP
      YIN=YY(NYP,N)
      GØ TØ 300
  290 J = 2
      YIN=YY(1,N)
C     CØMPUTE Z(Y) INTERCEPTS AND SLØPES
  300 XDEL = XX(I,N)-XX(I-1,N)
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000074          YDEL(NR) = YY(J,N)-YY(J-1,N)
00000075          LL=IDX(I-1,J-1,N,NX,NY)
00000076          ZPT1(NR)=ZZZ(LL)
00000077          LL=IDX(I-1,J,N,NX,NY)
00000100          ZPT2(NR)=ZZZ(LL)
00000101          LL=IDX(I,J-1,N,NX,NY)
00000102          SLP1(NR)=(ZZZ(LL)-ZPT1(NR))/XDEL
00000103          LL=IDX(I,J,N,NX,NY)
00000104          SLP2(NR)=(ZZZ(LL)-ZPT2(NR))/XDEL
00000105     C    INTERPOLATE FOR ANSWER
00000106      400 II(NR) = I
00000107          JJ(NR) = J
00000110          XINC = XIN-XX(I-1,N)
00000111          P1ZZ = ZPT1(NR)+XINC*SLP1(NR)
00000112          P2ZZ = ZPT2(NR)+XINC*SLP2(NR)
00000113          YFRAC = (YIN-YY(J-1,N))/YDEL(NR)
00000114          FUN2 = P1ZZ + YFRAC*(P2ZZ-P1ZZ)
00000115          RETURN
00000116          END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      SUBROUTINE DYNAM(A,PV,TV,KGAL,KVBL,KNR,RAD,KRAD,KA,TAV,WD,AV,KBLD,
     1DPRB,INIT)
      DIMENSION A(20),PV(20),TV(20),KGAL(20),KVBL(20),KNR(8),RAD(8)
      DIMENSION KRAD(8),KA(30),TAV(20),WD(20),AV(20),KBLD(8),DPRB(14)
      COMMON/TDATA/TIME,DTH
      COMMON/DATA/X( 2),U(4),ETA(3),DXN( 6),DX( 6),DX1( 6),CLM( 6),KVBLI
     1G,       RTHN,     KVBLBG,KGALBG,KBGV,WTC,KVBLCD,KGALCD,    KAB,KGALB,
     2HT,       K4,K2,WT,HCD,KVBLB,PO,WN,KNAB,KSPEED,KGALIG,KFIGV,K3,
     3WBL3,WBL4,WBL5,WCD,WDCD,TWCD,ETAB,DHT
     4,TCD,     WB,HB,PB,ERROR
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVBL
      REAL KVBLBG,KGALBG,KVBLCD,KGALCD,KGALB,KAB,KVBLB,KVBLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KBGV,KNAB,NRTTB,ICPVO,ICWDO,ICWD1
      REAL          ICWD2,                ICWD3,                ICWD4
      REAL          ICWD5,                ICWD6,                ICWD7
      REAL          ICWD8,                            ICWDBG,ICTWCD,ICWCD
      REAL ICWDCD,ICWB,ICPB,ICHB,ICRT,ICRHT,ICWFWP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMD,ITER,IMPL,INTGRL,KIC
      REAL KAB,ICWDBG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVBLIG
      EQUIVALENCE(ICN,N,X(1))
      EQUIVALENCE
     2             (NDT,DX( 1)),(WF,U(1)),(BVB,U(2)),(AB,U(3)),(P2,ETA(1
     3)),(TV0,T2,ETA(2)),(PB,ETA(3)),(U(4),ABL)
      EQUIVALENCE (TMIC,TM,X(2)),(TMDT,DX(2))
      EQUIVALENCE (PCD,DX(3)),(PT,DX(4)),(TB,DX(5)),(TT,DX(6))
      WB=WT-WF
      WDC=WB+WTC+WBL3+WBL4+WBL5
   98 CONTINUE
      DELPT=0.1
      DELWDO=0.01
      ITER1=0
      ITER2=0
   99 CONTINUE
      RTHO=SQRT(TV0/518.7)
      DO 299 I=1,8
  299 KNR(I)=(N*RAD(I))**2/K2
C
C DYNAMICS
C
C  INLET AND STAGE ONE
C
      NC1 = N/RTHO
      NC1N = NC1/16500
      IGVPR = FUN1(2,NC1N,2)
      PV0 = P2*IGVPR - .005*P2
      WD1 = WD0
      DELO = PV0/14.7
      FP1 = WD1*RTHO/(DELO*A(11))
      VZT1 = KA(1) + KA(11)*FP1 + KA(21)*FP1*FP1
      PHI1 = VZT1/(KRAD(1)*NC1)
      PSIP1 = FUN2(2,PHI1,BVB,4)
      PD1= PV0*(1.+PSIP1*KNR(1)/TV0)**3.5
      PV1 = PD1
      PSIT1=FUN2(5,PHI1,BVB,10)
      TD1 = TV0+KNR(1)*PSIT1
      TV1 = TD1
C
C  STAGE TWO
C
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000074          RTH1 = SQRT(TV1/518.7)
00000075          NC2 = N/RTH1
00000076          DEL1 = PV1/14.7
00000077          WD2 = WD1
00000100          FP2 = WD2*RTH1/(DEL1*A(12))
00000101          VZT2 = KA(2) + KA(12)*FP2 + KA(22)*FP2*FP2
00000102          PHI2 = VZT2/(KRAD(2)*NC2)
00000103          PSIP2=FUN1(5,PHI2,7)
00000104          PD2 = PV1*(1.+PSIP2*KNR(2)/TV1)**3.5
00000105          PV2 = PD2
00000106          PSIT2=FUN1(6 ,PHI2,9 )
00000107          TD2 = TV1+KNR(2)*PSIT2
00000110          TV2 = TD2
00000111    C
00000112    C  STAGE THREE
00000113    C
00000114          RTH2 = SQRT(TV2/518.7)
00000115          NC3 =N/RTH2
00000116          DEL2 = PV2/14.7
00000117          WD3 = WD2
00000120          FP3 = WD3*RTH2/(DEL2*A(13))
00000121          VZT3 = KA(3) + KA(13)*FP3 + KA(23)*FP3*FP3
00000122          PHI3 = VZT3/(KRAD(3)*NC3)
00000123          PSIP3=FUN1(7,PHI3,11)
00000124          PD3 = PV2*(1.+PSIP3*KNR(3)/TV2)**3.5
00000125          PV3 = PD3
00000126          PSIT3=FUN1(8 ,PHI3,13)
00000127          TD3 = TV2+KNR(3)*PSIT3
00000130          TV3 = TD3
00000131          RTH3 = SQRT(TV3/518.7)
00000132          WBL3 =KBLD(3)*ABL*PV3/(K3*RTH3)
00000133    C
00000134    C  STAGE FOUR
00000135    C
00000136          WD4 = WD3-WBL3
00000137          NC4 = N/RTH3
00000140          DEL3 = PV3/14.7
00000141          FP4 = WD4*RTH3/(DEL3*A(14))
00000142          VZT4 = KA(4) + KA(14)*FP4 + KA(24)*FP4*FP4
00000143          PHI4 = VZT4/(KRAD(4)*NC4)
00000144          PSIP4=FUN1(9 ,PHI4,15)
00000145          PD4 = PV3*(1.+PSIP4*KNR(4)/TV3)**3.5
00000146          PV4 = PD4
00000147          PSIT4=FUN1(10,PHI4,17)
00000150          TD4 = TV3+KNR(4)*PSIT4
00000151          TV4 = TD4
00000152          RTH4 = SQRT(TV4/518.7)
00000153          WBL4 =KBLD(4)*ABL*PV4/(K3*RTH4)
00000154    C
00000155    C  STAGE FIVE
00000156    C
00000157          WD5 = WD4-WBL4
00000160          NC5 = N/RTH4
00000161          DEL4 = PV4/14.7
00000162          FP5 = WD5*RTH4/(DEL4*A(15))
00000163          VZT5 = KA(5) + KA(15)*FP5 + KA(25)*FP5*FP5
00000164          PHI5 = VZT5/(KRAD(5)*NC5)
00000165          PSIP5=FUN1(11,PHI5,19)
00000166          PD5 = PV4*(1.+PSIP5*KNR(5)/TV4)**3.5
00000167          PV5 = PD5
00000170          PSIT5=FUN1(12,PHI5,21)
```

Table A-2. Reduced-Order Component Model (Continued)

```
122  00000171           TD5 = TV4+KNR(5)*PSIT5
123  00000172           TV5 = TD5
124  00000173           RTH5 = SQRT(TV5/518.7)
125  00000174           WBL5 =KBLD(5)*ABL*PV5/(K3*RTH5)
126  00000175      C
127  00000176      C  STAGE SIX
128  00000177      C
129  00000200           WD6 = WD5-WBL5
130  00000201           NC6 = N/RTH5
131  00000202           DEL5 = PV5/14.7
132  00000203           FP6 = WD6*RTH5/(DEL5*A(16))
133  00000204           VZT6 = KA(6) + KA(16)*FP6 + KA(26)*FP6*FP6
134  00000205           PHI6 = VZT6/(KRAD(6)*NC6)
135  00000206           PSIP6=FUN1(13,PHI6,23)
136  00000207           PD6 = PV5*(1.+PSIP6*KNR(6)/TV5)**3.5
137  00000210           PV6=PD6
138  00000211           PSIT6=FUN1(14,PHI6,25)
139  00000212           TD6 = TV5+KNR(6)*PSIT6
140  00000213           TV6=TD6
141  00000214      C
142  00000215      C  STAGE SEVEN
143  00000216      C
144  00000217           WD7=WD6
145  00000220           RTH6 = SQRT(TV6/518.7)
146  00000221           NC7 = N/RTH6
147  00000222           DEL6 = PV6/14.7
148  00000223           FP7 = WD7*RTH6/(DEL6*A(17))
149  00000224           VZT7 = KA(7) + KA(17)*FP7 + KA(27)*FP7*FP7
150  00000225           PHI7 = VZT7/(KRAD(7)*NC7)
151  00000226           PSIP7=FUN1(15,PHI7,27)
152  00000227           PD7 = PV6*(1.+PSIP7*KNR(7)/TV6)**3.5
153  00000230           PV7=PD7
154  00000231           PSIT7=FUN1(16,PHI7,29)
155  00000232           TD7 = TV6+KNR(7)*PSIT7
156  00000233           TV7=TD7
157  00000234      C
158  00000235      C  STAGE EIGHT
159  00000236      C
160  00000237           WD8=WD7
161  00000240           RTH7 = SQRT(TV7/518.7)
162  00000241           NC8 = N/RTH7
163  00000242           DEL7 = PV7/14.7
164  00000243           FP8 = WD8*RTH7/(DEL7*A(18))
165  00000244           VZT8 = KA(8) + KA(18)*FP8 + KA(28)*FP8*FP8
166  00000245           PHI8 = VZT8/(KRAD(8)*NC8)
167  00000246           PSIP8=FUN1(17,PHI8,31)
168  00000247           PD8 = PV7*(1.+PSIP8*KNR(8)/TV7)**3.5
169  00000250           PV8=PD8
170  00000251           PSIT8=FUN1(18,PHI8,33)
171  00000252           TD8 = TV7+KNR(8)*PSIT8
172  00000253           TV8=TD8
173  00000254      C
174  00000255      C  OUTLET GUIDE VANES
175  00000256      C
176  00000257           WOGV = WD8
177  00000260           TOGV=TD8
178  00000261           OGVPR=FUN1(3,NC1N,3)
179  00000262           POGV=OGVPR*PD8
180  00000263      C
181  00000264      C  COMPRESSOR DISCHARGE
182  00000265      C
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000266            WTC = .033*WDO
00000267            TCD=TOGV
00000270            WCD=WOGV
00000271            PCD=POGV
00000272            TWCD=PCD/KVOLCD
00000273            WDCD=TWCD/TCD
00000274      C
00000275      C  BURNER
00000276      C
00000277            CALL PROCOM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
00000300            WB=WCD-WTC
00000301            FAB=WF/WB
00000302            NRAT=N/16500.
00000303            KWB=FUN1(20,NRAT,37)
00000304        140 ETABO=ETAB
00000305            HB=HCD+18650.*ETAB*FAB
00000306            TEB=TFNH(2,FAB,HB,TV)
00000307            IF(INIT.EQ.1) TM=TEB
00000310            TMDT=4.5*0.248*(TEB-TM)/(15.*0.12)
00000311            TB=(0.24*WB*TEB-15.*0.12*TMDT)/(0.24*WB)
00000312            DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
00000313            PB=PCD-DELPB
00000314            PBDLTB=PB*(TB-TCD)
00000315            ETAB=FUN1(19,PBDLTB,35)
00000316            IF(ABS(ETAB-ETABO).GT.1.E-10) GO TO 140
00000317            NRTTB = N/SQRT(TB)
00000320            WT=WB+WF
00000321            FAT=WF/(WT+WTC)
00000322            PTPB = PT/PB
00000323            WTTNPB = FUN2(3,PTPB,NRTTB,6)
00000324            WTCAL = WTTNPB*N*PB/TB
00000325            PTERR=WTCAL-WT
00000326            WN=WT+WTC
00000327            DHTNTB = FUN2(4,PTPB,NRTTB,8)
00000330            DHT=N/1000.*DHTNTB*SQRT(TB)
00000331            HT=HB-DHT
00000332            HT=(WT*HT+WTC*HCD)/(WT+WTC)
00000333            TT=TFNH(3,FAT,HT,TV)
00000334            POPT=PB/PT
00000335            WNTKNP=HOKEY(POPT)
00000336            KNA8=5.0405-.0429772*A8+.000126664*A8**2
00000337            WNCAL = WNTKNP*A8*KNA8*PT/SQRT(TT)
00000340            WNERR=WNCAL-WN
00000341            WBLTBL = WBL3*TV3+WBL4*TV4+WBL5*TV5
00000342            DLWHC=HCD*WCD+.24*(WBLTBL-TVO*WDO)
00000343            DLWHT=WT*DHT
00000344            NDT=KSPEED/N*(DLWHT-DLWHC)
00000345            IF(ABS(PTERR).LT.ERROR.AND.ABS(WNERR).LT.ERROR) GO TO 100
00000346      C     GRADIENT CALCULATION
00000347            ITER1=ITER1+1
00000350            GO TO (10,20,30,40,50) ITER1
00000351         10 F=PTERR
00000352            G=WNERR
00000353            IF(SENSE SWITCH 5) 11,12
00000354         11 OUTPUT(9) WDO,PVO,TVO,WD1,PD1,TD1,WD2,PD2,TD2,WD3,PD3,TD3,WBL3,WD4
00000355           1,PD4,TD4,WBL4,WD5,PD5,TD5,WBL5,WD6,PD6,TD6,WD7,PD7,TD7,WD8,PD8,
00000356           2TD8,WOGV,POGV,TOGV,WTC,PCD,TCD,WCD,HCD,WF,WB,PB,TB,HB,WT,PT,TT,HT,
00000357           3WN,FAB,FAT,ETAB,KNA8,DELPB,NRTTB,WTTNPB,PBDLTB,DHTNTB,DHT,WBLTBL,
00000360           4DLWHC,DLWHT,NDT,N,PT,WDO,PTERR,WNERR,WTCAL,WT,WNCAL,WN,ITER1,ITER2
00000361            OUTPUT(9) TEB,TM,TMDT
00000362            IF(SENSE SWITCH 6) 13,12
```

Table A-2. Reduced-Order Component Model (Concluded)

```
00000363          13 CONTINUE
00000364             PAUSE
00000365             READ(5,300) IDUM
00000366             READ(5,300) PT,WDO
00000367         300 FORMAT(2E12.5)
00000370             GO TO 95
00000371          12 ITER2=ITER2+1
00000372             PT=PT+DELPT
00000373             GO TO 99
00000374          20 FX=PTERR
00000375             GX=WNERR
00000376             PT=PT-2.*DELPT
00000377             GO TO 99
00000400          30 FX=(FX-PTERR)/(2.*DELPT)
00000401             GX=(GX-WNERR)/(2.*DELPT)
00000402             PT=PT+DELPT
00000403             WDO=WDO+DELWDO
00000404             GO TO 99
00000405          40 FY=PTERR
00000406             GY=WNERR
00000407             WDO=WDO-2.*DELWDO
00000410             GO TO 99
00000411          50 FY=(FY-PTERR)/(2.*DELWDO)
00000412             GY=(GY-WNERR)/(2.*DELWDO)
00000413             WDO=WDO+DELWDO
00000414             D=FX*GY-GX*FY
00000415             IF(ABS(D).LT.0.000001) STOP 77
00000416             DXX=(-F*GY+G*FY)/D
00000417             DYY=(-G*FX+F*GX)/D
00000420             IF(ABS(DXX).LT.(2.*DELPT)) GO TO 60
00000421             FACTOR=2.*DELPT/ABS(DXX)
00000422             DXX=FACTOR*DXX
00000423             DYY=FACTOR*DYY
00000424          60 IF(ABS(DYY).LT.(2.*DELWDO)) GO TO 70
00000425             FACTOR=2.*DELWDO/ABS(DYY)
00000426             DYY=FACTOR*DYY
00000427             DXX=FACTOR*DXX
00000430          70 PT=PT+DXX
00000431             WDO=WDO+DYY
00000432             ITER1=0
00000433             GO TO 99
00000434         100 CONTINUE
00000435             N = INTGRL(ICN,NDT)
00000436             IF(SENSE SWITCH 5) 110,120
00000437         110 WRITE(9,511) ITER2
00000440         511 FORMAT(1H1,5X,12HCONVERGED IN,I10,12H  ITERATIONS)
00000441             OUTPUT(9) N,WF,AB,BVO,ABL,NDT,PTERR,WNERR,PT,WDO
00000442             WRITE(9,512)
00000443         512 FORMAT(1H1)
00000444         120 CONTINUE
00000445             RETURN
00000446             END
```

```
00000000             FUNCTION HOKEY(POPT)
00000001             IF(POPT.GE.1.) GOTO 1
00000002             IF(POPT.GE..53) HOKEY=POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
00000003             IF(POPT.GE.0..AND.POPT.LE..53) HOKEY=.2588
00000004             RETURN
00000005           1 HOKEY=0.
00000006             RETURN
00000007             END
```

Table A-3. Engine Component Characteristics

FUNCTION F11: ABLB = f [BVOB]

BVOB	ABLB
.00000E 00	.00000E 00
.10000E 00	.18000E 00
.20000E 00	.33000E 00
.25000E 00	.39500E 00
.30000E 00	.45500E 00
.40000E 00	.54500E 00
.50000E 00	.63000E 00
.70000E 00	.78800E 00
.10000E 01	.10000E 01

FUNCTION F12: IGVPR = f [N/N$_{MAX}$]

N/N MAX	IGVPR
.00000E 00	.99800E 00
.60000E 00	.99800E 00
.65000E 00	.99750E 00
.70000E 00	.99680E 00
.75000E 00	.99570E 00
.80000E 00	.99400E 00
.85000E 00	.99200E 00
.90000E 00	.98980E 00
.95000E 00	.98750E 00
.10000E 01	.98500E 00

FUNCTION F13: OGVPR = f [N/N$_{MAX}$]

N/N MAX	OGVPR
.00000E 00	.99800E 00
.60000E 00	.99800E 00
.65000E 00	.99750E 00
.70000E 00	.99680E 00
.75000E 00	.99620E 00
.80000E 00	.99570E 00
.85000E 00	.99530E 00
.90000E 00	.99500E 00
.10000E 01	.99500E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F15: $\psi_2^P = f\,[\phi_2]$

ϕ_2	ψ^P_2
.00000E 00	.25000E 00
.45000E 00	.69500E 00
.50000E 00	.74550E 00
.55000E 00	.79200E 00
.56800E 00	.80700E 00
.58000E 00	.81600E 00
.60000E 00	.83100E 00
.62000E 00	.84400E 00
.64000E 00	.85600E 00
.66000E 00	.86600E 00
.68000E 00	.87300E 00
.70000E 00	.87800E 00
.72000E 00	.87900E 00
.73000E 00	.87800E 00
.74000E 00	.86800E 00
.75000E 00	.85300E 00
.76000E 00	.82700E 00
.76700E 00	.78000E 00
.79000E 00	.50000E 00
.80500E 00	.25000E-01

FUNCTION F16: $\psi_2^T = f\,[\phi_2]$

ϕ_2	ψ_2^T
.00000E 00	.29500E 01
.45000E 00	.10000E 01
.50000E 00	.97000E 00
.55000E 00	.95500E 00
.56800E 00	.95300E 00
.58000E 00	.95300E 00
.60000E 00	.95200E 00
.62000E 00	.95600E 00
.64000E 00	.96000E 00
.66000E 00	.97000E 00
.68000E 00	.97500E 00
.70000E 00	.98000E 00
.72000E 00	.98000E 00
.73000E 00	.97800E 00
.74000E 00	.97200E 00
.75000E 00	.96200E 00
.76000E 00	.93500E 00
.76700E 00	.90300E 00
.79000E 00	.62000E 00
.80500E 00	.22000E 00
.82000E 00	-.26000E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F17: $\psi_3^P = f\,[\phi_3]$

ϕ_3	ψ_3^P
.00000E 00	.55000E 00
.50000E 00	.69300E 00
.53000E 00	.70200E 00
.57000E 00	.71200E 00
.58000E 00	.71500E 00
.60000E 00	.71900E 00
.62000E 00	.72400E 00
.64000E 00	.72800E 00
.65000E 00	.73000E 00
.66000E 00	.73300E 00
.67000E 00	.73400E 00
.68000E 00	.72900E 00
.69000E 00	.71800E 00
.69500E 00	.70400E 00
.69800E 00	.67000E 00
.69900E 00	.62400E 00
.70400E 00	.39400E 00

FUNCTION F18: $\psi_3^T = f\,[\phi_3]$

ϕ_3	ψ_3^T
.00000E 00	.10600E 01
.50000E 00	.83500E 00
.53000E 00	.82500E 00
.57000E 00	.82000E 00
.58000E 00	.81800E 00
.60000E 00	.82000E 00
.62000E 00	.82200E 00
.64000E 00	.82500E 00
.65000E 00	.82800E 00
.66000E 00	.83100E 00
.67000E 00	.83200E 00
.68000E 00	.83000E 00
.69000E 00	.81800E 00
.69500E 00	.80200E 00
.69800E 00	.71600E 00
.69900E 00	.68500E 00
.70400E 00	.62000E 00
.72000E 00	.40000E 00
.74000E 00	.12300E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F19: $\psi_4^P = f[\phi_4]$

ϕ_4	ψ_4^P
.00000E 00	.88000E 00
.53000E 00	.84200E 00
.55000E 00	.84100E 00
.57000E 00	.83600E 00
.58000E 00	.83000E 00
.60000E 00	.81900E 00
.61000E 00	.81300E 00
.62000E 00	.80700E 00
.63000E 00	.79900E 00
.64000E 00	.79200E 00
.65000E 00	.78300E 00
.65700E 00	.77700E 00
.66000E 00	.77300E 00
.66300E 00	.76600E 00
.66900E 00	.75200E 00
.67500E 00	.73800E 00
.72500E 00	.00000E 00
.77500E 00	-.73800E 00

FUNCTION F110: $\psi_4^T = f[\phi_4]$

ϕ_4	ψ_4^T
.00000E 00	.14650E 01
.53000E 00	.98500E 00
.55000E 00	.96300E 00
.57000E 00	.94800E 00
.58000E 00	.93200E 00
.60000E 00	.92300E 00
.61000E 00	.91400E 00
.62000E 00	.90400E 00
.63000E 00	.89300E 00
.64000E 00	.88400E 00
.65000E 00	.87700E 00
.65700E 00	.87500E 00
.66000E 00	.87500E 00
.66300E 00	.87500E 00
.66900E 00	.88000E 00
.67500E 00	.88500E 00
.68500E 00	.86200E 00
.70000E 00	.62000E 00
.72500E 00	.13000E 00
.77500E 00	-.87000E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F111: $\psi_5^P = f[\phi_5]$

ϕ_5	ψ_4^P
.00000E 00	.70000E 00
.52000E 00	.70000E 00
.54000E 00	.69700E 00
.55800E 00	.69100E 00
.57000E 00	.68500E 00
.58000E 00	.67800E 00
.59000E 00	.67200E 00
.59500E 00	.66700E 00
.60000E 00	.66300E 00
.61000E 00	.64800E 00
.61500E 00	.63600E 00
.62000E 00	.61700E 00
.62500E 00	.57900E 00
.64000E 00	.37200E 00
.66250E 00	.00000E 00
.68500E 00	-.37200E 00

FUNCTION F112: $\psi_5^T = f[\phi_5]$

ϕ_5	ψ_5^T
.00000E 00	.35800E 01
.42500E 00	.10070E 01
.47500E 00	.91200E 00
.52000E 00	.85300E 00
.54000E 00	.82600E 00
.55800E 00	.80500E 00
.57000E 00	.78700E 00
.58000E 00	.77500E 00
.59000E 00	.76600E 00
.59500E 00	.76000E 00
.60000E 00	.74500E 00
.61000E 00	.73000E 00
.61500E 00	.71500E 00
.62000E 00	.70000E 00
.62500E 00	.67500E 00
.64000E 00	.51000E 00
.66250E 00	.79000E-01
.68500E 00	-.40200E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F113: $\psi_6^P = f\,[\phi_6]$

ϕ_6	ψ_6^P
.00000E 00	.61600E 00
.50000E 00	.61600E 00
.52000E 00	.61200E 00
.53500E 00	.60500E 00
.55000E 00	.58500E 00
.57000E 00	.55000E 00
.58000E 00	.52500E 00
.60000E 00	.47800E 00
.61000E 00	.45000E 00
.62500E 00	.40000E 00
.67500E 00	.20000E 00
.72500E 00	.00000E 00
.77500E 00	-.20000E 00

FUNCTION F114: $\psi_6^T = f\,[\phi_6]$

ϕ_6	ψ_6^T
.00000E 00	.82000E 00
.50000E 00	.70500E 00
.52000E 00	.69500E 00
.53500E 00	.68300E 00
.55000E 00	.66600E 00
.57000E 00	.63200E 00
.58000E 00	.61200E 00
.60000E 00	.56200E 00
.61000E 00	.53000E 00
.62500E 00	.48200E 00
.67500E 00	.29700E 00
.72500E 00	.75000E-01
.77500E 00	-.14700E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F115: $\psi_7^P = f[\phi_7]$

ϕ_7	ψ_7^P
.00000E 00	.48600E 00
.47500E 00	.48600E 00
.48500E 00	.48600E 00
.50000E 00	.48400E 00
.51500E 00	.48000E 00
.52500E 00	.46500E 00
.55000E 00	.41500E 00
.56500E 00	.37500E 00
.57500E 00	.34500E 00
.59000E 00	.29500E 00
.59500E 00	.27500E 00
.60000E 00	.25500E 00
.62500E 00	.15500E 00
.66000E 00	.00000E 00
.69500E 00	-.15500E 00

FUNCTION F116: $\psi_7^T = f[\phi_7]$

ϕ_7	ψ_7^T
.00000E 00	.56200E 00
.50000E 00	.56000E 00
.51500E 00	.55200E 00
.52500E 00	.53700E 00
.55000E 00	.48700E 00
.56500E 00	.44300E 00
.57500E 00	.41200E 00
.59000E 00	.36200E 00
.59500E 00	.34200E 00
.60000E 00	.32300E 00
.62500E 00	.22000E 00
.66000E 00	.00000E 00
.69500E 00	-.25200E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F117: $\phi_8^P = f\ [\phi_8]$

ϕ_8	ψ_8^P
.45000E 00	.40000E 00
.46000E 00	.48400E 00
.46500E 00	.48200E 00
.47500E 00	.47600E 00
.49000E 00	.46000E 00
.50000E 00	.43500E 00
.51000E 00	.39400E 00
.52500E 00	.33000E 00
.54000E 00	.26500E 00
.55000E 00	.22500E 00
.56500E 00	.16300E 00
.57500E 00	.12200E 00
.60000E 00	.25000E-01
.60550E 00	.00000E 00
.66100E 00	-.22500E 00

FUNCTION F118: $\psi_8^T = f\ [\phi_8]$

ϕ_8	ψ_8^T
.00000E 00	.56000E 00
.45000E 00	.56000E 00
.46000E 00	.56000E 00
.46500E 00	.56000E 00
.47500E 00	.56000E 00
.49000E 00	.53500E 00
.50000E 00	.50700E 00
.51000E 00	.46500E 00
.52500E 00	.40000E 00
.54000E 00	.32000E 00
.55000E 00	.27000E 00
.56500E 00	.20500E 00
.57500E 00	.16000E 00
.60000E 00	.45000E-01
.60550E 00	.00000E 00
.66100E 00	-.45200E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F119: η_B = f [PB*(TB-TCD)]

PB*(TB-TCD)	η_B
.00000E 00	.79450E 00
.90000E 04	.88000E 00
.15000E 05	.93100E 00
.13250E 05	.95500E 00
.24000E 05	.97100E 00
.30000E 05	.98100E 00
.36500E 05	.98700E 00
.47500E 05	.99000E 00
.55000E 05	.99000E 00
.72500E 05	.98620E 00
.95000E 05	.98320E 00
.12500E 06	.98100E 00
.14000E 06	.98050E 00
.16000E 06	.98000E 00

FUNCTION F120: KWB = f [N/N_{MAX}]

N/N_{MAX}	KWB
.60000E 00	.72600E-03
.70000E 00	.70700E-03
.80000E 00	.69800E-03
.85000E 00	.69000E-03
.90000E 00	.69600E-03
.97000E 00	.69600E-03
.10000E 01	.73800E-03

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F1: BVOB = f [$N/N_{MAX}, T_0$]

T_0 / N/N_{MAX}	.48000E 03	.49250E 03	.50300E 03	.51850E 03	.53000E 03
.00000E 00	.10000E 01	.10000E 01	.10000E 01	.10000E 01	.10000E 01
.80000E 00	.10000E 01	.10000E 01	.10000E 01	.10000E 01	.10000E 01
.82000E 00	.83500E 00	.83500E 00	.83500E 00	.83500E 00	.83500E 00
.84000E 00	.70500E 00	.69700E 00	.69000E 00	.68400E 00	.67800E 00
.86000E 00	.592[illegible]0E 00	.58000E 00	.56800E 00	.55500E 00	.53500E 00
.88000E 00	.52000E 00	.50000E 00	.47000E 00	.43500E 00	.39500E 00
.90000E 00	.46800E 00	.43200E 00	.39000E 00	.32500E 00	.26500E 00
.92000E 00	.41500E 00	.36500E 00	.30000E 00	.22000E 00	.13000E 00
.94000E 00	.34500E 00	.27500E 00	.19000E 00	.10500E 00	.00000E 00
.95500E 00	.27500E 00	.19000E 00	.10000E 00	.00000E 00	.00000E 00
.97000E 00	.20000E 00	.10000E 00	.00000E 00	.00000E 00	.00000E 00
.98500E 00	.10000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F2: $\psi_2^P = f[\phi_2, IGV]$

ϕ_2 \ IGV	.00000E 00	.50000E 00	.75000E 00	.10000E 01
.00000E 00	.42000E 00	.30000E 00	.28000E 00	.26000E 00
.45000E 00	.84500E 00	.86400E 00	.83000E 00	.79200E 00
.47500E 00	.87000E 00	.89200E 00	.86100E 00	.82200E 00
.50000E 00	.89300E 00	.91000E 00	.88200E 00	.84300E 00
.52500E 00	.90900E 00	.92000E 00	.88900E 00	.85000E 00
.55000E 00	.92500E 00	.91500E 00	.88500E 00	.84900E 00
.57500E 00	.93000E 00	.90300E 00	.87000E 00	.84000E 00
.60000E 00	.93000E 00	.87500E 00	.84800E 00	.81300E 00
.62500E 00	.92000E 00	.84000E 00	.82000E 00	.78200E 00
.65000E 00	.90500E 00	.79500E 00	.78700E 00	.74700E 00
.67500E 00	.88300E 00	.74600E 00	.74600E 00	.70500E 00
.70000E 00	.85900E 00	.67500E 00	.67500E 00	.65600E 00
.72500E 00	.82700E 00	.61500E 00	.61500E 00	.60000E 00
.75000E 00	.77000E 00	.51000E 00	.51000E 00	.51000E 00
.77500E 00	.61500E 00	.36200E 00	.36200E 00	.36200E 00
.79000E 00	.40000E 00	.26500E 00	.26500E 00	.26500E 00
.80500E 00	.25000E-01	.25000E-01	.25000E-01	.25000E-01

Table A-3. Engine Compone

FUNCTION F3: $\frac{WT \cdot TB}{N \cdot PB} = f \left[\frac{PT}{PB}, \sqrt{} \right.$

$\frac{PT}{PB}$ \ $\frac{N}{\sqrt{TB}}$	.10000E 03	.15000E 03	.20000E 03	.24000E 03	.26000E 03	.28000E 03	.30000E 03
.00000E 00	.22480E 00	.14870E 00	.11120E 00	.92500E-01	.83300E-01	.77300E-01	.72000E-01
.10000E 00	.22480E 00	.14870E 00	.11120E 00	.92500E-01	.83300E-01	.77300E-01	.72000E-01
.20000E 00	.22480E 00	.14870E 00	.11100E 00	.92500E-01	.83300E-01	.77300E-01	.72000E-01
.30000E 00	.22390E 00	.14800E 00	.11000E 00	.91500E-01	.83300E-01	.77300E-01	.72000E-01
.35000E 00	.22380E 00	.14700E 00	.10910E 00	.90600E-01	.83200E-01	.77200E-01	.71900E-01
.40000E 00	.22270E 00	.14600E 00	.10830E 00	.89800E-01	.82800E-01	.76900E-01	.71600E-01
.45000E 00	.22110E 00	.14510E 00	.10750E 00	.89100E-01	.81900E-01	.76000E-01	.70800E-01
.50000E 00	.21920E 00	.14390E 00	.10630E 00	.88000E-01	.80800E-01	.74900E-01	.69700E-01
.55000E 00	.21690E 00	.14230E 00	.10470E 00	.86400E-01	.79500E-01	.73500E-01	.68300E-01
.60000E 00	.21430E 00	.13960E 00	.10240E 00	.84200E-01	.77100E-01	.71300E-01	.66400E-01
.70000E 00	.20410E 00	.12970E 00	.93000E-01	.74900E-01	.68600E-01	.62800E-01	.58000E-01
.80000E 00	.16310E 00	.99700E-01	.68700E-01	.55000E-01	.50500E-01	.44500E-01	.41000E-01
.90000E 00	.88700E-01	.53200E-01	.37800E-01	.28500E-01	.26500E-01	.22400E-01	.21300E-01
.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

FUNCTION F4: $\frac{\Delta HT}{N\sqrt{TB}} = f \left[\frac{PT}{PB}, \right.$

$\frac{PT}{PB}$ \ $\frac{N}{\sqrt{TB}}$	.10000E 03	.15000E 03	.20000E 03	.24000E 03	.26000E 03	.28000E 03	.30000E 03
.00000E 00	.26000E 00	.24900E 00	.23600E 00	.22400E 00	.21800E 00	.21100E 00	.20500E 00
.10000E 00	.26000E 00	.24900E 00	.23600E 00	.22400E 00	.21800E 00	.21100E 00	.20500E 00
.20000E 00	.26000E 00	.24900E 00	.23600E 00	.22400E 00	.21800E 00	.21100E 00	.20500E 00
.30000E 00	.26000E 00	.24900E 00	.22900E 00	.20900E 00	.20300E 00	.20000E 00	.19600E 00
.35000E 00	.26000E 00	.24900E 00	.20700E 00	.19000E 00	.18500E 00	.18000E 00	.17500E 00
.40000E 00	.26000E 00	.23900E 00	.18800E 00	.17100E 00	.16600E 00	.16100E 00	.15600E 00
.45000E 00	.26000E 00	.20900E 00	.17100E 00	.15400E 00	.14800E 00	.14200E 00	.13700E 00
.50000E 00	.25000E 00	.18800E 00	.15400E 00	.13800E 00	.13100E 00	.12600E 00	.12100E 00
.55000E 00	.22300E 00	.16700E 00	.13700E 00	.12200E 00	.11500E 00	.11000E 00	.10500E 00
.60000E 00	.19700E 00	.14700E 00	.12000E 00	.10600E 00	.10000E 00	.94900E-01	.90100E-01
.70000E 00	.14700E 00	.10800E 00	.87700E-01	.76200E-01	.70800E-01	.66000E-01	.61500E-01
.80000E 00	.96400E-01	.70100E-01	.56100E-01	.47700E-01	.44100E-01	.40600E-01	.37600E-01
.90000E 00	.47600E-01	.33800E-01	.25000E-01	.21700E-01	.19800E-01	.18300E-01	.16300E-01
.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

a

ne Component Characteristics (Continued)

$$\frac{WT\cdot TB}{N\cdot PB} = f\left[\frac{PT}{PB},\ \frac{N}{\sqrt{TB}}\right]$$

.30000E 03	.32000E 03	.34000E 03	.36000E 03	.38000E 03	.40000E 03	.42000E 03	.44000E 03
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.71900E-01	.67300E-01	.63200E-01	.59600E-01	.56300E-01	.53300E-01	.50700E-01	.48400E-01
.71500E-01	.67000E-01	.63000E-01	.59300E-01	.56000E-01	.53100E-01	.50500E-01	.48100E-01
.70800E-01	.66300E-01	.62300E-01	.58700E-01	.55400E-01	.52400E-01	.49700E-01	.47300E-01
.69700E-01	.65100E-01	.61200E-01	.57600E-01	.54500E-01	.51600E-01	.49000E-01	.46500E-01
.68300E-01	.63900E-01	.60000E-01	.56600E-01	.53500E-01	.50700E-01	.47900E-01	.45200E-01
.66400E-01	.62200E-01	.58500E-01	.55200E-01	.52000E-01	.48900E-01	.45600E-01	.42400E-01
.58000E-01	.53700E-01	.50100E-01	.46600E-01	.43800E-01	.40800E-01	.38200E-01	.36100E-01
.41000E-01	.37700E-01	.34[illegible]E-01	.33100E-01	.3[illegible]100E-01	.31000E-01	.30200E-01	.29600E-01
.21300E-01	.19000E-01	.18[illegible]E-01	.17400E-01	.17000E-01	.16600E-01	.16200E-01	.15800E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

$$\frac{\Delta HT}{N\sqrt{TB}} = f\left[\frac{PT}{PB},\ \frac{N}{\sqrt{TB}}\right]$$

.30000E 03	.32000E 03	.34000E 03	.36000E 03	.38000E 03	.40000E 03	.42000E 03	.44000E 03
.20500E 00	.19800E 00	.19000E 00	.18300E 00	.17600E 00	.16800E 00	.16100E 00	.15300E 00
.20500E 00	.19800E 00	.19000E 00	.18300E 00	.17600E 00	.16800E 00	.16100E 00	.15300E 00
.20500E 00	.19800E 00	.19000E 00	.18300E 00	.17600E 00	.16800E 00	.16100E 00	.15300E 00
.19600E 00	.19100E 00	.18400E 00	.17500E 00	.16700E 00	.16000E 00	.15300E 00	.14600E 00
.17500E 00	.17000E 00	.16400E 00	.15600E 00	.14900E 00	.14200E 00	.13600E 00	.12900E 00
.15600E 00	.15100E 00	.14500E 00	.13800E 00	.13200E 00	.12600E 00	.12000E 00	.11300E 00
.13700E 00	.13300E 00	.12700E 00	.12100E 00	.11600E 00	.11000E 00	.10300E 00	.95500E-01
.12100E 00	.11600E 00	.11100E 00	.10500E 00	.99600E-01	.93000E-01	.85700E-01	.78200E-01
.10500E 00	.10000E 00	.95300E-01	.90200E-01	.84100E-01	.76800E-01	.68800E-01	.62800E-01
.90100E-01	.85600E-01	.81000E-01	.76000E-01	.69400E-01	.61800E-01	.54600E-01	.49800E-01
.61500E-01	.57000E-01	.55500E-01	.51300E-01	.43800E-01	.39200E-01	.35100E-01	.31800E-01
.37600E-01	.34700E-01	.32000E-01	.29600E-01	.25200E-01	.21700E-01	.18300E-01	.16300E-01
.16300E-01	.14700E-01	.13200E-01	.12000E-01	.10100E-01	.82000E-02	.60000E-02	.48000E-02
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

b

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Table A-3. Engine Component Characteristics (Concluded)

FUNCTION F5: $\psi_2^T = f\,[\phi_2, \text{IGV}]$

ψ_2 \ IGV	.00000E 00	.50000E 00	.75000E 00	.10000E 01
.00000E 00	.84000E 01	.60000E 01	.56000E 01	.52000E 01
.45000E 00	.11520E 01	.11770E 01	.11320E 01	.10800E 01
.47500E 00	.11250E 01	.11550E 01	.11130E 01	.10630E 01
.50000E 00	.11[illegible]E 01	.11300E 01	.10950E 01	.10470E 01
.52500E 00	.10950E 01	.11100E 01	.10720E 01	.10260E 01
.55000E 00	.10850E 01	.10730E 01	.10380E 01	.9[illegible]600E 00
.57500E 00	.10720E 01	.10390E 01	.10000E 01	.96700E 00
.60000E 00	.10580E 01	.99500E 00	.96500E 00	.92500E 00
.62500E 00	.10380E 01	.94800E 00	.92500E 00	.88200E 00
.65000E 00	.10170E 01	.89300E 00	.88400E 00	.83900E 00
.67500E 00	.99100E 00	.83800E 00	.83800E 00	.79200E 00
.70000E 00	.96500E 00	.75800E 00	.75800E 00	.73700E 00
.72500E 00	.93400E 00	.69500E 00	.[illegible]00E 00	.67700E 00
.75000E 00	.87500E 00	.58000E 00	.58000E 00	.58000E 00
.77500E 00	.72500E 00	.42600E 00	.42500E 00	.42600E 00
.79000E 00	.55100E 00	.36550E 00	.36550E 00	.36550E 00
.80500E 00	.48000E-01	.48000E-01	.48000E-01	.48000E-01

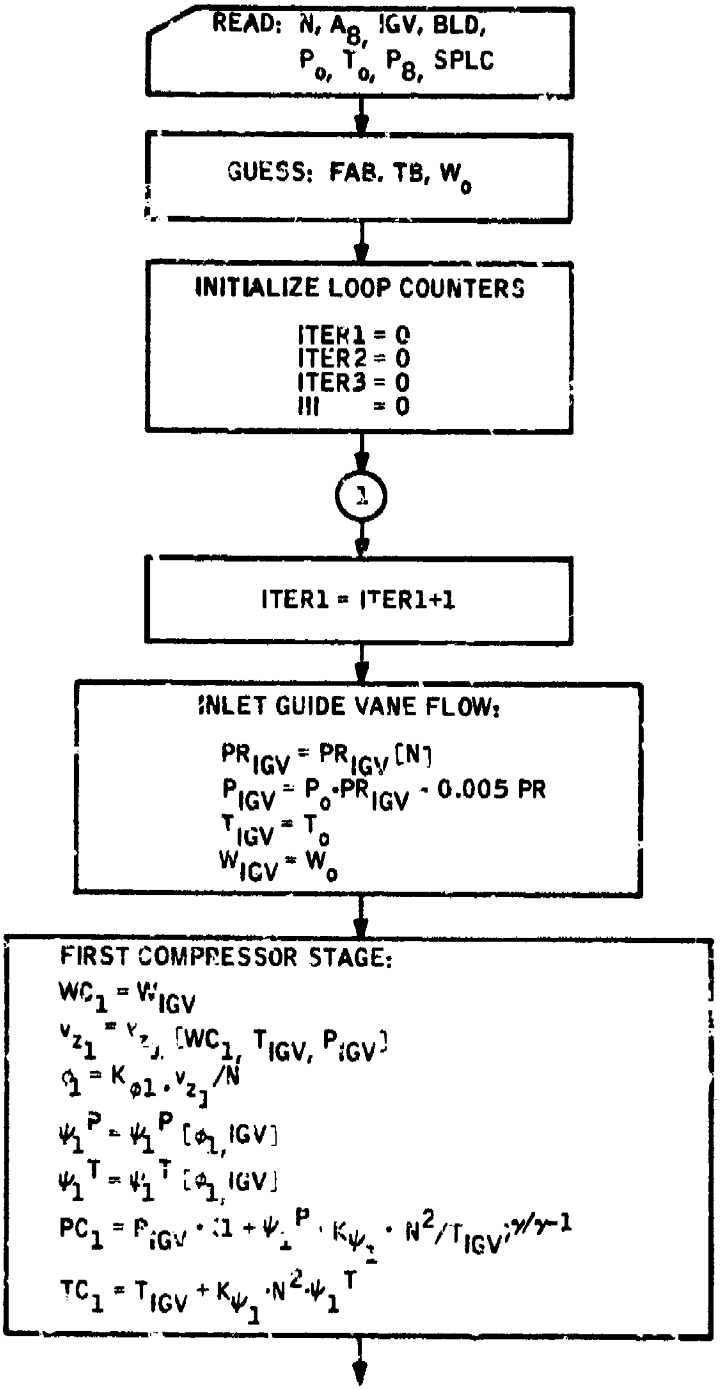
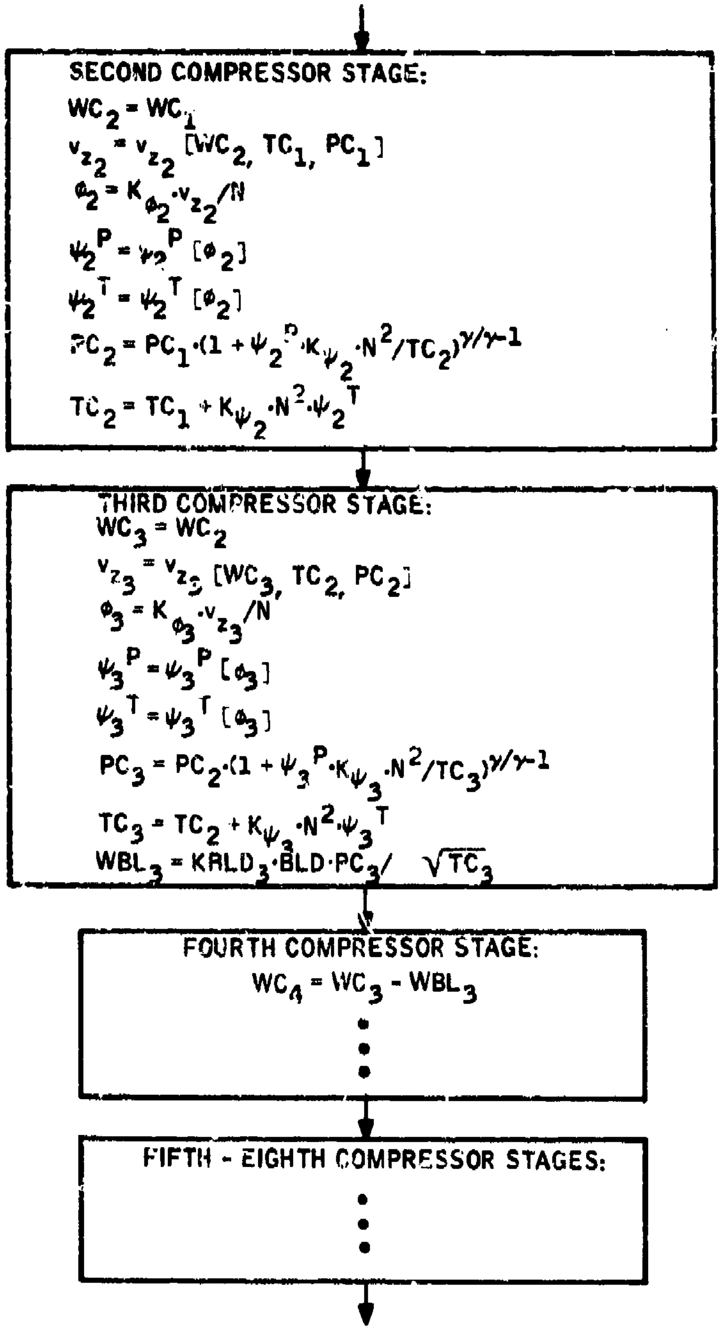


Figure A-1. Trim Routine Flow Chart (Steady-State Trim)



SECOND COMPRESSOR STAGE:

$WC_2 = WC_1$

$v_{z_2} = v_{z_2}[WC_2, TC_1, PC_1]$

$\phi_2 = K_{\phi_2} \cdot v_{z_2}/N$

$\psi_2{}^P = \psi_2{}^P[\phi_2]$

$\psi_2{}^T = \psi_2{}^T[\phi_2]$

$PC_2 = PC_1 \cdot (1 + \psi_2{}^P \cdot K_{\psi_2} \cdot N^2/TC_2)^{\gamma/\gamma-1}$

$TC_2 = TC_1 + K_{\psi_2} \cdot N^2 \cdot \psi_2{}^T$

THIRD COMPRESSOR STAGE:

$WC_3 = WC_2$

$v_{z_3} = v_{z_3}[WC_3, TC_2, PC_2]$

$\phi_3 = K_{\phi_3} \cdot v_{z_3}/N$

$\psi_3{}^P = \psi_3{}^P[\phi_3]$

$\psi_3{}^T = \psi_3{}^T[\phi_3]$

$PC_3 = PC_2 \cdot (1 + \psi_3{}^P \cdot K_{\psi_3} \cdot N^2/TC_3)^{\gamma/\gamma-1}$

$TC_3 = TC_2 + K_{\psi_3} \cdot N^2 \cdot \psi_3{}^T$

$WBL_3 = KBLD_3 \cdot BLD \cdot PC_3 / \sqrt{TC_3}$

FOURTH COMPRESSOR STAGE:

$WC_4 = WC_3 - WBL_3$

•
•
•

FIFTH - EIGHTH COMPRESSOR STAGES:

•
•
•

Figure A-1b. Trim Routine Flow Chart (Steady-State Trim)

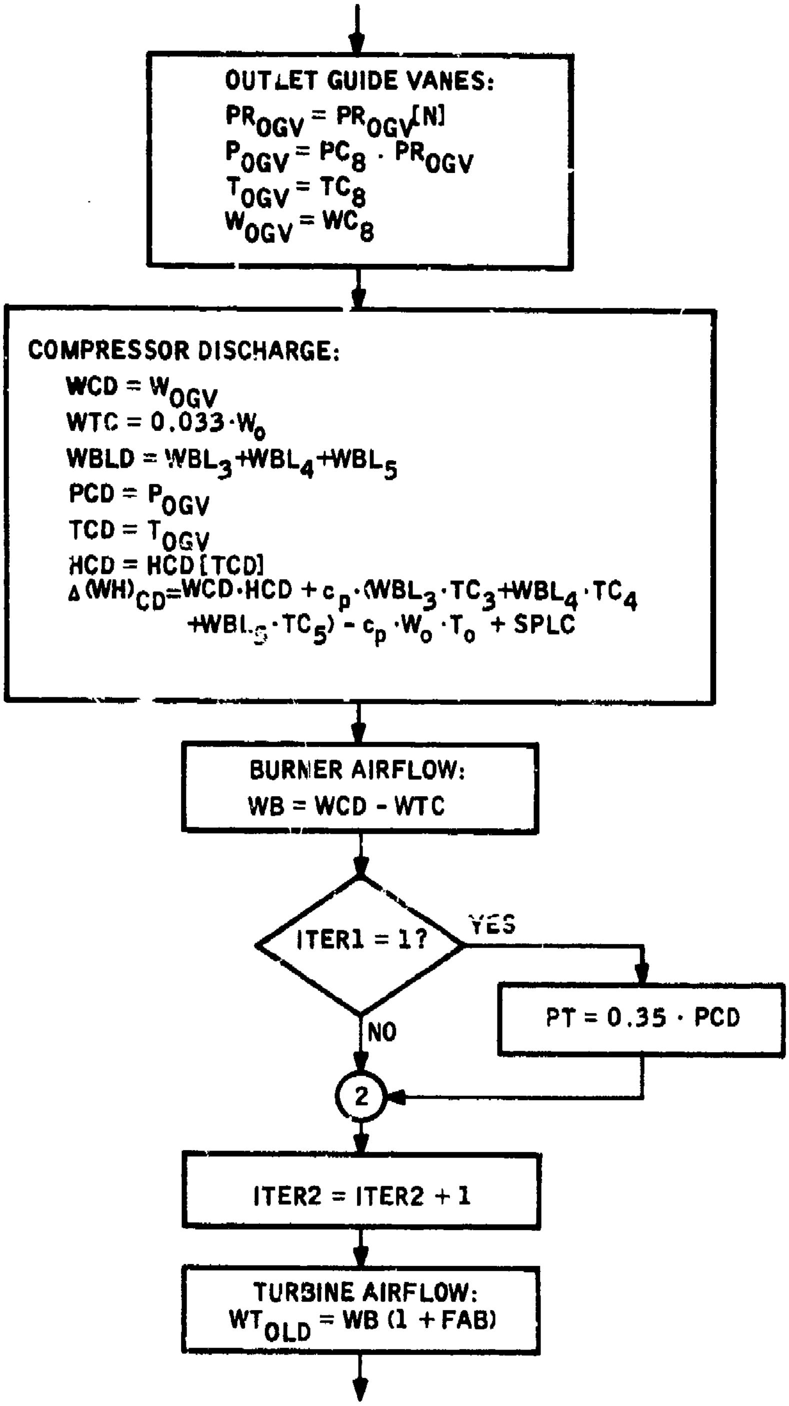


Figure A-1c. Trim Routine Flow Chart (Steady-State Trim)

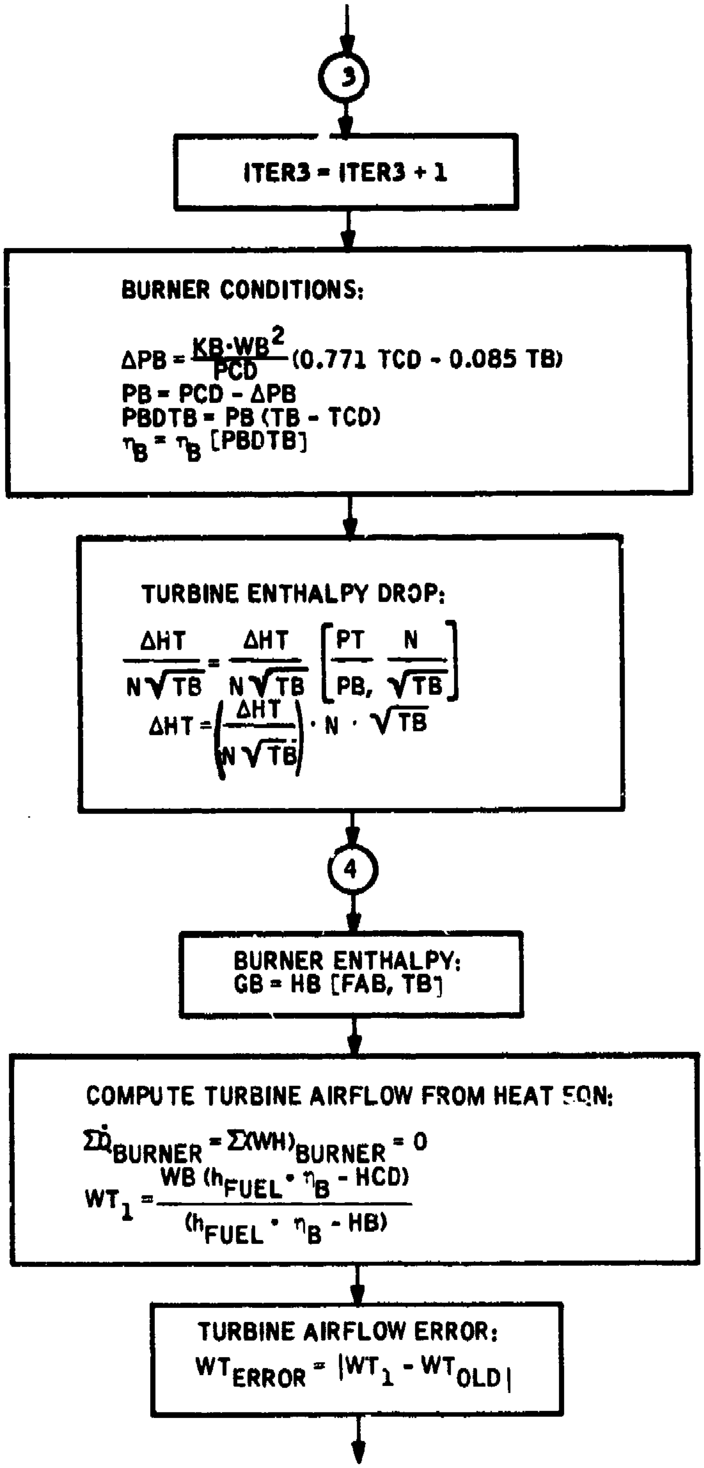


Figure A-1d. Trim Routine Flow Chart (Steady-State Trim)

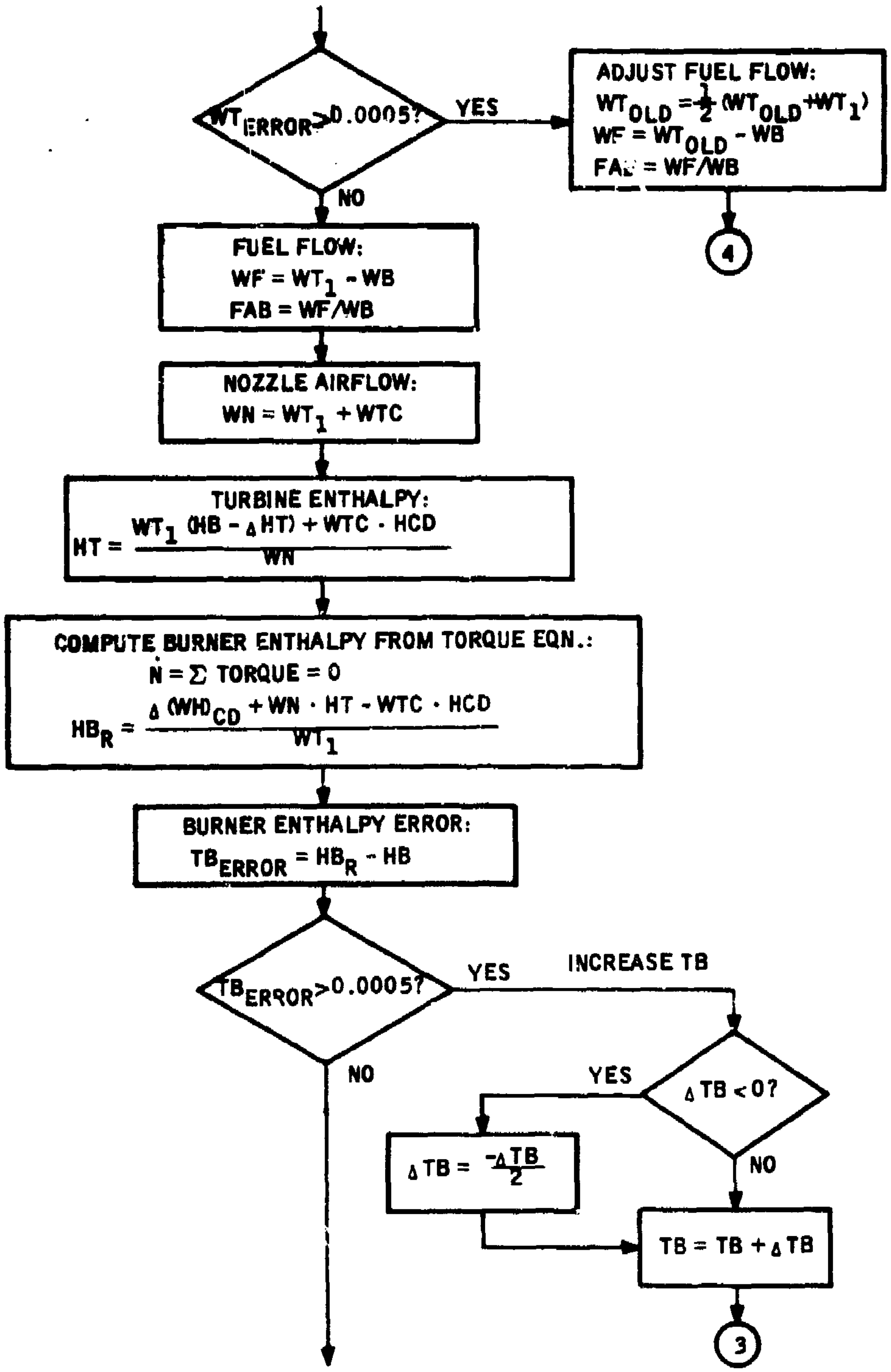


Figure A-1e. Trim Routine Flow Chart (Steady-State Trim)

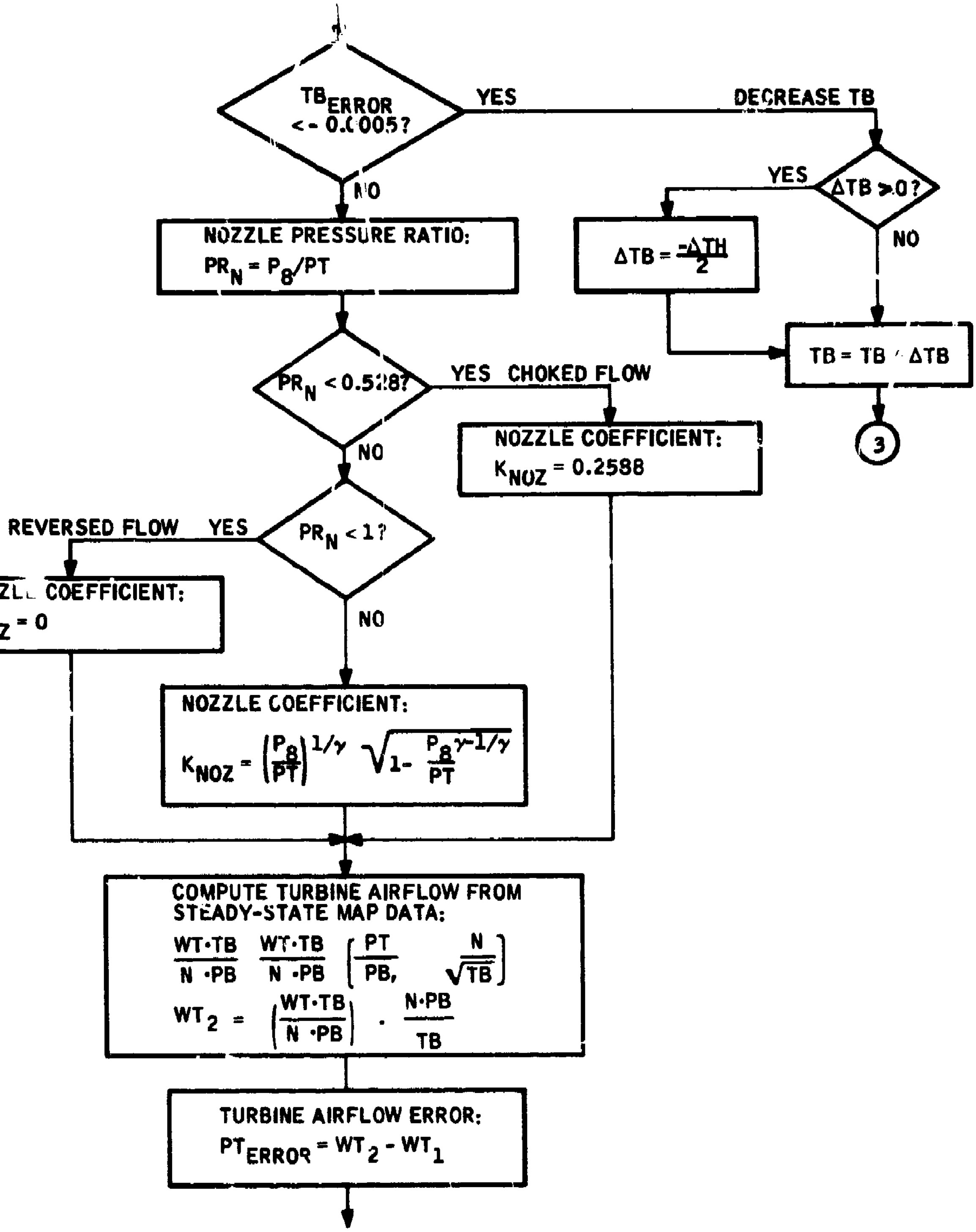


Figure A-1f. Trim Routine Flow Chart (Steady-State Trim)

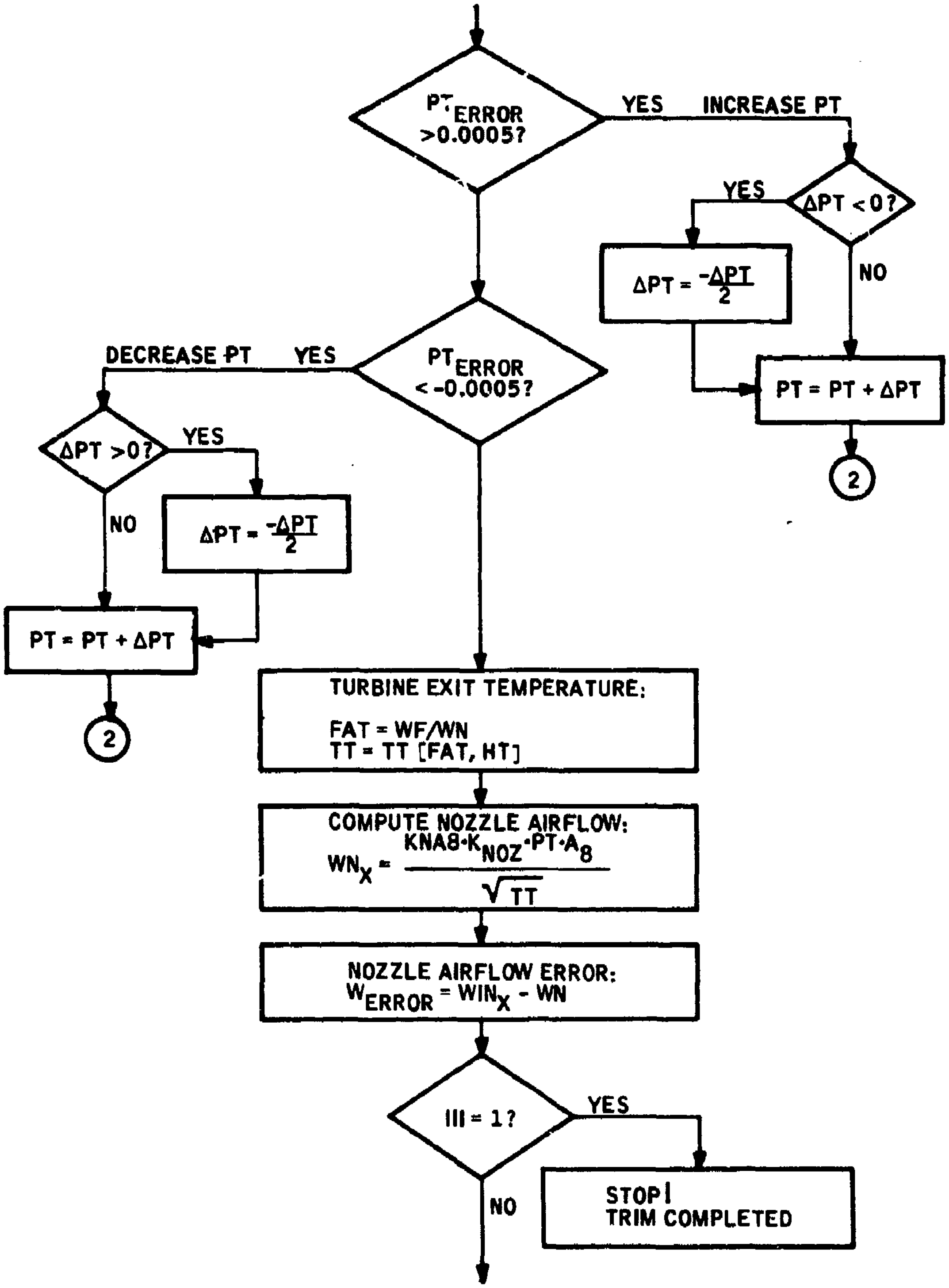


Figure A-1g. Trim Routine Flow Chart (Steady-State Trim)

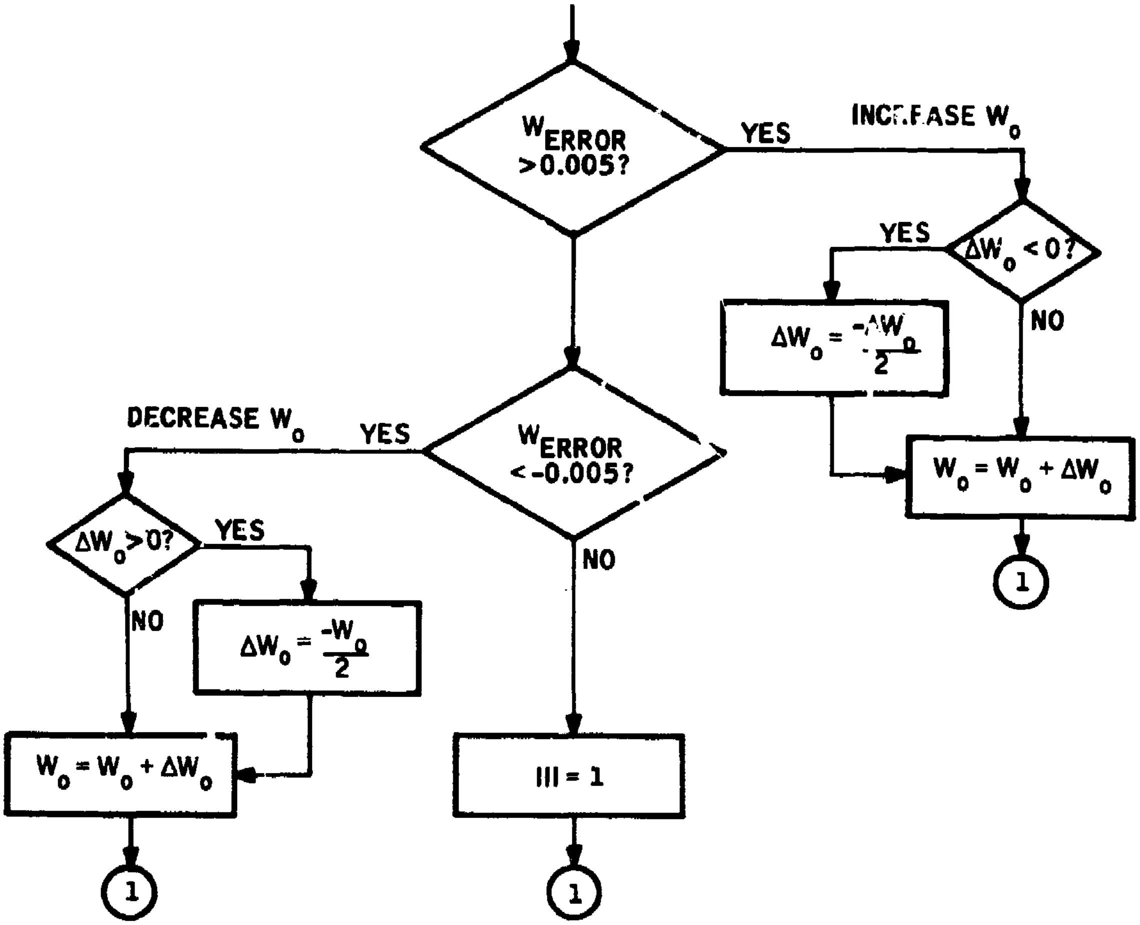


Figure A-1h. Trim Routine Flow Chart (Steady-State Trim)

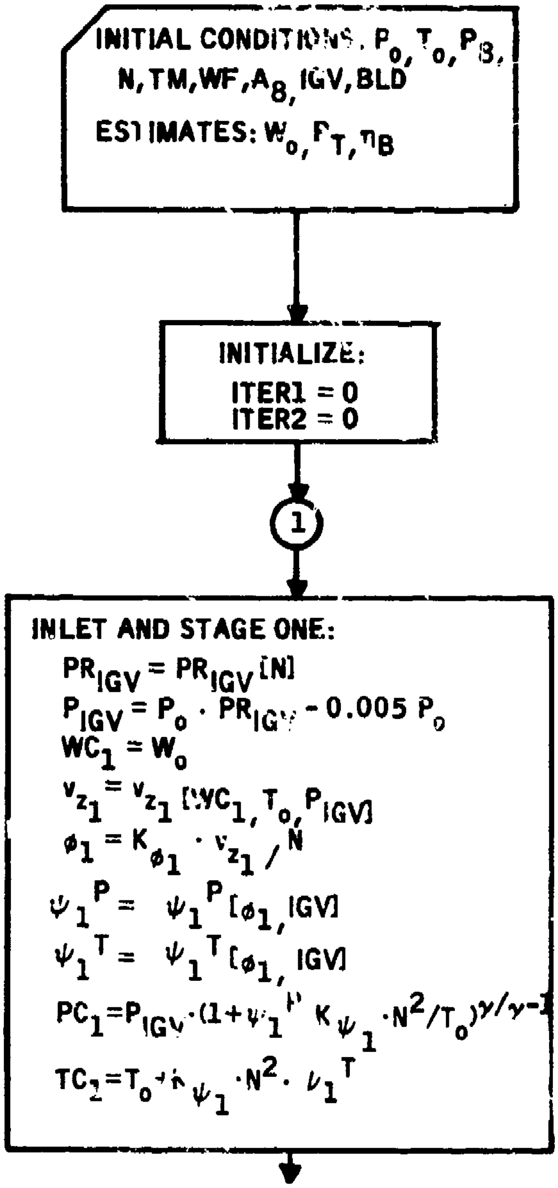


Figure A-2. Subroutine Dynamic Flow Chart

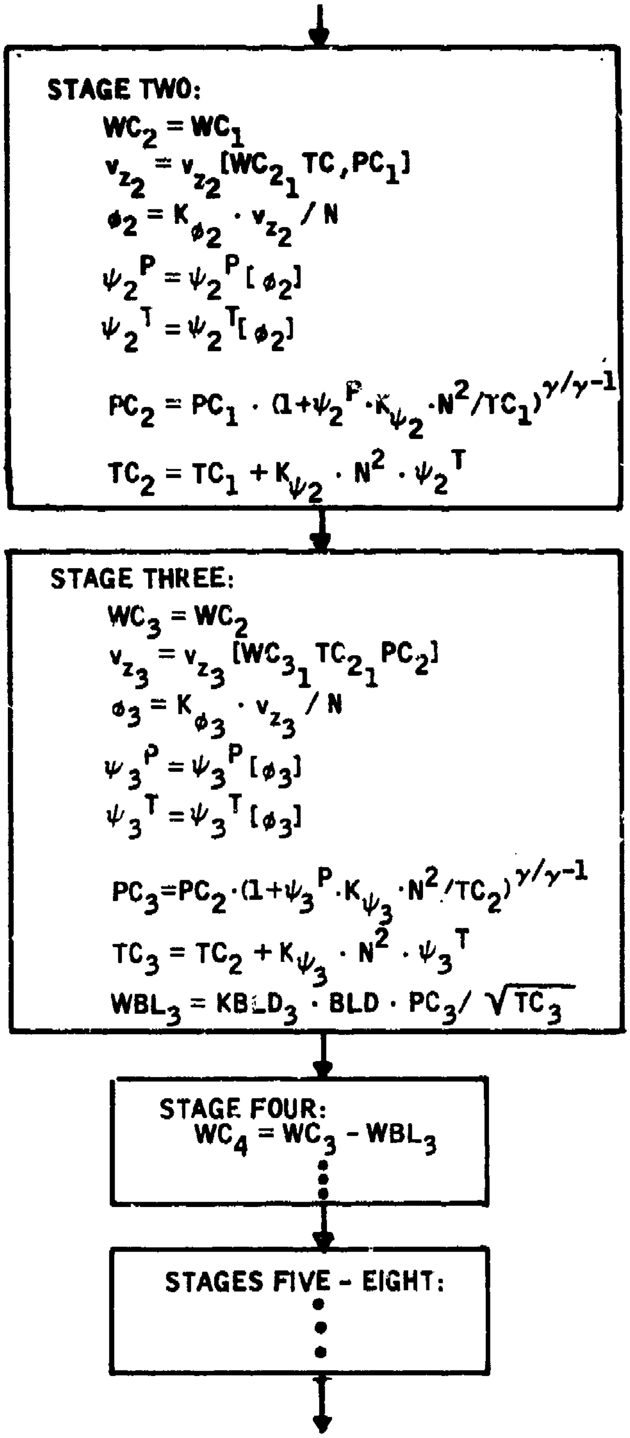


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

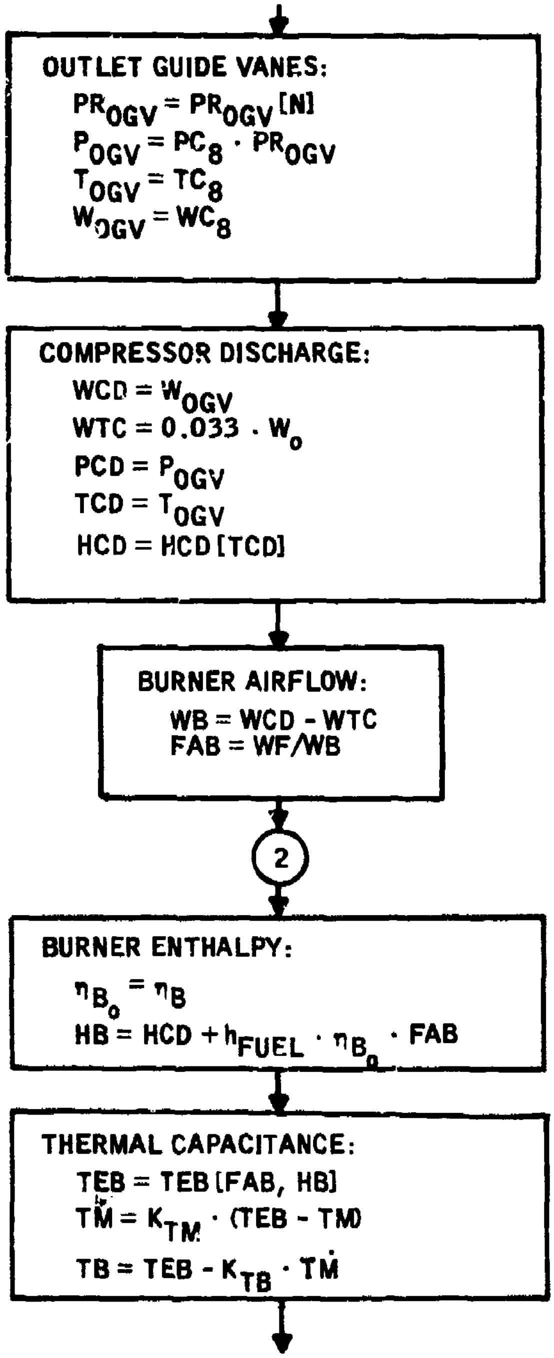


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

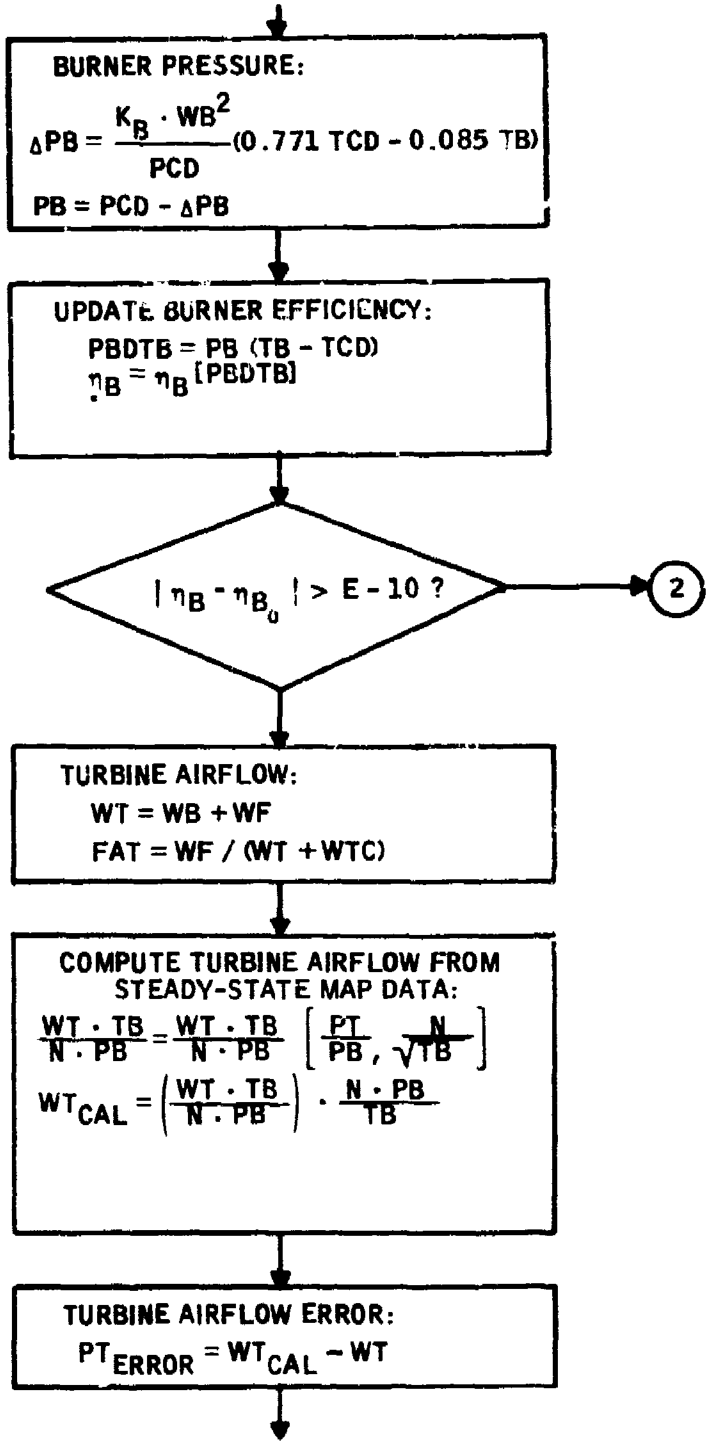


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

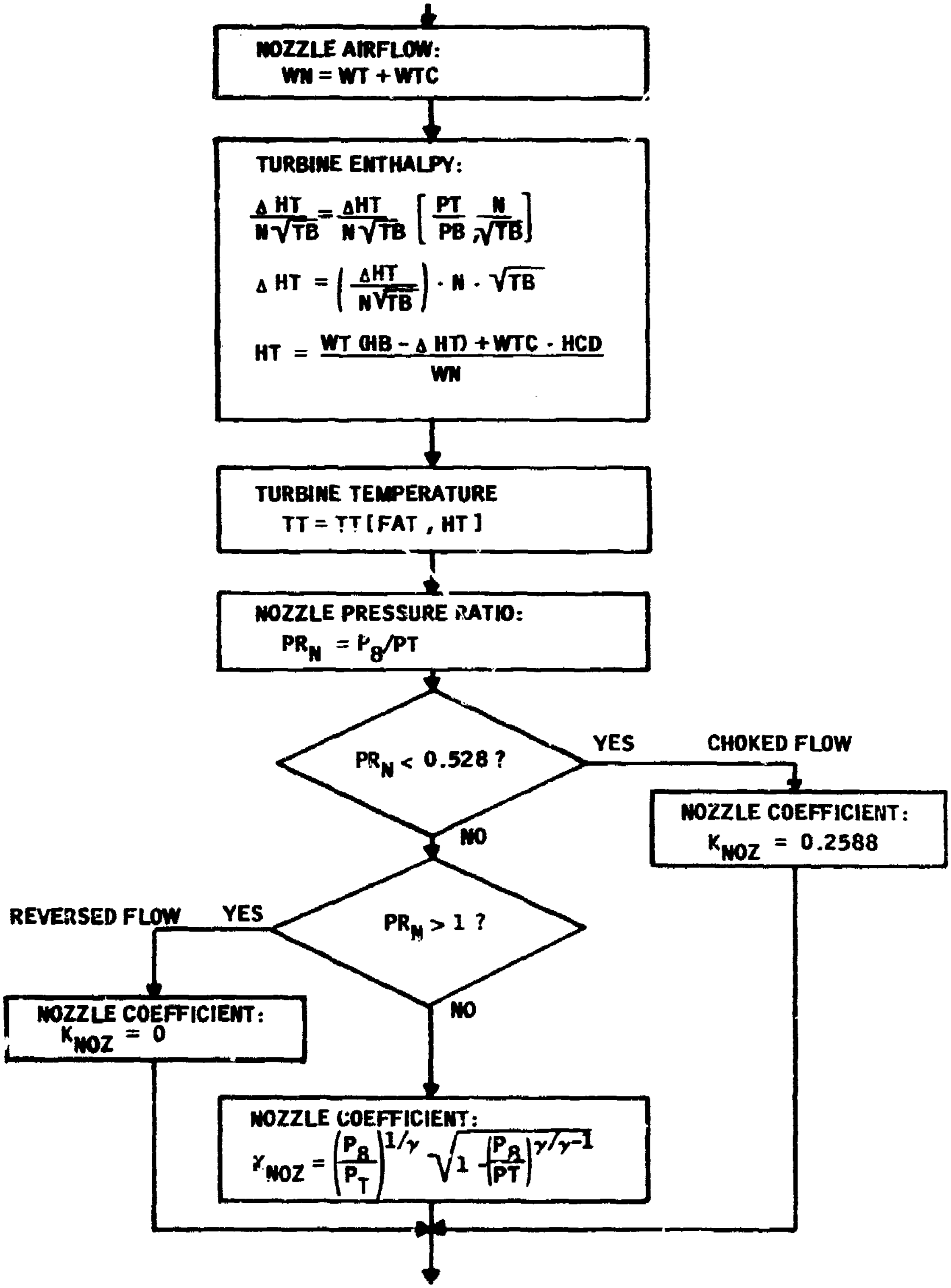


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

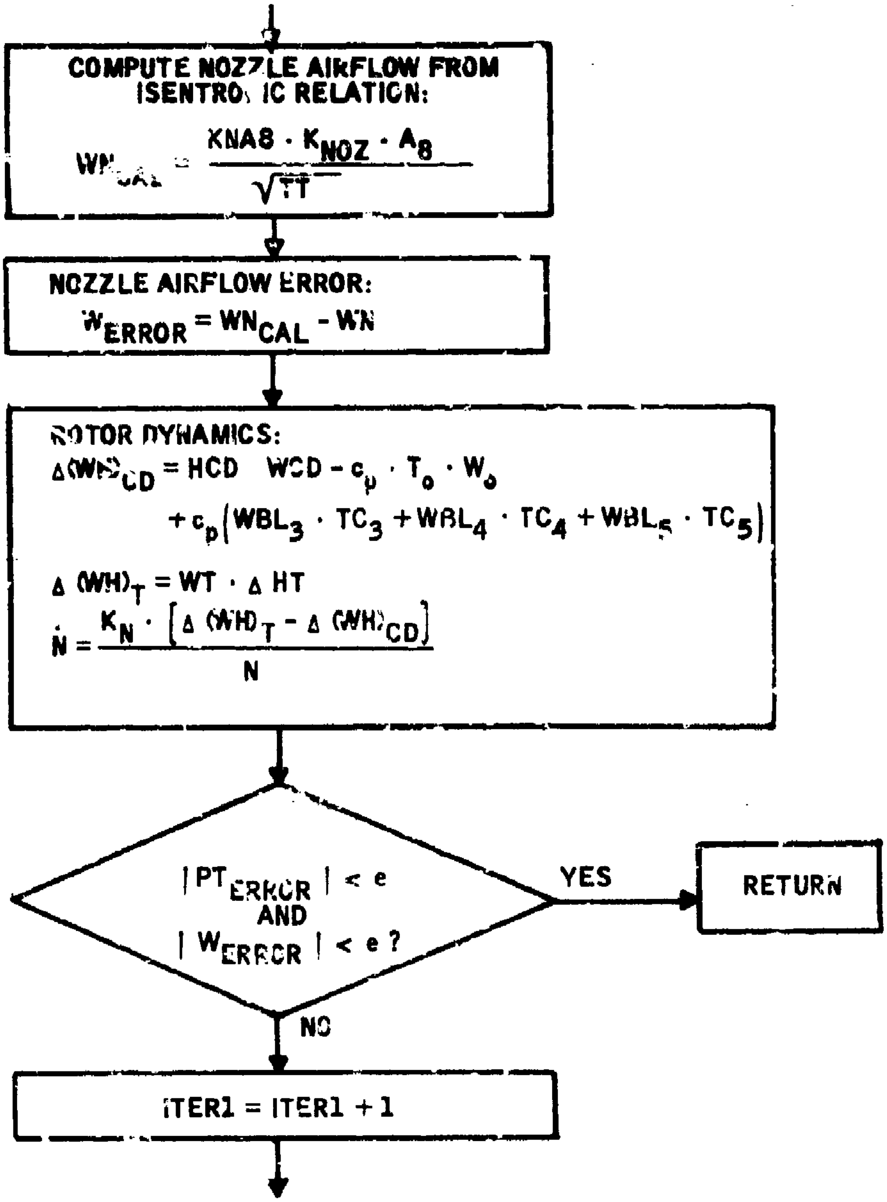


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

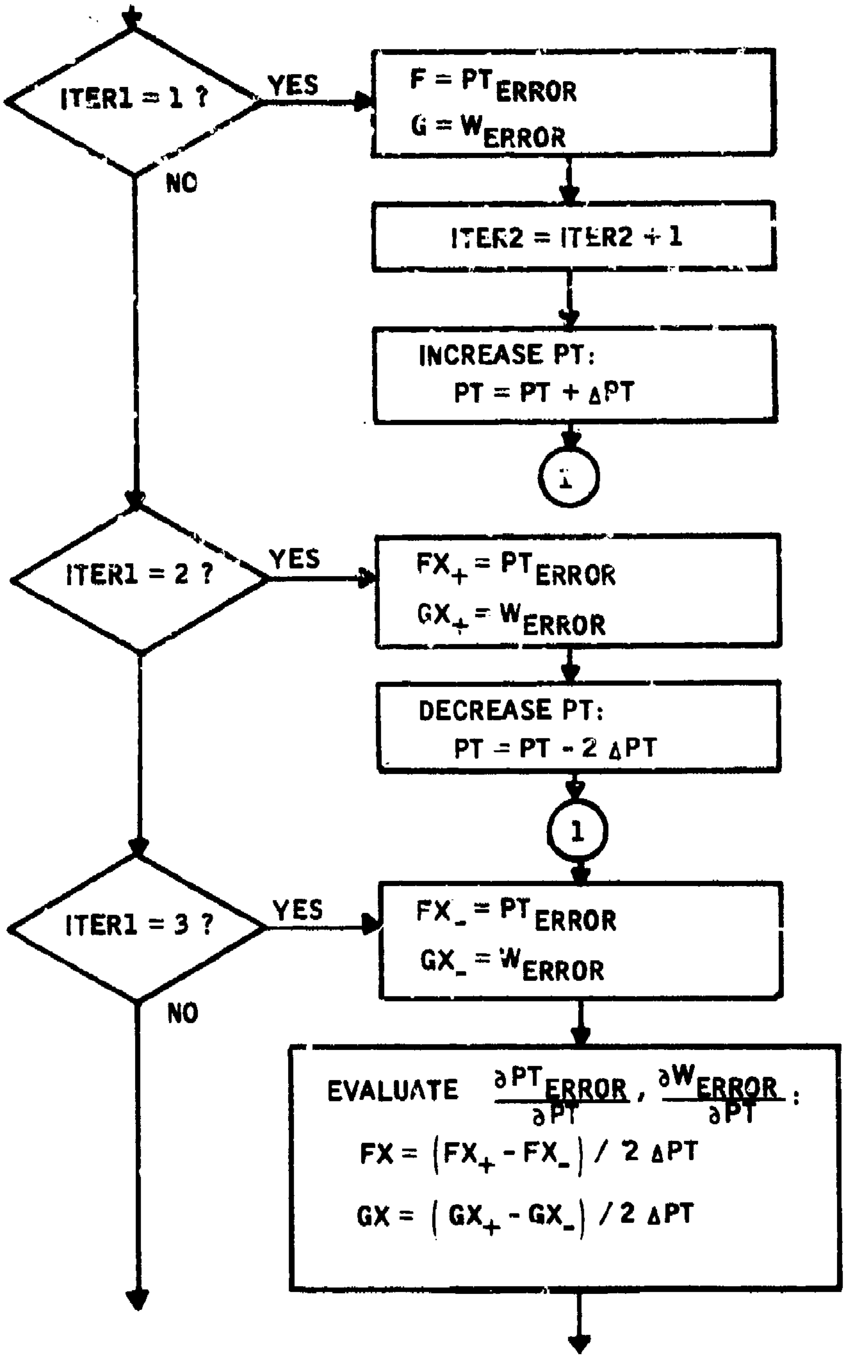


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

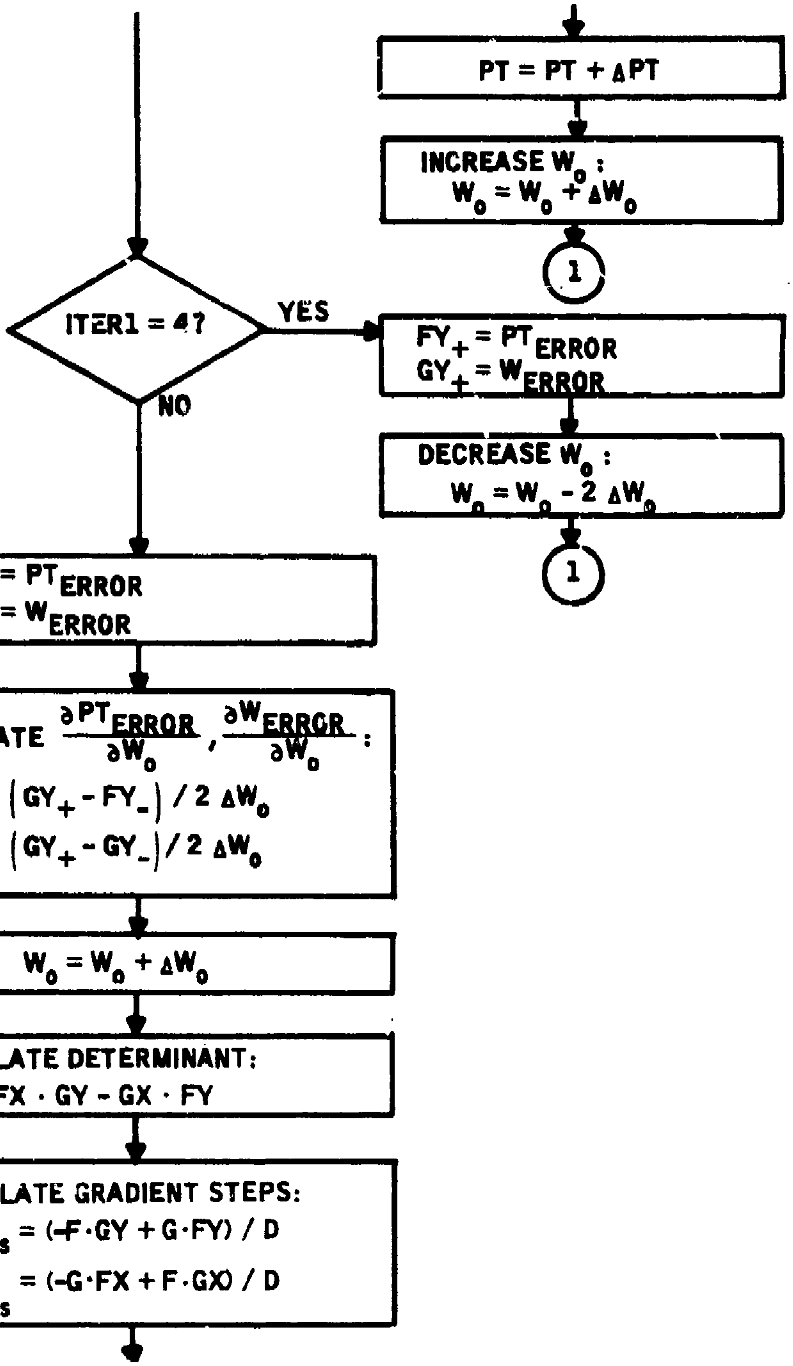


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

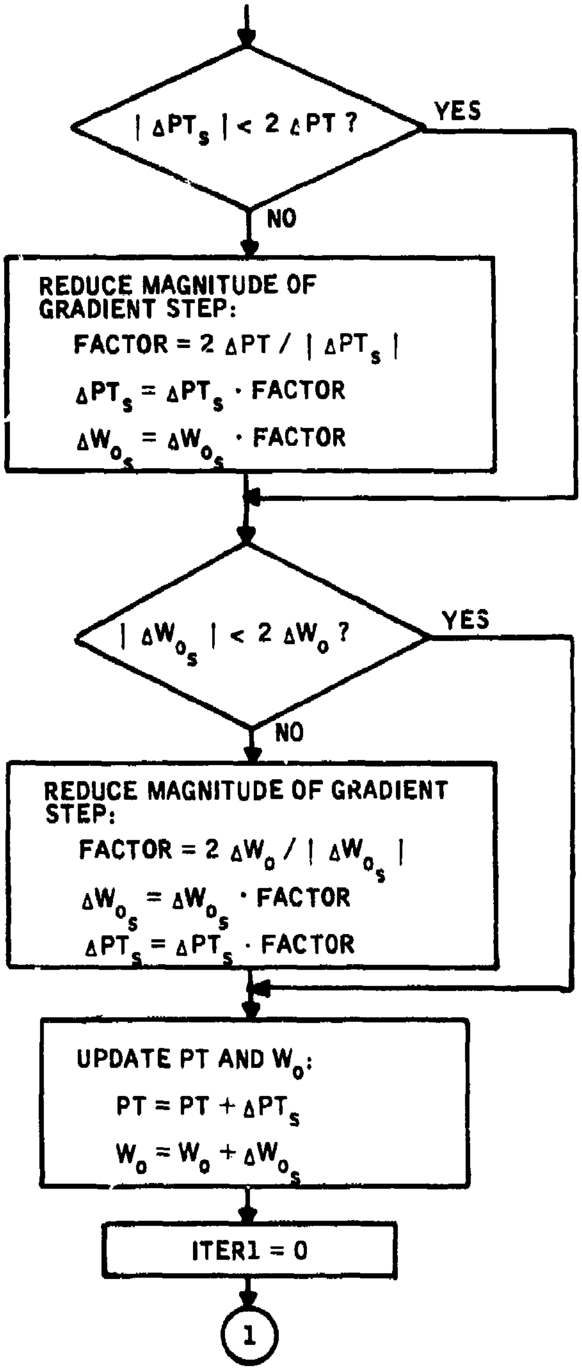


Figure A-2. Subroutine Dynamic Flow Chart (Concluded)

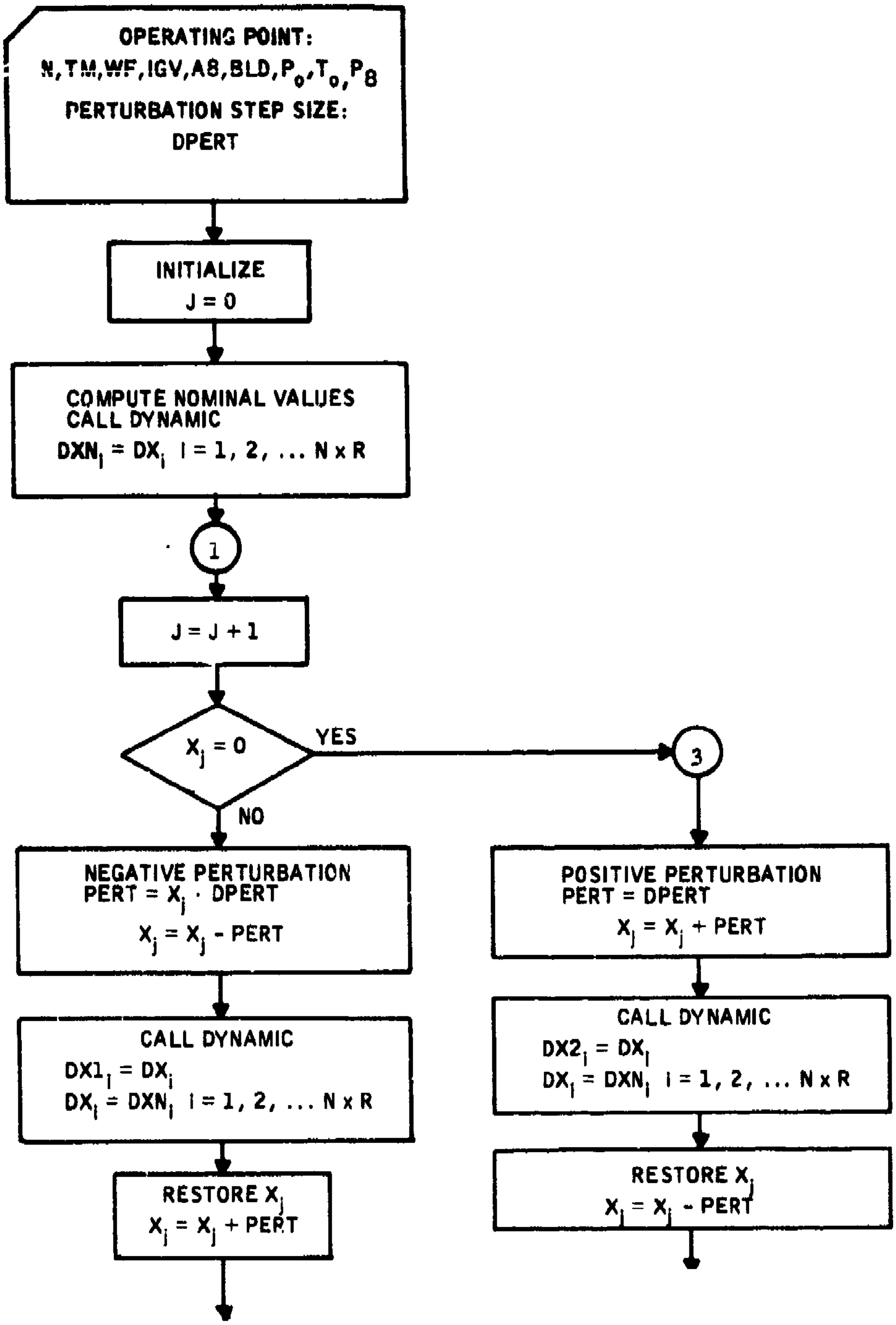


Figure A-3. Linearization Flow Chart

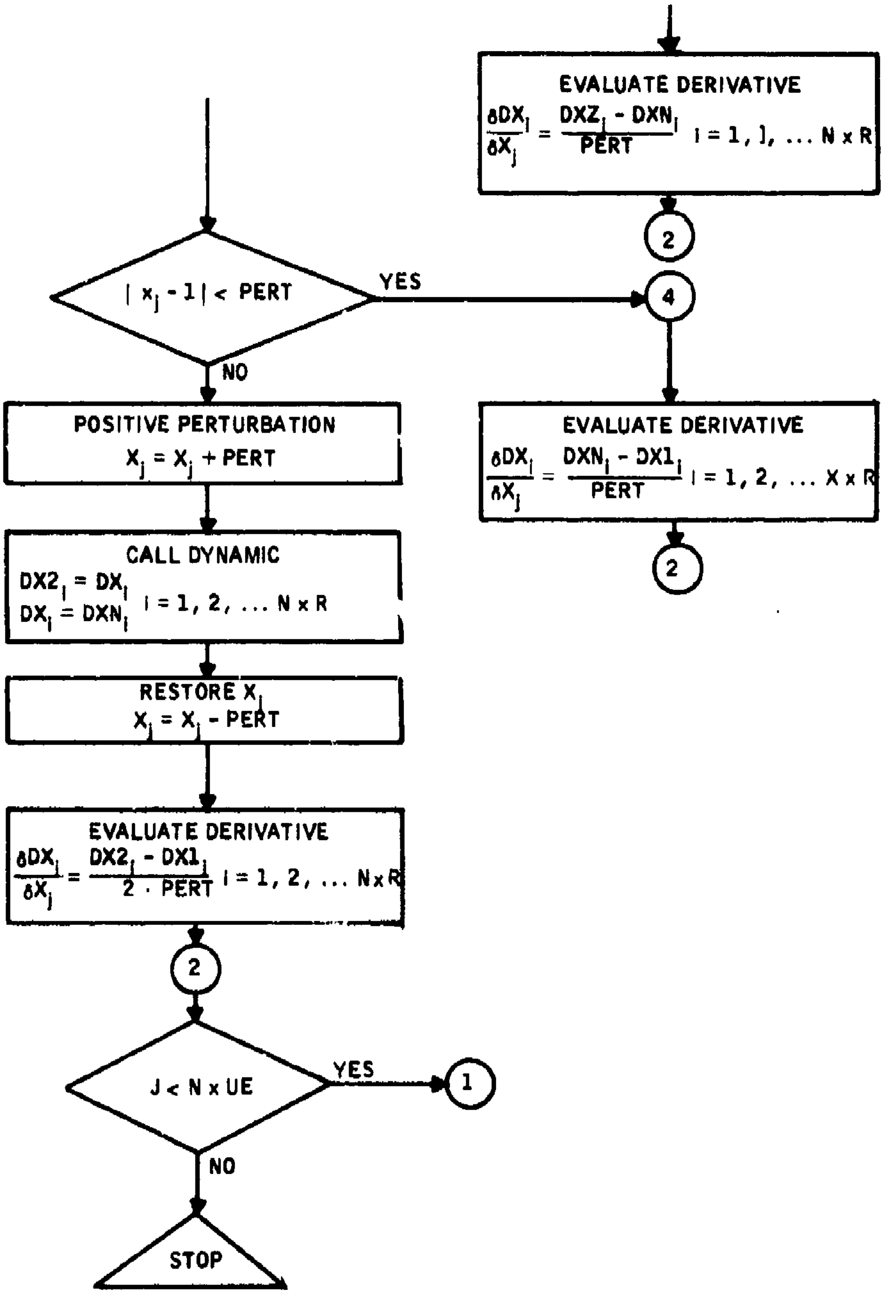


Figure A-3. Linearization Flow Chart (Concluded)

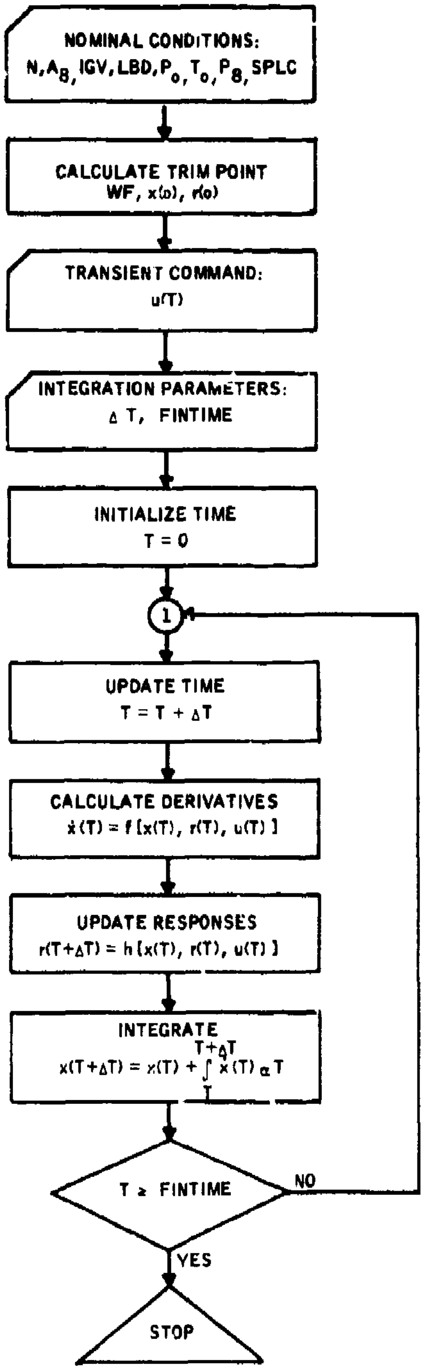


Figure A-4. Nonlinear Engine Simulation Flow Chart

REFERENCES

A-1. Seldner, Kurt, Mihalow, James R., and Blaha, Ronald J., "Generalized Simulation Technique for Turbojet Engine System Analysis," NASA TN D-6610, Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio, February 1972.

A-2. Hsu, Jay C. and Meyer, Andrew V., Modern Control Principles and Applications, McGraw-Hill Book Company, New York, 1960.

APPENDIX B

CONTROLLER SOFTWARE FOR THE APL WIND TUNNEL TEST FACILITY

Software for the optimal command controller synthesized in Section IV (Volume I) is presented. The software is for the IBM 1800 computer at APL. This software inserts the Honeywell optimal controller within the Bendix Bounds program (Reference B-1). The reader is assumed to be familiar with the IBM 1800 (Reference B-2) and with the Bendix Bounds program.

This appendix is divided into three major parts:

- Controller data
- Equilibrium-pressure software
- Equilibrium-temperature software

In the first part of this Appendix, controller data for deceleration-equilibrium-pressure-temperature modes are combined. This system will provide precise speed control and rapid spool speed responses without surge-stall, excessive temperatures, or flameouts. This is close to a control system that we recommend. The adjective close would be deleted by applying standard correction procedures to permit operation at other than the sea level standard design condition.

For expediency, in testing in the APL wind tunnel, the system was divided into two parts:

- Deceleration-equilibrium-pressure
- Deceleration-equilibrium-temperature

The first part does not explicitly provide over-temperature protection while the second does not explicitly provide surge-stall protection. Protection is obtained, however, by setting the pressure limit low enough to prevent over-temperature and the temperature limit low enough to prevent surge-stall.

CONTROLLER DATA

The inlet guide vanes (IGV), bleed (BLD), and exhaust actuator (A8) are operated on open-loop schedules (for reasons discussed in Section IV). Closed-loop control is used on the fuel valve.

For control synthesis the IGV and BLD were set on the G.E. schedule. As Bendix employs the same schedule in the Bounds program, the Bounds schedule for IGV and BLD are used with the Honeywell controllers.

The A8 schedule is the same as that used on a previous Honeywell contract to APL; it is not the bill of materials schedule.

Table B-1 summarizes the open-loop schedules for IGV, BLD, and A8.

Fuel valve command data are presented in Tables B-2 through B-5. Table B-2 presents the generic form for the complete control law.

For deceleration-equilibrium-pressure control ut is deleted from u2 in Equation (3) of Table B-2. For deceleration-equilibrium-temperature control, up is deleted from u2. Feedback gains, open-loop fuel flows, and "equilibrium" data are presented in Tables B-3, B-4, and B-5, respectively.

The equations and data of Tables B-2 through B-5 could have been programmed; a simplification is made before programming. The simplification permits either variable limits (ENL, EPL, or ETL) to be achieved by constants or variable integration parameters to be made constant. For example, in the $E\dot{P}$ equation (Table B-2) the parameter PC is variable. It can be made constant without changing the resulting control. This is demonstrated by Table B-6. The generic form of the modified state equations and controllers is presented above the dashed line. The integration parameter (d) can be made to take an arbitrary non-zero value by dividing d by μ and by multiplying the integral gain λ by μ; this is shown by the equations below the dashed line.

EQUILIBRIUM-PRESSURE SOFTWARE

Flow charts are presented in Figures B-1 through B-11. Table B-7 contains a glossary of terms. The program is presented in Table B-8.

The main computational blocks of the speed and pressure control program are shown in Figure B-1. A detailed flow chart for each block is subsequently presented.

Initialization

In this section of the program (Figure B-2), all of the gains and open-loop information (i.e., fuels and pressures as a function of speed) are transferred from variable-trim locations. (The variable-trim locations are the sole means of communication between the Honeywell control program and the Bendix Bounds program to the proper locations in the control program.) The labels associated with the variable-trim locations have the prefix VT followed by three digits. There are 254 VT locations. The contents of the first 70 variable-trim locations VT001 - VT070 can be monitored and manually changed from the Bendix interface console. Nominal values of these variables are stored in the Bendix Bounds program in the standard trim locations ST001 - ST070. The section of the Bounds program in which ST001 - ST070 are defined is presented in Table B-9. The contents of locations VT071 - VT254 can only be monitored from console. VT039 acts as a logical switch for the initialization section of the program. If VT039 = 16 this portion of the program will be executed and VT039 will be set to zero. If VT039 $\neq$ 16 the initialization section will be bypassed. Since all the VT numbers encountered in this portion of the program are in the range VT001 - VT070, they can all be manually changed from Bendix interface console.

Interpolation Interval Determination

The gains (associated with the feedback quantities) and the open-loop information (fuel and pressure values) for both the speed controller and the pressure controller are given at four values of speed. To obtain values for the gains and open-loop information over the whole speed regime linear interpolation is used (Figure B-3). Since the quantities to be interpolated are given at four values of speed N, there are three possible intervals of interpolation. The four values of speed are N_1 = 8250 rpm, N_2 = 11,550 rpm, N_3 = 14,025 rpm, and N_4 = 16,500 rpm. Thus, the three intervals are $[N_1, N_2]$, $[N_2, N_3]$, $[N_3, N_4]$. The sensed speed N (in the program sensed speed is VT157) is tested to determine into which interval it falls. Then any quantity, call it f, given at the four values of N can be written as a linear function of N as follows:

$$f(N) = f(N_i)\, C_1 + f(N_{i+1})\, C_2 \qquad \text{(B-1)}$$

where

$$C_1 = \frac{(N_{i+1} - N)}{(N_{i+1} - N_i)} \quad \text{and} \quad C_2 = \frac{(N - N_i)}{(N_{i+1} - N_i)} \quad \text{for } i = 1, 2, 3.$$

The interval and the quantities C_1 and C_2 are calculated in this portion of the program.

Exits from this section of the program are given the labels IN1F, IN2F or IN3F, depending on whether the sensed speed N satisfies $N_1 \le N \le N_2$, $N_2 \le N \le N_3$, or $N_3 \le N \le N_4$.

Interpolation Logic

The three sections in this portion of the program (Figure B-4) all evaluate an equation like Equation (B-1). Therefore, the logic in each section is the same. The difference is in the label used for $f(N_i)$ and $f(N_{i+1})$. The different labels represent the initial address in a sequence of addresses of quantities associated with the same speed. In each case the label is influenced by index register one (XR1). Initially (XR1) is set to zero and an equation similar to (B-1) is evaluated in double precision. XR1 is then incremented by one and tested against label NGFT (NGFT = 18). If XR1 < NGFT the interpolation continues, if XR1 ≥ NGFT, the interpolation is done and we are transferred to label FUELM.

Interpolation Scaling

Both C_1 and C_2 are numbers such that $0 \le C_1, C_2 \le 1$ and $C_1 + C_2 = 1$. In the IBM 1800, fractional numbers cannot be represented except as the ratio of two integer numbers. Therefore, the computation of C_1 and C_2 has to be scaled. The scale factor used in the program is $2^7 = 128$. The scale factor of 2^7 is removed after the interpolation by a shift right seven.

Integral Speed and Integral Pressure

The integral speed and integral pressure portion of the program (Figure B-5) consists of logic to initialize, integrate, and limit two simple differential equations in time. The integral speed differential equation is

$$\dot{EN} = -5.3333\,(N - N_{PLA}) \tag{B-2}$$

where EN is the integral of the error between sensed speed N(VT157) and requested speed N_{PLA} (VT128).

The integral pressure differential equation is

$$\dot{EP} = -5.3333\,(PT3 - PT3B)\,F(N) \tag{B-3}$$

where EP is the integral of the error between sensed PT3 (VT102) and a boundary value PT3B (PT3NB) and F(N) is a function of sensed speed (i.e., the coefficient in the differential equation is not constant; c.f. Table B-6 and the related discussion).

Initialization of the Differential Equations

The initial values of EN and EP are in VT-36 and VT037, respectively. The limiting values of EN and EP are taken to be the absolute values of VT036 and VT037, respectively. The initial value and the limiting value are changed whenever VT039 contains a sixty-four (64) or a sixteen (16).

Integration of the Differential Equations

The differential equations are integrated numerically using the trapezoidal rule

$$X_{n+1} = X_n + \frac{\Delta t}{2}\,(\dot{X}_n + \dot{X}_{n-1}) \tag{B-4}$$

where Δt is 0.015 second, X_n is the current value of the integral, $\dot{X}_n$ is the current value of the derivative, and $\dot{X}_{n-1}$ is the previous value of the derivative.

Interpolation as a Function of Power Lever

Early controllers (not documented) used PT5 and PT3 as well as an open-loop fuel as a function of the power lever (Figure B-7). The speed controllers used in engine tests require only open-loop fuel as a function of power lever. The power lever position is given in terms of a speed request in rpms in VT128. The method of interpolation is the same as it was for sensed speed. However, since only three quantities are being interpolated, no index registers are used.

Fuel Request Calculation

Three fuel requests are calculated: a speed fuel request, a pressure fuel request and a minimum fuel request (Figure B-8). The minimum fuel request is calculated in the interpllation logic as a function of sensed speed and is stored in WFMNN. The speed control fuel request is calculated as the sum of an open-loop fuel scheduled as a linear function of power lever and the following feedback quantities:

- The error between sensed and requested speed
- An integral of the error between sensed and requested speed

The pressure control fuel request is calculated as the sum of an open-loop fuel scheduled as a linear function of sensed speed and the following feedback quantities:

- The error between PT5 sensed and a given PT5 scheduled as a linear function of speed
- The error between P3 sensed and a given P3 scheduled as a linear function of speed
- The integral of the error between P3 sensed and a given P3 as a linear function of speed.

Starting at label MDW6, all of the ingredients used in calculating the fuel request for the speed and pressure controllers are stored in VT162 - VT176 for checking purposes. Beginning at label MEPT, the five feedback quantities mentioned previously are calculated and stored in VT196 - VT200. The speed control fuel request starts at label FREQE and each of the products involved in the sum is stored in VT201 - VT204. Finally, the fuel request for the speed controller is stored in SUMEF and VT071. The pressure fuel request calculation starts at label FREQP and each of the products involved in the sum is stored in VT205 - VT207. The fuel request for the pressure controller is stored in SUMPF and VT072.

Mode Select Logic

In Figure B-9 the mode select logic starts at level MDSWT. The minimum between the speed fuel request VT071 and the pressure fuel request VT072 is stored in VT180. The maximum between VT180 and WFMNN (minimum fuel) is stored in VT180. At this point a mode number is stored in VT074, depending on which controller is used. The mode numbers are: 3276 for the speed controller, 6552 for the pressure controller, and 9828 for the minimum fuel request.

Fuel Request Filter Logic

The fuel request in VT180 is put through a first-order lag [30/(S+30)]. The lag is digitized using Tustin's method with the resulting difference equation

$$y_n = \left(\frac{31}{49}\right) y_{n-1} + \left(\frac{9}{49}\right) U_n + \left(\frac{9}{49}\right) U_{n-1} \qquad \text{(B-5)}$$

where y_n is the current output (i.e., filtered fuel request), y_{n-1} is the previous output, U_n is the current input (unfiltered fuel request) and U_{n-1} is the previous input. The coefficients in the difference equation are a function of the sample time Δt which is taken to be 0.015 second.

Exhaust Nozzle Request Calculation

Figure B-11 presents the flow chart.

The nozzle is open for speeds less than or equal to 14,025 rpm. The nozzle request representing "open" is stored in VT034. The nozzle is closed for speeds greater than or equal to 16,500 rpm. The nozzle request representing "closed" is stored in VT035. For speeds between 14,025 rpm and 16,500 rpm the nozzle request decreases linearly from "open" to "closed." The "speed" used in the nozzle request calculation is sensed speed (VT157) if the control mode is not speed control. If the control mode is speed control the speed used is that requested by the power lever (VT128). The nozzle request is stored in VT081. After this calculation has been completed and index register one has been restored, one control cycle update has been completed and control is passed to the Bendix program.

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Flow charts for the main computational blocks and for each block are presented in Figures B-12 through B-23. Table B-10 is a glossary of terms. The program is presented in Tables B-11 through B-14. A listing of the Bendix Bounds program corresponding to the Equilibrium-Temperature Program is presented in Table B-13.

The main computational blocks for the speed temperature control program are shown in Figure B-12. The major differences between this program and the speed pressure control program are the filtering logic for T4 whistle, the number of feedbacks, and the names given to the gains and open-loop information. Consequently, a description of each of the blocks in Figure B-12 will be given in comparative terms of the description given for the speed and pressure controller.

Initialization

It is clear from looking at the detached flow chart (Figure B-13) that more items are transferred from variable trim locations to locations in the control program. This is true, because the temperature controller has more feedbacks than the pressure controller. Consequently, the VT numbers encountered in this section of the program are in the range VT001 - VT090 (rather than the previous VT001 - VT070). The Bendix Bounds program has been modified to allow the first 90 VT numbers to be changed at the interface console. Nominal values of these VT variables are stored in the standard trim locations ST001 - ST090 in the beginning of the Bounds program (Table B-13). The logic to get into this section of the program is the same as previously described. In addition to the increased number gains and open-loop information to be transferred, an added logic switch, ISW, is initialized. This switch is used to initialize the filtering logic for T4 whistle.

Interpolation Interval Determination

This section of the program (Figure B-14) is exactly the same as for the speed and pressure control program.

Interpolation Logic

The only differences in this section of the program are the labels (names) given to the gains and open-loop information (fuel, pressures, and temperature) associated with temperature controller as opposed to the pressure controller; cf Figure B-15.

Filtering Logic for T4 Whistle

The temperature sensed by the whistle (VT097) goes through a lead-lag filter and the output of the filter is stored in T4WF, Figure B-16. The transfer function for the filter with VT097 as input and T4WF as output is

$$\frac{T4WF}{VT097} = \frac{\tau_2 S + 1}{(K_1)(\tau_2)S + 1} \qquad \text{(B-6)}$$

where τ_2 and K_1 are piecewise linear functions of PT3.

The table below gives τ_2 and K_1 versus PT3.

PT3 (psi)	K_1	τ_2
24.5	0.50	30.0
39.0	0.53	17.0
58.5	0.56	10.0
102.0	0.60	8.0

The filter is implemented digitally by the following two equations.

$$\begin{aligned} \dot{X}T4 &= \frac{1}{K_1 \tau_2} (VT097 - XT4) \\ T4WF &= \tau_2 \dot{X}T4 + XT4 \end{aligned} \qquad \text{(B-7)}$$

In the program, K_1 is scaled up by 100 and τ_2 is scaled up by 10. The label for $K_1 \cdot 100$ is K1THD and the label for $\tau_2 \cdot 10$ is TAU2T. The coding starts at label FUELM with the calculation of K1THD and TAU2T as a function of PG3. At label STP1 the logical switch ISW is tested. If ISW is unequal to 1234, initialization of the filter equations takes place. Otherwise branch to STP2. In the initialization logic $\dot{XT4}$ is set equal to VT097, $\dot{XT4}$ is set equal to zero and ISW is set equal to 1234 followed by a branch to STP3. Starting at label STP2, the derivative $\dot{XT4}$ is calculated double precision and stored in XT4D. At label STP3 the differential equation is integrated one step forward in time using the trapezoidal rule (Δt taken to be 0.015 second). The updated value of XT4 is stored in XT4 in double precision. At this point the filtered T4 whistle is computed and stored in T4WF.

Integral Speed and Integral Temperature

In this portion of the program (Figure B-17) the integral pressure differential equation has been replaced with an integral temperature differential equation

$$\dot{ET} = -13.3333\,(T4WF - T4\partial) \qquad \text{(B-8)}$$

where ET is the integral of the error between sensed T4 whistle filtered and a boundary value T4 as a function of sensed speed. The initial value of ET is stored in VT038 and the limiting value of ET is taken to be the absolute value of VT033.

Additional logic was added to the integration routine in this section to reset the values of EN and ET to zero under the following conditions:

$EN = 0$ if VT074 (mode switch) $\neq$ 3276

$ET = 0$ if VT074 $\neq$ 6552

This logic is inserted in the program immediately after the integrals have been updated (section of the program beginning with statement number HWS03300). The parameters EN and ET are updated only if the program is in the right mode; EN is updated if the speed control loop is regulating the engine and ET is updated if the temperature control loop is regulating the engine.

The rest of this section of the program is the same as described previously.

Interpolation as a Function of Power Lever

This portion of the program (Figure B-19) is exactly the same as previously described for the pressure controller.

Fuel Request Calculation

The pressure fuel request calculation is replaced with a temperature fuel request (Figure B-20). The temperature fuel request is calculated as the sum of an open-loop fuel scheduled as a linear function of sensed speed and the following feedback quantities:

- The error between PT5 sensed and a given PT5 scheduled as a linear function of speed
- The error between PT3 sensed and a given PT3 scheduled as a linear function of speed
- The error between T4 whistle filtered and a T4 given scheduled as a linear function of speed
- The integral of the error between PT3 sensed and a given PT3 scheduled as a linear function of speed.

The temperature fuel request calculation starts at label FREQT and each of the products involved in the sum is stored in VT205 - VT207. The fuel request for the temperature controller is stored in SUMTF and VT073.

Mode Select Logic

The only difference in this section of the program is that the minimum between the speed fuel request VT071 and the temperature fuel request VT073 (rather than the pressure fuel request VT072) is stored in VT180; cf Figure B-21.

Fuel Request Filter Logic

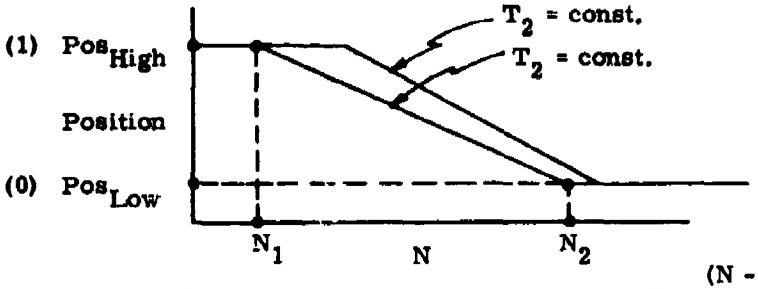
The same as previously described for pressure; Figure B-22.

Exhaust Nozzle Request Calculation

This is the same as previously described for pressure (Figure B-23).

Table B-1. IGV, BLD, and A8 Schedules

IGV and BLD



$$\text{Position} = Pos_{Low} + (Pos_{High} - Pos_{Low}) \times \frac{(N - N_1)}{(N_2 - N_1)}$$

where N is spool speed.

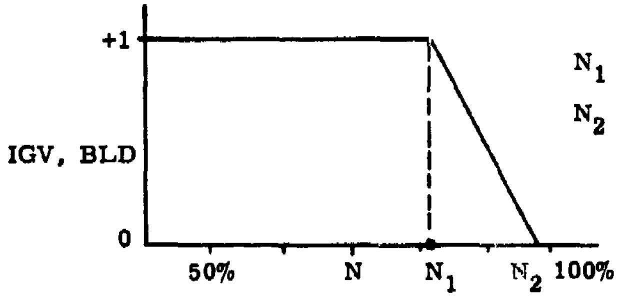
$$N_1\ (\text{rpm}) = 11,800 + (T_2\,°R - 420°R) \times \frac{2100}{160}$$

$$N_2\ (\text{rpm}) = 14,900 + (T_2\,°R - 428°R) \times \frac{1100}{64} \quad \text{if } T_2\,°F \le 25°F$$

$$= 16,000 - (T_2\,°R - 484°R) \times \frac{200}{50} \quad \text{if } 25°F < T_2\,°F < 75°F$$

$$= 15,800 + (T_2\,°R - 534°R) \times \frac{500}{32} \quad \text{if } T_2\,°F \ge 75°F$$

∴ on a normal day (T_2 = 70°F) the schedules are:



N_1 = 13,244 rpm, 80.3%

N_2 = 15,816 rpm, 95.8%

A8

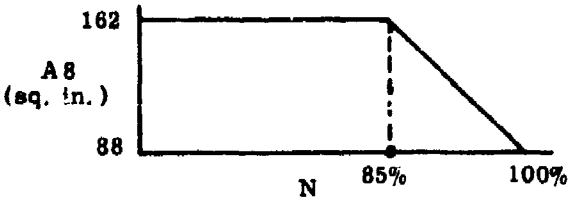


Table B-2. Generic Fuel Control Law

$$u_f = \frac{30.0\,u1}{s + 30.0}$$

$$u1 = \mathrm{Max}\begin{cases} u2 \\ ud \end{cases}$$

$$u2 = \mathrm{Min}\begin{cases} ue \\ up \\ ut \end{cases}$$

$$ud = ud\,[N]$$

$$\begin{aligned} ue = {} & k_N\,[N - N_o\,(pla)] + k_{EN}\,EN + k_{P3}\,[P3 - P3_o\,(pla)] \\ & + k_{PT5}\,[PT5 - PT5_o\,(pla)] + ue_o\,(pla) \end{aligned}$$

$$up = k_{EP} + k_{P3}\,[P3 - P3_o\,(N)] + k_{PT5}\,[PT5 - PT5_o(N)] + up_o\,(N)$$

$$ut = k_{ET}ET + k_{TT4}\,[PT5 - PT5_o\,(N)] + ut_o\,(N)$$

$$\dot{EN} = \begin{cases} 0 & \text{If } EN \geq ENL \ \&\ -5.3333\,(N - N_o) \geq 0 \\ 0 & \text{If } EN \leq ENL \ \&\ -5.3333\,(N - N_o) \leq 0 \\ -5.3333\,[N - N_o\,(pla)] & \text{otherwise} \end{cases}$$

$$\dot{EP} = \begin{cases} 0 & \text{If } EP \geq EPL \ \&\ -PC\,(P3 - P3_o) \geq 0 \\ 0 & \text{If } EP \leq EPL \ \&\ -PC\,(P3 - P3_o) \leq 0 \\ -PC(N)\,[P3 - P3_o(N)] & \text{otherwise} \end{cases}$$

Table B-2. Generic Fuel Control Law (Concluded)

where

$$\mathrm{PC} = \begin{cases} 5.333 \text{ If } N < 14{,}025 \text{ rpm} \\ 13.333 \text{ If } N \geq 14{,}025 \text{ rpm} \end{cases}$$

$$\dot{\mathrm{ET}} = \begin{cases} 0 \quad \text{If } \mathrm{ET} \geq \mathrm{ETL} \;\&\; -13.333\,(\mathrm{T4WF} - \mathrm{TT4}_o) \geq 0 \\ 0 \quad \text{If } \mathrm{ET} \leq \mathrm{ETL} \;\&\; -13.333\,(\mathrm{T4WF} - \mathrm{TT4}_o) \leq 0 \\ -13.333\,[\mathrm{T4WF} - \mathrm{TT4}_o\,(N)] \text{ otherwise} \end{cases}$$

N (rpm), P3 (psi), and PT5 (psi) are taken to be the outputs of engine sensors, pla is throttle in part of full; e.g., 0.75 pla commands 75 percent rpm, T4W (°R) is the output of the Honeywell fluidic (whistle) T4 sensor

$$\mathrm{T4WF} = \left[\frac{1}{(\mathrm{KI})\tau 2} \left(1 - \frac{1}{\mathrm{KI}}\right) (\mathrm{P3})\right] \mathrm{T4DUM} + \frac{1}{\mathrm{KI}} (\mathrm{P3})\ \mathrm{TT4W}$$

$$\mathrm{T4DUM} = \left[\frac{1}{(\mathrm{KI})\ (\mathrm{T2})} (\mathrm{P3})\right] \mathrm{T4DUM} + \mathrm{TT4W}$$

$$\mathrm{T4WF} \approx \frac{50.0}{S + 50}\ \mathrm{TT4}$$

$$\mathrm{ENL} = 200.0$$

$$\mathrm{EPL} = 1.0$$

$$\mathrm{ETL} = 100.0$$

Table B-3. Perturbation Gains

% N	k_N (lb/sec)/rpm	k_E N P T	k_{P3} (lb/sec)/psi	k_{PT5} (lb/sec)/psi	k_{TT4} (lb/sec)/(deg F)
50E	-0.46718-3	+0.58461-4	---	---	---
50P	---	+0.45650-1	-0.18636+0	+0.15861+0	---
50T	---	+0.11304-3	-0.15966-2	+0.12096-2	-0.22757-3
70E	-0.27[illegible]36-3	+0.53844-4	---	---	---
70P	---	+0.20271-1	-0.62334-1	-0.44936-1	---
70T	---	+0.14074-3	+0.53354-1	-0.20311-2	-0.28462-3
85E	-0.26479-3	+0.12239-3	---	---	---
85P	---	+0.15561-2	-0.71783-1	+0.51485-1	---
85T	---	+0.16155-3	+0.91896-2	-0.74486-3	-0.18812-3
100E	-0.53363-3	+0.31975-3	---	---	---
100P	---	+0.12779-1	-0.49166-1	+0.43431-1	---
100T	---	+0.23413-3	-0.18094-1	+0.13297-1	-0.78669-5

Table B-4. Open-Loop Fuel Flows* (lb/hr)

% N	ue_o[pla]	up_o[N]	ut_o[N]	ud[N]
50.0	519.0	779.0	651.0	200.0
70.0	693.0	1740.0	1000.0	350.0
85.0	934.0	2573.0	2000.0	500.0
100.0	1648.0	3478.0	2400.0	1000.0

* These are for the APL engine at 29.55 inches of Hg and 82°F.
They should be corrected with ambient conditions.

Table B-5. Equilibrium and Boundary States*

%N	50	70	85	100
Equilibrium				
N_o[pla]rpm	8,250.0	11,550.0	14,025.0	16,500.0
Pressure				
$P3_o$[N]psi	22.0	35.5	55.0	80.0
$PT5_o$[N]psi	14.8	16.4	20.5	25.6
Temperature				
$TT4_o$[N]°F	1,020.0	900.0	1,050.0	1,160.0
$P3_o$[N]psi	23.5	35.5	55.0	80.0
$PT5_o$[N]psi	14.8	16.4	20.5	26.5

*These are for the APL engine at 99.99 inches of Hg and 99°F. They should be corrected with ambient conditions.

Table B-6. An Integral Transformation

$$\begin{aligned}
\dot{x} &= +Fx \\
\dot{E} &= -dx \\
\dot{w}_f &= +Fx \qquad\qquad -a\,w_f + gu \\
u &= +kx
\end{aligned}$$

- -

$$\begin{aligned}
\dot{x} &= +Fx \\
\frac{\dot{E}}{\mu} &= -\frac{d}{\mu}\,x \\
\dot{w}_f &= \qquad\qquad\qquad -a\,w_f + gu \\
u &= +kx + (\lambda\mu)\frac{E}{\mu}
\end{aligned}$$

Table B-7. Glossary for Equilibrium - Pressure Control

VT Number	Transferred To (Program Label)	Description	Standard Value (Defined in the Bendix Program)
009	---	Logic switch: If VT009 > 123 the Honeywell controller is in; otherwise not	0
012	DEF11	Speed control gain associated with $(N-N_{pla})$ at 8250 rpm	(-215) x 16
013	WEF1	Open-loop fuel-speed control at 8250 rpm	519 lb/hr
014	P3P1	Open-loop PT3-speed control at 8250 rpm	2200 (psi x 100)
015	KEF14	Speed control gain associated with EN at 8250 rpm	(27) x 16
016	KEF21	Speed control gain associated with $(N-N_{pla})$ at 11, 550 rpm	(-126) x 16
017	WEF2	Open-loop fuel-speed control at 11, 550 rpm	693 lb/hr
018	P3P2	Open-loop PT3 - speed control at 11, 550 rpm	3550 (psi x 100)
019	KEF24	Speed control gain associated with EN at 11, 550 rpm	(25) x 16
020	KEF31	Speed control gain associated with $(N-N_{pla})$ at 14, 025 rpm	(-122) x 16
021	WEF3	Open-loop fuel-speed control at 14, 025 rpm	934 lb/hr
022	P3P3	Open-loop PT_3 - speed control at 14, 025 rpm	5500 (psi) x 100
023	KEF34	Speed control gain associated with EN at 14, 025 rpm	(56) x 16
026	---	If this number is made large, Bendix bound on fuel will not be in effect	2^{14}
028	---	Logical switch: if VT028 = 64 Honeywell nozzle is used; otherwise not	0

Table B-7. Glossary for Equilibrium - Pressure Control (Continued)

VT Number	Transferred To (Program Label)	Description	Standard Value (Defined in the Bendix Program)
034	---	Exhaust request open	9640
035	---	Exhaust request closed	2650
036	ENK, ENKL	Initial value of integral speed limits value	1600
037	EPK, EPKL	Initial value of integral pressure limits value	1600
039	---	Logic switch: VT039 = 16 initializes everything. VT039=64 initializes EN, EP only	16
040	KEF41	Speed control gain associated with $(N-N_{pla})$ at 16,500 rpm	(-246) x 16
041	WEF4	Open-loop fuel-speed control at 16,500 rpm	1648 lb/hr
042	P3P4	Open-loop PT3 - speed control at 16,500 rpm	0090 (psi x 100)
043	KEF44	Speed control gain associated with EN at 16,500 rpm	(147) x 16
044	KPF11	Fudge factor used in EP at 8250 rpm	3089
045	KPF12	Pressure control gain - (PT5 - PT5∂) at 8250 rpm	(571) x 16
046	KPF13	Pressure control gain - (PT3 - PT3∂) at 8250 rpm	(-671) x 16
047	WPF1	Open-loop fuel-pressure control at 8250 rpm	779 lb/hr
048	KPF21	Fudge factor used in EP at 11,550 rpm	(576) x 16
049	KPF22	Pressure control gain - (PT5 - PT5∂) at 11,550 rpm	(-162) x 16
050	KPF23	Pressure control gain - (PT3 - PT3∂) at 11,550 rpm	(-224) x 16

Table B-7. Glossary for Equilibrium - Pressure Control (Concluded)

VT Number	Transferred To (Program Label)	Description	Standard Value (Defined in the Bendix Program)
061	WPF2	Open-loop fuel-pressure control at 11,550 rpm	1740 lb/hr
062	KPF31	Fudge factor used in EP at 14,025 rpm	(59) x 16
063	KPF32	Pressure control gain - (PT5 - PT5∂) at 14,025 rpm	(185) x 16
064	KPF33	Pressure control gain - (PT3 - PT3∂) at 14,025 rpm	(-258) x 16
065	WPF3	Open-loop fuel-pressure control at 14,025 rpm	2573 lb/hr
066	KPF41	Fudge factor used in EP at 16,500 rpm	(364) x 16
067	KPF42	Pressure control gain - (PT5 - PT5∂) at 16,500 rpm	(156) x 16
068	KPF43	Pressure control gain (PT3 - PT3∂) at 16,500 rpm	(-177) x 16
069	WPF4	Open-loop fuel-pressure control at 16,500 rpm	3478 lb/hr
071	---	Speed fuel request 1 count = 4 lb/hr	0
072	---	Pressure fuel request 1 count = 4 lb/hr	0
074	---	Mode number 3276 = speed control 6552 = pressure control 9228 = minimum fuel	0
081	--	Exhaust actuator request	0
180	---	Fuel request calculated by control program 3.25 counts = 1 lb/hr	---

Table B-8. Equilibrium - Pressure Subprogram

```
// JOB        VDISK
// DMP
*DELETE             HWECT
// ASM                                                                    HWS00010
*OVERFLOW SECTORS ,,,9                                                    HWS00020
*LIST                                                                     HWS00030
*XREF                                                                     HWS00040
*ONEWORDINTEGERS                                                          HWS00050
*COMMON IDUMY(127),IVT00,JDUMY(127),ISTO,MEAST(64),IASCW(8)               HWS00060
                           ENT       HWECT                                HWS00070
                     HWECT DC        *-*                                  HWS00080
                           STX  L1 XR1+1                                  HWS00090
                     *                                                    HWS00100
                           LDX  L1 0                                      HWS00110
                           B    L  TESTN                                  HWS00120
                     *
                     *  INITIALIZATION
                     *
                     TESTN EQU       *                                    HWS00190
                           LD     2 VT039
                           S    L  +16
                           BNZ       MICK
                           STO    2 VT039
                           LD     2 VT012
                           SRT       4
                           STO  L  KEF11
                           LD     2 VT013
                           STO  L  WEF1
                           LD     2 VT014
                           STO  L  P3P1
                           LD     2 VT015
                           SRT       4
                           STO  L  KEF14
                           LD     2 VT016
                           SRT       4
                           STO  L  KEF21
                           LD     2 VT017
                           STO  L  WEF2
                           LD     2 VT018
                           STO  L  P3P2
                           LD     2 VT019
                           SRT       4
                           STO  L  KEF24
                           LD     2 VT020
                           SRT       4
                           STO  L  KEF31
                           LD     2 VT021
                           STO  L  WEF3
                           LD     2 VT022
                           STO  L  P3P3
                           LD     2 VT023
                           SRT       4
                           STO  L  KEF34
                           LD     2 VT040
                           SRT       4
                           STO  L  KEF41
                           LD     2 VT041
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
      STO  L  WEF4
      LD     2 VT042
      STO  L  P3P4
      LD     2 VT043
      SRT       4
      STO  L  KEF44
      LD     2 VT044
      STO  L  KPF11
      LD     2 VT045
      SRT       4
      STO  L  KPF12
      LD     2 VT046
      SRT       4
      STO  L  KPF13
      LD     2 VT047
      STO  L  WPF1
      LD     2 VT048
      SRT       4
      STO  L  KPF21
      LD     2 VT049
      SRT       4
      STO  L  KPF22
      LD     2 VT050
      SRT       4
      STO  L  KPF23
      LD     2 VT061
      STO  L  WPF2
      LD     2 VT062
      SRT       4
      STO  L  KPF31
      LD     2 VT063
      SRT       4
      STO  L  KPF32
      LD     2 VT064
      SRT       4
      STO  L  KPF33
      LD     2 VT065
      STO  L  WPF3
      LD     2 VT066
      SRT       4
      STO  L  KPF41
      LD     2 VT067
      SRT       4
      STO  L  KPF42
      LD     2 VT068
      SRT       4
      STO  L  KPF43
      LD     2 VT069
      STO  L  WPF4
      LD   L  *0
      STO  L  TIME
      STO  L  SWLAG                                      HWS00160
*                                                        HWS00170
*INTERVAL DETERMINATION                                  HWS00180
*
MICK  EQU       *                                        HWS00200
      LD     2 VT157                                     HWS00210
      S         *6250
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
        BP          TMAX                                          HWS00220
        LD          =1                                            HWS00230
        STO         NIN                                           HWS00240
        LD          =128
        STO         C1                                            HWS00260
        LD          =0                                            HWS00270
        STO         C2                                            HWS00280
        B      L    IN1F                                          HWS00290
C1      DC          *-*                                           HWS00130
C2      DC          *-*                                           HWS00140
NIN     DC          *-*                                           HWS00150
        LORG
TMAX    LD          =16500                                        HWS00300
        S         2 VT157                                         HWS00310
        BP          TIN1                                          HWS00320
        LD          =3                                            HWS00330
        STO         NIN                                           HWS00340
        LD          =0                                            HWS00350
        STO         C1                                            HWS00360
        LD          =128
        STO         C2                                            HWS00380
        B      L    IN3F                                          HWS00390
TIN1    LD          =11550                                        HWS00400
        S         2 VT157                                         HWS00410
        BN          TIN2                                          HWS00420
        SRT         9
        D           =3300                                         HWS00440
        STO         C1                                            HWS00450
        LD          =128
        S           C1                                            HWS00470
        STO         C2                                            HWS00480
        LD          =1                                            HWS00490
        STO         NIN                                           HWS00500
        B      L    IN1F                                          HWS00510
TIN2    LD          =14025                                        HWS00520
        S         2 VT157                                         HWS00530
        BN          TIN3                                          HWS00540
        SRT         9
        D           =2475                                         HWS00560
        STO         C1                                            HWS00570
        LD          =128
        S           C1                                            HWS00590
        STO         C2                                            HWS00600
        LD          =2                                            HWS00610
        STO         NIN                                           HWS00620
        B      L    IN2F                                          HWS00630
TIN3    LD          =16500                                        HWS00640
        S         2 VT157                                         HWS00650
        SRT         9
        D           =2475                                         HWS00670
        STO         C1                                            HWS00680
        LD          =128
        S           C1                                            HWS00700
        STO         C2                                            HWS00710
        LD          =3                                            HWS00720
        STO         NIN                                           HWS00730
        B      L    IN3F                                          HWS00740
        LORG                                                      HWS00750
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
*          EQUILIBRIUM FUEL FLOW 50 GAINS                         HWS00760
KEF11 DC        ***
KEF12 DC        0
KEF13 DC        0
KEF14 DC        ***
WEF1  DC        ***
P3E1  DC        2705
P5E1  DC        1633
*          PRESSURE   FUEL FLOW 50 GAINS                          HWS00840
KPF11 DC        ***
KPF12 DC        ***
KPF13 DC        ***
KPF14 DC        53
WPF1  DC        ***
P3P1  DC        ***
P5P1  DC        1480
WTF1  DC        1118                                              HWS00930
A61   DC        162                                               HWS00940
WFMN1 DC        650
TB1   DC        2602                                              HWS00970
BUMP1 DC        1                                                 HWS00980
SETX1 DC        0                                                 HWS00990
NGFT  DC        18
C11   DC        ***                                               HWS01010
C21   DC        ***                                               HWS01020
TST1  DC        ***                                               HWS01040
SUM1  BSS   E   0
      DC        0
      DC        0
*
*  INTERPOLATE INTERVAL 1
*
IN1F  EQU       *                                                 HWS01050
      LD    L   C1                                                HWS01060
      STO       C11                                               HWS01070
      LD    L   C2                                                HWS01080
      STO       C21                                               HWS01090
      LD    L   SETX1                                             HWS01100
      STO       TST1                                              HWS01110
LUP1  LDX   I1  TST1                                              HWS01120
      LD    L1  KEF11                                             HWS01130
      M         C11                                               HWS01140
      STD       SUM1
      LD    L1  KEF21                                             HWS01170
      M         C21                                               HWS01180
      AD        SUM1
      SRT       7
      SLT       16
      STO   L1  KEFN1                                             HWS01220
      LD        TST1                                              HWS01230
      A     L   BUMP1                                             HWS01240
      STO       TST1                                              HWS01250
      S     L   NGFT                                              HWS01260
      BN        LUP1                                              HWS01270
      B     L   FUFLM                                             HWS01280
*          EQUILIBRIUM FUEL FLOW 70 GAINS                         HWS01290
KEF21 DC        ***
KEF22 DC        0
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
KEF23 DC       0
KEF24 DC       ***
WEF2  DC       ***
P3E2  DC       4361
P5E2  DC       1893
*        PRESSURE     FUEL FLOW 70 GAINS                      HWS01370
KPF21 DC       ***
KPF22 DC       ***
KPF23 DC       ***
KPF24 DC       127
WPF2  DC       ***
P3P2  DC       ***
P5P2  DC       1640
WTF2  DC       1877                                           HWS01460
AB2   DC       162                                            HWS01470
WFMN2 DC       1138
TB2   DC       2563                                           HWS01500
C12   DC       ***                                            HWS01510
C22   DC       ***                                            HWS01520
TST2  DC       ***                                            HWS01540
SUM2  BSS   E  0
      DC       0
      DC       0
*
*  INTERPOLATE INTERVAL 2
*
IN2F  EQU      *                                              HWS01550
      LD    L  C1                                             HWS01560
      STO      C12                                            HWS01570
      LD    L  C2                                             HWS01580
      STO      C22                                            HWS01590
      LD    L  SETX1                                          HWS01600
      STO      TST2                                           HWS01610
LUP2  LDX   I1 TST2                                           HWS01620
      LD    L1 KEF21                                          HWS01630
      M        C12                                            HWS01640
      STD      SUM2
      LD    L1 KEF31                                          HWS01670
      M        C22                                            HWS01680
      AD       SUM2
      SRT      7
      SLT      16
      STO   L1 KEFN1                                          HWS01720
      LD       TST2                                           HWS01730
      A     L  BUMP1                                          HWS01740
      STO      TST2                                           HWS01750
      S     L  NGFT                                           HWS01760
      BN       LUP2                                           HWS01770
      B     L  FUELM                                          HWS01780
*        EQUILIBRIUM FUEL FLOW 85 GAINS                       HWS01790
KEF31 DC       ***
KEF32 DC       0
KEF33 DC       0
KEF34 DC       ***
WEF3  DC       ***
P3E3  DC       6161
P5E3  DC       2243
*        PRESSURE     FUEL FLOW 85 GAINS                      HWS01870
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
KPF31 DC       ***
KPF32 DC       ***
KPF33 DC       ***
KPF34 DC       236
WPF3  DC       ***
P3P3  DC       ***
P5P3  DC       2050
WTF3  DC       3102                                       HWS01960
AB3   DC       162                                        HWS01970
WFMN3 DC       1625
TB3   DC       2743                                       HWS02000
C13   DC       ***                                        HWS02010
C23   DC       ***                                        HWS02020
TST3  DC       ***                                        HWS02040
SUM3  BSS   E  0
      DC       0
      DC       0
*
*  INTERPOLATE INTERVAL 3
*
IN3F  EQU      *                                          HWS02050
      LD    L  C1                                         HWS02060
      STO      C13                                        HWS02070
      LD    L  C2                                         HWS02080
      STO      C23                                        HWS02090
      LD    L  SETX1                                      HWS02100
      STO      TST3                                       HWSC2110
LUP3  LDX   I1 TST3                                       HWS02120
      LD    L1 KEF31                                      HWS02130
      M        C13                                        HWS02140
      STD      SUM3
      LD    L1 KEF41                                      HWS02170
      M        C23                                        HWS02180
      AD       SUM3
      SRT      7
      SLT      16
      STO   L1 KEFN1                                      HWS02220
      LD       TST3                                       HWS02230
      A     L  BUMP1                                      HWS02240
      STO      TST3                                       HWS02250
      S     L  NGFT                                       HWS02260
      BN       LUP3                                       HWS02270
      B     L  FUELM                                      HWS02280
*         EQUILIBRIUM FUEL FLOW 100 GAINS                 HWS02290
KEF41 DC       ***
KEF42 DC       0
KEF43 DC       0
KEF44 DC       ***
WEF4  DC       ***
P3E4  DC       10110
P5E4  DC       3988
*         PRESSURE FUEL FLOW 100 GAINS                    HWS02370
KPF41 DC       ***
KPF42 DC       ***
KPF43 DC       ***
KPF44 DC       317
WPF4  DC       ***
P3P4  DC       ***
P5P4  DC       2650
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
       DC        91                                             [illegible]
ATM44  DC        3250
T84    DC        2684                                           HWS02500
FUELM  EQU       *                                              HWS02510
*
*  INITIALIZE INTEGRALS AND LIMITS ON INTEGRALS
*
       LD      2 VT039                                          HWS02520
       S         *64                                            HWS02530
       BNZ       MOW9                                           HWS02540
       STO     2 VT039
       LD      2 VT036                                          HWS02550
       STO       ENK
       BNN       SENL
       LD        *0
       S         ENK
SENL   STO       ENKL
       LD      2 VT037                                          HWS02570
       SRT       4
       STO       EPK
       BNN       SEPL
       LD        *0
       S         EPK
SEPL   STO       EPKL
       LD      2 VT038                                          HWS02590
       STO       ETKL                                           HWS02600
       STO       ETK
MOW9   EQU       *                                              HWS02610
*                                                               HWS02620
*                                                               HWS02630
*                                                               HWS02720
* CALCULATE DERIVATIVES FOR EN EP ET                            HWS02730
*                                                               HWS02740
       LD      2 VT158                                          HWS02750
       S       2 VT157                                          HWS02760
       STO       ENDK                                           HWS02770
       LD      L PT3NB                                          HWS02820
       S       2 VT102
       STO       EPDK                                           HWS02840
       LD      2 VT097                                          HWS02850
       SRT       16                                             HWS02860
       D         *10                                            HWS02870
       S       L T8BN                                           HWS02880
       STO       ETDK                                           HWS02890
       LD        TIME                                           HWS02900
       BNZ       INTEG                                          HWS02910
       LD        ENDK                                           HWS02920
       STO       ENDK1                                          HWS02930
       LD        EPDK                                           HWS02940
       STO       EPDK1                                          HWS02950
       LD        ETDK                                           HWS02960
       STO       ETDK1                                          HWS02970
       LD      2 VT036                                          HWS02980
       STO       ENK                                            HWS02990
       BNN       STENL
       LD        *0
       S         ENK
STENL  STO       ENKL
       LD      2 VT037                                          HWS03010
       SRT       4
       STO       EPK                                            HWS03030
       BNN       STEPL
       LD        *0
       S         EPK
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
STEPL STO      EPKL
      LD    2  VT038                                      HWS03050
      STO      ETK                                        HWS03060
      STO      ETKL                                       HWS03070
      LD       *1                                         HWS03080
      STO      TIME                                       HWS03090
      B     L  INTEG
      LORG                                                HWS03110
*GENERATE EN EP ET                                        HWS03120
TIME  DC       0
ENDK  DC       *-*                                        HWS03140
ENDK1 DC       *-*                                        HWS03150
EPDK  DC       *-*                                        HWS03160
EPDK1 DC       *-*                                        HWS03170
ETDK  DC       *-*                                        HWS03180
ETDK1 DC       *-*                                        HWS03190
DT    DC       15                                         HWS03200
ENK   DC       *-*                                        HWS03210
ENKL  DC       *-*                                        HWS03220
EPK   DC       *-*                                        HWS03230
EPKL  DC       *-*                                        HWS03240
ETK   DC       *-*                                        HWS03250
ETKL  DC       *-*                                        HWS03260
*                                                         HWS03280
INTEG EQU      *                                          HWS03290
*                       CALCULATE EN                      HWS03300
      LD       ENDK
      A        ENDK1
      M        DT
      SLT      3            EN SCALED UP BY 8
      D        *375
      A        ENK                                        HWS03400
      STO      ENK                                        HWS03410
*                       CALCULATE EP                      HWS03420
      LD       EPDK
      A        EPDK1
      M        DT
      D        *375
      M     L  KPFN1
      D        *1000
      A        EPK                                        HWS03490
      STO      EPK                                        HWS03500
*                       CALCULATE ET                      HWS03510
      LD       ETDK                                       HWS03520
      M        *3                                         HWS03530
      SLT      16                                         HWS03540
      S        ETDK1                                      HWS03550
      M        DT                                         HWS03560
      D        *2000                                      HWS03570
      A        ETK                                        HWS03580
      STO      ETK                                        HWS03590
*                       LIMLTS ON EN EP ET                HWS03600
      LD       ENK                                        HWS03610
      BN       MW1                                        HWS03620
      S        ENKL                                       HWS03630
      BNP      MW2                                        HWS03640
      LD       ENKL                                       HWS03650
      STO      ENK                                        HWS03660
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
         B     L  MW2                                                          HWS03670
MW1      EQU      *                                                            HWS03680
         LD       ENK                                                          HWS03690
         A        ENKL                                                         HWS03700
         BP       MW2                                                          HWS03710
         LD       =0                                                           HWS03720
         S        ENKL                                                         HWS03730
         STO      ENK                                                          HWS03740
MW2      EQU      *                                                            HWS03750
         LD       EPK                                                          HWS03760
         BN       MW3                                                          HWS03770
         S        EPKL                                                         HWS03780
         BNP      MW4                                                          HWS03790
         LD       EPKL                                                         HWS03800
         STO      EPK                                                          HWS03810
         B     L  MW4                                                          HWS03820
MW3      EQU      *                                                            HWS03830
         LD       EPK                                                          HWS03840
         A        EPKL                                                         HWS03850
         BP       MW4                                                          HWS03860
         LD       =0                                                           HWS03870
         S        EPKL                                                         HWS03880
         STO      EPK                                                          HWS03890
MW4      EQU      *                                                            HWS03900
         LD       ETK                                                          HWS03910
         BN       MW5                                                          HWS03920
         S        ETKL                                                         HWS03930
         BNP      MW6                                                          HWS03940
         LD       ETKL                                                         HWS03950
         STO      ETK                                                          HWS03960
         B     L  MW6                                                          HWS03970
MW5      EQU      *                                                            HWS03980
         LD       ETK                                                          HWS03990
         A        ETKL                                                         HWS04000
         BP       MW6                                                          HWS04010
         LD       =0                                                           HWS04020
         S        ETKL                                                         HWS04030
         STO      ETK                                                          HWS04040
         B     L  MW6                                                          HWS04050
         LORG                                                                  HWS04060
*                           AGE DERIVATIVES                                    HWS04070
MW6      EQU      *                                                            HWS04080
         LD    L  ENDK                                                         HWS04090
         STO   L  ENDK1                                                        HWS04100
         LD    L  EPDK                                                         HWS04110
         STO   L  EPDK1                                                        HWS04120
         LD    L  ETDK                                                         HWS04130
         STO   L  ETDK1                                                        HWS04140
*                                                                              HWS04150
*                         INTERPOLATE FOR PT3 AND PT4                          HWS04160
*                         AS A FUNCTION OF PLA                                 HWS04170
PLA      EQU      *
         LD       NPL1                                                         HWS04180
         S     ,  VT128                                                        HWS04190
         BN       MDW1                                                         HWS04200
         LD    L  P3E1                                                         HWS04210
         STO   L  P3PL                                                         HWS04220
         LD    L  P5F1                                                         HWS04230
```

Table E-8. Equilibrium - Pressure Subprogram (Continued)

```
      STO   L   PSPL                                            HWS04240
      LD    L   WEF1                                            HWS04250
      STO   L   WEFN                                            HWS04260
      B     L   MDW6                                            HWS04270
MDW1  LD        NPL4                                            HWS04280
      S       2 VT128                                           HWS04290
      BP        MDW2                                            HWS04300
      LD    L   P3E4                                            HWS04310
      STO   L   P3PL                                            HWS04320
      LD    L   P5E4                                            HWS04330
      STO   L   P5FL                                            HWS04340
      LD    L   WEF4                                            HWS04350
      STO   L   WEFN                                            HWS04360
      B     L   MDW6                                            HWS04370
MDW2  LD    L   NPL2                                            HWS04380
      S       2 VT128                                           HWS04390
      BN        MDW3                                            HWS04400
      SRT       9
      D         *3300                                           HWS04420
      STO       CX1                                             HWS04430
      LD        *128
      S         CX1                                             HWS04450
      STO       CX2                                             HWS04460
      LD    L   P3E1                                            HWS04470
      STO       P3L                                             HWS04480
      LD    L   P3E2                                            HWS04490
      STO       P3M                                             HWS04500
      LD    L   P5E1                                            HWS04510
      STO       P5L                                             HWS04520
      LD    L   P5E2                                            HWS04530
      STO       P5M                                             HWS04540
      LD    L   WEF1                                            HWS04550
      STO   L   WEFL                                            HWS04560
      LD    L   WEF2                                            HWS04570
      STO   L   WEFM                                            HWS04580
      B     L   MDW5                                            HWS04590
      LORG                                                      HWS04600
MDW3  LD        NPL3                                            HWS04610
      S       2 VT128                                           HWS04620
      BN        MDW4                                            HWS04630
      SRT       9
      D         *2475                                           HWS04650
      STO       CX1                                             HWS04660
      LD        *128
      S         CX1                                             HWS04680
      STO       CX2                                             HWS04690
      LD    L   P3E2                                            HWS04700
      STO       P3L                                             HWS04710
      LD    L   P3E3                                            HWS04720
      STO       P3M                                             HWS04730
      LD    L   P5E2                                            HWS04740
      STO       P5L                                             HWS04750
      LD    L   P5E3                                            HWS04760
      STO       P5M                                             HWS04770
      LD    L   WEF2                                            HWS04780
      STO   L   WEFL                                            HWS04790
      LD    L   WEF3                                            HWS04800
      STO   L   WEFM                                            HWS04810
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
      B    L  MDW5                                   HWS04820
NPL1  DC      8250                                   HWS04830
NPL2  DC      11550                                  HWS04840
NPL3  DC      14025                                  HWS04850
NPL4  DC      16500                                  HWS04[illegible]0
CX1   DC      ***                                    HWS04870
CX2   DC      ***                                    HWS04880
P3L   DC      ***                                    HWS04890
P3M   DC      ***                                    HWS04900
P5L   DC      ***                                    HWS04910
P5M   DC      ***                                    HWS04920
WEFL  DC      ***                                    HWS04940
WEFM  DC      ***                                    HWS04950
SUMX  BSS  E  0
      DC      0
      DC      0
MDW4  LD      NPL4                                   HWS04960
      S     I VT128                                  HWS04970
      SRT     9
      D       *2475                                  HWS04990
      STO     CX1                                    HWS05000
      LD      *128
      S       CX1                                    HWS05020
      STO     CX2                                    HWS05030
      LD   L  P3E3                                   HWS05040
      STO     P3L                                    HWS05050
      LD   L  P3E4                                   HWS05060
      STO     P3M                                    HWS05070
      LD   L  P5E3                                   HWS05080
      STO     P5L                                    HWS05090
      LD   L  P5E4                                   HWS05100
      STO     P5M                                    HWS05110
      LD   L  WEF3                                   HWS05120
      STO  L  WEFL                                   HWS05130
      LD   L  WEF4                                   HWS05140
      STO  L  WEFM                                   HWS05150
MDW5  LD      P3L                                    HWS05160
      M       CX1                                    HWS05170
      STD     SUMX
      LD      P3M                                    HWS05200
      M       CX2                                    HWS05210
      AD      SUMX
      SRT     7
      SLT     16
      STO     P3PL                                   HWS05250
      LD      P5L                                    HWS05260
      M       CX1                                    HWS05270
      STD     SUMX
      LD      P5M                                    HWS05300
      M       CX2                                    HWS05310
      AD      SUMX
      SRT     7
      SLT     16
      STO     P5PL                                   HWS05350
      LD   L  WEFL                                   HWS05360
      M       CX1                                    HWS05370
      STD     SUMX
      LD      WEFM                                   HWS05400
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
         M          CX2                                             HWS05410
         AD         SUMX
         SRT        7
         SLT        16
         STO        WEFN                                            HWS05480
         B      L   MDW6                                            HWS05460
         LORG                                                       HWS05470
MDW6     EQU        *                                               HWS05510
         LD     L   P5PL                                            HWS05520
         STO     2  VT162                                           HWS05530
         LD     L   P3PL                                            HWS05540
         STO     2  VT163                                           HWS05550
         LD     L   ENK                                             HWS05560
         STO     2  VT164                                           HWS05570
         LD     L   WEFN                                            HWS05580
         STO     2  VT165                                           HWS05590
         LD     L   KEFN1                                           HWS05600
         STO     2  VT166                                           HWS05610
         LD     L   KEFN2                                           HWS05620
         STO     2  VT167                                           HWS05630
         LD     L   KEFN3                                           HWS05640
         STO     2  VT168                                           HWS05650
         LD     L   KEFN4                                           HWS05660
         STO     2  VT169                                           HWS05670
         LD     L   PT5NB                                           HWS05680
         STO     2  VT170                                           HWS05690
         LD     L   PT3NB                                           HWS05700
         STO     2  VT171                                           HWS05710
         LD     L   EPK                                             HWS05720
         STO     2  VT172                                           HWS05730
         LD     L   WPFN                                            HWS05740
         STO     2  VT173                                           HWS05750
         LD     L   KPFN2                                           HWS05760
         STO     2  VT174                                           HWS05770
         LD     L   KPFN3                                           HWS05780
         STO     2  VT175                                           HWS05790
         LD     L   KPFN4                                           HWS05800
         STO     2  VT176                                           HWS05810
*                                                                   HWS05480
*        CALCULATE X-XO  FOR EQUILIBRIUM PRESSURE                   HWS05490
*                                                                   HWS05500
MEPT     EQU        *
         LD      2  VT157                                           HWS05820
         S       2  VT128                                           HWS05830
         STO        ME1                                             HWS05840
         STO     2  VT196
         LD      2  VT108                                           HWS05850
         S      L   P5PL                                            HWS05880
         STO        ME2                                             HWS05890
         S       2  VT073  *                                        HWS07460
         STO     2  VT197
         LD      2  VT102                                           HWS05900
         S      L   P3PL                                            HWS05930
         STO        ME3                                             HWS05940
         STO     2  VT198
         LD     L   ENK                                             HWS05950
         STO        ME4                                             HWS05960
*                                                                   HWS05970
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
         LD     2 VT106                                      HWS05980
         S    L   PT5NB                                      HWS06010
         STO      MP2                                        HWS06020
         STO    2 VT199
         LD     2 VT102                                      HWS06030
         S    L   PT3NB                                      HWS06060
         STO      MP3                                        HWS06070
         STO    2 VT200
         LD   L   EPK                                        HWS06080
         STO      MP4                                        HWS06090
         B    L   FREQE                                      HWS06100
ME1      DC       *-*                                        HWS06110
ME2      DC       *-*                                        HWS06120
ME3      DC       *-*                                        HWS06130
ME4      DC       *-*                                        HWS06140
MP1      DC       *-*                                        HWS06150
MP2      DC       *-*                                        HWS06160
MP3      DC       *-*                                        HWS06170
MP4      DC       *-*                                        HWS06180
KEFN1    DC       *-*                                        HWS06190
KEFN2    DC       *-*                                        HWS06200
KEFN3    DC       *-*                                        HWS06210
KEFN4    DC       *-*                                        HWS06220
WEFN     DC       *-*                                        HWS06230
P3PL     DC       *-*                                        HWS06240
P5PL     DC       *-*                                        HWS06250
KPFN1    DC       *-*                                        HWS06260
KPFN2    DC       *-*                                        HWS06270
KPFN3    DC       *-*                                        HWS06280
KPFN4    DC       *-*                                        HWS06290
WPFN     DC       *-*                                        HWS06300
PT3NB    DC       *-*                                        HWS06310
PT5NB    DC       *-*                                        HWS06320
WTFN     DC       *-*                                        HWS06330
AWN      DC       *-*                                        HWS06340
WFMNN    DC       *-*
TBBN     DC       *-*                                        HWS06370
SUMEF    DC       *-*                                        HWS06380
*
*  CALCULATE FUEL REQ. .ST FOR SPEED AND PRESSURE
*
FREQE    EQU      *                                          HWS06450
         LD   L   KEFN1                                      HWS06460
         M        ME1                                        HWS06470
         SLT      7
         STO    2 VT201
         STO      SUMEF                                      HWS06490
         LD   L   KEFN2                                      HWS06500
         M        ME2                                        HWS06510
         D        *100
         SRT      7
         STO    2 VT202
         A        SUMEF                                      HWS06530
         STO      SUMEF                                      HWS06540
         LD   L   KEFN3                                      HWS06550
         M        ME3                                        HWS06560
         D        *100
         SRT      9
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
       STO    2 VT203
       A        SUMEF                                  HWS06580
       STO      SUMEF                                  HWS06590
       LD     L KEFN4                                  HWS06600
       M        ME4                                    HWS06610
       SLT      4
       STO    2 VT204
       A        SUMEF                                  HWS06630
       STO      SUMEF                                  HWS06650
       LD     L WEFN                                   HWS06670
       SRT      2
       A        SUMEF                                  HWS06700
       STO      SUMEF                                  HWS06720
       B      L FREQP                                  HWS06770
       LORG                                            HWS06780
SUMPF  DC       ***                                    HWS06790
FREQP  EQU      *                                      HWS06800
       LD     L KPFN2                                  HWS06850
       M        MP2                                    HWS06860
       D        *100
       SRT      2
       STO      SUMPF                                  HWS06890
       STO    2 VT205
       LD     L KPFN3                                  HWS06900
       M        MP3                                    HWS06910
       D        *100
       SRT      2
       STO    2 VT206
       A        SUMPF                                  HWS06930
       STO      SUMPF                                  HWS06940
       LD     L KPFN4                                  HWS06950
       M        MP4                                    HWS06960
       D        *100
       SRT      2
       STO    2 VT207
       A        SUMPF                                  HWS06980
       STO      SUMPF                                  HWS07010
       LD     L WPFN                                   HWS07020
       SRT      2
       A        SUMPF                                  HWS07050
       STO      SUMPF                                  HWS07070
       B      L FREQT                                  HWS07120
       LORG                                            HWS07130
SUMTF  DC       ***                                    HWS07140
FREQT  EQU      *                                      HWS07150
       LD       *32700                                 HWS07160
       STO      SUMTF                                  HWS07170
       B      L MDSWT                                  HWS07180
       LORG                                            HWS07190
ONE    DC       3276                                   HWS07200
TWO    DC       6552                                   HWS07210
THREE  DC       9828                                   HWS07220
WFMOD  DC       ***                                    HWS07230
*
*  MODE SWITCHING LOGIC
*
MDSWT  EQU      *                                      HWS07240
       LD     L SUMEF                                  HWS07250
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
      STO    2 VT071                                      HWS07260
      LD    L  SUMPF                                      HWS07270
      STO    2 VT072                                      HWS07280
      LD    L  SUMTF                                      HWS07290
      STO    2 VT073                                      HWS07300
      CMP    2 VT072                                      HWS07310
      LD     2 VT072                                      HWS07320
      NOP                                                 HWS07330
      STO      WFMOD                                      HWS07340
      CMP    2 VT071                                      HWS07350
      LD     2 VT071                                      HWS07360
      NOP                                                 HWS07370
      STO    2 VT180                                      HWS07380
      BN       MINFL
      M     L  *13                                        HWS06990
      SLT      16                                         HWS07000
      STO    2 VT180
      LD     2 VT180
      S     L  WFMNN
      BNN      MINSS
MINFL LD    L  WFMNN
      STO    2 VT180
MINSS EQU      *
      LD     2 VT180                                      HWS07390
      SRT      16
      D        *13
      S      2 VT071                                      HWS07400
      BNZ      MIKE1                                      HWS07410
      LD       ONE                                        HWS07420
      STO    2 VT074                                      HWS07430
      B     L  RQAIB                                      HWS07440
MIKE1 LD     2 VT180                                      HWS07450
      SRT      16
      D        *13
      S      2 VT072                                      HWS07460
      BNZ      MIKE2                                      HWS07470
      LD       TWO                                        HWS07480
      STO    2 VT074                                      HWS07490
      B     L  RQAIB                                      HWS07500
MIKE2 LD       THREE                                      HWS07510
      STO    2 VT074                                      HWS07520
      B     L  RQAIB                                      HWS07530
KLAGD DC       49
K1NUM DC       31
K2NUM DC.      9
YNM1  DC       *-*
UNM1  DC       *-*
TEMF  BSS   E  0
      DC       0
      DC       0
SWLAG DC       *-*
*
*  FINAL FUEL REQUEST IS LAGGED HERE
*
RUAIB EQU      *                                          HWS07540
      LD    L  SWLAG
      BNZ      FILT
      LD    L  *123
```

Table B-5. Equilibrium - Pressure Subprogram (Continued)

```
        STO  L  SWLAG
        LD    2 VT180
        STO  L  YNM1
        STO  L  UNM1
        B    L  DONOZ
FILT    LD   L  UNM1
        M    L  K2NUM
        STD  L  TEMF
        LD    2 VT180
        STO  L  UNM1
        M    L  K2NUM
        AD   L  TEMF
        STD  L  TEMF
        LD   L  YNM1
        M    L  K1NUM
        AD   L  TEMF
        D    L  KLAGD
        STO  L  YNM1
        STO   2 V7180
*
*  EXHAUST  NOZZLE REQUEST CALCULATION
*
DONOZ  EQU      *
        LD    2 VT074
        S    L  ONE
        BNZ     GT10
        LD    2 VT128
        STO  L  NA8
        B    L  CALA8
GT10    LD    2 VT157
        STO  L  NA8
CALA8  LD    L  NA8
        S    L  =14025
        BNN     GT11
        LD    2 VT034
        STO   2 VT081
        B    L  CONT
GT11    S    L  =2475
        BN      GT12
        LD    2 VT035
        STO   2 VT081
        B    L  CONT
GT12    LD    2 VT034
        S     2 VT035
        STO  L  ANOZN
        LD   L  =16500
        S    L  NA8
        M    L  ANOZN
        D    L  =2475
        A     2 VT035
        STO   2 VT081
        B    L  CONT
        LORG
NA8     DC      ***
ANOZN  DC      ***
CONT    EQU     *                                             HWS07700
XR1     LDX  L1 ***                                           HWS07710
        BSC  I  HAFCT                                         HWS07720
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
VT071 EQU    -71                                               HWS07730
VT072 EQU    -72                                               HWS07740
VT073 EQU    -73                                               HWS07750
VT074 EQU    -74                                               HWS07760
VT081 EQU    -81                                               HWS07770
VT082 EQU    -82                                               HWS07780
VT083 EQU    -83                                               HWS07790
VT157 EQU    +30                                               HWS07800
VT180 EQU    +53                                               HWS07810
VT128 EQU    +1                                                HWS07820
VT102 EQU    -102                                              HWS07830
VT108 EQU    -108                                              HWS07840
VT097 EQU    -97                                               HWS07850
VT036 EQU    -36                                               HWS07860
VT037 EQU    -37                                               HWS07870
VT038 EQU    -38                                               HWS07880
VT039 EQU    -39                                               HWS07890
VT162 EQU    +3E                                               HWS07900
VT163 EQU    +36                                               HWS07910
VT164 EQU    +37                                               HWS07920
VT163 EQU    +3A                                               HWS07930
VT166 EQU    +39                                               HWS07940
VT167 EQU    +40                                               HWS07950
VT168 EQU    +41                                               HWS07960
VT169 EQU    +42                                               HWS07970
VT170 EQU    +43                                               HWS07980
VT171 EQU    +44                                               HWS07990
VT172 EQU    +45                                               HWS08000
VT173 EQU    +46                                               HWS08010
VT174 EQU    +47                                               HWS08020
VT175 EQU    +48                                               HWS08030
VT176 EQU    +49                                               HWS08040
VT206 EQU    +79
VT207 EQU    +80
VT196 EQU    +69
VT197 EQU    +70
VT198 EQU    +71
VT199 EQU    +72
VT200 EQU    +73
VT201 EQU    +74
VT202 EQU    +75
VT203 EQU    +76
VT204 EQU    +77
VT205 EQU    +78
VT012 EQU    -12
VT013 EQU    -13
VT014 EQU    -14
VT015 EQU    -15
VT016 EQU    -16
VT017 EQU    -17
VT018 EQU    -18
VT019 EQU    -19
VT020 EQU    -20
VT021 EQU    -21
VT022 EQU    -22
VT023 EQU    -23
VT040 EQU    -40
VT041 EQU    -41
```

Table B-8. Equilibrium - Pressure Subprogram (Concluded)

```
VT042 EQU      *42
VT043 EQU      *43
VT044 EQU      *44
VT045 EQU      *45
VT046 EQU      *46
VT047 EQU      *47
VT048 EQU      *48
VT049 EQU      *49
VT050 EQU      *50
VT061 EQU      *61
VT062 EQU      *62
VT063 EQU      *63
VT064 EQU      *64
VT065 EQU      *65
VT066 EQU      *66
VT067 EQU      *67
VT068 EQU      *68
VT069 EQU      *69
VT034 EQU      *34
VT035 EQU      *35
      END
```

Table B-9. Standard Trim Adjustments in Bounds Program (Equilibrium Pressure)

```
// JOB          VDISK    12 JUN 74 08.612 HRS
// DMP    12 JUN 74 08.612 HRS
*DELETE                GTECT
DMP FUNCTION COMPLETED
// ASM GTECT    12 JUN 74 08.613 HRS                                           HWE00010
*OVERFLOW SECTORS ,,,9                                                         HWE00020
*LIST                                                                          HWE00030
*XREF                                                                          HWE00040
*ONE WORD INTEGERS                                                             HWE00050
*COMMON IDUMY(127),IVTOO,JDUMY(127),IWTO,MEAST(64),IASCW(2)                    HWE00060
0000      078C50E3      1            ENT      GTECT                                    HWE00070
0000 0    0000          2      GTECT DC       *-*                                      HWE00080
0001 01   6D000512      3            STX   L1 XR1+1                                    HWE00090
0003 01   6E000514      4            STX   L2 XR2+1                                    HWE00100
0005 01   6F000516      5            STX   L3 XR3+1                                    HWE00110
                        6      *                                                       HWE00120
0007 03   6700FEC0      7            LDX   L3 MEAST-63                                 HWE00130
0009 03   6600FF80      8            LDX   L2 IVT00                                    HWE00140
000B 00   65000000      9            LDX   L1 0                                        HWE00150
000D 0    C03F         10            LD       =0                                       HWE00160
                       11      *                                                       HWE00170
000E 01   4C00C0F7     12            B     L  START                                    HWE00180
0010                   13      RSTAL EQU      *              RESET ALL DIGITAL ADJUST  HWE00190
0010 0    C03E         14            LD       ST001                                    HWE00200
0011 0    D2FF         15            STO    2 VT001                                    HWE00210
0012 0    C03D         16            LD       ST002                                    HWE00220
0013 0    D2FE         17            STO    2 VT002                                    HWE00230
0014 0    C03C         18            LD       ST003                                    HWE00240
0015 0    D2FD         19            STO    2 VT003                                    HWE00250
0016 0    C03B         20            LD       ST004                                    HWE00260
0017 0    D2FC         21            STO    2 VT004                                    HWE00270
0018 0    C03A         22            LD       ST005                                    HWE00280
0019 0    D2FB         23            STO    2 VT005                                    HWE00290
001A 0    C039         24            LD       ST006                                    HWE00300
001B 0    D2FA         25            STO    2 VT006                                    HWE00310
001C 0    C038         26            LD       ST007                                    HWE00320
001D 0    D2F9         27            STO    2 VT007                                    HWE00330
001E 0    C037         28            LD       ST008                                    HWE00340
001F 0    D2F8         29            STO    2 VT008                                    HWE00350
0020 0    C036         30            LD       ST009                                    HWE00360
0021 0    D2F7         31            STO    2 VT009                                    HWE00370
0022 0    C035         32            LD       ST010                                    HWE00380
0023 0    D2F6         33            STO    2 VT010                                    HWE00390
0024 0    C034         34            LD       ST011                                    HWE00400
0025 0    D2F5         35            STO    2 VT011                                    HWE00410
0026 0    C033         36            LD       ST012                                    HWE00420
0027 0    D2F4         37            STO    2 VT012                                    HWE00430
0028 0    C032         38            LD       ST013                                    HWE00440
0029 0    D2F3         39            STO    2 VT013                                    HWE00450
002A 0    C031         40            LD       ST014                                    HWE00460
002B 0    D2F2         41            STO    2 VT014                                    HWE00470
002C 0    C030         42            LD       ST015                                    HWE00480
002D 0    D2F1         43            STO    2 VT015                                    HWE00490
002E 0    C02F         44            LD       ST016                                    HWE00500
002F 0    D2F0         45            STO    2 VT016                                    HWE00510
0030 0    C02E         46            LD       ST017                                    HWE00520
0031 0    D2EF         47            STO    2 VT017                                    HWE00530
0032 0    C02D         48            LD       ST018                                    HWE00540
0033 0    D2EE         49            STO    2 VT018                                    HWE00550
0034 0    C02C         50            LD       ST019                                    HWE00560
```

Table B-9. Standard Trim Adjustments in Bounds Program (Equilibrium Pressure) (Continued)

```
                                                    12 JUN 74     PAGE 002

0035 0  D2ED       51          STO    2 VT019                                  HWE00570
0036 0  C02B       52          LD       ST020                                  HWE00580
0037 0  D2EC       53          STO    2 VT020                                  HWE00590
0038 0  C02A       54          LD       ST021                                  HWE00600
0039 0  D2EB       55          STO    2 VT021                                  HWE00610
003A 0  C029       56          LD       ST022                                  HWE00620
003B 0  D2EA       57          STO    2 VT022                                  HWE00630
003C 0  C028       58          LD       ST023                                  HWE00640
003D 0  D2E9       59          STO    2 VT023                                  HWE00650
003E 0  C027       60          LD       ST024                                  HWE00660
003F 0  D2E8       61          STO    2 VT024                                  HWE00670
0040 0  C026       62          LD       ST025                                  HWE00680
0041 0  D2E7       63          STO    2 VT025                                  HWE00690
0042 0  C025       64          LD       ST026                                  HWE00700
0043 0  D2E6       65          STO    2 VT026                                  HWE00710
0044 0  C024       66          LD       ST027                                  HWE00720
0045 0  D2E5       67          STO    2 VT027                                  HWE00730
0046 0  C023       68          LD       ST028                                  HWE00740
0047 0  D2E4       69          STO    2 VT028                                  HWE00750
0048 0  C022       70          LD       ST029                                  HWE00760
0049 0  D2E3       71          STO    2 VT029                                  HWE00770
004A 0  C021       72          LD       ST030                                  HWE00780
004B 0  D2E2       73          STO    2 VT030                                  HWE00790
004C 0  7048       74          B        STTVT                                  HWE00800
                   75          LORG                                            HWE00810
004D 0  0000       76    +     DC       0
                   77    *                           SPEED CONTROL FIG10-3&4   HWE00820
004E 0  0000       78    ST000 DC       0                                      HWE00830
004F 0  0000       79    ST001 DC       0            IDLE SPEED TRIM           HWE00840
0050 0  0000       80    ST002 DC       0            MAX  SPEED TRIM           HWE00850
0051 0  4E20       81    ST003 DC       20000                                  HWE00860
0052 0  0000       82    ST004 DC       0                 BRANCH COMMAND  64+  HWE00870
0053 0  1000       83    ST005 DC       4096              N INTEGRATION INC    HWE00880
0054 0  1388       84    ST006 DC       5000              N INT PRESS GAIN     HWE00890
0055 0  F000       85    ST007 DC       -4096             N INT DECREASE       HWE00900
0056 0  EC78       86    ST008 DC       -5000             N INT DEC PRESS GAIN HWE00910
                   87    *                                                     HWE00920
                   88    *              FIG10-5   PROP.TEMPERATURE CONTROL     HWE00930
0057 0  0000       89    ST009 DC       0            SPEED CONTROL SELECTION   HWE00940
0058 0  32C8       90    ST010 DC       11000                                  HWE00950
0059 0  0000       91    ST011 DC       0            ZERO FLOW ADJUST          HWE00960
                   92    *           HONEYWELL ST VALUES
                   93    *
005A 0  F290       94    ST012 DC       -3440        N    GAIN (50 ,E)
005B 0  0177       95    ST013 DC       519          WF        (50 ,E)
005C 0  0000       96    ST014 DC       2200         PT3[illegible]      (50 ,E)
005D 0  0180       97    ST015 DC       432          EN   GAIN (50 ,E)
005E 0  F820       98    ST016 DC       -2016        N    GAIN (70 ,E)
005F 0  0315       99    ST017 DC       693          WF        (70 ,E)
0060 0  0000      100    ST018 DC       3550         PT3[illegible]      (70 ,E)
0061 0  0190      101    ST019 DC       400          EN   GAIN (70 ,E)
0062 0  F860      102    ST020 DC       -1952        N    GAIN (85 ,E)
0063 0  04A6      103    ST021 DC       934          WF        (85 ,E)
0064 0  0000      104    ST022 DC       3500         PT3[illegible]      (85 ,E)
0065 0  0380      105    ST023 DC       896          EN   GAIN (85 ,E)
                  106    *
                  107    *           END HONEYWELL ST VALUES
```

Table B-9. Standard Trim Adjustments in Bounds Program (Equilibrium Pressure) (Concluded)

```
                                                              12 JUN 74    PAGE 003

                   108   *
0066 0  1770       109   ST024 DC    6000      ZERO N RATIOS INTERCEPT    HWE01140
0067 0  A240       110   ST025 DC    -24000    BACK SLOPE SPEED BREAK PT  HWE01150
0068 0  4000       111   ST026 DC    16384
                   112   *                                                HWE01170
                   113   *                  FIGURE10-8   RATIOS INTEGRATIONHWE01180
0069 0  7FF8       114   ST027 DC    32760
006A 0  0000       115   ST028 DC    0
006B 0  0000       116   ST029 DC    0         MINIMUM RATIOS SLOPE       HWE01210
006C 0  5014       117   ST030 DC    20500     MINIMUM RATIOS LEVEL       HWE01220
006D 0  0000       118   ST031 DC    0                                    HWE01230
006E 0  7FF8       119   ST032 DC    32760     VALVE MAXIMUM POSITION     HWE01240
006F 0  0000       120   ST033 DC    0         VALVE MINIMUM POSITION     HWE01250
0070 0  25A8       121   ST034 DC    9640
0071 0  0A5A       122   ST035 DC    2650
                   123   *
                   124   *          HONEYWELL ST VALUES
                   125   *
0072 0  0640       126   ST036 DC    1600
0073 0  0640       127   ST037 DC    1600
0074 0  000A       128   ST038 DC    10
0075 0  0010       129   ST039 DC    16
0076 0  F0A0       130   ST040 DC    -3936     N   GAIN (100,E)
0077 0  0960       131   ST041 DC    1648      WF       (100,E)
0078 0  0000       132   ST042 DC    8000      PT3      (100,E)
0079 0  0930       133   ST043 DC    2352      EN  GAIN (100,E)
007A 0  0C11       134   ST044 DC    3089      FUG GAIN (50 ,P)
007B 0  23B0       135   ST045 DC    9136      PT5 GAIN (50 ,P)
007C 0  D610       136   ST046 DC    -10736    PT3 GAIN (50 ,P)
007D 0  030B       137   ST047 DC    651       EP  GAIN (50 ,P)
007E 0  2400       138   ST048 DC    9216      FUG GAIN (70 ,P)
007F 0  F5E0       139   ST049 DC    -2592     PT5 GAIN (70 ,P)
0080 0  F200       140   ST050 DC    -3584     PT3 GAIN (70 ,P)
                   141   *
                   142   *          END HONEYWELL ST VALUES
                   143   *
                   144   *                                                HWE01460
                   145   *                 FIGURE10-12  IGV & BLEED CONTR HWE01470
0081 0  0000       146   ST051 DC    0         LOW N TRIM OF IGV          HWE01480
0082 0  3E80       147   ST052 DC    16000     HIGH N TRIM OFIGV          HWE01490
0083 0  0000       148   ST053 DC    0         LOW N TRIM OF BLEEDS       HWE01500
0084 0  3E80       149   ST054 DC    16000     HIGH N TRIM OF BLEEDS      HWE01510
                   150   *                                                HWE01520
                   151   *                 FIGURE10-14 NOZZLE CONTROL     HWE01530
0085 0  105E       152   ST055 DC    4190      NOZZLE FLAT                BEN01530
0086 0  40D8       153   ST056 DC    16600     T5 REQUEST                 HWE01550
0087 0  4000       154   ST057 DC    16384     T5 CONTROL GAIN            HWE01560
0088 0  0000       155   ST058 DC    0                                    HWE01570
0089 0  0000       156   ST059 DC    0                                    HWE01580
008A 0  0000       157   ST060 DC    0                                    HWE01590
008B 0  06CC       158   ST061 DC    1000      EP  GAIN (70 ,P)
008C 0  03B0       159   ST062 DC    944       FUG GAIN (85 ,P)
008D 0  0B90       160   ST063 DC    2960      PT5 GAIN (85 ,P)
008E 0  EFE0       161   ST064 DC    -4128     PT3 GAIN (85 ,P)
008F 0  0A0D       162   ST065 DC    2000      EP  GAIN (85 ,P)
0090 0  16C0       163   ST066 DC    5824      FUG GAIN (100,P)
0091 0  09C0       164   ST067 DC    2496      PT5 GAIN (100,P)
0092 0  F4F0       165   ST068 DC    -2832     PT3 GAIN (100,P)
0093 0  0D96       166   ST069 DC    2400      EP  GAIN (100,P)
0094 0  0000       167   ST070 DC    0
```

Table B-10. Glossary for Equilibrium-Temperature Control

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
009	---	Logic switch: If VT009 > 123 the Honeywell controller is in; otherwise not	0
012	KEF11	Speed control gain associated with $(N-N_{pla})$ at 8250 rpm	(-215 x 16)
013	WEF1	Open-loop fuel-speed control at 8250 rpm	519 lb/hr
014	P3P1	Open-loop PT3-speed control at 8250 rpm	2200 psi x 100
015	KEF14	Speed control gain associated with EN at 825 rpm	(27) x 16
016	KEF21	Speed control gain associated with $(N-N_{pla})$ at 11,550 rpm	(-126) x 16
017	WEF2	Open-loop fuel-speed control at 11,550 rpm	693 lb/hr
018	P3P2	Open-loop PT3 - speed control at 11,550 rpm	3550 psi x 100
019	KEF24	Speed control gain associated with EN at 11,550 rpm	(25) x 16
020	KEF31	Speed control gain associated with $(N-N_{pla})$ at 14,025 rpm	(-122) x 16
021	WEF3	Open-loop fuel-speed control at 14,025 rpm	934 lb/hr
022	P3P3	Open-loop PT3-speed control at 14,025 rpm	5500 psi x 100
023	KEF34	Speed control gain associated with EN at 14,025 rpm	(56) x 16
026	---	If this number is made large, Bendix bound on fuel will not be in effect	2^{14}
028	---	Logical switch: if VTO28 = 64 Honeywell nozzle is used; otherwise not	0

Table B-16. Glossary for Equilibrium-Temperature Control (Continued)

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
034	---	Exhaust request: open	9640
035	---	Exhaust request: closed	2650
036	ENK, ENKL	Initial value of integral speed and limits valve	1600
038	ETK, ETKL	Initial value of integral temperature and limiting valve	25,600
039	---	Logical switch: VT089 = 16 initialize everything. VT039 = 64 initializes EN and ET only	16
040	KEF41	Speed control gain associated with $(N-N_{pla})$ at 16,500 rpm	(-246) x 16
041	WEF4	Open-loop fuel-speed control at 16,500 rpm	1648 lb/hr
042	P3P4	Open-loop PT3-speed control at 16,500 rpm	8000 psi x 100
043	KEF44	Speed control gain associated with EN at 16,500 rpm	(147) x 16
044	KTF11	Temperature control gain - $(PT5-PT5\delta)$ - at 8250 rpm	(557) x 16
045	KTF12	Temperature control gain - $(PT3-PT3\delta)$ - at 8250 rpm	(-736) x 16
046	KTF13	Temperature control gain - $(T4WF - T4\delta)$ at 8250 rpm	(-105) x 16
047	KTF14	Temperature control gain - ET at 8250 rpm	(52) x 16
048	WTF1	Open-loop fuel-temperature control - at 8250 rpm	651 lb/hr
049	KTF21	Temperature control gain - $(PT5-PT5\delta)$ at 11,550 rpm	(936) x 16
050	KTF22	Temperature control gain - $(PT3-PT3\delta)$ at 11,550 rpm	24585

Table B-10. Glossary for Equilibrium-Temperature Control (Continued)

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
061	KTF23	Temperature control gain - (T4WF-T4δ) at 11,550 rpm	(-131) x 16
062	KTF24	Temperature control gain - ET at 11,550 rpm	(65) x 16
063	WTF2	Open-loop fuel - temperature control at 11,550 rpm	1000 lb/hr
064	KTF31	Temperature control gain - (PT5-PT5δ) at 14,025 rpm	(-343) x 16
065	KTF32	Temperature control gain - (PT3-PT3δ) at 14,025 rpm	4235
066	KTF33	Temperature control gain - (T4WF - T4δ) at 14,025 rpm	(-87) x 16
067	KTF34	Temperature control gain - ET at 14,025 rpm	(74) x 16
068	WTF3	Open-loop fuel - temperature control at 14,025 rpm	2000 lb/hr
069	KTF41	Temperature control gain - (PT5-PT5δ) at 16,500 rpm	6127
071	---	Fuel request - speed control 1 count = 4 lb/hr	0
073	---	Fuel request - temperature control, 1 count = 4 lb/hr	0
074	---	Mode number 3276 = speed control 6552 = temperature control 9828 = minimum fuel control	0
075	KTF42	Temperature control gain - (PT3-PT3δ) at 16,500 rpm	-8338
076	KTF43	Temperature control gain - (T4WF-T4δ)	(-4) x 16
077	KTF44	---	(108) x 16

Table B-10. Glossary for Equilibrium-Temperature Control (Concluded)

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
078	WTF4	---	2400 lb/hr
081	---	Nozzle fuel request	---
082	TB1	T4δ at 8250 rpm	10,200 °F x 10
083	TB2	T4δ at 11,550 rpm	9000 °F x 10
084	TB3	T4δ at 14,025 rpm	10,500 °F x 10
085	TB4	T4δ at 16,500 rpm	11,600 °F x 10
086	P5T1	PT5δ at 8250 rpm	1480 psi x 100
087	P5T2	PT5δ at 11,550 rpm	1640 psi x 100
088	P5T3	PT5δ at14,025 rpm	2050 psi x 100
089	P5T4	PT5δ at 16,500 rpm	2550 psi x 100
180	---	Fuel request 3.25 counts = 1 lb/hr	---

Table B-11. Honeywell Control Program

```
// JOB          VDISK   17 JUL 74 15.584 HRS
// DMP   17 JUL 74  15.585 HRS
*DELETE               HWECT
DMP FUNCTION COMPLETED
// ASM   17 JUL 74 15.586 HRS
*OVERFLOW SECTORS ,,,9
*LIST
*XREF
*ONEWORDINTEGERS
*COMMON IDUMY(127),IVT00,JDUMY(127),IBT0,MEAST(64),IASCW(2)
0000     089850E3      1           ENT      HWECT                          HWS00070
0000 0   0000          2     HWECT DC       *-*                            HWS00080
0001 01  6D00050A      3           STX  L1  XR1+1                          HWS00090
                       4     *                                             HWS00100
0003 00  65000000      5           LDX  L1  0                              HWS00110
0005 01  4C000007      6           B    L   TESTN                          HWS00120
                       7     *                                             HWS00160
                       8     *INTERVAL DETERMINATION                       HWS00170
                       9     *                                             HWS00180
0007                  10     TESTN EQU      *                              HWS00190
0007 0   C2D9         11           LD     2 VT039
0008 01  940000BC     12           S    L   =16
000A 01  4C2000AD     13           BNZ      MICK
000C 0   D2D9         14           STO    2 VT039
000D 0   C2F4         15           LD     2 VT012
000E 0   1884         16           SRT      4
000F 01  D40000FC     17           STO  L   KEF11
0011 0   C2F3         18           LD     2 VT013
0012 01  D4000100     19           STO  L   WEF1
0014 0   C2F2         20           LD     2 VT014
0015 01  D4000108     21           STO  L   P3T1
0017 0   C2F1         22           LD     2 VT015
0018 0   1884         23           SRT      4
0019 01  D40000FF     24           STO  L   KEF14
001B 0   C2F0         25           LD     2 VT016
001C 0   1884         26           SRT      4
001D 01  D4000135     27           STO  L   KEF21
001F 0   C2EF         28           LD     2 VT017
0020 01  D4000139     29           STO  L   WEF2
0022 0   C2EE         30           LD     2 VT018
0023 01  D4000141     31           STO  L   P3T2
0025 0   C2ED         32           LD     2 VT019
0026 0   1884         33           SRT      4
0027 01  D400013B     34           STO  L   KEF24
0029 0   C2EC         35           LD     2 VT020
002A 0   1884         36           SRT      4
002B 01  D400016B     37           STO  L   KEF31
002D 0   C2EB         38           LD     2 VT021
002E 01  D400016F     39           STO  L   WEF3
0030 0   C2EA         40           LD     2 VT022
0031 01  D4000177     41           STO  L   P3T3
0033 0   C2E9         42           LD     2 VT023
0034 0   1884         43           SRT      4
0035 01  D400016E     44           STO  L   KEF34
0037 0   C2D8         45           LD     2 VT040
0038 0   1884         46           SRT      4
0039 01  D40001A1     47           STO  L   KEF41
003B 0   C2D7         48           LD     2 VT041
003C 01  D40001A5     49           STO  L   WEF4
003E 0   C2D6         50           LD     2 VT042
```

Table B-11. Honeywell Control Program (Continued)

```
                                                                 17 JUL 74      PAGE 002

    003F 01 D40001AD     51             STO   L   P3T4
    0041 0  C2D5         52             LD      2 VT043
    0042 0  1884         53             SRT       4
    0043 01 D40001A4     54             STO   L   KEF44
    0045 0  C2D4         55             LD      2 VT044
    0046 0  1884         56             SRT       4
    0047 01 D4000103     57             STO   L   KTF11
    0049 0  C2D3         58             LD      2 VT045
    004A 0  1884         59             SRT       4
    004B 01 D4000104     60             STO   L   KTF12
    004D 0  C2D2         61             LD      2 VT046
    004E 0  1884         62             SRT       4
    004F 01 D4000105     63             STO   L   KTF13
    0051 0  C2D1         64             LD      2 VT047
    0052 0  1884         65             SRT       4
    0053 01 D4000106     66             STO   L   KTF14
    0055 0  C2D0         67             LD      2 VT048
    0056 01 D4000107     68             STO   L   WTF1
    0058 0  C2C          69             LD      2 VT049
    0059 0  1884         70             SRT       4
    005A 01 D400013C     71             STO   L   KTF21
    005C 0  C2CE         72             LD      2 VT050
    005D 01 D400013D     73             STO   L   KTF22
    005F 0  C2C3         74             LD      2 VT061
    0060 0  1884         75             SRT       4
    0061 01 D400013E     76             STO   L   KTF23
    0063 0  C2C2         77             LD      2 VT062
    0064 0  1884         78             SRT       4
    0065 01 D400013F     79             STO   L   KTF24
    0067 0  C2C1         80             LD      2 VT063
    0068 01 D4000140     81             STO   L   WTF2
    006A 0  C2C0         82             LD      2 VT064
    006B 0  1884         83             SRT       4
    006C 01 D4000172     84             STO   L   KTF31
    006E 0  C2BF         85             LD      2 VT065
    006F 01 D4000173     86             STO   L   KTF32
    0071 0  C2BE         87             LD      2 VT066
    0072 0  1884         88             SRT       4
    0073 01 D4000174     89             STO   L   KTF33
    0075 0  C2BD         90             LD      2 VT067
    0076 0  1884         91             SRT       4
    0077 01 D4000175     92             STO   L   KTF34
    0079 0  C2BC         93             LD      2 VT068
    007A 01 D4000176     94             STO   L   WTF3
    007C 0  C2BB         95             LD      2 VT069
    007D 01 D40001A8     96             STO   L   KTF41
    007F 0  C2B5         97             LD      2 VT075
    0080 01 D40001A9     98             STO   L   KTF42
    0082 0  C2B4         99             LD      2 VT076
    0083 0  1884        100             SRT       4
    0084 01 D40001AA    101             STO   L   KTF43
    0086 0  C2B3        102             LD      2 VT077
    0087 0  1884        103             SRT       4
    0088 01 D40001AB    104             STO   L   KTF44
    008A 0  C2B2        105             LD      2 VT078
    008B 01 D40001AC    106             STO   L   WTF4
    008D 01 C400005D    107             LD    L   =0
```

Table B-11. Honeywell Control Program (Continued)

```
                                                      17 JUL 74     PAGE 003

 008F 01 D40004AC    108             STO   L  SWLAG
 0091 01 D4000287    109             STO   L  TIME
 0093 01 D40001FD    110             STO   L  ISW
 0095 0  C2AE        111             LD      2 VT082
 0096 01 D400010A    112             STO   L  TB1
 0098 0  C2AD        113             LD      2 VT083
 0099 01 D4000143    114             STO   L  TB2
 009B 0  C2AC        115             LD      2 VT084
 009C 01 D4000179    116             STO   L  TB3
 009E 0  C2AB        117             LD      2 VT085
 009F 01 D40001AF    118             STO   L  TB4
 00A1 0  C2AA        119             LD      2 VT086
 00A2 01 D4000109    120             STO   L  P5T1
 00A4 0  C2A9        121             LD      2 VT087
 00A5 01 D4000142    122             STO   L  P5T2
 00A7 0  C2A8        123             LD      2 VT088
 00A8 01 D4000178    124             STO   L  P5T3
 00AA 0  C2A7        125             LD      2 VT089
 00AB 01 D40001AE    126             STO   L  P5T4
 00AD                127      MICK   EQU      *
 00AD 0  C21E        128             LD      2 VT157                            HWS00200
 00AE 0  900F        129             S        =8250                             HWS00210
 00AF 01 4C3000C1    130             BP       TMAX                              HWS00220
 00B1 0  C00D        131             LD       =1                                HWS00230
 00B2 0  D008        132             STO      NIN                               HWS00240
 00B3 0  C00C        133             LD       =128
 00B4 0  D004        134             STO      C1                                HWS00260
 00B5 0  C007        135             LD       =0                                HWS00270
 00B6 0  D003        136             STO      C2                                HWS00280
 00B7 01 4C000114    137             B     L  IN1F                              HWS00290
 00B9 0  0000        138      C1     DC       *-*                               HWS00130
 00BA 0  0000        139      C2     DC       *-*                               HWS00140
 00BB 0  0000        140      NIN    DC       *-*                               HWS00150
                     141             LORG
 00BC 0  0010        142      +      DC       16
 00BD 0  0000        143      +      DC       0
 00BE 0  203A        144      +      DC       8250
 00BF 0  0001        145      +      DC       1
 00C0 0  0080        146      +      DC       128
 00C1 0  C033        147      TMAX   LD       =16500                            HWS00300
 00C2 0  921E        148             S       2 VT157                            HWS00310
 00C3 01 4C3000CD    149             BP       TIN1                              HWS00320
 00C5 0  C030        150             LD       =3                                HWS00330
 00C6 0  D0F4        151             STO      NIN                               HWS00340
 00C7 0  C0F5        152             LD       =0                                HWS00350
 00C8 0  D0F0        153             STO      C1                                HWS00360
 00C9 0  C0F6        154             LD       =128
 00CA 0  D0EF        155             STO      C2                                HWS00380
 00CB 01 4C000180    156             B     L  IN3F                              HWS00390
 00CD 0  C029        157      TIN1   LD       =11550                            HWS00400
 00CE 0  921E        158             S       2 VT157                            HWS00410
 00CF 01 4C2800D8    159             BN       TIN2                              HWS00420
 00D1 0  1889        160             SRT      9
 00D2 0  A825        161             D        =3300                             HWS00440
 00D3 0  D0E5        162             STO      C1                                HWS00450
 00D4 0  C0E8        163             LD       =128
 00D5 0  90E3        164             S        C1                                HWS00470
```

Table B-11. Honeywell Control Program (Continued)

```
                                                  17 JUL 74      PAGE 004

00D6 0  D0E3        165         STO     C2                                  HWS00480
00D7 0  C0E7        166         LD      =1                                  HWS00490
00D8 0  D0E2        167         STO     NIN                                 HWS00500
00D9 01 4C000114    168         B    L  IN1F                                HWS00510
00DB 0  C01D        169  TIN2   LD      =14025                              HWS00520
00DC 0  921E        170         S    2  VT157                               HWS00530
00DD 01 4C2800E9    171         BN      TIN3                                HWS00540
00DF 0  1889        172         SRT     9
00E0 0  A819        173         D       =2475                               HWS00560
00E1 0  D0D7        174         STO     C1                                  HWS00570
00E2 0  C0DD        175         LD      =128
00E3 0  90D5        176         S       C1                                  HWS00590
00E4 0  D0D5        177         STO     C2                                  HWS00600
00E5 0  C015        178         LD      =2                                  HWS00610
00E6 0  D0D4        179         STO     NIN                                 HWS00620
00E7 01 4C00014A    180         B    L  IN2F                                HWS00630
00E9 0  C00B        181  TIN3   LD      =16500                              HWS00640
00EA 0  921E        182         S    2  VT157                               HWS00650
00EB 0  1889        183         SRT     9
00EC 0  A80D        184         D       =2475                               HWS00670
00ED 0  D0CB        185         STO     C1                                  HWS00680
00EE 0  C0D1        186         LD      =128
00EF 0  90C9        187         S       C1                                  HWS00700
00F0 0  D0C9        188         STO     C2                                  HWS00710
00F1 0  C004        189         LD      =3                                  HWS00720
00F2 0  D0C8        190         STO     NIN                                 HWS00730
00F3 01 4C000180    191         B    L  IN3F                                HWS00740
                    192         LORG                                        HWS00750
00F5 0  4074        193  +      DC      16500
00F6 0  0003        194  +      DC      3
00F7 0  2D1E        195  +      DC      11550
00F8 0  0CE4        196  +      DC      3300
00F9 0  36C9        197  +      DC      14025
00FA 0  09AB        198  +      DC      2475
00FB 0  0002        199  +      DC      2
                    200  *         EQULIBRIUM FUEL FLOW 50 GAINS            HWS00760
00FC 0  0000        201  KEF11  DC      *-*
00FD 0  0000        202  KEF12  DC      0
00FE 0  0000        203  KEF13  DC      0
00FF 0  0000        204  KEF14  DC      *-*
0100 0  0000        205  WEF1   DC      *-*
0101 0  0A91        206  P3E1   DC      2705
0102 0  0661        207  P5E1   DC      1633
                    208  *         TEMPERATURE FUEL FLOW 50 GAINS           HWS00920
0103 0  0000        209  KTF11  DC      *-*
0104 0  0000        210  KTF12  DC      *-*
0105 0  0000        211  KTF13  DC      *-*
0106 0  0000        212  KTF14  DC      *-*
0107 0  0000        213  HTF1   DC      *-*
0108 0  0000        214  P3T1   DC      *-*
0109 0  0000        215  P5T1   DC      *-*
010A 0  0000        216  TB1    DC      *-*
010B 0  028A        217  WFMN1  DC      650
010C 0  0001        218  BUMP1  DC      1                                   HWS00980
010D 0  0000        219  SETX1  DC      0                                   HWS00990
010E 0  0010        220  NGFT   DC      16
010F 0  0000        221  C11    DC      *-*                                 HWS01010
```

Table B-11. Honeywell Control Program (Continued)

```
                                                    17 JUL 74      PAGE 005

0110 0  0000          222   C21   DC       *-*                         HWS01020
0111 0  0000          223   TST1  DC       *-*                         HWS01040
0112    0000          224   SUM1  BSS   E  0
0112 0  0000          225         DC       0
0113 0  0000          226         DC       0
0114                  227   IN1F  EQU      *                           HWS01050
0114 01 C40000B9      228         LD    L  C1                          HWS01060
0116 0  D0F8          229         STO      C11                         HWS01070
0117 01 C40000BA      230         LD    L  C2                          HWS01080
0119 0  D0F6          231         STO      C21                         HWS01090
011A 01 C400010D      232         LD    L  SETX1                       HWS01100
011C 0  D0F4          233         STO      TST1                        HWS01110
011D 01 65800111      234   LUP1  LDX   I1 TST1                        HWS01120
011F 01 C50000FC      235         LD    L1 KEF11                       HWS01130
0121 0  A0ED          236         M        C11                         HWS01140
0122 0  D8EF          237         STD      SUM1
0123 01 C5000135      238         LD    L1 KEF21                       HWS01170
0125 0  A0EA          239         M        C21                         HWS01180
0126 0  88EB          240         AD       SUM1
0127 0  1887          241         SRT      7
0128 0  1090          242         SLT      16
0129 01 D5000406      243         STO   L1 KEFN1                       HWS01220
012B 0  C0E5          244         LD       TST1                        HWS01230
012C 01 8400010C      245         A     L  BUMP1                       HWS01240
012E 0  D0E2          246         STO      TST1                        HWS01250
012F 01 9400010E      247         S     L  NGFT                        HWS01260
0131 01 4C28011D      248         BN       LUP1                        HWS01270
0133 01 4C0001B1      249         B     L  FUELM                       HWS01280
                      250   *        EQUILIBRIUM FUEL FLOW 70 GAINS    HWS01290
0135 0  0000          251   KEF21 DC       *-*
0136 0  0000          252   KEF22 DC       0
0137 0  0000          253   KEF23 DC       0
0138 0  0000          254   KEF24 DC       *-*
0139 0  0000          255   WEF2  DC       *-*
013A 0  1109          256   P3E2  DC       4361
013B 0  0765          257   P5E2  DC       1893
                      258   *        TEMPERATURE FUEL FLOW 70 GAINS    HWS01450
013C 0  0000          259   KTF21 DC       *-*
013D 0  0000          260   KTF22 DC       *-*
013E 0  0000          261   KTF23 DC       *-*
013F 0  0000          262   KTF24 DC       *-*
0140 0  0000          263   WTF2  DC       *-*
0141 0  0000          264   P3T2  DC       *-*
0142 0  0000          265   P5T2  DC       *-*
0143 0  0000          266   TB2   DC       *-*
0144 0  0472          267   WFMN2 DC       1138
0145 0  0000          268   C12   DC       *-*                         HWS01510
0146 0  0000          269   C22   DC       *-*                         HWS01520
0147 0  0000          270   TST2  DC       *-*                         HWS01540
0148    0000          271   SUM2  BSS   E  0
0148 0  0000          272         DC       0
0149 0  0000          273         DC       0
014A                  274   IN2F  EQU      *                           HWS01550
014A 01 C40000B9      275         LD    L  C1                          HWS01560
014C 0  D0F8          276         STO      C12                         HWS01570
014D 01 C40000BA      277         LD    L  C2                          HWS01580
014F 0  D0F6          278         STO      C22                         HWS01590
```

Table B-11. Honeywell Control Program (Continued)

```
                                                     17 JUL 74     PAGE 006

0150 01 C400010D   279          LD    L  SETX1                              HWS01600
0152 0  D0F4       280          STO      TST2                               HWS01610
0153 01 65800147   281    LUP2  LDX   I1 TST2                               HWS01620
0155 01 C5000135   282          LD    L1 KEF21                              HWS01630
0157 0  A0ED       283          M        C12                                HWS01640
0158 0  D8EF       284          STD      SUM2
0159 01 C5000168   285          LD    L1 KEF31                              HWS01670
015B 0  A0EA       286          M        C22                                HWS01680
015C 0  88EB       287          AD       SUM2
015D 0  1887       288          SRT      7
015E 0  1090       289          SLT      16
015F 01 D5000406   290          STD   L1 KEFN1                              HWS01720
0161 0  C0E5       291          LD       TST2                               HWS01730
0162 01 8400010C   292          A     L  BUMP1                              HWS01740
0164 0  D0E2       293          STO      TST2                               HWS01750
0165 01 9400010E   294          S     L  NGFT                               HWS01760
0167 01 4C280153   295          BN       LUP2                               HWS01770
0169 01 4C0001B1   296          B     L  FUELM                              HWS01780
                   297    *        EQUILIBRIUM FUEL FLOW 85 GAINS           HWS01790
0168 0  0000       298    KEF31 DC       *-*
016C 0  0000       299    KEF32 DC       0
016D 0  0000       300    KEF33 DC       0
016E 0  0000       301    KEF34 DC       *-*
016F 0  0000       302    WEF3  DC       *-*
0170 0  1811       303    P3E3  DC       6161
0171 0  08C3       304    P5E3  DC       2243
                   305    *        TEMPERATURE FUEL FLOW 85 GAINS           HWS01950
0172 0  0000       306    KTF31 DC       *-*
0173 0  0000       307    KTF32 DC       *-*
0174 0  0000       308    KTF33 DC       *-*
0175 0  0000       309    KTF34 DC       *-*
0176 0  0000       310    WTF3  DC       *-*
0177 0  0000       311    P3T3  DC       *-*
0178 0  0000       312    P5T3  DC       *-*
0179 0  0000       313    TB3   DC       *-*
017A 0  0659       314    WFMN3 DC       1625
017B 0  0000       315    C13   DC       *-*                                HWS02010
017C 0  0000       316    C23   DC       *-*                                HWS02020
017D 0  0000       317    TST3  DC       *-*                                HWS02040
017E    0000       318    SUM3  BSS   E  0
017E 0  0000       319          DC       0
017F 0  0000       320          DC       0
0180               321    IN3F  EQU      *                                  HWS02050
0180 01 C40000B9   322          LD    L  C1                                 HWS02060
0182 0  D0F8       323          STO      C13                                HWS02070
0183 01 C40000BA   324          LD    L  C2                                 HWS02080
0185 0  D0F6       325          STO      C23                                HWS02090
0186 01 C400010D   326          LD    L  SETX1                              HWS02100
0188 0  D0F4       327          STO      TST3                               HWS02110
0189 01 6580017D   328    LUP3  LDX   I1 TST3                               HWS02120
018B 01 C500016B   329          LD    L1 KEF31                              HWS02130
018D 0  A0ED       330          M        C13                                HWS02140
018E 0  D8EF       331          STD      SUM3
018F 01 C50001A1   332          LD    L1 KEF41                              HWS02170
0191 0  A0EA       333          M        C23                                HWS02180
0192 0  88EB       334          AD       SUM3
0193 0  1887       335          SRT      7
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Table B-11. Honeywell Control Program (Continued)

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                                                          17 JUL 74      PAGE 007

0194 0  1090         336              SLT      15
0195 01 D5000406     337              STO   L1 KEFN1                                  HWS02220
0197 0  C0E5         338              LD       TST3                                   HWS02230
0198 01 8400010C     339              A     L  BUMP1                                  HWS02240
019A 0  D0E2         340              STO      TST3                                   HWS02250
019B 01 9400010E     341              S     L  NGFT                                   HWS02260
019D 01 4C280189     342              BN       LUP3                                   HWS02270
019F 01 4C0001B1     343              B     L  FUELM                                  HWS02280
                     344        *       EQUILIBRIUM FUEL FLOW 100 GAINS               HWS02290
01A1 0  0000         345        KEF41 DC       *-*
01A2 0  0000         346        KEF42 DC       0
01A3 0  0000         347        KEF43 DC       0
01A4 0  0000         348        KEF44 DC       *-*
01A5 0  0000         349        WEF4  DC       *-*
01A6 0  277E         350        P3E4  DC       10110
01A7 0  0F94         351        P5E4  DC       3988
                     352        *       TEMPERATURE FUEL FLOW 100 GAINS               HWS02450
01A8 0  0000         353        KTF41 DC       *-*
01A9 0  0000         354        KTF42 DC       *-*
01AA 0  0000         355        KTF43 DC       *-*
01AB 0  0000         356        KTF44 DC       *-*
01AC 0  0000         357        WTF4  DC       *-*
01AD 0  0000         358        P3T4  DC       *-*
01AE 0  0000         359        P5T4  DC       *-*
01AF 0  0000         360        T84   DC       *-*
01B0 0  0CB2         361        WFMN4 DC       3250
01B1                 362        FUELM EQU      *                                      HWS02510
01B1                 363        FT4W  EQU      *
01B1 0  C29A         364              LD     2 VT102         LOAD PBX100
01B2 0  9032         365              S        =5850
01B3 01 4C3001CD     366              BP       NEXT
01B5 0  C030         367              LD       =1553
01B6 0  A030         368              M        =100
01B7 01 DC0001F2     369              STD   L  TMPF
01B9 0  C29A         370              LD     2 VT102
01BA 0  A02D         371              M        =6
01BB 01 8C0001F2     372              AD    L  TMPF
01BD 0  A828         373              D        =3400
01BF 01 D40001FB     374              STO   L  K1THD
01C0 0  C29A         375              LD     2 VT102
01C1 0  A028         376              M        =200
01C2 01 DC0001F2     377              STD   L  TMPF
01C4 0  C026         378              LD       =15100
01C5 0  A021         379              M        =100
01C6 01 9C0001F2     380              SD    L  TMPF
01C8 0  A820         381              D        =3400
01C9 01 D40001FC     382              STO   L  TAU2T
01CB 01 4C0001E3     383              B     L  FT4WC
01CD 0  C01E         384        NEXT  LD       =2202
01CE 0  A018         385              M        =100
01CF 01 DC0001F2     386              STD   L  TMPF
01D1 0  C29A         387              LD     2 VT102
01D2 0  A01A         388              M        =4
01D3 01 8C0001F2     389              AD    L  TMPF
01D5 0  A818         390              D        =4350
01D6 01 D40001FB     391              STO   L  K1THD
01D8 0  C29A         392              LD     2 VT102
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Table B-11. Honeywell Control Program (Continued)

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                                                                17 JUL 74     PAGE 008

 01D9 0  A015        393               M        =20
 01DA 01 DC0001F2    394               STD   L  TMPF
 01DC 0  C013        395               LD       =5520
 01DD 0  A009        396               M        =100
 01DE 01 9C0001F2    397               SD    L  TMPF
 01E0 0  A80D        398               D        =4350
 01E1 01 D40001FC    399               STO   L  TAU2T
 01E3 01 4C0001FE    400        FT4WC  B     L  STP1
                     401               LORG
 01E5 0  16DA        402      +        DC       5850
 01E6 0  0611        403      +        DC       1553
 01E7 0  0064        404      +        DC       100
 01E8 0  0006        405      +        DC       6
 01E9 0  0D48        406      +        DC       3400
 01EA 0  00C8        407      +        DC       200
 01EB 0  3AFC        408      +        DC       15100
 01EC 0  089A        409      +        DC       2202
 01ED 0  0004        410      +        DC       4
 01EE 0  10FE        411      +        DC       4350
 01EF 0  0014        412      +        DC       20
 01F0 0  1590        413      +        DC       5520
 01F2    0000        414        TMPF   BSS   E  0
 01F2 0  0000        415               DC       0
 01F3 0  0000        416               DC       0
 01F4    0000        417        XT4    BSS   E  0
 01F4 0  0000        418               DC       0
 01F5 0  0000        419               DC       0
 01F6    0000        420        XT4D   BSS   E  0
 01F6 0  0000        421               DC       0
 01F7 0  0000        422               DC       0
 01F8    0000        423        XT4D1  BSS   F  0
 01F8 0  0000        424               DC       0
 01F9 0  0000        425               DC       0
 01FA 0  0000        426        T4WF   DC       *-*
 01FB 0  0000        427        K1THD  DC       *-*
 01FC 0  0000        428        TAU2T  DC       *-*
 01FD 0  0000        429        ISW    DC       0
 01FE 01 C4000280    430        STP1   LD    L  =1234
 0200 0  90FC        431               S        ISW
 0201 01 4C18020E    432               BZ       STP2
 0203 0  D0F9        433               STO      ISW
 0204 01 C40000BD    434               LD    L  =0
 0206 0  1890        435               SRT      16
 0207 0  D8EE        436               STD      XT4D
 0208 0  D8EF        437               STD      XT4D1
 0209 0  C29F        438               LD     2 VT097
 020A 0  1890        439               SRT      16
 020B 0  D0E8        440               STD      XT4
 020C 01 4C000219    441               B     L  STP3
 020E 01 C40000BD    442        STP2   LD    L  =0
 0210 0  1890        443               SRT      16
 0211 0  C29F        444               LD     2 VT097
 0212 0  1890        445               SRT      16
 0213 0  98E0        446               SD       XT4
 0214 0  A3E6        447               D        K1THD
 0215 0  A0D1        448               M        =100
 0216 0  A8E5        449               D        TAU2T
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Table B-11. Honeywell Control Program (Continued)

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                                                            17 JUL 74     PAGE 009

 0217 0  A069        450            M          =10
 0218 0  D8DD        451            STD        XT4D
 0219 0  C8DC        452     STP3   LDD        XT4D          *** UPDATE D E  ***
 021A 0  88DD        453            AD         XT4D1
 021B 0  A866        454            D          =50
 021C 01 A400028E    455            M       L  DT
 021E 0  A864        456            D          =40
 021F 0  1890        457            SRT        16
 0220 0  88D3        458            AD         XT4
 0221 0  D8D2        459            STD        XT4
 0222 0  D2B0        460            STO     2  VT080         *** MOST SIGNIFICANT PART
 0223 0  1090        461            SLT        16                OF XT4
 0224 0  D2A6        462            STO     2  VT090             LEAST SIGNIFICANT PART
 0225 0  C8D0        463            LDD        XT4D
 0226 0  D8D1        464            STD        XT4D1         *** CALCULATE T4WF ***
 0227 0  A859        465            D          =10
 0228 0  A0D3        466            M          TAU2T
 0229 0  88CA        467            AD         XT4
 022A 0  1090        468            SLT        16
 022B 0  D0CE        469            STO        T4WF
 022C 0  D24C        470            STO     2  VT203
 022D 0  C2D9        471            LD      2  VT039                              HWS02520
 022E 0  9055        472            S          =64                                HWS02530
 022F 01 4C20024B    473            BNZ        MDW9                               HWS02540
 0231 0  D2D9        474            STO     2  VT039
 0232 0  C20C        475            LD      2  VT036                              HWS02550
 0233 0  D05B        476            STO        ENK
 0234 01 4C100238    477            BNN        SENL
 0236 0  C04E        478            LD         =0
 0237 0  9057        479            S          ENK
 0238 0  D057        480     SENL   STD        ENKL
 0239 0  C2DB        481            LD      2  VT037                              HWS02570
 023A 0  1884        482            SRT        4
 023B 0  D055        483            STD        EPK
 023C 01 4C100240    484            BNN        SEPL
 023E 0  C046        485            LD         =0
 023F 0  9051        486            S          EPK
 0240 0  D051        487     SEPL   STO        EPKL
 0241 0  C2DA        488            LD      2  VT038                              HWS02590
 0242 01 D4000293    489            STO     L  ETK
 0244 01 4C100249    490            BNN        SETL
 0246 0  C03E        491            LD         =0
 0247 01 94000293    492            S       L  ETK
 0249 01 D4000294    493     SETL   STU     L  ETKL
 024B                494     MDW9   EQU        *                                  HWS02610
                     495     *                                                    HWS02620
                     496     *                                                    HWS02630
                     497     *                                                    HWS02640
                     498     *                                                    HWS02650
                     499     *    THIS SECTION OF THE PROGRAM                     HWS02660
                     500     *    WILL SET UP THE MEASUREMENT FEED-BACK           HWS02670
                     501     *    VECTOR FOR THE THREE CONTROLLERS                HWS02680
                     502     *    EQUILIBPIUM,PRESSURE,TEMPERATURE                HWS02690
                     503     *                                                    HWS02700
                     504     *                                                    HWS02710
                     505     *                                                    HWS02720
                     506     * CALCULATE DERIVATIVES FOR EN EP ET                 HWS02730
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Table B-11. Honeywell Control Program (Continued)

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                                                        17 JUL 74      PAGE 010

                         507     *                                                      HWS02740
  024B 0  C201           508           LD     2 VT128                                   HWS02750
  024C 0  921E           509           S      2 VT157                                   HWS02760
  024D 0  D03A           510           STO      ENDK                                    HWS02770
  024E 01 C4000412       511           LD     L P3TNB
  0250 0  929A           512           S      2 VT102
  0251 0  D038           513           STO      EPDK                                    HWS02840
  0252 01 C4000414       514           LD     L TBBN          *** CALCULATE ETDOT ***
  0254 0  90A5           515           S        T4WF
  0255 01 D400028C       516           STO    L ETDK
  0257 0  C02F           517           LD       TIME                                    HWS02900
  0258 01 4C200295       518           BNZ      INTEG                                   HWS02910
  025A 01 C400046A       519           LD     L ONE
  025C 0  D2B6           520           STO    2 VT074
  025D 0  C02A           521           LD       ENDK                                    HWS02920
  025E 0  D02A           522           STO      ENDK1                                   HWS02930
  025F 0  C02A           523           LD       EPDK                                    HWS02940
  0260 0  D02A           524           STO      EPDK1                                   HWS02950
  0261 0  C02A           525           LD       ETDK                                    HWS02960
  0262 0  D02A           526           STO      ETDK1                                   HWS02970
  0263 0  C2DC           527           LD     2 VT036                                   HWS02980
  0264 0  D02A           528           STO      ENK                                     HWS02990
  0265 01 4C100269       529           BNN      STENL
  0267 0  C01D           530           LD       =0
  0268 0  9026           531           S        ENK
  0269 0  D026           532     STENL STO      ENKL
  026A 0  C2DD           533           LD     2 VT037                                   HWS03010
  026B 0  1884           534           SRT      4
  026C 0  D024           535           STO      EPK                                     HWS03030
  026D 01 4C100271       536           BNN      STEPL
  026F 0  C015           537           LD       =0
  0270 0  9020           538           S        EPK
  0271 0  D020           539     STEPL STO      EPKL
  0272 0  C2DA           540           LD     2 VT038                                   HWS03050
  0273 01 D4000293       541           STO    L ETK
  0275 01 4C10027A       542           BNN      STETL
  0277 0  C000           543           LD       =0
  0278 01 94000293       544           S      L ETK
  027A 01 D4000294       545     STETL STO    L ETKL
  027C 0  C009           546           LD       =1                                      HWS03080
  027D 0  D009           547           STO      TIME                                    HWS03090
  027E 01 4C000295       548           B      L INTEG
                         549           LORG                                             HWS03110
  0280 0  04D2           550     +     DC       1234
  0281 0  000A           551     +     DC       10
  0282 0  0032           552     +     DC       50
  0283 0  0028           553     +     DC       40
  0284 0  0040           554     +     DC       64
  0285 0  0000           555     +     DC       0
  0286 0  0001           556     +     DC       1
                         557     *GENERATE EN EP ET                                     HWS03120
  0287 0  0000           558     TIME  DC       0
  0288 0  0000           559     ENDK  DC       *-*                                     HWS03140
  0289 0  0000           560     ENDK1 DC       *-*                                     HWS03150
  028A 0  0000           561     EPDK  DC       *-*                                     HWS03160
  028B 0  0000           562     EPDK1 DC       *-*                                     HWS03170
  028C 0  0000           563     ETDK  DC       *-*                                     HWS03180
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Table B-11. Honeywell Control Program (Continued)

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                                                       17 JUL 74     PAGE 011

028D 0  0000        564  ETDK1 DC       *-*                                 HWS03190
028E 0  000F        565  DT    DC       15                                  HWS03200
028F 0  0000        566  ENK   DC       *-*                                 HWS03210
0290 0  0000        567  ENKL  DC       *-*                                 HWS03220
0291 0  0000        568  EPK   DC       *-*                                 HWS03230
0292 0  0000        569  EPKL  DC       *-*                                 HWS03240
0293 0  0000        570  ETK   DC       *-*                                 HWS03250
0294 0  0000        571  ETKL  DC       *-*                                 HWS03260
                    572  *                                                  HWS03280
0295                573  INTEG EQU      *                                   HWS03290
                    574  *                    CALCULATE EN                  HWS03300
0295 0  C0F2        575        LD       ENDK
0296 0  80F2        576        A        ENDK1
0297 0  A0F6        577        M        DT
0298 0  1083        578        SLT      3
0299 0  A84F        579        D        =375
029A 0  80r4        580        A        ENK                                 HWS03400
029B 0  D0F3        581        STO      ENK                                 HWS03410
029C 0  C2B6        582        LD     2 VT074
029D 01 9400046A    583        S      L ONE
029F 01 4C1802A3    584        BZ       NM1
02A1 0  C0E3        585        LD       =0
02A2 0  D0EC        586        STO      ENK
                    587  *                    CALCULATE EP                  HWS03420
                    588  *                    CALCULATE ET                  HWS03510
02A3 01 C400028C    589  NM1   LD     L ETDK
02A5 01 8400028D    590        A      L ETDK1
02A7 01 A400028E    591        M      L DT
02A9 0  1084        592        SLT      4            *** SCALE FACTOR 16 ***
02AA 0  A83F        593        D        =1500
02AB 0  80E7        594        A        ETK
02AC 0  D0E6        595        STO      ETK
02AD 0  C2B6        596        LD     2 VT074
02AE 01 9400046B    597        S      L TWO
02B0 01 4C1802B4    598        BZ       NM2
02B2 0  C0D2        599        LD       =0
02B3 0  D0DF        600        STO      ETK
                    601  *                    LIMLTS ON EN EP ET            HWS03600
02B4 0  C0DA        602  NM2   LD       ENK
02B5 01 4C2802BE    603        BN       MW1                                 HWS03620
02B7 0  90D8        604        S        ENKL                                HWS03630
02B8 01 4C0802C5    605        BNP      MW2                                 HWS03640
02BA 0  C0D5        606        LD       ENKL                                HWS03650
02BB 0  D0D3        607        STO      ENK                                 HWS03660
02BC 01 4C0002C5    608        B      L MW2                                 HWS03670
02BE                609  MW1   EQU      *                                   HWS03680
02BE 0  C0D0        610        LD       ENK                                 HWS03690
02BF 0  80D0        611        A        ENKL                                HWS03700
02C0 01 4C3002C5    612        BP       MW2                                 HWS03710
02C2 0  C0C2        613        LD       =0                                  HWS03720
02C3 0  90CC        614        S        ENKL                                HWS03730
02C4 0  D0CA        615        STO      ENK                                 HWS03740
02C5                616  MW2   EQU      *                                   HWS03750
02C5 0  C0CB        617        LD       EPK                                 HWS03760
02C6 01 4C2802CF    618        BN       MW3                                 HWS03770
02C8 0  90C9        619        S        EPKL                                HWS03780
02C9 01 4C080206    620        BNP      MW4                                 HWS03790
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Table B-11. Honeywell Control Program (Continued)

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                                                               17 JUL 74     PAGE 012

 02CB 0  C0C6        621          LD        EPKL                                      HWS03800
 02CC 0  D0C4        622          STO       EPK                                       HWS03810
 02CD 01 4C0002D6    623          B     L   MW4                                       HWS03820
 02CF                624    MW3   EQU       *                                         HWS03830
 02CF 0  C0C1        625          LD        EPK                                       HWS03840
 02D0 0  80C1        626          A         EPKL                                      HWS03850
 02D1 01 4C3002D6    627          BP        MW4                                       HWS03860
 02D3 0  C0B1        628          LD        =0                                        HWS03870
 02D4 0  90BD        629          S         EPKL                                      HWS03880
 02D5 0  D0BB        630          STO       EPK                                       HWS03890
 02D6                631    MW4   EQU       *                                         HWS03900
 02D6 0  C0BC        632          LD        ETK                                       HWS03910
 02D7 01 4C2802E0    633          BN        MW5                                       HWS03920
 02D9 0  90BA        634          S         ETKL                                      HWS03930
 02DA 01 4C0802EB    635          BNP       MW6                                       HWS03940
 02DC 0  C0B7        636          LD        ETKL                                      HWS03950
 02DD 0  D0B5        637          STO       ETK                                       HWS03960
 02DE 01 4C0002EB    638          B     L   MW6                                       HWS03970
 02E0                639    MW5   EQU       *                                         HWS03980
 02E0 0  C0B2        640          LD        ETK                                       HWS03990
 02E1 0  80B2        641          A         ETKL                                      HWS04000
 02E2 01 4C3002EB    642          BP        MW6                                       HWS04010
 02E4 0  C0A0        643          LD        =0                                        HWS04020
 02E5 0  90AE        644          S         ETKL                                      HWS04030
 02E6 0  D0AC        645          STO       ETK                                       HWS04040
 02E7 01 4C0002EB    646          B     L   MW6                                       HWS04050
                     647          LORG                                                HWS04060
 02E9 0  0177        648    +     DC        375
 02CA 0  05DC        649    +     DC        1500
                     650    *                        AGE DERIVATIVES                  HWS04070
 02EB                651    MW6   EQU       *                                         HWS04080
 02EB 01 C4000288    652          LD    L   ENDK                                      HWS04090
 02ED 01 D4000289    653          STO   L   ENDK1                                     HWS04100
 02EF 01 C400028A    654          LD    L   EPDK                                      HWS04110
 02F1 01 D400028B    655          STO   L   EPDK1                                     HWS04120
 02F3 01 C400028C    656          LD    L   ETDK                                      HWS04130
 02F5 01 D400028D    657          STO   L   ETDK1                                     HWS04140
                     658    *                                                         HWS04150
                     659    *                   INTERPOLATE FOR PT3 AND PT5           HWS04160
                     660    *                   AS A FUNCTION OF PLA                  HWS04170
 02F7                661    PLA   EQU       *
 02F7 0  C066        662          LD        NPL1                                      HWS04180
 02F8 0  9201        663          S       2 VT128                                     HWS04190
 02F9 01 4C280309    664          BN        MDW1                                      HWS04200
 02FB 01 C4000101    665          LD    L   P3E1                                      HWS04210
 02FD 01 D400040B    666          STO   L   P3PL                                      HWS04220
 02FF 01 C4000102    667          LD    L   P5E1                                      HWS04230
 0301 01 D400040C    668          STO   L   P5PL                                      HWS04240
 0303 01 C4000100    669          LD    L   WEF1                                      HWS04250
 0305 01 D400040A    670          STO   L   WEFN                                      HWS04260
 0307 01 4C0003A7    671          B     L   MDW6                                      HWS04270
 0309 0  C057        672    MDW1  LD        NPL4                                      HWS04280
 030A 0  9201        673          S       2 VT128                                     HWS04290
 030B 01 4C300318    674          BP        MDW2                                      HWS04300
 030D 01 C40001A6    675          LD    L   P3E4                                      HWS04310
 030F 01 D400040B    676          STO   L   P3PL                                      HWS04320
 0311 01 C40001A7    677          LD    L   P5E4                                      HWS04330
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Table B-11. Honeywell Control Program (Continued)

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                                                          17 JUL 74      PAGE 013

0313 01 D400040C   678           STO  L  P5PL                          HWS04340
0315 01 C40001A5   679           LD   L  WEF4                          HWS04350
0317 01 D400040A   680           STO  L  WEFN                          HWS04360
0319 01 4C0003A7   681           B    L  MDW6                          HWS04370
031B 01 C400035F   682     MDW2  LD   L  NPL2                          HWS04380
031D 0  9201       683           S      2 VT128                        HWS04390
031E 01 4C28033E   684           BN      MDW3                          HWS04400
0320 0  1889       685           SRT     9
0321 0  A81A       686           D       =3300                         HWS04420
0322 0  D03F       687           STO     CX1                           HWS04430
0323 0  C019       688           LD      =128
0324 0  903D       689           S       CX1                           HWS04450
0325 0  D03D       690           STO     CX2                           HWS04460
0326 01 C4000101   691           LD   L  P3E1                          HWS04470
0328 0  D03B       692           STO     P3L                           HWS04480
0329 01 C400013A   693           LD   L  P3E2                          HWS04490
032B 0  D039       694           STO     P3M                           HWS04500
032C 01 C4000102   695           LD   L  P5E1                          HWS04510
032E 0  D037       696           STO     P5L                           HWS04520
032F 01 C400013B   697           LD   L  P5E2                          HWS04530
0331 0  D035       698           STO     P5M                           HWS04540
0332 01 C4000100   699           LD   L  WEF1                          HWS04550
0334 01 D4000368   700           STO  L  WEFL                          HWS04560
0336 01 C4000139   701           LD   L  WEF2                          HWS04570
0338 01 D4000369   702           STO  L  WEFM                          HWS04580
033A 01 4C000388   703           B    L  MDW5                          HWS04590
                   704           LORG                                  HWS04600
033C 0  0CE4       705     +     DC      3300
033D 0  0080       706     +     DC      128
033E 0  C021       707     MDW3  LD      NPL3                          HWS04610
033F 0  9201       708           S      2 VT128                        HWS04620
0340 01 4C28036C   709           BN      MDW4                          HWS04630
0342 0  1889       710           SRT     9
0343 0  A862       711           D       =2475                         HWS04650
0344 0  D01D       712           STO     CX1                           HWS04660
0345 0  C0F7       713           LD      =128
0346 0  901B       714           S       CX1                           HWS04680
0347 0  D01B       715           STO     CX2                           HWS04690
0348 01 C400013A   716           LD   L  P3E2                          HWS04700
034A 0  D019       717           STO     P3L                           HWS04710
034B 01 C4000170   718           LD   L  P3E3                          HWS04720
034D 0  D017       719           STO     P3M                           HWS04730
034E 01 C400013B   720           LD   L  P5E2                          HWS04740
0350 0  D015       721           STO     P5L                           HWS04750
0351 01 C4000171   722           LD   L  P5E3                          HWS04760
0353 0  D013       723           STO     P5M                           HWS04770
0354 01 C4000139   724           LD   L  WEF2                          HWS04780
0356 01 D4000368   725           STO  L  WEFL                          HWS04790
0358 01 C400016F   726           LD   L  WEF3                          HWS04800
035A 01 D4000369   727           STO  L  WEFM                          HWS04810
035C 01 4C000388   728           B    L  MDW5                          HWS04820
035E 0  203A       729     NPL1  DC      8250                          HWS04830
035F 0  2D1E       730     NPL2  DC      11550                         HWS04840
0360 0  36C9       731     NPL3  DC      14025                         HWS04850
0361 0  4074       732     NPL4  DC      16500                         HWS04860
0362 0  0000       733     CX1   DC      *-*                           HWS04870
0363 0  0000       734     CX2   DC      *-*                           HWS04880
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Table B-11. Honeywell Control Program (Continued)

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                                                        17 JUL 74     PAGE 014

0364 0  0000        735   P3L    DC         *-*                    HWS04890
0365 0  0000        736   P3M    DC         *-*                    HWS04900
0366 0  0000        737   P5L    DC         *-*                    HWS04910
0367 0  0000        738   P5M    DC         *-*                    HWS04920
0368 0  0000        739   WEFL   DC         *-*                    HWS04940
0369 0  0000        740   WEFM   DC         *-*                    HWS04950
036A    0000        741   SUMX   BSS    E   0
036A 0  0000        742          DC         0
036B 0  0000        743          DC         0
036C 0  C0F4        744   MDW4   LD         NPL4                   HWS04960
036D 0  9201        745          S        2 VT128                  HWS04970
036E 0  1889        746          SRT        9
036F 0  A836        747          D          =2475                  HWS04990
0370 0  D0F1        748          STO        CX1                    HWS05000
0371 0  C0CB        749          LD         =128
0372 0  90EF        750          S          CX1                    HWS05020
0373 0  D0EF        751          STO        CX2                    HWS05030
0374 01 C4000170    752          LD     L   P3E3                   HWS05040
0376 0  D0ED        753          STO        P3L                    HWS05050
0377 01 C40001A6    754          LD     L   P3E4                   HWS05060
0379 0  D0EB        755          STO        P3M                    HWS05070
037A 01 C4000171    756          LD     L   P5E3                   HWS05080
037C 0  D0E9        757          STO        P5L                    HWS05090
037D 01 C40001A7    758          LD     L   P5E4                   HWS05100
037F 0  D0E7        759          STO        P5M                    HWS05110
0380 01 C400016F    760          LD     L   WEF3                   HWS05120
0382 01 D4000368    761          STO    L   WEFL                   HWS05130
0384 01 C40001A5    762          LD     L   WEF4                   HWS05140
0386 01 D4000369    763          STO    L   WEFM                   HWS05150
0388 0  C0DB        764   MDW5   LD         P3L                    HWS05160
0389 0  A0D8        765          M          CX1                    HWS05170
038A 0  D8DF        766          STD        SUMX
038E 0  C0D9        767          LD         P3M                    HWS05200
038C 0  A0D6        768          M          CX2                    HWS05210
038D 0  88DC        769          AD         SUMX
038E 0  1887        770          SRT        7
038F 0  1090        771          SLT        16
0390 0  D07A        772          STO        P3PL                   HWS05250
0391 0  C0D4        773          LD         P5L                    HWS05260
0392 0  A0CF        774          M          CX1                    HWS05270
0393 0  D8D6        775          STD        SUMX
0394 0  C0D2        776          LD         P5M                    HWS05300
0395 0  A0C0        777          M          CX2                    HWS05310
0396 0  88D3        778          AD         SUMX
0397 0  1887        779          SRT        7
0398 0  1090        780          SLT        16
0399 0  D072        781          STO        P5PL                   HWS05350
039A 01 C4000368    782          LD     L   WEFL                   HWS05360
039C 0  A0C5        783          M          CX1                    HWS05370
039D 0  D8CC        784          STD        SUMX
039E 0  C0CA        785          LD         WEFM                   HWS05400
039F 0  A0C3        786          M          CX2                    HWS05410
03A0 0  88C9        787          AD         SUMX
03A1 0  1887        788          SRT        7
03A2 0  1090        789          SLT        16
03A3 0  D066        790          STO        WEFN                   HWS05450
03A4 01 4C0003A7    791          B      L   MDW6                   HWS05460
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Table B-11. Honeywell Control Program (Continued)

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                                                     17 JUL 74      PAGE 015

                          792            LORG                                         HWS05470
03A6 0  09AB              793    +       DC       2475
03A7                      794    MDW6    EQU       *                                  HWS05510
03A7 01 C400040C          795            LD    L  P5PL                                HWS05520
03A9 0  D223              796            STO   2  VT162                               HWS05530
03AA 01 C4000408          797            LD    L  P3PL                                HWS05540
03AC 0  D224              798            STO   2  VT153                               HWS05550
03AD 01 C400028F          799            LD    L  ENK                                 HWS05560
03AF 0  D225              800            STO   2  VT164                               HWS05570
03B0 01 C400040A          801            LD    L  WEFN                                HWS05580
03B2 0  D226              802            STO   2  VT165                               HWS05590
03B3 01 C4000406          803            LD    L  KEFN1                               HWS05600
03B5 0  D227              804            STO   2  VT166                               HWS05610
03B6 01 C4000407          805            LD    L  KEFN2                               HWS05620
03B8 0  D228              806            STO   2  VT167                               HWS05630
03B9 01 C4000411          807            LD    L  WTFN
03BB 0  D229              808            STO   2  VT168                               HWS05650
03BC 01 C4000409          809            LD    L  KEFN4                               HWS05660
03BE 0  D22A              810            STO   2  VT169                               HWS05670
03BF 01 C4000413          811            LD    L  P5TNB
03C1 0  D22B              812            STO   2  VT170                               HWS05690
03C2 01 C4000412          813            LD    L  P3TNB
03C4 0  D22C              814            STO   2  VT171                               HWS05710
03C5 01 C4000293          815            LD    L  ETK
03C7 0  D22D              816            STO   2  VT172                               HWS05730
03C8 01 C400040D          817            LD    L  KTFN1
03CA 0  D22E              818            STO   2  VT173                               HWS05750
03CB 01 C400040E          819            LD    L  KTFN2
03CD 0  D22F              820            STO   2  VT174                               HWS05770
03CE 01 C400040F          821            LD    L  KTFN3
03D0 0  D230              822            STO   2  VT175                               HWS05790
03D1 01 C4000410          823            LD    L  KTFN4
03D3 0  D231              824            STO   2  VT176                               HWS05810
03D4 01 C4000414          825            LD    L  TBBN
03D6 0  D24B              826            STO   2  VT202
                          827    *                                                    HWS05480
                          828    *     CALCULATE X-XO  FOR EQUILIBRIUM PRESSURE       HWS05490
                          829    *                                                    HWS05500
03D7                      830    MEPT    EQU       *
03D7 0  C21E              831            LD    2  VT157                               HWS05820
03D8 0  9201              832            S     2  VT128                               HWS05830
03D9 0  D024              833            STO      ME1                                 HWS05840
03DA 0  D245              834            STO   2  VT196
03DB 0  C294              835            LD    2  VT108                               HWS05850
03DC 01 9400040C          836            S     L  P5PL                                HWS05880
03DE 0  D020              837            STO      ME2                                 HWS05890
03DF 0  D246              838            STO   2  VT197
03E0 0  C29A              839            LD    2  VT102                               HWS05900
03E1 01 94000408          840            S     L  P3PL                                HWS05930
03E3 0  D01C              841            STO      ME3                                 HWS05940
03E4 0  D247              842            STO   2  VT198
03E5 01 C400028F          843            LD    L  ENK                                 HWS05950
03E7 0  D019              844            STO      ME4                                 HWS05960
                          845    *                                                    HWS05970
03E8 0  C294              846            LD    2  VT108
03E9 01 94000413          847            S     L  P5TNB
03EB 01 D4000402          848            STO   L  MT1
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Table B-11. Honeywell Control Program (Continued)

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                                                17 JUL 74     PAGE 016

  03ED 0  C29A         849              LD    2 VT102
  03EE 01 94000412     850              S     L P3TNB
  03F0 01 D4000403     851              STO   L MT2
  03F2 0  D248         852              STO   2 VT199
  03F3 01 C40001FA     853              LD    L T4WF
  03F5 01 94000414     854              S     L T8BN
  03F7 0  D00C         855              STO     MT3
  03F8 0  D249         856              STO   2 VT200
  03F9 01 C4000293     857              LD    L ETK
  03FB 0  D009         858              STO     MT4
  03FC 01 4C000417     859              B     L FREQE                          HWS06100
  03FE 0  0000         860        ME1   DC      *-*                            HWS06110
  03FF 0  0000         861        ME2   DC      *-*                            HWS06120
  0400 0  0000         862        ME3   DC      *-*                            HWS06130
  0401 0  0000         863        ME4   DC      *-*                            HWS06140
  0402 0  0000         864        MT1   DC      *-*
  0403 0  0000         865        MT2   DC      *-*
  0404 0  0000         866        MT3   DC      *-*
  0405 0  0000         867        MT4   DC      *-*
  0406 0  0000         868        KEFN1 DC      *-*                            HWS06190
  0407 0  0000         869        KEFN2 DC      *-*                            HWS06200
  0408 0  0000         870        KEFN3 DC      *-*                            HWS06210
  0409 0  0000         871        KEFN4 DC      *-*                            HWS06220
  040A 0  0000         872        WEFN  DC      *-*                            HWS06230
  040B 0  0000         873        P3PL  DC      *-*                            HWS06240
  040C 0  0000         874        P5PL  DC      *-*                            HWS06250
  040D 0  0000         875        KTFN1 DC      *-*
  040E 0  0000         876        KTFN2 DC      *-*
  040F 0  0000         877        KTFN3 DC      *-*
  0410 0  0000         878        KTFN4 DC      *-*
  0411 0  0000         879        WTFN  DC      *-*                            HWS06330
  0412 0  0000         880        P3TNB DC      *-*
  0413 0  0000         881        P5TNB DC      *-*
  0414 0  0000         882        T8BN  DC      *-*                            HWS06370
  0415 0  0000         883        VFMNN DC      *-*
  0416 0  0000         884        SUMEF DC      *-*                            HWS06380
                       885        *                                            HWS06390
                       886        * AT THIS POINT THE FUEL FLOW REQUEST IS     HWS06400
                       887        * COMPUTED FOR THE THREE CONTROLLERS         HWS06410
                       888        * *IE EQUILIBRIUM,PRESSURE,AND TEMPERATURE   HWS06420
                       889        * AND A SELECT LOW DETERMINS WHICH CONTROLLER HWS06430
                       890        * WILL BE USED                               HWS06440
  0417                 891        FREQE EQU     *                              HWS06450
  0417 01 C4000406     892              LD    L KEFN1                          HWS06460
  0419 0  A0E4         893              M       ME1                            HWS06470
  041A 0  1087         894              SLT     7
  041B 0  D24A         895              STO   2 VT201
  041C 0  D0F9         896              STO     SUMEF                          HWS06490
  041D 01 C4000407     897              LD    L KEFN2                          HWS06500
  041F 0  A0DF         898              M       ME2                            HWS06510
  0420 0  A818         899              D       =100
  0421 0  1989         900              SRT     9
  0422 0  8CF3         901              A       SUMEF                          HWS06530
  0423 0  D0F2         902              STO     SUMEF                          HWS06540
  0424 01 C4000408     903              LD    L KEFN3                          HWS06550
  0426 0  A0D9         904              M       ME3                            HWS06560
  0427 0  A811         905              D       =100
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Table B-11. Honeywell Control Program (Continued)

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                                                   17 JUL 74     PAGE 017

0428 0  1889        906            SRT     9
0429 0  80EC        907            A       SUMEF                        HWS06580
042A 0  D0EB        908            STO     SUMEF                        HWS06590
042B 01 C4000409    909            LD    L KEFN4                        HWS06600
042D 0  A0D3        910            M       ME4                          HWS06610
042E 0  1084        911            SLT     4
042F 0  D24D        912            STO   2 VT204
0430 0  80E5        913            A       SUMEF                        HWS06630
0431 0  D0E4        914            STO     SUMEF                        HWS06650
0432 01 C400040A    915            LD    L WEFN                         HWS06670
0434 0  1882        916            SRT     2
0435 0  80E0        917            A       SUMEF                        HWS06700
0436 0  D0DF        918            STO     SUMEF                        HWS06720
0437 01 4C00043B    919            B     L FREQP                        HWS06770
                    920            LORG                                 HWS06780
0439 0  0064        921      +     DC      100
043A 0  0000        922      SUMPF DC      *-*                          HWS06790
043B                923      FREQP EQU     *                            HWS06800
043B 0  C003        924            LD      =32700                       HWS07160
043C 0  D0FD        925            STO     SUMPF                        HWS07070
043D 01 4C000441    926            B     L FREQT                        HWS07120
                    927            LORG                                 HWS07130
043F 0  7FBC        928      +     DC      32700
0440 0  0000        929      SUMTF DC      *-*                          HWS07140
0441                930      FREQT EQU     *                            HWS07150
0441 01 C400040D    931            LD    L KTFN1
0443 01 A4000402    932            M     L MT1
0445 0  A8F3        933            D       =100
0446 0  1889        934            SRT     9
0447 0  D0F8        935            STO     SUMTF
0448 01 C400040E    936            LD    L KTFN2
044A 01 A4000403    937            M     L MT2
044C 0  A8EC        938            D       =100
044D 0  1889        939            SRT     9
044E 0  D24E        940            STO   2 VT205
044F 0  80F0        941            A       SUMTF
0450 0  D0EF        942            STO     SUMTF
0451 01 C400040F    943            LD    L KTFN3
0453 01 A4000404    944            M     L MT3
0455 0  A813        945            D       =10
0456 0  1889        946            SRT     9
0457 0  D24F        947            STO   2 VT206
0458 0  80E7        948            A       SUMTF
0459 0  D0E6        949            STO     SUMTF
045A 01 C4000410    950            LD    L KTFN4
045C 01 A4000405    951            M     L MT4
045E 0  1083        952            SLT     3
045F 0  D250        953            STO   2 VT207
0460 0  80DF        954            A       SUMTF
0461 0  D0DE        955            STO     SUMTF
0462 01 C4000411    956            LD    L WTFN
0464 0  1882        957            SRT     2
0465 0  80DA        958            A       SUMTF
0466 0  D0D9        959            STO     SUMTF
0467 01 4C00046E    960            B     L MDSWT                        HWS07180
                    961            LORG                                 HWS07190
0469 0  000A        962      +     DC      10
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Table B-11. Honeywell Control Program (Continued)

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                                                        17 JUL 74      PAGE 018

046A 0  0CCC          963   ONE   DC        3276                            HWS07200
046B 0  1998          964   TWO   DC        6552                            HWS07210
046C 0  2664          965   THREE DC        9828                            HWS07220
046D 0  0000          966   WFMOD DC        *-*                             HWS07230
046E                  967   MDSWT EQU       *                               HWS07240
046E 01 C4000416      968         LD    L   SUMEF                           HWS07250
0470 0  D2B9          969         STO   2   VT071                           HWS07260
0471 01 C400043A      970         LD    L   SUMPF                           HWS07270
0473 0  D2B8          971         STO   2   VT072                           HWS07280
0474 01 C4000440      972         LD    L   SUMTF                           HWS07290
0476 0  D2B7          973         STO   2   VT073                           HWS07300
0477 0  B2B8          974         CMP   2   VT072                           HWS07310
0478 0  C2B8          975         LD    2   VT072                           HWS07320
0479 0  1000          976         NOP                                       HWS07330
047A 0  D0F2          977         STO       WFMOD                           HWS07340
047B 0  B2B9          978         CMP   2   VT071                           HWS07350
047C 0  C2B9          979         LD    2   VT071                           HWS07360
047D 0  1000          980         NOP                                       HWS07370
047E 0  D235          981         STO   2   VT180                           HWS07380
047F 01 4C28048A      982         BN        MINFL
0481 01 A4000505      983         M     L   =13                             HWS06990
0483 0  1090          984         SLT       16                              HWS07000
0484 0  D235          985         STO   2   VT180
0485 0  C235          986         LD    2   VT180
0486 01 94000415      987         S     L   WFMNN
0488 01 4C10048D      988         BNN       MINSS
048A 01 C4000415      989   MINFL LD    L   WFMNN
048C 0  D235          990         STO   2   VT180
048D                  991   MINSS EQU       *
048D 0  C235          992         LD    2   VT180                           HWS07390
048E 0  1890          993         SRT       16
048F 0  A875          994         D         =13
0490 0  92B9          995         S     2   VT071                           HWS07400
0491 01 4C200497      996         BNZ       MIKE1                           HWS07410
0493 0  C0D6          997         LD        ONE                             HWS07420
0494 0  D2B6          998         STO   2   VT074                           HWS07430
0495 01 4C0004AD      999         B     L   RQAIB                           HWS07440
0497 0  C235         1000   MIKE1 LD    2   VT180                           HWS07450
0498 0  1890         1001         SRT       16
0499 0  A868         1002         D         =13
049A 0  92B7         1003         S     2   VT073                           HWS07460
049B 01 4C2004A1     1004         BNZ       MIKE2                           HWS07470
049D 0  C0CD         1005         LD        TWO                             HWS07480
049E 0  D2B6         1006         STO   2   VT074                           HWS07490
049F 01 4C0004AD     1007         B     L   RQAIB                           HWS07500
04A1 0  C0CA         1008   MIKE2 LD        THREE                           HWS07510
04A2 0  D2B6         1009         STO   2   VT074                           HWS07520
04A3 01 4C0004AD     1010         B     L   RQAIB                           HWS07530
04A5 0  0031         1011   KLAGD DC        49
04A6 0  001F         1012   K1NUM DC        31
04A7 0  0009         1013   K2NUM DC        9
04A8 0  0000         1014   YNM1  DC        *-*
04A9 0  0000         1015   UNM1  DC        *-*
04AA    0000         1016   TEMF  BSS   E   0
04AA 0  0000         1017         DC        0
04AB 0  0000         1018         DC        0
04AC 0  0000         1019   SWLAG DC        *-*
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Table B-11. Honeywell Control Program (Continued)

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                                                    17 JUL 74      PAGE 019

04AD                   1020     RQAIB EQU       *                      HWS07540
04AD 01 C40004AC       1021           LD    L  SWLAG
04AF 01 4C2004BC       1022           BNZ      FILT
04B1 01 C4000506       1023           LD    L  =123
04B3 01 D40004AC       1024           STO   L  SWLAG
04B5 0  C235           1025           LD     2 VT180
04B6 01 D40004A8       1026           STO   L  YNM1
04B8 01 D40004A9       1027           STO   L  UNM1
04BA 01 4C0004D6       1028           B     L  DONOZ
04BC 01 C40004A9       1029     FILT  LD    L  UNM1
04BE 01 A40004A7       1030           M     L  K2NUM
04C0 01 DC0004AA       1031           STD   L  TEMF
04C2 0  C235           1032           LD     2 VT180
04C3 01 D40004A9       1033           STO   L  UNM1
04C5 01 A40004A7       1034           M     L  K2NUM
04C7 01 8C0004AA       1035           AD    L  TEMF
04C9 01 DC0004AA       1036           STD   L  TEMF
04CB 01 C40004A8       1037           LD    L  YNM1
04CD 01 A40004A6       1038           M     L  K1NUM
04CF 01 8C0004AA       1039           AD    L  TEMF
04D1 01 AC0004A5       1040           D     L  KLAGD
04D3 01 D40004A8       1041           STO   L  YNM1
04D5 0  D235           1042           STO    2 VT180
04D6                   1043     DONOZ EQU       *
04D6 0  C286           1044           LD     2 VT074
04D7 01 9400046A       1045           S     L  ONE
04D9 01 4C2004E0       1046           BNZ      GT10
04DB 0  C201           1047           LD     2 VT128
04DC 01 D4000507       1048           STO   L  NA8
04DE 01 4C0004E3       1049           B     L  CALA8
04E0 0  C21E           1050     GT10  LD     2 VT157
04E1 01 D4000507       1051           STO   L  NA8
04E3 01 C4000507       1052     CALA8 LD    L  NA8
04E5 01 940000F9       1053           S     L  =14025
04E7 01 4C1004ED       1054           BNN      GT11
04E9 0  C2DE           1055           LD     2 VT034
04EA 0  D2AF           1056           STO    2 VT081
04EB 01 4C000509       1057           B     L  CONT
04ED 01 940000FA       1058     GT11  S     L  =2475
04EF 01 4C2804F5       1059           BN       GT12
04F1 0  C2DD           1060           LD     2 VT035
04F2 0  D2AF           1061           STO    2 VT081
04F3 01 4C000509       1062           B     L  CONT
04F5 0  C2DE           1063     GT12  LD     2 VT034
04F6 0  92DD           1064           S      2 VT035
04F7 01 D4000508       1065           STO   L  ANOZN
04F9 01 C40000F5       1066           LD    L  =16500
04FB 01 94000507       1067           S     L  NA8
04FD 01 A4000508       1068           M     L  ANOZN
04FF 01 AC0000FA       1069           D     L  =2475
0501 0  82DD           1070           A      2 VT035
0502 0  D2AF           1071           STO    2 VT081
0503 01 4C000509       1072           B     L  CONT
                       1073           LORG
0505 0  000D           1074     +     DC       13
0506 0  007B           1075     +     DC       123
0507 0  0000           1076      NA8  DC       *-*
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Table B-11. Honeywell Control Program (Continued)

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                                                              17 JUL 74     PAGE 020

0508 0   0000       1077   ANOZN DC        *-*
0509                1078   CONT  EQU       *                                   HWS07700
0509 00 65000000    1079   XR1   LDX   L1  *-*                                 HWS07710
050B 01 4C800000    1080         BSC   I   HWECT                               HWS07720
FFB9                1081   VT071 EQU       -71                                 HWS07730
FFB8                1082   VT072 EQU       -72                                 HWS07740
FFB7                1083   VT073 EQU       -73                                 HWS07750
FFB6                1084   VT074 EQU       -74                                 HWS07760
FFAF                1085   VT081 EQU       -81                                 HWS07770
FFAE                1086   VT082 EQU       -82                                 HWS07780
FFAD                1087   VT083 EQU       -83                                 HWS07790
001E                1088   VT157 EQU       +30                                 HWS07800
0035                1089   VT180 EQU       +53                                 HWS07810
0001                1090   VT128 EQU       +1                                  HWS07820
FF9A                1091   VT102 EQU       -102                                HWS07830
FF94                1092   VT108 EQU       -108                                HWS07840
FF9F                1093   VT097 EQU       -97                                 HWS07850
FFDC                1094   VT036 EQU       -36                                 HWS07860
FFDB                1095   VT037 EQU       -37                                 HWS07870
FFDA                1096   VT038 EQU       -38                                 HWS07880
FFD9                1097   VT039 EQU       -39                                 HWS07890
0023                1098   VT162 EQU       +35                                 HWS07900
0024                1099   VT163 EQU       +36                                 HWS07910
0025                1100   VT164 EQU       +37                                 HWS07920
0026                1101   VT165 EQU       +38                                 HWS07930
0027                1102   VT166 EQU       +39                                 HWS07940
0028                1103   VT167 EQU       +40                                 HWS07950
0029                1104   VT168 EQU       +41                                 HWS07960
002A                1105   VT169 EQU       +42                                 HWS07970
002B                1106   VT170 EQU       +43                                 HWS07980
002C                1107   VT171 EQU       +44                                 HWS07990
002D                1108   VT172 EQU       +45                                 HWS08000
002E                1109   VT173 EQU       +46                                 HWS08010
002F                1110   VT174 EQU       +47                                 HWS08020
0030                1111   VT175 EQU       +48                                 HWS08030
0031                1112   VT176 EQU       +49                                 HWS08040
004F                1113   VT206 EQU       +79
0050                1114   VT207 EQU       +80
0045                1115   VT196 EQU       +69
0046                1116   VT197 EQU       +70
0047                1117   VT198 EQU       +71
0048                1118   VT199 EQU       +72
0049                1119   VT200 EQU       +73
004A                1120   VT201 EQU       +74
004B                1121   VT202 EQU       +75
004C                1122   VT203 EQU       +76
004D                1123   VT204 EQU       +77
004E                1124   VT205 EQU       +78
FFF4                1125   VT012 EQU       -12
FFF3                1126   VT013 EQU       -13
FFF2                1127   VT014 EQU       -14
FFF1                1128   VT015 EQU       -15
FFF0                1129   VT016 EQU       -16
FFEF                1130   VT017 EQU       -17
FFEE                1131   VT018 EQU       -18
FFED                1132   VT019 EQU       -19
FFEC                1133   VT020 EQU       -20
```

Table B-11. Honeywell Control Program (Concluded)

```
                                                          17 JUL 74      PAGE 021

FFEB              1134    VT021  EQU      -21
FFEA              1135    VT022  EQU      -22
FFE9              1136    VT023  EQU      -23
FFD8              1137    VT040  EQU      -40
FFD7              1138    VT041  EQU      -41
FFD6              1139    VT042  EQU      -42
FFD5              1140    VT043  EQU      -43
FFD4              1141    VT044  EQU      -44
FFD3              1142    VT045  EQU      -45
FFD2              1143    VT046  EQU      -46
FFD1              1144    VT047  EQU      -47
FFD0              1145    VT048  EQU      -48
FFCF              1146    VT049  EQU      -49
FFCE              1147    VT050  EQU      -50
FFC3              1148    VT061  EQU      -61
FFC2              1149    VT062  EQU      -62
FFC1              1150    VT063  EQU      -63
FFC0              1151    VT064  EQU      -64
FFBF              1152    VT065  EQU      -65
FFBE              1153    VT066  EQU      -66
FFBD              1154    VT067  EQU      -67
FFBC              1155    VT068  EQU      -68
FFBB              1156    VT069  EQU      -69
FFDE              1157    VT034  EQU      -34
FFDD              1158    VT035  EQU      -35
FFB5              1159    VT075  EQU      -75
FFB4              1160    VT076  EQU      -76
FFB3              1161    VT077  EQU      -77
FFB2              1162    VT078  EQU      -78
FFAC              1163    VT084  EQU      -84
FFAB              1164    VT085  EQU      -85
FFAA              1165    VT086  EQU      -86
FFA9              1166    VT087  EQU      -87
FFA8              1167    VT088  EQU      -88
FFA7              1168    VT089  EQU      -89
FFB1              1169    VT079  EQU      -79
FFB0              1170    VT080  EQU      -80
FFA6              1171    VT090  EQU      -90
050E              1172           END

000 ERROR(S) AND 000 WARNING(S) IN ABOVE ASSEMBLY.
```

Table B-12. Honeywell Control Program Cross Reference

```
SYMBOL  VALUE REL  DEFN    REFERENCES-
AMOZN   0508   1   1077    1065M  1068R
BUMP1   010C   1    218     245R   292R   339R
CALAB   04E3   1   1052    1049R
COUNT   0509   1   1078    1057R  1C62R  1072R
CX1     0362   1    733     687M   689R   712M   714R   748M   750R   765R   774R   783R
CX2     0363   1    734     690M   715M   751M   768R   777R   786R
C1      0089   1    138     134M   153M   162M   164R   174M   176R   185M   187R   228R   275R   322R
C11     010F   1    221     229M   236R
C12     0145   1    268     276M   283R
C13     017B   1    315     323M   330R
C2      008A   1    139     136M   155M   165M   177M   188M   230R   277R   324R
C21     0110   1    222     231M   239R
C22     0146   1    269     278M   286R
C23     017C   1    316     325M   333R
DONOZ   04D6   1   1043    1028R
DT      028E   1    565     455R   577R   591R
ENDK    0288   1    559     510M   521R   575R   652R
ENDK1   0289   1    560     522M   576R   653M
ENK     028F   1    566     476M   479R   528M   531R   580R   581M   586M   602R   607M   610R   615M   799R
                            843R
ENKL    0290   1    567     480M   532M   604R   606R   611R   614R
EPDK    028A   1    561     513M   523R   654R
EPDK1   028B   1    562     524M   655M
EPK     0291   1    568     483M   486R   535M   538R   617R   622M   625R   630M
EPKL    0292   1    569     487M   539M   619R   621R   626R   629R
ETDK    028C   1    563     516M   525R   589R   656R
ETDK1   028D   1    564     526M   590R   657M
ETK     0293   1    570     489M   492R   [illegible]   544R   594R   595M   600M   632R   637M   640R   645M   815R
                            857R
ETKL    0294   1    571     493M   545M   634R   636R   641R   644R
FILT    04BC   1   1029    1022R
FREQE   0417   1    891     859R
FREQP   0438   1    925     919R
FREQT   0441   1    930     926R
FT4W    0181   1    363
FT4WC   01E3   1    400     383R
FUELM   0181   1    362     249R   296R   343R
GT10    04E0   1   1050    1046R
GT11    04ED   1   1058    1054R
GT12    04F5   1   1063    1059M
HWECT   0000   1      2       1R  1030R
IASCW   FEBF    C-COMMON
IBTO    FF00    C-COMMON
IDUMY   FFFF    C-COMMON
INTEG   0295   1    573     518R   548R
IN1F    0114   1    227     137R   168R
IN2F    014A   1    274     180R
IN3F    0180   1    321     156R   191R
ISW     01FD   1    429     110M   431R   433M
IVT00   FF80    C-COMMON
JDUMY   FF7F    C-COMMON
KEFN1   0406   1    868     243M   290M   337M   803R   892R
KEFN2   0407   1    869     805R   897R
KEFN3   0408   1    870     903R
KEFN4   0409   1    871     809R   909R
KEF11   00FC   1    201      17M   235R
KEF12   00FD   1    202
KEF13   00FE   1    203
KEF14   00FF   1    204      24M
```

Table B-12. Honeywell Control Program Cross Reference (Continued)

```
SYMBOL   VALUE REL   DEFN    REFERENCES-
KEF21     0135  1     251       27M    238R     282R
KEF22     0136  1     252
KEF23     0137  1     253
KEF24     0138  1     254       34M
KEF31     016B  1     298       37M    285R     329R
KEF32     016C  1     299
KEF33     016D  1     300
KEF34     016E  1     301       44M
KEF41     01A1  1     345       47M    332R
KEF42     01A2  1     346
KEF43     01A3  1     347
KEF44     01A4  1     348       54M
KLAGD     04A5  1    1011     1040R
KTFN1     040D  1     875      817R    931R
KTFN2     040E  1     876      819R    936R
KTFN3     040F  1     877      821R    943R
KTFN4     0410  1     878      823R    950R
KTF11     0103  1     209       57M
KTF12     0104  1     210       60M
KTF13     0105  1     211       63M
KTF14     0106  1     212       66M
KTF21     013C  1     259       71M
KTF22     013D  1     260       73M
KTF23     013E  1     261       76M
KTF24     013F  1     262       79M
KTF31     0172  1     305       84M
KTF32     0173  1     307       86M
KTF33     0174  1     308       89M
KTF34     0175  1     309       92M
KTF41     01A8  1     353       96M
KTF42     01A9  1     35        98M
KTF43     01AA  1     355      101M
KTF44     01AB  1     356      104M
K1NUM     04A6  1    1012     1038R
K1THD     01FB  1     427      374M    391M     447R
K2NUM     04A7  1    1013     1030R   1034R
LUP1      011D  1     234      248M
LUP2      0153  1     281      295M
LUP3      0189  1     328      342M
MDSWT     046E  1     967      960R
MDW1      0309  1     672      664M
MDW2      031B  1     682      674R
MDW3      033E  1     707      684M
MDW4      036C  1     744      709M
MDW5      0388  1     764      703R    728R
MDW6      03A7  1     794      671R    681R     791R
MDW9      024B  1     494      473R
MEAST     FEFF    C-COMMON
MEPT      03D7  1     830
ME1       03FE  1     860      833M    893R
ME2       03FF  1     861      837M    898R
ME3       0400  1     862      841M    904R
ME4       0401  1     863      844M    910R
MICK      00AD  1     127       13R
MIKE1     0497  1    1000      996R
MIKE2     04A1  1    1008     1004R
MINFL     048A  1     989      982M
MINSS     048D  1     991      988R
MT1       0402  1     864      848M    932R
```

Table B-12. Honeywell Control Program Cross Reference (Continued)

```
SYMBOL    VALUE  REL   DEFN     REFERENCES-
MT2        0403   1     865      851M    937R
MT3        0404   1     866      855M    944R
MT4        0405   1     867      858M    951R
MW1        028E   1     609      603M
MW2        02C5   1     616      605R    608R    612R
MW3        02CF   1     624      618M
MW4        02D6   1     631      620R    623R    627R
MW5        02E0   1     639      633M
MW6        02E8   1     651      635R    638R    642R    646R
NA8        0507   1    1076     1048M   1051M   1052R   1067R
NEXT       01C0   1     384      366R
NGFT       010E   1     220      247R    294R    341R
NIN        00BB   1     140      132M    151M    167M    179M    190M
NM1        02A3   1     589      584R
NM2        02B4   1     602      598R
NPL1       035E   1     729      662R
NPL2       035F   1     730      682R
NPL3       0360   1     731      707R
NPL4       0361   1     732      672R    744R
ONE        046A   1     963      519R    583R    997R   1045R
PLA        02F7   1     661
P3E1       0101   1     206      665R    691R
P3E2       013A   1     256      693R    716R
P3E3       0170   1     303      718R    752R
P3E4       01A6   1     350      675R    754R
P3L        0364   1     735      692M    717M    753M    764R
P3M        0365   1     736      694M    719M    755M    767R
P3PL       0408   1     873      666M    676M    772M    797R    840R
P3TNB      0412   1     880      511R    813R    850R
P3T1       0108   1     214       21M
P3T2       0141   1     264       31M
P3T3       0177   1     311       41M
P3T4       01AD   1     358       51M
P5E1       0102   1     207      667R    695R
P5E2       013B   1     257      697R    720R
P5E3       0171   1     304      722R    756R
P5E4       01A7   1     351      677R    758R
P5L        0366   1     737      696M    721M    757M    773R
P5M        0367   1     738      698M    723M    759M    776R
P5PL       040C   1     874      668M    678M    781M    795R    836R
P5TNB      0413   1     881      811R    847R
P5T1       0109   1     215      120M
P5T2       0142   1     265      122M
P5T3       0178   1     312      124M
P5T4       01AE   1     359      126M
RQAIB      04AD   1    1020      999R   1007R   1010R
SENL       0238   1     480      477R
SEPL       0240   1     487      484R
SETL       0249   1     493      490R
SETX1      010D   1     219      232R    279R    326R
STENL      0269   1     532      529R
STEPL      0271   1     539      536R
STETL      027A   1     545      542R
STP1       01FE   1     430      400R
STP2       020E   1     442      432R
STP3       0219   1     452      441R
SUMEF      0416   1     884      896M    901R    902M    907R    908M    913R    914M    917R    918M    968R
SUMPF      043A   1     922      925M    970R
SUMTF      0440   1     929      935M    941R    942M    948R    949M    954R    955M    958R    959M    972R
```

Table B-12. Honeywell Control Program Cross Reference (Continued)

```
SYMBOL   VALUE REL   DEFN    REFERENCES-
SUMX     036A   1     741     766M    769R    775M    778R    784M    787R
SUM1     0112   1     224     237M    240R
SUM2     0148   1     271     284M    287R
SUM3     017E   1     318     331M    334R
SWLAG    04AC   1    1019     108M   1021R   1024M
TAU2T    01FC   1     428     382M    399M    449R    466R
TBBN     0414   1     802     514R    825R    854R
TB1      010A   1     216     112M
TB2      0143   1     265     114M
TB3      0179   1     313     116M
TB4      01AF   1     360     118M
TEMF     04AA   1    1016    1031M   1035R   1036M   1039R
TESTN    0007   1      10       6R
THREE    046C   1     965    1008R
TIME     0287   1     558     109M    517R    547M
TIN1     00C0   1     157     149R
TIN2     00DB   1     169     159M
TIN3     00E9   1     181     171M
TMAX     00C1   1     147     130R
TMPF     01F2   1     414     369M    372R    377M    380R    386M    389R    394M    397R
TST1     0111   1     223     233M    234R    244R    246M
TST2     0147   1     270     280M    281R    291R    293M
TST3     017D   1     317     327M    328R    338R    340M
TWO      046B   1     964     597R   1005R
T4WF     01FA   1     426     469M    515R    853R
UNM1     04A9   1    1015    1027M   1029R   1033M
VT012    FFF4   0    1125      15R
VT013    FFF3   0    1126      18R
VT014    FFF2   0    1127      20R
VT015    FFF1   0    1128      22R
VT016    FFF0   0    1129      25R
VT017    FFEF   0    1130      28R
VT018    FFEE   0    1131      30R
VT019    FFED   0    1132      32R
VT020    FFEC   0    1133      35R
VT021    FFEB   0    1134      38R
VT022    FFEA   0    1135      40R
VT023    FFE9   0    1136      42R
VT034    FFDE   0    1157    1055R   1063R
VT035    FFDD   0    1158    1060R   1064R   1070R
VT036    FFDC   0    1094     475R    527R
VT037    FFDB   0    1095     481R    533R
VT038    FFDA   0    1096     488R    540R
VT039    FFD9   0    1097      11R     14M    471R    474M
VT040    FFD8   0    1137      45R
VT041    FFD7   0    1138      48R
VT042    FFD6   0    1139      50R
VT043    FFD5   0    1140      52R
VT044    FFD4   0    1141      55R
VT045    FFD3   0    1142      58R
VT046    FFD2   0    1143      61R
VT047    FFD1   0    1144      64R
VT048    FFD0   0    1145      67R
VT049    FFCF   0    1146      69R
VT050    FFCE   0    1147      72R
VT061    FFC3   0    1148      74R
VT062    FFC2   0    1149      77R
VT063    FFC1   0    1150      80R
VT064    FFC0   0    1151      82R
```

Table B-12. Honeywell Control Program Cross Reference (Continued)

```
SYMBOL  VALUE REL  DEFN    REFERENCES-
VT065   FFBF   0   1152     65R
VT066   FFBF   0   1153     87R
VT067   FFBD   0   1154     90R
VT068   FFBC   0   1155     93R
VT069   FFBB   0   1156     95R
VT071   FFB9   0   1081    969M   978R   979R   995R
VT072   FFB8   0   1082    971M   974R   975R
VT073   FFB7   0   1083    973M  1003R
VT074   FFB6   0   1084    520M   582R   596R   998M  1006M  1009M  1044R
VT075   FFB5   0   1159     97R
VT076   FFB4   0   1160     99R
VT077   FFB3   0   1161    102R
VT078   FFB2   0   1162    105R
VT079   FFB1   0   1169
VT080   FFB0   0   1170    460M
VT081   FFAF   0   1085   1056M  1061M  1071M
VT082   FFAE   0   1086    111R
VT083   FFAD   0   1087    113R
VT084   FFAC   0   1163    115R
VT085   FFAB   0   1164    117R
VT086   FFAA   0   1165    119R
VT087   FFA9   0   1166    121R
VT088   FFA8   0   1167    123R
VT089   FFA7   0   1168    125R
VT090   FFA6   0   1171    462M
VT097   FF9F   0   1093    438R   444R
VT102   FF9A   0   1091    364R   370R   375R   387R   392R   512R   839R   849R
VT108   FF94   0   1092    835R   846R
VT128   0001   0   1090    508R   663R   673R   683R   708R   745R   832R  1047R
VT157   001E   0   1088    128R   148R   158R   170R   182R   509R   831R  1050R
VT162   0023   0   1098    796M
VT163   0024   0   1099    798M
VT164   0025   0   1100    800M
VT165   0026   0   1101    802M
VT166   0027   0   1102    804M
VT167   0028   0   1103    806M
VT168   0029   0   1104    808M
VT169   002A   0   1105    810M
VT170   002B   0   1106    812M
VT171   002C   0   1107    814M
VT172   002D   0   1108    816M
VT173   002E   0   1109    818M
VT174   002F   0   1110    820M
VT175   0030   0   1111    822M
VT176   0031   0   1112    824M
VT180   0035   0   1089    981M   985M   986R   990M   992R  1000R  1025R  1032R  1042M
VT196   0045   0   1115    834M
VT197   0046   0   1116    838M
VT198   0047   0   1117    842M
VT199   0048   0   1118    852M
VT200   0049   0   1119    856M
VT201   004A   0   1120    895M
VT202   004B   0   1121    826M
VT203   004C   0   1122    470M
VT204   004D   0   1123    912M
VT205   004E   0   1124    940M
VT206   004F   0   1113    947M
VT207   0050   0   1114    953M
WEFL    0368   1    739    700M   725M   761M   782R
```

Table B-12. Honeywell Control Program Cross Reference (Concluded)

```
SYMBOL  VALUE REL  DEFN    REFERENCES-
WEFM    0369   1    740     702M    727M    763M    785R
WEFN    040A   1    872     670M    680M    790M    801R    915R
WEF1    0100   1    205      19M    669R    699R
WEF2    0139   1    255      29M    701R    724R
WEF3    016F   1    302      39M    726R    760R
WEF4    0145   1    349      49M    679R    762R
WFMNN   0415   1    883     987R    989R
WFMN1   0108   1    217
WFMN2   0144   1    267
WFMN3   017A   1    314
WFMN4   01B0   1    361
WFMOD   046D   1    966     977M
WTFN    0411   1    879     807R    956R
WTF1    0107   1    213      68M
WTF2    0140   1    263      81M
WTF3    0176   1    310      94M
WTF4    01AC   1    357     106M
XR1     0509   1   1079       3M
XT4     01F4   1    417     440M    446R    458R    459M    467R
XT4D    01F6   1    420     436M    451M    452R    463R
XT4D1   01F8   1    423     437M    453R    464M
YNM1    04A8   1   1014    1026M   1037R   1041M
HWECT
DMP FUNCTION COMPLETED
*STORE              HWECT
HWECT
DMP FUNCTION COMPLETED
```

Table B-13. Bendix Bounds Program

```
// JOB          VDISK    17 JUL 74 15.768 HRS
// DMP   17 JUL 74 15.768 HRS
*DELETE                GTECT
DMP FUNCTION COMPLETED
// ASM GTECT    17 JUL 74 15.769 HRS                                                  HWE00010
*OVERFLOW SECTORS ,,,9                                                                HWE00020
*LIST                                                                                 HWE00030
*XREF                                                                                 HWE00040
*ONE WORD INTEGERS                                                                    HWE00050
*COMMON IDUMY(127),IVT00,JDUMY(127),IST0,MEAST(64),IASCW(2)                           HWE00060
0000      078C50E3     1          ENT      GTECT                                           HWE00070
0000 0    0000         2    GTECT DC       *-*                                             HWE00080
0001 01   6D000568     3          STX  L1  XR1+1                                           HWE00090
0003 01   6E00056A     4          STX  L2  XR2+1                                           HWE00100
0005 01   6F00056C     5          STX  L3  XR3+1                                           HWE00110
                       6    *                                                              HWE00120
0007 03   67C0FEC0     7          LDX  L3  MEAST-63                                        HWE00130
0009 03   6600FF80     8          LDX  L2  IVT00                                           HWE00140
000B 00   65000000     9          LDX  L1  0                                               HWE00150
000D 0    C03F        10          LD       =0                                              HWE00160
                      11    *                                                              HWE00170
000E 01   4C000147    12          B    L   START                                           HWE00180
0                     13    RSTAL EQU      *                 RESET ALL DIGITAL ADJUST      HWE00190
0010 0    C03E        14          LD       ST001                                           HWE00200
0011 0    D2FF        15          STO   2  VT001                                           HWE00210
0012 0    C03D        16          LD       ST002                                           HWE00220
0013 0    D2FE        17          STO   2  VT002                                           HWE00230
0014 0    C03C        18          LD       ST003                                           HWE00240
0015 0    D2FD        19          STO   2  VT003                                           HWE00250
0016 0    C03B        20          LD       ST004                                           HWE00260
0017 0    D2FC        21          STO   2  VT004                                           HWE00270
0018 0    C03A        22          LD       ST005                                           HWE00280
0019 0    D2FB        23          STO   2  VT005                                           HWE00290
001A 0    C039        24          LD       ST006                                           HWE00300
001B 0    D2FA        25          STO   2  VT006                                           HWE00310
001C 0    C038        26          LD       ST007                                           HWE00320
001D 0    D2F9        27          STO   2  VT007                                           HWE00330
001E 0    C037        28          LD       ST008                                           HWE00340
001F 0    D2F8        29          STO   2  VT008                                           HWE00350
0020 0    C036        30          LD       ST009                                           HWE00360
0021 0    D2F7        31          STO   2  VT009                                           HWE00370
0022 0    C035        32          LD       ST010                                           HWE00380
0023 0    D2F6        33          STO   2  VT010                                           HWE00390
0024 0    C034        34          LD       ST011                                           HWE00400
0025 0    D2F5        35          STO   2  VT011                                           HWE00410
0026 0    C033        36          LD       ST012                                           HWE00420
0027 0    D2F4        37          STO   2  VT012                                           HWE00430
0028 0    C032        38          LD       ST013                                           HWE00440
0029 0    D2F3        39          STO   2  VT013                                           HWE00450
002A 0    C031        40          LD       ST014                                           HWE00460
002B 0    D2F2        41          STO   2  VT014                                           HWE00470
002C 0    C030        42          LD       ST015                                           HWE00480
002D 0    D2F1        43          STO   2  VT015                                           HWE00490
002E 0    C02F        44          LD       ST016                                           HWE00500
002F 0    D2F0        45          STO   2  VT016                                           HWE00510
0030 0    C02E        46          LD       ST017                                           HWE00520
0031 0    D2EF        47          STO   2  VT017                                           HWE00530
0032 0    C02D        48          LD       ST018                                           HWE00540
0033 0    D2EE        49          STO   2  VT018                                           HWE00550
0034 0    C02C        50          LD       ST019                                           HWE00560
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Table B-13. Bendix Bounds Program (Continued)

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                                                              17 JUL 74      PAGE 002

0035 0   D2ED         51           STO    2 VT019                                      HWE00570
0036 0   C02B         52           LD       ST020                                      HWE00580
0037 0   D2EC         53           STO    2 VT020                                      HWE00590
0038 0   C02A         54           LD       ST021                                      HWE00600
0039 0   D2EB         55           STO    2 VT021                                      HWE00610
003A 0   C029         56           LD       ST022                                      HWE00620
003B 0   D2EA         57           STO    2 VT022                                      HWE00630
003C 0   C028         58           LD       ST023                                      HWE00640
003D 0   D2E9         59           STO    2 VT023                                      HWE00650
003E 0   C027         60           LD       ST024                                      HWE00660
003F 0   D2E8         61           STO    2 VT024                                      HWE00670
0040 0   C026         62           LD       ST025                                      HWE00680
0041 0   D2E7         63           STO    2 VT025                                      HWE00690
0042 0   C025         64           LD       ST026                                      HWE00700
0043 0   D2E6         65           STO    2 VT026                                      HWE00710
0044 0   C024         66           LD       ST027                                      HWE00720
0045 0   D2E5         67           STO    2 VT027                                      HWE00730
0046 0   C023         68           LD       ST028                                      HWE00740
0047 0   D2E4         69           STO    2 VT028                                      HWE00750
0048 0   C022         70           LD       ST029                                      HWE00760
0049 0   D2E3         71           STO    2 VT029                                      HWE00770
004A 0   C021         72           LD       ST030                                      HWE00780
004B 0   D2E2         73           STO    2 VT030                                      HWE00790
004C 0   705C         74           B        STTVT                                      HWE00800
                      75           LORG                                                HWE00810
004D 0   0000         76     +     DC       0
                      77     *                        SPEED CONTROL FIG10-3&4          HWE00820
004E 0   0000         78     ST000 DC       0                                          HWE00830
004F 0   0000         79     ST001 DC       0         IDLE SPEED TRIM                  HWE00840
0050 0   0000         80     ST002 DC       0         MAX  SPEED TRIM                  HWE00850
0051 0   4E20         81     ST003 DC       20000                                      HWE00860
0052 0   0000         82     ST004 DC       0              BRANCH COMMAND  64+         HWE00870
0053 0   1000         83     ST005 DC       4096           N INTEGRATION INC           HWE00880
0054 0   1388         84     ST006 DC       5000           N INT PRESS GAIN            HWE00890
0055 0   F000         85     ST007 DC       -4096          N INT DECREASE              HWE00900
0056 0   EC78         86     ST008 DC       -5000          N INT DEC PRESS GAIN        HWE00910
                      87     *                                                         HWE00920
                      88     *              FIG10-5  PROP.TEMPERATURE CONTROL          HWE00930
0057 0   0000         89     ST009 DC       0         SPEED CONTROL SELECTION          HWE00940
0058 0   2AF8         90     ST010 DC       11000                                      HWE00950
0059 0   0000         91     ST011 DC       0         ZERO FLOW ADJUST                 HWE00960
                      92     *           HONEYWELL ST VALUES
                      93     *
005A 0   F290         94     ST012 DC       -3440     N   GAIN  (50,E)
005B 0   0207         95     ST013 DC       519       WF        (50 ,E)
005C 0   0992         96     ST014 DC       2450      PT3 BOND (50 ,P)
005D 0   01B0         97     ST015 DC       432       EN  GAIN (50 ,E)
005E 0   F820         98     ST016 DC       -2016     N   GAIN (70 ,E)
005F 0   02B5         99     ST017 DC       693       WF       (70 ,E)
0060 0   0FA0        100     ST018 DC       4000      PT3 BOND (70 ,P)
0061 0   0190        101     ST019 DC       400       EN  GAIN (70 ,E)
0062 0   F860        102     ST020 DC       -1952     N   GAIN (85 ,E)
0063 0   03A6        103     ST021 DC       934       WF       (85 ,E)
0064 0   109C        104     ST022 DC       6300      PT3 BOND (85 ,P)
0065 0   0380        105     ST023 DC       896       EN  GAIN (85 ,E)
                     106     *
                     107     *            END HONEYWELL ST VALUES
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Table B-13. Bendix Bounds Program (Continued)

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                                                                   17 JUL 74     PAGE 003

                       108    *
0066 0  1770           109    ST024 DC      6000        ZERO N RATIOS INTERCEPT       HWE01140
0067 0  A240           110    ST025 DC      -24000      BACK SLOPE SPEED BREAK PT     HWE01150
0068 0  4000           111    ST026 DC      16384
                       112    *                                                       HWE01170
                       113    *                     FIGURE10-8   RATIOS INTEGRATIONHWE01180
0069 0  7FF8           114    ST027 DC      32760
006A 0  0000           115    ST028 DC      0
006B 0  0000           116    ST029 DC      0           MINIMUM RATIOS SLOPE          HWE01210
006C 0  5014           117    ST030 DC      20500       MINIMUM RATIOS LEVEL          HWE01220
006D 0  0000           118    ST031 DC      0                                         HWE01230
006E 0  7FF8           119    ST032 DC      32760       VALVE MAXIMUM POSITION        HWE01240
006F 0  0000           120    ST033 DC      0           VALVE MINIMUM POSITION        HWE01250
0070 0  25A8           121    ST034 DC      9640
0071 0  0A5A           122    ST035 DC      2650
                       123    *
                       124    *             HONEYWELL ST VALUES
                       125    *
0072 0  0640           126    ST036 DC      1600
0073 0  0640           127    ST037 DC      1600
0074 0  567D           128    ST038 DC      22141
0075 0  0010           129    ST039 DC      16
0076 0  F0A0           130    ST040 DC      -3936       N   GAIN (100,E)
0077 0  0670           131    ST041 DC      1648        WF        (100,E)
0078 0  1FA4           132    ST042 DC      8100        PT3 BOND (100,P)
0079 0  0930           133    ST043 DC      2352        EN  GAIN (100,E)
007A 0  22D0           134    ST044 DC      8912       PT5 GAIN (50  T)
007B 0  FB66           135    ST045 DC      -1178      PT3 GAIN (50  T)
007C 0  F970           136    ST046 DC      -1680      T4W GAIN (50  T)
007D 0  0340           137    ST047 DC      832        ET GAIN (50  T)
007E 0  028B           138    ST048 DC      651        WTF (50  T)
007F 0  3A80           139    ST049 DC      14976      PT5 GAIN (70  T)
0080 0  6009           140    ST050 DC      24585      PT3 GAIN (70  T)
                       141    *
                       142    *             END HONEYWELL ST VALUES
                       143    *
                       144    *                                                       HWE01460
                       145    *                   FIGURE10-12  IGV & BLEED CONTR      HWE01470
0081 0  0000           146    ST051 DC      0           LOW N TRIM OF IGV             HWE01480
0082 0  3E80           147    ST052 DC      16000       HIGH N TRIM OFIGV             HWE01490
0083 0  0000           148    ST053 DC      0           LOW N TRIM OF BLEEDS          HWE01500
0084 0  3E80           149    ST054 DC      16000       HIGH N TRIM OF BLEEDS         HWE01510
                       150    *                                                       HWE01520
                       151    *                   FIGURE10-14 NOZZLE CONTROL          HWE01530
0085 0  105E           152    ST055 DC      4190        NOZZLE FLAT                   BEN01530
0086 0  40D8           153    ST056 DC      16600       T5 REQUEST                    HWE01550
0087 0  4000           154    ST057 DC      16384       T5 CONTROL GAIN               HWE01560
0088 0  0000           155    ST058 DC      0                                         HWE01570
0089 0  0000           156    ST059 DC      0                                         HWE01580
008A 0  0000           157    ST060 DC      0                                         HWE01590
008B 0  F7CE           158    ST061 DC      -2098      T4W GAIN (70  T)
008C 0  0410           159    ST062 DC      1040       ET GAIN (70  T)
008D 0  03E8           160    ST063 DC      1000       WTF (70  T)
008E 0  EA90           161    ST064 DC      -5488      PT5 GAIN (85  T)
008F 0  108B           162    ST065 DC      4235       PT3 GAIN (85  T)
0090 0  FA95           163    ST066 DC      -1387      T4W GAIN (85  T)
0091 0  04A0           164    ST067 DC      1184       ET GAIN (85  T
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Table B-13. Bendix Bounds Program (Continued)

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                                                              17 JUL 74      PAGE 004

0092 0  0898       165    ST068 DC        2200       WTF (85  T)
0093 0  17EF       166    ST069 DC        6127       PT5 GAIN (100 T)
0094 0  0000       167    ST070 DC        0
0095 0  0000       168    ST071 DC        0
0096 0  0000       169    ST072 DC        0
0097 0  0000       170    ST073 DC        0
0098 0  0000       171    ST074 DC        0
0099 0  DF6E       172    ST075 DC        -8338      PT3 GAIN (100 T)
009A 0  FFC0       173    ST076 DC        -64        T4W GAIN (100 T)
009B 0  06C0       174    ST077 DC        1728       ET GAIN (100 T)
009C 0  0BB8       175    ST078 DC        3000       WTF (100 T)
009D 0  0000       176    ST079 DC        0
009E 0  0000       177    ST080 DC        0
009F 0  0000       178    ST081 DC        0
00A0 0  299A       179    ST082 DC        10650
00A1 0  2666       180    ST083 DC        9830
00A2 0  30AC       181    ST084 DC        12460
00A3 0  2EE0       182    ST085 DC        12000
00A4 0  05DC       183    ST086 DC        1500
00A5 0  0690       184    ST087 DC        1680
00A6 0  0898       185    ST088 DC        2200
00A7 0  0B54       186    ST089 DC        2900
00A8 0  0000       187    ST090 DC        0
00A9               188    STTVT EQU       *                                HWE01600
00A9 0  C0C3       189          LD        ST031                            HWE01610
00AA 0  D2E1       190          STO     2 VT031                            HWE01620
00AB 0  C0C2       191          LD        ST032                            HWE01630
00AC 0  D2E0       192          STO     2 VT032                            HWE01640
00AD 0  C0C1       193          LD        ST033                            HWE01650
00AE 0  D2DF       194          STO     2 VT033                            HWE01660
00AF 0  C0C0       195          LD        ST034                            HWE01670
00B0 0  D2DE       196          STO     2 VT034                            HWE01680
00B1 0  C0BF       197          LD        ST035                            HWE01690
00B2 0  D2DD       198          STO     2 VT035                            HWE01700
00B3 0  C0BE       199          LD        ST036                            HWE01710
00B4 0  D2DC       200          STO     2 VT036                            HWE01720
00B5 0  C0BD       201          LD        ST037                            HWE01730
00B6 0  D2DB       202          STO     2 VT037                            HWE01740
00B7 0  C0BC       203          LD        ST038                            HWE01750
00B8 0  D2DA       204          STO     2 VT038                            HWE01760
00B9 0  C0BB       205          LD        ST039                            HWE01770
00BA 0  D2D9       206          STO     2 VT039                            HWE01780
00BB 0  C0BA       207          LD        ST040                            HWE01790
00BC 0  D2D8       208          STO     2 VT040                            HWE01800
00BD 0  C0B9       209          LD        ST041                            HWE01810
00BE 0  D2D7       210          STO     2 VT041                            HWE01820
00BF 0  C0B8       211          LD        ST042                            HWE01830
00C0 0  D2D6       212          STO     2 VT042                            HWE01840
00C1 0  C0B7       213          LD        ST043                            HWE01850
00C2 0  D2D5       214          STO     2 VT043                            HWE01860
00C3 0  C0B6       215          LD        ST044                            HWE01870
00C4 0  D2D4       216          STO     2 VT044                            HWE01880
00C5 0  C0B5       217          LD        ST045                            HWE01890
00C6 0  D2D3       218          STO     2 VT045                            HWE01900
00C7 0  C0B4       219          LD        ST046                            HWE01910
00C8 0  D2D2       220          STO     2 VT046                            HWE01920
00C9 0  C0B3       221          LD        ST047                            HWE01930
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Table B-13. Bendix Bounds Program (Continued)

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00CA 0  D2D1        222          STO   2 VT047                             HWE01940
00CB 0  C0B2        223          LD      ST048                             HWE01950
00CC 0  D2D0        224          STO   2 VT048                             HWE01960
00CD 0  C0B1        225          LD      ST049                             HWE01970
00CE 0  D2CF        226          STO   2 VT049                             HWE01980
00CF 0  C0B0        227          LD      ST050                             HWE01990
00D0 0  D2CE        228          STO   2 VT050                             HWE02000
00D1 0  C0AF        229          LD      ST051                             HWE02010
00D2 0  D2CD        230          STO   2 VT051                             HWE02020
00D3 0  C0AE        231          LD      ST052                             HWE02030
00D4 0  D2CC        232          STO   2 VT052                             HWE02040
00D5 0  C0AD        233          LD      ST053                             HWE02050
00D6 0  D2CB        234          STO   2 VT053                             HWE02060
00D7 0  C0AC        235          LD      ST054                             HWE02070
00D8 0  D2CA        236          STO   2 VT054                             HWE02080
00D9 0  C0AB        237          LD      ST055                             HWE02090
00DA 0  D2C9        238          STO   2 VT055                             HWE02100
00DB 0  C0AA        239          LD      ST056                             HWE02110
00DC 0  D2C8        240          STO   2 VT056                             HWE02120
00DD 0  C0A9        241          LD      ST057                             HWE02130
00DE 0  D2C7        242          STO   2 VT057                             HWE02140
00DF 0  C0A8        243          LD      ST058                             HWE02150
00E0 0  D2C6        244          STO   2 VT058                             HWE02160
00E1 0  C0A7        245          LD      ST059                             HWE02170
00E2 0  D2C5        246          STO   2 VT059                             HWE02180
00E3 0  C0A6        247          LD      ST060                             HWE02190
00E4 0  D2C4        248          STO   2 VT060                             HWE02200
00E5 0  C0A5        249          LD      ST061
00E6 0  D2C3        250          STO   2 VT061
00E7 0  C0A4        251          LD      ST062
00E8 0  D2C2        252          STO   2 VT062
00E9 0  C0A3        253          LD      ST063
00EA 0  D2C1        254          STO   2 VT063
00EB 0  C0A2        255          LD      ST064
00EC 0  D2C0        256          STO   2 VT064
00ED 0  C0A1        257          LD      ST065
00EE 0  D2BF        258          STO   2 VT065
00EF 0  C0A0        259          LD      ST066
00F0 0  D2BE        260          STO   2 VT066
00F1 0  C09F        261          LD      ST067
00F2 0  D2BD        262          STO   2 VT067
00F3 0  C09E        263          LD      ST068
00F4 0  D2BC        264          STO   2 VT068
00F5 0  C09D        265          LD      ST069
00F6 0  D2BB        266          STO   2 VT069
00F7 0  C09C        267          LD      ST070
00F8 0  D2BA        268          STO   2 VT070
00F9 01 C4000095    269          LD    L ST071
00FB 0  D2B9        270          STO   2 VT071
00FC 01 C4000096    271          LD    L ST072
00FE 0  D2B8        272          STO   2 VT072
00FF 01 C4000097    273          LD    L ST073
0101 0  D2B7        274          STO   2 VT073
0102 01 C4000098    275          LD    L ST074
0104 0  D2B6        276          STO   2 VT074
0105 01 C4000099    277          LD    L ST075
0107 0  D2B5        278          STO   2 VT075
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Table B-13. Bendix Bounds Program (Continued)

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                                                        17 JU  74     PAGE 006

0108 01 C400009A   279           LD    L  ST076
010A 0  D2B4       280           STO    2 VT076
010B 01 C400009B   281           LD    L  ST077
010D 0  D2B3       282           STO    2 VT077
010E 01 C400009C   283           LD    L  ST078
0110 0  D2B2       284           STO    2 VT078
0111 01 C400009D   285           LD    L  ST079
0113 0  D2B1       286           STO    2 VT079
0114 01 C400009E   287           LD    L  ST080
0116 0  D2B0       288           STO    2 VT080
0117 01 C400009F   289           LD    L  ST081
0119 0  D2AF       290           STO    2 VT081
011A 01 C40000A0   291           LD    L  ST082
011C 0  D2AE       292           STO    2 VT082
011D 01 C40000A1   293           LD    L  ST083
011F 0  D2AD       294           STO    2 VT083
0120 01 C40000A2   295           LD    L  ST084
0122 0  D2AC       296           STO    2 VT084
0123 01 C40000A3   297           LD    L  ST085
0125 0  D2AB       298           STO    2 VT085
0126 01 C40000A4   299           LD    L  ST086
0128 0  D2AA       300           STO    2 VT086
0129 01 C40000A5   301           LD    L  ST087
012B 0  D2A9       302           STO    2 VT087
012C 01 C40000A6   303           LD    L  ST088
012E 0  D2A8       304           STO    2 VT088
012F 01 C40000A7   305           LD    L  ST089
0131 0  D2A7       306           STO    2 VT089
0132 01 C40000A8   307           LD    L  ST090
0134 0  D2A6       308           STO    2 VT090
0135 0  7054       309           B        DAC4L       BRANCH TO DAC4 OUTPUT LOOP HWE02210
                   310     *                                                     HWE02220
0136    0000       311     CEON  BSS   E  0                                      HWE02230
0136 0  0000       312           DC       0                                      HWE02240
0137 0  E401       313           DC       /E401                                  HWE02250
                   314     *                    DIGITAL ADJUSTMENT               HWE02260
0138    0000       315     DIV64 BSS   E  0                                      HWE02270
0138 0  0000       316           DC       0                                      HWE02280
0139 0  5F40       317           DC       /5F40                                  HWE02290
                   318     *                    SAFETY RESET DIGITAL WORD        HWE02300
013A    0000       319     DIV40 BSS   E  0                                      HWE02310
013A 0  0000       320           DC       0                                      HWE02320
013B 0  DF40       321           DC       /DF40                                  HWE02330
                   322     *                                                     HWE02340
013C    0000       323     DO7E  BSS   E  0                                      HWE02350
013C 1  013E       324           DC       VALUE                                  HWE02360
013D 0  617E       325           DC       /617E                                  HWE02370
                   326     *                                                     HWE02380
013E 0  0000       327     VALUE DC       *-*                                    HWE02390
013F 0  0000       328     NUM   DC       *-*                                    HWE02400
0140 0  0000       329     TMNR  DC       *-*                                    HWE02410
0141 0  0032       330     TRIMS DC       50                                     HWE02420
0142 0  0000       331     TEMP3 DC       *-*                                    HWE02430
0143 0  0000       332     TEMP4 DC       *-*                                    HWE02440
0144 0  0000       333     TEMP5 DC       *-*                                    HWE02450
0145 0  0000       334     DKOUT DC       *-*                                    HWE02460
0146 0  0000       335     DK2OT DC       *-*                                    HWE02470
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Table B-13. Bendix Bounds Program (Continued)

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                                                          17 JUL 74     PAGE 007

                        336   *                   OBTAIN INPUT DATA               HWE02480
 0147                   337   START EQU     *                                     HWE02490
 0147 0  08EE           338         XIO     CEON                                  HWE02500
                        339   *                   DIGITAL ADJUSTMENTS             HWE02510
 0148 0  08EF           340         XIO     DIV64                                 HWE02520
 0149 01 E40001E4       341         AND   L =/7F80                                HWE02540
 014B 0  D2A2           342         STO   2 VT094       DIGITAL ADJUSTMENT        HWE02530
 014C 0  1807           343         SRA     7                                     HWE02550
 014D 0  D0F1           344         STO     NUM                                   HWE02560
 014E 01 940001E5       345         S     L =127                                  HWE02570
 0150 0  D0EF           346         STO     TMNR                                  HWE02580
 0151 01 4C300157       347         BP      PLUS                                  HWE02590
 0153 01 C400004D       348         LD    L =0                                    HWE02600
 0155 0  90E9           349         S       NUH                                   HWE02610
 0156 0  D0E9           350         STO     TMNR                                  HWE02620
 0157 01 65800140       351   PLUS  LDX  I1 TMNR                                  HWE02630
 0159 03 C500FF80       352         LD   L1 IVT00                                 HWE02640
 015B 0  D0E2           353         STO     VALUE                                 HWE02650
 015C 0  D0E6           354         STO     TEMP4                                 HWE02660
 015D 01 4C300  5       355         BP      RDOUT                                 HWE02670
 015F 01 C400   D       356         LD    L =0                                    HWE02680
 0161 0  90DC           357         S       VALUE                                 HWE02690
 0162 01 EC0001E6       358         OR    L =/8000                                HWE02700
 0164 0  D0D9           359         STO     VALUE                                 HWE02710
 0165                   360   RDOUT EQU                                           HWE02720
 0165 0  08D6           361         XIO     D07E                                  HWE02730
                        362   *                   VTXXX VALUE OUTPUT              HWE02740
                        363   *                   RESET AND SAFETY                HWE02750
 0166 0  08D3           364         XIO     DIV40                                 HWE02760
 0167 0  E07F           365         AND     =/7FFF                                HWE02770
 0168 0  D0D9           366         STO     TEMP3                                 HWE02780
 0169 0  D29B           367         STO   2 VT101                                 HWE02790
 016A 0  E07D           368         AND     =/4000                                HWE02800
 016B 01 4C300010       369         BP      RSTAL       RESET ALL ADJUSTMENTS     HWE02810
                        370   *                   SINGLE ADJUSTMENT RESET ROUTINE HWE02820
 016D 0  C29D           371         LD    2 VT099                                 HWE02830
 016E 0  9000           372         S       NUM                                   HWE02840
 016F 01 4C18017        373         BZ      RSTSA                                 HWE02850
 0171 0  C0CD           374         LD      NUM                                   HWE02860
 0172 0  D29D           375         STO   2 VT099                                 HWE02870
 0173 0  C0CF           376         LD      TEMP4                                 HWE02880
 0174 0  D29C           377         STO   2 VT100                                 HWE02890
 0175 0  C29B           378   RSTSA LD    2 VT101                                 HWE02900
 0176 0  E072           379         AND     =/2000                                HWE02910
 0177 01 4C18018A       380         BZ      DAC4L                                 HWE02920
 0179 0  C0C5           381         LD      NUM                                   HWE02930
 017A 0  906F           382         S       =90         NUMBER OF ADJUSTMENTS     HWE02940
 017B 01 4C30018A       383         BP      DAC4L                                 HWE02950
                        384   *RESET ONLY ONE TRIM                                HWE02960
 017D 0  C06D           385         LD      =C                                    HWE02970
 017E 0  90C0           386         S       NUM                                   HWE02980
 017F 0  D0C4           387         STO     TEMP5                                 HWE02990
 0180 01 6500004E       388         LDX  L1 ST000                                 HWE03000
 0182 01 7580013F       389         MDX  I1 NUM                                   HWE03010
 0184 0  C100           390         LD    1 0                                     HWE03020
 0185 03 6500FF80       391         LDX  L1 IVT00                                 HWE03030
 0187 01 75800144       392         MDX  I1 TEMP5                                 HWE03040
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Table B-13. Bendix Bounds Program (Continued)

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                                                                17 JUL 74      PAGE 008

0189 0  D100        393          STO   1 0                                             HWE03050
                    394     * END RESET ONLY ONE TRIM                                  HWE03060
                    395     *                            DAC4 OUTPUT                   HWE03070
018A                396     DAC4L EQU    *                                             HWE03080
018A 0  C29B        397          LD    2 VT101                                         HWE03090
018B 0  E060        398          AND     =/1000                                        HWE03100
018C 01 4C180190    399          BZ      DAC40                                         HWE03110
018E 0  C0B1        400          LD      TMNR                                          HWE03120
018F 0  D216        401          STO   2 VT149                                         HWE03130
                    402     *                            DAC4 OUTPUT ROUTINE           HWE03140
0190                403     DAC40 EQU    *                                             HWE03150
0190 0  C216        404          LD    2 VT149                                         HWE03160
0191 0  D0B3        405          STO     DKOUT                                         HWE03170
0192 01 65800145    406          LDX  I1 DKOUT                                         HWE03180
0194 03 C500FF80    407          LD   L1 IVT00                                         HWE03190
0196 0  1881        408          SRT     1                                             HWE03200
0197 01 D4000589    409          STO  L  ALOG4                                         HWE03210
0199 0  D25D        410          STO   2 VT220                                         HWE03220
                    411     *                                                          HWE03230
                    412     *                               OUTPUT VTXXX TO DAC 2      HWE03240
019A 0  C29B        413          LD    2 VT101                                         HWE03250
019B 0  E051        414          AND     =/0800                                        HWE03260
019C 01 4C1801A0    415          BZ      DAC20                                         HWE03270
019E 0  C0A1        416          LD      TMNR                                          HWE03280
019F 0  D261        417          STO   2 VT224                                         HWE03290
                    418     *                                                          HWE03300
01A0                419     DAC20 EQU    *                                             HWE03310
01A0 0  C261        420          LD    2 VT224                                         HWE03320
01A1 0  D0A4        421          STO     DK2OT                                         HWE03330
01A2 01 65800146    422          LDX  I1 DK2OT                                         HWE03340
01A4 03 C500FF80    423          LD   L1 IVT00                                         HWE03350
01A6 0  1881        424          SRT     1                                             HWE03360
01A7 01 D4000587    425          STO  L  BLEED                                         HWE03370
01A9 0  D262        426          STO   2 VT225                                         HWE03380
                    427     *                                                          HWE03390
                    428     *                            VALVE POSITION SIMULATION     HWE03400
01AA 0  C29B        429          LD    2 VT101                                         HWE03410
01AB 0  E042        430          AND     =/0400                                        HWE03420
01AC 01 4C3001B8    431          BP      VLVEG       VALVE POSITION ENGINE             HWE03430
01AE 0  C29B        432          LD    2 VT101                                         HWE03440
01AF 0  E03F        433          AND     =/00FF                                        HWE03450
01B0 0  903F        434          S       =/00AA                                        HWE03460
01B1 01 4C1801C6    435          BZ      SAFND       END OF SAFETY ROUTINE             HWE03470
01B3 0  C03D        436          LD      =-5000                                        HWE03480
01B4 01 D4000585    437          STO  L  FUEL                                          HWE03490
01B6 01 4C000551    438          B    L  DONE                                          HWE03500
                    439     *                        VALVE POSITION ENGINE RUN         HWE03510
01B8                440     VLVEG EQU    *                                             HWE03520
01B8 0  C21E        441          LD    2 VT157                                         HWE03530
01B9 0  9038        442          S       =7000                                         HWE03540
01BA 01 4C3001C6    443          BP      SAFND                                         HWE03550
01BC 0  C29B        444          LD    2 VT101                                         HWE03560
01BD 0  E031        445          AND     =/00FF                                        HWE03570
01BE 0  9034        446          S       =/0055                                        HWE03580
01BF 01 4C1801C6    447          BZ      SAFND                                         HWE03590
01C1 0  C02F        448          LD      =-5000                                        HWE03600
01C2 01 D4000585    449          STO  L  FUEL                                          HWE03610
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Table B-13. Bendix Bounds Program (Continued)

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                                                               17 JUL 74     PAGE 009

01C4 01 4C000551    450              B     L  DONE                                      HWE03620
01C6                451       SAFND EQU       *                                         HWE03630
                    452       *                          SPEED COMPUTATION              HWE03640
01C6 0  C02D        453              LD       =10                                       HWE03650
01C7 01 D40001E2    454              STO   L  TESTN                                     HWE03660
01C9 0  0816        455       GETN  XIO       RPM                                       HWE03670
01CA 01 4C2801CF    456              BN       VALID                                     HWE03680
01CC 01 74FF01E2    457              MDM      TESTN,-1                                  HWE03690
01CE 0  70FA        458              B        GETN                                      HWE03700
01CF                459       VALID EQU       *                                         HWE03710
01CF 0  EC17        460              AND      =/7FFF                                    HWE03720
01D0 0  D012        461              STO      RAWN                                      HWE03730
01D1 0  D2A3        462              STO    2 VT093        RAW SPEED                    HWE03740
01D2 01 CC0001DE    463              LDD   L  KSUBN                                     HWE03750
01D4 0  1885        464              SRT      5                                         HWE03760
01D5 0  A80D        465              D        RAWN                                      HWE03770
01D6 0  D21E        466              STO    2 VT157                                     HWE03780
01D7 01 74FF0141    467              MDM      TRIMS,-1                                  HWE03790
01D9 0  7042        468              MDX      ENDTM                                     HWE03800
                    469       *                                                         HWE03810
01DA 0  701A        470              B        LORG1                                     HWE03820
                    471       *                                                         HWE03830
01DC    0000        472              BSS   E  0                                         HWE03840
01DC 0  0000        473              DC       *-*                                       HWE03850
01DD 0  0000        474       TEMP2 DC        *-*                                       HWE03860
01DE                475              ORG      *-1                                       HWE03870
01DD 9A 5DD77000    476              XFLC     4.92E7                                    HWE03880
01DE                477       KSUBN EQU       TEMP2+1                                   HWE03890
                    478       *                        ENGINE SPEED                     HWE03900
01E0    0000        479       RPM   BSS   E  0                                          HWE03910
01E0 0  0000        480              DC       0                                         HWE03920
01E1 0  5F41        481              DC       /5F41                                     HWE03930
01E2 0  0000        482       TESTN DC        *-*                                       HWE03940
01E3 0  0000        483       RAWN  DC        *-*                                       HWE03950
                    484              LORG                                               HWE03960
01E4 0  7F80        485       +      DC       /7F80
01E5 0  007F        486       +      DC       127
01E6 0  8000        487       +      DC       /8000
01E7 0  7FFF        488       +      DC       /7FFF
01E8 0  4000        489       +      DC       /4000
01E9 0  2000        490       +      DC       /2000
01EA 0  005A        491       +      DC       90
01EB 0  0000        492       +      DC       0
01EC 0  1000        493       +      DC       /1000
01ED 0  0800        494       +      DC       /0800
01EE 0  0400        495       +      DC       /0400
01EF 0  00FF        496       +      DC       /00FF
01F0 0  00AA        497       +      DC       /00AA
01F1 0  EC78        498       +      DC       -5000
01F2 0  1B58        499       +      DC       7000
01F3 0  0055        500       +      DC       /0055
01F4 0  000A        501       +      DC       10
01F5                502       LORG1 EQU       *                                         HWE03970
                    503       *                                                         HWE03980
                    504       *                   ANALOG VOLTAGE ADJUSTMENTS            HWE03990
                    505       *                           STRIP 3                       HWE04000
01F5 0  C312        506       ANALT LD      3 P18                                       HWE04010
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Table B-13. Bendix Bounds Program (Continued)

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                                                        17 JUL 74    PAGE 010

01F6 0  D292        507          STO   2 VT110                                  HWE04020
01F7 0  C313        508          LD    3 P19                                    HWE04030
01F8 0  D291        509          STO   2 VT111                                  HWE04040
01F9 0  C314        510          LD    3 P20                                    HWE04050
01FA 0  D290        511          STO   2 VT112                                  HWE04060
01FB 0  C315        512          LD    3 P21                                    HWE04070
01FC 0  D28F        513          STO   2 VT113                                  HWE04080
01FD 0  C316        514          LD    3 P22                                    HWE04090
01FE 0  D28E        515          STO   2 VT114                                  HWE04100
01FF 0  C317        516          LD    3 P23                                    HWE04110
0200 0  D28D        517          STO   2 VT115                                  HWE04120
0201 0  C318        518          LD    3 P24                                    HWE04130
0202 0  D28C        519          STO   2 VT116                                  HWE04140
0203 0  C319        520          LD    3 P25                                    HWE04150
0204 0  D28B        521          STO   2 VT117                                  HWE04160
0205 0  C31A        522          LD    3 P26                                    HWE04170
0206 0  D28A        523          STO   2 VT118                                  HWE04180
                    524    *                       STRIP 4                      HWE04190
0207 0  C31B        525          LD    3 P27                                    HWE04200
0208 0  D289        526          STO   2 VT119                                  HWE04210
0209 0  C31C        527          LD    3 P28                                    HWE04220
020A 0  D288        528          STO   2 VT120                                  HWE04230
020B 0  C31D        529          LD    3 P29                                    HWE04240
020C 0  D287        530          STO   2 VT121                                  HWE04250
020D 0  C31E        531          LD    3 P30                                    HWE04260
020E 0  D286        532          STO   2 VT122                                  HWE04270
020F 0  C31F        533          LD    3 P31                                    HWE04280
0210 0  D285        534          STO   2 VT123                                  HWE04290
0211 0  C320        535          LD    3 P32                                    HWE04300
0212 0  D284        536          STO   2 VT124                                  HWE04310
0213 0  C321        537          LD    3 P33                                    HWE04320
0214 0  D283        538          STO   2 VT125                                  HWE04330
0215 0  C322        539          LD    3 P34                                    HWE04340
0216 0  D282        540          STO   2 VT126                                  HWE04350
0217 0  C323        541          LD    3 P35                                    HWE04360
0218 0  D281        542          STO   2 VT127                                  HWE04370
0219 0  C050        543          LD      =50                                    HWE04380
021A 01 D4000141    544          STO   L TRIMS                                  HWE04390
021C                545    ENDTM EQU     *                                      HWE04400
                    546    *                       STRIP 5                      HWE04410
021C 0  C324        547          LD    3 P36                  DP/P         EK14 HWE04420
021D 0  D264        548          STO   2 VT227                                  HWE04430
021E 0  C325        549          LD    3 P37                         SPARE      HWE04440
021F 0  D265        550          STO   2 VT228                                  HWE04450
0220 0  C326        551          LD    3 P38                         SPARE      HWE04460
0221 0  D266        552          STO   2 VT229                                  HWE04470
0222 0  C327        553          LD    3 P39                  P3           EK14 HWE04480
0223 0  D267        554          STO   2 VT230                                  HWE04490
0224 0  C328        555          LD    3 P40                  PB           EK15 HWE04500
0225 0  D268        556          STO   2 VT231                                  HWE04510
0226 0  A054        557          M       =20000                                 HWE04520
0227 0  1081        558          SLT     1                                      HWE04530
0228 0  D29A        559          STO   2 VT102          PB=100XPSI              HWE04540
0229 0  C329        560          LD    3 P41                  DP           EK15 HWE04550
022A 0  D269        561          STO   2 VT232                                  HWE04560
022B 0  A050        562          M       =30000                                 HWE04570
022C 0  1081        563          SLT     1                                      HWE04580
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Table B-13. Bendix Bounds Program (Continued)

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                                                          17 JUL 74     PAGE 011

0022D 0  D299        564        STO  2 VT103     DP=1000XPSI                   HWE04590
022E 0  C32A         565        LD   3 P42            P2                  EK15 HWE04600
022F 0  D26A         566        STO  2 VT233                                   HWE04610
0230 0  A04C         567        M      =25000                                  HWE04620
0231 0  1081         568        SLT    1                                       HWE04630
0232 0  D298         569        STO  2 VT104     P2=1000XPSI                   HWE04640
0233 0  C32B         570        LD   3 P43            P23-P2              EK15 HWE04650
0234 0  D26B         571        STO  2 VT234                                   HWE04660
0235 0  A048         572        M      =15000                                  HWE04670
0236 0  D297         573        STO  2 VT105     P23-P2=100XPSI                HWE04680
0237 0  C32C         574        LD   3 P44            POSITION            EK15 HWE04690
0238 0  D26C         575        STO  2 VT235                                   HWE04700
                     576   *                     STRIP 6                       HWE04710
0239 0  C32D         577        LD   3 P45            N ANALOG            EK15 HWE04720
023A 0  D26D         578        STO  2 VT236                                   HWE04730
023B 0  C32E         579        LD   3 P46            P24-P2              EK15 HWE04740
023C 0  D26E         580        STO  2 VT237                                   HWE04750
023D 0  A040         581        M      =15000                                  HWE04760
023E 0  D296         582        STO  2 VT106     P24-P2=100XPSI                HWE04770
023F 0  C32F         583        LD   3 P47            P25-P2              EK15 HWE04780
0240 0  D26F         584        STO  2 VT238                                   HWE04790
0241 0  A03C         585        M      =15000                                  HWE04800
0242 0  D295         586        STO  2 VT107     P25-P2=100XPSI                HWE04810
0243 0  C330         587        LD   3 P48            P5                  EK15 HWE04820
0244 0  D270         588        STO  2 VT239                                   HWE04830
0245 0  A039         589        M      =10000                                  HWE04840
0246 0  D294         590        STO  2 VT108     P5=100XPSI                    HWE04850
0247 0  C331         591        LD   3 P49            P0                  EK15 HWE04860
0248 0  D271         592        STO  2 VT240                                   HWE04870
0249 0  A033         593        M      =25000                                  HWE04880
024A 0  1081         594        SLT    1                                       HWE04890
024B 0  D293         595        STO  2 VT109    P0=1000 PSI                    HWE04900
024C 0  C332         596        LD   3 P50        P/P        EK15              HWE04910
024D 0  D272         597        STO  2 VT241                                   HWE04920
024E 0  C333         598        LD   3 P51                                EK15 HWE04930
024F 0  D273         599        STO  2 VT242                                   HWE04940
0250 0  C334         600        LD   3 P52                                EK15 HWE04950
0251 0  D274         601        STO  2 VT243                                   HWE04960
0252 0  C335         602        LD   3 P53                                EK15 HWE04970
0253 0  D275         603        STO  2 VT244                                   HWE04980
                     604   *                     STRIP 7                       HWE04990
0254 0  C336         605        LD   3 P54            T2                  EK18 HWE05000
0255 0  802A         606        A      =19520                                  HWE05010
0256 0  D276         607        STO  2 VT245                                   HWE05020
0257 0  A029         608        M      =20480                                  HWE05030
0258 0  9029         609        S      =4600                                   HWE05040
0259 0  D2A1         610        STO  2 VT095     T2=10XF                       HWE05050
025A 0  C337         611        LD   3 P55            T3                  EK18 HWE05060
025B 0  8024         612        A      =19520                                  HWE05070
025C 0  D277         613        STO  2 VT246                                   HWE05080
025D 0  A023         614        M      =20480                                  HWE05090
025E 0  9023         615        S      =4600                                   HWE05100
025F 0  D2A0         616        STO  2 VT096     T3=10XF                       HWE05110
0260 0  C338         617        LD   3 P56            T4                  EK18 HWE05120
0261 01 A4000283     618        M    L =4000
0263 01 AC000284     619        D    L =10813
0265 01 84000285     620        A    L =1645
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Table B-13. Bendix Bounds Program (Continued)

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                                                          17 JUL 74      PAGE 012

 0267 0  D29F        621            STO   2 VT097      T4=10XF                       HWE05160
 0268 0  C339        622            LD    3 P57              T5               EK18 HWE05170
 0269 0  801C        623            A        =6100                                   HWE05180
 026A 0  D279        624            STO   2 VT248                                    HWE05190
 026B 0  9016        625            S        =4600                                   HWE05200
 026C 0  D29E        626            STO   2 VT098      T5=10XF                       HWE05210
 026D 0  C33A        627            LD    3 P58              PLA1             EK18 HWE05220
 026E 0  D27A        628            STO   2 VT249                                    HWE05230
 026F 0  C33B        629            LD    3 P59              PLA2             EK18 HWE05240
 0270 0  D27B        630            STO   2 VT250                                    HWE05250
 0271 0  C33C        631            LD    3 P60              LEAD-LAG SIGNAL  EK18 HWE05260
 0272 0  D27C        632            STO   2 VT251                                    HWE05270
 0273 0  C33D        633            LD    3 P61                               EK18 HWE05280
 0274 0  D27D        634            STO   2 VT252                                    HWE05290
 0275 0  C33E        635            LD    3 P62                               EK18 HWE05300
 0276 0  D27E        636            STO   2 VT253                                    HWE05310
                     637      *                            64TH POINT                HWE05320
 0277 0  C33F        638            LD    3 P63                                      HWE05330
 0278 0  D27F        639            STO   2 VT254                                    HWE05340
 0279 0  700D        640            B       GOTO1                                    HWE05350
                     641            LORG                                         HWE05360
 027A 0  0032        642      +     DC      50
 027B 0  4E20        643      +     DC      20000
 027C 0  7530        644      +     DC      30000
 027D 0  61A8        645      +     DC      25000
 027E 0  3A98        646      +     DC      15000
 027F 0  2710        647      +     DC      10000
 0280 0  4C40        648      +     DC      19520
 0281 0  5000        649      +     DC      20480
 0282 0  11F8        650      +     DC      4600
 0283 0  0FA0        651      +     DC      4000
 0284 0  2A3D        652      +     DC      10813
 0285 0  066D        653      +     DC      1645
 0286 0  17D4        654      +     DC      6100
 0287                655     GOTO1 EQU      *                                        HWE05370
                     656      *                           POWER REQUEST              HWE05380
 0287 0  C2FF        657            LD    2 VT001       IDLE SPEED TRIM              HWE05390
 0288 0  1883        658            SRT     3                                        HWE05400
 0289 0  806E        659            A        =7950                                   HWE05410
 028A 0  D218        660            STO   2 VT151                                    HWE05420
 028B 0  C2FE        661            LD    2 VT002       MAX SPEED TRIM               HWE05430
 028C 0  1883        662            SRT     3                                        HWE05440
 028D 0  806B        663            A        =16542                                  HWE05450
 028E 0  D219        664            STO   2 VT152                                    HWE05460
 028F 0  C27A        665            LD    2 VT249       POWER LEVER                  HWE05470
 0290 0  1881        666            SRT     1                                        HWE05480
 0291 0  8068        667            A        =7212                                   HWE05490
 0292 0  D217        668            STO   2 VT150                                    HWE05500
                     669      *   SELECT HIGH                                        HWE05510
 0293 0  B218        670            CMP   2 VT151                                    HWE05520
 0294 0  7002        671            MDX      *+2                                     HWE05530
 0295 0  1000        672            NOP                                              HWE05540
 0296 0  C218        673            LD    2 VT151                                    HWE05550
                     674      *   SELECT LOW                                         HWE05560
 0297 0  B219        675            CMP   2 VT152                                    HWE05570
 0298 0  C219        676            LD    2 VT152                                    HWE05580
 0299 0  1000        677            NOP                                              HWE05590
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Table B-13. Bendix Bounds Program (Continued)

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                                                                17 JUL 74    PAGE 013

029A 0  D201       678         STO   2 VT126                                HWE05600
029B 0  C2FC       679         LD    2 VT004                                HWE05610
029C 0  905E       680         S       =64                                  HWE05620
029D 01 4C2802C2   681         BN      SAM1                                 HWE05630
029F 0  C2FB       682         LD    2 VT005                                HWE05640
02A0 0  1889       683         SRT     9                                    HWE05650
02A1 0  D206       684         STO   2 VT133                                HWE05660
02A2 0  C2FA       685         LD    2 VT006                                HWE05670
02A3 0  A268       686         M     2 VT231                                HWE05680
02A4 0  1886       687         SRT     6                                    HWE05690
                   688     *  SELECT HIGH                                   HWE05700
02A5 0  B206       689         CMP   2 VT133                                HWE05710
02A6 0  7002       690         MDX     *+2                                  HWE05720
02A7 0  1000       691         NOP                                          HWE05730
02A8 0  C206       692         LD    2 VT133                                HWE05740
02A9 0  D21A       693         STO   2 VT153                                HWE05750
02AA 0  C2F9       694         LD    2 VT007                                HWE05760
02AB 0  1889       695         SRT     9                                    HWE05770
02AC 0  D207       696         STO   2 VT134                                HWE05780
02AD 0  C2F8       697         LD    2 VT008                                HWE05790
02AE 0  A268       698         M     2 VT231                                HWE05800
02AF 0  1886       699         SRT     6                                    HWE05810
                   700     *  SELECT LOW                                    HWE05820
02B0 0  B207       701         CMP   2 VT134                                HWE05830
02B1 0  C207       702         LD    2 VT134                                HWE05840
02B2 0  1000       703         NOP                                          HWE05850
02B3 0  D21B       704         STO   2 VT154                                HWE05860
02B4 0  C201       705         LD    2 VT128                                HWE05870
02B5 0  9205       706         S     2 VT132                                HWE05880
02B6 0  D202       707         STO   2 VT129                                HWE05890
                   708     *  SELECT LOW                                    HWE05900
02B7 0  B21A       709         CMP   2 VT153                                HWE05910
02B8 0  C21A       710         LD    2 VT153                                HWE05920
02B9 0  1000       711         NOP                                          HWE05930
02BA 0  D203       712         STO   2 VT130                                HWE05940
                   713     *  SELECT HIGH                                   HWE05950
02BB 0  B21B       714         CMP   2 VT154                                HWE05960
02BC 0  7002       715         MDX     *+2                                  HWE05970
02BD 0  1000       716         NOP                                          HWE05980
02BE 0  C21B       717         LD    2 VT154                                HWE05990
02BF 0  D204       718         STO   2 VT131                                HWE06000
02C0 0  8205       719         A     2 VT132                                HWE06010
02C1 0  7001       720         B       SAM2                                 HWE06020
02C2 0  C201       721    SAM1 LD    2 VT128                                HWE06030
02C3 0  D205       722    SAM2 STO   2 VT132                                HWE06040
02C4 0  C276       723         LD    2 VT245                                HWE06050
02C5 0  9036       724         S       =12640                               HWE06060
02C6 0  A0BA       725         M       =20480                               HWE06070
02C7 0  1081       726         SLT     1                                    HWE06080
02C8 0  8034       727         A       =15542                               HWE06090
02C9 0  D21C       728         STO   2 VT155                                HWE06100
                   729     *  SELECT LOW                                    HWE06110
02CA 0  B205       730         CMP   2 VT132                                HWE06120
02CB 0  C205       731         LD    2 VT132                                HWE06130
02CC 0  1000       732         NOP                                          HWE06140
02CD 0  D21D       733         STO   2 VT156                                HWE06150
                   734     *                     SPEED CONTROL              HWE06160
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Table B-13. Bendix Rounds Program (Continued)

```
                                                              17 JUL 74    PAGE 014

02CE 0  C02F       735          LD       =-1600                                HWE06170
                   736     *                       SELECT LOW                  HWE06180
02CF 0  B26D       737          CMP   2 VT236                                  HWE06190
02D0 0  C26D       738          LD    2 VT236                                  HWE06200
02D1 0  1000       739          NOP                                            HWE06210
02D2 0  821E       740          A     2 VT157                                  HWE06220
02D3 01 4C2802D9   741          BN      NEG1     SPEED                         HWE06230
02D5 0  9029       742          S       =800     COMPARISON                    HWE06240
02D6 01 4C3002DC   743          BP      POS1                                   HWE06250
02D8 0  7007       744          B       SAM3                                   HWE06260
02D9 0  8025       745     NEG1 A       =800                                   HWE06270
02DA 01 4C3002E0   746          BP      SAM3                                   HWE06280
02DC 0  C26A       747     POS1 LD    2 VT233                                  HWE06290
02DD 0  A022       748          M       =8873                                  HWE06300
02DE 0  1080       749          SLT     0                                      HWE06310
02DF 0  7001       750          B       SAM4                                   HWE06320
02E0 0  C020       751     SAM3 LD      =21000                                 HWE06330
02E1 0  D21F       752     SAM4 STO   2 VT158                                  HWE06340
                   753     *                                                   HWE06350
02E2 0  C2F7       754          LD    2 VT009                                  HWE06360
02E3 0  801E       755          A       =-123                                  HWE06370
02E4 01 4C3002F3   756          BP      NOUT                                   HWE06380
02E6 0  C01A       757          LD      =21000                                 HWE06390
02E7 0  D235       758          STO   2 VT180      INPUT POINT OF VALVE POS    HWE06400
02E8 0  C21D       759          LD    2 VT156                                  HWE06410
02E9 0  921E       760          S     2 VT157                                  HWE06420
02EA 0  D220       761          STO   2 VT159                                  HWE06430
02EB 0  A2FD       762          M     2 VT003                                  HWE06440
02EC 0  1082       763          SLT     2                                      HWE06450
02ED 0  D221       764          STO   2 VT160                                  HWE06460
02EE 0  C2F6       765          LD    2 VT010                                  HWE06470
02EF 0  1882       766          SRT     2                                      HWE06480
02F0 0  8221       767          A     2 VT160                                  HWE06490
02F1 0  D222       768          STO   2 VT161                                  HWE06500
02F2 0  7004       769          B       WFP3                                   HWE06510
                   770     *
                   771     *
                   772     *                     *****************************
                   773     *                     *****************************
                   774     *
                   775     *                     CALL HONEYWELL CONTROL PROG
02F3 0  C087       776     NOUT LD      =20000                                 HWE06520
02F4 0  D222       777          STO   2 VT161                                  HWE06530
02F5 30 089850E3   778          CALL    HWECT
                   779     *                     *****************************
                   780     *                     *****************************
                   781     *
                   782     *
                   783     *
                   784     *
02F7               785     WFP3 EQU     *                                      HWE06540
02F7 0  700B       786          B       GOTO2                                  HWE06550
                   787          LORG                                           HWE06560
02F8 0  1F0E       788     +    DC      7950
02F9 0  409E       789     +    DC      16542
02FA 0  1C2C       790     +    DC      7212
02FB 0  0040       791     +    DC      64
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Table B-13. Bendix Bounds Program (Continued)

```
02FC 0  3160       792   +      DC       12640
02FD 0  3CB6       793   +      DC       15542
02FE 0  F9C0       794   +      DC       -1600
02FF 0  0320       795   +      DC       800
0300 0  22A9       796   +      DC       8873
0301 0  5208       797   +      DC       21000
0302 0  FF85       798   +      DC       -123
0303               799    GOTO2 EQU      *                                    HWE06570
                   800   *                      THIS FOLLOWS BEN06220         HWE06580
                   801   *                      TEMPERATURE TRACK COMPUTE     HWE06590
0303 0  C276       802          LD     2 VT245  T2                            HWE06600
0304 0  9064       803          S        =18320 112.5 DEGREES F               HWE06610
0305 01 4C300422   804          BP     L T2125                                HWE06620
0307 0  80F7       805          A        =800   25 DEG F                      HWE06630
0308 01 4C3003E1   806          BP     L T2100                                HWE06640
030A 0  80F4       807          A        =800                                 HWE06650
030B 01 4C3003B6   808          BP     L T275                                 HWE06660
030D 0  80F1       809          A        =800                                 HWE06670
030E 01 4C300381   810          BP     L T250                                 HWE06680
0310 0  80EE       811          A        =800                                 HWE06690
0311 01 4C30033E   812          BP       T225                                 HWE06700
                   813   *                      ZERO DEGREES F TRACK          HWE06710
0313 0  C2E7       814          LD     2 VT025                                HWE06720
0314 0  1885       815          SRT      5                                    HWE06730
0315 0  8054       816          A        =15715                               HWE06740
0316 0  921E       817          S      2 VT157                                HWE06750
0317 01 4C30031E   818          BP       PATH4                                HWE06760
0319 0  A051       819          M        =24800                               HWE06770
031A 0  1084       820          SLT      4                                    HWE06780
031B 0  8050       821          A        =19500                               HWE06790
031C 01 4C00044D   822          B      L MAXWP                                HWE06800
031E 0  C04E       823    PATH4 LD       =13234                               HWE06810
031F 0  921E       824          S      2 VT157                                HWE06820
0320 01 4C300327   825          BP       PATH3                                HWE06830
0322 0  A04B       826          M        =0                                   HWE06840
0323 0  1084       827          SLT      4                                    HWE06850
0324 0  8047       828          A        =19500                               HWE06860
0325 01 4C00044D   829          B      L MAXWP                                HWE06870
0327 0  9047       830    PATH3 S        =3561                                HWE06880
0328 01 4C30032F   831          BP       PATH2                                HWE06890
032A 0  A045       832          M        =-6320                               HWE06900
032B 0  1084       833          SLT      4                                    HWE06910
032C 0  8044       834          A        =14000                               HWE06920
032D 01 4C00044D   835          B      L MAXWP                                HWE06930
032F 0  9042       836    PATH2 S        =4710                                HWE06940
0330 01 4C300337   837          BP       PATH1                                HWE06950
0332 0  A040       838          M        =1730                                HWE06960
0333 0  1084       839          SLT      4                                    HWE06970
0334 0  803F       840          A        =16000                               HWE06980
0335 01 4C00044D   841          B      L MAXWP                                HWE06990
0337 0  C03C       842    PATH1 LD       =16000                               HWE07000
0338 0  92E8       843          S      2 VT024                                HWE07010
0339 0  A21E       844          M      2 VT157                                HWE07020
033A 0  A83A       845          D        =4963                                HWE07030
033B 0  82E8       846          A      2 VT024                                HWE07040
033C 01 4C00044D   847          B      L MAXWP                                HWE07050
                   848   *                      25 DEGREES F TRACK            HWE07060
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Table B-13. Bendix Bounds Program (Continued)

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                                                                17 JUL 74    PAGE 016

033E 0  C2E7        849   T225  LD     2 VT025                                   HWE07070
033F 0  1885        850         SRT      5                                       HWE07080
0340 0  8035        851         A        =15797                                  HWE07090
0341 0  921E        852         S      2 VT157                                   HWE07100
0342 01 4C300349    853         BP       PTH14                                   HWE07110
0344 0  A026        854         M        =24800                                  HWE07120
0345 0  1084        855         SLT      4                                       HWE07130
0346 0  8030        856         A        =19000                                  HWE07140
0347 01 4C00044D    857         B      L MAXWP                                   HWE07150
0349 0  C023        858   PTH14 LD       =13234                                  HWE07160
034A 0  921E        859         S      2 VT157                                   HWE07170
034B 01 4C300352    860         BP       PTH13                                   HWE07180
034D 0  A02A        861         M        =399                                    HWE07190
034E 0  1084        862         SLT      4                                       HWE07200
034F 0  8029        863         A        =19250                                  HWE07210
0350 01 4C00044D    864         B      L MAXWP                                   HWE07220
0352 0  9027        865   PTH13 S        =3309                                   HWE07230
0353 01 4C30035A    866         BP       PTH12                                   HWE07240
0355 0  A025        867         M        =-5870                                  HWE07250
0356 0  1084        868         SLT      4                                       HWE07260
0357 0  8024        869         A        =14250                                  HWE07270
0358 01 4C00044D    870         B      L MAXWP                                   HWE07280
035A 0  9022        871   PTH12 S        =4549                                   HWE07290
035B 01 4C300362    872         BP       PTH11                                   HWE07300
035D 0  A020        873         M        =1570                                   HWE07310
035E 0  1084        874         SLT      4                                       HWE07320
035F 0  801F        875         A        =16250                                  HWE07330
0360 01 4C00044D    876         B      L MAXWP                                   HWE07340
0362 0  C01C        877   PTH11 LD       =16250                                  HWE07350
0363 0  92E8        878         S      2 VT024                                   HWE07360
0364 0  A21E        879         M      2 VT157                                   HWE07370
0365 0  A81A        880         D        =5376                                   HWE07380
0366 0  82E8        881         A      2 VT024                                   HWE07390
0367 01 4C00044D    882         B      L MAXWP                                   HWE07400
                    883         LORG                                             HWE07410
0369 0  4790        884   +     DC       18320
036A 0  3063        885   +     DC       15715
036B 0  60E0        886   +     DC       24800
036C 0  4C2C        887   +     DC       19500
036D 0  33B2        888   +     DC       13234
036E 0  0000        889   +     DC       0
036F 0  0DE9        890   +     DC       3561
0370 0  E750        891   +     DC       -6320
0371 0  36B0        892   +     DC       14000
0372 0  1266        893   +     DC       4710
0373 0  06C2        894   +     DC       1730
0374 0  3E80        895   +     DC       16000
0375 0  1363        896   +     DC       4963
0376 0  3DB5        897   +     DC       15797
0377 0  4A38        898   +     DC       19000
0378 0  018F        899   +     DC       399
0379 0  4B32        900   +     DC       19250
037A 0  0CED        901   +     DC       3309
037B 0  E912        902   +     DC       -5870
037C 0  37AA        903   +     DC       14250
037D 0  11C5        904   +     DC       4549
037E 0  0622        905   +     DC       1570
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Table B-13. Bendix Bounds Program (Continued)

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                                                                   17 JUL 74      PAGE 017

037F 0  3F7A        906   +        DC       16250
0380 0  1500        907   +        DC       5376
                    908   *                              50 DEGREE TRACK              HWE07420
0381 0  C2E7        909   T250     LD.    2 VT025                                     HWE07430
0382 0  1885        910            SRT      5                                         HWE07440
0383 0  8028        911            A        =15879                                    HWE07450
0384 0  921E        912            S      2 VT157                                     HWE07460
0385 01 4C30038C    913            BP       PTH24                                     HWE07470
0387 0  A0E3        914            M        =24800                                    HWE07480
0388 0  1084        915            SLT      4                                         HWE07490
0389 0  8023        916            A        =18500                                    HWE07500
038A 01 4C00044D    917            B      L MAXWP                                     HWE07510
038C 0  C0E0        918   PTH24    LD       =13234                                    HWE07520
038D 0  921E        919            S      2 VT157                                     HWE07530
038E 01 4C300395    920            BP       PTH23                                     HWE07540
0390 0  A01D        921            M        =774                                      HWE07550
0391 0  1084        922            SLT      4                                         HWE07560
0392 0  80E4        923            A        =19000                                    HWE07570
0393 01 4C00044D    924            B      L MAXWP                                     HWE07580
0395 0  9019        925   PTH23    S        =3071                                     HWE07590
0396 01 4C30039D    926            BP       PTH22                                     HWE07600
0398 0  A017        927            M        =-5330                                    HWE07610
0399 0  1084        928            SLT      4                                         HWE07620
039A 0  8016        929            A        =15000                                    HWE07630
039B 01 4C00044D    930            B      L MAXWP                                     HWE07640
039D 0  9014        931   PTH22    S        =4373                                     HWE07650
039E 01 4C3003A5    932            BP       PTH21                                     HWE07660
03A0 0  A012        933            M        =1404                                     HWE07670
03A1 0  1084        934            SLT      4                                         HWE07680
03A2 0  8011        935            A        =16500                                    HWE07690
03A3 01 4C00044D    936            B      L MAXWP                                     HWE07700
03A5 0  C00E        937   PTH21    LD       =16500                                    HWE07710
03A6 0  92E8        938            S      2 VT024                                     HWE07720
03A7 0  A21E        939            M      2 VT157                                     HWE07730
03A8 0  A80C        940            D        =5790                                     HWE07740
03A9 0  82E8        941            A      2 VT024                                     HWE07750
03AA 01 4C00044D    942            B      L MAXWP                                     HWE07760
                    943            LORG                                               HWE07770
03AC 0  3E07        944   +        DC       15879
03AD 0  4844        945   +        DC       18500
03AE 0  0306        946   +        DC       774
03AF 0  0BFF        947   +        DC       3071
03B0 0  EB2E        948   +        DC       -5330
03B1 0  3A98        949   +        DC       15000
03B2 0  1115        950   +        DC       4373
03B3 0  057C        951   +        DC       1404
03B4 0  4074        952   +        DC       16500
03B5 0  169E        953   +        DC       5790
                    954   *                              75 DEGREE F TRACK            HWE07780
03B6 0  C2E7        955   T275     LD     2 VT025                                     HWE07790
03B7 0  1885        956            SRT      5                                         HWE07800
03B8 0  8054        957            A        =15961                                    HWE07810
03B9 0  921E        958            S      2 VT157                                     HWE07820
03BA 01 4C3003C1    959            BP       PTH34                                     HWE07830
03BC 0  A0AE        960            M        =24800                                    HWE07840
03BD 0  1084        961            SLT      4                                         HWE07850
03BE 0  804F        962            A        =18000                                    HWE07860
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Table B-13. Bendix Bounds Program (Continued)

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03BF 01 4C00044D    963           B     L  MAXWP                                          HWE07870
03C1 0  C0AB        964    PTH34  LD       =13234                                         HWE07880
03C2 0  921E        965           S      2 VT157                                          HWE07890
03C3 01 4C3003CA    966           BP       PTH33                                          HWE07900
03C5 0  A049        967           M        =1127                                          HWE07910
03C6 0  1084        968           SLT      4                                              HWE07920
03C7 0  8048        969           A        =18750                                         HWE07930
03C8 01 4C00044D    970           B     L  MAXWP                                          HWE07940
03CA 0  9046        971    PTH33  S        =2823                                          HWE07950
03CB 01 4C3003D2    972           BP       PTH32                                          HWE07960
03CD 0  A044        973           M        =-4710                                         HWE07970
03CE 0  1084        974           SLT      4                                              HWE07980
03CF 0  8043        975           A        =15500                                         HWE07990
03D0 01 4C00044D    976           B     L  MAXWP                                          HWE08000
03D2 0  9041        977    PTH32  S        =4208                                          HWE08010
03D3 01 4C3003DA    978           BP       PTH31                                          HWE08020
03D5 0  A03F        979           M        =1215                                          HWE08030
03D6 0  1084        980           SLT      4                                              HWE08040
03D7 0  803E        981           A        =16750                                         HWE08050
03D8 01 4C00044D    982           B     L  MAXWP                                          HWE08060
03DA 0  C03B        983    PTH31  LD       =16750                                         HWE08070
03DB 0  92E8        984           S      2 VT024                                          HWE08080
03DC 0  A21E        985           M      2 VT157                                          HWE08090
03DD 0  AB39        986           D        =6203                                          HWE08100
03DE 0  82E8        987           A      2 VT024                                          HWE08110
03DF 01 4C00044D    988           B     L  MAXWP                                          HWE08120
                    989    *                            100 DEGREE F TRACK                HWE08130
03E1 0  C2E7        990    T2100  LD     2 VT025                                          HWE08140
03E2 0  1885        991           SRT      5                                              HWE08150
03E3 0  8034        992           A        =16045                                         HWE08160
03E4 0  921E        993           S      2 VT157                                          HWE08170
03E5 01 4C3003EC    994           BP       PTH44                                          HWE08180
03E7 0  A083        995           M        =24800                                         HWE08190
03E8 0  1084        996           SLT      4                                              HWE08200
03E9 0  802F        997           A        =17500                                         HWE08210
03EA 01 4C00044D    998           B     L  MAXWP                                          HWE08220
03EC 01 C400036D    999    PTH44  LD    L  =13234                                         HWE08230
03EE 0  921E       1000           S      2 VT157                                          HWE08240
03EF 01 4C3003F6   1001           BP       PTH43                                          HWE08250
03F1 0  A028       1002           M        =1455                                          HWE08260
03F2 0  1084       1003           SLT      4                                              HWE08270
03F3 0  80B9       1004           A        =18500                                         HWE08280
03F4 01 4C00044D   1005           B     L  MAXWP                                          HWE08290
03F6 0  9024       1006    PTH43  S        =2573                                          HWE08300
03F7 01 4C3003FE   1007           BP       PTH42                                          HWE08310
03F9 0  A022       1008           M        =-3980                                         HWE08320
03FA 0  1084       1009           SLT      4                                              HWE08330
03FB 0  8021       1010           A        =16000                                         HWE08340
03FC 01 4C00044D   1011           B     L  MAXWP                                          HWE08350
03FE 0  901F       1012    PTH42  S        =4042                                          HWE08360
03FF 01 4C300406   1013           BP       PTH41                                          HWE08370
0401 0  A01D       1014           M        =1012                                          HWE08380
0402 0  1084       1015           SLT      4                                              HWE08390
0403 0  801C       1016           A        =17000                                         HWE08400
0404 01 4C00044D   1017           B     L  MAXWP                                          HWE08410
0406 0  C019       1018    PTH41  LD       =17000                                         HWE08420
0407 0  92E8       1019           S      2 VT024                                          HWE08430
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Table B-13. Bendix Bounds Program (Continued)

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                                                                    17 JUL 74     PAGE 019

0408 0  A21E        1020             M      2 VT157                                    HWE08440
0409 0  A817        1021             D        =6617                                    HWE08450
040A 0  82E8        1022             A      2 VT024                                    HWE08460
040B 01 4C00044D    1023             B    L   MAXWP                                    HWE08470
                    1024             LORG                                              HWE08480
040D 0  3E59        1025    +        DC       15961
040E 0  4650        1026    +        DC       18000
040F 0  0467        1027    +        DC       1127
0410 0  493E        1028    +        DC       18750
0411 0  0B07        1029    +        DC       2823
0412 0  ED9A        1030    +        DC       -4710
0413 0  3C8C        1031    +        DC       15500
0414 0  1070        1032    +        DC       4208
0415 0  04BF        1033    +        DC       1215
0416 0  416E        1034    +        DC       16750
0417 0  183B        1035    +        DC       6203
0418 0  3EAD        1036    +        DC       16045
0419 0  445C        1037    +        DC       17500
041A 0  05AF        1038    +        DC       1455
041B 0  0A0D        1039    +        DC       2573
041C 0  F074        1040    +        DC       -3980
041D 0  3E80        1041    +        DC       16000
041E 0  0FCA        1042    +        DC       4042
041F 0  03F4        1043    +        DC       1012
0420 0  4268        1044    +        DC       17000
0421 0  19D9        1045    +        DC       6617
                    1046    *                             125 DEGREE F TRACK           HWE08490
0422 0  C2E7        1047    T2125    LD     2 VT025                                    HWE08500
0423 0  1885        1048             SRT      5                                        HWE08510
0424 0  904C        1049             A        =16128                                   HWE08520
0425 0  921E        1050             S      2 VT157                                    HWE08530
0426 01 4C30042D    1051             BP       PTH54                                    HWE08540
0428 0  A049        1052             M        =24800                                   HWE08550
0429 0  1084        1053             SLT      4                                        HWE08560
042A 0  80F5        1054             A        =17000                                   HWE08570
042B 01 4C00044D    1055             B    L   MAXWP                                    HWE08580
042D 0  C045        1056    PTH54    LD       =13234                                   HWE08590
042E 0  921E        1057             S      2 VT157                                    HWE08600
042F 01 4C300436    1058             BP       PTH53                                    HWE08610
0431 0  A042        1059             M        =1769                                    HWE08620
0432 0  1084        1060             SLT      4                                        HWE08630
0433 0  8041        1061             A        =18250                                   HWE08640
0434 01 4C00044D    1062             B    L   MAXWP                                    HWE08650
0436 0  903F        1063    PTH53    S        =2327                                    HWE08660
0437 01 4C30043E    1064             BP       PTH52                                    HWE08670
0439 0  A030        1065             M        =-3080                                   HWE08680
043A 0  1084        1066             SLT      4                                        HWE08690
043B 0  803C        1067             A        =16500                                   HWE08700
043C 01 4C00044D    1068             B    L   MAXWP                                    HWE08710
043E 0  903A        1069    PTH52    S        =3877                                    HWE08720
043F 01 4C300446    1070             BP       PTH51                                    HWE08730
0441 0  A038        1071             M        =792                                     HWE08740
0442 0  1084        1072             SLT      4                                        HWE08750
0443 0  8037        1073             A        =17250                                   HWE08760
0444 01 4C00044D    1074             B    L   MAXWP                                    HWE08770
0446 0  C034        1075    PTH51    LD       =17250                                   HWE08780
0447 0  92E8        1076             S      2 VT024                                    HWE08790
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Table B-13. Bendix Bounds Program (Continued)

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                                                                    17 JUL 74     PAGE 020

 0448 0  A21E      1077            M      2 VT157                                     HWE08800
 0449 0  A832      1078            D        =7030                                     HWE08810
 044A 0  82E8      1079            A      2 VT024                                     HWE08820
 044B 01 4C00044D  1080            B    L   MAXWP                                     HWE08830
 044D 0  1882      1081     MAXWP  SRT      2                                         HWE08840
 044E 0  D236      1082            STO    2 VT181                                     HWE08850
                   1083     *                            MINIMUM RATIOS COMPUTATION  HWE08860
 044F 0  C2E2      1084            LD     2 VT030                                     HWE08870
 0450 0  1882      1085            SRT      2                                         HWE08880
 0451 0  D20D      1086            STO    2 VT140                                     HWE08890
 0452 0  C21E      1087            LD     2 VT157                                     HWE08900
 0453 0  9029      1088            S        =7100                                     HWE08910
 0454 0  A2E3      1089            M      2 VT029                                     HWE08920
 0455 0  1881      1090            SRT      1                                         HWE08930
 0456 0  820D      1091            A      2 VT140                                     HWE08940
 0457 0  1882      1092            SRT      2                                         HWE08950
 0458 0  D23F      1093            STO    2 VT190                                     HWE08960
                   1094     *                            SELECT HIGH                  HWE08970
 0459 0  C21E      1095            LD     2 VT157                                     HWE08980
 045A 0  B022      1096            CMP      =7100                                     HWE08990
 045B 0  7002      1097            MDX      *+2                                       HWE09000
 045C 0  1000      1098            NOP                                                HWE09010
 045D 0  C01F      1099            LD       =7100                                     HWE09020
 045F 0  D011      1100            STO      TEMP6                                     HWE09030
 045F 0  C01E      1101            LD       =9600                                     HWE09040
 0460 0  900F      1102            S        TEMP6                                     HWE09050
 0461 0  A01D      1103            M        =19650                                    HWE09060
 0462 0  1082      1104            SLT      2                                         HWE09070
 0463 0  D23D      1105            STO    2 VT188                                     HWE09080
                   1106     *                            SELECT LOW                   HWE09090
 0464 0  C01B      1107            LD       =27687                                    HWE09100
 0465 0  A21E      1108            M      2 VT157                                     HWE09110
 0466 0  B23D      1109            CMP    2 VT188                                     HWE09120
 0467 0  C23D      1110            LD     2 VT188                                     HWE09130
 0468 0  1000      1111            NOP                                                HWE09140
 0469 0  D23E      1112            STO    2 VT189                                     HWE09150
                   1113     *                            SELECT HIGH                  HWE09160
 046A 0  B23F      1114            CMP    2 VT190                                     HWE09170
 046B 0  7002      1115            MDX      *+2                                       HWE09180
 046C 0  1000      1116            NOP                                                HWE09190
 046D 0  C23F      1117            LD     2 VT190                                     HWE09200
 046E 0  D240      1118            STO    2 VT191            MINIMUM RATIOS               HWE09210
                   1119     *                            BRANCH TO VALVE CONTROL      HWE09220
 046F 0  7011      1120            B        CNTLB                                     HWE09230
 0470 0  0000      1121     TEMP6  DC       *-*                                       HWE09240
                   1122            LORG                                               HWE09250
 0471 0  3F00      1123     +      DC       16128
 0472 0  60E0      1124     +      DC       24800
 0473 0  3382      1125     +      DC       13234
 0474 0  06E9      1126     +      DC       1769
 0475 0  474A      1127     +      DC       18250
 0476 0  0917      1128     +      DC       2327
 0477 0  F3F8      1129     +      DC       -3080
 0478 0  4074      1130     +      DC       16500
 0479 0  0F25      1131     +      DC       3877
 047A 0  0318      1132     +      DC       792
 047B 0  4362      1133     +      DC       17250
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Table B-13. Bendix Bounds Program (Continued)

```
047C 0  1876     1134   +       DC        7030
047D 0  188C     1135   +       DC        7100
047E 0  2580     1136   +       DC        9600
047F 0  4CC2     1137   +       DC        19650
0480 0  6C27     1138   +       DC        27687
0481             1139     CNTLB EQU       *          ADD VALVE CONTROL HERE       HWE09260
0481 0  C235     1140           LD      2 VT180      THIS WILL BE COMPUTED VALU   HWE09270
0482 0  D235     1141           STO     2 VT180      FROM ADDED CONTROL LOOP      HWE09280
0483 0  7000     1142           B         VALPO                                   HWE09290
0484             1143     VALPO EQU       *                                       HWE09300
0484 0  C2E6     1144           LD      2 VT026                                   HWE09310
0485 0  A236     1145           M       2 VT181                                   HWE09320
0486 0  1082     1146           SLT       2
0487 0  D237     1147           STO     2 VT182                                   HWE09340
0488 0  C2E1     1148           LD      2 VT031                                   HWE09350
0489 0  1885     1149           SRT       5                                       HWE09360
048A 0  804A     1150           A         =5320                                   HWE09370
048B 0  A268     1151           M       2 VT231                                   HWE09380
048C 0  1083     1152           SLT       3                                       HWE09390
048D 0  D243     1153           STO     2 VT194                                   HWE09400
048E 0  C2E0     1154           LD      2 VT032                                   HWE09410
048F 0  1080     1155           SRT       0                                       HWE09420
0490 0  D20F     1156           STO     2 VT142                                   HWE09430
0491 0  C20F     1157           LD      2 VT033                                   HWE09440
0492 0  1083     1158           SRT       3                                       HWE09450
0493 0  D210     1159           STO     2 VT143                                   HWE09460
                 1160    *                           VALVE ZERO FLOW TRIM         HWE09470
0494 0  C2F5     1161           LD      2 VT011                                   HWE09480
0495 0  1886     1162           SRT       6                                       HWE09490
0496 0  D20E     1163           STO     2 VT141                                   HWE09500
0497 0  803E     1164           A         =5400                                   HWE09510
0498 0  D214     1165           STO     2 VT147                                   HWE09520
                 1166    *                           MINIMUM VALVE                HWE09530
0499 0  C2E5     1167           LD      2 VT027
049A 0  A240     1168           M       2 VT191                                   HWE09550
049B 0  1081     1169           SLT       1                                       HWE09560
049C 0  A243     1170           M       2 VT194                                   HWE09570
049D 0  1084     1171           SLT       4                                       HWE09580
049E 0  D241     1172           STO     2 VT192                                   HWE09590
049F 0  B210     1173           CMP     2 VT143                                   HWE09600
04A0 0  7002     1174           MDX       *+2                                     HWE09610
04A1 0  1000     1175           NOP                                               HWE09620
04A2 0  C210     1176           LD      2 VT143                                   HWE09630
04A3 0  D215     1177           STO     2 VT148                                   HWE09640
04A4 0  C237     1178           LD      2 VT182                                   HWE09650
04A5 0  B222     1179           CMP     2 VT161      SELECT LOW WITH SPEED        HWE09660
04A6 0  C222     1180           LD      2 VT161                                   HWE09670
04A7 0  1000     1181           NOP                                               HWE09680
                 1182    *      SELECT HIGH                                       HWE09690
04A8 0  802E     1183           CMP       =-4000                                  HWE09700
04A9 0  7002     1184           MDX       *+2                                     HWE09710
04AA 0  1000     1185           NOP                                               HWE09720
04AB 0  C028     1186           LD        =-4000                                  HWE09730
04AC 0  D238     1187           STO     2 VT183                                   HWE09740
04AD 0  A243     1188           M       2 VT194                                   HWE09750
04AE 0  1084     1189           SLT       4                                       HWE09760
04AF 0  D239     1190           STO     2 VT184                                   HWE09770
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Table B-13. Bendix Bounds Program (Continued)

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                                                            17 JUL 74     PAGE 022

04B0 0  B20F      1191          CMP   2 VT142     SELECT LOW VALVE LIMIT   HWE09790
04B1 0  C20F      1192          LD    2 VT142                              HWE09790
04B2 0  1000      1193          NOP                                        HWE09800
04B3 0  D23A      1194          STO   2 VT185                              HWE09810
04B4 0  B21F      1195          CMP   2 VT158     SELECT LOW WITH N SAFETY HWE09820
04B5 0  C21F      1196          LD    2 VT158                              HWE09830
04B6 0  1000      1197          NOP                                        HWE09840
04B7 0  D23B      1198          STO   2 VT186                              HWE09850
04B8 0  B235      1199          CMP   2 VT180     SELECT LOW WITH CON LOOP HWE09860
04B9 0  C235      1200          LD    2 VT180                              HWE09870
04BA 0  1000      1201          NOP                                        HWE09880
04BB 0  D23C      1202          STO   2 VT187                              HWE09890
04BC 0  B215      1203          CMP   2 VT148     SELECT HIGH WITH MINIMUM HWE09900
04BD 0  7002      1204          MDX     *+2                                HWE09910
04BE 0  1000      1205          NOP                                        HWE09920
04BF 0  C215      1206          LD    2 VT148                              HWE09930
04C0 0  D242      1207          STO   2 VT193                              HWE09940
04C1 0  8214      1208          A     2 VT147                              HWE09950
04C2 0  D244      1209          STO   2 VT195                              HWE09960
04C3 01 D4000585  1210          STO   L FUEL                               HWE09970
                  1211     *                                               HWE09980
                  1212     *                     IGV AND BLEED SCHEDULES   HWE09990
04C5 0  C276      1213          LD    2 VT245                              HWE10000
04C6 0  9011      1214          S       =13440                             HWE10010
04C7 0  A011      1215          M       =210                               HWE10020
04C8 0  1087      1216          SLT     7                                  HWE10030
04C9 0  8010      1217          A       =11800                             HWE10040
04CA 0  D251      1218          STO   2 VT208                              HWE10050
04CB 0  C276      1219          LD    2 VT245                              HWE10060
04CC 0  900E      1220          S       =17088                             HWE10070
04CD 01 4C2804DF  1221          BN      SAM6                               HWE10080
04CF 0  A00C      1222          M       =500                               HWE10090
04D0 0  1086      1223          SLT     6                                  HWE10100
04D1 0  800B      1224          A       =15800                             HWE10110
04D2 0  D253      1225          STO   2 VT210                              HWE10120
04D3 0  701C      1226          B       SAM8                               HWE10130
04D4 0  700A      1227          B       GOTO5                              HWE10140
                  1228          LORG                                       HWE10150
04D5 0  14C8      1229     +    DC      5320
04D6 0  1518      1230     +    DC      5400
04D7 0  F060      1231     +    DC      -4000
04D8 0  3480      1232     +    DC      13440
04D9 0  00D2      1233     +    DC      210
04DA 0  2E18      1234     +    DC      11800
04DB 0  42C0      1235     +    DC      17088
04DC 0  01F4      1236     +    DC      500
04DD 0  3DB8      1237     +    DC      15800
04DE 0  0000      1238     TEMPA DC     *-*                                HWE10160
04DF              1239     GOTO5 EQU    *                                  HWE10170
                  1240     *                                               HWE10180
04DF 0  C276      1241     SAM6 LD    2 VT245                              HWE10190
04E0 0  903A      1242          S       =15488                             HWE10200
04E1 01 4C2804EA  1243          BN      SAM7                               HWE10210
04E3 0  A038      1244          M       =128                               HWE10220
04E4 0  1086      1245          SLT     6                                  HWE10230
04E5 0  D0F8      1246          STO     TEMPA                              HWE10240
04E6 0  C036      1247          LD      =16000                             HWE10250
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Table B-13. Bendix Bounds Program (Continued)

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                                                          17 JUL 74     PAGE 023

04E7 0  90F6       1248            S        TEMPA                              HWE10260
04E8 0  D253       1249            STO    2 VT210                              HWE10270
04E9 0  7006       1250            B        SAM8                               HWE10280
                   1251    *                                                   HWE10290
04EA 0  C276       1252    SAM7    LD     2 VT245                              HWE10300
04EB 0  90EC       1253            S        =13440                             HWE10310
04EC 0  A031       1254            M        =1100                              HWE10320
04ED 0  1085       1255            SLT      5                                  HWE10330
04EE 0  8030       1256            A        =14900                             HWE10340
04EF 0  D253       1257            STO    2 VT210                              HWE10350
                   1258    *                                                   HWE10360
04F0 0  C2CD       1259    SAM8    LD     2 VT051                              HWE10370
04F1 0  1884       1260            SRT      4                                  HWE10380
04F2 0  D211       1261            STO    2 VT144                              HWE10390
04F3 0  C2CC       1262            LD     2 VT052                              HWE10400
04F4 0  1884       1263            SRT      4                                  HWE10410
04F5 0  8253       1264            A      2 VT210                              HWE10420
04F6 0  9211       1265            S      2 VT144                              HWE10430
04F7 0  9251       1266            S      2 VT208                              HWE10440
04F8 0  D255       1267            STO    2 VT212                              HWE10450
04F9 0  C21E       1268            LD     2 VT157                              HWE10460
04FA 0  9251       1269            S      2 VT208                              HWE10470
04FB 0  9211       1270            S      2 VT144                              HWE10480
                   1271    *  SELECT HIGH                                      HWE10490
04FC 0  8023       1272            CMP      =0                                 HWE10500
04FD 0  7002       1273            MDX      *+2                                HWE10510
04FE 0  1000       1274            NOP                                         HWE10520
04FF 0  C020       1275            LD       =0                                 HWE10530
0500 0  A020       1276            M        =8340                              HWE10540
0501 0  AA55       1277            D      2 VT212                              HWE10550
0502 0  801F       1278            A        =5100                              HWE10560
0503 0  D256       1279            STO    2 VT213                              HWE10570
0504 01 D4000586   1280            STO    L PIGV                               HWE10580
0506 0  C2CB       1281            LD     2 VT053                              HWE10590
0507 0  1884       1282            SRT      4                                  HWE10600
0508 0  D212       1283            STO    2 VT145                              HWE10610
0509 0  C2CA       1284            LD     2 VT054                              HWE10620
050A 0  1884       1285            SRT      4                                  HWE10630
050B 0  8253       1286            A      2 VT210                              HWE10640
050C 0  9212       1287            S      2 VT145                              HWE10650
050D 0  9251       1288            S      2 VT208                              HWE10660
050E 0  D257       1289            STO    2 VT214                              HWE10670
050F 0  C21E       1290            LD     2 VT157                              HWE10680
0510 0  9251       1291            S      2 VT208                              HWE10690
0511 0  9212       1292            S      2 VT145                              HWE10700
                   1293    *  SELECT HIGH                                      HWE10710
0512 0  B00D       1294            CMP      =0                                 HWE10720
0513 0  7002       1295            MDX      *+2                                HWE10730
0514 0  1000       1296            NOP                                         HWE10740
0515 0  C00A       1297            LD       =0                                 HWE10750
0516 0  A00C       1298            M        =5050                              HWE10760
0517 0  AA57       1299            D      2 VT214                              HWE10770
0518 0  800B       1300            A        =3600                              HWE10780
0519 0  D258       1301            STO    2 VT215                              HWE10790
                   1302    *                                                   HWE10800
                   1303    *                STORE HERE IN BLEED IF SEPERATE CONTROHWE10810
                   1304    *                OF THE BLEEDS IS DESIRED           HWE10820
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Table B-13. Bendix Bounds Program (Continued)

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                                                         17 JUL 74     PAGE 024

                  1305   *              DAC 2 IS NOW USED FOR VTXXX OUTPUT    HWE10830
                  1306   *                                                    HWE10840
051A 0   700A     1307          B       GOTO6                                 BEN10424
                  1308          LORG                                          BEN10425
051B 0   3C80     1309   +      DC      15488
051C 0   0080     1310   +      DC      128
051D 0   3E80     1311   +      DC      16000
051E 0   044C     1312   +      DC      1100
051F 0   3A34     1313   +      DC      14900
0520 0   0000     1314   +      DC      0
0521 0   2094     1315   +      DC      8340
0522 0   13EC     1316   +      DC      5100
0523 0   13BA     1317   +      DC      5050
0524 0   0E10     1318   +      DC      3600
0525              1319   GOTO6  EQU     *                                     BEN10426
                  1320   *                        NOZZLE CONTROL              HWE10850
0525 0   C049     1321          LD      =9250                                 BEN10430
0526 0   921D     1322          S     2 VT156                                 BEN10440
0527 0   A048     1323          M       =14320                                BEN10450
0528 0   1083     1324          SLT     3                                     BEN10460
0529 0   8047     1325          A       =13740                                BEN10470
                  1326   * SELECT LOW                                         BEN10480
052A 0   B047     1327          CMP     =12200                                BEN10490
052B 0   C046     1328          LD      =12200                                BEN10500
052C 0   1000     1329          NOP                                           BEN10510
052D 0   D25A     1330          STO   2 VT217                                 BEN10570
052E 0   C044     1331          LD      =16042                                BEN10580
052F 0   921D     1332          S     2 VT156                                 BEN10590
                  1333   * SELECT LOW                                         BEN10600
0530 0   B0EF     1334          CMP     =0                                    BEN10610
0531 0   C0EE     1335          LD      =0                                    BEN10620
0532 0   1000     1336          NOP                                           DEN10630
0533 0   A040     1337          M       =28900                                BEN10640
0534 0   1084     1338          SLT     4                                     BEN10650
0535 0   82C9     1339          A     2 VT055                                 BEN10660
                  1340   * SELECT HIGH
0536 0   B25A     1341          CMP   2 VT217                                 BEN10680
0537 0   7002     1342          MDX     *+2
0538 0   1000     1343          NOP
0539 0   C25A     1344          LD    2 VT217
053A 0   D25B     1345          STO   2 VT218                                 BEN10710
                  1346   *                     TEMPERANCE CONTROL             BEN10720
053B 0   C279     1347          LD    2 VT240                                 BEN10730
053C 0   92C8     1348          S     2 VT056                                 BEN10740
                  1349   * SELECT HIGH                                        BEN10750
053D 0   B0E2     1350          CMP     =0                                    BEN10760
053E 0   7002     1351          MDX     *+2                                   BEN10770
053F 0   1000     1352          NOP                                           BEN10780
0540 0   C0DF     1353          LD      =0                                    BEN10790
0541 0   A2C7     1354          M     2 VT057                                 BEN10800
0542 0   1084     1355          SLT     4                                     BEN10810
0543 0   825B     1356          A     2 VT218                                 BEN10820
                  1357   * SELECT HIGH                                        BEN10830
0544 0   B25B     1358          CMP   2 VT218                                 BEN10840
0545 0   7002     1359          MDX     *+2                                   BEN10850
0546 0   1000     1360          NOP                                           BEN10860
0547 0   C25B     1361          LD    2 VT218                                 BEN10870
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Table B-13. Bendix Bounds Program (Continued)

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0548 0  D25C       1362             STO    2 VT219                                       BEN10880
0549 0  D03E       1363             STO      NOZ                                         BEN10890
054A 0  C2E4       1364             LD     2 VT028          THIS GOES IN THE BOUNDS
054B 01 940002FB   1365             S      L =64            PROGRAM AT ADDRESS DONE
054D 01 4C200551   1366             BNZ      DONE           IF VT028=64 HW NOZ IS IN
054F 0  C2AF       1367             LD     2 VT081          IF VT028 NOT 64 BENDX IN
0550 0  D037       1368             STO      NOZ
0551               1369     DONE    EQU      *                                           HWE11220
                   1370     *                                                            HWE11230
                   1371     *                                                            HWE11240
0551 30 040565C0   1372             CALL     DAOP                                        HWE11250
0553 1  057A       1373             DC       DALST                                       HWE11260
                   1374     *                                                            HWE11270
                   1375     *                           FOLLOWS BEN11070                 HWE11280
                   1376     *                          LOOP DETERMINATION                HWE11290
0554 0  C242       1377             LD     2 VT193                                       HWE11300
0555 0  901F       1378             S        =20                                         HWE11310
0556 0  9215       1379             S      2 VT148                                       HWE11320
0557 01 4C280561   1380             BN       NEGA                                        HWE11330
0559 0  C242       1381             LD     2 VT193                                       HWE11340
055A 0  801A       1382             A        =20                                         HWE11350
055B 0  9239       1383             S      2 VT144                                       HWE11360
055C 01 4C300564   1384             BP       POSA                                        HWE11370
055E 0  C286       1385             LD     2 VT074                                       HWE11380
055F 0  D263       1386             STO    2 VT226                                       HWE11390
0560 0  7005       1387             B        CON1                                        HWE11400
0561 0  C014       1388     NEGA    LD       =-32000        MIN CONTROL -5V OUT          HWE11410
0562 0  D263       1389             STO    2 VT226                                       HWE11420
0563 0  7002       1390             B        CON1                                        HWE11430
0564 0  C012       1391     POSA    LD       =32000         MAX CONTROL  5V OUT          HWE11440
0565 0  D263       1392             STO    2 VT226                                       HWE11450
0566               1393     CON1    EQU      *                                           HWE11460
                   1394     *                                                            HWE11470
0566 0  0811       1395             XIO      CEOFF                                       HWE11480
0567 00 65000000   1396     XR1     LDX   L1 *-*                                         HWE11490
0569 00 66000000   1397     XR2     LDX   L2 *-*                                         HWE11500
056B 00 67000000   1398     XR3     LDX   L3 *-*                                         HWE11510
056D 01 4C800000   1399             BSC   I  GTECT                                       HWE11520
                   1400             LORG                                                 HWE11530
056F 0  2422       1401    +        DC       9250
0570 0  37F0       1402    +        DC       14320
0571 0  35AC       1403    +        DC       13740
0572 0  2FA8       1404    +        DC       12200
0573 0  3EAA       1405    +        DC       16042
0574 0  70E4       1406    +        DC       28900
0575 0  0014       1407    +        DC       20
0576 0  8300       1408    +        DC       -32000
0577 0  7D00       1409    +        DC       32000
0578    0000       1410     CEOFF   BSS   E  0                                           HWE11540
0578 0  0000       1411             DC       0                                           HWE11550
0579 0  E400       1412             DC       /E400                                       HWE11560
                   1413     *                                                            HWE11570
057A 0  0000       1414     DALST   DC       0                                           HWE11580
057B 0  0000       1415             DC       0
057C    0004       1416             BSS      4                                           HWE11600
0580 0  0000       1417             DC       *-*                                         HWE11610
0581 0  3000       1418             DC       /3000
0582 1  0583       1419             DC       AOLST                                       HWE11630
0583 0  0006       1420     AOLST   DC       /0000+6
0584 0  0000       1421     APZ     DC       0
0585 0  0000       1422     FUEL    DC       *-*
0586 0  0000       1423     PIGV    DC       *-*
0587 0  0000       1424     BLEED   DC       *-*
0588 0  0000       1425     NOZ     DC       *-*
0589 0  0000       1426     ALOG4   DC       *-*
                   1427     *                                                            HWE11750
                   1428     *                                                            HWE11760
                   1429     *                                                            HWE11770
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Table B-13. Bendix Bounds Program (Continued)

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0000        1431    P00    EQU    00        HWE11820
0001        1432    P01    EQU    01        HWE11830
0002        1433    P02    EQU    02        HWE11840
0003        1434    P03    EQU    03        HWE11850
0004        1435    P04    EQU    04        HWE11860
0005        1436    P05    EQU    05        HWE11870
0006        1437    P06    EQU    06        HWE11880
0007        1438    P07    EQU    07        HWE11890
0008        1439    P08    EQU    08        HWE11900
0009        1440    P09    EQU    09        HWE11910
000A        1441    P10    EQU    10        HWE11920
000B        1442    P11    EQU    11        HWE11930
000C        1443    P12    EQU    12        HWE11940
000D        1444    P13    EQU    13        HWE11950
000E        1445    P14    EQU    14        HWE11960
000F        1446    P15    EQU    15        HWE11970
0010        1447    P16    EQU    16        HWE11980
0011        1448    P17    EQU    17        HWE11990
0012        1449    P18    EQU    18        HWE12000
0013        1450    P19    EQU    19        HWE12010
0014        1451    P20    EQU    20        HWE12020
0015        1452    P21    EQU    21        HWE12030
0016        1453    P22    EQU    22        HWE12040
0017        1454    P23    EQU    23        HWE12050
0018        1455    P24    EQU    24        HWE12060
0019        1456    P25    EQU    25        HWE12070
001A        1457    P26    EQU    26        HWE12080
001B        1458    P27    EQU    27        HWE12090
001C        1459    P28    EQU    28        HWE12100
001D        1460    P29    EQU    29        HWE12110
001E        1461    P30    EQU    30        HWE12120
001F        1462    P31    EQU    31        HWE12130
0020        1463    P32    EQU    32        HWE12140
0021        1464    P33    EQU    33        HWE12150
0022        1465    P34    EQU    34        HWE12160
0023        1466    P35    EQU    35        HWE12170
0024        1467    P36    EQU    36        HWE12180
0025        1468    P37    EQU    37        HWE12190
0026        1469    P38    EQU    38        HWE12200
0027        1470    P39    EQU    39        HWE12210
0028        1471    P40    EQU    40        HWE12220
0029        1472    P41    EQU    41        HWE12230
002A        1473    P42    EQU    42        HWE12240
002B        1474    P43    EQU    43        HWE12250
002C        1475    P44    EQU    44        HWE12260
002D        1476    P45    EQU    45        HWE12270
002E        1477    P46    EQU    46        HWE12280
002F        1478    P47    EQU    47        HWE12290
0030        1479    P48    EQU    48        HWE12300
0031        1480    P49    EQU    49        HWE12310
0032        1481    P50    EQU    50        HWE12320
0033        1482    P51    EQU    51        HWE12330
0034        1483    P52    EQU    52        HWE12340
0035        1484    P53    EQU    53        HWE12350
0036        1485    P54    EQU    54        HWE12360
0037        1486    P55    EQU    55        HWE12370
0038        1487    P56    EQU    56        HWE12380
0039        1488    P57    EQU    57        HWE12390
003A        1489    P58    EQU    58        HWE12400
003B        1490    P59    EQU    59        HWE12410
003C        1491    P60    EQU    60        HWE12420
003D        1492    P61    EQU    61        HWE12430
003E        1493    P62    EQU    62        HWE12440
003F        1494    P63    EQU    63        HWE12450
            1495    *                       HWE12460
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Table B-13. Bendix Bounds Program (Continued)

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                                                      17 JUL 74     PAGE 029

                  1497    *                        TRIM VALUES               HWE12480
                  1498    *                        STANDARD TRIMS XR1        HWE12490
                  1499    *                            ANALOG TRIM EQU       HWE12500
                  1500    *                             COMPUTED VALUES EQU  HWE12510
0001              1501    VT128 EQU    +1    SPEED REQUEST                  HWE12520
0002              1502    VT129 EQU    +2    SPEED REQUEST ERROR FOR INTEGRATHWE12530
0003              1503    VT130 EQU    +3    SPEED REQUEST INTEGRATION UP   HWE12540
0004              1504    VT131 EQU    +4    SPEED REQUEST INTEGRATION DOWN HWE12550
0005              1505    VT132 EQU    +5    INTEGRATED SPEED REQUEST       HWE12560
0006              1506    VT133 EQU    +6    LIMIT UP                       HWE12570
0007              1507    VT134 EQU    +7    LIMIT DOWN                     HWE12580
0008              1508    VT135 EQU    +8    SCALED BASE RATIOS     FIG10-5 HWE12590
0009              1509    VT136 EQU    +9    SCALED START INTERCEPT FIG10-7 HWE12600
000A              1510    VT137 EQU    +10   SCALED THIRD RANGE     FIG10-7 HWE12610
000B              1511    VT138 EQU    +11   SCALED INC INTEGRATION FIG10-8 HWE12620
000C              1512    VT139 EQU    +12   SCALED DEC INTEGRATION FIG10-8 HWE12630
000D              1513    VT140 EQU    +13        SCALED MINIMUM RATIOS     HWE12640
000E              1514    VT141 EQU    +14        ZERO FLOW ADJUSTMENT      HWE12650
000F              1515    VT142 EQU    +15        MAXIMUM VALVE SETTING     HWE12660
0010              1516    VT143 EQU    +16        MINIMUM VALVE SETTING     HWE12670
0011              1517    VT144 EQU    +17   SCALED LOW N IGV       FIG10-12 HWE12680
0012              1518    VT145 EQU    +18   SCALED LOW N BLEEDS    FIG10-12 HWE12690
0013              1519    VT146 EQU    +19             TEMPERATURE REQ      HWE12700
0014              1520    VT147 EQU    +20   FUEL RATIOS FINAL      FIG10-8 HWE12710
0015              1521    VT148 EQU    +21   COMPUTED FUEL REQUEST  FIG10-8 HWE12720
0016              1522    VT149 EQU    +22   SELECTED VARIABLE STORAGE      HWE12730
                  1523    *                  FIG10-3   RPM REQUEST CONTROL  HWE12740
0017              1524    VT150 EQU    +23             POWER LEVER RPM REQ  HWE12750
0018              1525    VT151 EQU    +24             LOW SPEED SET        HWE12760
0019              1526    VT152 EQU    +25             HIGH SPEED SET       HWE12770
001A              1527    VT153 EQU    +26             POS RPM DN/DT        HWE12780
001B              1528    VT154 EQU    +27             NEG RPM DN/DT        HWE12790
001C              1529    VT155 EQU    +28             SPEED LIMIT TEMP     HWE12800
001D              1530    VT156 EQU    +29             SPEED REQUEST        HWE12810
                  1531    *                 FIG10-4    COMPUTED DIGITAL RPM HWE12820
001E              1532    VT157 EQU    +30                                  HWE12830
001F              1533    VT158 EQU    +31             MAX FUEL REQUEST     HWE12840
0020              1534    VT159 EQU    +32             SPEED ERROR          HWE12850
0021              1535    VT160 EQU    +33             SPEED RATIOS ERROR   HWE12860
                  1536    *                                                 HWE12870
                  1537    *                  FIG10-5   PROPORTIONAL TEMP CON HWE12880
                  1538    *                            VT146 TEMP REQ       HWE12890
0022              1539    VT161 EQU    +34        RATIOS SPEED CONTROL      HWE12900
0023              1540    VT162 EQU    +35             TEMP.RATIOS ERROR    HWE12910
0024              1541    VT163 EQU    +36             LOW OF RPM AND TEMP  HWE12920
                  1542    *                  FIG10-5   PROP.PRESSURE CONTROL HWE12930
0025              1543    VT164 EQU    +37             PRESS REQUEST        HWE12940
0026              1544    VT165 EQU    +38             PRESS ERROR          HWE12950
0027              1545    VT166 EQU    +39             RATIOS PRESS ERROR   HWE12960
0028              1546    VT167 EQU    +40             LOW OF P,T,AND RPM   HWE12970
                  1547    *                                                 HWE12980
0029              1548    VT168 EQU    +41             RESERVED =VT167      HWE12990
                  1549    *                  FIG10-5   BASE RATIOS INTEGRATE HWE13000
002A              1550    VT169 EQU    +42             INTEGRATION VALUE    HWE13010
002B              1551    VT170 EQU    +43             BASE RATIOS INT PLUS HWE13020
002C              1552    VT171 EQU    +44             RATIOS REQUEST       HWE13030
                  1553    *                                                 HWE13040
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Table B-13. Bendix Bounds Program (Continued)

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             1554   *                     FIG10-7   MAX RATIOS SCHEDULE    HWE13050
0020         1555   VT172 EQU     +45               SCHEDULE T2 VALUE      HWE13060
002E         1556   VT173 EQU     +46               START RATIOS           HWE13070
002F         1557   VT174 EQU     +47               2ND RANGE START RATIO  HWE13080
0030         1558   VT175 EQU     +48               LOW OF 173 AND 174     HWE13090
0031         1559   VT176 EQU     +49               3RD RANGE VALUE        HWE13100
0032         1560   VT177 EQU     +50               HIGH OF 175 & 176      HWE13110
0033         1561   VT178 EQU     +51               ACC SCHEDULE           HWE13120
0034         1562   VT179 EQU     +52               LOW 178 & 177          HWE13130
0035         1563   VT180 EQU     +53           VALVE CONTROL INPUT POINT  HWE13140
0036         1564   VT181 EQU     +54           MAXIMUM RATIOS             HWE13150
0037         1565   VT182 EQU     +55           RATIOS MODIFIED            HWE13160
0038         1566   VT183 EQU     +56           LOW RATIOS WITH SPEED      HWE13170
0039         1567   VT184 EQU     +57           MAXIMUM VALVE DUE TO RATIO HWE13180
             1568   *                     FIGURE 10A-3 AND 4 VALVE POS     HWE13190
003A         1569   VT185 EQU     +58           MAXIMUM VALVE              HWE13200
003B         1570   VT186 EQU     +59           MAX VALVE AFTER N SAFETY   HWE13210
003C         1571   VT187 EQU     +60           MAX VALVE AFTER OTHER CONT HWE13220
003D         1572   VT188 EQU     +61           IDLE MINIMUM SCHEDULE      HWE13230
003E         1573   VT189 EQU     +62           IDLE MINIMUM RATIOS        HWE13240
003F         1574   VT190 EQU     +63           MINIMUM RATIOS             HWE13250
0040         1575   VT191 EQU     +64           MINIMUM RATIOS OUT         HWE13260
0041         1576   VT192 EQU     +65           MINIMUM VALVE REQUEST      HWE13270
0042         1577   VT193 EQU     +66           FUEL REQUEST               HWE13280
0043         1578   VT194 EQU     +67           FACTORED BURNER PRESSURE   HWE13290
0044         1579   VT195 EQU     +68           FUEL REQUEST OUTPUT        HWE13300
0045         1580   VT196 EQU     +69         FUEL RATIOS PROP. ADDER      HWE13310
             1581   *                                                      HWE13320
             1582   *                    FIG10-9  TEMPERATURE CONTROL      HWE13330
0046         1583   VT197 EQU     +70          TEMPERATURE REQUEST ACC     HWE13340
0047         1584   VT198 EQU     +71           TEMPERATURE ERROR ACC      HWE13350
0048         1585   VT199 EQU     +72           TEMPERATURE RATIO PROP ACC HWE13360
0049         1586   VT200 EQU     +73           TEMPERATURE REQUEST DECEL  HWE13370
004A         1587   VT201 EQU     +74           TEMPERATURE ERROR DECEL    HWE13380
004B         1588   VT202 EQU     +75           TEMPERATURE RATIOS DECEL   HWE13390
             1589   *                                                      HWE13400
             1590   *                     FIG10-10  PRESSURE RATIO CONT    HWE13410
004C         1591   VT203 EQU     +76           DP/P LOW N SCHEDULE REQ    HWE13420
004D         1592   VT204 EQU     +77           DP/P MID N SCHEDULE REQ    HWE13430
004E         1593   VT205 EQU     +78           DP/P HIGH N SCHEDULE REQ   HWE13440
004F         1594   VT206 EQU     +79           DP/P ERROR                 HWE13450
0050         1595   VT207 EQU     +80           DP/P INTEGRATION           HWE13460
             1596   *                                                      HWE13470
             1597   *                    FIG10-12 1GV AND BLEED SCHEDULE   HWE13480
0051         1598   VT208 EQU     +81           LOW N SCHEDULE             HWE13490
0052         1599   VT209 EQU     +82                                      HWE13500
0053         1600   VT210 EQU     +83           HIGH N MID T               HWE13510
0054         1601   VT211 EQU     +84                                      HWE13520
0055         1602   VT212 EQU     +85           SPEED RANGE 1GV            HWE13530
0056         1603   VT213 EQU     +86           1GV REQUEST DAC /          HWE13540
0057         1604   VT214 EQU     +87           SPEED RANGE BLEEDS         HWE13550
0058         1605   VT215 EQU     +88           BLEED REQUEST DAC2         HWE13560
             1606   *                                                      HWE13570
             1607   *                     FIG10-14  NOZZLE CONTROL         HWE13580
0059         1608   VT216 EQU     +89                                      HWE13590
005A         1609   VT217 EQU     +90           NOZZLE MID SPEED           HWE13600
005B         1610   VT218 EQU     +91           NOZZLE HIGH SPEED          HWE13610
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Table B-13. Bendix Bounds Program (Continued)

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                                                      17 JUL 74     PAGE 031

 005C              1611    VT219 EQU    +92          NOZZLE REQUEST DAC 3      HWE13620
 005D              1612    VT220 EQU    +93          DAC4 OUTPUT VALUE         HWE13630
 005E              1613    VT221 EQU    +94                                    HWE13640
 005F              1614    VT222 EQU    +95                                    HWE13650
 0060              1615    VT223 EQU    +96                                    HWE13660
 0061              1616    VT224 EQU    +97          DAC2 OUTPUT ADJUSTMENT NO HWE13670
 0062              1617    VT225 EQU    +98          DAC2 OUTPUT VALUE         HWE13680
 0063              1618    VT226 EQU    +99          EFFECTIVE LOOP OUTPUT     HWE13690
                   1619    *                    ANALOG VARIABLE                HWE13700
                   1620    *                    FIRST STRIP                    HWE13710
 0064              1621    VT22  EQU    +100              DP/P         EK14    HWE13720
 0065              1622    VT228 EQU    +101              POWER LEVER  EK14    HWE13730
 0066              1623    VT229 EQU    +102              INSTRUMENT VAR EK14T4 HWE13740
 0067              1624    VT230 EQU    +103              BURNER PRESS   EK14  HWE13750
 0068              1625    VT231 EQU    +104              BURNER PRESS   EK15P1HWE13760
 0069              1626    VT232 EQU    +105          DP= P3-PS        EK15P2  HWE13770
 006A              1627    VT233 EQU    +106              P2 COMP INLET  EK15P3 HWE13780
 006B              1628    VT234 EQU    +107              BLEED PRESS P23EK15P4 HWE13790
 006C              1629    VT235 EQU    +108              POSITION INPUT EK15  HWE13800
 006D              1630    VT236 EQU    +109              ANALOG SPEED INST    HWE13810
 006E              1631    VT237 EQU    +110              BLEED PRESS P2.4  P5 HWE13820
 006F              1632    VT238 EQU    +111              BLEED PRESS P2.5  P6 HWE13830
 0070              1633    VT239 EQU    +112              TURBINE DISCH PRES P8 HWE13840
 0071              1634    VT240 EQU    +113              ENGINE DISCH PRES P9 HWE13850
 0072              1635    VT241 EQU    +114          PRESSURE RATIO            HWE13860
 0073              1636    VT242 EQU    +115                                    HWE13870
 0074              1637    VT243 EQU    +116                                    HWE13880
 0075              1638    VT244 EQU    +117                                    HWE13890
                   1639    *                    THIRD  STRIP          EK18     HWE13900
 0076              1640    VT245 EQU    +118              COMP TEMP INLET   TA HWE13910
 0077              1641    VT246 EQU    +119              COMP TEMP DISCH   TB HWE13920
 0078              1642    VT247 EQU    +120              TURBINE  INLET    TC HWE13930
 0079              1643    VT248 EQU    +121              TURBINE  DISCH    TD HWE13940
 007A              1644    VT249 EQU    +122              POWER LEVER     PLA1 HWE13950
 007B              1645    VT250 EQU    +123              POWER LEVER     PLA2 HWE13960
 007C              1646    VT251 EQU    +124              FILTER-LEAD-LAG VAR  HWE13970
 007D              1647    VT252 EQU    +125              SPARE                HWE13980
 007E              1648    VT253 EQU    +126              SPARE                HWE13990
                   1649    *                   SPARE POINT                     HWE14000
 007F              1650    VT254 EQU    +127                                    HWE14010
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Table B-13. Bendix Bounds Program (Continued)

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                                                        17 JUL 74     PAGE 032

                1652     *                  TRIMS LOCATION VALVES              HWE14030
    FFFF        1653     VT001 EQU    -1                                       HWE14040
    FFFE        1654     VT002 EQU    -2                                       HWE14050
    FFFD        1655     VT003 EQU    -3                                       HWE14060
    FFFC        1656     VT004 EQU    -4                                       HWE14070
    FFFB        1657     VT005 EQU    -5                                       HWE14080
    FFFA        1658     VT006 EQU    -6                                       HWE14090
    FFF9        1659     VT007 EQU    -7                                       HWE14100
    FFF8        1660     VT008 EQU    -8                                       HWE14110
    FFF7        1661     VT009 EQU    -9                                       HWE14120
    FFF6        1662     VT010 EQU    -10                                      HWE14130
    FFF5        1663     VT011 EQU    -11                                      HWE14140
    FFF4        1664     VT012 EQU    -12                                      HWE14150
    FFF3        1665     VT013 EQU    -13                                      HWE14160
    FFF2        1666     VT014 EQU    -14                                      HWE14170
    FFF1        1667     VT015 EQU    -15                                      HWE14180
    FFF0        1668     VT016 EQU    -16                                      HWE14190
    FFEF        1669     VT017 EQU    -17                                      HWE14200
    FFEE        1670     VT018 EQU    -18                                      HWE14210
    FFED        1671     VT019 EQU    -19                                      HWE14220
    FFEC        1672     VT020 EQU    -20                                      HWE14230
    FFEB        1673     VT021 EQU    -21                                      HWE14240
    FFEA        1674     VT022 EQU    -22                                      HWE14250
    FFE9        1675     VT023 EQU    -23                                      HWE14260
    FFE8        1676     VT024 EQU    -24                                      HWE14270
    FFE7        1677     VT025 EQU    -25                                      HWE14280
    FFE6        1678     VT026 EQU    -26                                      HWE14290
    FFE5        1679     VT027 EQU    -27                                      HWE14300
    FFE4        1680     VT028 EQU    -28                                      HWE14310
    FFE3        1681     VT029 EQU    -29                                      HWE14320
    FFE2        1682     VT030 EQU    -30                                      HWE14330
    FFE1        1683     VT031 EQU    -31                                      HWE14340
    FFE0        1684     VT032 EQU    -32                                      HWE14350
    FFDF        1685     VT033 EQU    -33                                      HWE14360
    FFDE        1686     VT034 EQU    -34                                      HWE14370
    FFDD        1687     VT035 EQU    -35                                      HWE14380
    FFDC        1688     VT036 EQU    -36                                      HWE14390
    FFDB        1689     VT037 EQU    -37                                      HWE14400
    FFDA        1690     VT038 EQU    -38                                      HWE14410
    FFD9        1691     VT039 EQU    -39                                      HWE14420
    FFD8        1692     VT040 EQU    -40                                      HWE14430
    FFD7        1693     VT041 EQU    -41                                      HWE14440
    FFD6        1694     VT042 EQU    -42                                      HWE14450
    FFD5        1695     VT043 EQU    -43                                      HWE14460
    FFD4        1696     VT044 EQU    -44                                      HWE14470
    FFD3        1697     VT045 EQU    -45                                      HWE14480
    FFD2        1698     VT046 EQU    -46                                      HWE14490
    FFD1        1699     VT047 EQU    -47                                      HWE14500
    FFD0        1700     VT048 EQU    -48                                      HWE14510
    FFCF        1701     VT049 EQU    -49                                      HWE14520
    FFCE        1702     VT050 EQU    -50                                      HWE14530
    FFCD        1703     VT051 EQU    -51                                      HWE14540
    FFCC        1704     VT052 EQU    -52                                      HWE14550
    FFCB        1705     VT053 EQU    -53                                      HWE14560
    FFCA        1706     VT054 EQU    -54                                      HWE14570
    FFC9        1707     VT055 EQU    -55                                      HWE14580
    FFC8        1708     VT056 EQU    -56                                      HWE14590
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Table B-13. Bendix Bounds Program (Continued)

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                                                     17 JUL 74      PAGE 033

FFC7          1709     VT057 EQU      -57                                  HWE14600
FFC6          1710     VT058 EQU      -58                                  HWE14610
FFC5          1711     VT059 EQU      -59                                  HWE14620
FFC4          1712     VT060 EQU      -60                                  HWE14630
FFC3          1713     VT061 EQU      -61                                  HWE14640
FFC2          1714     VT062 EQU      -62                                  HWE14650
FFC1          1715     VT063 EQU      -63                                  HWE14660
FFC0          1716     VT064 EQU      -64                                  HWE14670
FFBF          1717     VT065 EQU      -65                                  HWE14680
FFBE          1718     VT066 EQU      -66                                  HWE14690
FFBD          1719     VT067 EQU      -67                                  HWE14700
FFBC          1720     VT068 EQU      -68                                  HWE14710
FFBB          1721     VT069 EQU      -69                                  HWE14720
FFBA          1722     VT070 EQU      -70                                  HWE14730
FFB9          1723     VT071 EQU      -71                                  HWE14740
FFB8          1724     VT072 EQU      -72                                  HWE14750
FFB7          1725     VT073 EQU      -73                                  HWE14760
FFB6          1726     VT074 EQU      -74                                  HWE14770
FFB5          1727     VT075 EQU      -75                                  HWE14780
FFB4          1728     VT076 EQU      -76                                  HWE14790
FFB3          1729     VT077 EQU      -77                                  HWE14800
FFB2          1730     VT078 EQU      -78                                  HWE14810
FFB1          1731     VT079 EQU      -79                                  HWE14820
FFB0          1732     VT080 EQU      -80                                  HWE14830
FFAF          1733     VT081 EQU      -81                                  HWE14840
FFAE          1734     VT082 EQU      -82                                  HWE14850
FFAD          1735     VT083 EQU      -83                                  HWE14860
FFAC          1736     VT084 EQU      -84                                  HWE14870
FFAB          1737     VT085 EQU      -85                                  HWE14880
FFAA          1738     VT086 EQU      -86                                  HWE14890
FFA9          1739     VT087 EQU      -87                                  HWE14900
FFA8          1740     VT088 EQU      -88                                  HWE14910
FFA7          1741     VT089 EQU      -89                                  HWE14920
FFA6          1742     VT090 EQU      -90                                  HWE14930
FFA5          1743     VT091 EQU      -91                                  HWE14940
FFA4          1744     VT092 EQU      -92                                  HWE14950
FFA3          1745     VT093 EQU      -93                                  HWE14960
FFA2          1746     VT094 EQU      -94                                  HWE14970
FFA1          1747     VT095 EQU      -95         T2=10XF DEG              HWE14980
FFA0          1748     VT096 EQU      -96         T3=10XF DEG              HWE14990
FF9F          1749     VT097 EQU      -97         T4=10XF DEG              HWE15000
FF9E          1750     VT098 EQU      -98         T5=10XF DEG              HWE15010
FF9D          1751     VT099 EQU      -99         ADJUSTMENT NUMBER SELECTED HWE15020
FF9C          1752     VT100 EQU      -100        ADJUSTMENT REGISTER NUMBER HWE15030
FF9B          1753     VT101 EQU      -101        SAFETY DIGITAL NUMBER    HWE15040
FF9A          1754     VT102 EQU      -102        PB=100XPSI               HWE15050
FF99          1755     VT103 EQU      -103        DP=1000XPSI              HWE15060
FF98          1756     VT104 EQU      -104        P2=1000XPSI              HWE15070
FF97          1757     VT105 EQU      -105        P23-P2=100XPSI           HWE15080
FF96          1758     VT106 EQU      -106        P24-P2=100XPSI           HWE15090
FF95          1759     VT107 EQU      -107        P25-P2=100XPSI           HWE15100
FF94          1760     VT108 EQU      -108        P5  =100XPSI             HWE15110
FF93          1761     VT109 EQU      -109        P0  =1000XPSI            HWE15120
FF92          1762     VT110 EQU      -110                                 HWE15130
FF91          1763     VT111 EQU      -111                                 HWE15140
FF90          1764     VT112 EQU      -112                                 HWE15150
FF8F          1765     VT113 EQU      -113                                 HWE15160
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Table B-13. Bendix Bounds Program (Concluded)

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                                                                  17 JUL 74     PAGE 034

FF8E                1766   VT114 EQU    -114                                              HWE15170
FF8D                1767   VT115 EQU    -115                                              HWE15180
FF8C                1768   VT116 EQU    -116                                              HWE15190
FF8B                1769   VT117 EQU    -117                                              HWE15200
FF8A                1770   VT118 EQU    -118                                              HWE15210
FF89                1771   VT119 EQU    -119                                              HWE15220
FF88                1772   VT120 EQU    -120                                              HWE15230
FF87                1773   VT121 EQU    -121                                              HWE15240
FF86                1774   VT122 EQU    -122                                              HWE15250
FF85                1775   VT123 EQU    -123                                              HWE15260
FF84                1776   VT124 EQU    -124                                              HWE15270
FF83                1777   VT125 EQU    -125                                              HWE15280
FF82                1778   VT126 EQU    -126                                              HWE15290
FF81                1779   VT127 EQU    -127                                              HWE15300
058A                1780         END                                                      HWE15310

000 ERROR(S) AND 000 WARNING(S) IN ABOVE ASSEMBLY.
```

Table B-14. Bendix Bounds Program Cross Reference

SYMBOL	VALUE	REL	DEFN	REFERENCES-
PTH34	0789	1	964	959R
PTH41	0406	1	1018	1013R
PTH42	03FE	1	1012	1007R
PTH43	03F6	1	1006	1001R
PTH44	03EC	1	999	994R
PTH51	0446	1	1075	1070R
PTH52	043E	1	1069	1064R
PTH53	0436	1	1063	1058R
PTH54	042D	1	1056	1051R
POSA	0564	1	391	1384R
P00	0000	0	1431	
P01	0001	0	1432	
P02	0002	0	1433	
P03	0003	0	1434	
P04	0004	0	1435	
P05	0005	0	1436	
P06	0006	0	1437	
P07	0007	0	1438	
P08	0008	0	1439	
P09	0009	0	1440	
P10	000A	0	1441	
P11	000B	0	1442	
P12	000C	0	1443	
P13	000D	0	1444	
P14	000E	0	1445	
P15	000F	0	1446	
P16	0010	0	1447	
P17	0011	0	1448	
P18	0012	0	1449	506R
P19	0013	0	1450	508R
P20	0014	0	1451	510R
P21	0015	0	1452	512R
P22	0016	0	1453	514R
P23	0017	0	1454	516R
P24	0018	0	1455	518R
P25	0019	0	1456	520R
P26	001A	0	1457	522R
P27	001B	0	1458	525R
P28	001C	0	1459	527R
P29	001D	0	1460	529R
P30	001E	0	1461	531R
P31	001F	0	1462	533R
P32	0020	0	1463	535R
P33	0021	0	1464	537R
P34	0022	0	1465	539R
P35	0023	0	1466	541R
P36	0024	0	1467	547R
P37	0025	0	1468	549R
P38	0026	0	1469	551R
P39	0027	0	1470	553R
P40	0028	0	1471	555R
P41	0029	0	1472	560R
P42	002A	0	1473	565R
P43	002B	0	1474	570R
P44	002C	0	1475	574R
P45	002D	0	1476	577R
P46	002E	0	1477	579R
P47	002F	0	1478	583R
P48	0030	0	1479	587R

Table B-14. Bendix Bounds Program Cross Reference (Continued)

```
SYMBOL   VALUE  REL   DEFN      REFERENCES-
P49       0031   0    1480       591R
P50       0032   0    1481       596R
P51       0033   0    1482       598R
P52       0034   0    1483       600R
P53       0035   0    1484       602R
P54       0036   0    1485       605R
P55       0037   0    1486       611P
P56       0038   0    1487       617R
P57       0039   0    1488       622R
P58       003A   0    1489       627R
P59       003B   0    1490       629R
P60       003C   0    1491       631R
P61       003D   0    1492       633R
P62       003E   0    1493       635R
P63       0C3F   0    1494       638R
RAWN      01E3   1     483       461M     465R
RDOUT     0165   1     360       355R
RPM       01E0   1     479       455R
RSTAL     0010   1      13       369R
RSTSA     0175   1     378       373R
SAFND     01C6   1     451       435R     443R     447R
SAM1      02C2   1     721       681M
SAM2      02C3   1     722       720M
SAM3      02E0   1     751       744M     746R
SAM4      02E1   1     752       750M
SAM6      04DF   1    1241      1221M
SAM7      04EA   1    1252      1243M
SAM8      04F0   1    1259      1226M    1250M
START     0147   1     337        12R
STTVT     00A9   1     188        74M
ST000     004E   1      78       388R
ST001     004F   1      79        14R
ST002     0050   1      80        16R
ST003     0051   1      81        18R
ST004     0052   1      82        20R
ST005     0053   1      83        22R
ST006     0054   1      84        24R
ST007     0055   1      85        26R
ST008     0056   1      86        28R
ST009     0057   1      89        30R
ST010     0058   1      90        32R
ST011     0059   1      91        34R
ST012     005A   1      94        36R
ST013     005B   1      95        38R
ST014     005C   1      96        40R
ST015     005D   1      97        42R
ST016     005E   1      98        44R
ST017     005F   1      99        46R
ST018     0060   1     100        48R
ST019     0061   1     101        50R
ST020     0062   1     102        52R
ST021     0063   1     103        54R
ST022     0064   1     104        56R
ST023     0065   1     105        58R
ST024     0066   1     109        60R
ST025     0067   1     110        62R
ST026     0068   1     111        64R
ST027     0069   1     114        66R
ST028     006A   1     115        68R
```

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-
ST029	006B	1	116	70R
ST030	006C	1	117	72R
ST031	006D	1	118	189R
ST032	006E	1	119	191R
ST033	006F	1	120	193R
ST034	0070	1	121	195R
ST035	0071	1	122	197R
ST036	0072	1	126	199R
ST037	0073	1	127	201R
ST038	0074	1	128	203R
ST039	0075	1	129	205R
ST040	0076	1	130	207R
ST041	0077	1	131	209R
ST042	0078	1	132	211R
ST043	0079	1	133	213R
ST044	007A	1	134	215R
ST045	007B	1	135	217R
ST046	007C	1	136	219R
ST047	007D	1	137	221R
ST048	007E	1	138	223R
ST049	007F	1	139	225R
ST050	0080	1	140	227R
ST051	0081	1	146	229R
ST052	0082	1	147	231R
ST053	0083	1	148	233R
ST054	0084	1	149	235R
ST055	0085	1	152	237R
ST056	0086	1	153	239R
ST057	0087	1	154	241R
ST058	0088	1	155	243R
ST059	0089	1	156	245R
ST060	008A	1	157	247R
ST061	008B	1	158	249R
ST062	008C	1	159	251R
ST063	008D	1	160	253R
ST064	008E	1	161	255R
ST065	008F	1	162	257R
ST066	0090	1	163	259R
ST067	0091	1	164	261R
ST068	0092	1	165	263R
ST069	0093	1	166	265R
ST070	0094	1	167	267R
ST071	0095	1	168	269R
ST072	0096	1	169	271R
ST073	0097	1	170	273R
ST074	0098	1	171	275R
ST075	0099	1	172	277R
ST076	009A	1	173	279R
ST077	009B	1	174	281R
ST078	009C	1	175	283R
ST079	009D	1	176	285R
ST080	009E	1	177	287R
ST081	009F	1	178	289R
ST082	00A0	1	179	291R
ST083	00A1	1	180	293R
ST084	00A2	1	181	295R
ST085	00A3	1	182	297R
ST086	00A4	1	183	299R
ST087	00A5	1	184	301R

Table B-14. Bendix Bounds Program
Cross Reference (Continued)

```
SYMBOL  VALUE REL  DEFN     REFERENCES-
ST088    00A6  1    185      303R
ST089    00A7  1    186      305R
ST090    00A8  1    187      307R
TEMPA    04DE  1   1238     1246M  1248R
TEMP2    01DD  1    474      477R
TEMP3    0142  1    331      366M
TEMP4    0143  1    332      354M   376R
TEMP5    0144  1    333      387M   392M
TEMP6    0470  1   1121     1100M  1102R
TESTN    01E2  1    482      454M   457M
TMNR     0140  1    329      346M   350M   351R   400R   416R
TRIMS    0141  1    330      467M   544M
T2100    03E1  1    990      806R
T2125    0422  1   1047      804R
T225     033E  1    849      812R
T250     0381  1    909      810R
T275     03B6  1    955      808R
VALID    01CF  1    459      456M
VALPO    0484  1   1143     1142M
VALUE    013E  1    327      324R   353M   357R   359M
VLVEC    01B8  1    440      431R
VT001    FFFF  0   1653       15M   657R
VT002    FFFE  0   1654       17M   661R
VT003    FFFD  0   1655       19M   762R
VT004    FFFC  0   1656       21M   679R
VT005    FFFB  0   1657       23M   682R
VT006    FFFA  0   1658       25M   685R
VT007    FFF9  0   1659       27M   694R
VT008    FFF8  0   1660       29M   697R
VT009    FFF7  0   1661       31M   754R
VT010    FFF6  0   1662       33M   765R
VT011    FFF5  0   1663       35M  1161R
VT012    FFF4  0   1664       37M
VT013    FFF3  0   1665       39M
VT014    FFF2  0   1666       41M
VT015    FFF1  0   1667       43M
VT016    FFF0  0   1668       45M
VT017    FFEF  0   1669       47M
VT018    FFEE  0   1670       49M
VT019    FFED  0   1671       51M
VT020    FFEC  0   1672       53M
VT021    FFEB  0   1673       55M
VT022    FFEA  0   1674       57M
VT023    FFE9  0   1675       59M
VT024    FFE8  0   1676       61M   843R   846R   878R   881R   938R   941R   984R   987R  1019R  1022R  1076R
                            1079R
VT025    FFE7  0   1677       63M   814R   849R   909R   955R   990R  1047R
VT026    FFE6  0   1678       65M  1144R
VT027    FFE5  0   1679       67M  1167R
VT028    FFE4  0   1680       69M  1364R
VT029    FFE3  0   1681       71M  1089R
VT030    FFE2  0   1682       73M  1084R
VT031    FFE1  0   1683      190M  1148R
VT032    FFE0  0   1684      192M  1154R
VT033    FFDF  0   1685      194M  1157R
VT034    FFDE  0   1686      196M
VT035    FFDD  0   1687      198M
VT036    FFDC  0   1638      200M
VT037    FFDB  0   1689      202M
```

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-	
VT038	FFDA	0	1690	204M	
VT039	FFD9	0	1691	206M	
VT040	FFD8	0	1692	208M	
VT041	FFD7	0	1693	210M	
VT042	FFD6	0	1694	212M	
VT043	FFD5	0	1695	214M	
VT044	FFD4	0	1696	216M	
VT045	FFD3	0	1697	218M	
VT046	FFD2	0	1698	220M	
VT047	FFD1	0	1699	222M	
VT048	FFD0	0	1700	224M	
VT049	FFCF	0	1701	226M	
VT050	FFCE	0	1702	228M	
VT051	FFCD	0	1703	230M	1259R
VT052	FFCC	0	1704	232M	1262R
VT053	FFCB	0	1705	234M	1281R
VT054	FFCA	0	1706	236M	1284R
VT055	FFC9	0	1707	238M	1339R
VT056	FFC8	0	1708	240M	1348R
VT057	FFC7	0	1709	242M	1354R
VT058	FFC6	0	1710	244M	
VT059	FFC5	0	1711	246M	
VT060	FFC4	0	1712	248M	
VT061	FFC3	0	1713	250M	
VT062	FFC2	0	1714	252M	
VT063	FFC1	0	1715	254M	
VT064	FFC0	0	1716	256M	
VT065	FFBF	0	1717	258M	
VT066	FFBE	0	1718	260M	
VT067	FFBD	0	1719	262M	
VT068	FFBC	0	1720	264M	
VT069	FFBB	0	1721	266M	
VT070	FFBA	0	1722	268M	
VT071	FFB9	0	1723	270M	
VT072	FFB8	0	1724	272M	
VT073	FFB7	0	1725	274M	
VT074	FFB6	0	1726	276M	1385R
VT075	FFB5	0	1727	278M	
VT076	FFB4	0	1728	280M	
VT077	FFB3	0	1729	282M	
VT078	FFB2	0	1730	284M	
VT079	FFB1	0	1731	286M	
VT080	FFB0	0	1732	288M	
VT081	FFAF	0	1733	290M	1367R
VT082	FFAE	0	1734	292M	
VT083	FFAD	0	1735	294M	
VT084	FFAC	0	1736	296M	
VT085	FFAB	0	1737	298M	
VT086	FFAA	0	1738	300M	
VT087	FFA9	0	1739	302M	
VT088	FFA8	0	1740	304M	
VT089	FFA7	0	1741	306M	
VT090	FFA6	0	1742	308M	
VT091	FFA5	0	1743		
VT092	FFA4	0	1744		
VT093	FFA3	0	1745	462M	
VT094	FFA2	0	1746	342M	
VT095	FFA1	0	1747	610M	
VT096	FFA0	0	1748	616M	

Table B-14. Bendix Bounds Program Cross Reference (Continued)

```
SYMBOL    VALUE REL   DEFN     REFERENCES-
VT097      FF9F  0    1749      621M
VT098      FF9E  0    1750      626M
VT099      FF9D  0    1751      371R    375M
VT100      FF9C  0    1752      377M
VT101      FF9B  0    1753      367M    378R    397R    413R    429R    432R    444R
VT102      FF9A  0    1754      559M
VT103      FF99  0    1755      564M
VT104      FF98  0    1756      569M
VT105      FF97  0    1757      573M
VT106      FF96  0    1758      582M
VT107      FF95  0    1759      586M
VT108      FF94  0    1760      590M
VT109      FF93  0    1761      595M
VT110      FF92  0    1762      507M
VT111      FF91  0    1763      509M
VT112      FF90  0    1764      511M
VT113      FF8F  0    1765      513M
VT114      FF8E  0    1766      515M
VT115      FF8D  0    1767      517M
VT116      FF8C  0    1768      519M
VT117      FF8B  0    1769      521M
VT118      FF8A  0    1770      523M
VT119      FF89  0    1771      526M
VT120      FF88  0    1772      528M
VT121      FF87  0    1773      530M
VT122      FF86  0    1774      532M
VT123      FF85  0    1775      534M
VT124      FF84  0    1776      536M
VT125      FF83  0    1777      538M
VT126      FF82  0    1778      540M
VT127      FF81  0    1779      542M
VT128      0001  0    1501      678M    705R    721R
VT129      0002  0    1502      707M
VT130      0003  0    1503      712M
VT131      0004  0    1504      718M
VT132      0005  0    1505      706R    719R    722M    730R    731R
VT133      0006  0    1506      684M    689R    692R
VT134      0007  0    1507      696M    701R    702R
VT135      0008  0    1508
VT136      0009  0    1509
VT137      000A  0    1510
VT138      000B  0    1511
VT139      000C  0    1512
VT140      000D  0    1513     1086M   1091R
VT141      000E  0    1514     1163M
VT142      000F  0    1515     1156M   1191R   1192R
VT143      0010  0    1516     1159M   1173R   1176R
VT144      0011  0    1517     1261M   1265R   1270R
VT145      0012  0    1518     1283M   1287R   1292R
VT146      0013  0    1519
VT147      0014  0    1520     1165M   1208R
VT148      0015  0    1521     1177M   1203R   1206R   1379R
VT149      0016  0    1522      401M    404R
VT150      0017  0    1524      668M
VT151      0018  0    1525      660M    670R    673R
VT152      0019  0    1526      664M    675R    676R
VT153      001A  0    1527      693M    709R    710R
VT154      001B  0    1528      704M    714R    717R
VT155      001C  0    1529      728M
```

Table B-14. Bendix Bounds Program Cross Reference (Continued)

```
SYMBOL   VALUE REL  DEFN     REFERENCES-
VT156     001D  0   1530      733M    759R   1322R   1332R
VT157     001E  0   1532      441R    466M    740R    760R    817R    824R    844R    852R    859R    879R    912R    919R
                              939R    958R    965R    985R    993R   1000R   1020R   1050R   1057R   1077R   1087R   1095R
                             1108R   1268R   1290R
VT158     001F  0   1533      752M   1195R   1196R
VT159     0020  0   1534      761M
VT160     0021  0   1535      764M    767R
VT161     0022  0   1539      768M    777M   1179R   1180R
VT162     0023  0   1540
VT163     0024  0   1541
VT164     0025  0   1543
VT165     0026  0   1544
VT166     0027  0   1545
VT167     0028  0   1546
VT168     0029  0   1548
VT169     002A  0   1550
VT170     002B  0   1551
VT171     002C  0   1552
VT172     002D  0   1555
VT173     002E  0   1556
VT174     002F  0   1557
VT175     0030  0   1558
VT176     0031  0   1559
VT177     0032  0   1560
VT178     0033  0   1561
VT179     0034  0   1562
VT180     0035  0   1563      758M   1140R   1141M   1199R   1200R
VT181     0036  0   1564     1082M   1145R
VT182     0037  0   1565     1147M   1178R
VT183     0038  0   1566     1187M
VT184     0039  0   1567     1190M   1383R
VT185     003A  0   1569     1194M
VT186     003B  0   1570     1198M
VT187     003C  0   1571     1202M
VT188     003D  0   1572     1105M   1109R   1110R
VT189     003E  0   1573     1112M
VT190     003F  0   1574     1093M   1114R   1117R
VT191     0040  0   1575     1118M   1168R
VT192     0041  0   1576     1172M
VT193     0042  0   1577     1207M   1377R   1381R
VT194     0043  0   1578     1153M   1170R   1168R
VT195     0044  0   1579     1209M
VT196     0045  0   1580
VT197     0046  0   1583
VT198     0047  0   1584
VT199     0048  0   1585
VT200     0049  0   1586
VT201     004A  0   1587
VT202     004B  0   1588
VT203     004C  0   1591
VT204     004D  0   1592
VT205     004E  0   1593
VT206     004F  0   1594
VT207     0050  0   1595
VT208     0051  0   1598     1218M   1266R   1269R   1268R   1291R
VT209     0052  0   1599
VT210     0053  0   1600     1225M   1249R   1257M   1264R   1286R
VT211     0054  0   1601
VT212     0055  0   1602     1267M   1277R
```

Table B-14. Bendix Bounds Program Cross Reference (Continued)

```
SYMBOL   VALUE  REL   DEFN     REFERENCES-
VT213     0056   0    1603     1279M
VT214     0057   0    1604     1289M    1299R
VT215     0058   0    1605     1301M
VT216     0059   0    1608
VT217     005A   0    1609     1330M    1341R    1344R
VT218     005B   0    1610     1345M    1356R    1358R    1361R
VT219     005C   0    1611     1362M
VT220     005D   0    1612      410M
VT221     005E   0    1613
VT222     005F   0    1614
VT223     0060   0    1615
VT224     0061   0    1616      417M     420R
VT225     0062   0    1617      426M
VT226     0063   0    1618     1386M    1389M    1392M
VT227     0064   0    1621      548M
VT228     0065   0    1622      550M
VT229     0066   0    1623      552M
VT230     0067   0    1624      554M
VT231     0068   0    1625      556M     686R     698R    1151R
VT232     0069   0    1626      561M
VT233     006A   0    1627      566M     747R
VT234     006B   0    1628      571M
VT235     006C   0    1629      575M
VT236     006D   0    1630      578M     737R     738R
VT237     006E   0    1631      580M
VT238     006F   0    1632      584M
VT239     0070   0    1633      588M
VT240     0071   0    1634      592M
VT241     0072   0    1635      597M
VT242     0073   0    1636      599M
VT243     0074   0    1637      601M
VT244     0075   0    1638      603M
VT245     0076   0    1640      607M     723R     802R    1213R    1219R    1241R    1252R
VT246     0077   0    1641      613M
VT247     0078   0    1642
VT248     0079   0    1643      624M    1347R
VT249     007A   0    1644      628M     665R
VT250     007B   0    1645      630M
VT251     007C   0    1646      632M
VT252     007D   0    1647      634M
VT253     007E   0    1648      636M
VT254     007F   0    1650      639M
WFP3      02F7   1     785      769M
XR1       0567   1    1396        3M
XR2       0569   1    1397        4M
XR3       056F   1    1398        5M
GTECT
DMP FUNCTION COMPLETED
*STORE                GTECT                                                          HWE15320
GTECT
DMP FUNCTION COMPLETED
```

Table B-14. Bendix Bounds Program Cross Reference (Concluded)

```
// JOB          VDISK    17 JUL 74 16.083 HRS
// DMP    17 JUL 74 16.083 HRS
*DELETE    S            GTE85 *****
DMP FUNCTION COMPLETED
*STORECI   S            GTE85                      04

*INCLDGTEIN/0400,GTECT/0604,GETTM/0909
*CCEND



 MPX, BUILD GTE85

 R20  GTEIN LEV.0 NON-REENT PROG

 R20  GTECT LEV.0 NON-REENT PROG

 R20  GETTM LEV.0 NON-REENT PROG

 R20  HWECT LEV.0 NON-REENT PROG

 MPX, GTE85 LD XQ

CL WC OF  0D80 STORED AT  04FE
DMP FUNCTION COMPLETED
// END   17 JUL 74 16.105 HRS
```

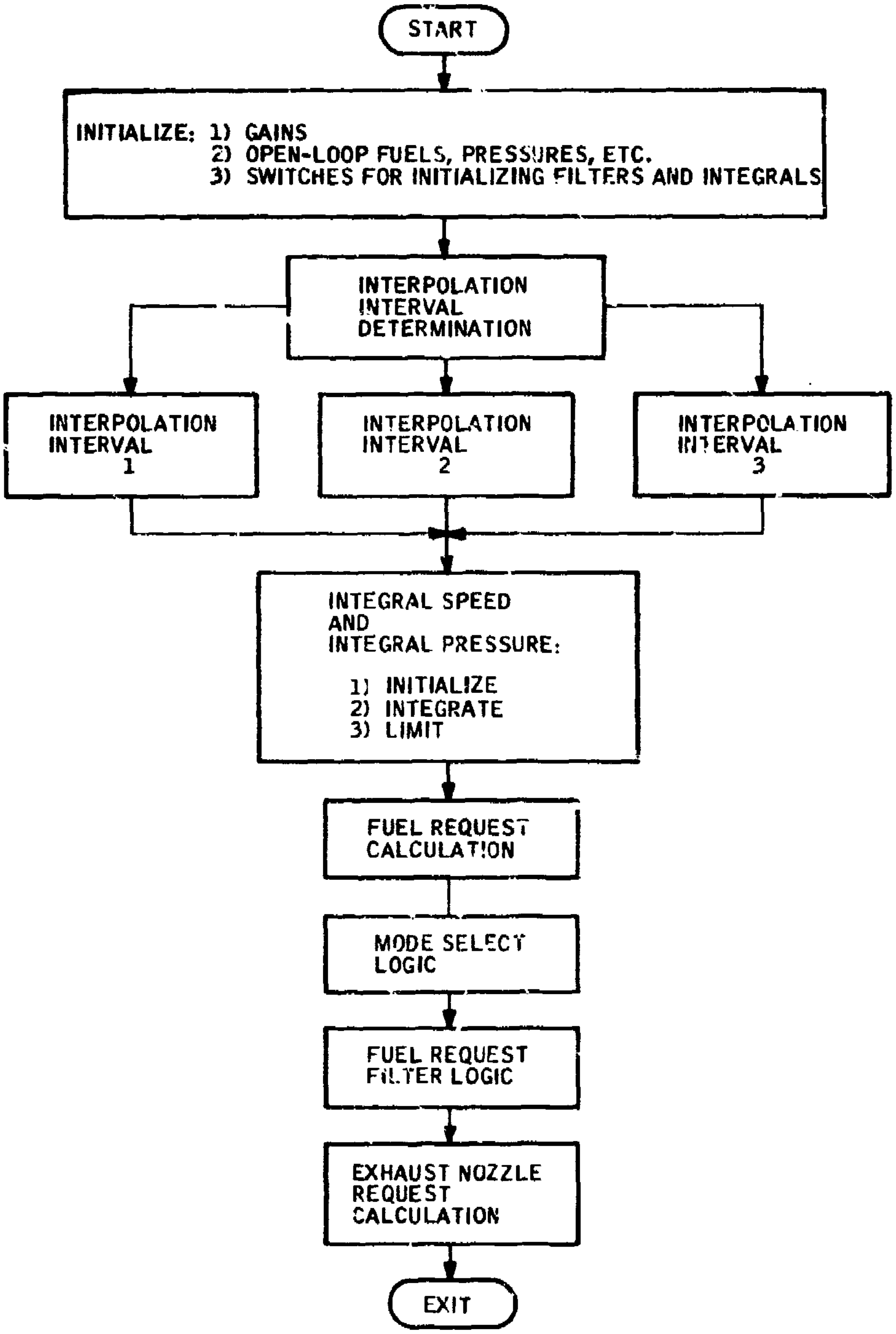

Figure B-1. Functional Flow Diagram Speed and Pressure Control Program

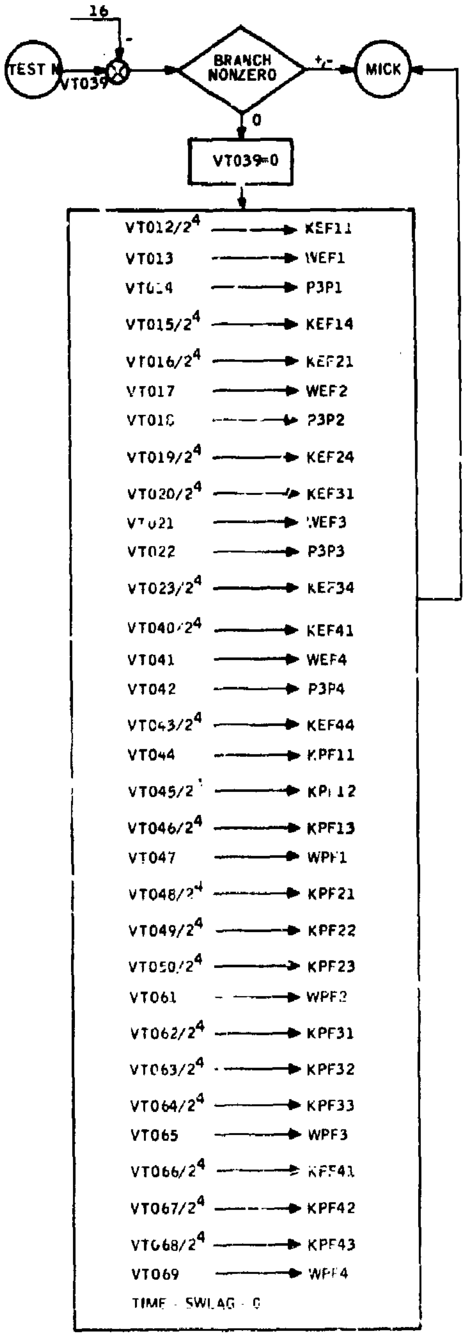

Figure B-2. Initialization Logic for Speed and Pressure Program

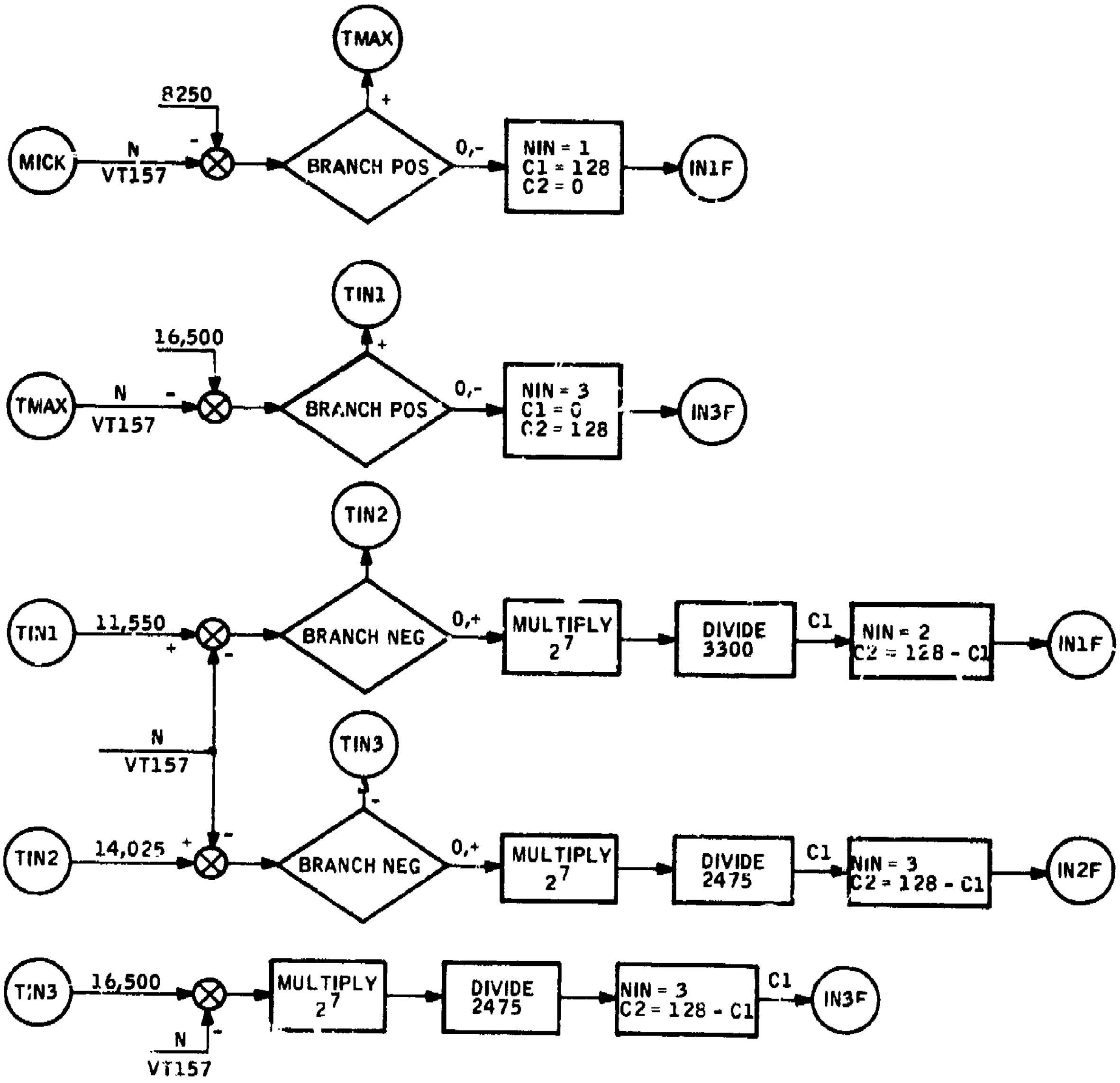

Figure B-3. Interval Determination

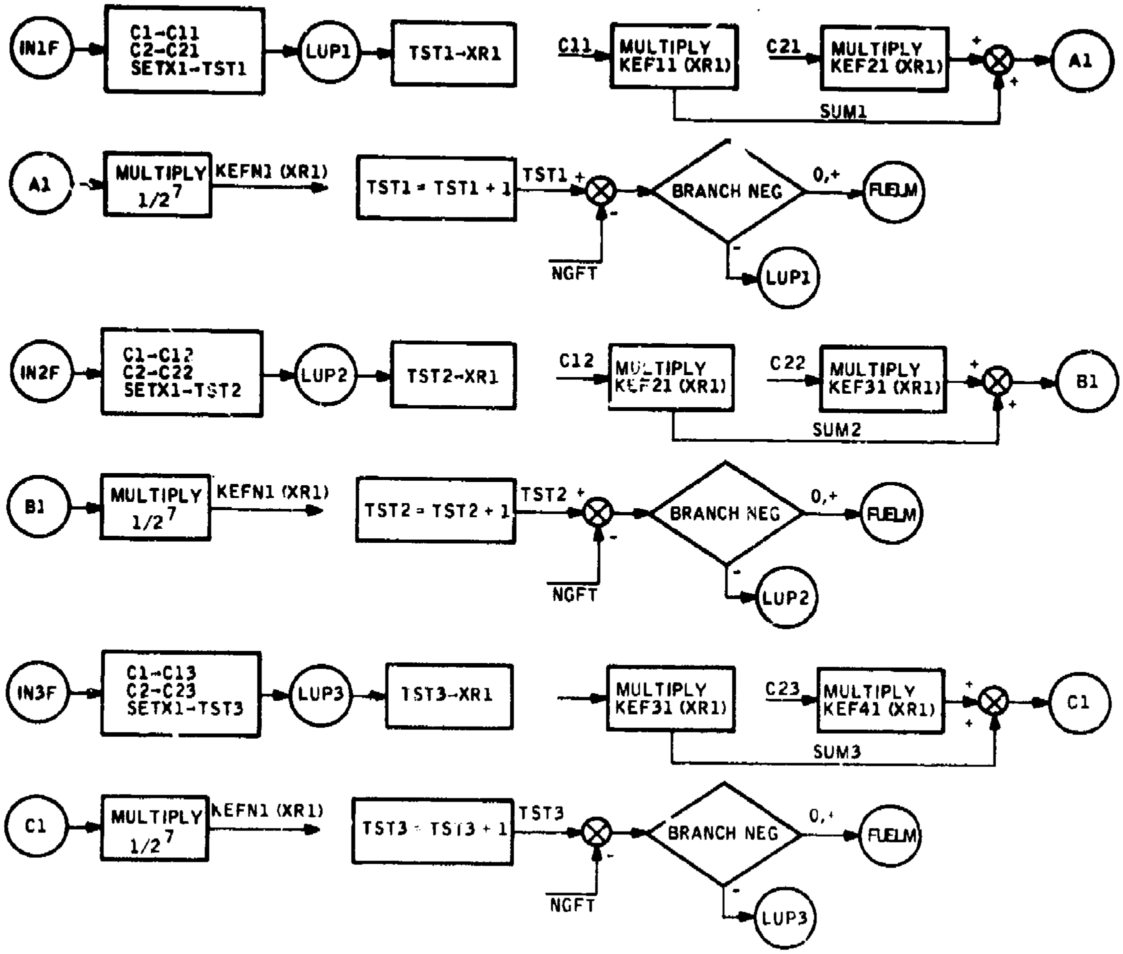

Figure B-4. Interpolation Logic

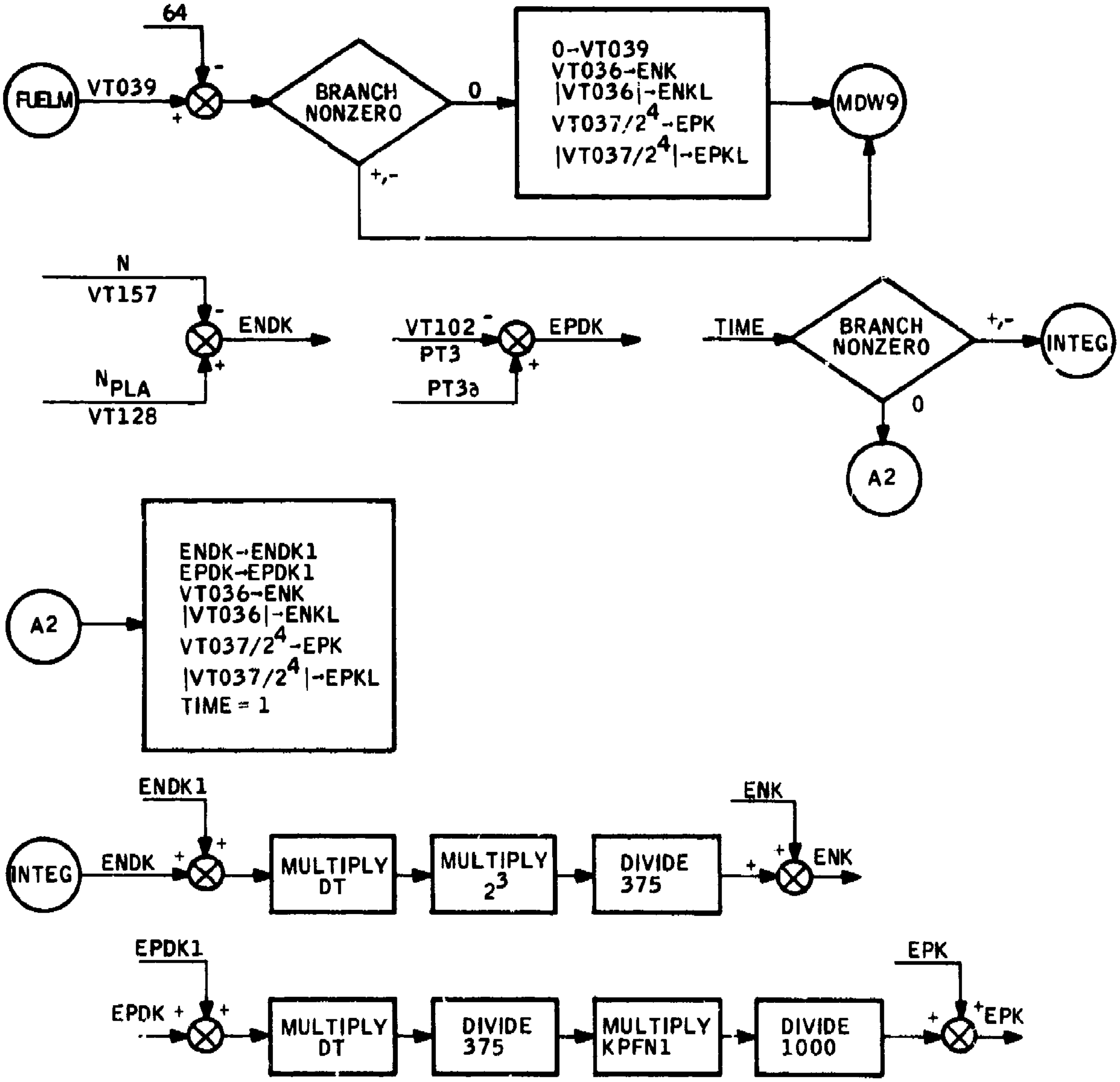

Figure B-5. Integral Speed and Pressure Calculation

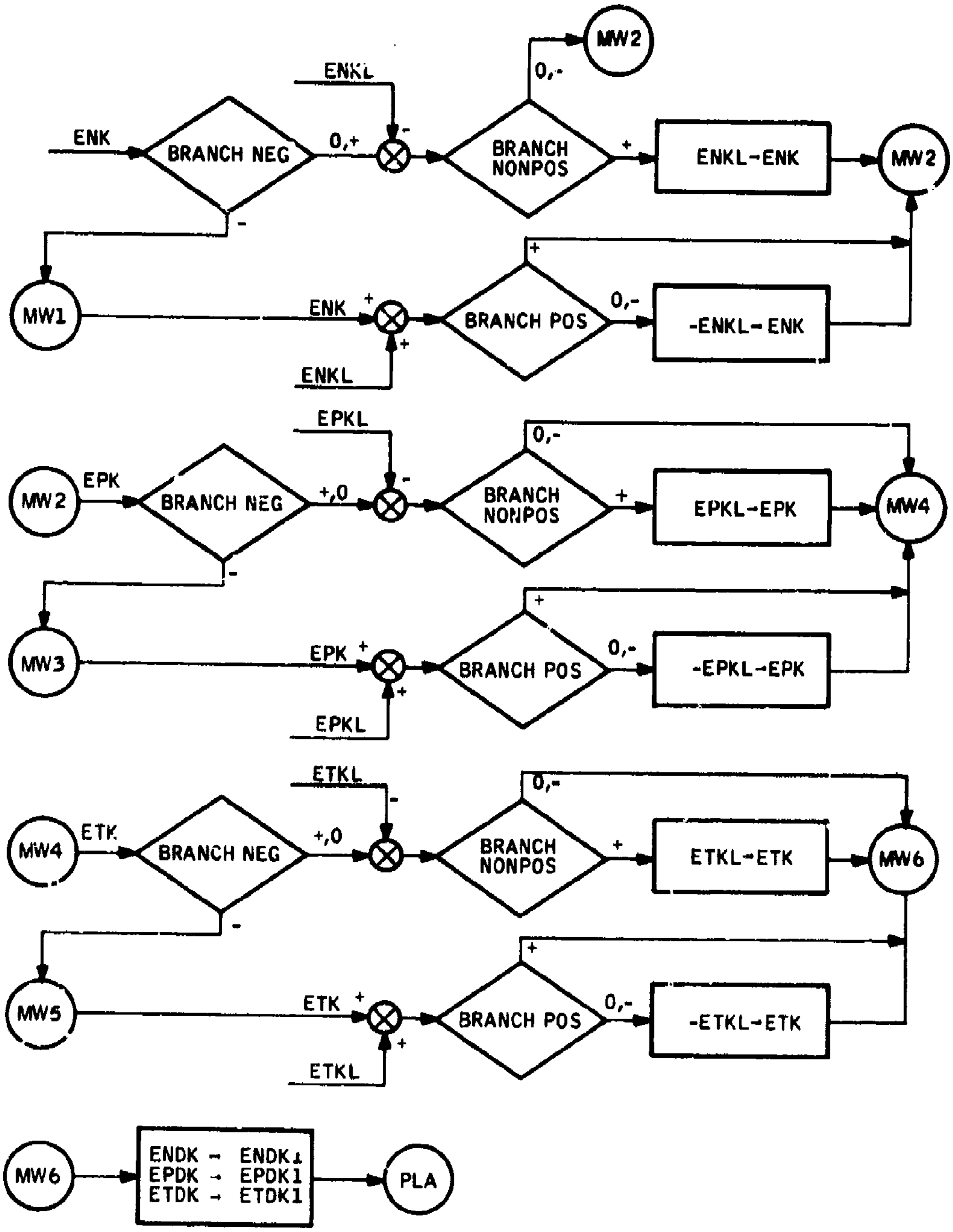

Figure B-6. Limiting Logic for Integral Speed and Pressure

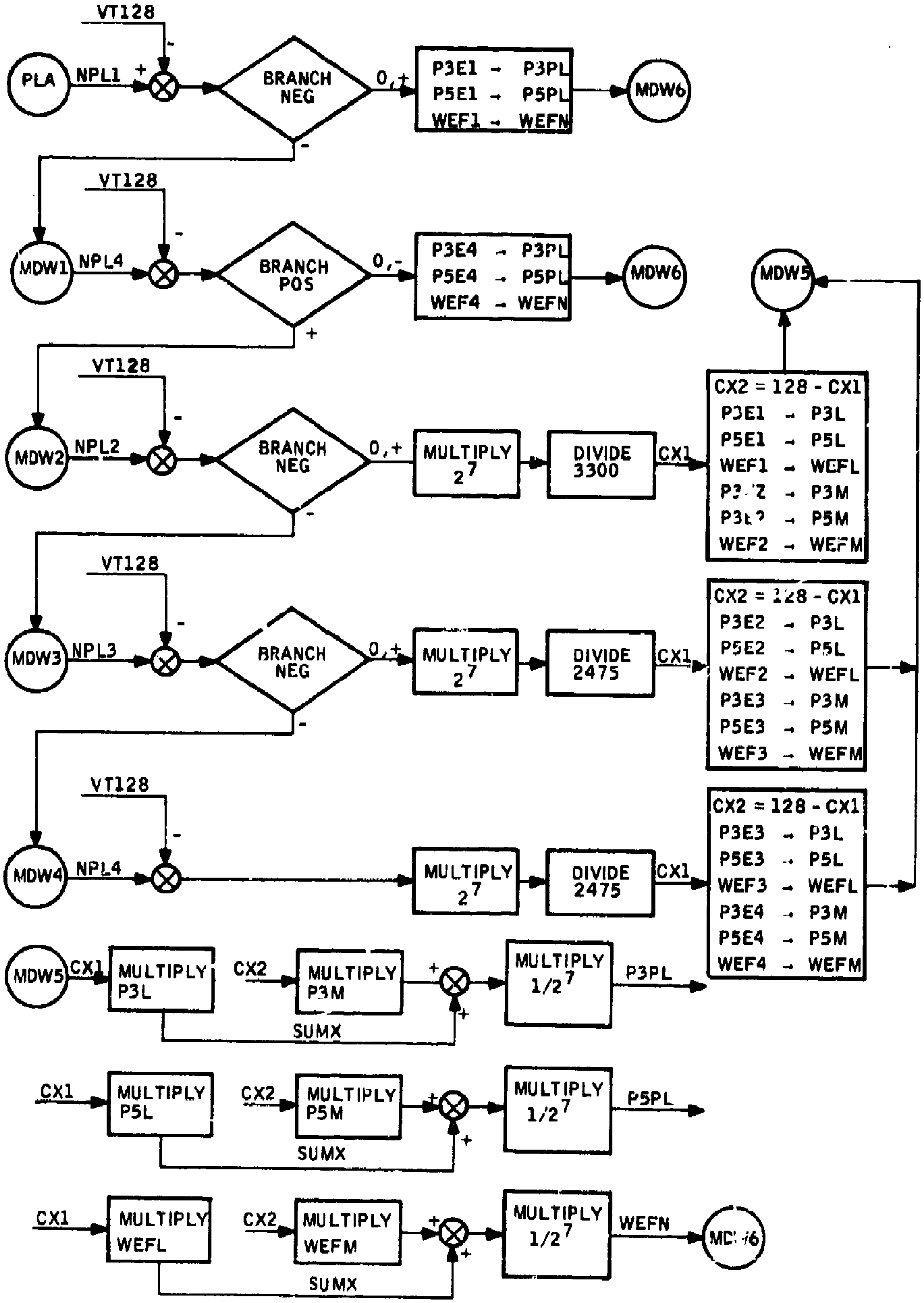

Figure B-7. Interpolation for PT3, PT5 and Fuel Request as a Function of Lower Lever

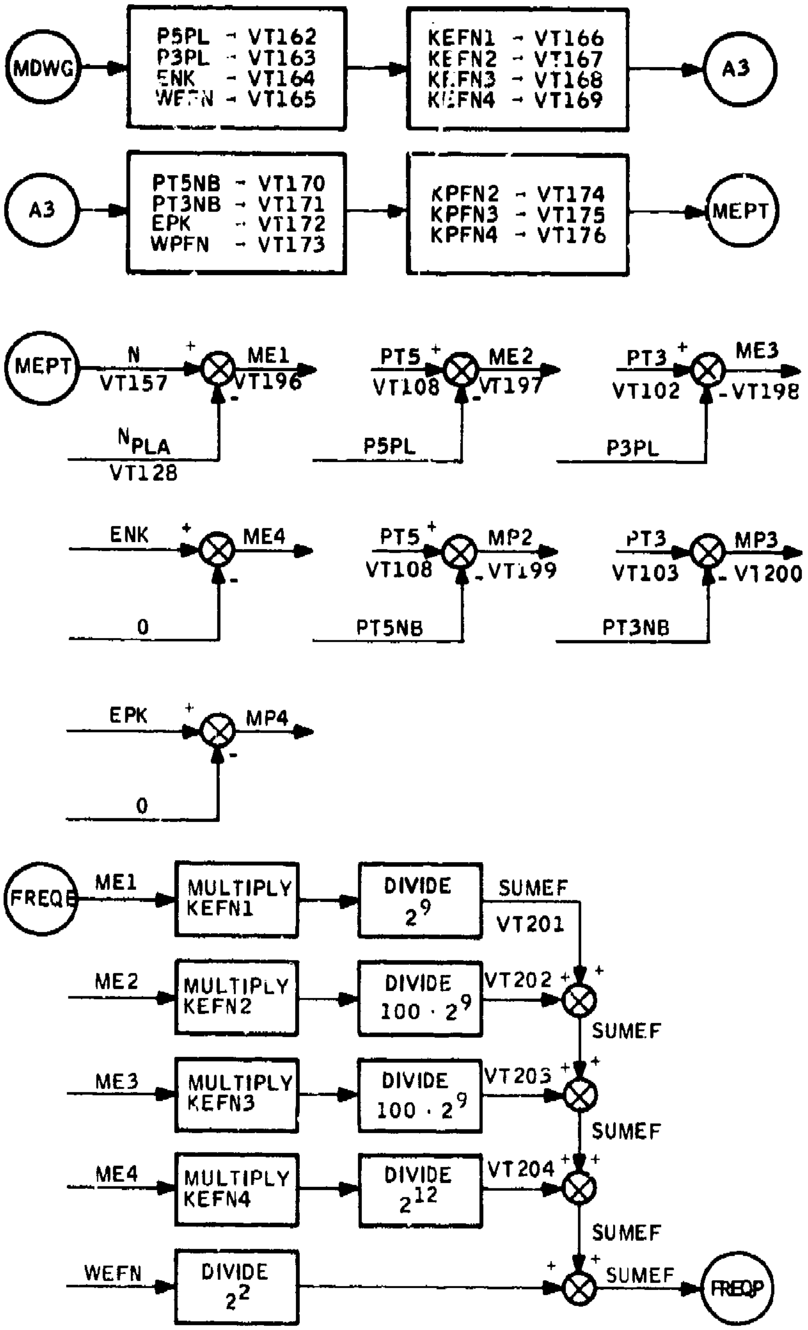

Figure B-8. Fuel Request Calculation

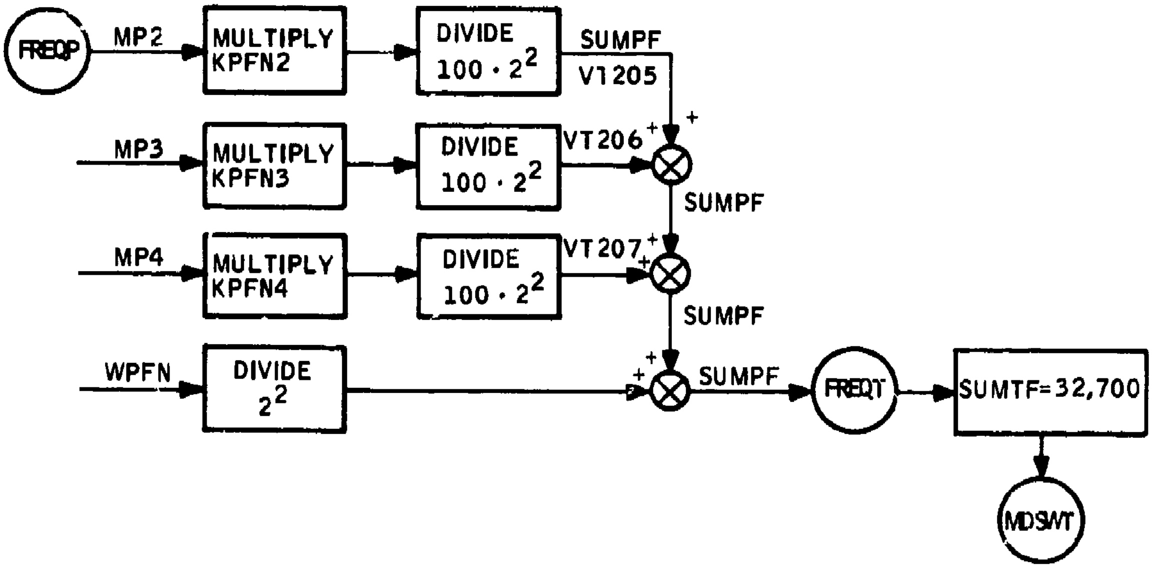

Figure B-8. Fuel Request Calculation (Concluded)

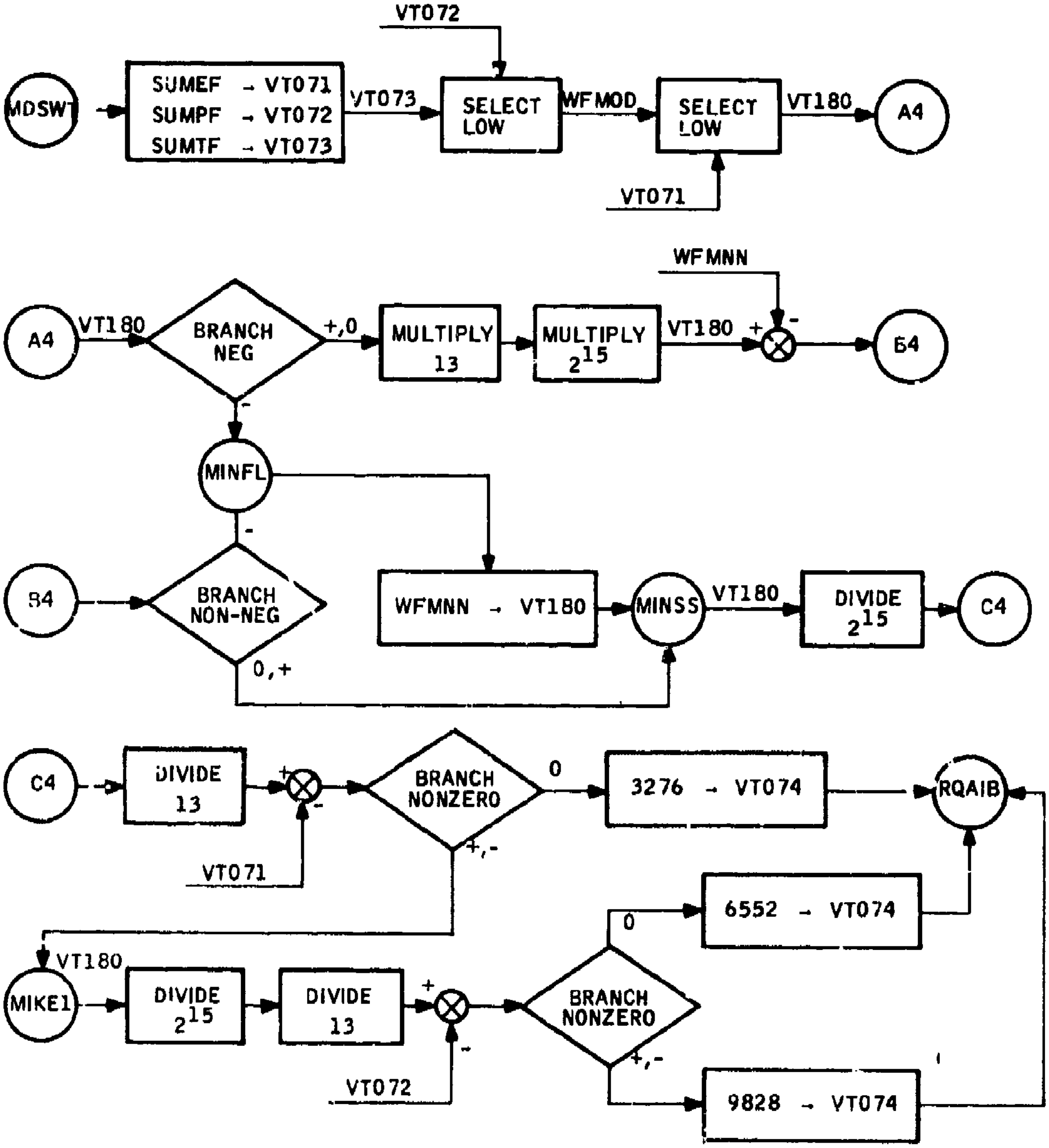

Figure B-9. Mode Select Logic

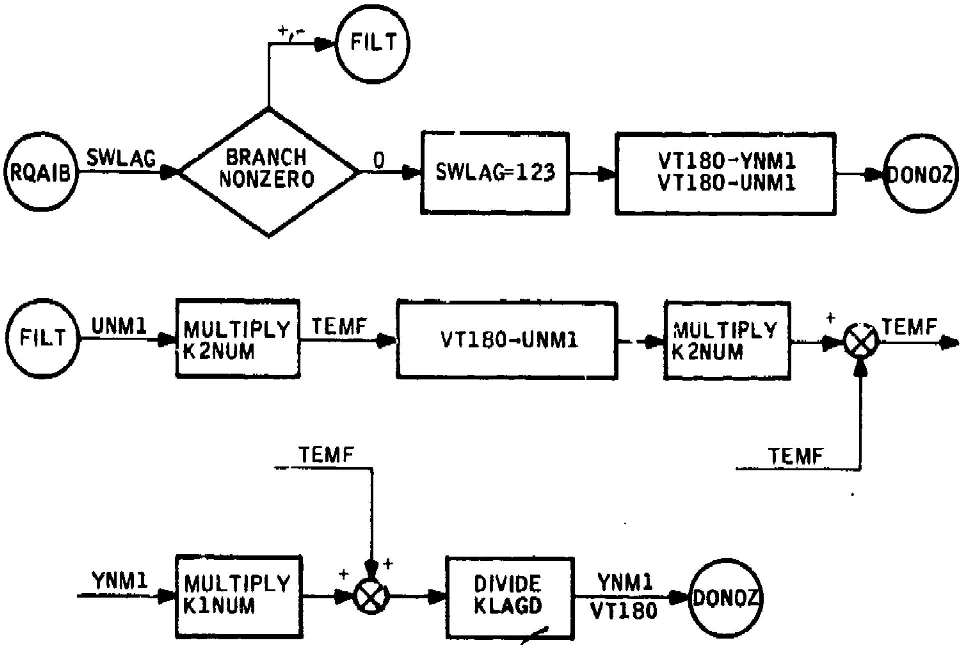

Figure B-10. Fuel Request Filter Logic

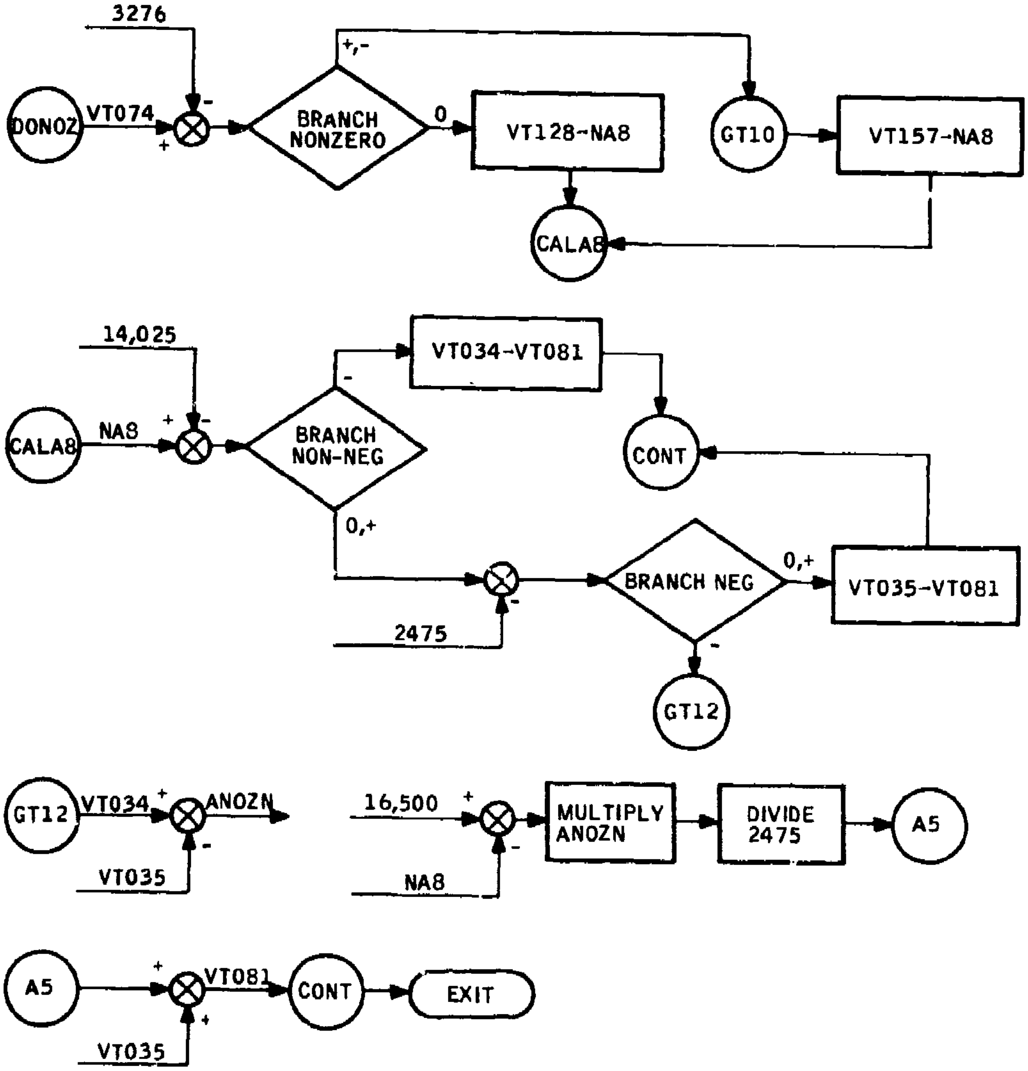

Figure B-11. Exhaust Nozzle Request Calculation

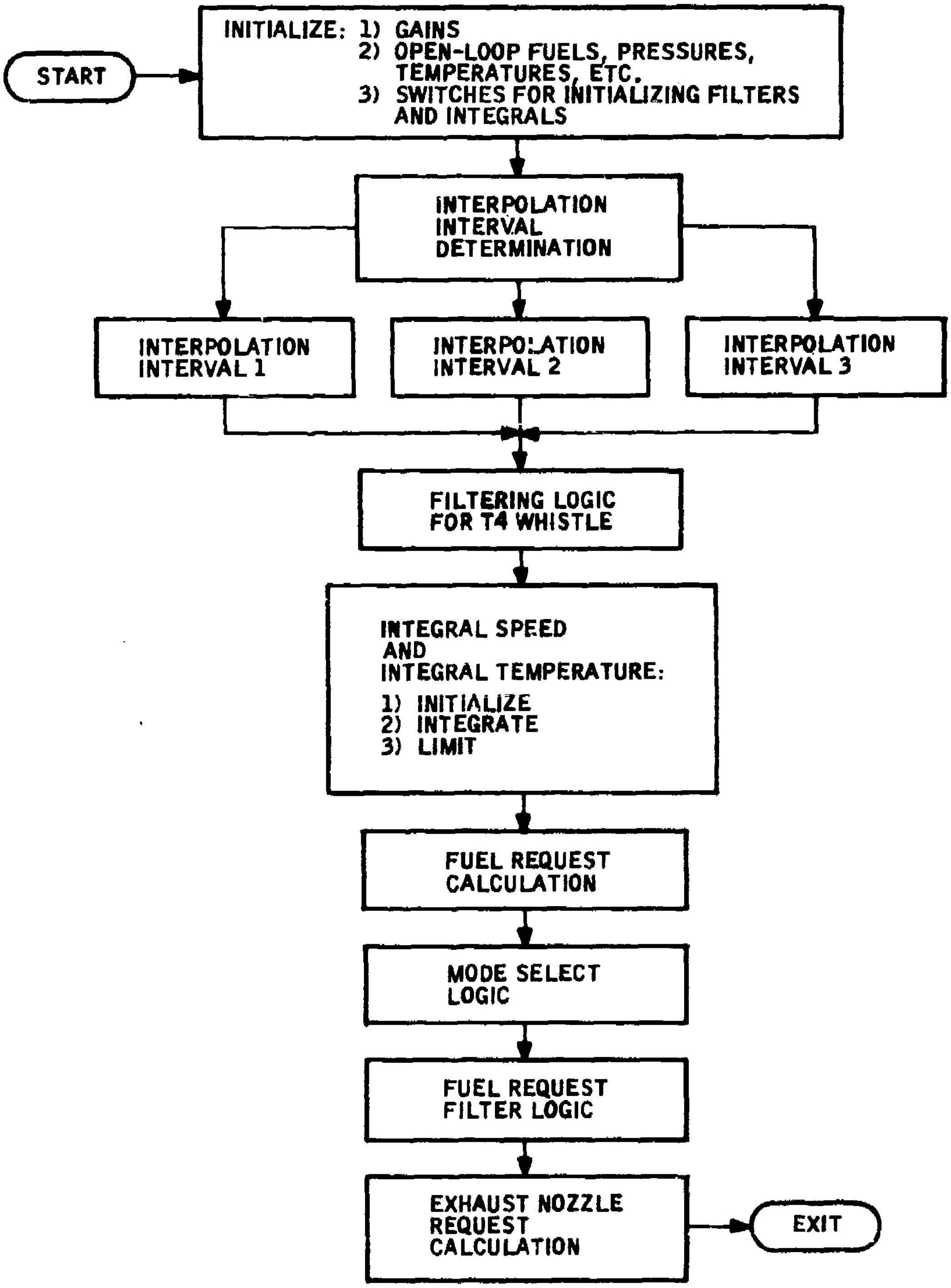

Figure B-12. Functional Flow Diagram Speed and Temperature Control Program

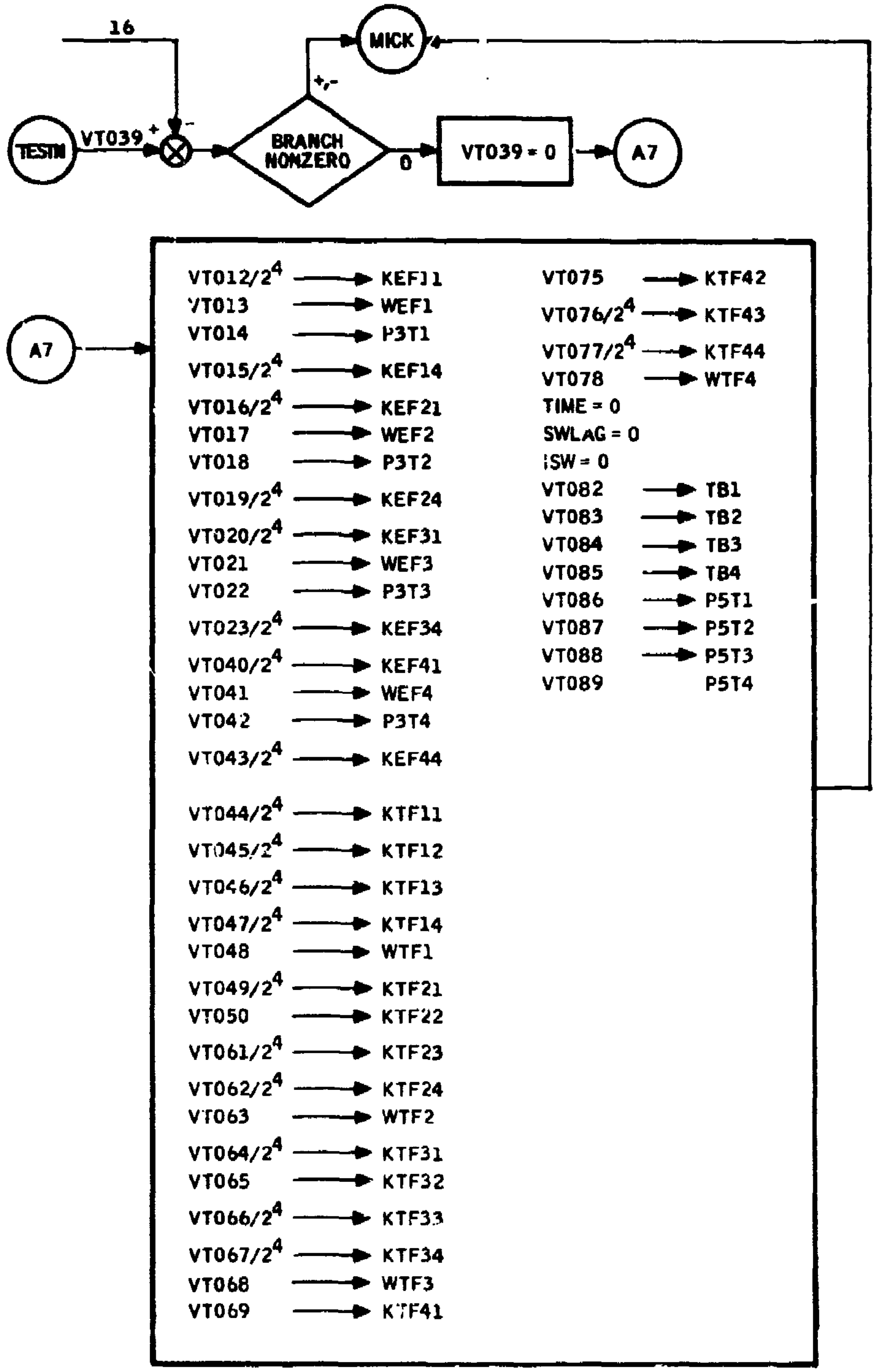

Figure B-13. Initialization Logic for Speed and Temperature Program

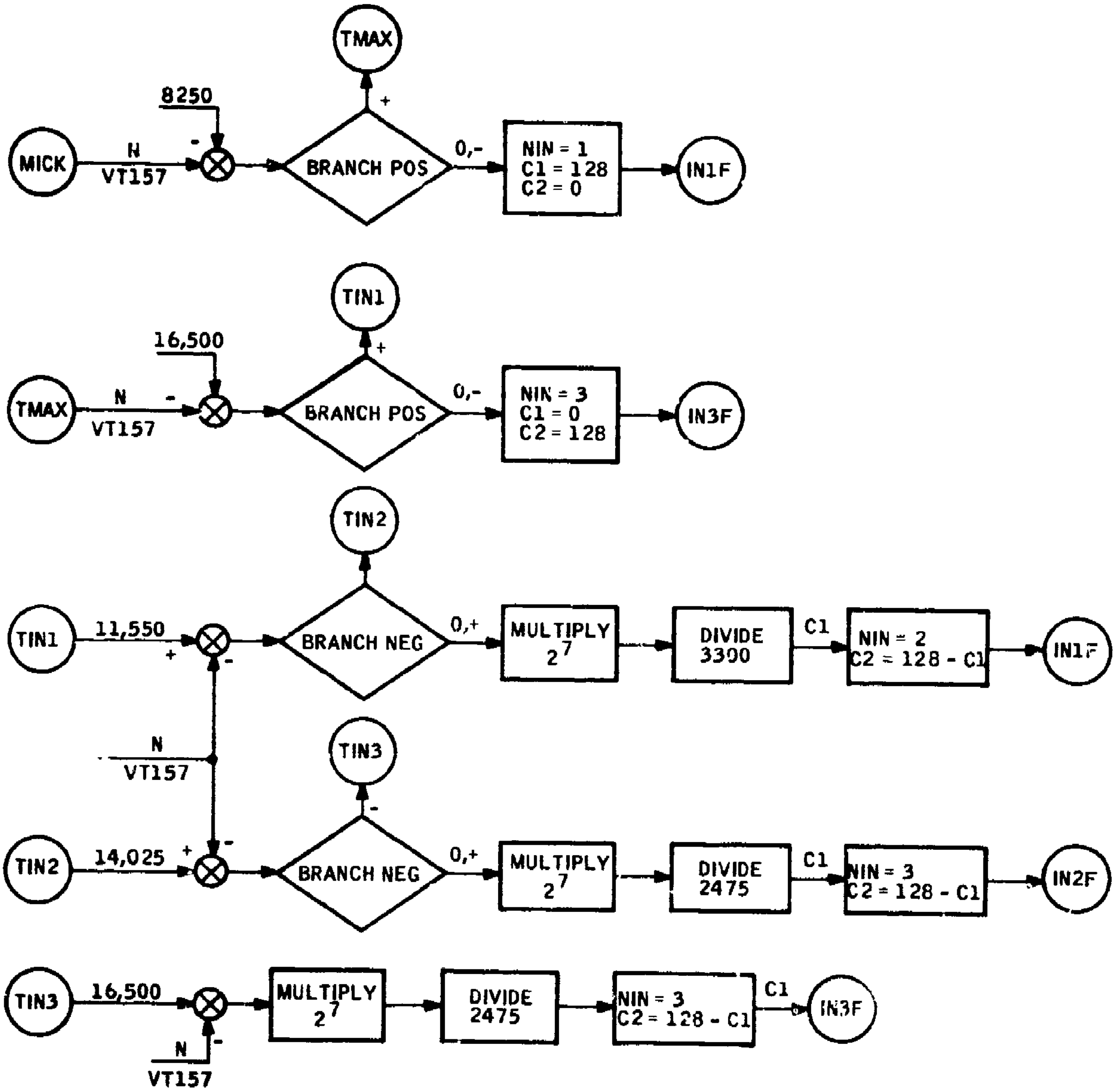

Figure B-14. Interval Determination

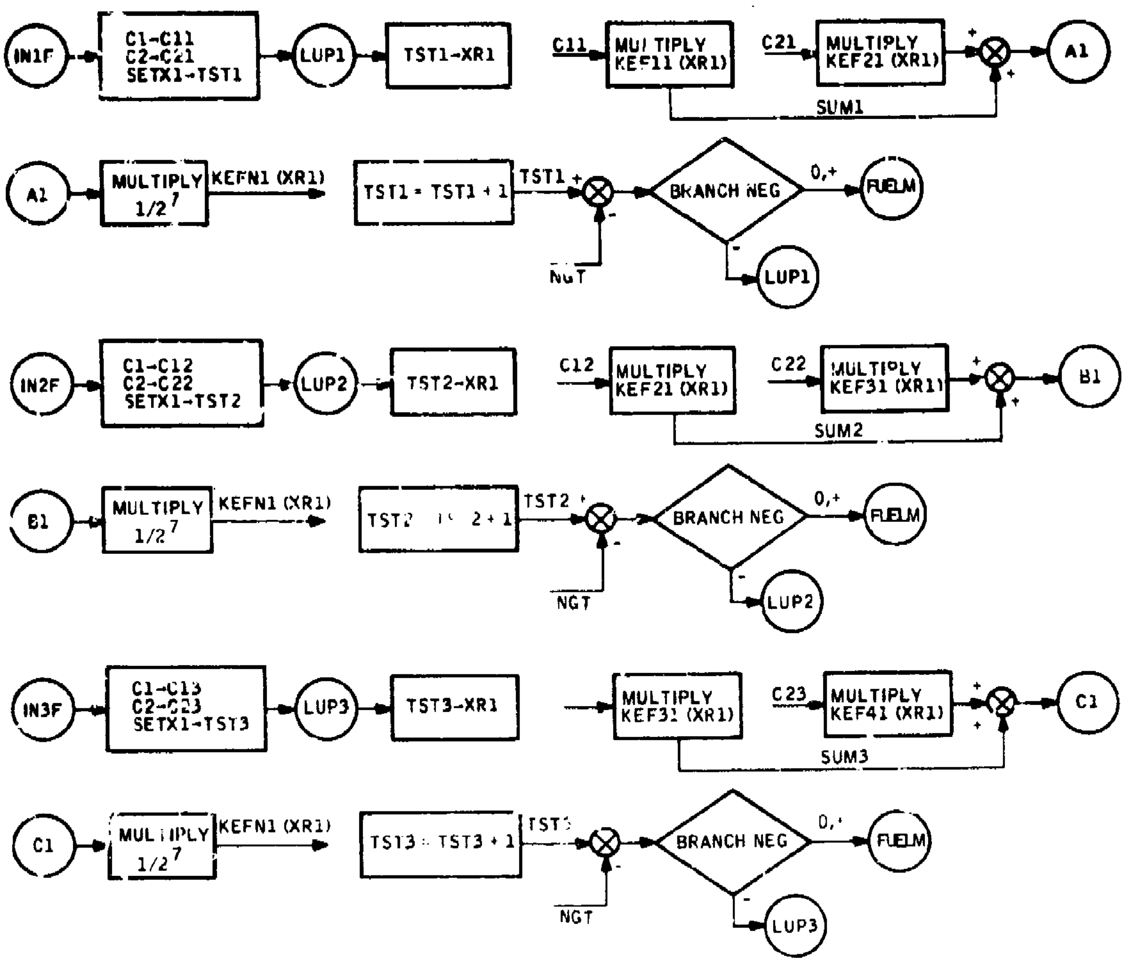

Figure B-15. Interpolation Logic

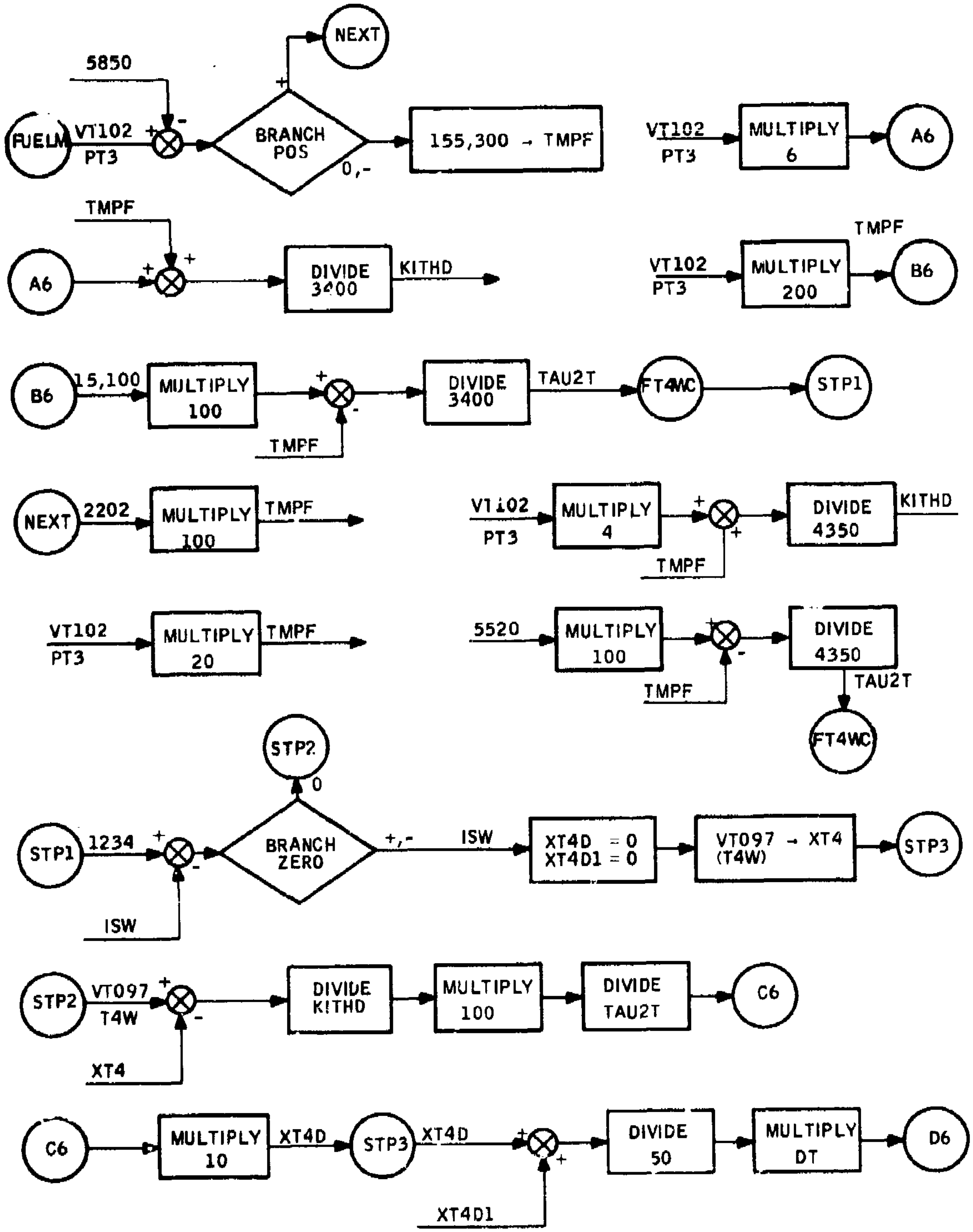

Figure B-16. Filter Logic for T4 Whistle Speed and Temperature Controller

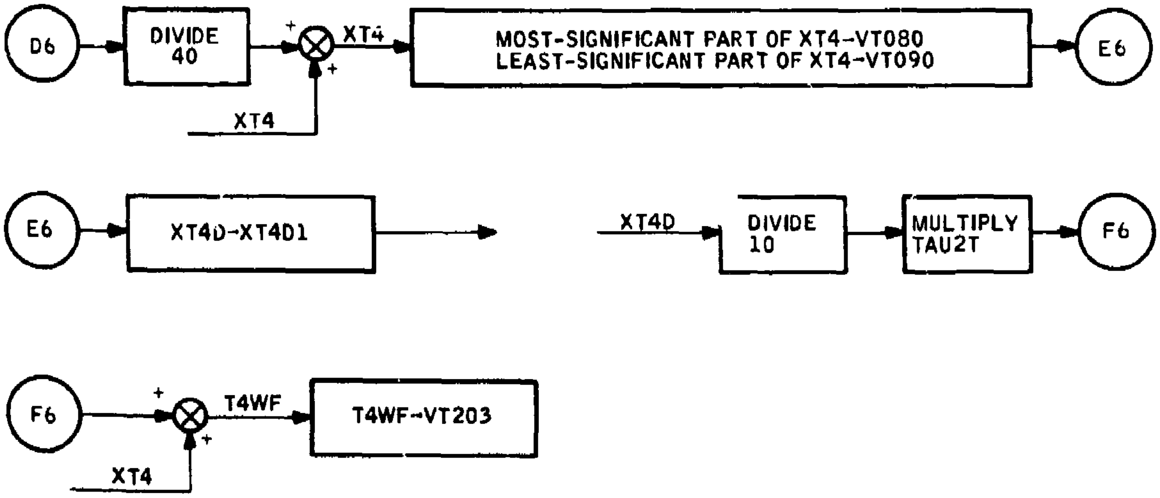

Figure B-16. Filter Logic for T4 Whistle Speed and Temperature Controller (Concluded)

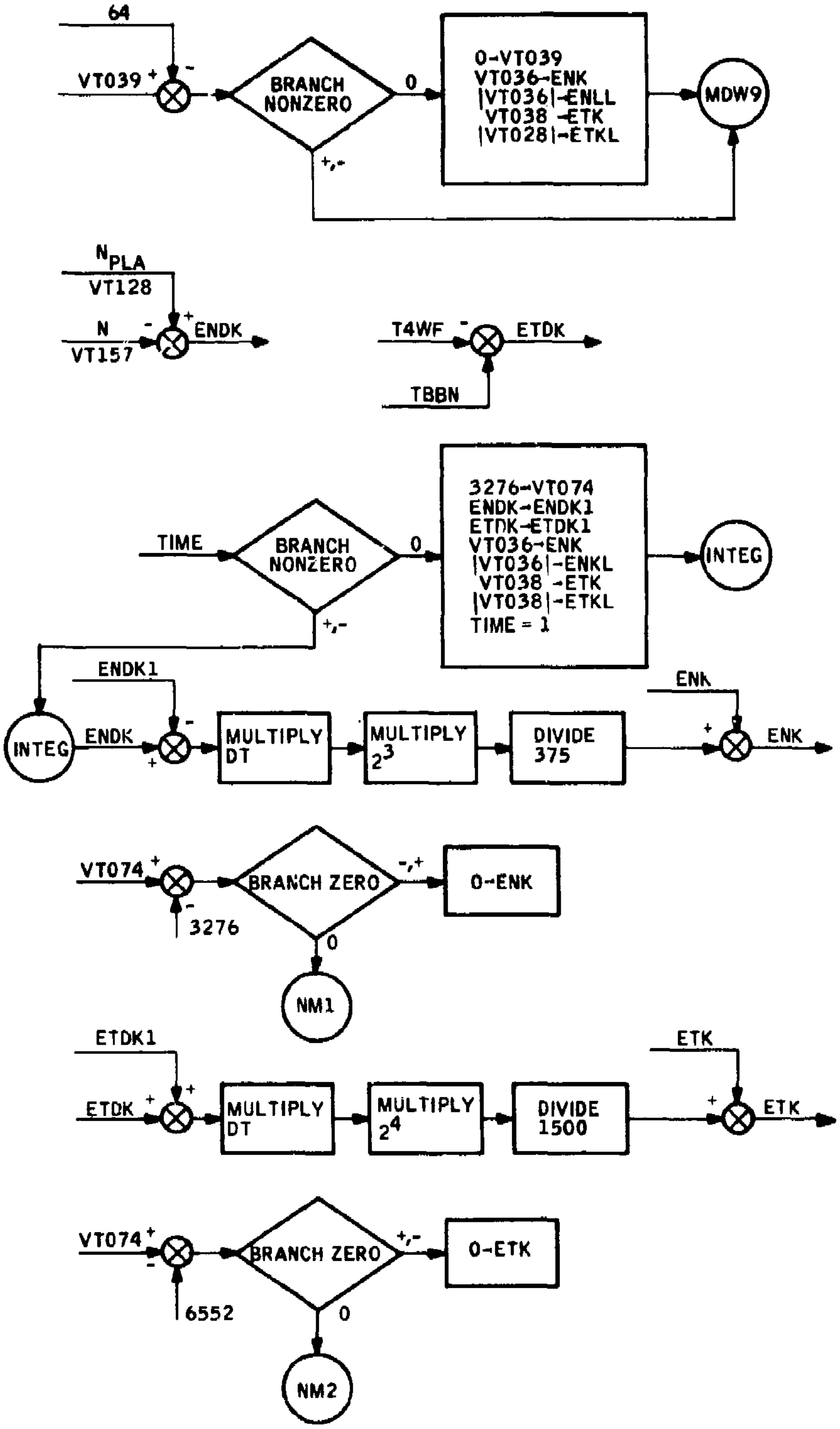

Figure B-17. Integral Speed and Integral Temperature

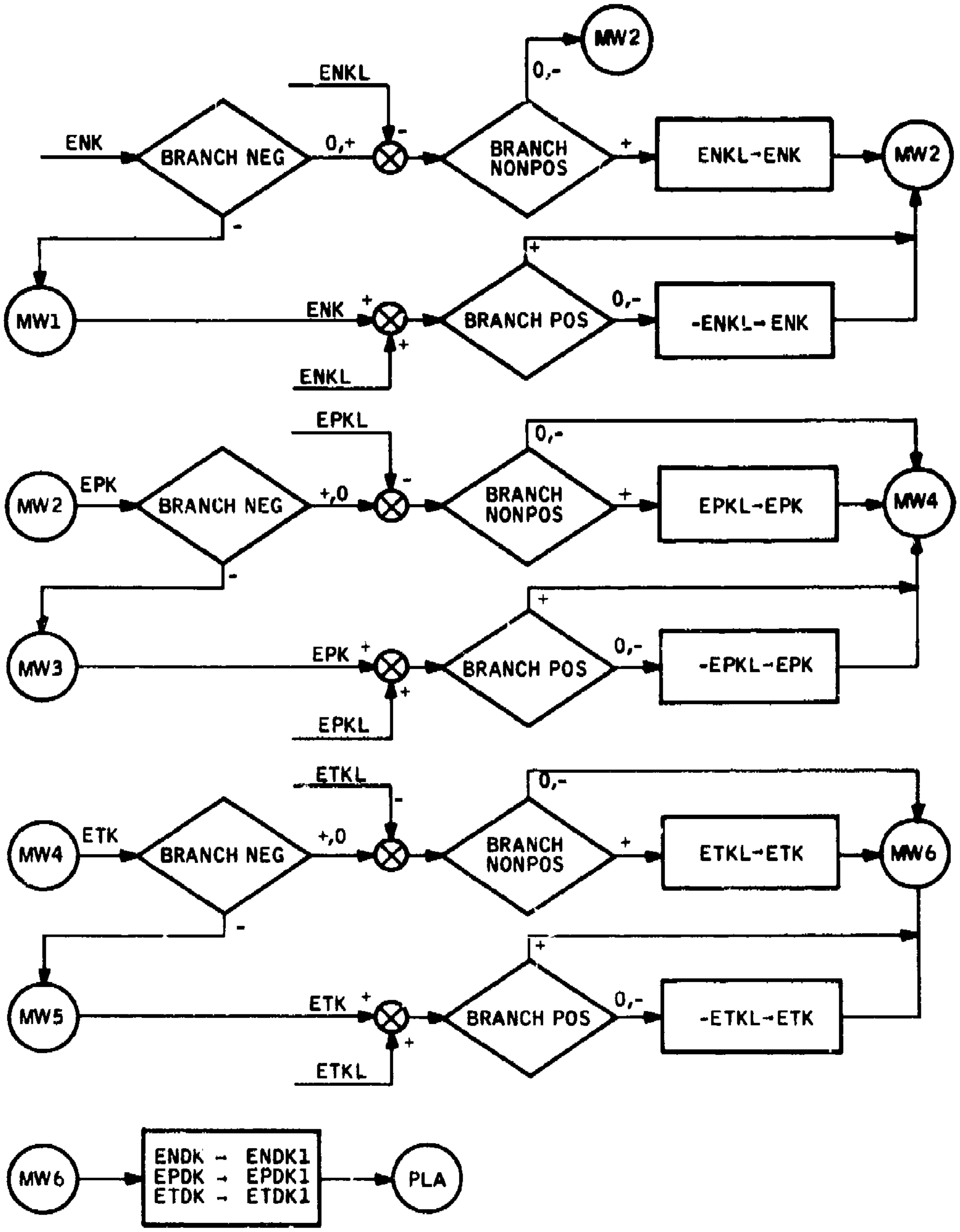

Figure B-18. Limiting Logic for Integral Speed and Integral Temperature

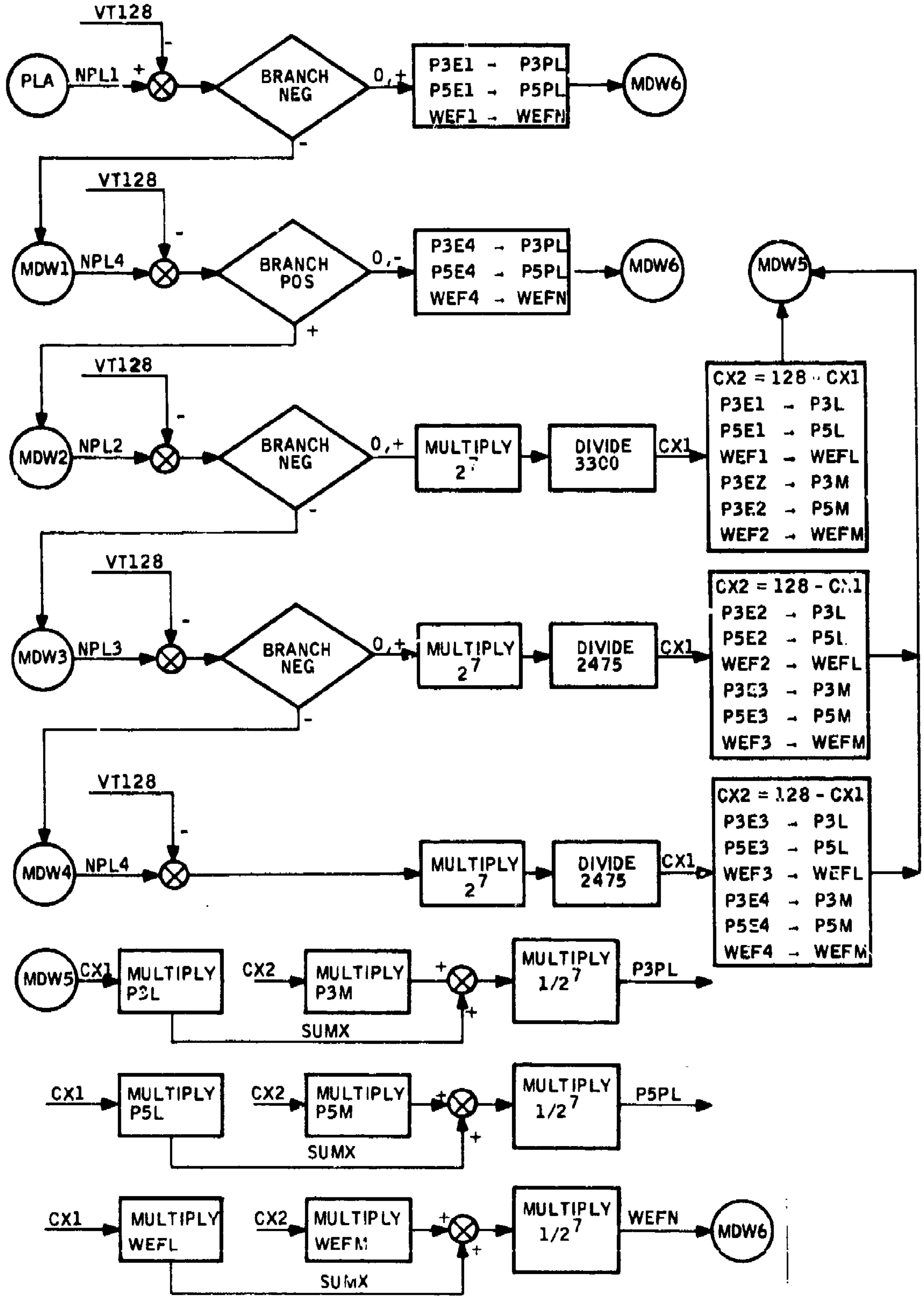

Figure B-19. Interpolation for PT3, PT5 and Fuel Request as a Function of Power Lever

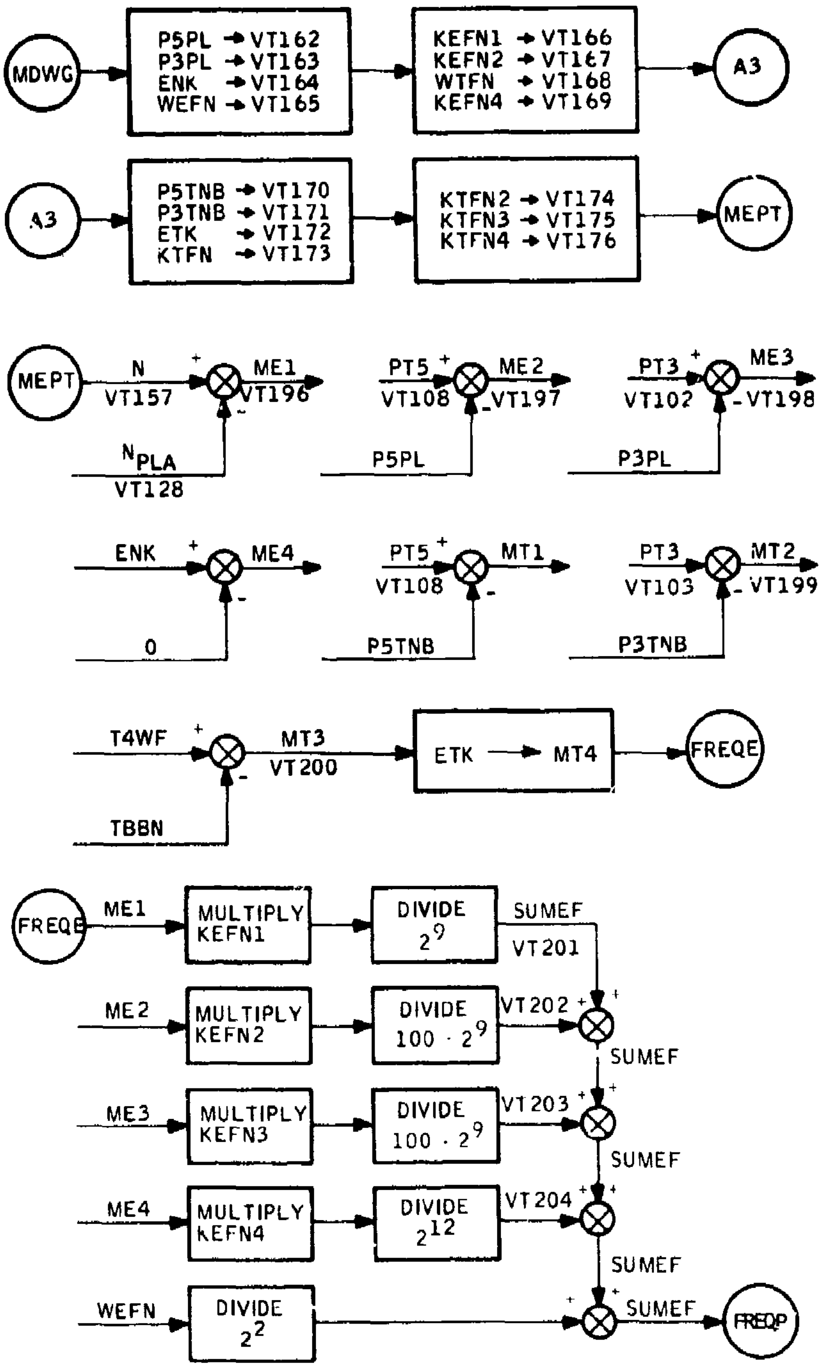

Figure B-20. Fuel Request Calculation

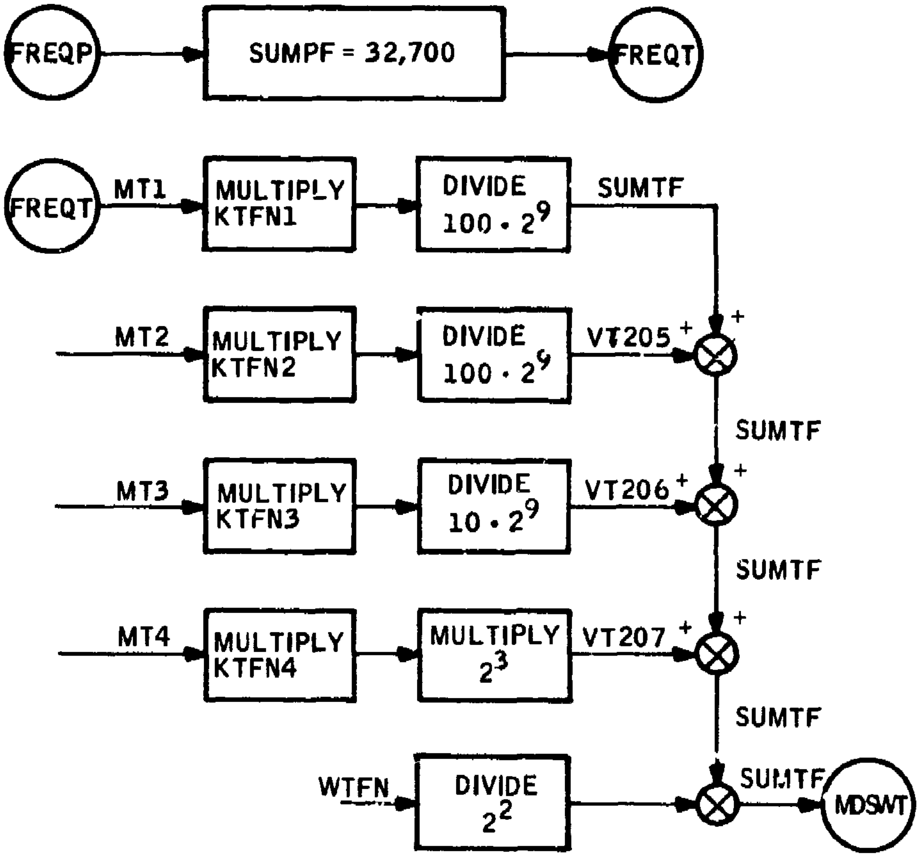

Figure B-20. Fuel Request Calculation (Concluded)

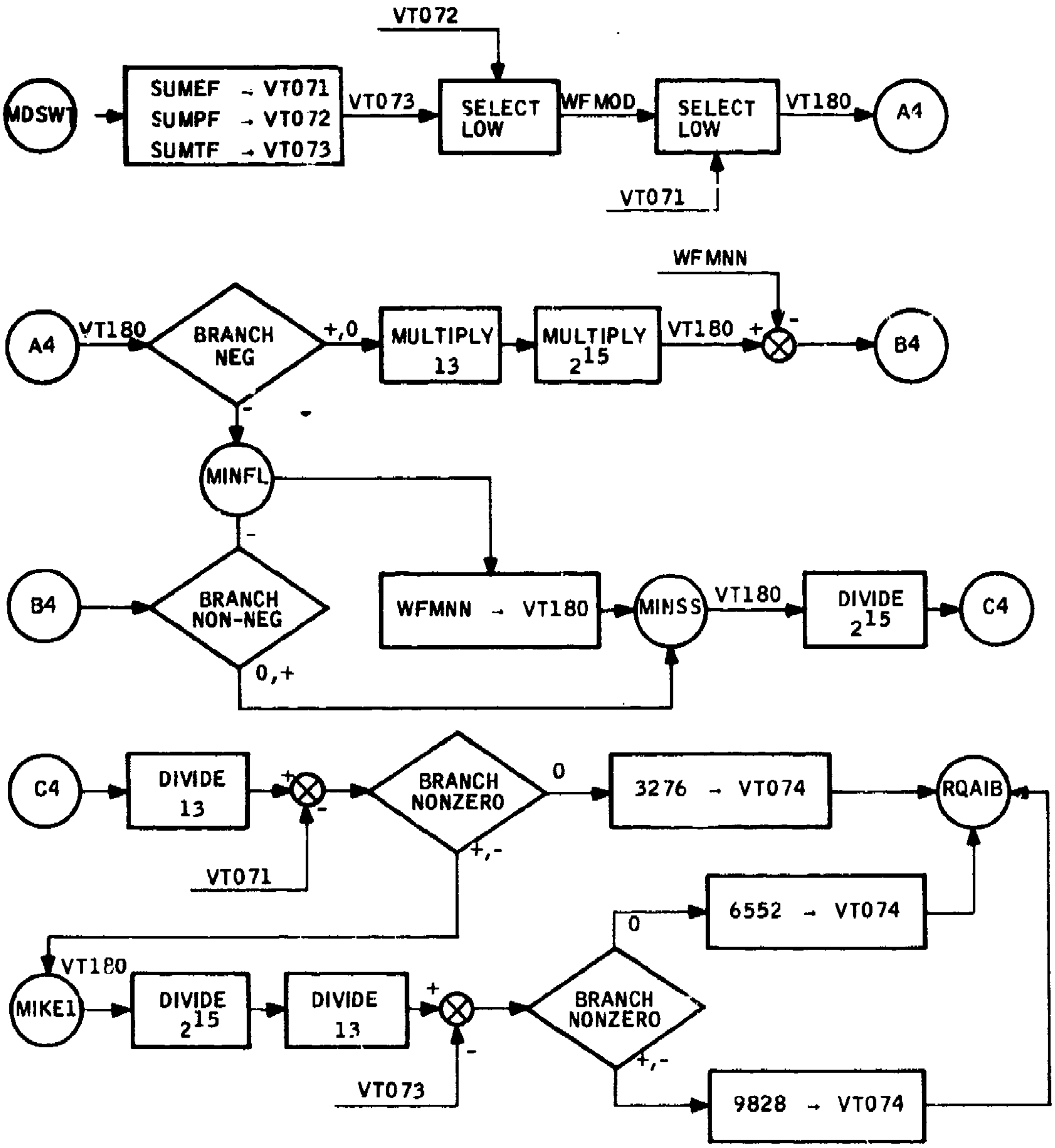

Figure B-21. Mode Select Logic

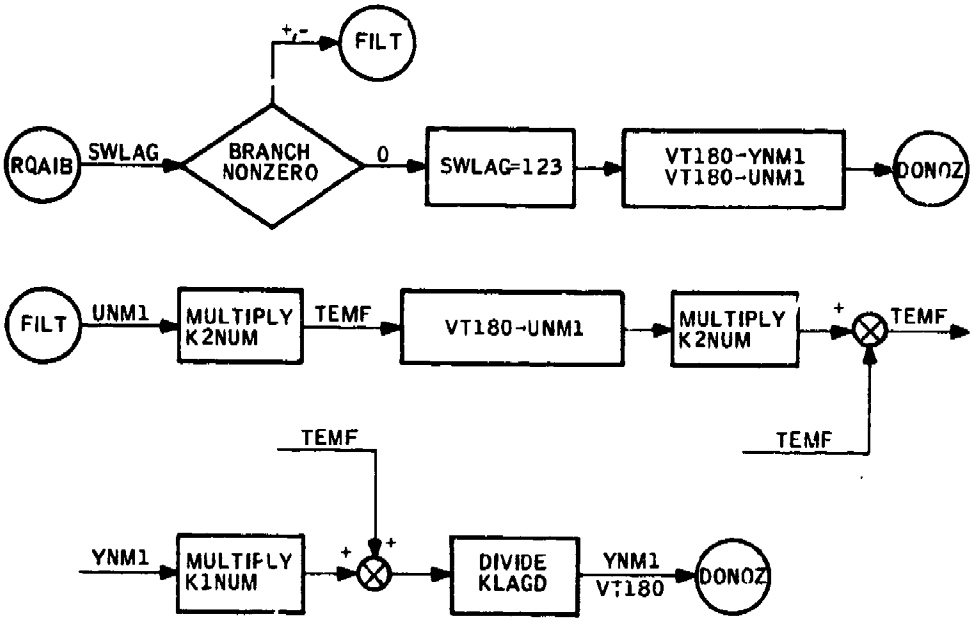

Figure B-22. Fuel Request Filter Logic

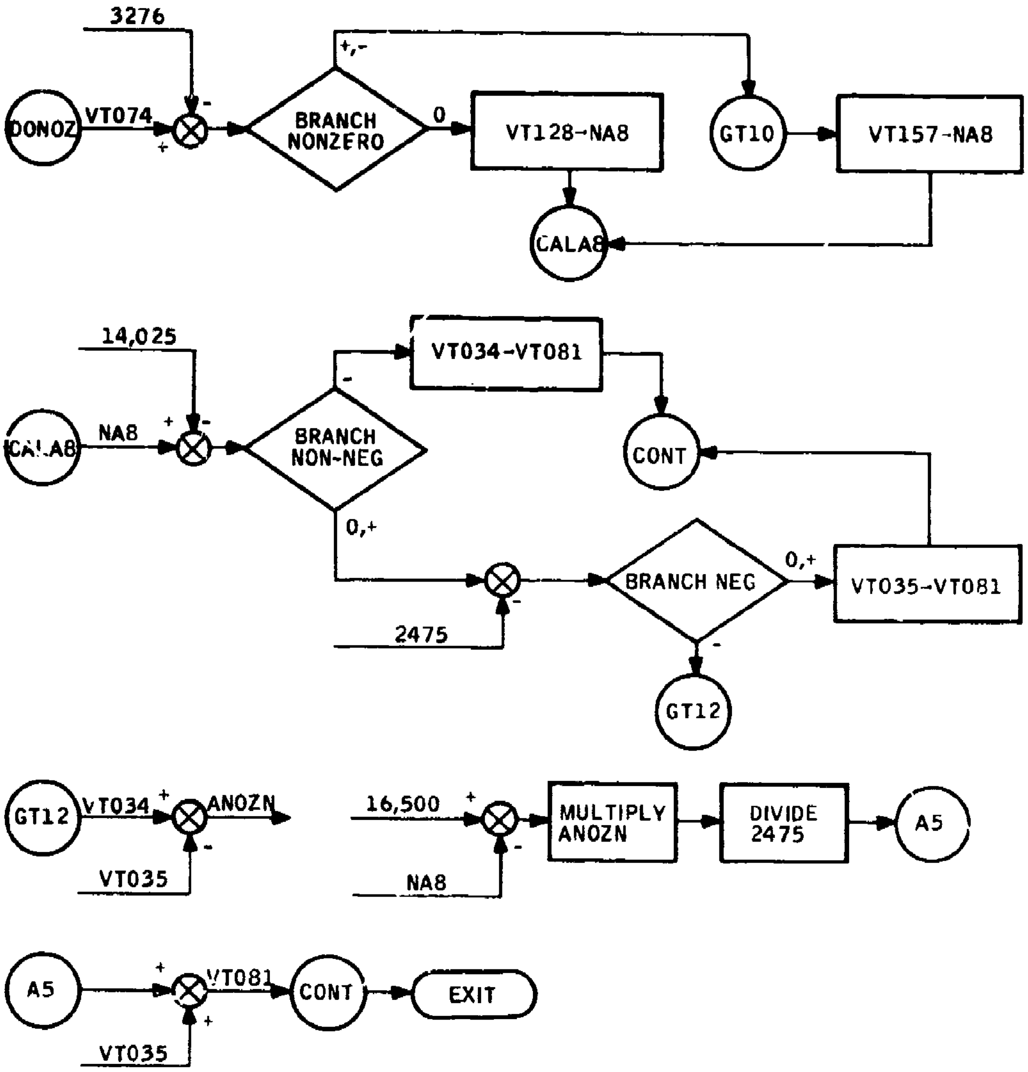

Figure B-23. Exhaust Nozzle Request Calculation

REFERENCES

B-1. Arnett, Samuel E., "Turbine Engine Control Synthesis," AFAPL-TR-74-113, Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, December 1974.

B-2. "IBM 1130/1800 Assembler-Language," GN34-0062, IBM Corporation, Systems Publications, Boca Raton, Florida, October 1971.

APPENDIX C
RATE MODELS FOR INTEGRAL CONTROL

In Sections III and IV of Volume I, a rate model (Reference 5) with integral control (Reference 6) is used in the linear quadratic synthesis (see Table 13 of Volume I).

The model is derived here. Spool speed notation is used although the results are applicable to pressure and temperature.

$$\dot{N} = aN + b\dot{e} + ce + \eta \qquad \text{(C-1)}$$

$$\dot{e} = dN + fP \qquad \text{(C-2)}$$

where

N = Model spool speed
e = Error
P = Model power lever
η = Disturbance

and a, b, c, d and f are constants to be determined to yield good response characteristics. Good response means that (1) N responds to P like a first-order plant, and (2) there is much integral control (sufficient to hold N against steady load disturbances η).

The model is derived in the following equations.

$$\frac{N}{P} = \frac{fb(s + c/b)}{s^2 - (a + bd)s - cd} \qquad \text{(C-3)}$$

$$s = \frac{(a + bd) \pm (a + bd)\sqrt{1 + \frac{4cd}{(a + bd)^2}}}{2} \qquad \text{(C-4)}$$

Choose (a + bd)/2 and λ (C-5, C-6)

Take

$$b = 1.0 \qquad \text{(C-7)}$$

$$c = -b\lambda(a + bd)/2 \qquad \text{(C-8)}$$

$$d = \frac{(a + bd)/2}{b\lambda} \qquad \text{(C-9)}$$

$$a = 2\left(\frac{a + bd}{2}\right) - bd \qquad \text{(C-10)}$$

Then

$$\frac{N}{P} = \frac{f\{s - \lambda(\frac{a + bd}{2})\}}{\{s - (\frac{a + bd}{2})\}^2} \qquad \text{(C-11)}$$

The transfer function and roots for Equations (C-1) and (C-2) are given by Equations (C-3) and (C-4). If the second term in the radical is equal to -1, two identical roots are obtained. This choice is made.

The quantity (a + bd)/2 is chosen equal to the desired pole position.

The value of λ = 0.75 yields an excellent approximation to first-order response.

Coefficient data are presented below. Equations (C-7), (C-8), (C-9), and (C-10) yield a, b, c and d;   is then selected by use of Equation (C-2) to yield the correct steady-state relationship between N and P.

Equation (C-11) presents the resulting transfer function. It is seen that λ positions the zero relative to the poles.

Coefficient data

Root	a	b	c	d
-2.0	-1.3333	+1.0	+1.5	-2.6667
-4.0	-2.6667	+1.0	+3.0	-5.3333
-10.0	-6.6667	+1.0	+7.5	-13.333

APPENDIX D
SIMPLE OPTIMIZATION

A derivation is presented of the algorithm used for control simplification (e.g., paragraph 3, page 131 through paragraph 2, page 134 of Volume I for simple speed control). This derivation is a slight modification of the original (pp. 7 - 19 of Reference D-1). The source program is listed in Appendix I of Reference D-1.

The algorithm has more capability than was used on the Turbine Engine Control Synthesis contract. On this contract, the algorithm was used to find the optimal (simple) gains at each of 12 operating conditions (four each for speed, pressure, and temperature). The algorithm could have been used to determine (say) the best single value of P3 gain (over the 12 operating conditions), while the other gains (N, EN, PT5, etc.) were optimized at each of the 12 operating conditions. In this case, the P3 gain is "fixed" and the N, EN, etc., gains are variable; hence, the Reference D-1 name for the algorithm: "Fixed-Plus-Variable Gain (FPVG)." For this turbine control synthesis, the fixed-gain feature was suppressed by working each operation condition separately.

BACKGROUND

The fixed-plus-variable (simple optimization) quadratic design procedure helps to solve a technical problem which confronts the major technical issues of engine control system design:

- High dimensionality
- Simplification
- Variability

High dimensionality is the reason the design procedure employs the theory of quadratics. This theory has been used before, on the B-52 LAMS (Ref. D-2), the C-5A LAMS (Ref. D-3), and the YF-12 LAMS (Ref. D-4). All of these programs involved design of flexure control, where the dynamic order of the models could be truncated to no less than 20 to 30 states.

Simplification arises because optimal quadratics, while promising solutions to dimensionality, yield control systems of substantial complexity. They demand feedbacks from all states to all controls. It is necessary to incorporate the constraints of measurement feasibility and control complexity into the fixed-plus-variable design procedure. These constraints were incorporated on the YF-12 LAMS program for single flight conditions and on the F-4 Lateral Axis program (Ref. D-5) for single and multiple flight conditions with fixed gains.

The third problem confronted is that of variability with respect to aerodynamic parameters, vehicle configuration, and mass distribution. Fixed gains were used on the F-4 Lateral-Axis program over an entire flight envelope, but the controller performance suffered because of it, even though the aircraft does not have flexure problems as do the B-52 and YF-12. On this contract (Ref. D-1), we use fixed-plus-variable gains to alleviate the problem of variability.

The formulation of the fixed-plus-variable quadratic design procedure, and the computational techniques used in the procedure, are discussed in this Appendix.

PROBLEM FORMULATION

The aircraft is represented at various points of the flight envelope and for various configurations and mass distributions by a collection of p frozen-point linear plants:

$$\frac{dx_i}{dt} = F_i x_i + G_{1i} u_i + G_{2i} \eta \qquad (D-1)$$

$$r_i = H_i x_i + D_i u_i \qquad i = 1, \ldots, p \qquad (D-2)$$

$$y_i = M_i x_i$$

Here x_i is the state vector for plant i which, for flexible aircraft, includes the following dynamics:

- Rigid-body states
- Actuator and servo states
- Significant flexure-mode states
- Low-frequency sensor states
- Model states (if state model-following is used)
- Küsner and Wagner states (associated with unsteady aerodynamics)
- Wind states (associated with atmospheric gust models).

The vector u_i represents control variables, η is a unity variance white noise vector, r_i is a vector of responses to be controlled (stresses and stress rates, accelerations at selected fuselage stations, model-following errors, control magnitudes and rates, etc.), and y_i is a vector of measurements (accelerometer outputs, gyro outputs, etc.). The matrices F_i (open-loop stability matrix), G_{1i} (control input matrix), G_{2i} (disturbance input matrix), H_i (response output matrix), D_i (control output matrix) and M_i (measurement matrix) are of appropriate order.

The above enumeration of components, vectors, and matrices is for an airplane for which Reference D-1 was concerned. Tables 40, 41, and 42 of Volume 1 list comparable items for turbine control synthesis.

We now look for a time-invariant controller of the form

$$u_i = K_i y_i \tag{D-3}$$

such that the following performance index is minimized:

$$J = \sum_{i=1}^{p} \alpha_i J_i \tag{D-4}$$

where

$$J_i = E\left\{\mathrm{Tr}\left[Q_i r_i r_i^T\right]\right\} \qquad i = 1, 2, \ldots, p \tag{D-5}$$

Here E $\{\cdot\}$ denotes expectation, Tr $[\cdot]$ is the trace operator, and $(\cdot)^T$ denotes transpose of $(\cdot)$.

The Q_i are quadratic weights for flight condition i which are selected through quadratic equivalence or by means of a few trial design iterations (the art of the design procedure). The α_i are flight-condition weights selected as needed. A few suggestions about how to select them appears later in the discussion of the specific examples. The cost functional J is a generalization of the standard quadratic performance index of a single plant and represents a weighted performance over the flight envelope.

For turbine control synthesis, an operating condition corresponds to a flight condition in aircraft control synthesis. An operating condition for turbine synthesis is given by: (1) equilibrium speed control at (2) sea level static at (3) 70-percent power lever setting.

The gains matrices K_i are in general of the form

$$K_i = K^1 + K_i^5 \qquad i = 1, \ldots, 1 \tag{D-6}$$

where K^1 is a matrix of fixed gains constant over the flight envelope, and K_i^5 are the matrices of variable gains which vary over the flight envelope. For a fixed-gain design, the K_i^5 are empty.

The necessary conditions for the optimality of the K_i are obtained from the Maximum Principle (Ref. D-6). Let us rewrite the performance index as

$$J = \sum_{i=1}^{p} \alpha_i \mathrm{Tr} \left\{ \left[H_i + D_i K_i M_i \right]^T Q_i \left[H_i + D_i K_i M_i \right] X_i \right\} \tag{D-7}$$

where the covariance matrices

$$X_i = E\left[x_i x_i^T \right], \qquad i = 1, \ldots, p \tag{D-8}$$

are solutions of the Lyapunov equations

$$0 = \left[F_i + G_{1i} K_i M_i \right] X_i + X_i \left[F_i + G_{1i} K_i M_i \right]^T, \quad i = 1, \ldots, p \tag{D-9}$$

Equations (D-7) and (D-9) are used to define a Hamiltonian:

$$\begin{aligned} H = \sum_{i=1}^{p} \Big\{ & \alpha_i \mathrm{Tr} \left[H_i + D_i K_i M_i \right]^T Q_i \left[H_i + D_i K_i M_i \right] X_i \\ & + \mathrm{Tr} S_i^T \Big[\left(F_i + G_{1i} K_i M_i \right) X_i + X_i \left(F_i + G_{1i} K_i M_i \right)^T \\ & + G_{2i} G_{2i}^T \Big] \Big\} \end{aligned} \tag{D-10}$$

H is differentiated with respect to the covariance matrices X_i, the adjoint matrices S_i, and with respect to all the nonconstrained gains of the matrices K^1 and K_i^5. The necessary conditions for optimality for this fixed-plus-variable-gain control are:

- $$\frac{\partial H}{\partial S_i} = \left(F_i + G_{1i}K_iM_i\right)X_i + X_i\left(F_i + G_{1i}K_iM_i\right)^T + G_{2i}G_{2i}^T = 0; \qquad i = 1, \ldots, p \tag{D-11}$$

- $$\frac{\partial H}{\partial X_i} = \left(F_i + G_{1i}K_iM_i\right)^T S_i + S_i\left(F_i + G_{1i}K_iM_i\right) + \alpha_i\left(H_i + D_iK_iM_i\right)^T Q_i\left(H_i + D_iK_iM_i\right) = 0; \tag{D-12}$$

  $i = 1, \ldots, p$

- $$\frac{\partial H}{\partial K^1_{\ell m}} = \left\{\sum_{i=1}^{p}\left[\alpha_i D_i^T Q_i\left(H_i + D_iK_iM_i\right) + G_{1i}^T S_i\right] X_i M_i^T\right\}_{\ell m} = 0 \tag{D-13}$$

for all nonconstrained elements $K^1_{\ell m}$ of fixed matrix K^1. (In the above, $\{A\}_{\ell m}$ denotes the ℓmth element of matrix A.)

- $$\frac{\partial H}{\partial K^5_{\ell mi}} = \left\{\left[\alpha_i D_i^T Q_i\left(H_i + D_iK_iM_i\right) + G_{1i}^T S_i\right] X_i M_i^T\right\}_{\ell m} = 0; \tag{D-14}$$

  $i = 1, \ldots, p$, for all nonconstrained elements $K^5_{\ell mi}$ of the variable-gain matrices K_i^5.

- $$K_i = K^1 + K_i^5; \qquad i = 1, \ldots, p \tag{D-15}$$

COMPUTATIONAL SOLUTION

The solutions of Equations (D-11) through (D-14) obviously do not exist in closed form. Thus, an iterative gradient search is necessary.

Equations (D-11) and (D-12) are solved quite readily for arbitrary gains matrices K_i through the use of computer algorithms that have been available for some time (such as explained in Ref. D-7). The solutions of these equations, the X_i and S_i, are used in the computation of the gradient components of Equations (D-13) and (D-14).

The development of the iterative gradient search algorithm to solve Equations (D-13) and (D-14) was the main effort of this contract.

A Newton-Raphson gradient technique was already developed and used for a fixed-gain design on the F-4 Lateral-Axis program (Ref. D-5); however, for the fixed-plus-variable quadratic design, the number of components in Equation (D-14) can be quite large, causing insurmountable computational difficulties with that technique, because it requires a matrix of second partial derivatives.

Computing a matrix of second partial derivatives requires solving a Lyapunov equation for each fixed gain and for each variable gain for each flight condition.

Other problems encountered with the Newton-Raphson gradient technique can be solved with a variable stepsize.

In view of the problems with this gradient technique, we decided to go with the straight gradient search, computing no second partial derivatives, and using a variable stepsize. We did, however, use some ideas of the predictor corrector scheme in implementing the gradient search. This resulted in what we call the incremental gradient.

INCREMENTAL GRADIENT

Let $K_i(\lambda)$ be the gain matrix for plant i defined as

$$K_i(\lambda) = K^1(\lambda) + K_i^5(\lambda) + \lambda K_i^2; \; 0 \le \lambda \le 1; \; i = 1, \ldots, p \tag{D-16}$$

and let

$$K_i(1) = K^1(1) + K_i^5(1) + K_i^2 \tag{D-17}$$

be the optimal quadratic gains for plant i on the measurements y_i found through the solution of the Riccati Differential Equation,* and let

$$K_i(0) = K^1(0) + K_i^5(0) = K^1 + K_i^5 = K_i \tag{D-18}$$

be the final gains matrix for plant i. The expression λ is a scalar parameter; K^1 and K_i^5 are found by using the incremental gradient procedure which starts with initial gains $K^1(1)$ and $K_i^5(1)$; K_i^2 are simply the difference between the optimal gains $K_i(1)$ and initial gains $K^1(1) + K_i^5(1)$.

In terms of Equation (D-16), the necessary conditions for optimality of K^1 and K_i^5 are that

$$\left. \frac{\partial J[K_i(\lambda)]}{\partial K^1} \right|_{\lambda = 0} = 0 \tag{D-19}$$

and

$$\left. \frac{\partial J[K_i(\lambda)]}{\partial K_i^5} \right|_{\lambda = 0} = 0 \tag{D-20}$$

---

*This requires that the M_i be square and nonsingular. They can be made so by adding direct measurements of states not necessarily measurable.

In fact, if we start with $\lambda = 1$ and satisfy Equations (D-19) and (D-20) for all λ in $[0, 1]$, Equations (D-19) and (D-20) are certainly true for $\lambda = 0$. At the same time, we are ensuring with high probability that a global minimum of $J(K^1 + K_i^5)$ is reached because we are starting in the "deepest valley of J" and forcing λ to zero along the trajectory $\{K^1(\lambda), K_i^5(\lambda), K_i^2; 1 \geq \lambda \geq 0\}$. Since we are then "on the walls of the deepest valley," along with the knowledge of $J[K_i(1)]$ and $J[K^1(0) + K_i^5(0)]$, we can terminate the search for the global minimum.

Stein and Henke (Ref. D-5) used the Implicit Function Theorem which defined K^1 (in their case it was fixed gains only) from the solution of the differential equation

$$\frac{dK^1(\lambda)}{d\lambda} = -\left[\frac{\partial^2 J(K^1 + \lambda K^2)}{\partial K^1 \partial K^{1T}}\right]^{-1} \frac{\partial^2 J(K^1 + \lambda K^2)}{\partial K^1 \partial \lambda} \qquad \text{(D-21)}^*$$

by starting with the known terminal condition $K = K^1 + K^2$ for $\lambda = 1$ and integrating it backward toward $\lambda = 0$. The method of numerical integration used was that which used an Adams-Moulton Predictor and a Newton-Raphson Corrector to step λ from 1 to 0.

The main problem with this procedure is that the evaluation of the second partial derivatives is very costly, and gets out of hand when the variable gains are included. Another problem is that the predictor or corrector steps are sometimes too big and can cause one plant or another to go unstable. The incremental gradient procedure alleviates this problem by approximating the second partial derivatives (discussed later), using a simple linear predictor, and a variable step size on the corrector. More than one gradient direction per prediction step and the variable gradient step size more than make up for the approximation and prediction simplification.

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*K, K^1 and K^2 must be stacked up as column vectors for this equation to make sense. This is assumed.

The incremental gradient procedure is summarized in Figure D-1 for a single-plant problem. Here, λ is stepped to zero in five steps. There are only two gains, K^1 and K^2. We wish to eliminate K^2. However, if we eliminate K^2 without changing K^1, the system is unstable, and a gradient direction cannot be found. (This frequently happens in real-world problems.)

The first prediction step is in the K^2 direction only. (In practice, this never presented a problem.) A correction is made with a Newton-Raphson gradient search using approximate second partial derivatives and a variable step size determined from a parabolic fit. The subsequent predictions are extrapolations from the initial point through the last correction points. The process continues for each step in λ.

The predicted gains are

$$K_p^{\ 1}(\lambda_{j+1}) = K_c^{\ 1}(\lambda_j) + \left[K_c^{\ 1}(\lambda_j) - K_c^{\ 1}(\lambda_{j-1})\right] \tag{D-22}$$

and

$$K_{ip}^{\ 5}(\lambda_{j+1}) = K_{ic}^{\ 5}(\lambda_j) + \left[K_{ic}^{\ 5}(\lambda_j) - K_{ic}^{\ 5}(\lambda_{j-1})\right]; \qquad i = 1, \ldots, p \tag{D-23}$$

where λ_j is the value of λ on the j^{th} predictor step, and the initial prediction is zero. The "c" and "p" denote "corrected" and "predicted." The predicted gains are the initial gains for the gradient search. The corrected gains result from the gradient search.

For the variable step size for the gradient search, the performance index J is computed for three step sizes -- 0, ϵ_1, and $2\epsilon_1$ -- and fit to a parabola

$$J(\epsilon) = J(0) + A\epsilon + B\epsilon^2 \tag{D-24}$$

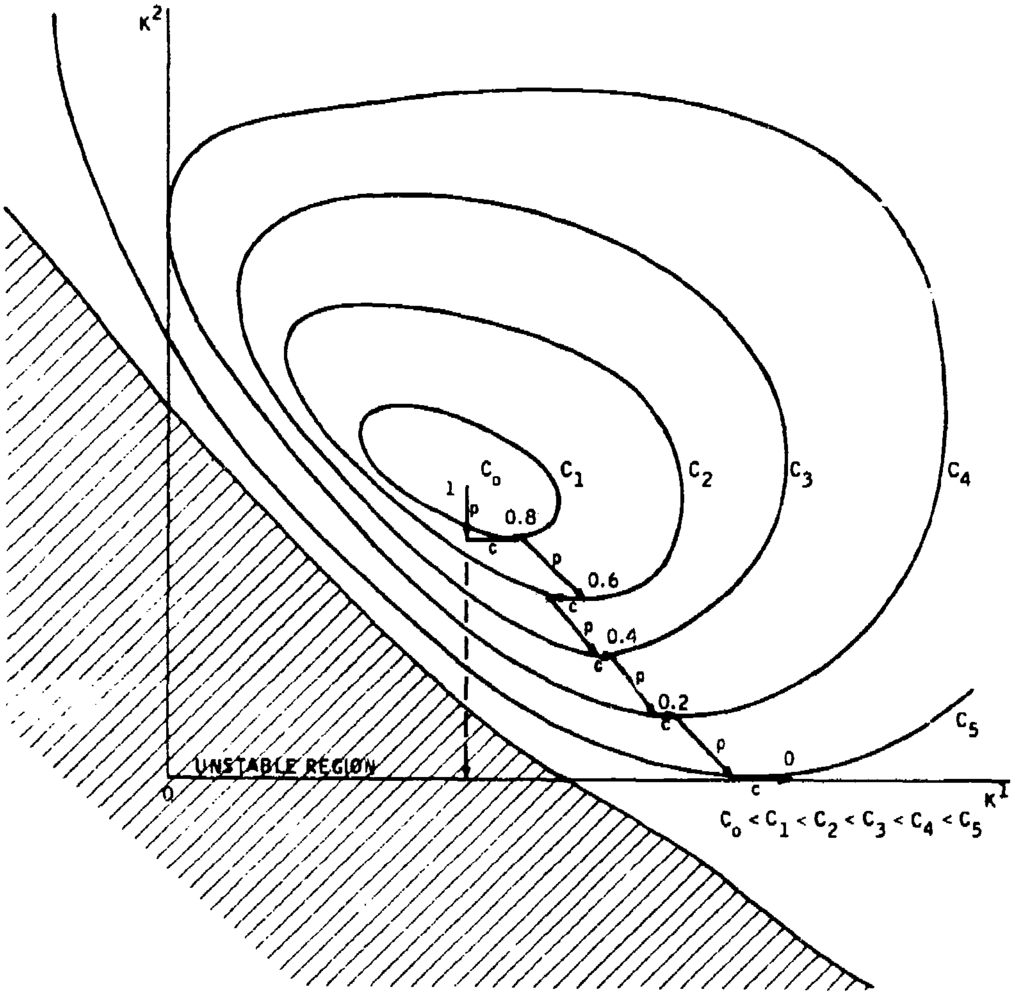

Figure D-1. Incremental Gradient Path

A minimum at

$$\epsilon = -\frac{A}{2B} \tag{D-25}$$

is computed, where A and B are a function of the performances $J(0)$, $J(\epsilon_1)$, $J(2\epsilon_1)$ and ϵ_1. The logic for halving and doubling the step size for computing these performances is discussed in Appendix I of Reference D-1.

THE GRADIENT TRANSFORMATION

An aircraft example presented a situation that exists on many minimization problems. That is, the performance contours are extremely ellipsoidal. This causes a straight gradient search to converge very slowly or not even noticeably. The ideal situation is to have the performance contours be spheroidal. Then the gradient direction would be right to the center of the spheroid. This is shown in Figure D-2.

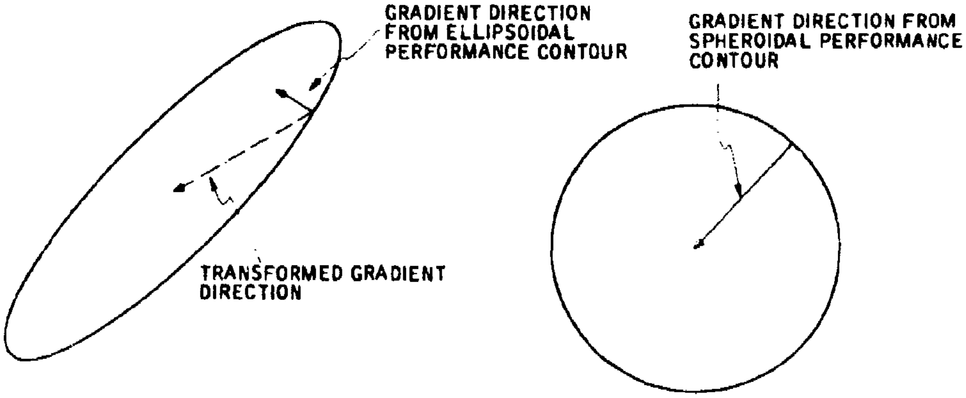

Figure D-2. Comparison of Gradient Directions for Two Performance Contours

If a performance contour is extremely ellipsoidal, the effect of a spheroidal contour can be realized by transforming the gradient vector. This effect is also shown in Figure D-2.

For a problem with a second-order minimum, the ideal transformation is that provided by the Newton-Raphson gradient direction, that is, the inverse of the matrix of second partial derivatives. However, as stated before, the evaluation of the second partial derivatives is very costly. Thus, an approximation was used that works extremely well.

An element in the matrix of second partial derivatives may be written as (assuming for the moment only a fixed-gains matrix for a single flight condition stacked up as vectors):

$$\frac{\partial^2 J(K)}{\partial K_{ij}{}^1 \partial K_{\ell m}{}^1} = 2R_{j\ell} M_j X M_m{}^T + 2 \sum_{k=1}^{n} \left[(K^T R)_{ki} + (SG_1)_{ki} \right] M_j \left(\frac{\partial X}{\partial K_{\ell m}{}^1} \right)_k$$

$$+ 2 \sum_{k=1}^{n} \left[(K^T R)_{k\ell} + (SG_1)_{k\ell} \right] M_m \left(\frac{\partial X}{\partial K_{ij}{}^1} \right)_k \tag{D-26}$$

where X is the state covariance matrix, S is the adjoint matrix and

$$R = D^T Q D \tag{D-27}$$

M_k denotes row k of M, and $(\partial X/\partial K_{ij}{}^1)_k$ denotes the kth column of the partial derivative of X with respect to $K_{ij}{}^1$.

The approximation neglects the last two terms of Equation (D-26) because the partial derivatives $(\partial X/\partial K_{ij}{}^1)$ require a Lyapunov equation solution for each element in K^1. This approximation is not a bad one, for the two terms take care of any warping due to the change in X with respect to K_{ij}^{1}, and additional gradient directions will take care of this warping.

To extend this transformation to the fixed-plus-variable design, it must include the cross-correlation between measurements with fixed gains and measurements with variable gains. To do this, the gradient vectors for each of r controls must be stacked up end to end to form a vector

$$\frac{\partial J}{\partial K} = \begin{bmatrix} \frac{\partial J^{T}}{\partial K_{1}^{1}} \\ \vdots \\ \frac{\partial J^{T}}{\partial K_{r}^{1}} \\ \vdots \\ \frac{\partial J_{1}^{T}}{\partial K_{11}^{5}} \\ \vdots \\ \frac{\partial J_{1}^{T}}{\partial K_{r1}^{5}} \\ \vdots \\ \frac{\partial J_{p}^{T}}{\partial K_{1p}^{5}} \\ \vdots \\ \frac{\partial J_{p}^{T}}{\partial K_{rp}^{5}} \end{bmatrix} \qquad \text{(D-28)}$$

where K_j^1 is the j^th^ row of the fixed-gain matrix, K_{ij}^5 is the j^th^ row of the variable-gain matrix for flight condition i, J is the total cost, and J_i is the cost for flight condition i.

The vector $(\partial J/\partial K)$ has $n_f + n_v \cdot p$ elements, where n_f is the number of fixed gains, n_v is the number of variable gains, and p is the number of flight conditions.

The transformation of the gradient for the fixed-plus-variable-gain design is then the inverse of the matrix in Figure D-3. That is

$$\frac{\partial J_T}{\partial K} = \Phi^{-1} \frac{\partial J}{\partial K} \tag{D-29}$$

where

$$\phi_{ijk\ell m} = \alpha_i d_{ji}^T Q_i d_{ki} M_i^{\ell j} X_i M_i^{mk^T} \tag{D-30}$$

In Equation (D-30), α_i is the flight condition weight, d_{ji} is column j of D_i, Q_i is the quadratic weighting matrix for flight condition i, and $M_i^{\ell j}$ is the measurement matrix for control j and flight condition i for the fixed gains if $\ell = 1$, or for the variable gains if $\ell = 5$. X_i is the covariance matrix for flight condition i.

Figure D-4 summarizes the incremental gradient scheme using the transformed gradient.

$$\begin{bmatrix} \sum_{i=1}^{p} \phi_{i1111} & \cdots & \sum_{i=1}^{p} \phi_{i1r11} & \phi_{11115} & \cdots & \phi_{p1115} & \cdots & \phi_{11r15} & \cdots & \phi_{p1r15} \\ & \ddots & \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ & & \sum_{i=1}^{p} \phi_{irr11} & \phi_{1r115} & \cdots & \phi_{pr115} & \cdots & \phi_{1rr15} & \cdots & \phi_{prr15} \\ & & & \phi_{11155} & \cdots & 0 & \cdots & \phi_{11r55} & \cdots & 0 \\ & & & & \ddots & \vdots & & \vdots & & \vdots \\ & \text{TRANSPOSED} & & & & \phi_{p1155} & \cdots & 0 & \cdots & \phi_{p1r55} \\ & & & & & & \ddots & \vdots & & \vdots \\ & & & & & & & \phi_{1rr55} & \cdots & 0 \\ & & & & & & & & \ddots & \vdots \\ & & & & & & & & & \phi_{prr55} \end{bmatrix}$$

Figure D-3. Transformation Matrix Φ

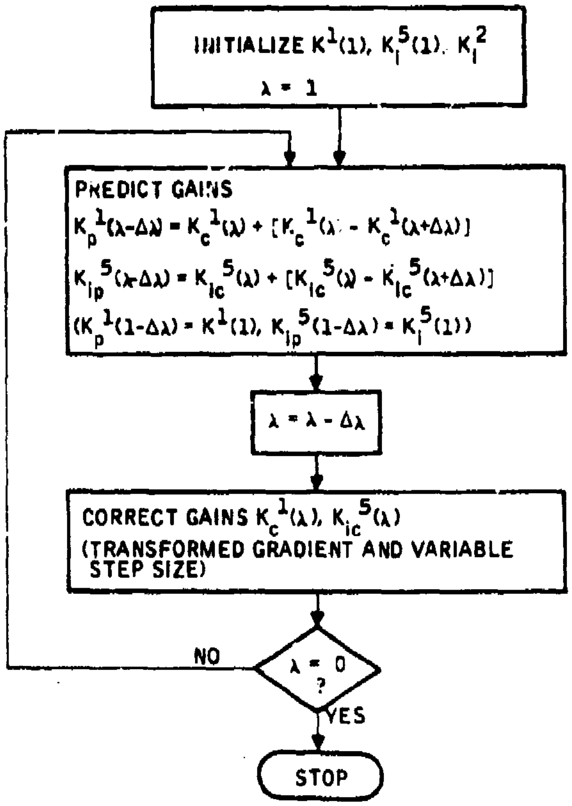

Figure D-4. Incremental Gradient Flow Diagram

REFERENCES

D-1. Vandierendonck, A. J., "Design Method for Fully Augmented Systems for Variable Flight Conditions," Air Force Flight Dynamics Laboratory Technical Report AFFDL-TR-71-152, Wright-Patterson Air Force Base, Ohio, January 1972.

D-2. Burris, P. M. and Bender, M. A., "Aircraft Load Alleviation and Mode Stabilization (LAMS)," Air Force Flight Dynamics Laboratory Technical Report AFFDL-TR-68-161, Wright-Patterson Air Force Base, Ohio, November 1969.

D-3. Burris, P. M. and Bender, M. A., "Aircraft Load Alleviation and Mode Stabilization (LAMS)," Air Force Flight Dynamics Laboratory Technical Report AFFDL-TR-68-162, Wright-Patterson Air Force Base, Ohio, November 1969.

D-4. Edinger, L. D., Schenk, F. L., and Curtis, A. R., "LAMS YF-12 Feasibility Study," NASA FRC Report, July 1971.

D-5. Stein, G. and Henke, A. H., "A Design Procedure and Handling-Quality Criteria for Lateral-Directional Flight Control Systems," Air Force Flight Dynamics Laboratory Technical Report AFFDL-TR-70-152, Wright-Patterson Air Force Base, Ohio, May 1971.

D-6. Athans, M., and Falb, P. L., Optimal Control, McGraw Hill, New York, N. Y., 1966, Chapter 9.

D-7. Ward, M. D., "Quadratic Computer Program Documentation," Research Memo No. MR 10924, Honeywell Systems and Research Center, Minneapolis, Minnesota, June 1970.