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DYNGEN - A PROGRAM FOR CALCULATING STEADY-STATE AND TRANSIENT PERFORMANCE OF TURBOJET AND TURBOFAN ENGINES

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16. Abstract

DYNGEN, a digital computer program for analyzing the steady-state and transient performance of turbojet and turbofan engines, is described. DYNGEN is based on earlier computer codes (SMOTE, GENENG, and GENENG II) which are capable of calculating the steady-state performance of turbojet and turbofan engines at design and off-design operating conditions. DYNGEN has the combined capabilities of GENENG and GENENG II for calculating steady-state performance; to these have been added the further capability for calculating transient performance. DYNGEN can be used to analyze one- and two-spool turbojet engines or two- and three-spool turbofan engines without modification to the basic program. DYNGEN uses a modified Euler method to solve the differential equations which model the dynamics of the engine. This new method frees the programmer from having to minimize the number of equations which require iterative solution. As a result, some of the approximations normally used in transient engine simulations can be eliminated. This tends to produce better agreement when answers are compared with those from purely steady-state simulations. The modified Euler method also permits the user to specify large time steps (about 0.10 sec) to be used in the solution of the differential equations. This saves computer execution time when long transients are run. However, convergence problems are sometimes encountered with DYNGEN when small time steps (less than 1 msec) are used. Examples of the use of the program are included in the report, and program results are compared with those from an existing hybrid-computer simulation of a two-spool turbofan.

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SUMMARY

This report describes DYNGEN, a digital computer program for analyzing the steady-state and transient performance of turbojet and turbofan engines. DYNGEN is based on earlier computer codes (SMOTE, GENENG, and GENENG II) which are capable of calculating the steady-state performance of turbojet and turbofan engines at design and off-design operating conditions. DYNGEN has the combined capabilities of GENENG and GENENG II for calculating steady-state performance; to these have been added the further capability for calculating transient performance. DYNGEN can be used to analyze one- and two-spool turbojet engines or two- and three-spool turbofan engines without modification to the basic program. The user needs only to supply appropriate component performance maps and certain design-point information.

DYNGEN uses a modified Euler method to solve the differential equations which model the dynamics of the engine. This modified Euler method is significantly different from the numerical integration methods which have typically been used in all-digital transient engine simulations. The major advantage of this new method is that it frees the programmer from having to minimize the number of equations which require iterative solution. As a result, some of the approximations normally used in transient engine simulations can be eliminated. This tends to produce better agreement when answers are compared with those from purely steady-state simulations. The modified Euler method also permits the user to specify large time steps (about 0.10 sec) to be used in the solution of the differential equations. This saves computer execution time when long transients are run. However, convergence problems are sometimes encountered with DYNGEN when small time steps (less than 1 msec) are used. A further discussion of the advantages and disadvantages of the modified Euler method is included in this report.

The intent of this report is to describe DYNGEN to make it useful for other researchers. A complete FORTRAN program listing is included in an appendix. Examples of the use of the program are included in the report, and program results are compared with those from an existing hybrid-computer simulation of a two-spool turbofan.

INTRODUCTION

Computer programs which predict the performance of theoretical turbojet and turbofan engines have long been recognized as valuable tools for preliminary and detail design work. Digital computer codes such as SMOTE (refs. 1 and 2), GENENG (ref. 3), and GENENG II (ref. 4) now enable the user to analyze the steady-state performance of a wide variety of engines simply by providing component performance maps and other pertinent data; the task of writing a new computer program for each engine configuration is largely eliminated.

GENENG and GENENG II (herein referred to simply as "GENENG") are only capable of calculating steady-state engine performance. However, the need to predict the transient performance of turbojet and turbofan engines is becoming more important in preliminary design. Thrust response requirements are becoming more stringent, especially for V/STOL aircraft, and the need to meet transient performance criteria can have a significant effect on overall engine design. As engines grow more complex, their control systems assume a greater importance, and this importance further implies the need for good transient performance prediction during preliminary design.

Digital, analog, and hybrid computer methods are available for use in generalized computer codes for transient engine analysis. Each approach has its merits, and no consensus exists as to which is the best method. The major advantage of analog and hybrid methods is the use of electronic amplifiers for integrating the differential equations which model the dynamics of the engine. Digital engine simulations have, in the past, used time-consuming numerical integration techniques, which can result in prohibitively long execution times. A disadvantage which digital, analog, and hybrid simulations have traditionally shared is the need to minimize the number of equations which require iterative solution. Such equations are to be avoided, either because an analog computer cannot easily solve them or because they take too long to solve in connection with a digital integration algorithm which may require thousands of passes through the engine modeling equations. Transient engine simulations usually resort to assumptions and approximations in an effort to avoid iterative solution procedures. As a result, their steady-state solutions tend to disagree with the solutions produced by purely steady-state programs, such as GENENG, which are written without any prohibition on iterative solution methods.

Despite the difficulties just mentioned, progress has been made in developing transient simulations which, like GENENG, can handle many engine configurations without changing the basic computer program. The HYDES program for hybrid computers (ref. 5) has proven to be a flexible tool for preliminary control studies on a wide variety of engine types. HYDES uses electronic amplifiers for integration and digital subroutines for most of the function generation and algebraic computations.

This report describes a digital computer program, DYNGEN, which enables the user to analyze the transient performance of many engine configurations and which also eliminates some of the problems frequently connected with all-digital transient simulations. DYNGEN solves the system of differential equations by a method substantially different from the forward-difference integration techniques frequently used in digital engine simulations. The new method used by DYNGEN is similar to the well-known Euler method of solving differential equations and will be called the "modified Euler method." It gives the analyst great freedom in selecting the equations needed to describe the system and eliminates the discrepancies which often occur between answers generated by transient and steady-state simulations. In fact, DYNGEN is a direct modification of GENENG and, although the capability to perform transient calculations has been added, none of the steady-state capabilities of GENENG have been sacrificed. Without modification to the basic program, DYNGEN can be used to analyze one- and two-spool turbojets and two- and three-spool turbofans. Possible engine configurations are described in the next section of this report. Another section describes the modified Euler method of solving the system of differential equations and clarifies its advantages and disadvantages. Appendix A discusses the modified Euler method from a numerical analysis viewpoint.

The program is written in FORTRAN IV and can be used without modification on any IBM 7094 Model 2 computer. With modifications, the program can be used on all computers that have a FORTRAN compiler.

The iteration and integration techniques used in DYNGEN are described in appendix A. A complete program listing, flow chart, subroutine descriptions, and an example case are shown in appendix B. Appendix C explains methods of control system simulation, and appendix D provides debugging hints. For users who are already familiar with GENENG or GENENG II, appendix E enumerates the differences between DYNGEN and those programs. All symbols are defined in appendix F.

ENGINE TYPES

Before describing the analytical techniques used in DYNGEN, a brief discussion of engine types will be given to inform potential users of their options for analyzing different engine configurations. Since DYNGEN is derived from GENENG, the user is referred to references 3 and 4 for a more detailed discussion of this subject. Figures 1 to 11 show some of the engine types that can be analyzed. The three-spool, three-stream turbofan (type a, fig. 1) is the most complicated configuration; all other types are derived from it by changes to the calculation procedure inside the program. Input requirements for the various configurations are discussed in the section PROGRAM INPUTS. The one-spool turbojet (type k, fig. 11) is the simplest engine that can be analyzed. In between configurations a and k are found such engines as the three-spool, two-stream turbofan (type d, fig. 4); the two-spool, two-stream turbofan (type e, fig. 5); and the two-spool, two-stream, aft-fan engine (type h, fig. 8). All the turbofan engines shown in figures 1 to 9 have separate core and fan ducts. If desired, the user may specify mixed flow, in which case fan and core flow will exhaust through a common nozzle. The user may also specify core duct or fan duct afterburning.

The engines in figures 1, 2, 3, 6, and 7 have a third duct which is supplied with bleed air from the intermediate compressor. The third duct is referred to as the "wing duct" since it was originally intended to supply air for blown-flap or ejector-wing STOL aircraft.

ENGINE MODELING TECHNIQUES

DYNGEN was formed by directly modifying its predecessor, GENENG. Except for the addition of differential equations to model rotor and gas dynamics, the equations used in DYNGEN are identical to those used in GENENG. Therefore, the reader is referred to references 3 and 4 for a detailed discussion of thermodynamic and component equations. The discussion in this report concentrates on how the programming techniques of GENENG were used to form a dynamic engine simulation and on the differential equations added to the analytical model. The modified Euler method of solving differential equations is discussed from a numerical analysis viewpoint in appendix A.

Steady-State Balancing Technique

An example case is presented here to assist the reader in understanding how DYNGEN calculates engine steady-state operating points. For simplicity a turbojet engine is used in the example, but similar methods are used for more complicated configurations. Figure 12 shows a turbojet engine with its major components labeled. Pressures P, temperatures T, and flows $\dot{w}$ are also labeled with appropriate station numbers. The example illustrates how the calculation of variables proceeds through the engine. DYNGEN is written so that the user can select off-design points by specifying speed N, turbine inlet temperature T_4, or fuel flow $\dot{w}_f$. In this example, fuel flow is assumed to be the specified variable. First, an inlet calculation is made to determine P_2 and T_2 from the free-stream values of pressure, temperature, and Mach number. In order to calculate $\dot{w}_C$, P_3, and T_3 from the compressor map (fig. 13) and thermodynamic relations, program-generated guesses are made for the values of speed N and pressure ratio P_3/P_2. Once $\dot{w}_C$, P_3, and T_3 are obtained, the combustor calculations for $\dot{w}_4$, P_4, and T_4 can be made by using the thermodynamic relations, the combustor map (fig. 14), and the user-specified values for fuel flow $\dot{w}_f$ and compressor bleed flow. In order to calculate turbine variables, the program generates another guess, this time for the value of turbine flow function $\dot{w}_4\sqrt{T_4}/P_4$. Then, from the known value of $N/\sqrt{T_4}$, the turbine map (fig. 15) is used to calculate turbine work Δh and efficiency. The values of P_7 and T_7 are then calculated by using thermodynamic relations. Finally, the compressible-flow relations are used to calculate nozzle pressure P_7 from $\dot{w}_8$, T_7, and user-specified values for P_0 and nozzle area.

The reader may have noticed that this calculation procedure is redundant; that is, certain variables can be calculated in more than one way. This fact is used to generate error variables, which must equal zero to yield a consistent solution of the equations. In developing a program such as DYNGEN, the analyst must choose what error variables to use. This discussion simply points out the choices which were inherited by DYNGEN from its predecessors, GENENG and SMOTE. Experience has shown that these are good choices for most engine configurations.

In the previous discussion it was stated that guesses were made for rotor speed N, compressor pressure ratio P_3/P_2, and turbine flow function $\dot{w}_4\sqrt{T_4}/P_4$. From the first two guesses (and other variables) one may calculate the power absorbed by the compressor $\dot{w}_C \Delta h_C$. From the turbine flow function (and other variables) one may calculate the power supplied by the turbine $\dot{w}_T \Delta h_T$. For steady-state operation the power supplied must equal the power absorbed. Therefore, the difference $\dot{w}_C \Delta h_C - \dot{w}_T \Delta h_T$ may be used for the first error variable.

Similarly, one can calculate a value for turbine flow function $\left(\dot{w}_4\sqrt{T_4}/P_4\right)'$ based only on the first two guesses, but for a consistent solution the calculated value must equal the guessed value. Hence, the difference $\left(\dot{w}_4\sqrt{T_4}/P_4\right) - \left(\dot{w}_4\sqrt{T_4}/P_4\right)'$ can be used as the second error variable.

Finally, from the compressible-flow equations, we know that the variable P_7 is specified by the variables $\dot{w}_8$, T_7, P_0, and nozzle area A_8. Since total conditions remain constant throughout the nozzle, this value for P_7 must equal the value P_7', which is calculated from the work and efficiency of the turbine and from adiabatic flow (with a specified pressure loss) in the duct between turbine and nozzle. Therefore, the third error variable is $P_7 - P_7'$.

Once three variables have been guessed and three errors have been specified, the analyst can use an iterative method to obtain a consistent solution to the equations. SMOTE, GENENG, and DYNGEN all use the Newton-Raphson technique of iteration. The details of this method are given in appendix A. Although more complicated engines will require more guesses and more error variables in the iterative procedure, the analyses will be quite similar to the one described in this example.

Differential Equations

So far the discussion has been devoted to the methods which DYNGEN uses to obtain steady-state operating points. Now the method of implementing and solving time-dependent differential equations is discussed. DYNGEN uses a modified Euler method of solving differential equations. This method is derived, from a numerical analysis viewpoint, in appendix A. Appendix A also discusses the numerical stability of the modified Euler method and shows that it does not require extremely small time steps to obtain a stable solution. Because it uses the modified Euler method, DYNGEN does not require small time steps to obtain a stable solution. However, DYNGEN sometimes experiences convergence problems for time steps less than about 1 millisecond.

The ability to use large time steps (about 0.10 sec) is an advantage in engine simulation since in the past it has often been necessary to select integration time steps small enough to guarantee stability for high-frequency dynamics typical of mass and energy storage in unsteady flow. This can result in very long execution times even though the simulation user may only be interested in low-frequency dynamics. With the modified Euler method the user can select larger time steps without worrying about numerical stability.

The main disadvantage of the modified Euler method is that an iterative solution is required for the equations which approximate the solution to the differential equations. However, this fact turns out to be useful in DYNGEN since it means that the analyst no longer has to solve explicitly for derivatives. They may be embedded anywhere in an overall set of simultaneous algebraic equations which are to be solved by an iterative method such as Newton-Raphson. The following discussion shows how this advantage was employed in converting a steady-state simulation, GENENG, to a dynamic simulation, DYNGEN. In order to accomplish the conversion, three kinds of equations had to be modified to include dynamic terms: the power balance, continuity, and energy equations. The steady-state power balance equation simply implies that the power output of a turbine must equal the power absorbed by a fan, a compressor, and their loads

$$\dot{w}_T \, \Delta h_T = \dot{w}_C \, \Delta h_C + (HP)_{ext} \tag{1}$$

By adding a rotor acceleration term, the equation can be used to model engine dynamics: any excess power provided by the turbine will go into rotor acceleration

$$\dot{w}_T \, \Delta h_T = \dot{w}_C \, \Delta h_C + \left(\frac{2\pi}{60}\right)^2 IN \frac{dN}{dt} + (HP)_{ext} \tag{2}$$

If the time derivative is arbitrarily set equal to zero, the dynamic equation becomes the steady-state equation. Similar considerations also hold for the continuity equation

$$\dot{w}_{out} = \dot{w}_{in} \tag{3}$$

DYNGEN treats unsteady flow dynamics in a way which has become traditional for engine simulation: a control volume is associated with each component; and pressure, temperature, and density are assumed to be constant throughout the control volume. At steady state the flow into the volume must equal the flow out; but for unsteady flow, mass can be stored in the volume at a rate proportional to the time derivative of pressure dP/dt

$$\dot{w}_{out} = \dot{w}_{in} - \frac{\tilde{V}}{\gamma RT} \frac{dP}{dt} \tag{4}$$

If dP/dt is zero, the continuity equation reverts to its steady-state form. The control-volume approach is also used for the energy equation. At steady-state the rate of energy into the volume must equal the rate out

$$\dot{w}_{out}h_{out} = \dot{w}_{in}h_{in} \tag{5}$$

In unsteady flow, energy storage is accounted for by two terms: one reflecting the rate of change of specific internal energy du/dt, and another reflecting energy storage caused by mass storage

$$\dot{w}_{out}h_{out} = \dot{w}_{in}h_{in} - (\dot{w}_{in} - \dot{w}_{out})u - \frac{P\tilde{V}}{RT} \frac{du}{dt} \tag{6}$$

The following discussion shows how these equations were used in DYNGEN. DYNGEN was formed from GENENG by modifying the power balance, continuity, and energy equations for major engine components. In GENENG the steady-state power balance equation was used to form an error variable

$$E_1 = \dot{w}_C \Delta h_C - \dot{w}_T \Delta h_T + (HP)_{ext} \tag{7}$$

In DYNGEN the same error is formed with the dynamic term added

$$E_1 = \dot{w}_C \Delta h_C + \left(\frac{2\pi}{60}\right)^2 IN \frac{dN}{dt} - \dot{w}_T \Delta h_T + (HP)_{ext} \tag{8}$$

In order to implement the dynamic forms of the continuity and energy equations, a volume was associated with each component, and the flow and enthalpy out of the component were modified by the dynamic terms.

For example, if $\dot{w}_C$ is the flow rate through the compressor specified by the compressor map and h_3 is the enthalpy at the compressor exit, the flow and enthalpy entering the combustor will be given by $\dot{w}_C^*$ and h_3^*, where

$$\dot{w}_C^* = \dot{w}_C - \frac{\tilde{V}_3}{\gamma R T_3} \frac{dP_3}{dt} \tag{9}$$

$$h_3^* = \frac{\dot{w}_C h_3 - (\dot{w}_C - \dot{w}_C^*) u_3 - \frac{P_3 \tilde{V}_3}{R T_3} \frac{du_3}{dt}}{\dot{w}_C^*} \tag{10}$$

The derivatives are calculated by the simplest possible approximation

$$\frac{dy}{dt} \approx \frac{y_i - y_{i-1}}{\Delta t} \tag{11}$$

where y_i is the current value of a variable and y_{i-1} is the value for the previous time step. This approximation is adequate provided that the time step Δt is no greater than one-tenth the magnitude of the smallest time constant the user wants to observe. A reasonable estimate for, say, a rotor time constant could be obtained by applying a step in main fuel flow as a disturbance. The rotor "time constant" would then be the time between the application of the step and the point when rotor speed reached $N_0 + 0.63\ \Delta N$, where N_0 is the initial speed and $N_0 + \Delta N$ is the final speed at the end of the transient. In order to observe rotor dynamics with a time constant of 1.0 second, the user should use a Δt no greater than 0.10 second. In selecting a value of Δt for a given engine simulation, some trial and error may be necessary to determine the optimum value of Δt. As mentioned earlier, Δt's smaller than 1 millisecond may cause convergence problems.

Adding the derivative terms to the steady-state equations did not require any change to the basic iteration scheme used in GENENG. Therefore, none of the flexibility or generality of the program was lost; its capability was simply extended to include dynamics.

PROGRAM INPUTS

DYNGEN requires four kinds of user-supplied information:

(1) Component maps, which are supplied in the form of BLOCK DATA subprograms

(2) Subroutines DISTRB, FCNTRL, and NOZCTR, which are dummies unless transient operation is desired

(3) A list of desired output variables, which is read in on data cards supplied at execution time

(4) Engine configuration data and operating point specification, which are read in at execution time on data cards by means of NAMELIST name $DATAIN

Component Maps

The components which are represented by maps in DYNGEN are the fan, intermediate compressor, compressor, combustor, high-pressure turbine, intermediate-pressure turbine, low-pressure turbine, and afterburner. All these maps except the afterburner map are supplied in the form of BLOCK DATA subprograms; the afterburner map is included in subroutine ETAAB. DYNGEN is set up so that maps for all components are specified. Thus, if a single-spool turbojet is simulated, the BLOCK DATA for the components which are not used do not have to be deleted. This results in no errors in the calculations. Dummy maps for all components are supplied with the program. However, if storage space is a problem, the user may set up only the component maps which are needed and delete the space occupied by the other maps. Table I lists the component maps that must be supplied for each engine configuration.

Choice of component maps - scaling laws. - Many engines that are studied by using DYNGEN are theoretical. Therefore, actual component maps for these engines do not exist. The program, however, does require component maps in order to do off-design-point calculations. In order to alleviate this problem, DYNGEN uses scaling laws to change data from one component map into a new component map. Hopefully, a component map can be found which could be expected to perform in a similar manner to the actual map for the engine being studied. In fact, most maps that the authors have obtained are identified as to the range of pressure ratio, airflow, etc., over which they are valid. Thus, a high-bypass-ratio fan map such as that from a CF-6 could be used to simulate other high-bypass-ratio fan maps.

The scaling equations used for the compressor maps are

$$PR = \frac{(PR)_{design} - 1}{(PR)_{map,\,design} - 1}\left[(PR)_{map} - 1\right] + 1$$

$$WA = \frac{(WA)_{design}}{(WA)_{map,\,design}} \times (WA)_{map}$$

$$ETA = \frac{(ETA)_{design}}{(ETA)_{map,\,design}} \times (ETA)_{map}$$

In the output are printed the correction factors used in scaling the maps. The closer these values are to 1.0, the more reasonable are the simulated maps of the engine. Conversely, however, not being close to 1.0 does not necessarily mean that the simulation is poor since many maps have been shown to be typical over quite large ranges in the variables.

BLOCK DATA input. - The three compressor performance maps are entered into the code as the BLOCK DATA subprograms BLKFAN, BLKINT, and BLKCMP. The subprograms supplied by the authors with the code and shown in appendix B are not to be taken as realistic maps. These maps are of an illustrative nature and are the ones used to run the sample calculations.

As an example, by using subprogram BLKFAN (the first nine cards of which are printed here) and referring to a typical compressor map (fig. 13), the data are programmed as follows: Card 1 reminds the reader that these maps are fictitious. Card 2

```
$IBFTC BLKFAN  DECK
C     THIS IS A GENERALIZED FAN MAP FOR UNREALISTIC SUPERSONIC ENGINE      1
      BLOCK DATA                                                           2
      COMMON /  FAN/CN(15),PR(15,15),WAC(15,15),ETA(15,15),N,NP(15)        3
      DATA N,NP/10,6,3*7,5*10,8,5*0/                                       4
      DATA CN/0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2,5*0./                5
      DATA (PR( 1,J),WAC( 1,J),ETA( 1,J),J=1, 6)/                          6
     1 1.00000,  243.600,  0.75592,  1.01200,  229.800,  0.76120,          7
     2 1.02800,  199.800,  0.76648,  1.03840,  166.800,  0.75592,          8
     3 1.04480,  133.200,  0.72512,  1.04800,   86.400,  0.64152/          9
```

identifies the subprogram as BLOCK DATA. Card 3 identifies common block FAN, into which data are to be stored, and dimensions the program variables. Card 4 indicates that there are 10 speed lines N and gives the number of points NP on each line (six on the lowest speed, seven on the next three lines, etc.). Card 5 assigns the value of speed to each of the 10 lines (low to high). Cards 6 to 9 along the speed line CN=0.3 set the pressure ratio PR, corrected airflow WAC, and efficiency ETA in sets of three, going from low pressure (PR=1.0) to the surge line (PR=1.048). Note there are six sets of three values (NP(1)=6). The rest of the cards (appendix B) set the values for each speed line.

The combustor map is also a BLOCK DATA subprogram (CMBDT). It is a plot of temperature rise across the combustor against efficiency for constant input pressure. Entry to the map is through temperature rise and input pressure, with efficiency being output. The cards in the subprogram CMBDT are reproduced here; a typical combustor map is shown in figure 14. The data are programmed as follows: Card 1 identifies the common block COMB, into which data are to be stored, and dimensions each variable. Card 3 indicates that there are 15 lines of constant PSI (P3) by the value of N and that there are 15 values of DELT (DT) and ETA (ETAB) along each line of constant PSI (P3).

```
   $IBFTC CMBDT    DECK
1        BLOCK DATA
2        COMMON / COMB/PSI(15),DELT(15,15),ETA(15,15),N,NP(15)
3        DATA N,NP / 15,15*15 /
4        DATA PSI/4.9116,9.8232,14.735,19.646,24.558,29.470,34.381,
5       139.293,44.207,73.674,100.,200.,300.,400.,500./
6        DATA DELT/15*200.,15*300.,15*400.,15*500.,15*600.,15*700.,15*800.,
7       115*900.,15*1000.,15*1100.,15*1200.,15*1300.,15*1400.,15*1500.,
8       215*1600./
9        DATA ETA/
10      1.600,.726,.777,.806,.826,.843,.855,.865,7*.870,
11      2.758,.825,.858,.875,.888,.898,.906,.912,.914,6*.915,
12      3.868,.893,.911,.925,.935,.942,.947,.951,7*.953,
13      4.925,.936,.946,.955,.963,.969,.974,.977,.978,6*.979,
14      5.960,.966,.972,.977,.982,.985,.990,.992,.993,6*.995,
15      6.988,.991,.992,.994,.995,.997,.998,8*.999,
16      78*1.00,7*.999,120*1.00/
17       END
```

Cards 4 and 5 assign values to each of the P3 lines from low to high pressure. Cards 6 to 8 assign values of ΔT to each of the P3 lines, starting at low ΔT. The lowest value of ΔT on each of the P3 lines is given, starting with the lowest value of ΔT on the lowest value of P3. Next comes the second lowest value of ΔT on each P3, etc. Again, this map is unrealistic, being used for illustrative purposes only. Cards 9 to 16 assign the value of η_B in a one-to-one correspondence with the ΔT values just assigned. The order is the same.

Also entered as BLOCK DATA subprograms are the turbine maps (HPTDAT, IPTDAT, and LPTDAT). In order to illustrate the entering of turbine data, LPTDAT is used. A typical turbine map is shown in figure 15; the data are programmed as follows: Card 1 identifies the subprogram as BLOCK DATA. Card 2 identifies common

```
   $IBFTC LPTDAT  DECK
1        BLOCK DATA
2        COMMON / LTURB/TFF(15),CN(15,15),DH(15,15),ETA(15,15),N,NP(15)
3        DATA N,NP/11,9*15,12,9,4*0/
4        DATA TFF /    88.470,  102.795,  116.835,  129.330,  141.045,
5       1  145.725,  150.000,  153.345,  156.405,  159.780,  163.170,4*0./
6        DATA (CN( 1,J),DH( 1,J),ETA( 1,J),J=1,15)/
7       1    0.3682,    0.0018,    0.7120,    0.5336,    0.0026,    0.7300,
8       2    0.7365,    0.0035,    0.7472,    0.9754,    0.0044,    0.7300,
9       3    1.2146,    0.0051,    0.7140,    1.4173,    0.0056,    0.7000,
10      4    1.6201,    0.0059,    0.6850,    1.7673,    0.0061,    0.6730,
11      5    2.0247,    0.0062,    0.6452,    2.2827,    0.0061,    0.6200,
12      6    2.4665,    0.0057,    0.6000,    2.6137,    0.0053,    0.5750,
13      7    2.8166,    0.0044,    0.5310,    2.9456,    0.0035,    0.5000,
14      8    3.3138,    0.0001,    0.3850/
```

block LTURB, into which data are to be loaded, and dimensions the program variables. Card 3 indicates the number of constant turbine flow function lines TFF as 11 (N) and gives the number of points on each line from low to high TFF. Cards 4 and 5 set values of corrected speed CN, work function DH, and efficiency ETA along TFF(1), starting from low CN (0.3682) and ending at high CN (3.3138). The rest of the cards set the values along higher TFF lines.

In many cases, turbine maps for high-performance engines operate at a choked condition (constant TFF). Thus, a turbine map to be represented could possibly have no lines representing constant TFF for a significant portion of the map. For complete map representation, lines of constant TFF may be estimated on the map up to the limit loading line by inputting slight changes for the values of TFF (e.g., if one line for TFF is 62.105, the next may be input as 62.108). This will eliminate computational difficulties which would arise if constant values for TFF lines were input.

Generalized afterburner performance has been programmed into subroutine COAFBN. The afterburner performance map included in the program is shown in a generalized form in figure 16(a). The performance map shows afterburner combustion efficiency as a function of fuel-air ratio. The values of the afterburner combustion efficiency correction factors ΔETAA during off-design operation are shown as functions of afterburner entrance Mach number (fig. 16(b)) and afterburner entrance pressure (fig. 16(c)). Other correction factors or performance maps may be added as desired. The afterburner efficiency, fuel-air ratio, inlet total pressure, and Mach number are generalized.

A specific afterburner performance map is generalized by dividing the specific off-design value by the design value, as shown below. The symbols shown are the symbols used in the ETAAB subroutine, where the generalized and specific values are input. The generalized afterburner values are obtained as follows:

$$\text{Efficiency (ETABRT)} = \frac{\text{ETAA}}{\text{ETAADS}}$$

$$\text{Fuel-air ratio (FART)} = \frac{\text{FART}}{\text{FARTDS}}$$

$$\text{Entrance total pressure (P6T)} = \frac{\text{P6}}{\text{P6DS}}$$

$$\text{Entrance Mach number (EM6T)} = \frac{\text{AM6}}{\text{AM6DS}}$$

However, the correction factor for efficiency ΔETAA is not a generalized value. Also input in ETAAB are the following:

(1) The change in efficiency as a function of EM6T is input as DELM6 (which is really ΔETAA = f(AM6)).

(2) The change in efficiency as a function of P6T is input as DELP6 (which is really ΔETTA = f(P6)).

At execution time for the design point, afterburner combustion efficiency ETAADS, exit total temperature T7DS, and entrance Mach number AM6DS design values are input. Then design fuel-air ratio and entrance pressure ratio are calculated from the input values and the other design engine characteristics.

In order to achieve a reasonable accuracy in cycle calculations when using a generalized component map, the usage of the map should be limited within a certain range of the original design values and configuration changes. Therefore if, for example, an afterburner has a design task that differs significantly from an example used, a new performance map should be used in order to simulate the component more accurately.

DYNGEN normally uses a single-point input for the nozzle velocity coefficients (CVMNOZ, CVDWNG, and CVDNOZ) when calculating engine performance. When desired, however, a map of nozzle velocity or thrust coefficients can be readily incorporated, as in reference 3.

Output Specification

Data cards are supplied by the user, at execution time, to specify the names of desired output variables. Any variable that is in one of the main commons (ALL1, ALL2, etc.) may be selected for output by punching, in columns 1 to 6, the name of the variable as it appears in the common. Up to 150 variables (25 lines of six variables) may be chosen for a particular run. During the output phase the name of the variable is printed out, with its value printed immediately below the name.

Another feature of the controlled output is the ability to change the name of a variable to be output; for example, it may be desired to change a station designation to one more common to a particular programmer. In this case, the variable name would be punched in columns 1 to 6 as described; but, in addition, the desired name would be punched in columns 13 to 18. Special symbols such as / may be used in the new name. The last card of the selected output must be a card with "THEEND" punched in columns 1 to 6.

Design-Point Specification

The engine design point is specified by reading in data cards by means of NAMELIST name $DATAIN. The design point is identified by setting IDES=1, and it must always be the first case run. Configuration specification (two-spool turbofan, one-spool turbojet, etc.) is done at the design point.

Table II contains a complete list of the variables that must be specified by the user at the design point for the 11 basic engines shown in this report. Table III contains further explanation of some of the program indices (MODE, INIT, IDUMP, etc.) which the user may employ to control the operation of the program.

One significant difference between DYNGEN and its predecessors, SMOTE and GENENG, is the ability to use the International System of Units (SI). If input variable SI is .TRUE., physical constants internal to the program will be set for SI units; if SI is .FALSE., they will be set for U.S. customary units (English units). When SI is .TRUE., most of the internal calculations are done in SI units, as opposed to simply leaving the internal calculations in English units and converting the input and output.

Off-Design Operating Points

So far the discussion has concentrated on specifying the engine design point. Once this has been done, the user has many options for running off-design points. These may be used to study steady-state performance, or they may be the initial conditions for transients. There are four basic modes for specifying off-design points:

(1) MODE=0, specify a new turbine inlet temperature T4

(2) MODE=1, specify a compressor rotational speed PCNC

(3) MODE=2, specify a fuel flow rate WFB

(4) MODE=3, specify a fan rotational speed PCNF

The variables T4, PCNC, WFB, and PCNF have special significance because specifying any one of them also specifies the other three (assuming a fixed engine cycle). In addition to these variables, however, the user may specify any parameter which is not recalculated inside the program. Table IV contains all the variable names which may be changed for off-design points by using NAMELIST input. Table IV is not, however, an exhaustive list of variables which might be changed. For example, the user might want to vary low-pressure-turbine exit area A55 in order to determine its effect on engine performance. To do so he would only need to add A55 to NAMELIST/DATAIN/ in subroutine PUTIN. The same procedure can be used for any variable the user wants to change, provided that the variable is not recalculated inside the program. There is no restriction on the number of variables which may be changed at one time (except for afterburning cases). For example, it would be permissible to change ALTP, AM, ETAR, HPEST, A8, A28, and A38 all in one step.

When calculating off-design points, DYNGEN needs an initial guess for the values of its iteration variables. Subroutine GUESS does the job of providing the guesses. However, for some engines, GUESS will lead to trouble by causing map inputs that are out of range for the data provided or other similar problems. Variable INIT can be used to bypass GUESS. If INIT=0, GUESS will be called; if INIT=1, GUESS will be bypassed, and the last converged case will be used as the initial guess for the next case. Sometimes INIT=1 can be used to solve for a point which has been causing convergence problems.

Transient Input

In order to use DYNGEN's transient capability, the user must provide additional NAMELIST input. Table V summarizes the variables which must be provided for each of the engine configurations discussed in this report. Except for ITRAN, the variables in table V may be input at any time; they do not affect program operation in the steady-state (ITRAN=0) mode. When the user inputs ITRAN=1, the next point will be the initial condition for a transient, and the program will print "TIME=0.0" above the output listing. From then on, until TIME exceeds TF, TIME will be incremented by DT before each point is calculated, and subroutine DISTRB will be called to provide time-varying input. The user must write subroutine DISTRB. For example, DISTRB might be used to provide a step in WFB to determine engine open-loop response. Examples of DISTRB are shown in appendixes B and C. DISTRB can be used to change any variable which is not recalculated inside the program, nor is the user restricted to the variables in NAMELIST. Table IV provides a reasonably complete list of possible time-varying inputs. The user should not, however, input a time-varying T4 (when MODE=0) unless VCOMB=0.0. If VCOMB is nonzero, T4 will be recalculated and the user-supplied value will be overridden. Similarly, a time-varying T7 should not be input unless VAFTBN=0.0, and a time-varying T24 should not be input unless VFDUCT=0.0. DISTRB should contain COMMON blocks ALL1, ALL2, etc., as required to communicate new values to the rest of the program.

DYNGEN also provides for user-written versions of subroutines FCNTRL (main fuel control) and NOZCTR (controlled A8). When ITRAN=1, FCNTRL is called by COCOMB (if MODE=2) and NOZCTR is called by COMNOZ. Appendix C contains examples of FCNTRL and NOZCTR. A set of general-purpose control system subroutines is also discussed in appendix C. The user may employ these to write his own control subroutines.

EXAMPLE CALCULATIONS

In order to show DYNGEN's capability, three examples are presented. The first example shows the response of a three-spool, three-stream turbofan (like the one shown in fig. 1) to an open-loop step in fuel flow. Figure 17 shows time histories of fan, middle spool, and core speeds. Also shown is the response of turbine inlet temperature. All variables are presented as percentages of their design values. Complete input and output listings for this example are shown in appendix B. Apart from showing DYNGEN's capability to simulate a three-spool turbofan, figure 17 also demonstrates the effect of using different time steps in the modified Euler solution of the simulation equations. The results are shown for two time steps: 0.01 and 0.10 second. Close examination shows some small differences between the two solutions, but they are substantially identical. There is a big difference, however, in computer execution time to run the 3-second transient shown in figure 17. With the 0.10-second time step, execution time was 1.4 minutes; with the 0.01-second time step, execution time was 12.3 minutes. This example demonstrates one of the main advantages of a modified Euler solution method: the user may select the time step to show the frequency range of interest. If low-frequency effects (less than 0.20 Hz), such as rotor dynamics, are the subject of interest, a time step of 0.10 second may be adequate. If higher frequency effects, such as temperature and pressure dynamics, are to be observed, a time step as small as 1 millisecond may be needed. Frequency ranges requiring a time step smaller than 1 millisecond may result in convergence problems in DYNGEN. In any case, execution times can be held to a minimum that is compatible with the user's interests.

The next example shows a large throttle transient for a two-spool turbofan similar to the one shown in figure 5. This engine was simulated, along with the speed control system shown in figure 18. A listing of subroutine FCNTRL for this example is shown in appendix C. The primary input to the control system is demand speed XNLDEM, which is set by the pilot's throttle lever. The only output of the control system is fuel flow WFB, which goes to the combustor. During small throttle transients the control is proportional-plus-integral on speed error, but for large transients the control is closed loop on the acceleration fuel flow schedule. Acceleration fuel flow is computed from compressor speed XNHM, compressor exit pressure P3M, and compressor inlet temperature T21M. This moderately complex control system was simulated by using subroutines that are compatible with DYNGEN's modified Euler solution method. A throttle step from 50 percent thrust to 100 percent thrust was applied to the simulation, and the results are shown in figure 19. Time histories of turbine inlet temperature and thrust are shown, with the variables expressed as percentages of their design values. This figure also presents a comparison of DYNGEN's results with those from a hybrid-computer simulation of the same engine. In figure 19, the continuous lines are the hybrid-computer solution and the discrete points are DYNGEN's solution. The hybrid-computer model is quite detailed (ref. 5), but because of differences in the simulation equations, the steady-state results of the two simulations differ by about 3 percent. The differences in the dynamic solutions are of the same order. The comparison shown in figure 19, though not perfect, tends to confirm the validity of DYNGEN's method of solving the differential equations used in modeling the engine and control system. Even though a fairly long time step of 0.10 second was used, DYNGEN's solution is quite similar to the continuous solution produced by the hybrid computer.

The final example of DYNGEN's flexibility involves a single-spool, afterburning turbojet similar to the one shown in figure 11. This type of engine requires exhaust nozzle and main fuel control subsystems as shown in figure 20. Listings of subroutines FCNTRL and NOZCTR for this engine are shown in appendix C.

The main fuel control is a simple proportional control on speed error with acceleration and deceleration fuel flow limiting. The main input is demand speed PCNFDM which is set by the pilot's throttle. The acceleration schedule is the usual WFB divided by P3 as a function of PCNF, and the deceleration schedule is obtained simply by taking one-third of the acceleration schedule. The nozzle control is used only in the afterburning mode of operation. Its purpose is to null out any change in compressor pressure ratio P3/P2 which might occur when going from nonafterburning to afterburning operation. This is accomplished by proportional-plus-integral control of nozzle area A8 in response to pressure ratio error.

This control system was simulated in connection with a turbojet engine, and a throttle slam from idle to full afterburning was applied. The results are shown in figure 21. Time histories of rotational speed, main fuel flow, afterburner fuel flow, nozzle area, and thrust are shown. All variables are presented as percentages of their design values. In order to simulate a throttle slam, afterburner fuel flow was ramped from zero to its maximum value in 2 seconds, beginning as soon as rotor speed reached 100 percent. The transient input for this example is shown in subroutine DISTRB (appendix C).

This example shows that DYNGEN can be used successfully to simulate the dynamics of an afterburning engine. Furthermore, it demonstrates that DYNGEN is not limited to small-perturbation problems. The 5-second transient shown in this example required about 2 minutes of computer execution time on the IBM 7094.

CONCLUDING REMARKS

A generalized digital computer program for simulating the steady-state and dynamic performance of turbojet and turbofan engines has been described and discussed. This computer program, called DYNGEN, possesses significant advantages over many earlier methods of digital engine simulation. Specifically, it eliminates the need to operate two separate computer programs to obtain steady-state and dynamic results. It uses a modified Euler method for solving differential equations, which enables the user to specify long solution time steps if only low-frequency information is required. This saves computer execution time when long transients are to be run. A limitation of DYNGEN is that it sometimes experiences convergence problems when small time steps (less than 1msec) are used. Finally, DYNGEN can simulate a wide variety of engine types without reprogramming. This saves money and man-hours when new engines are to be simulated.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, November 15, 1974,
505-05.

APPENDIX A

ITERATION AND INTEGRATION TECHNIQUES

Steady-State Balancing Technique

The following discussion explains the iterative method which DYNGEN and its predecessor GENENG use to calculate steady-state operating points. As noted earlier, the calculation of a steady-state operating point requires solution of a system of nonlinear equations, corresponding to various engine matching constraints such as rotational speeds, airflows, compressor and turbine work functions, and nozzle flow functions. In order to satisfy these constraints, there are available an equal number of engine parameters which may be varied, such as compressor and turbine pressure ratios and flow functions. The specific number of engine parameters (independent variables) to be varied and engine error variables (dependent variables) to be satisfied depends on the type of engine configuration being studied and varies from three for a single-spool turbojet engine to nine for a three-spool engine. DYNGEN searches for the values of the engine parameters which result in the engine error variables being reduced to nearly zero.

If the independent variables are denoted by V_j and the dependent variables by E_i, the matching equations can be written as

$$E_i(V_j) = 0 \qquad \begin{array}{l} i = 1, 2, \ldots, n \\ j = 1, 2, \ldots, n \end{array}$$

This is a set of nonlinear equations, which must be satisfied for a steady-state solution. The procedure used to satisfy these equations is the multivariable Newton-Raphson method (ref. 6). With this method, changes in E are assumed to be related to changes in V by first-order, finite-difference equations:

$$\Delta E = M \, \Delta V$$

where ΔV and ΔE are n-vectors denoting changes in V and E from some reference condition and M is an $n \times n$ matrix of partial derivatives of E with respect to V:

$$M_{ij} = \frac{\partial E_i}{\partial V_j}$$

The matrix M is obtained by calculating a reference case and n independent perturbed cases, such that only the j^{th} variable V_j is perturbed from its reference value on the

j^{th} case. Then for the j^{th} case,

$$M_{ij} \approx \frac{\Delta E_i}{\Delta V_j} \qquad i = 1, 2, . . ., n$$

Once the matrix M is obtained, the reference case is improved by using

$$V = V_r - M^{-1}E_r$$

If the system of equations were linear, this process would lead to convergence in one iteration. In practice, nonlinearities in the system prevent immediate convergence. In this case, the new V and E are taken to be the reference values, and a new matrix is generated. If the system is not too nonlinear and initial guesses for V are reasonably accurate, convergence is achieved in several iterations.

Dynamic Equations

Once an initial steady-state solution has been obtained, a time-varying solution may be generated. This requires the solution of a set of differential equations which model the system. The specific equations which are used to model the engine were discussed in the main text. In this section, the procedure used to solve the differential equations in DYNGEN is discussed.

Consider first the differential equation

$$\frac{dy}{dt} = f(y, t) \tag{A1}$$

In order to obtain a numerical solution on a digital computer, this differential equation must be replaced by a difference equation in such a way that the solution of the difference equation is, in some sense, close to that of the differential equation. There are many ways in which this can be done, as discussed, for example, in reference 6. A common method is to use a difference equation of the form

$$y_{j+1} = y_j + \Delta t\left[\epsilon f(y_j, t_j) + (1 - \epsilon)f(y_{j+1}, t_{j+1})\right] \tag{A2}$$

where

$$y_j \triangleq y(t_0 + j\ \Delta t)$$

and

$$0 \leq \epsilon \leq 1$$

The bracketed quantity in equation (A2) represents a weighted average of the derivative f(y, t) over the integration interval $\left[t_j, t_{j+1}\right]$. For $\epsilon = 1$, equation (A2) becomes

$$y_{j+1} = y_j + \Delta t \, f(y_j, t_j) \tag{A3}$$

Equation (A3) is known as Euler's method and allows explicit calculation of y_{j+1} as a function of the previous values y_j and t_j. On the other hand, for $\epsilon \neq 1$, equation (A2) is the modified Euler method. In general, it cannot be solved explicitly for y_{j+1} because of the dependence of f on y_{j+1} which appears on the right side of the equation. In this case, some form of iteration must be used at each integration step to solve for y_{j+1}.

From the standpoint of simplicity of the integration formula, use of equation (A3) is clearly preferable to use of equation (A2). However, there are two other important considerations: accuracy and stability. As discussed in the literature (e.g., ref. 6), use of equation (A2) can lead to greater integration accuracy. Even more important for the dynamic engine simulation problem is the stability consideration.

In order to illustrate the stability consideration, consider the linear differential equation

$$\frac{dy}{dt} = ay \tag{A4}$$

For this equation, equation (A2) becomes

$$y_{j+1} = y_j + a \, \Delta t\left[\epsilon y_j + (1 - \epsilon) y_{j+1}\right] \tag{A5}$$

which can be solved for y_{j+1} to give

$$y_{j+1} = \left(\frac{1 + a\epsilon \, \Delta t}{1 + a\epsilon \, \Delta t - a \, \Delta t}\right) y_j \tag{A6}$$

the general solution for y_j can be written

$$y_j = r^j y_0 \tag{A7}$$

where

$$r = \frac{1 + a\epsilon \, \Delta t}{1 + a\epsilon \, \Delta t - a \, \Delta t} \tag{A8}$$

The original differential equation (A4) is stable for $a < 0$; the difference equation solution, equation (A7), is stable for $|r| < 1$. From equation (A8) the requirements for stability of equation (A7) can be established in terms of the requirements on integration step size Δt. Solving equation (A8) for Δt yields

$$\Delta t = \frac{1 - r}{a(\epsilon r - r - \epsilon)} \tag{A9}$$

The upper and lower bounds for Δt are obtained by setting $r = \pm 1$ in equation (A9). This results in

$$\Delta t < \frac{2}{a(1 - 2\epsilon)} \qquad \epsilon > \frac{1}{2} \tag{A10a}$$

$$\Delta t \text{ is unconstrained for } \epsilon < \frac{1}{2} \tag{A10b}$$

In particular, for the Euler method ($\epsilon = 1$) the step size must be less than $-2/a$ in order to avoid numerically induced instability. For $\epsilon < 1/2$ the numerical method leads to a stable solution for any value of integration step size.

These results are readily generalized to a system of linear differential equations. Consider the system of equations

$$\frac{dy}{dt} = Ay \tag{A11}$$

where y is an n-vector and A is the $n \times n$ system matrix. Use of the numerical algorithm in equation (A2) results in

$$y_{j+1} = y_j + A\,\Delta t\left[\epsilon y_j + (1 - \epsilon)y_{j+1}\right] \tag{A12}$$

which has the general solution

$$y_j = \Phi^j y_0 \tag{A13}$$

where

$$\Phi = (I + A\epsilon\,\Delta t - A\,\Delta t)^{-1}(I + A\epsilon\,\Delta t)$$

As shown in reference 7, equation (A11) is stable if, and only if, the eigenvalues of A all have negative real parts; the difference equation solution (A13) is stable if, and only if, all the eigenvalues of Φ have magnitudes less than unity.

It will now be proved that if λ is an eigenvalue of A,

$$\mu = \frac{1 + \lambda\epsilon\ \Delta t}{1 + \lambda\epsilon\ \Delta t - \lambda\ \Delta t} \tag{A14}$$

is an eigenvalue of Φ. Proof: Let λ be an eigenvalue of A. Then

$$|A - \lambda I| = 0$$

If μ is an eigenvalue of Φ,

$$|\Phi - \mu I| = 0$$

But

$$|\Phi - \mu I| = |(I + A\epsilon\ \Delta t - A\ \Delta t)^{-1}(I + A\epsilon\ \Delta t) - \mu I|$$

$$= \frac{|(I + A\epsilon\ \Delta t) - \mu(I + A\epsilon\ \Delta t - A\ \Delta t)|}{|I + A\epsilon\ \Delta t - A\ \Delta t|}$$

$$= \frac{|(1 - \mu)(I + A\epsilon\ \Delta t) + \mu A\ \Delta t|}{|I + A\epsilon\ \Delta t - A\ \Delta t|}$$

But from equation (A14),

$$1 - \mu = - \frac{\lambda\ \Delta t}{1 + \lambda\epsilon\ \Delta t - \lambda\ \Delta t}$$

so that

$$|\Phi - \mu I| = \frac{|-\lambda\ \Delta t(I + A\epsilon\ \Delta t) + (1 + \lambda\epsilon\ \Delta t)\Delta t\ A|}{(1 + \lambda\epsilon\ \Delta t - \lambda\ \Delta t)|I + A\epsilon\ \Delta t - A\ \Delta t|}$$

$$= \frac{\Delta t|A - \lambda I|}{(1 + \lambda\epsilon\ \Delta t - \lambda\ \Delta t)|I + A\epsilon\ \Delta t - A\ \Delta t|}$$

$$= 0$$

which completes the proof.

The similarity of equations (A14) and (A8), together with the requirement that all eigenvalues μ have magnitudes less than unity, allows the conclusion, similar to equation (A10), that

$$\Delta t < \frac{2}{\lambda_{max}(1 - 2\epsilon)} \qquad \epsilon > \frac{1}{2} \tag{A15a}$$

$$\Delta t \text{ is unconstrained for } \epsilon < \frac{1}{2} \tag{A15b}$$

where λ_{max} is the eigenvalue of A having the greatest magnitude. In particular, for the Euler method the step size is restricted by

$$\Delta t < -\frac{2}{\lambda_{max}} \tag{A16}$$

in order to avoid numerical instability.

These results are valid only for a linear system, and no such general proofs are available for nonlinear systems. However, in an intuitive sense, it seems reasonable that equation (A16) would be applicable to nonlinear systems if the matrix A and eigenvalues λ were interpreted as "average" values over an integration step and if the system of equations (A11) was not too nonlinear.

The significance of equation (A16), particularly for the dynamic engine simulation problem, is the following: The dynamic engine simulation generally contains a mix of high and low frequencies. The high frequencies result from the lumped-volume representation of component dynamics, which includes the storage of mass and energy. The low frequencies result, for example, from rotor dynamics and the slow motion of the exhaust nozzle and its associated control logic. Frequently, the simulation user is interested in low-frequency effects, such as overall engine spool-up time, and is not concerned with high-frequency effects. Typical transients are 5 to 10 seconds in duration.

If the simulation uses Euler's method, the integration step size is restricted by the highest frequency in the system, even though the user is not interested in high-frequency information. In this case, a step size of 10^{-4} second, or smaller, is frequency required. On the other hand, if an implicit (modified Euler) technique is used ($\epsilon < 1/2$), there is no upper bound on step size. It can be chosen to suit the desired frequency content of the output, which typically allows a step size of 0.1 second or larger.

Iterative Solution Procedure

A problem which exists with the use of implicit methods, as noted previously, is that for nonlinear differential equations some iterative scheme is required to solve for the values of y_{j+1} at each integration step. The differential equations corresponding to the dynamic model of the engine may be written as

$$\frac{dy}{dt} = f(y) \tag{A17}$$

where y and f are vectors. The state vector y represents pressures, temperatures, and rotor speeds. The dimension of y (and f) depends on the type of engine configuration being studied. Nine state variables are required for a single-spool turbojet engine, and a greater number for more complex engines.

The difference-equation representation used in DYNGEN utilizes $\epsilon = 0$, so that equation (A17) becomes

$$y_{j+1} = y_j + \Delta t \, f(y_{j+1}) \tag{A18}$$

The discussion of the sample configuration in the main text of the report shows how the dynamic equations are incorporated into the structure of the steady-state solution. The steady-state continuity, energy, and power equations are modified to be dynamic equations. The resulting dynamic equations are then either included as error equations or are used to calculate flows and enthalpies at various stations throughout the engine.

APPENDIX B

DYNGEN PROGRAM

Listing of DYNGEN

```
$IBFTC AFQUIR
      SUBROUTINE AFQUIR (X,AIND,DEPEND,ANS,AJ,TOL,DIR,ANEW,ICON)
      DIMENSION X(9)
C X(1)=NAME OF ARRAY TO USE
C AIND= INDEPENDANT VARIABLE
C DEPEND= DEPENDANT VARIABLE
C ANS=ANSWER UPON WHICH TO CONVERGE
C AJ=MAX NUMBER OF TRYS
C TOL=PERCENT TOLERANCE FOR CONVERGENCE
C DIR=DIRECTION AND PERCENTAGE FOR FIRST GUESS
C ANEW=CALCULATED VALUE OF NEXT TRY AT INDEPENDANT VARIABLE
C ICON=CONTROL  =1 GO THRU LOOP AGAIN
C               =2 YOU HAVE REACHED THE ANSWER
C               =3 COUNTER HAS HIT LIMITS
C X(2)=COUNTER STORAGE
C X(3)=CHOOSES METHOD OF CONVERGENCE
C X(4)=THIRD DEPEND VAR
C X(5)=THIRD IND VAR
C X(6)=SECOND DEPEND VAR
C X(7)=SECOND IND VAR
C X(8)=FIRST DEPEND VAR
C X(9)=FIRST IND VAR
C X(3) MUST BE ZERO UPON FIRST ENTRY TO ROUTINE
      Y=0.
      IF (ANS) 1,2,1
1     DEP=DEPEND-ANS
      TOLANS=TOL*ANS
      GO TO 3
2     DEP=DEPEND
      TOLANS=TOL
3     IF (ABS(DEP)-TOLANS) 5,5,4
4     IF (X(2)-AJ) 8,8,7
5     ANEW=AIND
      X(2)=0.
      ICON=2
      RETURN
6     ANEW=Y
      X(2)=X(2)+1.
      ICON=1
      RETURN
7     ANEW=Y
      X(2)=0.
      ICON=3
      RETURN
8     IF (X(3)) 9,9,12
C *** FIRST GUESS USING DIR
9     X(3)=1.
      X(8)=DEP
      X(9)=AIND
      IF (AIND) 10,11,10
10    Y=DIR*AIND
      GO TO 6
11    Y=DIR
      GO TO 6
12    IF (X(3)-1.) 13,13,16
C *** LINEAR GUESS
13    X(3)=2.
      X(6)=DEP
      X(7)=AIND
```

[redacted]

```
      IF (X(8)-X(6)) 14,9,14
14    IF (X(9)-X(7)) 15,9,15
15    A=(X(9)-X(7))/(X(8)-X(6))
      Y=X(9)-A*X(8)
      IF (ABS(10.*X(9))-ABS(Y)) 9,9,6
C *** QUADRATIC GUESS
16    X(4)=DEP
      X(5)=AIND
      IF (X(7)-X(5)) 18,17,18
17    IF (X(6)-X(4)) 13,9,13
18    IF (X(6)-X(4)) 19,13,19
19    IF (X(9)-X(5)) 23,20,23
20    IF (X(8)-X(4)) 21,22,21
21    X(9)=X(7)
      X(8)=X(6)
      GO TO 13
22    X(9)=X(7)
      X(8)=X(6)
      X(3)=1.
      IF (X(9)) 10,11,10
23    IF (X(8)-X(4)) 24,21,24
24    F=(X(6)-X(4))/(X(7)-X(5))
      A=(X(8)-X(4)-F*(X(9)-X(5)))/((X(9)-X(7))*(X(9)-X(5)))
      B=F-A*(X(5)+X(7))
      C=X(4)+X(5)*(A*X(7)-F)
      IF (A) 27,25,27
25    IF (B) 26,7,26
26    Y=-C/B
      GO TO 47
27    IF (B) 32,28,32
28    IF (C) 30,29,30
29    Y=0.
      GO TO 47
30    G=-C/A
      IF (G) 7,7,31
31    Y=SQRT(G)
      YY=-SQRT(G)
      GO TO 37
32    IF (C) 34,33,34
33    Y=-B/A
      YY=0.
      GO TO 37
34    D=4.*A*C/B**2
      IF (1.-D) 13,35,36
35    Y=-B/(2.*A)
      GO TO 47
36    E=SQRT(1.-D)
      Y=(-B/(2.*A))*(1.+E)
      YY=(-B/(2.*A))*(1.-E)
37    J=4
      DEPMIN=ABS(X(4))
      DO 39 I=6,8,2
      IF (DEPMIN-ABS(X(I))) 39,39,38
38    J=I
      DEPMIN=ABS(X(I))
39    CONTINUE
      K=J+1
      IF ((X(K)-Y)*(X(K)-YY)) 42,42,40
40    IF (ABS(X(K)-Y)-ABS(X(K)-YY)) 47,47,41
41    Y=YY
      GO TO 47
42    IF (J-6) 43,44,44
43    JJ=J+2
      KK=K+2
      GO TO 45
44    JJ=J-2
      KK=K-2
45    SLOPE=(X(KK)-X(K))/(X(JJ)-X(J))
      IF (SLOPE*X(J)*(X(K)-Y)) 46,46,47
46    Y=YY
47    X(9)=X(7)
      X(8)=X(6)
      X(7)=X(5)
```

```
      X(6)=X(4)
      GO TO 6
      END
```

```
$IBFTC ATMOS
      SUBROUTINE ATMOS (ZFT,TM,SIGMA,RHO,THETA,DELTA,CA,AMU,K)
C    THIS IS A SUBROUTINE TO COMPUTE CERTAIN ELEMENTS OF THE 1962
C    U.S. STANDARD ATMOSPHERE UP TO 90 KILOMETERS.
C     CALLING SEQUENCE...
C
C     CALL ATMOS (ZFT, TM, SIGMA, RHO, THETA, DELTA, CA, AMU, K)
C          ZFT   =   GEOMETRIC ALTITUDE (FEET)
C          TM    =   MOLECULAR SCALE TEMPERATURE (DEGREES RANKINE)
C          SIGMA =   RATIO OF DENSITY TO THAT AT SEA LEVEL
C          RHO   =   DENSITY(LB-SEC**2-FT**(-4)    OR    SLUG-FT**(-3))
C          THETA =   RATIO OF TEMPERATURE TO THAT AT SEA LEVEL
C          DELTA =   RATIO OF PRESSURE TO THAT AT SEA LEVEL
C          CA    =   SPEED OF SOUND (FT/SEC)
C          AMU   =   VISCOSITY COEFFICIENT (LB-SEC/FT**2)
C
C          K = 1 NORMAL
C            = 2 ALTITUDE LESS THAN -5000 METERS OR GREATER THAN 90 KM
C            = 3 FLOATING POINT OVERFLOW
C
C    ALL DATA AND FUNDAMENTAL CONSTANTS ARE IN THE METRIC SYSTEM AS
C    THESE QUANTITIES ARE DEFINED AS EXACT IN THIS SYSTEM.
C
C    THE RADIUS OF THE EARTH (REFT59) IS THE VALUE ASSOCIATED WITH THE
C    1959 ARDC ATMOSPHERE SO THAT PROGRAMS CURRENTLY USING THE LIBRARY
C    ROUTINE WILL NOT REQUIRE ALTERATION TO USE THIS ROUTINE.
      COMMON/UNITS/SI
      LOGICAL SI
      DIMENSION HB(10),TMB(10),DELTAB(10),ALM(10)
      DATA(HB(I),    TMB(I),    DELTAB(I),      ALM(I),I=1,10)/
     1   -5.0,      320.65,    1.75363E 00,    -6.5,
     2    0.0,      288.15,    1.00000E 00,    -6.5,
     3   11.0,      216.65,    2.23361E-01,     0.0,
     4   20.0,      216.65,    5.40328E-02,     1.0,
     5   32.0,      228.65,    8.56663E-03,     2.8,
     6   47.0,      270.65,    1.09455E-03,     0.0,
     7   52.0,      270.65,    5.82289E-04,    -2.0,
     8   61.0,      252.65,    1.79718E-04,    -4.0,
     9   79.0,      180.65,    1.0241 E-05,     0.0,
     $   88.743,    180.65,    1.6223 E-06,     0.0/
      DATA  REFT59/2.0855531E 07/, GZ    /9.80665/,
     1       AMZ   /28.9644      /, RSTAR /8.31432/,
     2       FTTOKM/3.048E-04    /, S     /110.4 /,
     3       AMUZ  /1.2024E-05   /, CAZ   /1116.45/,
     4       RHOZ  /0.076474     /, GZENG /32.1741/
C   CONVERT GEOMETRIC ALTITUDE TO GEOPOTENTIAL ALTITUDE
C      IF IN SI UNITS, CHANGE ZFT TO FEET
      IF (SI) ZFT=ZFT*3.280833
      HFT=(REFT59/(REFT59+ZFT))*ZFT
C   CONVERT HFT AND ZFT TO KILOMETERS
      Z=FTTOKM*ZFT
      H=FTTOKM*HFT
      K=1
      TMZ=TMB(2)
      IF (H.LT.-5.0.OR.Z.GT.90.0) GO TO 7
      DO 1 M=1,10
      IF (H-HB(M)) 2,3,1
1     CONTINUE
      GO TO 7
2     M=M-1
3     DELH=H-HB(M)
      IF (ALM(M).EQ.0.0) GO TO 4
      TMK=TMB(M)+ALM(M)*DELH
C   GRADIENT IS NON ZERO, PAGE 10, EQUATION I.2.10-(3)
```


[redacted]

```
      DELTA=DELTAB(M)*((TMB(M)/TMK)**(GZ*AMZ/(RSTAR*ALM(M))))
      GO TO 5
4     TMK=TMB(M)
C  GRADIENT IS ZERO, PAGE 10, EQUATION I.2.10-(4)
      DELTA=DELTAB(M)*EXP(-GZ*AMZ*DELH/(RSTAR*TMB(M)))
5     THETA=TMK/TMZ
      SIGMA=DELTA/THETA
      ALPHA=SQRT(THETA**3)*((TMZ+S)/(TMK+S))
C  CONVERSION TO ENGLISH UNITS
      TM=1.8*TMK
      RHO=RHOZ*SIGMA/GZENG
      CA=CAZ*SQRT(THETA)
      AMU=AMUZ*ALPHA/GZENG
      IF (SI) GO TO 100
      GO TO 101
  100 TM=TM/1.8
      RHO=RHO*515.379
      CA=CA*.3048
      AMU=AMU*47.880258
      ZFT=ZFT/3.280833
C       IF IN SI UNITS*
C             TM         DEGREES KELVIN
C             RHO        KG/M**2
C             CA         M/SEC
C             AMU        (N-SEC)/M**2
C             ZFT        M
  101 CONTINUE
      CALL OVERFL (J)
      GO TO (6,8),J
6     K=K+2
      GO TO 8
7     K=2
8     RETURN
      END
```

```
$IBFTC COAFBN
      SUBROUTINE COAFBN
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES   ,JDES   ,KDES   ,MODE   ,INIT   ,IDUMP  ,IAMTP  ,IGASMX,
     2IDBURN,IAFTBN,IDCD   ,IMCD   ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU   ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS   ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS   ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS   ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
     7T24DS  ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS   ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55   ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21    ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4     ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55    ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF    ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC    ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP   ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP   ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM     ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP  ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21   ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24    ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28    ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD    ,WFD   ,WG24  ,FAR24 ,ETAC  ,DPDUC ,BYPASS,DUMS3 ,
```

```
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON/UNITS/SI
      LOGICAL SI
      COMMON/WHRERR/ICOAFB,ICODUC,ICOMIX
      DIMENSION Q(9)
      DATA AWORD/6HCOAFBN/
      WORD=AWORD
      Q(2)=0.
      Q(3)=0.
      IF (SI) GO TO 100
      AJ=778.26
      AJX=2.719
      CAPSF=2116.2170
      G=32.174049
      PRATM=14.696
      TDEL=2000.0
      T7MAX=4000.0
      RA=.0252
      GO TO 101
  100 AJ=1.0
      AJX=1.0
      CAPSF=101325.0
      G=1.0
      PRATM=14.696/101324.6
      TDEL=1111.0
      T7MAX=2222.0
      RA=286.9
  101 CONTINUE
      ICOAFB=0
C***  P6DS AND AM6DS ARE SET FOR GENERALIZATION OF AFTERBURNER
C***  EFFICIENCY MAP GENERALIZATION
      IF (IDES .EQ. 1) P6DS=P6*PRATM
      IF (IDES.EQ.1) AM6DS=AM6
      WF6 = FAR55*WG55/(FAR55+1.)
      IF(IGASMX.GT.0) WF6 = WF6 + FAR24*WG24/(FAR24+1.)
      WA6=WG6-WF6
C *** DRY LOSS
      WG6C=WG6*SQRT(T6)/P6
      IF (IDES.EQ.1) WG6CDS=WG6C
      DPAFT=DPAFDS*(WG6C/WG6CDS)
      IF (DPAFT.GT.1.) DPAFT=1.
      P7=P6*(1.-DPAFT)
      A7=A6
      FAR6=WF6/WA6
      CALL PROCOM (FAR6,T6,XX1,XX2,XX3,XX4.PHI6,XX6)
      WQA=WG6/A7
      C1=P7*SQRT(G/(T6*AJ))*CAPSF
      AM7=AM6
```

```
      TS7=0.875*T6
1     DO 2 I=1,15
      CALL PROCOM (FAR6,TS7,CS7,AK7,CP7,REX7,PHIS7,HS7)
      V7=AM7*CS7
      HSCAL=H6-V7**2/(2.*G*AJ)
      DELHS=HSCAL-HS7
      IF (ABS(DELHS).LE.0.0005*HSCAL) GO TO 3
2     TS7=TS7+DELHS/CP7
      ICOAFB=1
      GO TO 14
3     WQAT=C1*SQRT(AK7/REX7)*AM7/(1.+(AK7-1.)*AM7**2/2.)**((AK7+1.)/(2.*
     1(AK7-1.)))
      DIR=WQA/WQAT
      EW=(WQA-WQAT)/WQA
      CALL AFQUIR (Q(1),AM7,EW,0.,40.,.001,DIR,AM7T,IGO)
      ICOAFB=2
      GO TO (4,5,14),IGC
4     AM7=AM7T
      IF (AM7.GE.1.0) AM7=0.9
      GO TO 1
5     PS7=P7/EXP((PHI6-PHIS7)/REX7)
      IF (IAFTBN.GT.0) GO TO 7
C *** NON-AFTERBURNING
6     T7=T6
      WFA=0.0
      FAR7=FAR6
      WG7=WG6
      IF (IDES.EQ.1.AND.T7DS.NE.0.) GO TO 7
      GO TO 20
C *** AFTERBURNING
    7 IF (IAFTBN .EQ. 2) T7=T6+TDEL
      IF (IDES.EQ.1) T7=T7DS
      IF (T7.LE.T6) GO TO 6
      RHO65=CAPSF*PS7/(AJ*REX7*TS7)
      PS65=PS7
      V65=V7
      Q(2)=0.
      Q(3)=0.
    8 IF (T7 .GT. T7MAX) T7=T7MAX
      IF (T7 .LT. T6) T7=T6*1.001
      IF (SI) T7=T7*9.0/5.0
      HV=((((((-.4594317E-19*T7)-.2034116E-15)*T7+.2783643E-11)*T7+.2051
     1501E-07)*T7-.2453116E-03)*T7-.9433296E-01)*T7+.1845537E+05
      IF (SI) T7=T7*5.0/9.0
      IF (SI) HV=HV*2325.4295
      CALL THERMO (P7,HA,T7,XX1,XX2,1,FAR6,0)
C***  TO ALTER DESIGN ABETAA MAP FROM GENERAL TO SPECIFIC MAP
      IF (IDES.NE.1) GO TO 9
      FAR7DS=(HA-H6)/(HV*ETAADS)
      CALL ETAAB (0.,0.,0.,0.,ETAADS,ETAASV,P6DS,P6DSAV,AM6DS,AM6DSV,IDE
     1S,FAR7DS,FAR7SV)
      T7=T6
      GO TO 20
    9 P6GS=P6*PRATM
      FAR7GS=(HA-H6)/(HV*ETAADS)
      DO 10 II=1,15
      CALL ETAAB (FAR7GS,AM6,P6GS,ETAA,ETAADS,ETAASV,P6DS,P6DSAV,AM6DS,A
     1M6DSV,IDES,FAR7DS,FAR7SV)
      FAR7=(HA-H6)/(HV*ETAA)
      DELFA7=ABS(FAR7-FAR7GS)
      IF (DELFA7.LE.0.01*FAR7) GO TO 11
10    FAR7GS=FAR7
11    CONTINUE
      IF (FAR7.GT.0.) GO TO 12
      ICOAFB=3
      CALL ERROR
12    WFAX=FAR7*WG6
      IF (IAFTBN.EQ.1) GO TO 15
      ERRW=(WFA-WFAX)/WFA
      DIR=SQRT(WFA/WFAX)
      CALL AFQUIR (Q(1),T7,ERRW,0.,30.,.0005,DIR,T7T,IGO)
      ICOAFB=4
      GO TO (13,16,14), IGO
13    T7=T7T
```

```
      GO TO 8
14    CALL ERROR
15    WFA=WFAX
16    FAR7=(WF6+WFA)/WA6
      WG7=WG6+WFA
C *** MOMENTUM LOSS
      CALL PROCOM (FAR7,T7,XX1,XX2,XX3,REX7,PHI7,H7)
      RHO7=CAPSF*P7/(AJ*REX7*T7)
      V7=WG7/(RHO7*A7)
      Q(2)=0.
      Q(3)=0.
      PS7=PS65-0.01
17    RHO7=WG7/(V7*A7)
      HS7=H7-V7**2/(2.*G*AJ)
      CALL THERMO (1.0,HS7,TS7,PHIS7,XX2,1,FAR7,1)
      IF (TS7.GE.301.) GO TO 18
      CALL THERMO (1.0,HS7,400.,PHIS7,XX2,1,FAR7,0)
      V7=SQRT(2.*G*AJ*(H7-HS7))
      GO TO 17
18    PS7=RHO7*AJ*REX7*TS7/CAPSF
      PS7A=PS65+(RHO65*V65**2-RHO7*V7**2)/(G*CAPSF)
      DIR=SQRT(ABS(PS7/PS7A))
      EP=(PS7-PS7A)/PS7
      CALL AFQUIR (Q(1),V7,EP,0.,50.,.001,DIR,V7T,IGO)
      V7=V7T
      IF (V7.LT.100.) V7=100.
      ICOAFB=5
      GO TO (17,19,14),IGO
19    P7=PS7*EXP((PHI7-PHIS7)/REX7)
      CALL PROCOM (FAR7,TS7,CS7,XX2,XX3,XX4,XX5,XX6)
      AM7=V7/CS7
20    CALL THERMO (P7,H7,T7,S7,XX2,1,FAR7,0)
      IF(VAFTBN.EQ.0.0) GO TO 31
      Q(2)=0.0
      Q(3)=0.0
      WG7P=WG7
      H7P=H7
      P7DOT=DERIV(18,P7)
28    CONTINUE
      CALL THERMO(P7,H7,T7,S7,XX2,1,FAR7,0)
      WG7=WG7P-P7DOT*VAFTBN/T7/(1.4*RA)
      U7=H7-AJX*RA*T7
      U7DOT=DERIV(19,U7)
      H7X=(WG7P*H7P-(WG7P-WG7)*U7-U7DOT*P7*VAFTBN/T7/RA    )/WG7
      ERRW=(H7-H7X)/H7
      DIR=SQRT(ABS(H7/H7X))
      CALL AFQUIR(Q(1),T7,ERRW,0.,20.,0.0001,DIR,T7T,IGO)
      ICOAFB=6
      GO TO (29,31,30),IGO
29    T7=T7T
      GO TO 28
30    CALL ERROR
31    CONTINUE
      ICOAFB=0
      CALL COMNOZ
      RETURN
C
C
      END
```

```
$IBFTC COCOMB
      SUBROUTINE COCOMB
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
```

```
     2ZFDS   ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS   ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS   ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
     7T24DS  ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS   ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29    ,
     $PS55   ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2     ,
     2T21    ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3     ,
     3T4     ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5     ,
     4T55    ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB   ,
     5CNF    ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4   ,
     6CNC    ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT  ,
     9AM     ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB    ,
     $TFFHP  ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2  ,
     2XT21   ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23    ,
     3T24    ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25    ,
     4T28    ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29    ,
     5WAD    ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3  ,
     6TS28   ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29   ,
     7XT55   ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25   ,
     8XWFB   ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB   ,
     9T6     ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7     ,
     $T8     ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6    ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25    ,
     2PS6    ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25   ,
     3TS8    ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9    ,
     4VA     ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM   ,
     5FGM    ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38    ,
     7H38    ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39   ,
     8V39    ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50    ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI   ,
     2TFFIP  ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS   ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF  ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24    ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /UNITS/ SI
      LOGICAL FXFN2M,FXM2CP,SI
      COMMON / COMB/PSI(15),DELT(15,15),ETA(15,15),NPS,NPT(15)
      DIMENSION Q(9),DUMBO(15,15)
      DATA AWORD/6HCOCOMB/
      WORD=AWORD
      IF(SI) GO TO 100
      RA=.0252
      AJ=2.719
      TMAX=4000.
      TMIN=1000.
      GO TO 101
  100 RA=286.9
      AJ=1.0
      TMAX=2222.
      TMIN=555.5
  101 CONTINUE
      Q(2)=0.
      Q(3)=0.
      P3PSI=14.696*P3
      IF(SI) P3PSI=.14504E-3*P3
```

```
      WA3C=WA3*SQRT(T3)/P3PSI
      IF(SI) WA3C=WA3*SQRT(T3)/P3
      IF (IDES.EQ.1) WA3CDS=WA3C
      DPCOM=DPCODS*(WA3C/WA3CDS)
      IF (DPCOM.GT.1.) DPCOM=1.
      P4=P3*(1.-DPCOM)
      IF(IDES.EQ.1.AND.MODE.EQ.2) T4=(TMAX+TMIN)/2.
      IF(ITRAN.EQ.1.AND.MODE.EQ.2) CALL FCNTRL
1     IF(T4.GT.TMAX) T4=TMAX
      IF(T4.GE.TMIN) GO TO 2
      T4=TMIN
      IF (MODE.EQ.1) MAPEDG=1
2     DTCO=T4-T3
      IF(SI) DTCO=DTCO*9.0/5.0
      P3PSIN=P3PSI
      CALL SEARCH (-1.,P3PSIN,DTCO,ETAB,DUMMY,PSI(1),NPS,DELT(1,1),ETA(1
     1,1),DUMBO(1,1),NPT(1),15,15,IGO)
      IF (IGO.EQ.7) CALL ERROR
      IF (IDES.NE.1) GO TO 4
      ETABCF=ETABDS/ETAB
4     ETAB=ETABCF*ETAB
      IF (SI) T4=T4*9.0/5.0
      HV=((((((-.4594317E-19*T4)-.2034116E-15)*T4+.2783643E-11)*T4+.2051
     1501E-07)*T4-.2453116E-03)*T4-.9433296E-01)*T4+.1845537E+05
      IF (SI) T4=T4*5.0/9.0
      IF (SI) HV=HV*2325.4295
      CALL THERMO (P4,HA,T4,XX1,XX2,0,0.0,0)
      FAR4=(HA-H3)/(HV*ETAB)
      IF (FAR4.LT.0.) FAR4=0.
      WFBX=FAR4*WA3
      IF (MODE.NE.2) GO TO 7
      ERRW=(WFB-WFBX)/WFB
      DIR=SQRT(WFB/WFBX)
      CALL AFQUIR (Q(1),T4,ERRW,0.,20.,0.0001,DIR,T4T,IGO)
      GO TO (5,8,6),IGO
5     T4=T4T
      GO TO 1
6     CALL ERROR
7     WFB=WFBX
      IF(IDES.EQ.1) WFBDS=WFB
8     CALL THERMO (P4,H4,T4,S4,XX2,1,FAR4,0)
      WG4=WFB+WA3
      IF(VCOMB.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      WG4P=WG4
      H4P=H4
      P4DOT=DERIV(10,P4)
18    CONTINUE
      CALL THERMO(P4,H4,T4,S4,XX2,1,FAR4,0)
      WG4=WG4P-P4DOT*VCOMB/T4/1.4/RA
      U4=H4-AJ*RA*T4
      U4DOT=DERIV(11,U4)
      H4X=(WG4P*H4P-(WG4P-WG4)*U4-U4DOT*P4*VCOMB/T4/RA)/WG4
      ERRW=(H4-H4X)/H4
      DIR=SQRT(ABS(H4/H4X))
      CALL AFQUIR(Q(1),T4,ERRW,0.,20.,0.0001,DIR,T4T,IGO)
      GO TO (19,21,20),IGO
19    T4=T4T
      GO TO 18
20    CALL ERROR
21    CONTINUE
      IF(IDES.EQ.1) WRITE(6,10) WA3CDS,ETABCF
      IF (FXM2CP.OR.ISPOOL.EQ.1) GO TO 9
      CALL COHPTB
      RETURN
9     P50=P4
      H50=H4
      T50=T4
      S50=S4
      FAR50=FAR4
      WG50=WG4
C     SET HIGH PRESSURE TURBINE PARAMETERS TO ZERO, NOT USED
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```
      TFFHP=0.
      CNHP=0.
      DHTC=0.
      DHTCHP=0.
      ETATHP=0.
      IF (FXM2CP) CALL COIPTB
      IF (FXM2CP) RETURN
C     IF RUNNING 1 SPOOL TJ GO TO COHPTB TO ZERO OUT COIPTB
      CALL COHPTB
      RETURN
C
C
C
10    FORMAT (17HOCOMBUSTOR DESIGN,7X8H WA3CDS=,E15.8,8H ETA8CF=,E15.8)
      END
```

```
$IBFTC COCOMP
      SUBROUTINE COCOMP
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,CPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWDVFN,PS39  ,FFDVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
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     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /FLOWS/ WAFP,WAIP,WACP
      COMMON /UNITS/ SI
      LOGICAL FXFN2M,FXM2CP,DUMSPL,FAN,SI
      COMMON / COMP/CNX(15),PRX(15,15),WACX(15,15),ETAX(15,15),
     1NCN,NPT(15)
      DIMENSION Q(9),WLH(2)
      DATA AWORD,WLH/6HCOCOMP,6H (LO) ,6H (HI) /
      WORD=AWORD
      IF (SI) GO TO 100
      TSTD=518.668
      PSTD=1.0
      RA=.0252
      AJ=2.719
      GO TO 101
100   TSTD=288.149
      PSTD=101325.
      RA=286.9
      AJ=1.0
101   THETA=SQRT(T21/TSTD)
      DELTA=P21/PSTD
      IF (IDES.NE.1) GO TO 1
      THETAD=THETA
      WACDS=WAC
      WACC=WAC*THETA/DELTA
      IF (.NOT.FXM2CP) PCNC=PCNCDS
1     IF (.NOT.FXM2CP) GO TO 2
C     SPEEDS OF MIDDLE AND INNER SPOOL ARE THE SAME
      SPDMID=CNI*SQRT(T22/TSTD)
      CNC=SPDMID/THETA
      PCNC=100.*CNC*THETA/THETAD
      IF (IDES.EQ.1) PCNCDS=PCNC
2     CNC=PCNC*THETAD/(100.*THETA)
      IF (ZC.LT.0.) ZC=0.
      IF (ZC.GT.1.) ZC=1.
      CNCS=CNC
      IF (ISPOOL.EQ.1) GO TO 12
      CALL SEARCH (ZC,CNC,PRC,WACC,ETAC,CNX(1),NCN,PRX(1,1),WACX(1,1),ET
     1AX(1,1),NPT(1),15,15,IGO)
      GO TO 13
12    PRC=1.
      ETAC=1.
      WAC=WA21
      WACC=WAC*THETA/DELTA
      CNC=1.
      PRCCF=1.
13    IF (MODE.EQ.1) GO TO 4
      IF ((CNC-CNCS).GT.0.0005*CNC) MAPEDG=1
4     IF (IGO.EQ.1.OR.IGO.EQ.2) WRITE (8,9) CNCS,WLH(IGO)
      WAC=WACC*DELTA/THETA
      IF (IDES.NE.1) GO TO 5
      T21DS=T21
      IF (ISPOOL.GE.2) PRCCF=(PRCDS-1.)/(PRC-1.)
      ETACCF=ETACDS/ETAC
      IF (ISPOOL.EQ.1) ETACCF=1.0
      WACCF=WACDS/WAC
      WRITE (6,10) PRCCF,ETACCF,WACCF,T21DS
5     PRC=PRCCF*(PRC-1.)+1.
      ETAC=ETACCF*ETAC
      WAC=WACCF*WAC
      WACP=WAC
      IF (.NOT.DUMSPL.OR.PCBLID.NE.0..OR..NOT.FAN) GO TO 6
      WA22=WAC
      WAI=WA22
      WACI=WACC*WACCF
6     WA32=WAI-WAC
      BLI=WA32
      WA21=WAC
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      WACC=WACC*WACCF
      PCBLI=BLI/WAI
      CALL WDUCTI
      IF (PCBLID.EQ.0.) ERR(7)=(WAC-WAI)/WAC
      IF (.NOT.FAN) ERR(5)=(WAF-WAC-BLF)/WAC
      IF (IDES.EQ.1.AND.PCBLID.EQ.0.) ERR(7)=1.E-4
      CALL THCOMP (PRC,ETAC,T21,H21,S21,P21,T3,H3,S3,P3)
      IF(VCOMP.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      H3P=H3
      P3DOT=DERIV(8,P3)
   18 CONTINUE
      CALL THERMO(P3,H3,T3,S3,XX2,0,0.0,0)
      WAC=WACP-P3DOT*VCOMP/T3/1.4/RA
      U3=H3-AJ*RA*T3
      U3DOT=DERIV(9,U3)
      H3X=(WACP*H3P-(WACP-WAC)*U3-U3DOT*P3*VCOMP/T3/RA)/WAC
      ERRW=(H3-H3X)/H3
      DIR=SQRT(ABS(H3/H3X))
      CALL AFQUIR(Q(1),T3,ERRW,0.,20.,0.0001,DIR,T3T,IGO)
      GO TO (19,21,20), IGO
   19 T3=T3T
      GO TO 18
   20 CALL ERROR
   21 CONTINUE
      IF (PCBLC.GT.0.) BLC=PCBLC*WAC
      WA3=WAC-BLC
      BLDU=PCBLDU*BLC
      BLOB=PCBLOB*BLC
      BLHP=PCBLHP*BLC
      BLIP=PCBLIP*BLC
      BLLP=PCBLLP*BLC
      IF (MODE.NE.1) GO TO 7
      IF (ABS(CNC-CNCS).LE.0.001*CNCS) GO TO 8
      WRITE (8,11) CNCS,CNC
      CALL ERROR
    7 PCNC=100.*THETA*CNC/THETAD
    8 CALL COCOMB
      RETURN
C
C
C
    9 FORMAT (19H0* * *  CNC OFF MAP,F10.4,2XA6,11H* * *$$$$$$)
   10 FORMAT (18H0COMPRESSOR DESIGN,6X8H  PRCCF=,E15.8,8H ETACCF=,E15.8,
     18H  WACCF=,E15.8,8H  T21DS=,E15.8)
   11 FORMAT (10H0CNC WAS= ,E15.8,11H  AND NOW= ,E15.8,24H  CHECK PCNC I
     1NPUT$$$$$$)
      END
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```
$IBFTC CODUCT
      SUBROUTINE CODUCT
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
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```
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON/WHRERR/ICOAFB,ICODUC,ICCMIX
      COMMON/UNITS/SI
      LOGICAL SI
      LOGICAL AFTFAN
      DIMENSION Q(9)
      DATA AWORD1,AWORD2/6HCODUCT,6HDNOZZL/
      WORD=AWORD1
      Q(2)=0.
      Q(3)=0.
      GOGO=0.0
      IF (SI) GO TO 100
      AJ=778.26
      AJX=2.719
      CAPSF=2116.2170
      G=32.174049
      TSTD=518.67
      TDEL=2000.0
      TMAX=4000.0
      RA=.0252
      GO TO 101
  100 AJ=1.0
      AJX=1.0
      CAPSF=101325.0
      G=1.0
      TSTD=288.15
      TDEL=1111.0
      TMAX=2222.0
      RA=286.9
  101 CONTINUE
      ICODUC=0
      WAX=WAF-WAI-BLF
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```
      IF (PCBLID.EQ.0.) WAX=WAF-WAC-BLF
      IF (AFTFAN) WAX=WAF-BLF
      WAD=WAX+BLDU
      P23=P22
C***  DRY LOSS
      H23=(BLDU*H3+WAX*H22)/WAD
      CALL THERMO (P23,H23,T23,S23,XX2,1,0.0,1)
      WA23C=WAD*SQRT(T23)/P23
      IF (IDES.EQ.1) WA23DS=WA23C
      BYPASS=(WAF-WAI)/WAI
      IF (AFTFAN) BYPASS=WAF/WAI
      DPDUC=DPDUDS*(WA23C/WA23DS)
      IF (DPDUC.GT.1.) DPDUC=1.0
      P24=P23*(1.-DPDUC)
      CALL PROCOM (0.,T23,XX1,XX2,XX3,XX4,PHI23,XX6)
      IF (IGASMX.GT.0) IDBURN=0
      AM24=AM23
      TS24=T23*0.875
1     DO 2 I=1,15
      CALL PROCOM (0.,TS24,CS24,AK24,CP24,REX24,PHIS24,HS24)
      V24=AM24*CS24
      HSCAL=H23-V24**2/(2.*G*AJ)
      DELHS=HSCAL-HS24
      IF (ABS(DELHS).LE.0.001*HSCAL) GO TO 3
2     TS24=TS24+DELHS/CP24
      ICODUC=1
      GO TO 11
3     C1=P24*SQRT(G/(T23*AJ))*CAPSF
      IF (IDES.NE.1) GO TO 4
      IF (GOGO.GT.0.) GO TO 4
      ASTOA=((AK24+1.)/2.)**((AK24+1.)/(2.*(AK24-1.)))*AM24*(1.+(((AK24-
     1 1.)/2.)*AM24**2))**(-(AK24+1.)/(2.*(AK24-1.)))
      EQWCR=SQRT(G*AK24/REX24/AJ)/(SQRT(TSTD)/CAPSF)*(2.0/(AK24+1.))*
     1*((AK24+1.)/2./(AK24-1.))
      WA23CC=WA23C/SQRT(TSTD)
      A24=1./ASTOA*WA23CC/EQWCR
      GOGO=1.0
4     WQA=WAD/A24
      WQAT=C1*SQRT(AK24/REX24)*AM24/(1.+(AK24-1.)*AM24**2/2.)**((AK24+1.
     1)/(2.*(AK24-1.)))
      DIR=WQA/WQAT
      EW=(WQA-WQAT)/WQA
      CALL AFQUIR (Q(1),AM24,EW,0.,30.,0.001,DIR,AM24T,IGO)
      ICODUC=2
      GO TO (5,6,11),IGO
5     AM24=AM24T
      IF (AM24.GT.1.0) AM24=0.5
      GO TO 1
6     PS24=P24/EXP((PHI23-PHIS24)/REX24)
7     IF (IDBURN.GT.0) GO TO 8
C***  NON-DUCT BURNING
      T24=T23
      WFD=0.
      FAR24=0
      GO TO 17
    8 IF (IDBURN .EQ. 2) T24=T23+TDEL
    9 IF (T24 .GT. TMAX) T24=TMAX
      IF (T24.LT.T23) T24=T23
C***  DUCT BURNING
      RHO42=CAPSF*PS24/(AJ*REX24*TS24)
      PS42=PS24
      V42=V24
      Q(2)=0.
      Q(3)=0.
      IF (T24 .LT. T23) T24 = T23*1.001
C *** IF DESIRED, ENTER CALCULATIONS FOR ETAD HERE
      IF (SI) T24=T24*9.0/5.0
      HV=((((((-.4594317E-19*T24)-.2034116E-15)*T24+.2783643E-11)*T24+.2
     1051501E-07)*T24-.2453116E-03)*T24-.9433296E-01)*T24+.1845537E+05
      IF (SI) T24=T24*5.0/9.0
      IF (SI) HV=HV*2325.4295
      CALL THERMO (P24,HA,T24,XX1,XX2,0,0.0,0)
      FAR24=(HA-H23)/(HV*ETAD)
      IF (FAR24.LT.0.) FAR24=0.
```

```
      WFDX=FAR24*WAD
      IF (IDBURN.NE.2) GO TO 12
      ERRW=(WFD-WFDX)/WFD
      DIR=SQRT(WFD/WFDX)
      CALL AFQUIR (Q(1),T24,ERRW,0.,20.,0.0001,DIR,T24T,IGO)
      ICODUC=3
      GO TO (10,13,11),IGO
10    T24=T24T
      GO TO 9
11    CALL ERROR
12    WFD=WFDX
13    CONTINUE
C***  MOMENTUM LOSS
      WG24=WFD+WAD
      CALL PROCOM (FAR24,T24,XX1,XX2,XX3,REX24,PHI24,H24)
      RHO24=CAPSF*P24/(AJ*REX24*T24)
      V24=WG24/(RHO24*A24)
      Q(2)=0.
      Q(3)=0.
      PS24=PS42-0.01
14    RHO24=WG24/(V24*A24)
      HS24=H24-V24**2/(2.*G*AJ)
      CALL THERMO (1.0,HS24,TS24,PHIS24,XX2,1,FAR24,1)
      IF (TS24.GE.301.) GO TO 15
      CALL THERMO (1.0,HS24,400.,PHIS24,XX2,1,FAR24,1)
      V24=SQRT(2.*G*AJ*(H24-HS24))
      GO TO 14
15    PS24=RHO24*AJ*REX24*TS24/CAPSF
      PS24A=PS42+(RHO42*V42**2-RHO24*V24**2)/(G*CAPSF)
      DIR=SQRT(ABS(PS24/PS24A))
      EP=(PS24-PS24A)/PS24
      CALL AFQUIR (Q(1),V24,EP,0.,50.,0.001,DIR,V24T,IGO)
      V24=V24T
      IF (V24.LT.25.) V24=25.
      ICODUC=4
      GO TO (14,16,11),IGO
16    P24=PS24*EXP((PHI24-PHIS24)/REX24)
      CALL PROCOM (FAR24,TS24,CS24,XX2,XX3,XX4,XX5,XX6)
      AM24=V24/CS24
17    CALL THERMO (P24,H24,T24,S24,XXI,1,FAR24,0)
      WG24=WFD+WAD
      IF(VFDUCT.EQ.0.0) GO TO 31
      Q(2)=0.0
      Q(3)=0.0
      WG24P=WG24
      H24P=H24
      P24DOT=DERIV(20,P24)
28    CONTINUE
      CALL THERMO(P24,H24,T24,S24,XX2,1,FAR24,0)
      WG24=WG24P-P24DOT*VFDUCT/T24/(1.4*RA)
      U24=H24-AJX*RA*T24
      U24DOT=DERIV(21,U24)
      H24X=(WG24P*H24P-(WG24P-WG24)*U24-U24DOT*P24*VFDUCT/T24/RA    )/
     1 WG24
      ERRW=(H24-H24X)/H24
      DIR=SQRT(ABS(H24/H24X))
      CALL AFQUIR(Q(1),T24,ERRW,0.,20.,0.0001,DIR,T24T,IGO)
      ICODUC=5
      GO TO (29,31,30),IGO
29    T24=T24T
      GO TO 28
30    CALL ERROR
31    CONTINUE
      T25=T24
      P25=P24
      H25=H24
      S25=S24
      AM25=AM24
      IF (IGASMX.GT.0) GO TO 21
      WORD=AWORD2
      A28SAV=A28
      A29SAV=A29
      NOZD=0
      IDNOZ=0
```

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      IF (NOZFLT.EQ.2.OR.NOZFLT.EQ.3) NOZD=1
      IF (IDES.EQ.1.OR.IDBURN.GT.0.OR.NOZD.EQ.1) IDNOZ=1
      IF(ITRAN.EQ.1) IDNOZ=0
      IF (IDCD.EQ.1) GO TO 18
      CALL CONVRG (T25,H25,P25,S25,FAR24,WG24,P1,IDNOZ,A28,P25R,T28,H28,
     1P28,S28,TS28,PS28,V28,AM28,ICON)
      GO TO (19,19,19,11),ICON
18    CALL CONDIV (T25,H25,P25,S25,FAR24,WG24,P1,IDNOZ,A28,A29,P25R,T28,
     1H28,P28,S28,T29,H29,P29,S29,TS28,TS29,PS28,PS29,V28,V29,AM28,AM29,
     2ICON)
      IDSHOC=ICON
      ICODUC=6
      GO TO (20,20,20,11),ICON
19    T29=T28
      H29=H28
      P29=P28
      S29=S28
      TS29=TS28
      PS29=PS28
      V29=V28
      AM29=AM28
      A29=A28
      IDSHOC=ICON+3
20    ERR(5)=(P25R-P25)/P25R
      IF (IDNOZ.EQ.1) WRITE (6,22) A28,AM28,A29,AM29
   21 ICODUC=0
      CALL FASTBK
      RETURN
C
C
22    FORMAT (19H0DUCT NOZZLE DESIGN,5X8H    A28=,E15.8,8H   AM28=,E15.8
     1,8H    A29=,E15.8,8H   AM29=,E15.8)
      END
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$IBFTC COFAN
      SUBROUTINE COFAN
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
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     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /FLOWS/ WAFP,WAIP,WACP
      COMMON /UNITS/ SI
      LOGICAL SI
      LOGICAL FXM2CP
      COMMON /  FAN/CNX(15),PRX(15,15),WACX(15,15),ETAX(15,15),
     1NCN,NPT(15)
      DIMENSION Q(9),WLH(2)
      DATA AWORD,WLH/6H COFAN,6H (LO) ,6H (HI) /
      WORD=AWORD
      IF (SI) GO TO 100
      TSTD=518.668
      PSTD=1.0
      RA=.0252
      AJ=2.719
      GO TO 101
100   TSTD=288.149
      PSTD=101325.
      RA=286.9
      AJ=1.0
101   THETA=SQRT(T2/TSTD)
      DELTA=P2/PSTD
      IF (IDES.NE.1) GO TO 1
      THETAD=THETA
      WAFDS=WAFC*DELTA/THETA
1     CNF=PCNF*THETAD/(100.*THETA)
      IF (ZF.LT.0.) ZF=0.
      IF (ZF.GT.1.) ZF=1.
      CNFS=CNF
      CALL SEARCH (ZF,CNF,PRF,WAFC,ETAF,CNX(1),NCN,PRX(1,1),WACX(1,1),ET
     1AX(1,1),NPT(1),15,15,IGO)
      IF ((CNF-CNFS).GT.0.0005*CNF) MAPEDG=1
      IF (IGO.EQ.1.OR.IGO.EQ.2) WRITE (8,12) CNFS,WLH(IGO)
      WAF=WAFC*DELTA/THETA
      IF (IDES.NE.1) GO TO 2
      PRFCF=(PRFDS-1.)/(PRF-1.)
      ETAFCF=ETAFDS/ETAF
      WAFCF=WAFDS/WAF
      WRITE (6,13) PRFCF,ETAFCF,WAFCF,T2DS
2     PRF=PRFCF*(PRF-1.)+1.
      ETAF=ETAFCF*ETAF
      WAF=WAFCF*WAF
      WAFP=WAF
      WAFC=WAFC*WAFCF
      PCNF=100.*THETA*CNF/THETAD
      DUMD1=PCNF
      CALL THCOMP (PRF,ETAF,T2,H2,S2,P2,T22,H22,S22,P22)
      IF(VFAN.EQ.0.0) GO TO 21
      Q(2)=0.0
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      Q(3)=0.0
      H22P=H22
      P22DOT=DERIV(4,P22)
 18   CONTINUE
      CALL THERMO(P22,H22,T22,S22,XX2,0,0.0,0)
      WAF=WAFP-P22DOT*VFAN/T22/1.4/RA
      U22=H22-AJ*RA*T22
      U22DOT=DERIV(5,U22)
      H22X=(WAFP*H22P-(WAFP-WAF)*U22-U22DOT*P22*VFAN/T22/RA)/WAF
      ERRW=(H22-H22X)/H22
      DIR=SQRT(ABS(H22/H22X))
      CALL AFQUIR(Q(1),T22,ERRW,0.,20.,0.0001,DIR,T22T,IGO)
      GO TO (19,21,20), IGO
 19   T22=T22T
      GO TO 18
 20   CALL ERROR
 21   CONTINUE
      IF (PCBLF.GT.0.) BLF=PCBLF*WAF
      IF (JDES.EQ.1) GO TO 9
      JDES=1
      IF (INIT.EQ.1) GO TO 8
      IF (IDES.EQ.1) GO TO 6
      IF(JTRAN.EQ.1) GO TO 8
      IF (MODE.NE.2) GO TO 3
      T4=GUESS(3,Y1,Y2,PCNF,PCNFDS,WFB,WFBDS,Y7,Y8,T4DS)
      PCNI=GUESS(8,T4,T4DS,Y3,Y4,Y5,Y6,T22,T22DS,PCNIDS)
      PCNC=GUESS(4,Y1,Y2,PCNI,PCNIDS,WFB,WFBDS,Y7,Y8,PCNCDS)
      GO TO 7
 3    IF (MODE.EQ.1) GO TO 5
      IF (MODE.EQ.0) GO TO 4
      T4=GUESS(7,Y1,Y2,PCNF,PCNFDS,Y5,Y6,T2,T2DS,T4DS)
 4    CONTINUE
      PCNC=GUESS(5,T4,T4DS,Y3,Y4,Y5,Y6,T22,T22DS,PCNCDS)
      IF (FXM2CP) PCNC=PCNCDS*.99
      PCNCG1=PCNC
      PCNCG2=PCNCDS
      PCNI=GUESS(9,Y1,Y2,PCNCG1,PCNCG2,Y5,Y6,T22,T22DS,PCNIDS)
      GO TO 7
 5    T4=GUESS(6,Y1,Y2,PCNC,PCNCDS,Y5,Y6,T22,T22DS,T4DS)
      PCNI=GUESS(8,T4,T4DS,Y3,Y4,Y5,Y6,T22,T22DS,PCNIDS)
      GO TO 7
 6    PCNC=PCNCDS
      PCNI=PCNIDS
      T4=T4DS
      WFB=WFBDS
      T21DS=T21
 7    ZC=ZCDS
      ZI=ZIDS
      PCNIGU=PCNI
      PCNCGU=PCNC
      T4GU=T4
 8    INIT=0
 9    IF (MODE.NE.3) GO TO 10
      IF (ABS(CNF-CNFS).LE.0.001*CNFS) GO TO 11
      WRITE (8,14) CNFS,CNF
      CALL ERROR
 10   PCNF=100.*THETA*CNF/THETAD
 11   CALL COINTC
      RETURN
C
C
 12   FORMAT (19H0* * *  CNF OFF MAP,F10.4,2XA6,11H* * *$$$$$$)
 13   FORMAT (11H0FAN DESIGN,13X8H  PRFCF=,E15.8,8H ETAFCF=,E15.8,8H  WA
     1FCF=,E15.8,8H    T2DS=,E15.8)
 14   FORMAT (10H0CNF WAS= ,E15.8,11H  AND NOW= ,E15.8,24H  CHECK PCNF I
     1NPUT$$$$$$)
      END
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$IBFTC COHPTB
      SUBROUTINE COHPTB
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /FLOWS/ WAFP,WAIP,WACP
      COMMON /UNITS/ SI
      LOGICAL SI
      DIMENSION Q(9)
      LOGICAL FXFN2M,FXM2CP,DUMSPL
      COMMON /HTURB/TFFX(15),CNX(15,15),DHTCX(15,15),ETATX(15,15),
     1NTFFS,NPTTFF(15)
      DATA AWORD,WLO,WHI/6HCOHPTB,6H (LO) ,6H (HI) /
      WORD=AWORD
      IF(SI) GO TO 100
      RA=.0252
      AJ=2.719
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```
      CONFAC=1.4091E-5
      GO TO 101
100   RA=286.9
      AJ=1.0
      CONFAC=1.0966E-2
101   CONTINUE
      IF (ISPOOL.EQ.1) GO TO 8
      IF (IDES.EQ.0) GO TO 1
      CNHPCF=CNHPDS*SQRT(T4)/PCNC
1     CNHP=CNHPCF*PCNC/SQRT(T4)
      CNHPS=CNHP
      TFFHPS=TFFHP
      CALL SEARCH (-1.,TFFHP,CNHP,DHTCHP,ETATHP,TFFX(1),NTFFS,CNX(1,1),D
     1HTCX(1,1),ETATX(1,1),NPTTFF(1),15,15,IGO)
      IF (IGO.EQ.1.OR.IGO.EQ.11.OR.IGO.EQ.21) WRITE (8,9) TFFHPS,WLO
      IF (IGO.EQ.2.OR.IGO.EQ.12.OR.IGO.EQ.22) WRITE (8,9) TFFHPS,WHI
      IF (IGO.EQ.10.OR.IGO.EQ.11.OR.IGO.EQ.12) WRITE (8,10) CNHPS,WLO
      IF (IGO.EQ.20.OR.IGO.EQ.21.OR.IGO.EQ.22) WRITE (8,10) CNHPS,WHI
      IF (IGO.NE.7) GO TO 2
      CALL ERROR
      RETURN
2     NOMAP=0
      TFHCAL=WG4*SQRT(T4)/(14.696*P4)
      BTUEXT=0.706705*HPEXT
      IF(SI) TFHCAL=WG4*SQRT(T4)/P4
      IF(SI) BTUEXT=HPEXT
      XNHP=XNHPDS*PCNC/100.
      XNHDOT=DERIV(1,XNHP)
      DHTCC=(BTUEXT+WACP*(H3-H21)+CONFAC*PMIHP*XNHP*XNHDOT)/(WG4*T4)
      IF (IDES.EQ.0) GO TO 5
      TFHPCF=TFHPDS/TFHCAL
      DHHPCF=DHTCC/DHTCHP
      ETHPCF=ETHPDS/ETATHP
      WRITE (6,11) CNHPCF,TFHPCF,ETHPCF,DHHPCF
5     TFHCAL=TFHPCF*TFHCAL
      DHTCHP=DHHPCF*DHTCHP
      ETATHP=ETHPCF*ETATHP
      DHTC=DHTCC*T4
      ERR(1)=(TFHCAL-TFFHP)/TFHCAL
      ERR(2)=(DHTCC-DHTCHP)/DHTCC
      CALL THTURB (DHTC,ETATHP,FAR4,H4,S4,P4,T50,H50,S50,P50)
      IF(BLHP.LE.0.0) GO TO 6
      FAR50=FAR4*WG4/(WG4+BLHP*(FAR4+1.))
      WG50=WG4+BLHP
      H50=(BLHP*H3+WG4*H50)/WG50
      CALL THERMO(P50,H50,T50,S50,XX2,1,FAR50,1)
      GO TO 7
6     FAR50=FAR4
      WG50=WG4
7     CONTINUE
      IF(VHPTRB.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      WG50P=WG50
      H50P=H50
      P50DOT=DERIV(12,P50)
18    CONTINUE
      CALL THERMO(P50,H50,T50,S50,XX2,1,FAR50,0)
      WG50=WG50P-P50DOT*VHPTRB/T50/1.4/RA
      U50=H50-RA*AJ*T50
      U50DOT=DERIV(13,U50)
      H50X=(WG50P*H50P-(WG50P-WG50)*U50-U50DOT*P50*VHPTRB/T50/RA)/WG50
      ERRW=(H50-H50X)/H50
      DIR=SQRT(ABS(H50/H50X))
      CALL AFQUIR(Q(1),T50,ERRW,0.,20.,0.0001,DIR,T50T,IGO)
      GO TO (19,21,20), IGO
19    T50=T50T
      GO TO 18
20    CALL ERROR
21    CONTINUE
      IF(FXFN2M.OR.DUMSPL) GO TO 8
      CALL COIPTB
      RETURN
8     P5=P50
```

```
      H5=H50
      T5=T50
      S5=S50
      FAR5=FAR50
      WG5=WG50
C     SET MIDDLE TURBINE PARAMETERS TO ZERO, NOT USED
      TFFIP=0.
      CNIP=0.
      DHTI=0.
      DHTCIP=0.
      ETATIP=0.
      CALL COLPTB
      RETURN
C
C
C
9     FORMAT (19H0*****TFFHP OFF MAP,F10.4,2XA6,11H***** $$$$$$)
10    FORMAT (19H0***** CNHP OFF MAP,F10.4,2XA6,11H***** $$$$$$)
11    FORMAT (20H0H.P. TURBINE DESIGN,5X7HCNHPCF=,E15.8,8H TFHPCF=,E15.8
     1,8H ETHPCF=,E15.8,8H DHHPCF=,E15.8)
      END
```

```
$IBFTC COINLT
      SUBROUTINE COINLT
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
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     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DELCH/ DELT1
      COMMON /UNITS/ SI
      LOGICAL SI
      DATA AWORD/6HCOINLT/
      WORD=AWORD
      IF(SI) GO TO 10
      AJ=778.26
      G=32.174049
      REF59=2.0855531E07
      R=1.986375
      GO TO 11
   10 AJ=1.0
      G=1.0
      REF59=6.3567658E06
      R=8314.34
   11 ALT=ALTP*REF59/(REF59-ALTP)
      CALL ATMOS(ALT,T1STD,XX1,XX2,XX3,DELTA,CS,XX4,IIER)
      P1=DELTA
      IF(SI) P1=101325.*DELTA
      T1=T1STD
      IF(IAMTP.EQ.2) T1=T1STD+DELT1
      IF (IAMTP.EQ.5) CALL RAM2 (AM,ETAR)
      IF (IAMTP.NE.1.AND.IAMTP.NE.5) CALL RAM (AM,ETAR)
      FAR=0.0
      CALL PROCOM (FAR,T1,CS,XX2,XX3,R1,PHI1,H1)
      S1=PHI1-R1*ALOG(DELTA)
      H2=H1+(AM*CS)**2/(2.*AJ*G)
      P2T=1.
      IF(SI) P2T=101325.
      DO 1 I=1,10
      CALL THERMO (P2T,H2,T2T,S2T,AW,0,0.0,1)
      IF (ABS(S2T-S1).LE.0.0001*S1) GO TO 2
    1 P2T=P1*EXP((AW/R)*((S2T-S1)+(R/AW)*ALOG(P2T/P1)))
      CALL ERROR
      RETURN
    2 IF (IAMTP.EQ.3.OR.IAMTP.EQ.4) ETAR=P2/P2T
      P2=ETAR*P2T
      IF (IAMTP.NE.4) CALL THERMO (P2,H2,T2,S2,XX5,0,0.0,1)
      IF (IAMTP.EQ.4) CALL THERMO (P2,H2,T2,S2,XX5,0,0.0,0)
      IF (INIT.EQ.1) GO TO 5
      IF (IDES.EQ.1) GO TO 3
      IF (MODE.EQ.3) GO TO 4
      PCNF=GUESS(MODE,T4,T4DS,PCNC,PCNCDS,WF8,WF8DS,T2,T2DS,PCNFDS)
      PCNFGU=PCNF
      GO TO 4
    3 PCNF=PCNFDS
      PCNFGU=PCNF
      T2DS=T2
    4 ZF=ZFDS
    5 RETURN
      END
```

```
$IBFTC COINTC
      SUBROUTINE COINTC
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
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      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /FLOWS/ WAFP,WAIP,WACP
      COMMON /UNITS/ SI
      COMMON/INT/CNX(15),PRX(15,15),WACX(15,15),ETAX(15,15),
     1NCN,NPT(15)
      COMMON/DUMINT/CNXX(15),PRXX(15,15),WACXX(15,15),ETAXX(15,15),
     1NCNX,NPTX(15)
      LOGICAL FXFN2M,FXM2CP,AFTFAN,DUMSPL,FAN,SI
      DIMENSION Q(9),WLH(2)
      DATA AWORD,WLH/6HCOINTC,6H (LO) ,6H (HI) /
      WORD=AWORD
      IF (SI) GO TO 100
      TSTD=518.668
      PSTD=1.0
      RA=.0252
      AJ=2.719
      GO TO 101
  100 TSTD=288.149
      PSTD=101325.
      RA=286.9
      AJ=1.0
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101   CONTINUE
      IF (.NOT.AFTFAN) GO TO 1
      T22S=T22
      H22S=H22
      S22S=S22
      P22S=P22
      T22=T2
      H22=H2
      S22=S2
      P22=P2
1     THETA=SQRT(T22/TSTD)
      DELTA=P22/PSTD
      IF (.NOT.FAN) WAI=WAF-BLF
      IF (IDES.NE.1) GO TO 2
      PRI=PRIDS
      PCBLI=PCBLID
      IF (.NOT.FAN) WAICDS=WAI*THETA/DELTA
      IF (.NOT.FAN) DUMSPL=.TRUE.
      WACI=WAICDS
      THETAD=THETA
      WAIDS=WACI*DELTA/THETA
      ETAI=ETAIDS
2     IF (.NOT.FXFN2M) GO TO 3
C     FAN AND MIDDLE SPOOL ROTATE AT SAME SPEED
      SPDFAN=CNF*SQRT(T2/TSTD)
      CNI=SPDFAN/THETA
      PCNI=100.*CNI*THETA/THETAD
      IF (IDES.EQ.1) PCNIDS=PCNI
3     CNI=PCNI*THETAD/(100.*THETA)
      ZI=AMAX1(ZI,0.)
      ZI=AMIN1(ZI,1.)
      CNIS=CNI
      IF (.NOT.DUMSPL) GO TO 4
      CALL INDUMY (CNI,ZI,WAICDS,IDES)
      CALL SEARCH (ZI,CNI,PRI,WACI,ETAI,CNXX,NCNX,PRXX,WACXX,ETAXX,NPTX,
     115,15,IGO)
      GO TO 5
4     CONTINUE
      CALL SEARCH (ZI,CNI,PRI,WACI,ETAI,CNX(1),NCN,PRX(1,1),WACX(1,1),ET
     1AX(1,1),NPT(1),15,15,IGO)
5     CONTINUE
      IF ((CNI-CNIS).GT..0005*CNI) MAPEDG=1
      IF (IGO.EQ.1.OR.IGO.EQ.2) WRITE (8,12) CNIS,WLH(IGO)
      IF (.NOT.FAN) WACI=WAI*THETA/DELTA
      WAI=WACI*DELTA/THETA
      WA22=WAI
      IF (IDES.NE.1) GO TO 7
      T22DS=T22
      IF (AFTFAN) T22DS=T22S
      IF (.NOT.DUMSPL) PRICF=(PRIDS-1.)/(PRI-1.)
      ETAICF=ETAIDS/ETAI
      WAICF=WAIDS/WAI
      IF (.NOT.DUMSPL) GO TO 6
      PRICF=1.
      ETAICF=1.
      WAICF=1.
6     CONTINUE
      WRITE (6,13) PRICF,ETAICF,WAICF,T22DS
7     PRI=PRICF*(PRI-1.)+1.
      ETAI=ETAICF*ETAI
      WAI=WAICF*WAI
      WAIP=WAI
      WACI=WACI*WAICF
      WA22=WAI
      CALL THCOMP (PRI,ETAI,T22,H22,S22,P22,T21,H21,S21,P21)
      IF(VINTC.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      H21P=H21
      P21DOT=DERIV(6,P21)
18    CONTINUE
      CALL THERMO(P21,H21,T21,S21,XX2,0,0.0,0)
      WAI=WAIP-P21DOT*VINTC/T21/1.4/RA
      U21=H21-AJ*RA*T21
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      U21DOT=DERIV(7,U21)
      H21X=(WAIP*H21P-(WAIP-WAI)*U21-U21DOT*P21*VINTC/T21/RA)/WAI
      ERRW=(H21-H21X)/H21
      DIR=SQRT(ABS(H21/H21X))
      CALL AFQUIR(Q(1),T21,ERRW,0.,20.,0.0001,DIR,T21T,IGO)
      GO TO (19,21,20),IGO
   19 T21=T21T
      GO TO 18
   20 CALL ERROR
   21 CONTINUE
      IF (.NOT.DUMSPL) GO TO 8
      PRI=1.
      ETAI=1.
      T21=T22
      H21=H22
      S21=S22
      P21=P22
      IF(ISPOOL.EQ.1) WA21=WAI
    8 CONTINUE
      IF (IDES.NE.1) GO TO 9
      BLI=PCBLI*WAI
      WA21=WA22-BLI
      WA32=BLI
      IF (FAN.OR.IDES.EQ.1) WAC=WA21
    9 CONTINUE
      IF (ABS(CNI-CNIS).LE.0.001*CNIS) GO TO 10
      WRITE (8,14) CNIS,CNI
      CALL ERROR
      PCNI=100.*THETA*CNI/THETAD
   10 IF (.NOT.AFTFAN) GO TO 11
      T22=T22S
      H22=H22S
      S22=S22S
      P22=P22S
   11 CALL COCOMP
      RETURN
C
C
C
   12 FORMAT (19H0* * *  CNI OFF MAP,F10.4,2XA6,11H* * *$$$$$$)
   13 FORMAT (20H/MIDDLE SPOOL DESIGN,4X8H  PRICF=,E15.8,8H ETAICF=,E15.
     18,8H  WAICF=,E15.8,8H  T22DS=,E15.8)
   14 FORMAT (10HOCNI WAS= ,E15.8,11H  AND NOW= ,E15.8,24H  CHECK PCNI I
     1NPUT$$$$$$)
      END
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$IBFTC COIPTB
      SUBROUTINE COIPTB
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IANTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
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     5CNF    ,PRF    ,ETAF   ,WAFC   ,WAF    ,WA3    ,WG4    ,FAR4   ,
     6CNC    ,PRC    ,ETAC   ,WACC   ,WAC    ,ETAB   ,DPCOM  ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP   ,ETAR   ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP  ,PCBLF  ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF   ,XWAC   ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21   ,XH21   ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24    ,H24    ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28    ,H28    ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD    ,WG24   ,FAR24  ,ETAC   ,DPDUC  ,BYPASS,DUMS3  ,
     6TS28   ,PS28   ,V28    ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55   ,XH55   ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55  ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1   ,DUMB   ,
     9T6     ,P6     ,H6     ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8     ,H8     ,S8     ,T9     ,P9     ,H9     ,S9
      COMMON /ALL4/
     1WG6    ,WFA    ,WG7    ,FAR7   ,ETAA   ,DPAFT  ,V55    ,V25    ,
     2PS6    ,V6     ,AM6    ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
     3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
     4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
     5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
     7H38    ,P38    ,TS38   ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
     8V39    ,AM39   ,A39    ,BPRINT,WG37   ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39   ,FFCVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22    ,P22    ,H22    ,S22    ,T50    ,P50    ,H50
      COMMON /ALL5/
     1S50    ,WA22   ,ZI     ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
     2TFFIP  ,CNIP   ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
     3ZIDS   ,PCNIDS,PRIDS  ,ETAIDS,WAIDS  ,PRICF  ,ETAICF,WAICF  ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI  ,BLI    ,T22DS  ,WA21   ,WG50   ,FAR50  ,A24    ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL  ,T41    ,FAN    ,ISPOOL
      COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /FLOWS/ WAFP,WAIP,WACP
      COMMON /UNITS/ SI
      DIMENSION Q(9)
      COMMON/ITURB/TFFX(15),CNX(15,15),DHTCX(15,15),ETATX(15,15),
     1NTFFS,NPTTFF(15)
      LOGICAL AFTFAN,FXFN2M,FXM2CP,SI
      COMMON/HTURB/TFFY(15),CNY(15,15),DHTCY(15,15),ETATY(15,15),NTFYS,
     1NPTTSF(15)
      DATA AWORD,WLO,WHI/6HCOIPTB,6H (LO) ,6H (HI) /
      IF(SI) GO TO 100
      RA=.0252
      AJ=2.719
      CONFAC=1.4091E-5
      GO TO 101
  100 RA=286.9
      AJ=1.0
      CONFAC=1.0966E-2
  101 CONTINUE
      H22SAV=H22
      IF (AFTFAN) H22=H2
      WORD=AWORD
      IF (IDES.EQ.0) GO TO 1
      CNIPCF=CNIPDS*SQRT(T50)/PCNI
      IF (FXM2CP) CNIPCF=CNHPDS*SQRT(T50)/PCNI
    1 CNIP=CNIPCF*PCNI/SQRT(T50)
      CNIPS=CNIP
      TFFIPS=TFFIP
      IF (FXM2CP) GO TO 2
      CALL SEARCH (-1.,TFFIP,CNIP,DHTCIP,ETATIP,TFFX(1),NTFFS,CNX(1,1),D
     1HTCX(1,1),ETATX(1,1),NPTTFF(1),15,15,IGO)
    2 IF (FXM2CP) CALL SEARCH (-1.,TFFIP,CNIP,DHTCIP,ETATIP,TFFY(1),NTFY
     1S,CNY(1,1),DHTCY(1,1),ETATY(1,1),NPTTSF(1),15,15,IGO)
      IF (IGO.EQ.1.OR.IGO.EQ.11.OR.IGO.EQ.21) WRITE (8,9) TFFIPS,WLO
      IF (IGO.EQ.2.OR.IGO.EQ.12.OR.IGO.EQ.22) WRITE (8,9) TFFIPS,WHI
      IF (IGO.EQ.10.OR.IGO.EQ.11.OR.IGO.EQ.12) WRITE (8,9) CNIPS,WLO
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      IF (IGO.EQ.20.OR.IGO.EQ.21.OR.IGO.EQ.22) WRITE (8,10) CNIPS,WHI
      IF (IGO.NE.7) GO TO 3
      CALL ERROR
      RETURN
      NOMAP=0
      TFICAL=WG50*SQRT(T50)/(14.696*P50)
      IF(SI) TFICAL=WG50*SQRT(T50)/P50
      XNIP=XNIPDS*PCNI/100.
      XNIDOT=DERIV(2,XNIP)
      BTUEXT=.706705*HPEXT
      IF(SI) BTUEXT=HPEXT
      DHACEL=CONFAC*PMIIP*XNIP*XNIDOT
      DHTIC=(WAIP*(H21-H22)+DHACEL)/(WG50*T50)
      IF(FXM2CP) DHTIC=(BTUEXT+WACP*(H3-H21)+WAIP*(H21-H22)+DHACEL)/
     1 (WG50*T50)
      IF (IDES.EQ.0) GO TO 6
      TFIPCF=TFIPDS/TFICAL
      DHIPCF=DHTIC/DHTCIP
      ETIPCF=ETIPDS/ETATIP
      IF (FXM2CP) TFIPCF=TFHPDS/TFICAL
      IF (FXM2CP) ETIPCF=ETHPDS/ETATIP
      WRITE (6,11) CNIPCF,TFIPCF,ETIPCF,DHIPCF
    6 TFICAL=TFIPCF*TFICAL
      DHTCIP=DHIPCF*DHTCIP
      ETATIP=ETIPCF*ETATIP
      DHTI=DHTIC*T50
      N1=8
      N2=9
      IF (FXM2CP) N1=1
      IF (FXM2CP) N2=2
      ERR(N1)=(TFICAL-TFFIP)/TFICAL
      ERR(N2)=(DHTIC-DHTCIP)/DHTIC
      CALL THTURB (DHTI,ETATIP,FAR50,H50,S50,P50,T5,H5,S5,P5)
      IF(BLIP.LE.0.0) GO TO 7
      FAR5=FAR50*WG50/(WG50+BLIP*(FAR50+1.))
      WG5=WG50+BLIP
      H5=(BLIP*H3+WG50*H5)/WG5
      CALL THERMO(P5,H5,T5,S5,XX2,1,FAR5,1)
      GO TO 8
    7 FAR5=FAR50
      WG5=WG50
    8 CONTINUE
      IF(VIPTRB.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      WG5P=WG5
      H5P=H5
      P5DOT=DERIV(14,P5)
   18 CONTINUE
      CALL THERMO(P5,H5,T5,S5,XX2,1,FAR5,0)
      WG5=WG5P-P5DOT*VIPTRB/T5/1.4/RA
      U5=H5-RA*AJ*T5
      U5DOT=DERIV(15,U5)
      H5X=(WG5P*H5P-(WG5P-WG5)*U5-U5DOT*P5*VIPTRB/T5/RA)/WG5
      ERRW=(H5-H5X)/H5
      DIR=SQRT(ABS(H5/H5X))
      CALL AFQUIR(Q(1),T5,ERRW,0.,20.,0.0001,DIR,T5T,IGO)
      GO TO (19,21,20),IGO
   19 T5=T5T
      GO TO 18
   20 CALL ERROR
   21 CONTINUE
      H22=H22SAV
      CALL COLPTB
      RETURN
C
C
C
    9 FORMAT (19H0*****TFFIP OFF MAP,F10.4,2XA6,11H*****$$$$$$)
   10 FORMAT (19H0***** CNIP OFF MAP,F10.4,2XA6,11H*****$$$$$$)
   11 FORMAT (20H0I.P. TURBINE DESIGN,5X7HCNIPCF=,E15.8,8H TFIPCF=,E15.8
     1,8H ETIPCF=,E15.8,8H DHIPCF=,E15.8)
      END
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$IBFTC COLPTB
      SUBROUTINE COLPTB
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /FLOWS/ WAFP,WAIP,WACP
      COMMON /UNITS/ SI
      LOGICAL AFTFAN,FXFN2M,FXM2CP,SI
      COMMON /LTURB/TFFX(15),CNX(15,15),DHTCX(15,15),ETATX(15,15),
     1NTFFS,NPTTFF(15)
      DIMENSION Q(9)
      DATA AWORD,WLO,WHI/6HCOLPTB,6H (LO) ,6H (HI) /
      WORD=AWORD
      IF(SI) GO TO 100
      RA=.0252
      AJ=2.719
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```
      CONFAC=1.4091E-5
      GO TO 101
100   RA=286.9
      AJ=1.0
      CONFAC=1.0966E-2
101   CONTINUE
      IF (IDES.EQ.0) GO TO 1
      CNLPCF=CNLPDS*SQRT(T5)/PCNF
1     CNLP=CNLPCF*PCNF/SQRT(T5)
      CNLPS=CNLP
      TFFLPS=TFFLP
      CALL SEARCH (-1.,TFFLP,CNLP,DHTCLP,ETATLP,TFFX(1),NTFFS,CNX(1,1),D
     1HTCX(1,1),ETATX(1,1),NPTTFF(1),15,15,IGO)
      IF (IGO.EQ.1.OR.IGO.EQ.11.OR.IGO.EQ.21) WRITE (8,8) TFFLPS,WLO
      IF (IGO.EQ.2.OR.IGO.EQ.12.OR.IGO.EQ.22) WRITE (8,8) TFFLPS,WHI
      IF (IGO.EQ.10.OR.IGO.EQ.11.OR.IGO.EQ.12) WRITE (8,9) CNLPS,WLO
      IF (IGO.EQ.20.OR.IGO.EQ.21.OR.IGO.EQ.22) WRITE (8,9) CNLPS,WHI
      IF (IGO.NE.7) GO TO 2
      CALL ERROR
      RETURN
2     NOMAP=0
      TFLCAL=WG5*SQRT(T5)/(14.696*P5)
      IF(SI) TFLCAL=WG5*SQRT(T5)/P5
      XNLP=XNLPDS*PCNF/100.
      XNLDOT=DERIV(3,XNLP)
      DHACEL=CONFAC*PMILP*XNLP*XNLDOT
      DHTCF=(WAFP*(H22-H2)+DHACEL)/(WG5*T5)
      IF(FXFN2M) DHTCF=(WAFP*(H22-H2)+WAIP*(H21-H22)+DHACEL)/(WG5*T5)
      IF(FXFN2M.AND.AFTFAN) DHTCF=(WAFP*(H22-H2)+WAIP*(H21-H2)+DHACEL)
     1 /(WG5*T5)
      IF (ISPOOL.GE.2) GO TO 11
      BTUEXT=0.706706*HPEXT
      IF(SI) BTUEXT=HPEXT
      DHTCF=(BTUEXT+WAFP*(H22-H2)+DHACEL)/(WG5*T5)
11    IF (IDES.EQ.0) GO TO 5
      TFLPCF=TFLPDS/TFLCAL
      DHLPCF=DHTCF/DHTCLP
      ETLPCF=ETLPDS/ETATLP
      WRITE (6,10) CNLPCF,TFLPCF,ETLPCF,DHLPCF
5     TFLCAL=TFLPCF*TFLCAL
      DHTCLP=DHLPCF*DHTCLP
      ETATLP=ETLPCF*ETATLP
      DHTF=DHTCF*T5
      I1=3
      I2=4
      IF (ISPOOL.EQ.1)  I1=1
      IF (ISPOOL.EQ.1) I2=2
      ERR(I1)=(TFLCAL-TFFLP)/TFLCAL
      ERR(I2)=(DHTCF-DHTCLP)/DHTCF
      CALL THTURB (DHTF,ETATLP,FAR5,H5,S5,P5,T55,H55,S55,P55)
      IF(BLLP.LE.0.) GO TO 6
      FAR55 = FAR5*WG5/(WG5+BLLP*(1.+FAR5))
      WG55=WG5+BLLP
      H55=(BLLP*H3+WG5*H55)/WG55
      CALL THERMO(P55,H55,T55,S55,XX2,1,FAR55,1)
      GO TO 7
6     FAR55=FAR5
      WG55=WG5
7     CONTINUE
      IF(VLPTRB.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      WG55P=WG55
      H55P=H55
      P55DOT=DERIV(16,P55)
18    CONTINUE
      CALL THERMO(P55,H55,T55,S55,XX2,1,FAR55,0)
      WG55=WG55P-P55DOT*VLPTRB/T55/1.4/RA
      U55=H55-RA*AJ*T55
      U55DOT=DERIV(17,U55)
      H55X=(WG55P*H55P-(WG55P-WG55)*U55-U55DOT*P55*VLPTRB/T55/RA)/WG55
      ERRW=(H55-H55X)/H55
      DIR=SQRT(ABS(H55/H55X))
```

```
      CALL AFQUIR(Q(1),T55,ERRW,0.,20.,0.0001,DIR,T55T,IGO)
      GO TO (19,21,20), IGO
19    T55=T55T
      GO TO 18
20    CALL ERROR
21    CONTINUE
      CALL FRTOSD
      RETURN
C
C
8     FORMAT (19H0*****TFFLP OFF MAP,F10.4,2XA6,11H*****$$$$$$)
9     FORMAT (19H0***** CNLP OFF MAP,F10.4,2XA6,11H*****$$$$$$)
10    FORMAT (20HOL.P. TURBINE DESIGN,5X7HCNLPCF=,E15.8,8H TFLPCF=,E15.8
     1,8H ETLPCF=,E15.8,8H DHLPCF=,E15.8)
      END
```

```
$IBFTC COMIX
      SUBROUTINE COMIX
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES   ,JDES   ,KDES   ,MODE   ,INIT   ,IDUMP  ,IAMTP  ,IGASMX,
     2IDBURN,IAFTBN,IDCD   ,IMCD   ,IDSHOC,IMSHOC,NOZFLT,ITRYS  ,
     3LOOPER,NOMAP  ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU   ,DUMD1  ,DUMD2  ,DELFG  ,DELFN  ,DELSFC,
     2ZFDS   ,PCNFDS,PRFDS  ,ETAFDS,WAFDS  ,PRFCF  ,ETAFCF,WAFCF  ,
     3ZCDS   ,PCNCDS,PRCDS  ,ETACDS,WACDS  ,PRCCF  ,ETACCF,WACCF  ,
     4T4DS   ,WFBDS  ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
     7T24DS  ,WFDDS  ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS   ,WFADS  ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25    ,A6     ,A7     ,A8     ,A9     ,A28    ,A29    ,
     $PS55   ,AM55   ,CVDNOZ,CVMNOZ,A8SAV  ,A9SAV  ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1     ,H1     ,S1     ,T2     ,P2     ,H2     ,S2     ,
     2T21    ,P21    ,H21    ,S21    ,T3     ,P3     ,H3     ,S3     ,
     3T4     ,P4     ,H4     ,S4     ,T5     ,P5     ,H5     ,S5     ,
     4T55    ,P55    ,H55    ,S55    ,BLF    ,BLC    ,BLDU   ,BLOB   ,
     5CNF    ,PRF    ,ETAF   ,WAFC   ,WAF    ,WA3    ,WG4    ,FAR4   ,
     6CNC    ,PRC    ,ETAC   ,WACC   ,WAC    ,ETAB   ,DPCOM  ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP   ,ETAR   ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP  ,PCBLF  ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF   ,XWAC   ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21   ,XH21   ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24    ,H24    ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28    ,H28    ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD    ,WG24   ,FAR24  ,ETAD   ,DPDUC  ,BYPASS,DUMS3  ,
     6TS28   ,PS28   ,V28    ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55   ,XH55   ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55  ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1   ,DUMB   ,
     9T6     ,P6     ,H6     ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8     ,H8     ,S8     ,T9     ,P9     ,H9     ,S9
      COMMON /ALL4/
     1WG6    ,WFA    ,WG7    ,FAR7   ,ETAA   ,DPAFT  ,V55    ,V25    ,
     2PS6    ,V6     ,AM6    ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
     3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
     4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
     5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
     7H38    ,P38    ,TS38   ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
     8V39    ,AM39   ,A39    ,BPRINT,WG37   ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39   ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22    ,P22    ,H22    ,S22    ,T50    ,P50    ,H50
      COMMON /ALL5/
     1S50    ,WA22   ,ZI     ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
     2TFFIP  ,CNIP   ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
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     3ZIDS   ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF  ,ETAICF,WAICF  ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI  ,BLI    ,T22DS  ,WA21   ,WG50   ,FAR50  ,A24    ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL  ,T41    ,FAN    ,ISPOOL
      COMMON/WHRERR/ICOAFB,ICODUC,ICOMIX
      COMMON/UNITS/SI
      LOGICAL SI
      COMMON/LOOPPR/KKGO,PRFNEW,PRCNEW
      DATA AWORD/6H COMIX/
      DIMENSION QQ(9)
      WORD=AWORD
      IF (SI) GO TO 100
      AJ=778.26
      CAPSF=2116.2170
      G=32.17049
      RDEM=1.986375
      GO TO 101
  100 AJ=1.0
      CAPSF=1.0
      G=1.0
      RDEM=8316.41
  101 CONTINUE
      ICOMIX=0
      CALL PROCOM (FAR55,T55,XX1,XX2,XX3,XX4,PHI55,XX5)
      CALL PROCOM (FAR24,T25,XX1,XX2,XX3,XX4,PHI25,XX5)
      IF (IDES.EQ.0) GO TO 12
C *** CALCULATE A55 AND A25 WITH PS25=PS55
      IF (PS55.EQ.0.) GO TO 3
      TS55=T55*(PS55/P55)**0.286
      DO 1 I=1,15
      CALL PROCOM (FAR55,TS55,CS55,AK55,CP55,REX55,PHIS55,HS55)
      PHIS=PHI55-REX55*ALOG(P55/PS55)
      DELPHI=PHIS-PHIS55
      IF (ABS(DELPHI).LE.0.0001*PHIS) GO TO 6
1     TS55=TS55*EXP(4.0*DELPHI)
      ICOMIX=1
2     CALL ERROR
      RETURN
3     TS55=0.875*T55
      DO 4 I=1,15
      CALL PROCOM (FAR55,TS55,CS55,AK55,CP55,REX55,PHIS55,HS55)
      V55=AM55*CS55
      HSCAL=H55-V55**2/(2.*G*AJ)
      DELHS=HSCAL-HS55
      IF (ABS(DELHS).LE.0.0005*HSCAL) GO TO 5
4     TS55=TS55+DELHS/CP55
      ICOMIX=2
      GO TO 2
5     PS55=P55/EXP((PHI55-PHIS55)/REX55)
      IF (PS55.GT.P25.AND.IDES.EQ.1.AND.IGASMX.GT.0) GO TO 45
6     IF (H55.GT.HS55) GO TO 7
      WRITE (8,46) P55,PS55,T55,TS55,H55,HS55
      ICOMIX=3
      CALL ERROR
7     V55=SQRT(2.*G*AJ*(H55-HS55))
      RHO=CAPSF*PS55/(AJ*REX55*TS55)
      A55=WG55/(RHO*V55)
      AM55=V55/CS55
      IF (IGASMX.GT.0) GO TO 8
      WRITE (6,47) A55,AM55
      IF (IGASMX .EQ. 0) GO TO 41
      IF (IGASMX .EQ. -1) GO TO 35
8     PS25=PS55
      TS25=T25*(PS25/P25)**0.286
      DO 9 I=1,15
      CALL PROCOM (FAR24,TS25,CS25,AK25,CP25,REX25,PHIS25,HS25)
      PHIS=PHI25-REX25*ALOG(P25/PS25)
      DELPHI=PHIS-PHIS25
      IF (ABS(DELPHI).LE.0.0001*PHIS) GO TO 10
9     TS25=TS25*EXP(4.0*DELPHI)
      ICOMIX=4
      GO TO 2
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10    IF (H25.GT.HS25) GO TO 11
      WRITE (8,48) P25,PS25,T25,TS25,H25,HS25
      ICOMIX=5
      CALL ERROR
11    V25=SQRT(2.*G*AJ*(H25-HS25))
      RHO=CAPSF*PS25/(AJ*REX25*TS25)
      A25=WG24/(RHO*V25)
      AM25=V25/CS25
      WRITE (6,49) A55,AM55,A25,AM25
      GO TO 27
C *** CALCULATE PS55 AND PS25
12    WQA=WG55/A55
      C1=P55*SQRT(G/(T55*AJ))*CAPSF
      MCON=0
      QQ(2)=0.
      QQ(3)=0.
      AM55=0.50
      TS55=0.875*T55
13    DO 14 I=1,15
      CALL PROCOM (FAR55,TS55,CS55,AK55,CP55,REX55,PHIS55,HS55)
      V55=AM55*CS55
      HSCAL=H55-V55**2/(2.*G*AJ)
      DELHS=HSCAL-HS55
      IF (ABS(DELHS).LE.0.0005*HSCAL) GO TO 15
14    TS55=TS55+DELHS/CP55
      ICOMIX=6
      GO TO 2
15    WQAT=C1*SQRT(AK55/REX55)*AM55/(1.+(AK55-1.)*AM55**2/2.)**((AK55+1.
     1)/(2.*(AK55-1.)))
      AMX=AM55
      IGOGO=0
16    DIR=WQA/WQAT
      EW=(WQA-WQAT)/WQA
      CALL AFQUIR (QQ(1),AMX,EW,0.,30.,0.0005,DIR,AMXT,ICON)
      ICOMIX=7
      GO TO (17,22,2),ICON
17    IF (AMXT.LE.1.0) GO TO 20
      AMXT=0.7
      MCON=MCON+1
      IF (MCON.LE.1) GO TO 20
      IF (MODE.EQ.3) GO TO 19
      PCNF=DUMD1
      WRITE (8,50) PCNF,AMX,P55,PS55,P25,PS25
      PCNF=1.01*PCNF
      DUMD1=PCNF
18    NOMAP=7
      ICOMIX=0
      RETURN
19    WRITE (8,51) ZF,AMX,P55,PS55,P25,PS25
      ZF=0.99*ZF
      GO TO 18
20    IF (IGOGO.EQ.1) GO TO 21
      AM55=AMXT
      GO TO 13
21    AM25=AMXT
      GO TO 23
22    IF (IGOGO.EQ.1) GO TO 26
      PS55=P55/EXP((PHI55-PHIS55)/REX55)
      IF (IGASMX .EQ. 0) GO TO 41
      IF (IGASMX .EQ. -1) GO TO 35
      WQA=WG24/A25
      C1=P25*SQRT(G/(T25*AJ))*CAPSF
      MCON=0
      QQ(2)=0.
      QQ(3)=0.
      AM25=0.25
      TS25=0.875*T25
23    DO 24 I=1,15
      CALL PROCOM (FAR24,TS25,CS25,AK25,CP25,REX25,PHIS25,HS25)
      V25=AM25*CS25
      HSCAL=H25-V25**2/(2.*G*AJ)
      DELHS=HSCAL-HS25
      IF (ABS(DELHS).LE.0.0005*HSCAL) GO TO 25
24    TS25=TS25+DELHS/CP25
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      ICOMIX=8
      GO TO 2
25    WQAT=C1*SQRT(AK25/REX25)*AM25/(1.+(AK25-1.)*AM25**2/2.)**((AK25+1.
     1)/(2.*(AK25-1.)))
      AMX=AM25
      IGOGO=1
      GO TO 16
26    PS25=P25/EXP((PHI25-PHIS25)/REX25)
27    WG6=WG24+WG55
      ERR(5)=(PS25-PS55)/PS25
      WF55 = FAR55*WG55/(FAR55+1.)
      WA55 = WG55/(FAR55+1.)
      WF24 = FAR24*WG24/(FAR24+1.)
      WA24 = WG24/(FAR24+1.)
      FAR6 = (WF55+WF24)/(WA55+WA24)
      H6=(WG24*H25+WG55*H55)/WG6
      CALL THERMO (1.,H6,T6,PHI6,AMX,1,FAR6,1)
      C1=PS55*A55*(1.+AK55*AM55**2)+PS25*A25*(1.+AK25*AM25**2)
      TS6=0.833*T6
      DO 32 I=1,15
      CALL PROCOM (FAR6,TS6,CS6,AK6,CP6,REX6,PHIS6,HS6)
      C2=WG6*SQRT(AJ*REX6*T6/(AK6*G))
      C3=C2/(CAPSF*C1)
      C4=(AK6-1.)/2.-(C3*AK6)**2
      C5=1.-2.*AK6*C3**2
      C6=C5**2+4.*C4*C3**2
      ICOMIX=9
      IF (C6) 28,29,30
28    CALL ERROR
      RETURN
29    AM62G=-C5/(2.*C4)
      GO TO 31
30    AM62G=(SQRT(C6)-C5)/(2.*C4)
31    IF (AM62G.LE.0.) GO TO 28
      AM6G=SQRT(AM62G)
      V6=AM6G*CS6
      HSCAL=H6-V6**2/(2.*G*AJ)
      DELHS=HSCAL-HS6
      IF (ABS(DELHS).LE.0.0005*HSCAL) GO TO 33
32    TS6=TS6+DELHS/CP6
      ICOMIX=10
      CALL ERROR
   33 A6G=A25+A55
      C7=SQRT(1.+(AK6-1.)*AM62G/2.)
      PS6=C2/(CAPSF*A6G*AM6G*C7)
      P6=PS6*EXP((PHI6-PHIS6)/REX6)
      CALL THERMO (P6,H6,T6,S6,XX1,1,FAR6,0)
      S6AVE=(WG24*S25+WG55*S55)/WG6
      IF (S6.GE.S6AVE) GO TO 35
      S6=S6AVE
      P6=EXP(AMX*(PHI6-S6)/RDEM)
35    IF (IGASMX.EQ.1) GO TO 43
      IF (IGASMX .EQ. -1) GO TO 36
      IF (IGASMX .EQ. 2) GO TO 37
   36 T6  = T55
      P6  =P55
      H6  =H55
      S6  =S55
      WG6 =WG55
      PS6 =PS55
      FAR6=FAR55
      AK6 =AK55
   37 IF (IDES .EQ. 0) GO TO 38
C***  CALCULATES A6 AS A FUNCTION OF INPUT AM6
      TS6=T6/(1.0+(((AK6-1.0)/2.0)*AM6**2))
      DO 34 JJ=1,15
      AK6P=AK6
      CALL PROCOM (FAR6,TS6,CS6,AK6,CP6,REX6,PHIS6,HS6)
      V6=AM6*CS6
      DELAK6=AK6P-AK6
      IF (ABS(DELAK6) .LE. 0.0005*AK6) GO TO 54
   34 TS6=T6/(1.0+(((AK6-1.0)/2.0)*AM6**2))
      ICOMIX=11
      CALL ERROR
```

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   54 PS6=P6/((1.0+(((AK6-1.0)/2.0)*AM6**2))**(AK6/(AK6-1.0)))
      AM6ABD=AM6
      RHO=CAPSF*PS6/(AJ*REX6*TS6)
      A6=WG6/(RHO*V6)
      WRITE (6,52) A6
      GO TO 44
C     CALCULATES M6=F(A6DESIGN)
 38   TS6P=T6/(1.0+(((AK6-1.0)/2.0)*AM6ABD**2))
      DO 39 I=1,15
      CALL PROCOM (FAR6,TS6P,CS6,AK6,CP6,REX6,PHIS6,HS6)
      PS6P=PS6*(TS6P/TS6)**(AK6/(AK6-1.0))
      RHO6=CAPSF*PS6P/(AJ*REX6*TS6P)
      V6=SQRT(2.*G*AJ*(H6-HS6))
      IF ((H6-HS6).LT.0.0) GO TO 42
      A6P=WG6/(RHO6*V6)
      DELA6=A6P-A6
      V6=WG6/(RHO6*A6)
      AM6=V6/CS6
      AM62=AM6**2
      IF (ABS(DELA6).LE.00.002*A6) GO TO 40
 39   TS6P=T6/(1.0+(((AK6-1.0)/2.0)*AM62))
      ICOMIX=12
      CALL ERROR
 40   TS6=TS6P
      PS6=PS6P
      GO TO 44
 41   T6=T55
      P6=P55
      H6=H55
      S6=S55
      WG6=WG55
      PS6=PS55
      V6=V55
      AM6=AM55
      IF (IGASMX.EQ.0) A6=A55
      GO TO 44
 42   WRITE (6,53) H6,HS6
      ICOMIX=13
      CALL ERROR
 43   AM62=AM62G
      AM6=AM6G
      A6=A25+A55
      ICOMIX=0
 44   CALL COAFBN
      RETURN
 45   KKGO=1
      OPRDS=PRFDS*PRCDS
      PRFNEW=PRFDS*PS55/P25*1.02
      PRCNEW=OPRDS/PRFNEW
      ICOMIX=0
      CALL ENGBAL
      RETURN
C
C
 46   FORMAT (22H0SQRT OF H55-HS55 NEG ,6E15.6,6H$$$$$$)
 47   FORMAT (20H0TURBINE AREA DESIGN,6X6H  A55=,E15.8,8H    AM55=,E15.8)
 48   FORMAT (22H0SQRT OF H25-HS25 NEG ,6E15.6,6H$$$$$$)
 49   FORMAT (25H0TURBINE/DUCT AREA DESIGN,7H    A55=,E15.8,8H    AM55=,E1
     15.8,8H    A25=,E15.8,8H    AM25=,E15.8)
 50   FORMAT (12H0COMIX PCNF=,F7.4,4H AM=,F8.6,5H P55=,F9.5,6H PS55=,F9.
     15,5H P25=,F9.5,6H PS25=,F9.5,6H$$$$$$)
 51   FORMAT (10H0COMIX ZF=,F8.5,4H AM=,F8.6,5H P55=,F9.5,6H PS55=,F9.5,
     15H P25=,F9.5,6H PS25=,F9.5,6H$$$$$$)
 52   FORMAT (3X,27HAFTERBURNER DESIGN AREA A6 F8.3)
 53   FORMAT (3X,18HNEG.HS6 FACTOR H6 F9.4,3X,4HHS6 F9.4)
      END
```

```
$IBFTC COMNOZ
      SUBROUTINE COMNOZ
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      DATA AWORD/6HMNOZZL/
      WORD=AWORD
      A8SAV=A8
      A9SAV=A9
      NOZM=0
      IMNOZ=0
      IF (ITRAN .EQ. 1) CALL NOZCTR
      IF (NOZFLT.EQ.1.OR.NOZFLT.EQ.3) NOZM=1
      IF (IDES.EQ.1.OR.IAFTBN.GT.0.OR.NOZM.EQ.1) IMNOZ=1
      IF(ITRAN.EQ.1) IMNOZ=0
      IF (IMCD.EQ.1) GO TO 1
      CALL CONVRG (T7,H7,P7,S7,FAR7,WG7,P1,IMNOZ,A8,P7R,T8,H8,P8,S8,TS8,
     1PS8,V8,AM8,ICON)
      GO TO (3,3,3,2),ICON
```

```
1     CALL CONDIV (T7,H7,P7,S7,FAR7,WG7,P1,IMNOZ,A8,A9,P7R,T8,H8,P8,S8,T
     19,H9,P9,S9,TS8,TS9,PS8,PS9,V8,V9,AM8,AM9,ICON)
      IMSHOC=ICON
      GO TO (4,4,4,2),ICON
2     CALL ERROR
3     T9=T8
      H9=H8
      P9=P8
      S9=S8
      TS9=TS8
      PS9=PS8
      V9=V8
      AM9=AM8
      A9=A8
      IMSHOC=ICON+3
4     ERR(6)=(P7R-P7)/P7R
      IF(ISPOOL.EQ.1) ERR(3)=ERR(6)
      IF (IMNOZ.EQ.1) WRITE (6,5) A8,AM8,A9,AM9
      RETURN
C
C
5     FORMAT (14HONOZZLE DESIGN,10X8H      A8=,E15.8,8H     AM8=,E15.8,8H
     1    A9=,E15.8,8H    AM9=,E15.8)
      END
```

```
$IBFTC CONDIV
      SUBROUTINE CONDIV (TI,HI,PI,SI,FAR,WG,PA,IDES,AT,AO,PIR,TT,HT,PT,S
     1T,TO,HO,PO,SO,TST,TSO,PST,PSO,VT,VO,AMT,AMO,ICON)
C     ICON=1  SUBSONIC, COMPARE PIR WITH PI
C     ICON=2  SONIC, SHOCK INSIDE NOZZLE, COMPARE PIR WITH PI
C     ICON=3  SONIC, SHOCK OUTSIDE NOZZLE, COMPARE PIR WITH PI
C     ICON=4  ERROR
      COMMON/UNITS/ZI
      LOGICAL ZI
      DIMENSION Q(9)
      Q(2)=0.
      Q(3)=0.
      IF (ZI) GO TO 100
      AJ=778.26
      CAPSF=2116.2170
      G=32.174049
      GO TO 101
  100 AJ=1.0
      CAPSF=101325.0
      G=1.0
  101 CONTINUE
      CALL PROCOM (FAR,TI,XX1,XX2,XX3,XX4,PHII,XX6)
C *** SONIC CALCULATIONS
      J=0
      TSS=0.833*TI
1     J=J+1
      CALL PROCOM (FAR,TSS,CSS,AK,CP,REXS,PHISS,HSS)
      HSCAL=HI-CSS**2/(2.*G*AJ)
      DELHS=HSCAL-HSS
      IF (ABS(DELHS)-0.0005*HSCAL) 4,4,2
2     TSS=TSS+DELHS/CP
      IF (J-15) 1,1,3
3     ICON=4
      RETURN
4     IF (IDES) 11,11,5
C *** SONIC DESIGN. CALCULATE AT
5     VT=CSS
      TST=TSS
      PST=PI*(TST/TI)**(AK/(AK-1.))
      RHO=CAPSF*PST/(AJ*REXS*TST)
      AT=WG/(RHO*VT)
      AMT=1.0
C *** IDEAL EXPANSION DESIGN, CALCULATE AO
      PSO=PA
```

```
      J=0
      TSO=TI*(PSO/PI)**.286
6     J=J+1
      CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
      PHICAL=PHII-REX*ALOG(PI/PSO)
      DELPHI=PHICAL-PHISO
      IF (ABS(DELPHI)-0.0001*PHICAL) 8,8,7
7     TSO=TSO*EXP(4.*DELPHI)
      IF (J-15) 6,6,3
8     VO=SQRT(2.*G*AJ*(HI-HSO))
      AMO=VO/CSO
      AO=(AT/AMO)*(2.*(1.+(AK-1.)*AMO**2/2.)/(AK+1.))**((AK+1.)/(2.*(AK-
     11.)))
      PIR=PI
      ICON=3
9     TO=TI
      HO=HI
      PO=PI
      SO=SI
10    TT=TI
      HT=HI
      PT=PI
      ST=SI
      RETURN
C *** ASSUME SONIC THROAT AND ISENTROPIC EXPANSION TO AO
11    VT=CSS
      AMT=1.0
      TST=TSS
      RHO=WG/(AT*VT)
      PST=RHO*AJ*REXS*TST/CAPSF
      PIR=PST*(TI/TST)**(AK/(AK-1.))
      IF (PST-PA) 12,27,27
12    TSO=0.95*TI
      MAM=0
13    CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
      AMO=SQRT(2.*((TI/TSO)-1.)/(AK-1.))
      AOCAL=(AT/AMO)*(2.*(1.+(AK-1.)*AMO**2/2.)/(AK+1.))**((AK+1.)/(2.*(
     1AK-1.)))
      EA=(AO-AOCAL)/AO
      DIR=SQRT(AO/AOCAL)
      CALL AFQUIR (Q(1),TSO,EA,0.,100.,0.0001,DIR,TSOT,JCON)
      GO TO (14,18,3),JCON
14    TSO=TSOT
      IF (TSO-TI) 15,13,16
15    TSC=2.*TI/(AK+1.)
      IF (TSO.GT.TSC) GO TO 17
16    TSO=0.98*TI
      GO TO 13
17    IF (Q(2).LT.30.0.OR.AMO.LT.0.95.OR.MAM.EQ.1) GO TO 13
      TSO=2.*TI/(2.+0.98*(AK-1.))
      MAM=1
      GO TO 13
18    PSO=PIR*(TSO/TI)**(AK/(AK-1.))
      IF (PSO-PA) 20,19,27
C *** CRITICAL FLOW, ISENTROPIC EXPANSION TO PA
19    VO=AMO*CSO
      ICON=1
      GO TO 9
C *** SUBSONIC FLOW
20    PSO=PA
      Q(2)=0.
      Q(3)=0.
      J=0
      TSO=0.833*TI
21    J=J+1
      CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
      RHO=CAPSF*PSO/(AJ*REX*TSO)
      VO=WG/(RHO*AO)
      HSCAL=HI-VO**2/(2.*G*AJ)
      DELHS=HSCAL-HSO
      IF (ABS(DELHS)-0.0005*HSCAL) 23,23,22
22    TSO=TSO+DELHS/CP
      IF (J-15) 21,21,3
```

```
23    AMO=VO/CSO
      PIR=PSO*(TI/TSO)**(AK/(AK-1.))
      TST=TSO
24    CALL PROCOM (FAR,TST,CST,AK,CP,REX,PHIST,HST)
      PST=PIR*(TST/TI)**(AK/(AK-1.))
      RHO=PST*CAPSF/(AJ*REX*TST)
      VT=WG/(RHO*AT)
      HSCAL=HI-VT**2/(2.*G*AJ)
      EH=(HSCAL-HST)/HSCAL
      DIR=1.+(HSCAL-HST)/(CP*TST)
      CALL AFQUIR (Q(1),TST,EH,0.,20.,0.0005,DIR,TSTT,JCON)
      GO TO (25,26,3),JCON
25    TST=TSTT
      GO TO 24
26    AMT=VT/CST
      ICON=1
      GO TO 9
C *** SUPERCRITICAL FLOW, ISENTROPIC EXPANSION TO PA
27    PSO=PA
      J=0
      TSO=TI*(PSO/PIR)**.286
28    J=J+1
      CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
      PHICAL=PHII-REX*ALOG(PIR/PSO)
      DELPHI=PHICAL-PHISO
      IF (ABS(DELPHI)-0.0001*PHICAL) 30,30,29
29    TSO=TSO*EXP(4.0*DELPHI)
      IF (J-15) 28,28,3
30    VO=SQRT(2.*G*AJ*(HI-HSO))
      AMO=VO/CSO
      AOID=(AT/AMO)*(2.*(1.+(AK-1.)*AMO**2/2.)/(AK+1.))**((AK+1.)/(2.*(A
     1K-1.)))
      ICON=3
      N=0
      IF (AO-AOID) 31,9,32
C *** SUPERCRITICAL FLOW, ISENTROPIC EXPANSION TO AO
31    N=1
32    TSO=0.833*TI
      J=0
33    J=J+1
      CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
      AMO=SQRT(2.*((TI/TSO)-1.)/(AK-1.))
      AOCAL=(AT/AMO)*(2.*(1.+(AK-1.)*AMO**2/2.)/(AK+1.))**((AK+1.)/(2.*(
     1AK-1.)))
      DELA=AO-AOCAL
      IF (ABS(DELA)-0.0001*AO) 35,35,34
34    TSO=TSO*SQRT(AOCAL/AO)
      IF (J-50) 33,33,3
35    IF (N) 37,37,36
C *** UNDEREXPANDED, SHOCK OUTSIDE NOZZLE
36    PSO=PIR*(TSO/TI)**(AK/(AK-1.))
      VO=AMO*CSO
      GO TO 9
C *** OVEREXPANDED, FIND SHOCK POSITION
37    PSX=PIR*(TSO/TI)**(AK/(AK-1.))
      PSY=PSX*(2.*AK*AMO**2/(AK+1.)-(AK-1.)/(AK+1.))
      IF (PA-PSY) 38,39,39
C *** OVEREXPANDED, SHOCK OUTSIDE NOZZLE
38    PSO=PSX
      VO=AMO*CSO
      GO TO 9
C *** OVEREXPANDED, SHOCK INSIDE NOZZLE
39    PSO=PA
      J=0
      TSO=0.833*TI
40    J=J+1
      CALL PROCOM (FAR,TSO,CSO,AK.CP,REX,PHISO,HSO)
      RHO=CAPSF*PSO/(AJ*REX*TSO)
      VO=WG/(RHO*AO)
      HSCAL=HI-VO**2/(2.*G*AJ)
      DELHS=HSCAL-HSO
      IF (ABS(DELHS)-0.0005*HSCAL) 42,42,41
41    TSO=TSO+DELHS/CP
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```
      IF (J-15) 40,40,3
42    AMO=VO/CSO
      TO=TI
      HO=HI
      PO=PSO*(TO/TSO)**(AK/(AK-1.))
      SO=PHII-REX*ALOG(PO)
      ICON=2
      GO TO 10
      END
```

```
$IBFTC CONOUT
      SUBROUTINE CONOUT (ICON)
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
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      DIMENSION PARAM(424),WORDY(424),IOUT(150),AOUT(6),WOUT(6)
      EQUIVALENCE (PARAM,PCNFGU)
      DATA (WORDY(I),I=1,98)/
     16HPCNFGU,6HPCNCGU,6HT4GU  ,6HDUMD1 ,6HDUMD2 ,6HDELFG ,6HDELFN ,
     26HDELSFC,6HZFDS  ,6HPCNFDS,6HPRFDS ,6HETAFDS,6HWAFDS ,6HPRFCF ,
     36HETAFCF,6HWAFCF ,6HZCDS  ,6HPCNCDS,6HPRCDS ,6HETACDS,6HWACDS ,
     46HPRCCF ,6HETACCF,6HWACCF ,6HT4DS  ,6HWFBDS ,6HDTCODS,6HETABDS,
     56HWA3CDS,6HDPCODS,6HDTCOCF,6HETABCF,6HTFHPDS,6HCNHPDS,6HETHPDS,
     66HTFHPCF,6HCNHPCF,6HETHPCF,6HDHHPCF,6HT2DS  ,6HTFLPDS,6HCNLPDS,
     76HETLPDS,6HTFLPCF,6HCNLPCF,6HETLPCF,6HDHLPCF,6HT21DS ,6HT24DS ,
     86HWFDDS ,6HDTDUDS,6HETADDS,6HWA23DS,6HDPDUDS,6HDTDUCF,6HETADCF,
     96HT7DS  ,6HWFADS ,6HDTAFDS,6HETAADS,6HWG6CDS,6HDPAFDS,6HDTAFCF,
     $6HETAACF,6HA55   ,6HA25   ,6HA6    ,6HA7    ,6HA8    ,6HA9    ,
     $6HA28   ,6HA29   ,6HPS55  ,6HAM55  ,6HCVDNOZ,6HCVMNOZ,6HA8SAV ,
     $6HA9SAV ,6HA28SAV,6HA29SAV,6HT1    ,6HP1    ,6HH1    ,6HS1    ,
     $6HT2    ,6HP2    ,6HH2    ,6HS2    ,6HT21   ,6HP21   ,6HH21   ,
     $6HS21   ,6HT3    ,6HP3    ,6HH3    ,6HS3    ,6HT4    ,6HP4    /
      DATA (WORDY(I),I=99,189)/
     16HH4    ,6HS4    ,6HT5    ,6HP5    ,6HH5    ,6HS5    ,6HT55   ,
     26HP55   ,6HH55   ,6HS55   ,6HBLF   ,6HBLC   ,6HBLDU  ,6HBLOB  ,
     36HCNF   ,6HPRF   ,6HETAF  ,6HWAFC  ,6HWAF   ,6HWA3   ,6HWG4   ,
     46HFAR4  ,6HCNC   ,6HPRC   ,6HETAC  ,6HWACC  ,6HWAC   ,6HETAB  ,
     56HDPCOM ,6HDUMP  ,6HCNHP  ,6HETATHP,6HDHTCHP,6HDHTC  ,6HBLHP  ,
     66HWG5   ,6HFAR5  ,6HCS    ,6HCNLP  ,6HETATLP,6HDHTCLP,6HDHTF  ,
     76HBLLP  ,6HWG55  ,6HFAR55 ,6HHPEXT ,6HAM    ,6HALTP  ,6HETAR  ,
     86HZF    ,6HPCNF  ,6HZC    ,6HPCNC  ,6HWFB   ,6HTFFHP ,6HTFFLP ,
     96HPCBLF ,6HPCBLC ,6HPCBLDU,6HPCBLOB,6HPCBLHP,6HPCBLLP,6HXP1   ,
     $6HXWAF  ,6HXWAC  ,6HXBLF  ,6HXBLDU ,6HXH3   ,6HDUMS1 ,6HDUMS2 ,
     $6HXT21  ,6HXP21  ,6HXH21  ,6HXS21  ,6HT23   ,6HP23   ,6HH23   ,
     $6HS23   ,6HT24   ,6HP24   ,6HH24   ,6HS24   ,6HT25   ,6HP25   ,
     $6HH25   ,6HS25   ,6HT28   ,6HP28   ,6HH28   ,6HS28   ,6HT29   /
      DATA (WORDY(I),I=190,280)/
     16HP29   ,6HH29   ,6HS29   ,6HWAD   ,6HWFD   ,6HWG24  ,6HFAR24 ,
     26HETAD  ,6HDPDUC ,6HBYPASS,6HDUMS3 ,6HTS28  ,6HPS28  ,6HV28   ,
     36HAM28  ,6HTS29  ,6HPS29  ,6HV29   ,6HAM29  ,6HXT55  ,6HXP55  ,
     46HXH55  ,6HXS55  ,6HXT25  ,6HXP25  ,6HXH25  ,6HXS25  ,6HXWFB  ,
     56HXWG55 ,6HXFAR55,6HXWFD  ,6HXWG24 ,6HXFAR24,6HXXP1  ,6HDUMB  ,
     66HT6    ,6HP6    ,6HH6    ,6HS6    ,6HT7    ,6HP7    ,6HH7    ,
     76HS7    ,6HT8    ,6HP8    ,6HH8    ,6HS8    ,6HT9    ,6HP9    ,
     86HH9    ,6HS9    ,6HWG6   ,6HWFA   ,6HWG7   ,6HFAR7  ,6HETAA  ,
     96HDPAFT ,6HV55   ,6HV25   ,6HPS6   ,6HV6    ,6HAM6   ,6HTS7   ,
     $6HPS7   ,6HV7    ,6HAM7   ,6HAM25  ,6HTS8   ,6HPS8   ,6HV8    ,
     $6HAM8   ,6HTS9   ,6HPS9   ,6HV9    ,6HAM9   ,6HVA    ,6HFRD   ,
     $6HVJD   ,6HFGMD  ,6HVJM   ,6HFGMM  ,6HFGPD  ,6HFGPM  ,6HFGM   ,
     $6HFGP   ,6HWFT   ,6HWGT   ,6HFART  ,6HFG    ,6HFN    ,6HSFC   /
      DATA (WORDY(I),I=281,373)/
     16HWA32  ,6HDPWGDS,6HDPWING,6HWA32DS,6HA38   ,6HAM38  ,
     26HV38   ,6HT38   ,6HH38   ,6HP38   ,6HTS38  ,6HPS38  ,6HT39   ,
     36HH39   ,6HP39   ,6HTS39  ,6HV39   ,6HAM39  ,6HA39   ,6HBPRINT,
     46HWG37  ,6HCVDWNG,6HFGMWNG,6HFGPWNG,6HFNWING,6HFNMAIN,6HFWOVFN,
     56HPS39  ,6HFFOVFN,6HFCOVFN,6HFMNOFN,6HFNOVFD,6HVJW   ,
     96HT22   ,6HP22   ,6HH22   ,6HS22   ,6HT50   ,6HP50   ,6HH50   ,
     $6HS50   ,6HWA22  ,6HZI    ,6HPCNI  ,6HCNI   ,6HPRI   ,6HETAI  ,
     $6HWACI  ,6HTFFIP ,6HCNIP  ,6HETATIP,6HDHTCIP,6HDHTI  ,6HBLIP  ,
     $6HPCBLIP,6HPCNIGU,6HZIDS  ,6HPCNIDS,6HPRIDS ,6HETAIDS,6HWAIDS ,
     $6HPRICF ,6HETAICF,6HWAICF ,6HTFIPDS,6HCNIPDS,6HETIPDS,6HTFIPCF,
     $6HCNIPFC,6HETIPCF,6HDHIPCF,6HWAICDS,6HWAI   ,6HPCBLI ,6HBLI   ,
     $6HT22DS ,6HWA21  ,6HWG50  ,6HFAR50 ,6HA24   ,6HAM23  ,6HDUMSPL,
     $6HFXFN2M,6HFXM2CP,6HAFTFAN,6HPUNT  ,6HPCBLID,6HP6DSAV,6HAM6DSV,
     $6HETAASV,6HFAR7SV,6HT4PBL ,6HT41    /
      DATA THEEND,BLANK,LIMIT/6HTHEEND,6H      ,373/
      COMMON/UNITS/SI
      LOGICAL SI
      IF(ICON.EQ.1) GO TO 24
      IF (SI) GO TO 22
      WRITE (6,21)
   21 FORMAT (1X,30HTHE OUTPUT IS IN ENGLISH UNITS)
      GO TO 24
   22 WRITE (6,23)
   23 FORMAT (1X,25HTHE OUTPUT IS IN SI UNITS)
   24 CONTINUE
      GO TO (1,6),ICON
C *** INPUT SECTION
```

```
1       DO 4 N=1,150
        NUM=N
        PEAD (5,11) AIN,CHANGE
        IF (AIN.EQ.THEEND) GO TO 5
        DO 2 J=1,LIMIT
        JJ=J
        IF (AIN.EQ.WORDY(J)) GO TO 3
2       CONTINUE
        WRITE (6,12) AIN
        GO TO 4
3       IOUT(NUM)=JJ
        IF (CHANGE.NE.BLANK) WORDY(JJ)=CHANGE
4       CONTINUE
        WRITE (6,13)
5       NUM=NUM-1
        RETURN
C *** OUTPUT SECTION
6       IF (NUM.EQ.1) GO TO 10
        N=NUM
        J=6
        DO 9 I=1,NUM,6
        IF (N.GT.6) GO TO 7
        J=N
7       N=N-6
        DO 8 K=1,J
        L=I+K-1
        M=IOUT(L)
        WOUT(K)=WORDY(M)
8       AOUT(K)=PARAM(M)
        WRITE (6,14) (WOUT(K),K=1,J)
        WRITE (6,15) (AOUT(K),K=1,J)
        IF (N.LE.0) GO TO 10
9       CONTINUE
10      RETURN
C
C
C
11      FORMAT (A6,6X,A6)
12      FORMAT (10HOTHE WORD ,A6,26H NOT FCUND IN COMMON ARRAY)
13      FORMAT (22HOERROR IN CONOUT INPUT)
14      FORMAT (26X,A6,5(9XA6))
15      FORMAT (1H ,20X6E15.6)
        END
```

```
$IBFTC CONVRG
      SUBROUTINE CONVRG (TI,HI,PI,SI,FAR,WG,PA,IDES,AO,PR,TO,HO,PO,SO,TS
     1O,PSO,VO,AMO,ICON)
C     ICON=1     SUBSONIC, COMPARE PI WITH PR
C     ICON=2     SONIC, COMPARE PI WITH PR
C     ICON=4     ERROR
      COMMON/UNITS/ZI
      LOGICAL ZI
      IF (ZI) GO TO 100
      AJ=778.26
      CAPSF=2116.217
      G=32.174049
      CPG=.250
      GO TO 101
  100 AJ=1.0
      CAPSF=1.0
      G=1.0
      CPG=1048.
  101 CONTINUE
      CALL PROCOM (FAR,TI,XX1,XX2,XX3,XX4,PHII,XX6)
C *** SONIC CALCULATIONS
      J=0
      TSS=0.833*TI
1     J=J+1
      CALL PROCOM (FAR,TSS,CSS,AKS,CP,REXS,PHISS,HSS)
```

```
      HSCAL=HI-CSS**2/(2.*G*AJ)
      DELHS=HSCAL-HSS
      IF (ABS(DELHS)-0.0005*HSCAL) 4,4,2
 2    TSS=TSS+DELHS/CP
      IF (J-15) 1,1,3
 3    ICON=4
      RETURN
 4    IF (IDES) 12,12,5
C *** ISENTROPIC EXPANSION CALCULATICNS
 5    J=0
      TSI=TI*(PA/PI)**0.286
 6    J=J+1
      CALL THERMO (PA,HSI,TSI,SSI,XX1,1,FAR,0)
      IF (ABS(SSI-SI)-0.0001*SI) 8,8,7
 7    TSI=TSI/EXP((SSI-SI)/CPG)
      IF (J-30) 6,6,3
 8    VIS=SQRT(2.*G*AJ*(HI-HSI))
      IF (VIS-CSS) 9,11,11
C *** SUBSONIC DESIGN, CALCULATE AO
 9    VO=VIS
      TSO=TSI
      PSO=PA
      CALL PROCOM (FAR,TSO,CSO,XX2,XX3,REX,PHISO,HSO)
      RHO=CAPSF*PSO/(AJ*REX*TSO)
      AO=WG/(RHO*VO)
      AMO=VO/CSO
      PR=PI
      ICON=1
 10   TO=TI
      HO=HI
      PO=PI
      SO=SI
      RETURN
C *** SONIC DESIGN, CALCULATE AO
 11   VO=CSS
      TSO=TSS
      PSO=PI*(TSO/TI)**(AKS/(AKS-1.))
      RHO=CAPSF*PSO/(AJ*REXS*TSO)
      AO=WG/(RHO*VO)
      AMO=1.0
      PR=PI
      ICON=2
      GO TO 10
C *** NON-DESIGN, CALCULATE CRITICAL CONDITIONS
 12   VO=CSS
      TSO=TSS
      PSO=PA
      RHO=CAPSF*PSO/(AJ*REXS*TSO)
      AOCRIT=WG/(RHO*VO)
      AMO=1.0
      PR=PSO*(TI/TSO)**(AKS/(AKS-1.))
      IF (AO-AOCRIT) 13,13,14
C *** NON-DESIGN, CRITICAL AND SUPERCRITICAL CCNDITIONS
 13   PSO=PSO*AOCRIT/AO
      PR=PR*AOCRIT/AO
      ICON=2
      GO TO 10
C *** NON-DESIGN, SUBSONIC CALCULATICNS
 14   PSO=PA
      J=0
      TSO=0.833*TSO
 15   J=J+1
      CALL PROCOM (FAR,TSO,CSO,AKO,CP,REX,PHISO,HSO)
      RHO=CAPSF*PSO/(AJ*REX*TSO)
      VO=WG/(RHO*AO)
      HSCAL=HI-VO**2/(2.*G*AJ)
      DELHS=HSCAL-HSO
      IF (ABS(DELHS)-0.0005*HSCAL) 17,17,16
 16   TSO=TSO+DELHS/CP
      IF (J-15) 15,15,3
 17   AMO=VO/CSO
      PR=PSO*(TI/TSO)**(AKO/(AKO-1.))
      ICON=1
```

```
      GO TO 10
      END
```

```
$IBFTC DERIV
      FUNCTION DERIV(I,X)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      DERIV=0.0
      FO(I,1)= X
      FO(I,2)=X
      FO(I,3)=DERIV
      FO(I,4)=DERIV
      RETURN
    1 XO=FO(I,2)
      DERIV=(X-XO)/DT
      FO(I,1)= X
      FO(I,3)=DERIV
      RETURN
      END
```

```
$IBFTC ENGBAL
      SUBROUTINE ENGBAL
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
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      3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
      4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
      5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
      6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
      7H38    ,P38    ,TS38   ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
      8V39    ,AM39   ,A39    ,BPRINT,WG37   ,CVDWNG,FGMWNG,FGPWNG,
      9FNWING,FNMAIN,FWOVFN,PS39   ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
      $VJW    ,T22    ,P22    ,H22    ,S22    ,T50    ,P50    ,H50
       COMMON /ALL5/
      1S50    ,WA22   ,ZI     ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
      2TFFIP  ,CNIP   ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
      3ZIDS   ,PCNIDS,PRIDS  ,ETAIDS,WAIDS  ,PRICF  ,ETAICF,WAICF  ,
      4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
      5WAI    ,PCBLI  ,BLI    ,T22DS  ,WA21   ,WG50   ,FAR50  ,A24    ,
      6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
      7AM6DSV,ETAASV,FAR7SV,T4PBL  ,T41    ,FAN    ,ISPOOL
       COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
       LOGICAL ERRER,FXFN2M,FXM2CP,DUMSPL,FAN
       DIMENSION DELSAV(9)
       COMMON/ERER/ERRER
       DIMENSIONVAR(9),DEL(9),ERRB(9),DELVAR(9),EMAT(9,9),VMAT(9),AMAT(9)
       DATA AWORD/6HENGBAL/
       DATA VDELTA,VLIM,VCHNGE,NOMISX/
      1 1.E-4,0.100,0.850,4/
       DATA DEL/9*0./
       DATA DELSAV/9*1.E-4/
       IF(ITRAN.NE.1) GO TO 100
       CALL SYG(1)
       JTRAN=1
       INIT=1
       NSTEP=NSTEP+1
       TIME=DT*FLOAT(NSTEP)
       IF(TIME.GT.TF) GO TO 100
       CALL DISTRB
       CALL COINLT
       GO TO 101
100    CALL PUTIN
101    CONTINUE
       IF (INIT.EQ.1) GO TO 1
       TFFHP=TFHPDS
       TFFIP=TFIPDS
       IF (FXM2CP) TFFIP=TFHPDS
       TFFLP=TFLPDS
1      LOOPER=0
       NUMMAP=0
       NOMISS=0
2      LOOP=0
       MISMAT=0
       NOMAP=0
       IGO=2
       DO 3 I=1,9
       VMAT(I)=0.
       AMAT(I)=0.
       DELVAR(I)=0.
       DO 3 L=1,9
3      EMAT(I,L)=0.
4      LOOPER=LOOPER+1
       CALL COFAN
       WORD=AWORD
       IF(.NOT.FAN) DUMSPL=.TRUE.
       IF (LOOPER.GT.ITRYS) ERRER=.TRUE.
       IF (LOOPER.GT.ITRYS) GO TO 26
       IF (NOMAP.GT.0) GO TO 2
       NUMMAP=0
5      VAR(1)=ZF*100.
       IF (MODE.NE.3) VAR(2)=PCNF
       IF (MODE.EQ.3) VAR(2)=T4/10.
       VAR(3)=ZC*100.
       IF (MODE.NE.1) VAR(4)=PCNC
       IF (MODE.EQ.1) VAR(4)=T4/10.
       VAR(5)=TFFHP
       VAR(6)=TFFLP
       VAR(7)=ZI*100.
       VAR(8)=PCNI
```

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      VAR(9)=TFFIP
      NMAX=9
      IF(FAN) GO TO 39
      NMAX=6
      IF(ISPOOL.EQ.2) GO TO 7
      NMAX=3
      VAR(3)=TFFLP
      GO TO 7
39    IF(.NOT.FXFN2M.AND.(.NOT.DUMSPL)) GO TO 6
      NMAX=7
      IF (DUMSPL) NMAX=6
6     IF (.NOT.FXM2CP) GO TO 7
      NMAX=7
      VAR(4)=PCNI
      VAR(5)=TFFIP
7     CONTINUE
      DO 8 I=1,NMAX
      IF (ABS(ERR(I)).GT.TOLALL) GO TO 9
8     CONTINUE
      IF(ITRAN.EQ.1) CALL ROLL
      CALL PERF
      CALL ERROR
9     IF (LOOP.GT.0) GO TO 11
      MAPEDG=0
      MAPSET=0
      DO 10 I=1,NMAX
      ERRB(I)=ERR(I)
10    DEL(I)=VDELTA*VAR(I)
      GO TO 14
11    IF (MISMAT.GT.0) GO TO 29
      IF (MAPEDG.EQ.0) GO TO 12
      MAPEDG=0
      MAPSET=1
      VAR(LOOP)=VAR(LOOP)+2.*DEL(LOOP)
      GO TO 15
12    IF (MAPSET.EQ.0) VAR(LOOP)=VAR(LOOP)+DEL(LOOP)
      IF (MAPSET.EQ.1) VAR(LOOP)=VAR(LOOP)-DEL(LOOP)
      MAPSET=0
      DO 13 I=1,NMAX
      IF (DEL(LOOP).NE.0.) DELSAV(LOOP)=DEL(LOOP)
      IF (DEL(LOOP).EQ.0.) DEL(LOOP)=DELSAV(LOOP)
      EMAT(I,LOOP)=(ERRB(I)-ERR(I))/DEL(LOOP)
13    CONTINUE
14    LOOP=LOOP+1
      IF (LOOP.GT.NMAX) GO TO 17
      VAR(LOOP)=VAR(LOOP)-DEL(LOOP)
15    ZF=VAR(1)/100.
      IF (MODE.NE.3) PCNF=VAR(2)
      IF (MODE.EQ.3) T4=VAR(2)*10.
      ZC=VAR(3)/100.
      IF (MODE.NE.1) PCNC=VAR(4)
      IF (MODE.EQ.1) T4=VAR(4)*10.
      TFFHP=VAR(5)
      TFFLP=VAR(6)
      ZI=VAR(7)/100.
      PCNI=VAR(8)
      TFFIP=VAR(9)
      IF (.NOT.FXM2CP) GO TO 16
      PCNI=VAR(4)
      TFFIP=VAR(5)
16    IF (ISPOOL.EQ.1) TFFLP=VAR(3)
      IF (ZI.LT.0.) ZI=0.05
      IF (ZF.LT.0.) ZF=0.05
      IF (ZC.LT.0.) ZC=0.05
      GO TO (2,4),IGO
17    DO 18 I=1,NMAX
18    AMAT(I)=-ERRB(I)
      DO 20 I=1,NMAX
      IZERO=0
      DO 19 LOOP=1,NMAX
19    IF (EMAT(I,LOOP).EQ.0.) IZERO=IZERO+1
      IF (IZERO.LT.NMAX) GO TO 20
      WRITE (6,32) I
```

```
      LOOPER=ITRYS+100
      GO TO 26
20    CONTINUE
      DO 22 LOOP=1,NMAX
      IZERO=0
      DO 21 I=1,NMAX
21    IF (EMAT(I,LOOP).EQ.0.) IZERO=IZERO+1
      IF (IZERO.LT.NMAX) GO TO 22
      WRITE (6,33) LOOP
      LOOPER=ITRYS+100
      GO TO 26
22    CONTINUE
23    CALL MATRIX (EMAT,VMAT,AMAT,NMAX)
      LBIG=0
      VARBIG=0.
      DO 24 L=1,NMAX
      ABSVAR=ABS(VMAT(L))
      IF (ABSVAR.LE.VLIM*VAR(L)) GO TO 24
      IF (ABSVAR.LE.VARBIG) GO TO 24
      LBIG=L
      VARBIG=ABSVAR
24    CONTINUE
      VRATIO=1.0
      IF (LBIG.GT.0) VRATIO=VLIM*VAR(LBIG)/VARBIG
      ERRAVE=0.0
      VMTAVE=0.0
      DELAVE=0.0
      DO 25 L=1,NMAX
      DELVAR(L)=VRATIO*VMAT(L)
      ERRAVE=ERRAVE+ABS(AMAT(L))/FLOAT(NMAX)
      VAR(L)=VAR(L)+DELVAR(L)
      VMTAVE=VMTAVE+ABS(VMAT(L))/FLOAT(NMAX)
25    DELAVE=DELAVE+ABS(DELVAR(L))/FLOAT(NMAX)
      IF (MISMAT.GT.0) GO TO 31
      IF (NOMISS.EQ.0) MISMAT=1
      IF (MISMAT.EQ.0) IGO=1
26    WRITE (8,34) LOOPER
      DO 27 I=1,NMAX
27    WRITE (8,35) AMAT(I),(EMAT(I,L),L=1,9),VMAT(I),DELVAR(I),VAR(I)
      WRITE (8,36) ERRAVE,VMTAVE,DELAVE
28    IF (LOOPER.LT.ITRYS) GO TO 15
      CALL ERROR
      RETURN
29    VMTAVX=VMTAVE
      DO 30 I=1,NMAX
30    AMAT(I)=-ERR(I)
      GO TO 23
31    WRITE (8,37) AMAT,ERRAVE,DELVAR,DELAVE,VMAT,VMTAVE,VAR
      MISMAT=MISMAT+1
      IF (VMTAVE.LT.VCHNGE*VMTAVX) GO TO 28
      WRITE (8,38)
      IF (MISMAT.LT.NOMISX) NOMISS=1
      MISMAT=0
      LOOP=0
      IGO=2
      GO TO 5
C
C
32    FORMAT (4HOROW,I2,16H IS ZERO IN EMAT)
33    FORMAT (7HOCOLUMN,I2,16H IS ZERO IN EMAT)
34    FORMAT (8HB   ERRB,28X23HERROR MATRIX AFTER LOOP,I4,29X4HVMAT,6X6H
     1DELVAR,7X14HVARIABLE$$$$$$)
35    FORMAT (1H0,F8.4,10F9.3,2F11.4,6H$$$$$$)
36    FORMAT (1H0,F8.4,32X14HAVERAGE VALUES,31X,2F11.4,6H$$$$$$)
37    FORMAT (12H0-----  AMAT,10F11.6,6H$$$$$$,/,12H -----DELVAR,10F11.6
     1,6H$$$$$$,/,12H -----  VMAT,10F11.6,6H$$$$$$,/,12H -----   VAR,9F1
     21.6,6H$$$$$$)
38    FORMAT (1H0,50X22HCHANGE TOO SMALL$$$$$$)
      END
```

```
$IBFTC ERROR
      SUBROUTINE ERROR
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV.ETAASV,FAR7SV,T4PBL .T41   ,FAN   ,ISPOOL
      COMMON/WHRERR/ICOAFB,ICODUC,ICOMIX
      IF (ICOAFB .LT. 1) ICOAFB=0
      IF (ICOMIX .LT. 1) ICOMIX=0
      IF (ICODUC .LT. 1) ICODUC=0
      IF (ICOAFB .NE. 0) WRITE(6,10)ICOAFB
      IF (ICODUC .NE. 0) WRITE(6,11)ICODUC
      IF (ICOMIX .NE. 0) WRITE(6,12)ICOMIX
   10 FORMAT(27H THE ERROR IN COAFBN IS AT ,I3)
   11 FORMAT(27H THE ERROR IN CODUCT IS AT ,I3)
   12 FORMAT(27H THE ERROR IN COMIX  IS AT ,I3)
      LOGICAL ERRER
      COMMON/ERER/ERRER
      DIMENSION TRASH1(80),TRASH2(80),TRASH3(80),TRASH4(80),TRASH5(80)
      EQUIVALENCE (TRASH1,PCNFGU),(TRASH2,T1),(TRASH3,XP1),(TRASH4,WG6)
      EQUIVALENCE (TRASH5,S50)
```

```
      DATA AWORD/6HCOMMON/
      ERRER=.TRUE.
      WRITE (6,2) WORD
      WORD=AWORD
      WRITE (6,3) WORD,ZF,PCNF,ZI,PCNI,ZC,PCNC,T4,MODE
      WRITE (6,4)
      WRITE (6,5) (TRASH1(I),I=1,80)
      WRITE (6,6)
      WRITE (6,5) (TRASH2(I),I=1,80)
      WRITE (6,4)
      WRITE (6,5) (TRASH3(I),I=1,80)
      WRITE (6,4)
      WRITE (6,5) (TRASH4(I),I=1,80)
      WRITE (6,4)
      WRITE (6,8) (TRASH5(I),I=1,55)
      WRITE (6,4)
      WRITE (6,7) LOOPER
      IF (IDUMP.EQ.0) GO TO 1
      WRITE (6,6)
      CALL SYG (2)
1     CALL ENGBAL
      RETURN
C
C
2     FORMAT (28H0AN ERROR HAS BEEN FOUND IN ,A6)
3     FORMAT (1H0,A6,9X,7E15.6,I4)
4     FORMAT (2H0 )
5     FORMAT (1H ,8E15.6)
6     FORMAT (1H1)
7     FORMAT (25H0FAILED TO CONVERGE AFTER,I4,6H LOOPS)
8     FORMAT (1H+,30X,6E15.6/(1H ,8E15.6))
      END
```

```
$IBFTC ETAAB
      SUBROUTINE ETAAB (FAR,EM6,P6,ETA,ETAADS,ETAASV,P6DS,P6DSAV,AM6DS,A
     1M6DSV,IDES,FAR7DS,FAR7SV)
      DIMENSION FART(25),ETABRT(25),EM6T(7),DELM6(7),P6T(14),DELP6(14)
      DIMENSION X(3),Y(3)
      DATA FART/.0390,.0585,.0732,.0878,.0976,.1171,.1268,.1463,.1619,
     1.1834,.1951,.2195,.2439,.2927,.3415,.4146,.4634,.5366,.6341,.7317,
     2.8293,.9268,1.000,1.0634,1.7/
      DATA ETABRT/.9400,.9887,1.0193,1.0306,1.0227,.9672,.9377,.9207,
     1.9354,.9626,.9773,1.0193,1.0532,1.077,1.0781,1.077,1.0747,1.0668,
     21.0578,1.0510,1.0374,1.0192,1.00,.9626,.9151/
      DATA EM6T/1.00,1.071,1.190,1.309,1.428,1.547,1.666/
      DATA DELM6/0.,.013,.041,.073,.110,.147,.187/
      DATA P6T/.220,.2267,.250,.300,.3333,.3767,.4167,.500,.5833,.6667,
     1.75,.8333,.9167,1.0/
      DATA DELP6/-.142,-.125,-.10,-.075,-.062,-.05,-.041,-.027,-.019,
     1-.013,-.008,-.004,-.0021,0./
      IF (IDES.NE.1) GO TO 5
      DO 1 K=1,25
1     ETABRT(K)=ETABRT(K)*ETAADS/ETAASV
      DO 2 K=1,25
2     FART(K)=FART(K)*FAR7DS/FAR7SV
      DO 3 K=1,7
3     EM6T(K)=EM6T(K)*AM6DS/AM6DSV
      DO 4 M=1,14
4     P6T(M)=P6T(M)*P6DS/P6DSAV
      ETAASV=ETAADS
      P6DSAV=P6DS
      FAR7SV=FAR7DS
      AM6DSV=AM6DS
      RETURN
5     CONTINUE
      N=0
      IF (FAR.GT.0.067) GO TO 8
      DO 6 J=1,25
6     IF (FAR.GE.FART(J)) N=J-1
```

```
      IF (N.EQ.0) N=1
      IF (N.GE.24) N=23
      DO 7 I=1,3
      NN=N-1+I
      X(I)=FART(NN)
7     Y(I)=ETABRT(NN)
      CALL PARABO (X,Y,FAR,ETA1)
      GO TO 9
8     ETA1=-2.*FAR+.1948
9     M=0
      DO 10 J=1,7
10    IF (EM6.GE.EM6T(J)) M=J-1
      IF (M.EQ.0) M=1
      IF (M.GE.6) M=5
      DO 11 I=1,3
      MM=M-1+I
      X(I)=EM6T(MM)
11    Y(I)=DELM6(MM)
      CALL PARABO (X,Y,EM6,COR1)
      L=0
      DO 12 J=1,14
12    IF (P6.GE.P6T(J)) L=J-1
      IF (L.EQ.0) L=1
      IF (L.GE.13) L=12
      DO 13 I=1,3
      LL=L-1+I
      X(I)=P6T(LL)
13    Y(I)=DELP6(LL)
      CALL PARABO (X,Y,P6,COR2)
      ETA=ETA1*(1.-COR1)*(1.+COR2)
      RETURN
      END
```

```
$IBFTC FASTBK
      SUBROUTINE FASTBK
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLDB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
```

```
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      LOGICAL FAN
      XT55=T55
      XP55=P55
      XH55=H55
      XS55=S55
      IF(FAN) GO TO 1
      T25=T21
      P25=P21
      H25=H21
      S25=S21
      WG24=WAF-BLF
    1 XT25=T25
      XP25=P25
      XH25=H25
      XS25=S25
      XWFB=WFB
      XWG55=WG55
      XFAR55=FAR55
      XWFD=WFD
      XWG24=WG24
      XFAR24=FAR24
      XXP1=P1
      CALL COMIX
      RETURN
      END
```

```
$IBFTC FRTOSD
      SUBROUTINE FRTOSD
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
```

```
1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
$TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
 COMMON /ALL3/
1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
$T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
 COMMON /ALL4/
1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
$VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
 COMMON /ALL5/
1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
 LOGICAL FAN
 XP1=P1
 XWAF=WAF
 XWAC=WAC
 XBLF=BLF
 XBLDU=BLDU
 XH3=H3
 XT21=T21
 XP21=P21
 XH21=H21
 XS21=S21
 IF(FAN) CALL CODUCT
 IF(FAN) RETURN
 CALL FASTBK
 RETURN
 END
```

E-8111
SGM (54)
p. 75
70%

```
$IBFTC GEN2
 COMMON /WORDS/ WORD
 COMMON /DESIGN/
1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
2IDBURN,IAFTBN,IOCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
 COMMON /ALL1/
1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
```

```
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29    ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON/LOOPPR/KKGO,PRFNEW,PRCNEW
      DATAIII/0/
      DIMENSION X(1)
      EQUIVALENCE (X,IDES)
      LOGICAL ERRER,CLEAR
      DATA CLEAR/.TRUE./
      COMMON/ERER/ERRER
      LOGICAL RSTART
      RSTART=.TRUE.
      ERRER=.FALSE.
      ITRAN=0
      JTRAN=0
      NSTEP = 0
      TIME = 0.0
      TPRINT = 0.0
      DTPRNT = 0.0
      IF (.NOT.CLEAR) CALL ENGBAL
      CLEAR=.FALSE.
      DO 1 J=1,415
1     X(J)=0.
C     SET ARBITRARY VALUES FOR INTERMEDIATE SPOOL DESIGN PARAMETERS TO
C     AVOID ERROR WHEN RUNNING A DUMMYSPOOL ENGINE
      PRIDS=1.5
      ETAIDS=1.0
      PCNIDS=100.
```

```
      ZIDS=.75
      PCNCDS=100.
      IF (III.EQ.0) KKGO=0
      IF(RSTART) CALL CONOUT(1)
      P6DSAV=1.
      AM6DSV=1.
      ETAASV=1.
      FAR7SV=1.
      CALL ENGBAL
      STOP
      END
```

```
$IBFTC GUESS
      FUNCTION GUESS(M,T,TD,P,PD,W,WD,D,DD,VD)
      IF (M.EQ.0) GUESS=VD*((T/TD)**1.60)*((DD/D)**0.50)
      IF (M.EQ.1) GUESS=VD*((P/PD)**1.80)*((DD/D)**0.33)
      IF (M.EQ.2) GUESS=VD*((W/WD)**0.33)*((DD/D)**1.00)
      IF (M.EQ.3) GUESS=VD*((W/WD)**0.00)*((P/PD)**0.50)
      IF (M.EQ.4) GUESS=VD*((W/WD)**0.00)*((P/PD)**0.50)
      IF (M.EQ.5) GUESS=VD*((T/TD)**1.1)*((DD/D)**.7)
      IF (M.EQ.6) GUESS=VD*((P/PD)**1.00)*((D/DD)**0.25)
      IF (M.EQ.7) GUESS=VD*((P/PD)**0.62)*((D/DD)**0.31)
      IF (M.EQ.8) GUESS=VD*((T/TD)**1.2)*DD/D
      IF (M.EQ.9) GUESS=VD*P/PD*((D/DD)**1.5)
      RETURN
      END
```

```
$IBFTC INDUMY
      SUBROUTINE INDUMY (CNI,ZI,WACI,IDES)
      COMMON/DUMINT/CNXX(15),PRXX(15,15),WACXX(15,15),ETAXX(15,15),
     1NCNX,NPTX(15)
      DIMENSION WACAR(15),XCNXX(15)
      DATA XCNXX/.001,.1,.2,.3,.5,.8,1.,1.5,2.0,3.0,4.0,5.0,6.,7.,9./
      DATA WACAR/5.,4.5,4.,3.5,3.,2.5,2.,1.5,1.,.8,.6,.4,.25,.1,.05/
      IF (IDES.NE.1) GO TO 1
      WAIDS=WACI
      CNIDS=CNI
      ZI=2./3.5
    1 NCNX=15
      DO 2 I=1,15
      NPTX(I)=15
      CNXX(I)=XCNXX(I)*CNIDS
      DO 2 J=1,15
      PRXX(I,J)=FLOAT(J+3)/4.
      ETAXX(I,J)=1.
    2 WACXX(J,I)=WACAR(I)*(.993+.001*FLOAT(J))*WAIDS
      RETURN
      END
```

```
$IBFTC MATRIX
      SUBROUTINE MATRIX (E,V,A,N)
      DIMENSION E(9,9),V(9),A(9),PIV(10),T(9,10)
      NN=N+1
      NM=N-1
      DO 1 I=1,N
      T(I,NN)=A(I)
      DO 1 J=1,N
    1 T(I,J)=E(I,J)
      DO 7 I=1,N
      TEMP=0.
```

```
      DO 2 J=I,N
      IF (TEMP.GT.ABS(T(J,I))) GO TO 2
      TEMP=ABS(T(J,I))
      IPIV=J
 2    CONTINUE
      IP1=I+1
      DO 3 J=IP1,NN
 3    PIV(J)=T(IPIV,J)/T(IPIV,I)
      IFROM=N
      ITO=N
 4    IF (IFROM.EQ.IPIV) GO TO 6
      RM=-T(IFROM,I)
      DO 5 J=IP1,NN
 5    T(ITO,J)=T(IFROM,J)+RM*PIV(J)
      ITO=ITO-1
 6    IFROM=IFROM-1
      IF (IFROM.GE.I) GO TO 4
      DO 7 J=IP1,NN
 7    T(I,J)=PIV(J)
      DO 8 I=1,NM
      J=NN-I
      K=N-I
      DO 8 L=J,N
 8    T(K,NN)=T(K,NN)-T(K,L)*T(L,NN)
      DO 9 I=1,N
 9    V(I)=T(I,NN)
      RETURN
      END
```

```
$IBFTC OUTPUT
      SUBROUTINE OUTPUT
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES   ,JDES   ,KDES   ,MODE   ,INIT   ,IDUMP  ,IAMTP  ,IGASMX,
     2IDBURN,IAFTBN,IDCD   ,IMCD   ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP  ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU   ,DUMD1  ,DUMD2  ,DELFG  ,DELFN  ,DELSFC,
     2ZFDS   ,PCNFDS,PRFDS  ,ETAFDS,WAFDS  ,PRFCF  ,ETAFCF,WAFCF ,
     3ZCDS   ,PCNCDS,PRCDS  ,ETACDS,WACDS  ,PRCCF  ,ETACCF,WACCF ,
     4T4DS   ,WFBDS  ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
     7T24DS  ,WFDDS  ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS   ,WFADS  ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25    ,A6     ,A7     ,A8     ,A9     ,A28    ,A29    ,
     $PS55   ,AM55   ,CVDNOZ,CVMNOZ,A8SAV  ,A9SAV  ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1     ,H1     ,S1     ,T2     ,P2     ,H2     ,S2     ,
     2T21    ,P21    ,H21    ,S21    ,T3     ,P3     ,H3     ,S3     ,
     3T4     ,P4     ,H4     ,S4     ,T5     ,P5     ,H5     ,S5     ,
     4T55    ,P55    ,H55    ,S55    ,BLF    ,BLC    ,BLDU   ,BLOB   ,
     5CNF    ,PRF    ,ETAF   ,WAFC   ,WAF    ,WA3    ,WG4    ,FAR4   ,
     6CNC    ,PRC    ,ETAC   ,WACC   ,WAC    ,ETAB   ,DPCOM  ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP   ,ETAR   ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP  ,PCBLF  ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF   ,XWAC   ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21   ,XH21   ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24    ,H24    ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28    ,H28    ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD    ,WG24   ,FAR24  ,ETAD   ,DPDUC  ,BYPASS,DUMS3  ,
     6TS28   ,PS28   ,V28    ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55   ,XH55   ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55  ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1   ,DUMB   ,
     9T6     ,P6     ,H6     ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8     ,H8     ,S8     ,T9     ,P9     ,H9     ,S9
```

```
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV.T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      DIMENSION W(5,4),ANS1(80),ANS2(80),ANS3(80),ANS4(80),ANS5(80)
      EQUIVALENCE (ANS1,PCNFGU),(ANS2,T1),(ANS3,XP1),(ANS4,WG6)
      EQUIVALENCE (ANS5,S50)
      LOGICAL FXFN2M,FXM2CP,AFTFAN,DUMSPL,FAN
      DATA AWORD1,AWORD2/6HOUTPUT,6HCOMMON/
      DATA (W(1,I),I=1,4)/6HSUBSON,6HIC C-D,6H NOZZL,6HE      /
      DATA (W(2,I),I=1,4)/6HSHOCK ,6HINSIDE,6H C-D N,6HOZZLE /
      DATA (W(3,I),I=1,4)/6HSHOCK ,6HOUTSID,6HE C-D ,6HNOZZLE/
      DATA (W(4,I),I=1,4)/6HSUBSON,6HIC CON,6HVERG. ,6HNOZZLE/
      DATA (W(5,I),I=1,4)/6HSONIC ,6HCONVER,6HGENT N,6HOZZLE /
      TPRINT=TPRINT+DTPRNT
      IF(ITRAN.EQ.1) WRITE(6,29) TIME
   29 FORMAT(1H8,20X7H  TIME=,F7.4)
      WORD=AWORD1
      IF (IDBURN.GT.0) GO TO 2
      IF (IAFTBN.GT.0) GO TO 1
      WRITE (6,7) WORD,AM,ALTP,T4,ETAR
      GO TO 3
    1 WRITE (6,8) WORD,AM,ALTP,T4,T7,ETAR
      GO TO 3
    2 WRITE (6,9) WORD,AM,ALTP,T4,T24,ETAR
    3 IF (FXFN2M) WRITE (6,17)
      IF (FXM2CP) WRITE (6,18)
      IF(FAN) GO TO 25
      WRITE(6,26) ISPOOL
   26 FORMAT(1H0,I4,15H SPOOL TURBOJET)
      GO TO 27
   25 IF(.NOT.FXFN2M.AND.(.NOT.FXM2CP).AND.(.NOT.DUMSPL)) WRITE(6,19)
      IF (DUMSPL) WRITE (6,23)
      IF (PCBLID.EQ.0.) WRITE (6,20)
      IF (PCBLID.EQ.0..AND.AFTFAN) WRITE (6,21)
      IF (PCBLID.NE.0..AND.AFTFAN) WRITE (6,22)
   27 CALL CONOUT(2)
      WRITE (6,10) (W(IMSHOC,I),I=1,4),FG,FN,SFC
      IF(IGASMX.GT.0.OR..NOT.FAN) GO TO 4
      WRITE (6,11) (W(IDSHOC,I),I=1,4)
    4 WRITE (6,12) LOOPER
      IF (IDES.NE.1) GO TO 5
      WORD=AWORD2
      WRITE (6,13) WORD,ZF,PCNF,ZI,PCNI,ZC,PCNC,T4,MODE
      WRITE (6,14)
      WRITE (6,15) (ANS1(I),I=1,80)
      WRITE (6,14)
      WRITE (6,15) (ANS2(I),I=1,80)
      WRITE (6,14)
      WRITE (6,15) (ANS3(I),I=1,80)
      WRITE (6,14)
      WRITE (6,15) (ANS4(I),I=1,80)
      WRITE (6,14)
      WRITE (6,15) (ANS5(I),I=1,55)
      WRITE (6,14)
      WRITE (6,16)
      IF (IDES.EQ.1) GO TO 6
    5 CONTINUE
```

```
      A8=A8SAV
      A9=A9SAV
      A28=A28SAV
      A29=A29SAV
      IF (IDUMP.NE.2) GO TO 6
      WRITE (6,16)
      CALL SYG (2)
6     CALL ENGBAL
      RETURN
C
C
C
7     FORMAT (1HB,A6,14X7H    AM=,F7.3,6X7H  ALTP=,F7.0,6X7H    T4=,F8.2
     1,25X7H  ETAR=,F7.4)
8     FORMAT (1HB,A6,14X7H    AM=,F7.3,6X7H  ALTP=,F7.0,6X7H    T4=,F8.2
     1,5X7H    T7=,F8.2,5X7H  ETAR=,F7.4)
9     FORMAT (1HB,A6,14X7H    AM=,F7.3,6X7H  ALTP=,F7.0,6X7H    T4=,F8.2
     1,5X7H   T24=,F8.2,5X7H  ETAR=,F7.4)
10    FORMAT (6HOMAIN ,4A6,9X3HFG=,F9.2,18X3HFN=,F9.2,18X4HSFC=,F8.5)
11    FORMAT (6H DUCT ,4A6)
12    FORMAT (16HOCONVERGED AFTER,I4,6H LOOPS,/,1H1)
13    FORMAT (1H ,A6,9X,7E15.6,I4)
14    FORMAT (1H )
15    FORMAT (1H ,8E15.6)
16    FORMAT (1H1)
17    FORMAT (65HOFAN AND MIDDLE SPOOL ARE ATTACHED , USE INNER AND OUTE
     1R TURBINES)
18    FORMAT (74HOMIDDLE AND COMPRESSOR SPOOLS ARE ATTACHED , USE MIDDLE
     1 AND OUTER TURBINES)
19    FORMAT (19HOTHREE SPOOL ENGINE)
20    FORMAT (21HONO AIRFLOW INTO WING)
21    FORMAT (1H+22X,14H, AFT-TURBOFAN)
22    FORMAT (14HO AFT-TURBOFAN)
23    FORMAT (22HOMIDDLE SPOOL IS DUMMY)
      END
```

```
$IBFTC PARABO
      SUBROUTINE PARABO (X,Y,XD,YANS)
      DIMENSION X(3),Y(3)
      A=((X(1)-X(2))*(Y(1)-Y(3))-(X(1)-X(3))*(Y(1)-Y(2)))/((X(1)-X(2))*(
     1X(1)-X(3))*(X(3)-X(2)))
      B=((X(1)**2-X(2)**2)*(Y(1)-Y(3))-(X(1)**2-X(3)**2)*(Y(1)-Y(2)))/((
     1X(1)-X(2))*(X(1)-X(3))*(X(2)-X(3)))
      D=(Y(1)*X(2)**2-Y(2)*X(1)**2-B*X(2)*X(1)*(X(2)-X(1)))/(X(2)**2-X(1
     1)**2)
      YANS=(A*XD+B)*XD+D
      RETURN
      END
```

```
$IBFTC PERF
      SUBROUTINE PERF
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES   ,JDES   ,KDES   ,MODE   ,INIT   ,IDUMP  ,IAMTP  ,IGASMX,
     2IDBURN,IAFTBN,IDCD   ,IMCD   ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP  ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU   ,DUMD1  ,DUMD2  ,DELFG  ,DELFN  ,DELSFC,
     2ZFDS   ,PCNFDS,PRFDS  ,ETAFDS,WAFDS  ,PRFCF  ,ETAFCF,WAFCF  ,
     3ZCDS   ,PCNCDS,PRCDS  ,ETACDS,WACDS  ,PRCCF  ,ETACCF,WACCF  ,
     4T4DS   ,WFBDS  ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
     7T24DS  ,WFDDS  ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
```

```
     8T7DS   ,WFADS  ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25    ,A6     ,A7     ,A8     ,A9     ,A28    ,A29    ,
     $PS55   ,AM55   ,CVDNOZ,CVMNOZ,A8SAV  ,A9SAV  ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1     ,H1     ,S1     ,T2     ,P2     ,H2     ,S2     ,
     2T21    ,P21    ,H21    ,S21    ,T3     ,P3     ,H3     ,S3     ,
     3T4     ,P4     ,H4     ,S4     ,T5     ,P5     ,H5     ,S5     ,
     4T55    ,P55    ,H55    ,S55    ,BLF    ,BLC    ,BLDU   ,BLOB   ,
     5CNF    ,PRF    ,ETAF   ,WAFC   ,WAF    ,WA3    ,WG4    ,FAR4   ,
     6CNC    ,PRC    ,ETAC   ,WACC   ,WAC    ,ETAB   ,DPCOM  ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP   ,ETAR   ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP  ,PCBLF  ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF   ,XWAC   ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21   ,XH21   ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24    ,H24    ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28    ,H28    ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD    ,WG24   ,FAR24  ,ETAD   ,DPDUC  ,BYPASS,DUMS3  ,
     6TS28   ,PS28   ,V28    ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55   ,XH55   ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55  ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1   ,DUMB   ,
     9T6     ,P6     ,H6     ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8     ,H8     ,S8     ,T9     ,P9     ,H9     ,S9
      COMMON /ALL4/
     1WG6    ,WFA    ,WG7    ,FAR7   ,ETAA   ,DPAFT  ,V55    ,V25    ,
     2PS6    ,V6     ,AM6    ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
     3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
     4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
     5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
     7H38    ,P38    ,TS38   ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
     8V39    ,AM39   ,A39    ,BPRINT,WG37   ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39   ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22    ,P22    ,H22    ,S22    ,T50    ,P50    ,H50
      COMMON /ALL5/
     1S50    ,WA22   ,ZI     ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
     2TFFIP  ,CNIP   ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
     3ZIDS   ,PCNIDS,PRIDS  ,ETAIDS,WAIDS  ,PRICF  ,ETAICF,WAICF  ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI  ,BLI    ,T22DS  ,WA21   ,WG50   ,FAR50  ,A24    ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL  ,T41    ,FAN    ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON/UNITS/SI
      LOGICAL SI
      LOGICAL AFTFAN,DUMSPL,FAN
      DATA AWORD/6H  PERF/
      WORD=AWORD
      IF (SI) GO TO 100
      G=32.174049
      CAPSF=2116.2170
      GO TO 101
  100 G=1.0
      CAPSF=1.0
  101 CONTINUE
      WFT=WFB+WFD+WFA
      WAT=WAF-BLOB
      IF (AFTFAN) WAT=WAT+WAI
      WGT=WAT+WFT
      FART=WFT/WAT
      VA=AM*CS
      FRD=VA*WAF/G
      IF(AFTFAN) FRD=VA*(WAF+WAI)/G
      VJM=CVMNOZ*V9
      FGMM=VJM*WG7/G
      FGPM=CAPSF*(PS9-P1)*A9
      IF(IGASMX.GT.0.OR..NOT.FAN) GO TO 1
      VJD=CVDNOZ*V29
      FGMD=VJD*WG24/G
      FGPD=CAPSF*(PS29-P1)*A29
    1 VJW=0.
```

```
      FGMWNG=0.
      FGPWNG=0.
      FGWING=0.
      FNWING=0.
      IF (PCBLID.EQ.0.) GO TO 2
      VJW=CVDWNG*V39
      FGMWNG=VJW*WG37/G
      FGPWNG=CAPSF*(PS39-P1)*A39
      FGWING=FGMWNG+FGPWNG
      FNWING=FGWING-VA*WA32/G
 2    FGM=FGMM+FGMD+FGMWNG
      FGP=FGPM+FGPD+FGPWNG
      FNMAIN=(FGMM+FGMD+FGPM+FGPD)-VA*(WAF-WA32)/G
      IF (AFTFAN) FNMAIN=(FGMM+FGMD+FGPM+FGPD)-VA*(WAF+WAI-WA32)/G
      FG=FGM+FGP
      FN=FG-FRD
      SFC=3600.*WFT/FN
      FG=DELFG*FG
      FN=DELFN*FN
      SFC=DELSFC*SFC
      FFAN=FGMD+FGPD-VA*WAD/G
      FCORE=FNMAIN-FFAN
      FFOVFN=FFAN/FN
      FCOVFN=FCORE/FN
      FWOVFN=FNWING/FN
      FMNOFN=FNMAIN/FN
      IF (IDES.EQ.1) FDES=FN
      FNOVFD=FN/FDES
      IF (.NOT.DUMSPL) GO TO 3
      PCNI=1.C
      CNI=0.
 3    IF(ITRAN.EQ.1.AND.TIME.LT.TPRINT) CALL ENGBAL
      CALL OUTPUT
      CALL ERROR
      RETURN
      END
```

```
$IBFTC PROCOM
      SUBROUTINE PROCOM (FARX,TEX,CSEX,AKEX,CPEX,REX,PHI,HEX)
      COMMON/UNITS/SI
      LOGICAL SI
C      IF SI UNITS ARE USED, CONVERT TEX TO DEGREES RANKINE
      IF (SI) TEX=TEX*9.0/5.0
      IF (FARX.LE.0.067623) GO TO 1
      FARX=0.067623
1     IF (TEX.GE.300.) GO TO 2
      TEX=300.
2     IF (TEX.LE.4000.) GO TO 3
      TEX=4000.
3     IF (FARX.GE.0.0) GO TO 4
      FARX=0.0
C     AIR PATH
4     CPA=((((((1.0115540E-25*TEX-1.4526770E-21)*TEX+7.6215767E-18)*TEX-
     11.5128259E-14)*TEX-6.7178376E-12)*TEX+6.5519486E-08)*TEX-5.1536879
     2E-05)*TEX+2.5020051E-01
      HEA=(((((((1.2644425E-26*TEX-2.0752522E-22)*TEX+1.2702630E-18)*TEX
     1-3.0256518E-15)*TEX-1.6794594E-12)*TEX+2.1839826E-08)*TEX-2.576844
     20E-05)*TEX+2.5020C51E-01)*TEX-1.7558886E+00
      SEA=+2.5020051E-01*ALOG(TEX)+((((((1.4450767E-26*TEX-2.4211288E-22
     1)*TEX+1.5243153E-18)*TEX-3.7820648E-15)*TEX-2.2392790E-12)*TEX+3.2
     2759743E-08)*TEX-5.1576879E-05)*TEX+4.5432300E-02
      IF (FARX.LE.0.0) GO TO 5
C     FUEL/AIR PATH
      CPF=((((((7.2678710E-25*TEX-1.3335668E-20)*TEX+1.0212913E-16)*TEX-
     14.2051104E-13)*TEX+9.9686793E-10)*TEX-1.3771901E-06)*TEX+1.2258630
     2E-03)*TEX+7.3816638E-02
      HEF=(((((((9.0848388E-26*TEX-1.9050949E-21)*TEX+1.7021525E-17)*TEX
     1-8.4102208E-14)*TEX+2.4921698E-10)*TEX-4.5906332E-07)*TEX+6.129315
     20E-04)*TEX+7.3816638E-02)*TEX+3.0581530E+01
```

```
      SEF=+7.3816638E-02*ALOG(TEX)+((((((1.0382670E-25*TEX-2.2226118E-21
     1)*TEX+2.0425826E-17)*TEX-1.0512776E-13)*TEX+3.3228928E-10)*TEX-6.8
     2859505E-07)*TEX+1.2258630E-03)*TEX+6.483398E-01
5     CPEX=(CPA+FARX*CPF)/(1.+FARX)
      HEX=(HEA+FARX*HEF)/(1.+FARX)
      PHI=(SEA+FARX*SEF)/(1.+FARX)
      AMW=28.97-.946186*FARX
      REX=1.986375/AMW
      AKEX=CPEX/(CPEX-REX)
      CSEX=SQRT(AKEX*REX*TEX*25031.37)
      IF (SI) GO TO 100
      GO TO 101
  100 CPEX=CPEX*4185.7666
      HEX=HEX*2325.4259
      PHI=PHI*4185.7666
      REX=REX*4185.7666
      CSEX=CSEX*.3048
      TEX=TEX*5.0/9.0
  101 CONTINUE
      RETURN
      END
```

```
$IBFTC PUTIN
      SUBROUTINE PUTIN
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES   ,JDES   ,KDES   ,MODE   ,INIT   ,IDUMP  ,IAMTP  ,IGASMX,
     2IDBURN,IAFTBN,IDCD   ,IMCD   ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP  ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU   ,DUMD1  ,DUMD2  ,DELFG  ,DELFN  ,DELSFC,
     2ZFDS   ,PCNFDS,PRFDS  ,ETAFDS,WAFDS  ,PRFCF  ,ETAFCF,WAFCF  ,
     3ZCDS   ,PCNCDS,PRCDS  ,ETACDS,WACDS  ,PRCCF  ,ETACCF,WACCF  ,
     4T4DS   ,WFBDS  ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
     7T24DS  ,WFDDS  ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS   ,WFADS  ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25    ,A6     ,A7     ,A8     ,A9     ,A28    ,A29    ,
     $PS55   ,AM55   ,CVDNOZ,CVMNOZ,A8SAV  ,A9SAV  ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1     ,H1     ,S1     ,T2     ,P2     ,H2     ,S2     ,
     2T21    ,P21    ,H21    ,S21    ,T3     ,P3     ,H3     ,S3     ,
     3T4     ,P4     ,H4     ,S4     ,T5     ,P5     ,H5     ,S5     ,
     4T55    ,P55    ,H55    ,S55    ,BLF    ,BLC    ,BLDU   ,BLOB   ,
     5CNF    ,PRF    ,ETAF   ,WAFC   ,WAF    ,WA3    ,WG4    ,FAR4   ,
     6CNC    ,PRC    ,ETAC   ,WACC   ,WAC    ,ETAB   ,DPCOM  ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP   ,ETAR   ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP  ,PCBLF  ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF   ,XWAC   ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21   ,XH21   ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24    ,H24    ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28    ,H28    ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD    ,WG24   ,FAR24  ,ETAD   ,DPDUC  ,BYPASS,DUMS3  ,
     6TS28   ,PS28   ,V28    ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55   ,XH55   ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55  ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1   ,DUMB   ,
     9T6     ,P6     ,H6     ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8     ,H8     ,S8     ,T9     ,P9     ,H9     ,S9
      COMMON /ALL4/
     1WG6    ,WFA    ,WG7    ,FAR7   ,ETAA   ,DPAFT  ,V55    ,V25    ,
     2PS6    ,V6     ,AM6    ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
     3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
     4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
     5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
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     7H38   ,P38   ,TS38  ,PS38  ,T39    ,H39    ,P39    ,TS39  ,
     8V39   ,AM39  ,A39    ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWDVFN,PS39  ,FFDVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22    ,H22   ,S22    ,T50    ,P50    ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI     ,PCNI  ,CNI    ,PRI    ,ETAI   ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF  ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI    ,T22DS ,WA21   ,WG50   ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41    ,FAN    ,ISPOOL
      COMMON /DELCH/ DELT1
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /UNITS/ SI
      LOGICAL ERRER,FXFN2M,FXM2CP,DUMSPL,AFTFAN,FAN,SI
      DATA AWORD/6HPUTIN /
      COMMON/LOOPPR/KKGO,PRFNEW,PRCNEW
      DIMENSION XSAVE(405),XFILL(1)
      EQUIVALENCE (XFILL,IDES)
      COMMON/ERER/ERRER
C *** IDES  =1  FOR CALCULATING DESIGN POINT
C *** ITRAN =1  THIS POINT IS THE IC FOR A TRANSIENT
C *** MODE  =0  FOR CONSTANT T4
C *** MODE  =1  FOR CONSTANT PCNC
C *** MODE  =2  FOR CONSTANT WFB
C *** MODE  =3  FOR CONSTANT PCNF
C *** INIT  =1  WILL NOT INITIALIZE POINT
C *** IDUMP =1  WILL DUMP LOOPING WRITE-OUTS IF ERROR OCCURS
C *** IDUMP =2  WILL DUMP LOOPING WRITE-OUTS AFTER EVERY POINT
C *** IAMTP =0  WILL USE INPUT AM AND MIL SPEC ETAR
C *** IAMTP =1  WILL USE INPUT AM AND INPUT ETAR
C *** IAMTP =2  WILL USE T1=T1+DELT1 AND STANDARD P1
C *** IAMTP =3  WILL USE P2 AND STANDARD T1
C *** IAMTP =4  WILL USE T2 AND P2
C *** IAMTP =5  WILL USE RAM2 FOR SPECIAL RECOVERY
C *** IGASMX=-1 SEPARATE FLOW, INPUT AM6
C *** IGASMX=0  SEPARATE FLOW, A6=A55
C *** IGASMX=1  WILL MIX DUCT AND MAIN STREAMS, A6=A25+A55
C *** IGASMX=2  WILL MIX DUCT AND MAIN STREAMS, INPUT AM6
C *** IDBURN=1  FOR DUCT BURNING, INPUT T24
C *** IDBURN=2  FOR DUCT BURNING, INPUT WFD
C *** IAFTBN=1  FOR AFTERBURNING, INPUT T7
C *** IAFTBN=2  FOR AFTERBURNING, INPUT WFA
C *** IDCD  =1  DUCT NOZZLE WILL BE C-D
C *** IMCD  =1  MAIN NOZZLE WILL BE C-D
C *** NOZFLT=1  FOR FLOATING MAIN NOZZLE
C *** NOZFLT=2  FOR FLOATING DUCT NOZZLE
C *** NOZFLT=3  FOR FLOATING MAIN AND DUCT NOZZLES
C *** ITRYS =N  NUMBER OF PASSES THRU ENGINE BEFORE QUITTING
      NAMELIST /DATAIN/       ISPOOL,FAN,SI,DELT1,
     1IDES,MODE,IDUMP,IAMTP,IGASMX,IDBURN,IAFTBN,IDCD,IMCD,NOZFLT,ITRYS,
     2FXFN2M,FXM2CP,AFTFAN,DUMSPL,TOLALL,DELFG,DELFN,DELSFC,PCNFDS,PRFDS
     3,ETAFDS,PCNCDS,PRCDS,ETACDS,T4DS,WFBDS,ETABDS,DPCODS,ETHPDS,ETLPDS
     4,DPDUDS,T7DS,ETAADS,DPAFDS,A6,A8,A28,PS55,AM55,CVDNOZ,CVMNOZ,T2,P2
     5,T4,WAFCDS,WACCDS,HPEXT,AM,ALTP,ETAR,PCNF,PCNC,WFB,PCBLF,PCBLC,
     6PCBLDU,PCBLOB,PCBLHP,PCBLLP,T24,ETAD,T7,WFA,ETAA,AM6,AM23,DPWGDS,
     7A38,PCNIDS,PCBLIP,ZFDS,ZCDS,ZIDS,PCBLID,TFHPDS,CNHPDS,TFIPDS,
     8CNIPDS,TFLPDS,CNLPDS,PRIDS,ETAIDS,ETIPDS,WAICDS,PCBLI,CVDWNG,
     9ITRAN,DTPRNT,TF,INIT,DT,XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP,
     1VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,VFDUCT,VWDUCT
      WORD=AWORD
      ITRAN=0
      JTRAN=0
      TIME = 0.0
      NSTEP = 0
      TPRINT = 0.0
      DTPRNT = 0.0
1     CALL ZERO
      IF (KKGO.EQ.1) GO TO 5
      IDES=0
```

```
      READ (5,DATAIN)
      IF (ERRER.AND.IAFTBN.GT.0) GO TO 1
      IF (ERRER.AND.IDBURN.GT.0) GO TO 1
      IF (ERRER.AND.NOZFLT.GT.0) GO TO 1
      ERRER=.FALSE.
C     TABLE IS REFERENCED TO COMMON/ALL/FIRST ENTRY
      IF (IDES.EQ.0) GO TO 7
      IF (KKGO.NE.2) GO TO 3
      DO 2 I=1,397
2     XFILL(I)=XSAVE(I)
      READ (5,DATAIN)
3     CONTINUE
C     SAVE INPUT IN CASE OF LOOP ON PRESSURE RATIOS
      DO 4 I=1,397
4     XSAVE(I)=XFILL(I)
      GO TO 7
5     DO 6 I=1,397
6     XFILL(I)=XSAVE(I)
      WRITE (6,8) PRFDS,PRFNEW,PRCDS,PRCNEW
      PRCDS=PRCNEW
      PRFDS=PRFNEW
7     CONTINUE
      KKGO=2
      IF(IAFTBN.GT.0.OR.IDBURN.GT.0.OR.NOZFLT.GT.0) INIT=1
      IF (MODE.EQ.0) WRITE (8,9) IDES,AM,ALTP,T4,T24,T7
      IF (MODE.EQ.1) WRITE (8,10) IDES,AM,ALTP,PCNC,T24,T7
      IF (MODE.EQ.2) WRITE (8,11) IDES,AM,ALTP,WFB,T24,T7
      IF (IDES.EQ.1) WAFC=WAFCDS
      IF (DUMSPL) WAICDS=WACCDS
      IF (IDES.EQ.1) WACI=WAICDS
      IF(IDES.EQ.1) WACC=WACCDS
      CALL COINLT
      RETURN
C
C
8     FORMAT (18HOCHANGE PRFDS FROM,F9.3,4H  TO,F9.3,16H  AND PRCDS FROM
     1,F10.3,4H  TO,F10.3)
9     FORMAT (1H0,7H  IDES=,I3,10X7H    AM=,F7.3,6X7H  ALTP=,F7.0,6X7H
     1  T4=,F8.2,5X7H   T24=,F8.2,5X7H    T7=,F8.2,6H$$$$$$)
10    FORMAT (1H0,7H  IDES=,I3,10X7H    AM=,F7.3,6X7H  ALTP=,F7.0,6X7H
     1PCNC=,F8.3,5X7H   T24=,F8.2,5X7H    T7=,F8.2,6H$$$$$$)
11    FORMAT (1H0,7H  IDES=,I3,10X7H    AM=,F7.3,6X7H  ALTP=,F7.0,6X7H
     1 WFB=,F8.4,5X7H   T24=,F8.2,5X7H    T7=,F8.2,6H$$$$$$)
      END
```

```
$IBFTC RAM
      SUBROUTINE RAM (AM,ETAR)
      IF (AM.GT.1.) GO TO 2
      ETAR=1.
1     RETURN
2     IF (AM.GT.5.) GO TO 3
      ETAR=1.-0.075*((AM-1.)**1.35)
      GO TO 1
3     ETAR=800./((AM**4)+935.)
      GO TO 1
      END
```

```
$IBFTC RAM2
      SUBROUTINE RAM2 (AM,ETAR)
      DIMENSION PRINLT(15),FMN(15)
      DIMENSION Y(3),X(3)
      DATA FMN/0.,.1,.2,.3,.4,.5,.8,1.1,1.2,1.4,1.6,1.8,2.2,2.4,2.7/
      DATA PRINLT/.9,.932,.95,.961,.968,.97,.9701,.97,.9681,.958,.94,
     1.9181,.858,.8201,.75/
```

```
      M=0
      DO 1 J=1,15
1     IF (AM.GE.FMN(J)) M=J-1
      IF (M.EQ.0) M=1
      IF (M.GE.14) M=13
      DO 2 I=1,3
      MM=M-1+I
      X(I)=FMN(MM)
2     Y(I)=PRINLT(MM)
      CALL PARABO (X,Y,AM,ETAR)
      RETURN
      END
```

```
$IBFTC ROLL
      SUBROUTINE ROLL
      COMMON/FOC/FO(50,4)
      COMMON/SOC/SO(10,6)
      COMMON/CDELAY/PDATA(5,50),TIMEPT(50)
      DO 1 I=1,50
      FO(I,2)=FO(I,1)
1     FO(I,4)=FO(I,3)
      DO 2 I=1,10
      SO(I,6)=SO(I,5)
      SO(I,5)=SO(I,4)
      SO(I,3)=SO(I,2)
2     SO(I,2)=SO(I,1)
      DO 3 I=1,49
      N1=51-I
      NO=50-I
      TIMEPT(N1)=TIMEPT(NO)
      DO 3 J=1,5
3     PDATA(J,N1)=PDATA(J,NO)
      RETURN
      END
```

```
$IBFTC SEARCH
      SUBROUTINE SEARCH (P,A,B,C,D,AX,NA,BX,CX,DX,NO,NAM,NOM,NCODE)
      DIMENSION AX(NAM),BX(NAM,NOM),CX(NAM,NOM),DX(NAM,NOM),NO(NAM),Q(9)
C *** NEEDS SUBROUTINE AFQUIR
C *** AX AND BX MUST BE STORED LO TO HI
C *** P=INPUT PROPORTION BETWEEN 0.0 AND 1.0
C     IF NOT INPUT, P MUST EQUAL -1.
C *** NCODE=00   OK
C     NCODE=01   A LO
C     NCODE=02   A HI
C     NCODE=07   ERROR
C     NCODE=10   B LO
C     NCODE=20   B HI
      NCODE=0
      C=0.
      D=0.
C *** FIND A
      DO 1 I=1,NA
      IH=I
      IF (A.LT.AX(I)) GO TO 2
1     CONTINUE
      IF (A.GT.AX(IH)) NCODE=2
      A=AX(IH)
      GO TO 3
2     IF (IH.GT.1) GO TO 3
      NCODE=1
      IH=2
      A=AX(1)
3     IL=IH-1
```

```
      LIMH=NO(IH)
      LIML=NO(IL)
C *** FIND B
      PRM=(A-AX(IL))/(AX(IH)-AX(IL))
      PP=P
      IF (P.GE.0.) GO TO 6
      BL=BX(IL,1)+PRM*(BX(IH,1)-BX(IL,1))
      BH=BX(IL,LIML)+PRM*(BX(IH,LIMH)-BX(IL,LIML))
      IF (B.GE.BL) GO TO 4
      NCODE=NCODE+10
      B=BL
      GO TO 5
4     IF (B.LE.BH) GO TO 5
      NCODE=NCODE+20
      BHM=BX(IL,LIML-1)+PRM*(BX(IH,LIMH-1)-BX(IL,LIML-1))
      CHM=CX(IL,LIML-1)+PRM*(CX(IH,LIMH-1)-CX(IL,LIML-1))
      DHM=DX(IL,LIML-1)+PRM*(DX(IH,LIMH-1)-DX(IL,LIML-1))
      CH=CX(IL,LIML)+PRM*(CX(IH,LIMH)-CX(IL,LIML))
      DH=DX(IL,LIML)+PRM*(DX(IH,LIMH)-DX(IL,LIML))
      CSLOPE=(CH-CHM)/(BH-BHM)
      DSLOPE=(DH-DHM)/(BH-BHM)
      C=CH+CSLOPE*(B-BH)
      D=DH+DSLOPE*(B-BH)
      RETURN
5     PP=0.5
      Q(2)=0.
      Q(3)=0.
6     BH=PP*(BX(IH,LIMH)-BX(IH,1))+BX(IH,1)
      BL=PP*(BX(IL,LIML)-BX(IL,1))+BX(IL,1)
      DO 7 J=2,LIMH
      JH=J
      IF (BH.LT.BX(IH,J)) GO TO 8
7     CONTINUE
8     JL=JH-1
      DO 9 K=2,LIML
      KH=K
      IF (BL.LT.BX(IL,K)) GO TO 10
9     CONTINUE
10    KL=KH-1
      PR=(BX(IH,JL)-BH)/(BX(IH,JH)-BX(IH,JL))
      CH=CX(IH,JL)-PR*(CX(IH,JH)-CX(IH,JL))
      DH=DX(IH,JL)-PR*(DX(IH,JH)-DX(IH,JL))
      PR=(BX(IL,KL)-BL)/(BX(IL,KH)-BX(IL,KL))
      CL=CX(IL,KL)-PR*(CX(IL,KH)-CX(IL,KL))
      DL=DX(IL,KL)-PR*(DX(IL,KH)-DX(IL,KL))
      BT=BL+PRM*(BH-BL)
      CT=CL+PRM*(CH-CL)
      DT=DL+PRM*(DH-DL)
      IF (P.GE.0.) GO TO 13
      DIR=SQRT(B/BT)
      ERR=(B-BT)/B
      CALL AFQUIR (Q(1),PP,ERR,0.,25.,0.001,DIR,PT,ICON)
      GO TO (11,13,12),ICON
11    PP=PT
      IF (PP.LT.0.) PP=0.
      IF (PP.GT.1.) PP=1.
      GO TO 6
12    NCODE=7
13    B=BT
      C=CT
      D=DT
      RETURN
      END
```

```
$IBFTC SYG
      SUBROUTINE SYG (ICON)
      DIMENSION WORD(132)
      DATA ONEDOL/6H$     /
      GO TO (1,2),ICON
```

```
1     END FILE 8
      REWIND 8
      RETURN
C        TERMINATE THE FILE
2     WRITE (8,10)
      END FILE 8
      REWIND 8
C        READ RECORD
3     READ (8,11) (WORD(I),I=1,132)
C        CHECK FOR 12 LEADING DOLLAR SIGNS
      DO 4 I=1,12
      IF (WORD(I)-ONEDOL) 5,4,5
4     CONTINUE
      RETURN
C        CHECK FOR 6 TRAILING DOLLAR SIGNS
5     DO 8 I=1,132
      I=I
      IF (WORD(I)-ONEDOL) 8,6,8
6     K=I+5
      DO 7 J=I,K
      IF (WORD(J)-ONEDOL) 8,7,8
7     CONTINUE
      GO TO 9
8     CONTINUE
      WRITE (6,12)
      RETURN
C        PRINT LINE
9     I=I-1
      WRITE (6,11) (WORD(M),M=1,I)
      GO TO 3
C
C
10    FORMAT (12H$$$$$$$$$$$$)
11    FORMAT (132A1)
12    FORMAT (1H0,12HERROR IN SYG)
      END
```

```
$IBFTC THCOMP
      SUBROUTINE THCOMP (PR,ETA,T,H,S,P,TO,HO,SO,PO)
      COMMON /UNITS/ SI
      LOGICAL SI
      CPG=.250
      IF(SI) CPG=1048.
      PO=P*PR
      TP=T*PR**0.28572
      DO 1 I=1,25
      CALL THERMO (PO,HP,TP,SP,X1,0,X2,0)
      DELS=SP-S
      IF (ABS(DELS).LE.0.00005*S) GO TO 2
1     TP=TP/EXP(DELS/CPG)
      CALL ERROR
2     HO=H+((HP-H)/ETA)
      CALL THERMO (PO,HO,TO,SO,X1,0,X2,1)
      RETURN
      END
```

```
$IBFTC THERMO
      SUBROUTINE THERMO (PX,HX,TX,SX,AMX,L,FAR,K)
      COMMON/UNITS/SI
      LOGICAL SI
      IF (SI) GO TO 100
      DEM=1.986375
      CPG=.250
      PSTD=1.0
```

```
      GO TO 101
  100 DEM=8316.41
      CPG=1048.
      PSTD=101325.
  101 CONTINUE
      FX=0.
      IF (L.EQ.1) FX=FAR
      IF (K.EQ.1) GO TO 1
      CALL PROCOM (FX,TX,CS,AK,CP,R,PHI,HX)
      GO TO 3
1     TX=HX/CPG
      DO 2 I=1,15
      CALL PROCOM (FX,TX,CS,AK,CP,R,PHI,H)
      DELH=HX-H
      IF (ABS(DELH).LE.0.00001*HX) GO TO 3
2     TX=TX+DELH/CPG
      WRITE (8,4)
3     SX=PHI-R*ALOG(PX/PSTD)
      AMX=DEM/R
      RETURN
C
C
4     FORMAT (31HONO CONVERGENCE IN THERMO$$$$$$)
      END
```

```
$IBFTC THTURB
      SUBROUTINE THTURB (DH,ETA,FAR,H,S,P,TO,HO,SO,PO)
      COMMON/UNITS/ZI
      LOGICAL ZI
      IF (ZI) GO TO 100
      DEM=1.986375
      GO TO 101
  100 DEM=8316.41
  101 CONTINUE
      HO=H-DH
      HOP=H-DH/ETA
      PT=P/2.
      DO 1 I=1,25
      CALL THERMO (PT,HOP,TT,ST,AMWT,1,FAR,1)
      DELS=ST-S
      IF (ABS(DELS).LE.0.00005*S) GO TO 2
    1 PT=P*EXP(DELS*AMWT/DEM+ALOG(PT/P))
      CALL ERROR
2     PO=PT
      CALL THERMO (PO,HO,TO,SO,X1,1,FAR,1)
      RETURN
      END
```

```
$IBFTC WDUCTI
      SUBROUTINE WDUCTI
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS.DTAFCF,ETAACF,
```

```
     9A55    ,A25    ,A6     ,A7     ,A8     ,A9     ,A28    ,A29    ,
     $PS55   ,AM55   ,CVDNOZ,CVMNOZ,A8SAV  ,A9SAV  ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1     ,H1     ,S1     ,T2     ,P2     ,H2     ,S2     ,
     2T21    ,P21    ,H21    ,S21    ,T3     ,P3     ,H3     ,S3     ,
     3T4     ,P4     ,H4     ,S4     ,T5     ,P5     ,H5     ,S5     ,
     4T55    ,P55    ,H55    ,S55    ,BLF    ,BLC    ,BLDU   ,BLOB   ,
     5CNF    ,PRF    ,ETAF   ,WAFC   ,WAF    ,WA3    ,WG4    ,FAR4   ,
     6CNC    ,PRC    ,ETAC   ,WACC   ,WAC    ,ETAB   ,DPCOM  ,DUMP   ,
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP   ,ETAR   ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP  ,PCBLF  ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF   ,XWAC   ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21   ,XH21   ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24    ,H24    ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28    ,H28    ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD    ,WG24   ,FAR24  ,ETAD   ,DPDUC  ,BYPASS,DUMS3  ,
     6TS28   ,PS28   ,V28    ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55   ,XH55   ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55  ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1   ,DUMB   ,
     9T6     ,P6     ,H6     ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8     ,H8     ,S8     ,T9     ,P9     ,H9     ,S9
      COMMON /ALL4/
     1WG6    ,WFA    ,WG7    ,FAR7   ,ETAA   ,DPAFT  ,V55    ,V25    ,
     2PS6    ,V6     ,AM6    ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
     3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
     4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
     5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
     7H38    ,P38    ,TS38   ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
     8V39    ,AM39   ,A39    ,BPRINT,WG37   ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39   ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22    ,P22    ,H22    ,S22    ,T50    ,P50    ,H50
      COMMON /ALL5/
     1S50    ,WA22   ,ZI     ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
     2TFFIP ,CNIP   ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
     3ZIDS   ,PCNIDS,PRIDS  ,ETAIDS,WAIDS  ,PRICF  ,ETAICF,WAICF  ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI  ,BLI    ,T22DS  ,WA21   ,WG50   ,FAR50  ,A24    ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL  ,T41    ,FAN    ,ISPOOL
      COMMON /VOLS/ VFAN,VINTC,VCOMP,VCOMB,VHPTRB,VIPTRB,VLPTRB,VAFTBN,
     1 VFDUCT,VWDUCT
      COMMON /UNITS/ SI
      LOGICAL SI
      DATA AWORD/6HWDUCTI/
      DIMENSION Q(9)
      DIMENSION XZERO(26)
      EQUIVALENCE (XZERO,DPWING)
      WORD=AWORD
      IF(SI) GO TO 100
      RA=.0252
      AJ=2.719
      GO TO 101
100   RA=286.9
      AJ=1.0
101   CONTINUE
      IF (PCBLID.GT.0.) GO TO 3
      XZERS=CVDWNG
      DO 1 I=1,26
1     XZERO(I)=0.0
      CVDWNG=XZERS
      RETURN
3     CONTINUE
      P32=P21
      H32=H21
      T32=T21
      BPRINT=WA32/WAC
      WA32C=WA32*SQRT(T32)/P32
      IF (IDES.EQ.1) WA32DS=WA32C
      DPWING=DPWGDS*WA32C/WA32DS
```

```
      DPWING=AMIN1(1.0,DPWING)
      P36=P32*(1.-DPWING)
      T36=T32
      H36=H32
      CALL THERMO (P36,H36,T36,S36,XX2,1,0.0,0)
      WG37=WA32
      T37=T36
      P37=P36
      H37=H36
      S37=S36
      IF(VWDUCT.EQ.0.0) GO TO 21
      Q(2)=0.0
      Q(3)=0.0
      WG37P=WG37
      H37P=H37
      P37DOT=DERIV(22,P37)
18    CONTINUE
      CALL THERMO(P37,H37,T37,S37,XX2,1,0.0,0)
      WG37=WG37P-P37DOT*VWDUCT/T37/1.4/RA
      U37=H37-RA*AJ*T37
      U37DOT=DERIV(23,U37)
      H37X=(WG37P*H37P-(WG37P-WG37)*U37-U37DOT*P37*VWDUCT/T37/RA)/WG37
      ERRW=(H37-H37X)/H37
      DIR=SQRT(ABS(H37/H37X))
      CALL AFQUIR(Q(1),T37,ERRW,0.,20.,0.0001,DIR,T37T,IGO)
      GO TO (19,21,20),IGO
19    T37=T37T
      GO TO 18
20    CALL ERROR
21    CONTINUE
      NOZD=0
      CALL CONVRG (T37,H37,P37,S37,0.0,WG37,P1,IDES,A38,P38R,T38,H38,P38
     1,S38,TS38,PS38,V38,AM38,ICON)
      GO TO (5,5,5,4),ICON
4     CALL ERROR
5     T39=T38
      H39=H38
      P39=P38
      S39=S38
      TS39=TS38
      V39=V38
      AM39=AM38
      A39=A38
      PS39=PS38
      IDSHOC=ICON+3
      ERR(7)=(P38R-P38)/P38R
      IF (IDES.EQ.1) WRITE (6,6) A38,AM38,A39,AM39
      RETURN
C
C
6     FORMAT (18H0INTER DUCT DESIGN,5X,8H    A38=,E15.8,8H   AM38=,E15.8
     1,8H    A39=,E15.8,8H   AM39=,E15.8)
      END
```

```
$IBFTC ZERO
      SUBROUTINE ZERO
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
```

```
     8T7DS   ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55    ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55   ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1     ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21    ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4     ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55    ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF    ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC    ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP   ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP   ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM     ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP  ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21   ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24    ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28    ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD    ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28   ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55   ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB   ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6     ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8     ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6    ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6    ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8    ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA     ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM    ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38    ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39    ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50    ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP  ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS   ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   .FAN   ,ISPOOL
      DIMENSION Z1(63),Z2(48),Z3(10),Z4(62)
      EQUIVALENCE (Z1,T1),(Z2,XP1),(Z3,XT55),(Z4,XFAR55)
      IDES=0
      JDES=0
      INIT=0
      IDBURN=0
      IAFTBN=0
      IDSHOC=3
      IMSHOC=3
      NOZFLT=0
      T2Q=T2
      P2Q=P2
      T4Q=T4
      DO 1 I=1,63
    1 Z1(I)=0.
      DO 2 I=1,48
    2 Z2(I)=0.
      DO 3 I=1,10
    3 Z3(I)=0.
      DO 4 I=1,62
    4 Z4(I)=0.
      T2=T2Q
      P2=P2Q
      T4=T4Q
      CALL SYG (1)
      RETURN
      END
```

```
$IBFTC BLKCMP
C     THIS IS GENERALIZED COMP. MAP FOR UNREALISTIC SUPERSONIC ENGINE
      BLOCK DATA
      COMMON / COMP/CN(15),PR(15,15),WAC(15,15),ETA(15,15),N,NP(15)
      DATA N,NP/10,2*6,2*8,4*10,2*8,5*0/
      DATA CN/.562,.674,.787,.899,1.,1.034,1.067,1.124,1.236,1.292,5*0./
      DATA (PR( 1,J),WAC( 1,J),ETA( 1,J),J=1, 6)/
     1  1.00000,    51.000,   0.59082,   1.84000,    50.200,   0.62178,
     2  2.42800,    49.500,   0.64242,   2.86900,    48.800,   0.65274,
     3  3.83500,    46.700,   0.67338,   4.54900,    44.500,   0.64242/
      DATA (PR( 2,J),WAC( 2,J),ETA( 2,J),J=1, 6)/
     1  1.00000,    59.300,   0.59082,   1.96600,    59.300,   0.64242,
     2  3.09300,    58.800,   0.69402,   3.93300,    57.900,   0.72498,
     3  4.68900,    56.700,   0.74562,   5.52900,    55.000,   0.72498/
      DATA (PR( 3,J),WAC( 3,J),ETA( 3,J),J=1, 8)/
     1  1.00000,    70.000,   0.58566,   1.84000,    70.000,   0.64242,
     2  2.68000,    70.000,   0.68370,   3.40800,    69.500,   0.72498,
     3  4.52100,    68.800,   0.77744,   5.44500,    67.900,   0.79292,
     4  6.31300,    66.400,   0.77744,   6.52300,    65.700,   0.76970/
      DATA (PR( 4,J),WAC( 4,J),ETA( 4,J),J=1, 8)/
     1  1.00000,    84.800,   0.58050,   2.00800,    84.800,   0.64242,
     2  3.42900,    84.800,   0.72498,   4.60500,    84.800,   0.77744,
     3  5.69700,    84.000,   0.80840,   6.61400,    83.300,   0.82904,
     4  7.53800,    81.700,   0.80840,   7.95800,    80.500,   0.79292/
      DATA (PR( 5,J),WAC( 5,J),ETA( 5,J),J=1,10)/
     1  1.00000,   101.700,   0.57190,   2.51900,   101.700,   0.64242,
     2  3.98200,   101.700,   0.72498,   5.27700,   101.700,   0.77744,
     3  6.48800,   101.200,   0.80840,   7.20200,   101.000,   0.83936,
     4  8.00000,   100.000,   0.86000,   8.56700,    99.500,   0.83936,
     5  9.38600,    98.100,   0.80840,   9.59600,    97.400,   0.80582/
      DATA (PR( 6,J),WAC( 6,J),ETA( 6,J),J=1,10)/
     1  1.00000,   108.100,   0.57018,   2.85500,   108.100,   0.64242,
     2  4.29700,   108.100,   0.72498,   5.61300,   108.100,   0.77744,
     3  6.93600,   107.600,   0.80840,   7.62200,   107.100,   0.83936,
     4  8.54600,   106.700,   0.86000,   9.13400,   106.000,   0.83936,
     5  9.92500,   104.500,   0.80840,  10.21900,   104.000,   0.80410/
      DATA (PR( 7,J),WAC( 7,J),ETA( 7,J),J=1,10)/
     1  1.00000,   114.500,   0.55986,   3.26100,   114.500,   0.64242,
     2  4.75900,   114.500,   0.72498,   6.11700,   114.500,   0.77744,
     3  7.45400,   114.500,   0.80840,   8.30800,   114.300,   0.83936,
     4  9.21800,   113.600,   0.84968,   9.63800,   113.300,   0.83936,
     5 10.51300,   112.600,   0.80840,  10.99600,   112.400,   0.79808/
      DATA (PR( 8,J),WAC( 8,J),ETA( 8,J),J=1,10)/
     1  1.00000,   122.900,   0.53922,   1.68600,   122.900,   0.57018,
     2  3.84900,   122.900,   0.64242,   5.46600,   122.900,   0.72498,
     3  6.86600,   122.900,   0.77744,   8.37100,   122.900,   0.80840,
     4  8.96600,   122.600,   0.82388,   9.88300,   122.100,   0.83936,
     5 10.91200,   121.700,   0.80840,  11.81500,   120.700,   0.77744/
      DATA (PR( 9,J),WAC( 9,J),ETA( 9,J),J=1, 8)/
     1  1.00000,   139.800,   0.47644,   4.35300,   139.800,   0.60114,
     2  7.62200,   139.800,   0.72498,  10.21900,   139.800,   0.77744,
     3 11.05900,   139.800,   0.78260,  11.89900,   139.500,   0.77744,
     4 13.15900,   139.300,   0.72498,  13.65600,   139.000,   0.69918/
      DATA (PR(10,J),WAC(10,J),ETA(10,J),J=1, 8)/
     1  1.00000,   146.200,   0.46612,   3.76500,   146.200,   0.57018,
     2  6.48100,   146.200,   0.64242,   9.17600,   146.200,   0.72498,
     3 10.21900,   146.200,   0.75078,  11.47900,   146.200,   0.75078,
     4 12.71100,   146.200,   0.72498,  14.41200,   146.200,   0.64242/
      END
```

```
$IBFTC BLKFAN
C     THIS IS A GENERALIZED FAN MAP FOR UNREALISTIC SUPERSONIC ENGINE
      BLOCK DATA
      COMMON /  FAN/CN(15),PR(15,15),WAC(15,15),ETA(15,15),N,NP(15)
      DATA N,NP/10,6,3*7,5*10,8,5*0/
      DATA CN/0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2,5*0./
      DATA (PR( 1,J),WAC( 1,J),ETA( 1,J),J=1, 6)/
     1  1.00000,   243.600,   0.75592,   1.01200,   229.800,   0.76120,
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```
 2  1.02800,   199.800,   0.76648,   1.03840,   166.800,   0.75592,
 3  1.04480,   133.200,   0.72512,   1.04800,    86.400,   0.64152/
  DATA (PR( 2,J),WAC( 2,J),ETA( 2,J),J=1, 7)/
 1  1.00000,   286.800,   0.75592,   1.02000,   270.000,   0.77616,
 2  1.04000,   253.200,   0.79200,   1.05840,   233.400,   0.79728,
 3  1.07520,   209.400,   0.80256,   1.09200,   183.600,   0.77616,
 4  1.10000,   156.600,   0.74008/
  DATA (PR( 3,J),WAC( 3,J),ETA( 3,J),J=1, 7)/
 1  1.00000,   333.600,   0.75064,   1.02560,   322.800,   0.77616,
 2  1.05120,   310.200,   0.80256,   1.08000,   291.600,   0.82808,
 3  1.11600,   259.800,   0.84392,   1.13200,   240.000,   0.82808,
 4  1.14800,   213.600,   0.77616/
  DATA (PR( 4,J),WAC( 4,J),ETA( 4,J),J=1, 7)/
 1  1.00000,   383.400,   0.74536,   1.03680,   376.200,   0.77616,
 2  1.08800,   358.200,   0.82808,   1.12400,   340.200,   0.85448,
 3  1.16000,   313.200,   0.88000,   1.18960,   276.600,   0.82808,
 4  1.19520,   266.400,   0.80784/
  DATA (PR( 5,J),WAC( 5,J),ETA( 5,J),J=1,10)/
 1  1.00000,   439.800,   0.72512,   1.06400,   436.800,   0.77616,
 2  1.11840,   428.400,   0.82808,   1.14800,   420.600,   0.85448,
 3  1.18400,   406.800,   0.88000,   1.20960,   393.600,   0.90112,
 4  1.21760,   388.200,   0.90376,   1.22400,   383.400,   0.90112,
 5  1.24400,   368.400,   0.88000,   1.26720,   342.600,   0.82808/
  DATA (PR( 6,J),WAC( 6,J),ETA( 6,J),J=1,10)/
 1  1.00000,   499.800,   0.68816,   1.10000,   499.800,   0.77616,
 2  1.16000,   493.200,   0.82808,   1.20000,   485.400,   0.85448,
 3  1.22800,   476.400,   0.88000,   1.25520,   466.800,   0.90112,
 4  1.27200,   456.600,   0.91080,   1.28640,   448.200,   0.90112,
 5  1.30240,   433.200,   0.88000,   1.33200,   406.800,   0.82720/
  DATA (PR( 7,J),WAC( 7,J),ETA( 7,J),J=1,10)/
 1  1.00000,   566.400,   0.64152,   1.07600,   566.400,   0.72512,
 2  1.15200,   566.400,   0.77616,   1.21920,   559.800,   0.82808,
 3  1.26000,   553.200,   0.85888,   1.28960,   544.800,   0.88000,
 4  1.33120,   528.600,   0.90112,   1.36160,   509.400,   0.88000,
 5  1.39120,   483.600,   0.82808,   1.40000,   474.000,   0.81752/
  DATA (PR( 8,J),WAC( 8,J),ETA( 8,J),J=1,10)/
 1  1.00000,   633.600,   0.60016,   1.04400,   633.600,   0.64152,
 2  1.13520,   633.600,   0.72512,   1.22080,   633.000,   0.77616,
 3  1.29440,   625.800,   0.82808,   1.34000,   616.800,   0.85888,
 4  1.40000,   600.000,   0.88000,   1.42800,   586.800,   0.85888,
 5  1.44800,   576.600,   0.82808,   1.48000,   553.200,   0.78672/
  DATA (PR( 9,J),WAC( 9,J),ETA( 9,J),J=1,10)/
 1  1.00000,   700.200,   0.56936,   1.10400,   700.200,   0.64152,
 2  1.22000,   700.200,   0.72512,   1.32400,   700.200,   0.77616,
 3  1.40000,   700.200,   0.80256,   1.44800,   698.400,   0.80784,
 4  1.50000,   693.600,   0.80256,   1.53360,   683.400,   0.77616,
 5  1.56800,   666.600,   0.74536,   1.58400,   656.400,   0.72512/
  DATA (PR(10,J),WAC(10,J),ETA(10,J),J=1, 8)/
 1  1.00000,   750.000,   0.51744,   1.16320,   750.000,   0.64152,
 2  1.31200,   750.000,   0.72512,   1.40000,   750.000,   0.75592,
 3  1.48000,   750.000,   0.76120,   1.54000,   750.000,   0.75064,
 4  1.58000,   749.400,   0.72512,   1.66000,   736.800,   0.64152/
  END
```

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$IBFTC BLKINT
C      THIS IS A GENERALIZED FAN MAP FOR UNREALISTIC SUPERSONIC ENGINE
       BLOCK DATA
       COMMON / INT / CN(15),PR(15,15),WAC(15,15),ETA(15,15),N,NP(15)
       DATA N,NP/10,6,3*7,5*10,8,5*0/
       DATA CN/0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2,5*0./
       DATA (PR( 1,J),WAC( 1,J),ETA( 1,J),J=1, 6)/
     1  1.00000,   121.800,   0.75592,   1.01800,   114.900,   0.76120,
     2  1.04200,    99.900,   0.76648,   1.05760,    83.400,   0.75592,
     3  1.06720,    66.600,   0.72512,   1.07200,    43.200,   0.64152/
       DATA (PR( 2,J),WAC( 2,J),ETA( 2,J),J=1, 7)/
     1  1.00000,   143.400,   0.75592,   1.03000,   135.000,   0.77616,
     2  1.06000,   126.600,   0.79200,   1.08760,   116.700,   0.79728,
     3  1.11280,   104.700,   0.80256,   1.13800,    91.800,   0.77616,
     4  1.15000,    78.300,   0.74008/
```

```
      DATA (PR( 3,J),WAC( 3,J),ETA( 3,J),J=1, 7)/
     1 1.00000,  166.800,  0.75064,  1.03840,  161.400,  0.77616,
     2 1.07680,  155.100,  0.80256,  1.12000,  145.800,  0.82808,
     3 1.17400,  129.900,  0.84392,  1.19800,  120.000,  0.82808,
     4 1.22200,  106.800,  0.77616/
      DATA (PR( 4,J),WAC( 4,J),ETA( 4,J),J=1, 7)/
     1 1.00000,  191.700,  0.74536,  1.05520,  188.100,  0.77616,
     2 1.13200,  179.100,  0.82808,  1.18600,  170.100,  0.85448,
     3 1.24000,  156.600,  0.88000,  1.28440,  138.300,  0.82808,
     4 1.29280,  133.200,  0.80784/
      DATA (PR( 5,J),WAC( 5,J),ETA( 5,J),J=1,10)/
     1 1.00000,  219.900,  0.72512,  1.09600,  218.400,  0.77616,
     2 1.17760,  214.200,  0.82808,  1.22200,  210.300,  0.85448,
     3 1.27600,  203.400,  0.88000,  1.31440,  196.800,  0.90112,
     4 1.32640,  194.100,  0.90376,  1.33600,  191.700,  0.90112,
     5 1.36600,  184.200,  0.88000,  1.40080,  171.300,  0.82808/
      DATA (PR( 6,J),WAC( 6,J),ETA( 6,J),J=1,10)/
     1 1.00000,  249.900,  0.68816,  1.15000,  249.900,  0.77616,
     2 1.24000,  246.600,  0.82808,  1.30000,  242.700,  0.85448,
     3 1.34200,  238.200,  0.88000,  1.38280,  233.400,  0.90112,
     4 1.40800,  228.300,  0.91080,  1.42960,  224.100,  0.90112,
     5 1.45360,  216.600,  0.88000,  1.49800,  203.400,  0.82720/
      DATA (PR( 7,J),WAC( 7,J),ETA( 7,J),J=1,10)/
     1 1.00000,  283.200,  0.64152,  1.11400,  283.200,  0.72512,
     2 1.22800,  283.200,  0.77616,  1.32880,  279.900,  0.82808,
     3 1.39000,  276.600,  0.85888,  1.43440,  272.400,  0.88000,
     4 1.49680,  264.300,  0.90112,  1.54240,  254.700,  0.88000,
     5 1.58680,  241.800,  0.82808,  1.60000,  237.000,  0.81752/
      DATA (PR( 8,J),WAC( 8,J),ETA( 8,J),J=1,10)/
     1 1.00000,  316.800,  0.60016,  1.06600,  316.800,  0.64152,
     2 1.20280,  316.800,  0.72512,  1.33120,  316.500,  0.77616,
     3 1.44160,  312.900,  0.82808,  1.51000,  308.400,  0.85888,
     4 1.60000,  300.000,  0.88000,  1.64200,  293.400,  0.85888,
     5 1.67200,  288.300,  0.82808,  1.72000,  276.600,  0.78672/
      DATA (PR( 9,J),WAC( 9,J),ETA( 9,J),J=1,10)/
     1 1.00000,  350.100,  0.56936,  1.15600,  350.100,  0.64152,
     2 1.33000,  350.100,  0.72512,  1.48600,  350.100,  0.77616,
     3 1.60000,  350.100,  0.80256,  1.67200,  349.200,  0.80784,
     4 1.75000,  346.800,  0.80256,  1.80040,  341.700,  0.77616,
     5 1.85200,  333.300,  0.74536,  1.87600,  328.200,  0.72512/
      DATA (PR(10,J),WAC(10,J),ETA(10,J),J=1, 8)/
     1 1.00000,  375.000,  0.51744,  1.24480,  375.000,  0.64152,
     2 1.46800,  375.000,  0.72512,  1.60000,  375.000,  0.75592,
     3 1.72000,  375.000.  0.76120,  1.81000,  375.000,  0.75064,
     4 1.87000,  374.700,  0.72512,  1.99000,  368.400,  0.64152/
      END
```

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$IBFTC CMBDT
      BLOCK DATA
      COMMON / COMB/PSI(15),DELT(15,15),ETA(15,15),N,NP(15)
      DATA N,NP / 15,15*15 /
      DATA PSI/4.9116,9.8232,14.735,19.646,24.558,29.470,34.381,
     139.293,44.207,73.674,100.,200.,300.,400.,500./
      DATA DELT/15*200.,15*300.,15*400.,15*500.,15*600.,15*700.,15*800.,
     115*900.,15*1000.,15*1100.,15*1200.,15*1300.,15*1400.,15*1500.,
     215*1600./
      DATA ETA/
     1.600,.758,.868,.925,.960,.988,9*1.00,
     2.726,.825,.893,.936,.966,.991,9*1.00,
     3.777,.858,.911,.946,.972,.992,9*1.00,
     4.806,.875,.925,.955,.977,.994,9*1.00,
     5.826,.888,.935,.933,.982,.995,9*1.00,
     6.843,.898,.942,.969,.985,.997,9*1.00,
     7.855,.906,.947,.974,.990,.998,9*1.00,
     8.865,.912,.951,.977,.992,.999,9*1.00,
     9.870,.914,.953,.978,.993,.999,.999,8*1.00,
     A.870,.915,.953,.979,.995,.999,.999,8*1.00,
     B.870,.915,.953,.979,.995,.999,.999,8*1.00,
     C.870,.915,.953,.979,.995,.999,.999,8*1.00.
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D.870,.915,.953,.979,.995,.999,.999,8*1.00,
E.870,.915,.953,.979,.995,.999,.999,8*1.00,
F.870,.915,.953,.979,.995,.999,.999,8*1.00/
 END
```

```
$IBFTC HPTDAT
      BLOCK DATA
      COMMON / HTURB/TFF(15),CN(15,15),DH(15,15),ETA(15,15),N,NP(15)
      DATA N,NP/10,9*15,12,5*0/
      DATA TFF /   39.670,    42.990,    47.460,    48.610,    49.175,
     1   49.600,    50.000,    50.425,    50.920,    51.575,    5*0./
      DATA (CN( 1,J),DH( 1,J),ETA( 1,J),J=1,15)/
     1   0.1872,    0.0032,    0.6219,    0.3372,    0.0057,    0.7078,
     2   0.5156,    0.0084,    0.7868,    0.7128,    0.0108,    0.8090,
     3   0.9382,    0.0133,    0.8090,    1.1442,    0.0152,    0.7963,
     4   1.3138,    0.0164,    0.7779,    1.5382,    0.0174,    0.7422,
     5   1.7264,    0.0179,    0.7078,    1.9324,    0.0176,    0.7635,
     6   2.1500,    0.0167,    0.6068,    2.4058,    0.0144,    0.5309,
     7   2.5892,    0.0120,    0.4773,    2.7862,    0.0082,    0.4045,
     8   2.9460,    0.0034,    0.3034/
      DATA (CN( 2,J),DH( 2,J),ETA( 2,J),J=1,15)/
     1   0.1872,    0.0038,    0.6068,    0.3942,    0.0080,    0.7078,
     2   0.5814,    0.0113,    0.8090,    0.7128,    0.0136,    0.8292,
     3   0.8442,    0.0156,    0.8363,    0.9804,    0.0176,    0.8393,
     4   1.1068,    0.0192,    0.8368,    1.2754,    0.0212,    0.8302,
     5   1.4450,    0.0228,    0.8254,    1.7068,    0.0248,    0.8090,
     6   1.9696,    0.0260,    0.7696,    2.2706,    0.0261,    0.7078,
     7   2.6970,    0.0241,    0.6068,    3.0960,    0.0188,    0.5056,
     8   3.3774,    0.0128,    0.4197/
      DATA (CN( 3,J),DH( 3,J),ETA( 3,J),J=1,15)/
     1   0.1872,    0.0046,    0.5764,    0.4362,    0.0100,    0.7078,
     2   0.6568,    0.0144,    0.8090,    0.8726,    0.0184,    0.8494,
     3   1.0696,    0.0216,    0.8543,    1.2382,    0.0240,    0.8515,
     4   1.4638,    0.0268,    0.8494,    1.6882,    0.0292,    0.8409,
     5   1.9696,    0.0316,    0.8262,    2.2138,    0.0331,    0.8090,
     6   2.5520,    0.0344,    0.7579,    2.8050,    0.0346,    0.7078,
     7   3.0392,    0.0340,    0.6652,    3.2648,    0.0324,    0.6068,
     8   3.3774,    0.0312,    0.5865/
      DATA (CN( 4,J),DH( 4,J),ETA( 4,J),J=1,15)/
     1   0.1872,    0.0052,    0.5643,    0.2550,    0.0068,    0.6068,
     2   0.4784,    0.0120,    0.7078,    0.6942,    0.0164,    0.8090,
     3   0.9148,    0.0204,    0.8494,    1.1442,    0.0244,    0.8596,
     4   1.3882,    0.0280,    0.8596,    1.5618,    0.0304,    0.8575,
     5   1.8010,    0.0336,    0.8535,    1.9794,    0.0356,    0.8494,
     6   2.2794,    0.0388,    0.8363,    2.5138,    0.0412,    0.8262,
     7   2.8334,    0.0441,    0.8090,    3.1422,    0.0472,    0.7797,
     8   3.3774,    0.0494,    0.7584/
      DATA (CN( 5,J),DH( 5,J),ETA( 5,J),J=1,15)/
     1   0.1872,    0.0056,    0.5562,    0.3000,    0.0088,    0.6068,
     2   0.5254,    0.0144,    0.7078,    0.7500,    0.0192,    0.8090,
     3   0.9754,    0.0236,    0.8494,    1.2754,    0.0288,    0.8697,
     4   1.4824,    0.0321,    0.8696,    1.7638,    0.0360,    0.8662,
     5   2.0450,    0.0400,    0.8615,    2.3362,    0.0444,    0.8555,
     6   2.6450,    0.0496,    0.8520,    2.8706,    0.0540,    0.8494,
     7   3.0764,    0.0596,    0.8494,    3.1520,    0.0640,    0.8532,
     8   3.1618,    0.0661,    0.8570/
      DATA (CN( 6,J),DH( 6,J),ETA( 6,J),J=1,15)/
     1   0.1872,    0.0068,    0.5309,    0.3568,    0.0120,    0.6068,
     2   0.6196,    0.0192,    0.7078,    0.8628,    0.0252,    0.8090,
     3   1.0932,    0.0300,    0.8494,    1.2852,    0.0340,    0.8697,
     4   1.5010,    0.0384,    0.8819,    1.6882,    0.0421,    0.8899,
     5   1.9138,    0.0472,    0.8940,    2.1246,    0.0524,    0.8969,
     6   2.2706,    0.0564,    0.8975,    2.4226,    0.0612,    0.8976,
     7   2.4950,    0.0640,    0.8968,    2.5372,    0.0668,    0.8937,
     8   2.5558,    0.0698,    0.8896/
      DATA (CN( 7,J),DH( 7,J),ETA( 7,J),J=1,15)/
     1   0.1872,    0.0080,    0.5062,    0.4314,    0.0164,    0.6068,
     2   0.6844,    0.0236,    0.7078,    0.9568,    0.0308,    0.8090,
     3   1.2010,    0.0372,    0.8494,    1.3834,    0.0416,    0.8697,
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4   1.5108,    0.0448,    0.8797,    1.6186,    0.0476,    0.8899,
5   1.7450,    0.0510,    0.8954,    1.8618,    0.0544,    0.9000,
6   1.9558,    0.0576,    0.9010,    2.0000,    0.0600,    0.9000,
7   2.0450,    0.0624,    0.8980,    2.0824,    0.0660,    0.8925,
8   2.1010,    0.0700,    0.8793/
 DATA (CN( 8,J),DH( 8,J),ETA( 8,J),J=1,15)/
1   0.1872,    0.0088,    0.5051,    0.4834,    0.0196,    0.6068,
2   0.7314,    0.0272,    0.7078,    0.8814,    0.0316,    0.7665,
3   1.0226,    0.0356,    0.8090,    1.1442,    0.0392,    0.8292,
4   1.2804,    0.0432,    0.8494,    1.3696,    0.0460,    0.8596,
5   1.4638,    0.0488,    0.8697,    1.5950,    0.0528,    0.8808,
6   1.6746,    0.0560,    0.8848,    1.7450,    0.0596,    0.8848,
7   1.8010,    0.0640,    0.8788,    1.8156,    0.0664,    0.8697,
8   1.8196,    0.0693,    0.8590/
 DATA (CN( 9,J),DH( 9,J),ETA( 9,J),J=1,15)/
1   0.1872,    0.0093,    0.4909,    0.3372,    0.0159,    0.5380,
2   0.5344,    0.0232,    0.6068,    0.6754,    0.0284,    0.6573,
3   0.8068,    0.0330,    0.7078,    0.9196,    0.0368,    0.7463,
4   1.0128,    0.0400,    0.7776,    1.1254,    0.0442,    0.8090,
5   1.2196,    0.0480,    0.8191,    1.3138,    0.0524,    0.8302,
6   1.3696,    0.0556,    0.8347,    1.4068,    0.0580,    0.8363,
7   1.4450,    0.0612,    0.8322,    1.4638,    0.0640,    0.8241,
8   1.4676,    0.0668,    0.8090/
 DATA (CN(10,J),DH(10,J),ETA(10,J),J=1,12)/
1   0.1872,    0.0132,    0.4257,    0.2814,    0.0180,    0.4747,
2   0.3804,    0.0228,    0.5056,    0.4686,    0.0268,    0.5359,
3   0.5628,    0.0314,    0.5683,    0.6382,    0.0352,    0.5941,
4   0.6892,    0.0380,    0.6068,    0.7362,    0.0412,    0.6178,
5   0.7696,    0.0440,    0.6240,    0.8068,    0.0476,    0.6310,
6   0.8254,    0.0504,    0.6265,    0.8304,    0.0530,    0.6118/
 END
```

```
$IBFTC IPTDAT
      BLOCK DATA
      COMMON / ITURB / TFF(15),CN(15,15),DH(15,15),ETA(15,15),N,NP(15)
      DATA N,NP/11,9*15,12,9,4*0/
      DATA TFF /    70.776,    82.236,    93.468,   103.464,   112.836,
     1  116.580,   120.000,   122.676,   125.124,   127.824,   130.536,4*0./
      DATA (CN( 1,J),DH( 1,J),ETA( 1,J),J=1,15)/
     1   0.3522,    0.0016,    0.7120,    0.5104,    0.0023,    0.7300,
     2   0.7044,    0.0031,    0.7472,    0.9330,    0.0038,    0.7300,
     3   1.1618,    0.0045,    0.7140,    1.3556,    0.0049,    0.7000,
     4   1.5497,    0.0052,    0.6850,    1.6905,    0.0054,    0.6730,
     5   1.9367,    0.0055,    0.6452,    2.1835,    0.0054,    0.6200,
     6   2.3593,    0.0051,    0.6000,    2.5001,    0.0047,    0.5750,
     7   2.6941,    0.0038,    0.5310,    2.8175,    0.0031,    0.5000,
     8   3.1698,    0.0001,    0.3850/
      DATA (CN( 2,J),DH( 2,J),ETA( 2,J),J=1,15)/
     1   0.3522,    0.0023,    0.8000,    0.5278,    0.0035,    0.8100,
     2   0.7575,    0.0047,    0.8200,    1.0208,    0.0061,    0.8300,
     3   1.2322,    0.0070,    0.8300,    1.3818,    0.0076,    0.8290,
     4   1.6201,    0.0084,    0.8100,    1.8130,    0.0089,    0.8000,
     5   1.9723,    0.0092,    0.7850,    2.1305,    0.0094,    0.7600,
     6   2.2715,    0.0095,    0.7450,    2.5089,    0.0093,    0.7000,
     7   2.7471,    0.0089,    0.6800,    2.9227,    0.0083,    0.6450,
     8   3.1698,    0.0068,    0.5900/
      DATA (CN( 3,J),DH( 3,J),ETA( 3,J),J=1,15)/
     1   0.3522,    0.0027,    0.8000,    0.5654,    0.0045,    0.8300,
     2   0.8279,    0.0063,    0.8600,    1.0296,    0.0076,    0.8630,
     3   1.1975,    0.0087,    0.8670,    1.3730,    0.0098,    0.8700,
     4   1.5497,    0.0107,    0.8720,    1.7609,    0.0118,    0.8720,
     5   1.9367,    0.0126,    0.8700,    2.1479,    0.0134,    0.8670,
     6   2.3245,    0.0139,    0.8600,    2.4827,    0.0142,    0.8500,
     7   2.6583,    0.0146,    0.8300,    2.9227,    0.0147,    0.8000,
     8   3.1698,    0.0145,    0.7600/
      DATA (CN( 4,J),DH( 4,J),ETA( 4,J),J=1,15)/
     1   0.3522,    0.0029,    0.7995,    0.4052,    0.0034,    0.8000,
     2   0.6514,    0.0054,    0.8400,    0.8452,    0.0069,    0.8600,
     3   1.0567,    0.0084,    0.8680,    1.2322,    0.0097,    0.8730,
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     4   1.4434,    0.0111,    0.8800,    1.6722,    0.0124,    0.8830,
     5   1.9540,    0.0140,    0.8835,    2.1131,    0.0146,    0.8830,
     6   2.2715,    0.0153,    0.8800,    2.4915,    0.0161,    0.8740,
     7   2.7471,    0.0168,    0.8600,    2.9931,    0.0172,    0.8350,
     8   3.1698,    0.0173,    0.8200/
      DATA (CN( 5,J),DH( 5,J),ETA( 5,J),J=1,15)/
     1   0.3522,    0.0031,    0.7750,    0.4844,    0.0043,    0.8000,
     2   0.7044,    0.0062,    0.8480,    0.9330,    0.0081,    0.8600,
     3   1.2322,    0.0105,    0.8750,    1.4967,    0.0124,    0.8900,
     4   1.6548,    0.0136,    0.8912,    1.8834,    0.0152,    0.8940,
     5   2.0071,    0.0159,    0.8955,    2.1652,    0.0169,    0.8970,
     6   2.3274,    0.0178,    0.8961,    2.5531,    0.0189,    0.8900,
     7   2.8175,    0.0199,    0.8790,    3.0461,    0.0207,    0.8671,
     8   3.1698,    0.0210,    0.8600/
      DATA (CN( 6,J),DH( 6,J),ETA( 6,J),J=1,15)/
     1   0.3522,    0.0034,    0.7600,    0.5896,    0.0057,    0.8000,
     2   0.8008,    0.0076,    0.8450,    1.0567,    0.0100,    0.8600,
     3   1.2322,    0.0114,    0.8730,    1.4619,    0.0134,    0.8900,
     4   1.6722,    0.0150,    0.8950,    1.8660,    0.0165,    0.9000,
     5   2.1171,    0.0184,    0.9005,    2.3245,    0.0199,    0.9010,
     6   2.5357,    0.0214,    0.9004,    2.7375,    0.0228,    0.9000,
     7   3.0019,    0.0251,    0.8900,    3.1167,    0.0267,    0.8800,
     8   3.1698,    0.0280,    0.8735/
      DATA (CN( 7,J),DH( 7,J),ETA( 7,J),J=1,15)/
     1   0.3522,    0.0038,    0.7310,    0.7392,    0.0078,    0.8000,
     2   0.9689,    0.0101,    0.8300,    1.2109,    0.0124,    0.8600,
     3   1.4089,    0.0142,    0.8750,    1.6056,    0.0159,    0.8900,
     4   1.7609,    0.0173,    0.8930,    1.9367,    0.0190,    0.8975,
     5   2.0948,    0.0207,    0.8999,    2.2000,    0.0220,    0.9000,
     6   2.2889,    0.0233,    0.8980,    2.3949,    0.0250,    0.8937,
     7   2.4471,    0.0261,    0.8900,    2.5001,    0.0276,    0.8799,
     8   2.5175,    0.0290,    0.8710/
      DATA (CN( 8,J),DH( 8,J),ETA( 8,J),J=1,15)/
     1   0.3522,    0.0042,    0.7100,    0.5808,    0.0069,    0.7450,
     2   0.7575,    0.0090,    0.7680,    0.9330,    0.0109,    0.8000,
     3   1.1801,    0.0135,    0.8380,    1.3915,    0.0156,    0.8600,
     4   1.5671,    0.0177,    0.8712,    1.7609,    0.0199,    0.8780,
     5   1.8660,    0.0213,    0.8800,    1.9897,    0.0230,    0.8775,
     6   2.0601,    0.0241,    0.8760,    2.1131,    0.0251,    0.8722,
     7   2.1652,    0.0263,    0.8660,    2.2009,    0.0276,    0.8600,
     8   2.2048,    0.0283,    0.8480/
      DATA (CN( 9,J),DH( 9,J),ETA( 9,J),J=1,15)/
     1   0.3522,    0.0047,    0.6780,    0.5278,    0.0070,    0.7000,
     2   0.6340,    0.0084,    0.7125,    0.7922,    0.0104,    0.7350,
     3   0.9689,    0.0124,    0.7690,    1.1183,    0.0141,    0.8000,
     4   1.1801,    0.0148,    0.8060,    1.3209,    0.0166,    0.8225,
     5   1.4619,    0.0184,    0.8395,    1.5497,    0.0196,    0.8450,
     6   1.6722,    0.0214,    0.8470,    1.7609,    0.0232,    0.8445,
     7   1.8130,    0.0245,    0.8330,    1.8315,    0.0255,    0.8235,
     8   1.8401,    0.0267,    0.8080/
      DATA (CN(10,J),DH(10,J),ETA(10,J),J=1,12)/
     1   0.3522,    0.0054,    0.6380,    0.4574,    0.0069,    0.6550,
     2   0.6167,    0.0092,    0.6700,    0.7218,    0.0107,    0.6850,
     3   0.8279,    0.0123,    0.7000,    0.9330,    0.0138,    0.7110,
     4   1.0567,    0.0159,    0.7180,    1.1493,    0.0177,    0.7180,
     5   1.2148,    0.0191,    0.7170,    1.2505,    0.0202,    0.7140,
     6   1.2784,    0.0214,    0.7000,    1.2824,    0.0221,    0.6890/
      DATA (CN(11,J),DH(11,J),ETA(11,J),J=1, 9)/
     1   0.3522,    0.0061,    0.6000,    0.4226,    0.0075,    0.6000,
     2   0.5278,    0.0093,    0.6120,    0.6167,    0.0108,    0.6170,
     3   0.7044,    0.0124,    0.6210,    0.7922,    0.0140,    0.6258,
     4   0.8452,    0.0151,    0.6250,    0.8983,    0.0164,    0.6230,
     5   0.9293,    0.0177,    0.6009/
      END
```

```
$IBFTC LPTDAT
      BLOCK DATA
      COMMON / LTURB/TFF(15),CN(15,15),DH(15,15),ETA(15,15),N,NP(15)
      DATA N,NP/11,9*15,12,9,4*0/
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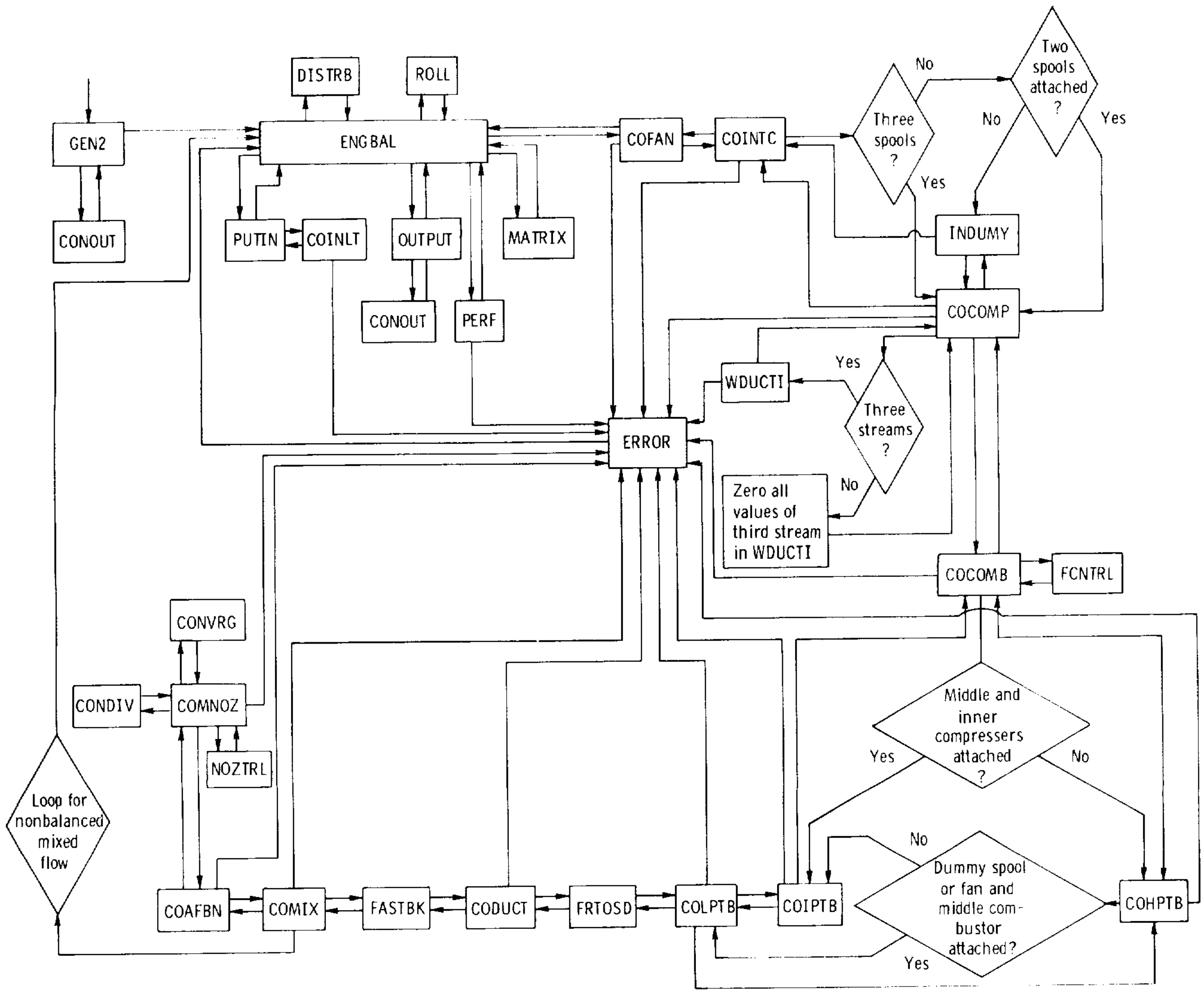
      DATA TFF /   88.470,  102.795,  116.835,  129.330,  141.045,
     1 145.725,  150.000,  153.345,  156.405,  159.780,  163.170,4*0./
      DATA (CN( 1,J),DH( 1,J),ETA( 1,J),J=1,15)/
     1   0.3682,   0.0018,   0.7120,   0.5336,   0.0026,   0.7300,
     2   0.7365,   0.0035,   0.7472,   0.9754,   0.0044,   0.7300,
     3   1.2146,   0.0051,   0.7140,   1.4173,   0.0056,   0.7000,
     4   1.6201,   0.0059,   0.6850,   1.7673,   0.0061,   0.6730,
     5   2.0247,   0.0062,   0.6452,   2.2827,   0.0061,   0.6200,
     6   2.4665,   0.0057,   0.6000,   2.6137,   0.0053,   0.5750,
     7   2.8166,   0.0044,   0.5310,   2.9456,   0.0035,   0.5000,
     8   3.3138,   0.0001,   0.3850/
      DATA (CN( 2,J),DH( 2,J),ETA( 2,J),J=1,15)/
     1   0.3682,   0.0026,   0.8000,   0.5518,   0.0039,   0.8100,
     2   0.7919,   0.0054,   0.8200,   1.0672,   0.0069,   0.8300,
     3   1.2882,   0.0080,   0.8300,   1.4446,   0.0087,   0.8290,
     4   1.6937,   0.0096,   0.8100,   1.8954,   0.0101,   0.8000,
     5   2.0619,   0.0104,   0.7850,   2.2273,   0.0107,   0.7600,
     6   2.3747,   0.0108,   0.7450,   2.6229,   0.0106,   0.7000,
     7   2.8720,   0.0101,   0.6800,   3.0555,   0.0094,   0.6450,
     8   3.3138,   0.0077,   0.5900/
      DATA (CN( 3,J),DH( 3,J),ETA( 3,J),J=1,15)/
     1   0.3682,   0.0031,   0.8000,   0.5911,   0.0051,   0.8300,
     2   0.8655,   0.0071,   0.8600,   1.0764,   0.0087,   0.8630,
     3   1.2519,   0.0099,   0.8670,   1.4354,   0.0111,   0.8700,
     4   1.6201,   0.0122,   0.8720,   1.8409,   0.0134,   0.8720,
     5   2.0247,   0.0143,   0.8700,   2.2455,   0.0152,   0.8670,
     6   2.4302,   0.0157,   0.8600,   2.5956,   0.0162,   0.8500,
     7   2.7791,   0.0166,   0.8300,   3.0555,   0.0167,   0.8000,
     8   3.3138,   0.0164,   0.7600/
      DATA (CN( 4,J),DH( 4,J),ETA( 4,J),J=1,15)/
     1   0.3682,   0.0033,   0.7995,   0.4237,   0.0038,   0.8000,
     2   0.6810,   0.0061,   0.8400,   0.8837,   0.0078,   0.8600,
     3   1.1047,   0.0096,   0.8680,   1.2882,   0.0110,   0.8730,
     4   1.5090,   0.0126,   0.8800,   1.7482,   0.0141,   0.8830,
     5   2.0429,   0.0159,   0.8835,   2.2091,   0.0166,   0.8830,
     6   2.3747,   0.0174,   0.8800,   2.6047,   0.0183,   0.8740,
     7   2.8720,   0.0191,   0.8600,   3.1291,   0.0195,   0.8350,
     8   3.3138,   0.0197,   0.8200/
      DATA (CN( 5,J),DH( 5,J),ETA( 5,J),J=1,15)/
     1   0.3682,   0.0036,   0.7750,   0.5065,   0.0049,   0.8000,
     2   0.7365,   0.0071,   0.8480,   0.9754,   0.0092,   0.8600,
     3   1.2882,   0.0119,   0.8750,   1.5647,   0.0141,   0.8900,
     4   1.7301,   0.0155,   0.8912,   1.9690,   0.0172,   0.8940,
     5   2.0983,   0.0181,   0.8955,   2.2637,   0.0192,   0.8970,
     6   2.4332,   0.0202,   0.8961,   2.6691,   0.0214,   0.8900,
     7   2.9456,   0.0226,   0.8790,   3.1846,   0.0235,   0.8671,
     8   3.3138,   0.0239,   0.8600/
      DATA (CN( 6,J),DH( 6,J),ETA( 6,J),J=1,15)/
     1   0.3682,   0.0038,   0.7600,   0.6164,   0.0064,   0.8000,
     2   0.8372,   0.0087,   0.8450,   1.1047,   0.0113,   0.8600,
     3   1.2882,   0.0130,   0.8730,   1.5283,   0.0152,   0.8900,
     4   1.7482,   0.0171,   0.8950,   1.9509,   0.0187,   0.9000,
     5   2.2133,   0.0209,   0.9005,   2.4302,   0.0226,   0.9010,
     6   2.6510,   0.0244,   0.9004,   2.8619,   0.0259,   0.9000,
     7   3.1384,   0.0286,   0.8900,   3.2584,   0.0303,   0.8800,
     8   3.3138,   0.0319,   0.8735/
      DATA (CN( 7,J),DH( 7,J),ETA( 7,J),J=1,15)/
     1   0.3682,   0.0044,   0.7310,   0.7728,   0.0089,   0.8000,
     2   1.0129,   0.0115,   0.8300,   1.2659,   0.0141,   0.8600,
     3   1.4729,   0.0162,   0.8750,   1.6785,   0.0181,   0.8900,
     4   1.8409,   0.0197,   0.8930,   2.0247,   0.0216,   0.8975,
     5   2.1901,   0.0235,   0.8999,   2.3000,   0.0250,   0.9000,
     6   2.3929,   0.0265,   0.8980,   2.5038,   0.0284,   0.8937,
     7   2.5583,   0.0296,   0.8900,   2.6137,   0.0314,   0.8799,
     8   2.6319,   0.0329,   0.8710/
      DATA (CN( 8,J),DH( 8,J),ETA( 8,J),J=1,15)/
     1   0.3682,   0.0048,   0.7100,   0.6072,   0.0078,   0.7450,
     2   0.7919,   0.0102,   0.7680,   0.9754,   0.0124,   0.8000,
     3   1.2337,   0.0153,   0.8380,   1.4548,   0.0177,   0.8600,
     4   1.6383,   0.0201,   0.8712,   1.8409,   0.0226,   0.8780,
     5   1.9509,   0.0242,   0.8800,   2.0801,   0.0261,   0.8775,
     6   2.1537,   0.0274,   0.8760,   2.2091,   0.0285,   0.8722,
     7   2.2637,   0.0299,   0.8660,   2.3009,   0.0314,   0.8600,
     8   2.3051,   0.0321,   0.8480/
```

```
      DATA (CN( 9,J),DH( 9,J),ETA( 9,J),J=1,15)/
     1    0.3682,   0.0054,   0.6780,   0.5518,   0.0080,   0.7000,
     2    0.6629,   0.0096,   0.7125,   0.8282,   0.0119,   0.7350,
     3    1.0129,   0.0141,   0.7690,   1.1691,   0.0160,   0.8000,
     4    1.2337,   0.0169,   0.8060,   1.3809,   0.0188,   0.8225,
     5    1.5283,   0.0209,   0.8395,   1.6201,   0.0223,   0.8450,
     6    1.7482,   0.0244,   0.8470,   1.8409,   0.0263,   0.8445,
     7    1.8954,   0.0279,   0.8330,   1.9147,   0.0289,   0.8235,
     8    1.9237,   0.0303,   0.8080/
      DATA (CN(10,J),DH(10,J),ETA(10,J),J=1,12)/
     1    0.3682,   0.0061,   0.6380,   0.4782,   0.0078,   0.6550,
     2    0.6447,   0.0104,   0.6700,   0.7546,   0.0122,   0.6850,
     3    0.8655,   0.0139,   0.7000,   0.9754,   0.0157,   0.7110,
     4    1.1047,   0.0181,   0.7180,   1.2015,   0.0201,   0.7180,
     5    1.2701,   0.0217,   0.7170,   1.3073,   0.0230,   0.7140,
     6    1.3365,   0.0244,   0.7000,   1.3407,   0.0251,   0.6890/
      DATA (CN(11,J),DH(11,J),ETA(11,J),J=1, 9)/
     1    0.3682,   0.0069,   0.6000,   0.4418,   0.0086,   0.6000,
     2    0.5518,   0.0106,   0.6120,   0.6447,   0.0123,   0.6170,
     3    0.7365,   0.0141,   0.6210,   0.8282,   0.0159,   0.6258,
     4    0.8837,   0.0172,   0.6250,   0.9391,   0.0186,   0.6230,
     5    0.9715,   0.0201,   0.6009/
      END
```

Flow Chart of DYNGEN



DYNGEN Subroutine Functions and Their Descriptions

AFQUIR	general quadratic interpolation routine
ATMOS	1962 U.S. Standard Atmosphere Table
BLKCMP	performance data for inner-compressor map (BLOCK DATA)
BLKFAN	performance data for fan map (BLOCK DATA)
BLKINT	performance data for intermediate-compressor map (BLOCK DATA)
CMBDT	BLOCK DATA for combustor
COAFBN	performs afterburning calculations; may use either T7 or WFA as main parameter
COCOMB	uses BLOCK DATA to perform combustor calculations; may use either T_4 or WFB as main parameter
COCOMP	uses BLOCK DATA to perform inner-compressor calculations
CODUCT	performs duct and ductburning calculations for turbofans; may use either T24 or WFD as main parameter
COFAN	uses BLOCK DATA to perform fan calculations
COHPTB	uses BLOCK DATA to perform inner-turbine calculations (not used in engine configurations c and g)
COINLT	determines ram recovery and performs inlet calculations
COINTC	uses BLOCK DATA to perform intermediate-compressor calculations
COIPTB	uses BLOCK DATA to perform intermediate-turbine calculations (not used in engine configurations b, e, and h)
COLPTB	uses BLOCK DATA to perform outer-turbine calculations
COMIX	performs gas-mixing calculations if in mixed-flow mode; at design points, calculates areas either from an input static pressure PS55 or from an input Mach number AM55 if PS55=0; at off-design points, calculates static pressures and Mach numbers from design areas; calculates ERR (5); rescales pressure ratios for mixed-flow turbofans to match duct and core static pressures just prior to mixing; also calculates afterburner entrance area A6 as a function of afterburner entrance Mach number AM6
COMNOZ	performs main nozzle calculations
CONDIV	performs nozzle calculations for a convergent-divergent (C-D) nozzle

CONOUT	controls and prints the controlled output variables
CONVRG	performs nozzle calculations for a convergent nozzle
DERIV	computes time derivatives
DISTRB	user-written subroutine which provides transient inputs
ENGBAL	main subroutine; controls all engine balancing loops; checks tolerances and number of loops and loads matrix; calls PUTIN
ERROR	controls all printouts if an error occurs; prints names of subroutine where error occurred and also prints values of all variables in main commons
ETAAB	generalized afterburner performance BLOCK DATA as a function of fuel-air ratio with correction factors for off-design afterburner entrance pressure and Mach number
FASTBK	dummy routine to transfer values
FCNTRL	user-written fuel control subroutine
FRTOSD	dummy routine to transfer values
GEN2	dummy main program to initiate calculations and cause input of controlled output variables (Because of looping between subroutines, control is never transferred back to this routine.)
GUESS	determines initial values of independent variables at each point
HPTDAT	performance data for inner-turbine map (BLOCK DATA)
INDUMY	makes intermediate compressor not change air conditions for engine configurations e and h
IPTDAT	performance data for intermediate-turbine map (BLOCK DATA)
LPTDAT	performance data for outer-turbine map (BLOCK DATA)
MATRIX	solves error matrix
NOZCTR	user-written nozzle control subroutine
OUTPUT	prints output except for controlled output; prints main commons after design point
OVERFL	IBM 7094 system routine for flagging overflows (User's system may have similar routine with different name. This routine is called in ATMOS as OVERFL(J), where if J=1 there is overflow and if J=2 there is no overflow.)
PARABO	parabolic curve-fit routine

PERF	calculates performance after engine is balanced
PROCOM	calculates thermodynamic gas properties for either air or a fuel-air mixture based on JP-4
PUTIN	reads input data; controls loop on static pressures for mixed-flow turbofan
RAM	calculates ram recovery defined by MIL-E-5008B specifications
RAM2	calculates special cases of input ram recovery as a function of flight Mach number
ROLL	saves past values of dynamic variables needed for calculating derivatives, etc.
SEARCH	general table lookup and interpolation routine to obtain data from BLOCK DATA subroutines
SYG	controls printing from UNIT08 (Throughout the program and particularly in ENGBAL, certain messages, variables, and matrix values are written on UNIT08 as an aid in determining why an error occurred or why a point did not balance. These values are printed out if subroutine ERROR is called and IDUMP is greater than zero, or after a good point if IDUMP=2.)
THERMO	provides thermodynamic conditions using PROCOM
THCOMP	performs isentropic calculations for compressors
THTURB	performs isentropic calculations for turbines
WDUCTI	performs third-stream (wing) duct calculations (not used in two-stream engines)
ZERO	zeros nearly all of common and certain controls

Example Case - Three-Spool Turbofan

In order to aid the user in understanding all that must be provided so that DYNGEN can be used, a three-spool turbofan example case is shown. As indicated in table I, all BLOCK DATA subroutines are needed for this engine configuration (a). The BLOCK DATA for the engine simulated are listed on pages 93 to 100. Next, subroutines DISTRB, FCNTRL, and NOZCTR must be written. For this example, an open-loop fuel flow step is to be simulated. Subroutine DISTRB is written as follows:

```
$IBFTC DISTRB
      SUBROUTINE DISTRB
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TOLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
```

```
COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
WFB=1.858
RETURN
END
```

Shown in subroutine DISTRB are COMMON blocks ALL1, ALL2, ALL3, ALL4, ALL5, DYN, and RPMS. All these COMMON blocks can be used to transfer information to DYNGEN. COMMON block WORDS can be used to transfer the subroutine name to subroutine ERROR if an error occurs. COMMON block DESIGN transfers program indices (table III) into DYNGEN if a change is required as a transient is run. An example of this will be shown later. COMMON blocks ALL1 to ALL5 transfer time-varying variables into DYNGEN as discussed earlier. COMMON blocks DYN and RPMS transfer data about the transient solution to be run (table V). All these COMMON blocks are shown here for illustration purposes although in this example only fuel flow is changed; thus, only COMMON block ALL2 is needed.

Since this example is an open-loop fuel flow step, the fuel control (FCNTRL) and main nozzle control (NOZTR) subroutines are not used. However, they must be written as shown here since they will be called by DYNGEN when it is running in the transient mode.

```
$IBFTC FCNTRL
      SUBROUTINE FCNTRL
      RETURN
      END
```

```
$IBFTC NOZCTR
      SUBROUTINE NOZCTR
      RETURN
      END
```

Next, the NAMELIST input is shown. The first case in DYNGEN, as in GENENG, must always be a design case (thus, IDES=1). All design inputs are shown; their explanation is found in tables II and III. The last four lines of the NAMELIST input contain the data that must be added to provide information to DYNGEN for transient capability.

(These variables are explained in table V.) Note also that SI=.TRUE.; thus, the output will be in SI units. The user must be careful here if he specifies SI units to be used. Since DYNGEN does most of its calculations in SI units if this system of units is specified, the NAMELIST data must also be in SI units. The BLOCK DATA for the components, however, can be in either set of units since the maps are scaled by DYNGEN; however, if the BLOCK DATA are in English units and the simulation is run in SI units (or conversely) the correction factors for the weight flows may be quite large.

```
$DATAIN AM=0.0,ALTP=0.0,IAFTBN=0,IDBURN=0,AM23=.18,AM55=.238,/
NOZFLT=0,IDUMP=1,IDCD=0,IMCD=0,IGASMX=0,MODE=0,TOLALL=.010,ITRYS=400,IDES=1,/
FXFN2M=.FALSE.,FXM2CP=.FALSE.,AFTFAN=.FALSE.,DUMSPL=.FALSE.,PRFDS=1.4,/
ETAFDS=.88,WAFCDS=280.1707,PCNFDS=100.0,PCBLF=0.0,PRIDS=1.571,WAICDS=140.8,/
ETAIDS=.87,PCNIDS=100.0,PCBLID=.5,ETABDS=.983,DPCODS=.05,DPWGDS=.10,/
PRCDS=7.273,PCNCDS=100.0,ETACDS=.86,PCBLC=0.0,DPDUDS=.05,ETHPDS=.9,ETIPDS=.9,/
ETLPDS=.9,DELSFC=1.0,DELFN=1.0,DELFG=1.0,PCBLOB=0.0,T4DS=1422.22,IAMTP=2,/
DELT1=17.2,TFHPDS=50.0,CNHPDS=2.0,TFIPDS=120.0,CNIPDS=2.2,TFLPDS=130.0,/
CNLPDS=2.3,ZFDS=.83333333,ZIDS=.83333333,ZCDS=.81433225,CVDNOZ=.985,/
CVMNOZ=.985,CVDWNG=.985,FAN=.TRUE.,ISPOOL=3,XNHPDS=10000.,XNLPDS=5000.,/
XNIPDS=7500.,PMIHP=35.25,PMILP=70.50,PMIIP=52.88,VFAN=.142,VINTC=.142,/
VCOMB=.142,VHPTRB=.057,VLPTRB=.057,VIPTRB=.057,VAFTBN=.283,VFDUCT=.283,/
VWDUCT=.283,VCOMP=.142,SI=.TRUE.,DPAFDS=0.0$/
```

The first output DYNGEN provides is shown next. This is the design case for the three-spool turbofan. The fuel flow (WFB) is 1.858 kg/sec. The means of specifying the output shown is discussed in the main-text section Output Specification. This is the same output given by GENENG. One difference is that DYNGEN tells the user that "THE OUTPUT IS IN SI UNITS." (If SI had been set .FALSE. in the NAMELIST input, DYNGEN would specify that "THE OUTPUT IS IN ENGLISH UNITS.")

```
FAN DESIGN             PRFCF= 0.10000000E+01 ETAFCF= 0.10000000E+01  WAFCF= 0.46695116E+00   T2DS= 0.30534883E+03
MIDDLE SPOOL DESIGN    PRICF= 0.95166666E+00 ETAICF= 0.98863635E+00  WAICF= 0.46933333E+00  T22DS= 0.34035630E+03
COMPRESSOR DESIGN      PRCCF= 0.89614286E+00 ETACCF= 0.10000000E+01  WACCF= 0.48218785E+00  T21DS= 0.35406999E+03
INTER DUCT DESIGN        A38= 0.22159284E+00   AM38= 0.10000000E+01    A39= 0.22159284E+00   AM39= 0.10000000E+01
COMBUSTOR DESIGN      WA3CDS= 0.15101303E-02 ETABCF= 0.98300000E+00
H.P. TURBINE DESIGN   CNHPCF= 0.75424662E+00 TFHPCF= 0.22059431E+05 ETHPCF= 0.10000000E+01 DHHPCF= 0.40061476E+04
I.P. TURBINE DESIGN   CNIPCF= 0.74420217E+00 TFIPCF= 0.20704784E+05 ETIPCF= 0.10000000E+01 DHIPCF= 0.42148784E+04
L.P. TURBINE DESIGN   CNLPCF= 0.74736389E+00 TFLPCF= 0.16049822E+05 ETLPCF= 0.10201339E+01 DHLPCF= 0.56982800E+04
DUCT NOZZLE DESIGN       A28= 0.34868393E+00   AM28= 0.65148608E+00    A29= 0.34868393E+00   AM29= 0.65148608E+00
TURBINE AREA DESIGN      A55= 0.73676639E+00   AM55= 0.23826636E+00
NOZZLE DESIGN             A8= 0.28800043E+00    AM8= 0.10000000E+01     A9= 0.28800043E+00    AM9= 0.10000000F+01
OUTPUT                AM=  0.          ALTP=     0.          T4= 1422.22                       ETAR= 1.0000
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
THE OUTPUT IS IN SI UNITS
 PCNF           CNF            ZF             PRF            WAFC           WAF
0.100000E+03   0.100000E+01   0.833333E+00   0.140000E+01   0.280171E+03   0.272166E+03
 PCNI           CNI            ZI             PRI            WACI           WAI
0.100000E+03   0.100000E+01   0.833333E+00   0.157100E+01   0.140800E+03   0.181373E+03
 PCNC           CNC            ZC             PRC            WACC           WAC
0.100000E+03   0.100000E+01   0.814332E+00   0.727300E+01   0.482188E+02   0.906864E+02
 T2             P2             T22            P22            T21            P21
0.305349E+03   0.101325E+06   0.340356E+03   0.141855E+06   0.394070E+03   0.222854E+06
 T3             P3             PCBLF          BLF            PCBLC          BLC
0.728472E+03   0.162082E+07   0.             0.             0.             0.
 PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
0.             0.             0.             0.             0.             0.
 WA3            WFB            WG4            FAR4           T4             P4
0.906864E+02   0.185800E+01   0.925444E+02   0.204882E-01   0.142222E+04   0.153978E+07
 TFFHP          CNHP           DHTCHP         DHTC           T50            P50
0.500000E+02   0.200000E+01   0.240369E+03   0.341857E+06   0.114429E+04   0.540142E+06
 TFFIP          CNIP           DHTCIP         DHTI           T5             P5
0.120000E+03   0.220000E+01   0.927273E+02   0.106107E+06   0.105587E+04   0.371263E+06
 TFFLP          CNLP           DHTCLP         DHTF           T55            P55
0.130000E+03   0.230000E+01   0.978677E+02   0.103335E+06   0.968474E+03   0.249603E+06
 ETAB           PCBLDU         ETAD           DPDUC          T24            P24
0.983000E+00   0.             0.             0.500000E-01   0.340355E+03   0.134762E+06
 WAD            WFD            WG24           FAR24          T25            P25
0.907927E+02   0.             0.907927E+02   0.             0.340355E+03   0.134762E+06
 ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
0.880000E+00   0.870000E+00   0.860000E+00   0.900000E+00   0.900000E+00   0.900000E+00
 T6             P6             PS6            AM6            V6             WG6
0.968474E+03   0.249603E+06   0.240433E+06   0.238266E+00   0.143982E+03   0.925444E+02
 T7             WFA            WG7            FAR7           ETAA           DPAFT
0.968474E+03   0.             0.925444E+02   0.204882E-01   0.             0.
 PS8            AM8            V8             PS9            AM9            V9
0.135759E+06   0.100000E+01   0.564732E+03   0.135759E+06   0.100000E+01   0.564732E+03
 PS28           AM28           V28            PS29           AM29           V29
0.101325E+06   0.651486E+00   0.231367E+03   0.101325E+06   0.651486E+00   0.231367E+03
 BPPINT         DPCOM          DPWING         PS38           AM38           V38
0.100000E+01   0.500000E-01   0.100000E+00   0.106207E+06   0.100000E+01   0.363392E+03
 BYPASS         HPEXT          WFT            WGT            VA             FRD
0.500586E+00   0.             0.185800E+01   0.274024E+03   0.             0.
 PCBLT          WG37           VJW            PS39           AM39           V39
0.500000E+00   0.906864E+02   0.357941E+03   0.106207E+06   0.100000E+01   0.363392E+03
 CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
0.985000E+00   0.324604E+05   0.108184E+04   0.335422E+05   0.820871E+05   0.134762E+06
 FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
0.178945E+00   0.290084E+00   0.530971E+00   0.709916E+00   0.100000E+01   0.200569E+06
 CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
0.985000E+00   0.556261E+03   0.985000E+00   0.227896E+03   0.104630E+06   0.109988E+05

MAIN SONIC CONVERGENT NOZZLE     FG=115629.31             FN=115629.31                SFC= 0.05785
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER    1 LOOPS
```

Following the design-case output, a list of COMMON blocks ALL1 to ALL5 is given. The numbers presented in this printout can be associated with their variable names by comparing the output locations with the list of COMMON blocks ALL1 to ALL5 in subroutine DISTRB. The COMMON block printout occurs only at the design point. Also, on the same line as the word COMMON, eight variables are printed; they are ZF, PCNF, ZI, PCNI, ZC, PCNC, T4, and MODE.

```
COMMON          0.833333E+00  0.100000E+03  0.833333E+00  0.100000E+03  0.814332E+00  0.100000E+03  0.142222E+04

 0.100000E+03   0.100000E+03  0.142222E+04  0.100000E+03  0.            0.100000E+01  0.100000E+01  0.100000E+01
 0.833333E+00   0.100000E+03  0.140000E+01  0.880000E+00  0.272166E+03  0.100000E+01  0.100000E+01  0.466951E+00
 0.814332E+00   0.100000E+03  0.727300E+01  0.860000E+00  0.906864E+02  0.896143E+00  0.100000E+01  0.482188E+00
 0.142222E+04   0.185800E+01  0.            0.983000E+00  0.151013E-02  0.500000E-01  0.            0.983000E+00
 0.500000E+02   0.200000E+01  0.900000E+00  0.220594E+05  0.754247E+00  0.100000E+01  0.400615E+04  0.305349E+03
 0.130000E+03   0.230000E+01  0.900000E+00  0.160498E+05  0.747364E+00  0.102013E+01  0.569828E+04  0.394070E+03
 0.             0.            0.            0.            0.118079E-01  0.500000E-01  0.            0.
 0.             0.            0.            0.            0.115384E-01  0.            0.            0.
 0.736766E+00   0.            0.736766E+00  0.736766E+00  0.288000E+00  0.288000E+00  0.348684E+00  0.348684E+00
 0.240433E+06   0.238266E+00  0.985000E+00  0.985000E+00  0.            0.            0.            0.

 0.305350E+03   0.101325E+06  0.305399E+06  0.671778E+04  0.305349E+03  0.101325E+06  0.305399E+06  0.671777E+04
 0.394070E+03   0.222854E+06  0.394677E+06  0.674817E+04  0.728472E+03  0.162082E+07  0.743538E+06  0.681738E+04
 0.142222E+04   0.153978E+07  0.158403E+07  0.764712E+04  0.105587E+04  0.371263E+06  0.113606E+07  0.769198E+04
 0.968474E+03   0.249603E+06  0.103273E+07  0.770389E+04  0.            0.            0.            0.
 0.100000E+01   0.140000E+01  0.880000E+00  0.280171E+03  0.272166E+03  0.906864E+02  0.925444E+02  0.204882E-01
 0.100000E+01   0.727300E+01  0.860000E+00  0.482188E+02  0.906864E+02  0.983000E+00  0.500000E-01  0.
```

```
0.200000E+01   0.900000E+00   0.240369E+03   0.341857E+06   0.             0.925444E+02   0.204882E-01   0.350415E+03
0.230000E+01   0.900000E+00   0.978677E+02   0.103335E+06   0.             0.925444E+02   0.204882E-01   0.
0.             0.             0.100000E+01   0.833333E+00   0.100000E+03   0.814332E+00   0.100000E+03   0.185800E+01
0.500000E+02   0.130000E+03   0.             0.             0.             0.             0.             0.

0.101325E+06   0.272166E+03   0.906864E+02   0.             0.             0.743538E+06   0.             0.
0.394070E+03   0.222854E+06   0.394677E+06   0.674817E+04   0.340355E+03   0.141855E+06   0.340537E+06   0.673013E+04
0.340355E+03   0.134762E+06   0.340535E+06   0.674485E+04   0.340355E+03   0.134762E+06   0.340535E+06   0.674485E+04
0.340355E+03   0.134762E+06   0.340535E+06   0.674485E+04   0.340355E+03   0.134762E+06   0.340535E+06   0.674485E+04
0.907927E+02   0.             0.907927E+02   0.             0.             0.500000E-01   0.500586E+00   0.
0.313697E+03   0.101325E+06   0.231367E+03   0.651486E+00   0.313697E+03   0.101325E+06   0.231367E+03   0.651486E+00
0.968474E+03   0.249603E+06   0.103273E+07   0.770389E+04   0.340355E+03   0.134762E+06   0.340535E+06   0.674485E+04
0.185800E+01   0.925444E+02   0.204882E-01   0.             0.907927E+02   0.             0.101325E+06   0.
0.968474E+03   0.249603E+06   0.103273E+07   0.770389E+04   0.968474E+03   0.249603E+06   0.103273E+07   0.770389E+04
0.968474E+03   0.249603E+06   0.103273E+07   0.770389E+04   0.968474E+03   0.249603E+06   0.103273E+07   0.770389E+04

0.925444E+02   0.             0.925444E+02   0.204882E-01   0.             0.             0.143982E+03   0.
0.240433E+06   0.143982E+03   0.238266E+00   0.968481E+03   0.249611E+06   0.138141E-02   0.227615E-05   0.189884E+00
0.830758E+03   0.135759E+06   0.564732E+03   0.100000E+01   0.830758E+03   0.135759E+06   0.564732E+03   0.100000E+01
0.             0.             0.227896E+03   0.206913E+05   0.556261E+03   0.514788E+05   0.             0.991697E+04
0.104630E+06   0.109989E+05   0.185800E+01   0.274024E+03   0.682674E-02   0.115629E+06   0.115629E+06   0.578470E-01
0.906864E+02   0.100000E+00   0.100000E+00   0.807808E-02   0.221593E+00   0.100000E+01   0.363392E+03   0.394070E+03
0.394677E+06   0.200569E+06   0.328590E+03   0.106207E+06   0.394070E+03   0.394677E+06   0.200569E+06   0.328590E+03
0.363392E+03   0.100000E+01   0.221593E+00   0.100000E+01   0.906864E+02   0.985000E+00   0.324604E+05   0.108184E+04
0.335422E+05   0.820871E+05   0.290084E+00   0.106207E+06   0.178945E+00   0.530971E+00   0.709916E+00   0.100000E+01
0.357941E+03   0.340356E+03   0.141855E+06   0.340537E+06   0.673014E+04   0.114429E+04   0.540142E+06   0.124217E+07

0.768077E+04   0.181373E+03   0.833333E+00   0.100000E+03   0.100000E+01   0.157100E+01   0.870000E+00   0.140800E+03
0.120000E+03   0.220000E+01   0.900000E+00   0.927273E+02   0.106107E+06   0.             0.             0.100000E+03
0.833333E+00   0.100000E+03   0.157100E+01   0.870000E+00   0.181373E+03   0.951667E+00   0.988636E+00   0.469333E+00
0.120000E+03   0.220000E+01   0.900000E+00   0.207048E+05   0.744202E+00   0.100000E+01   0.421488E+04   0.140800E+03
0.181373E+03   0.500000E+00   0.906864E+02   0.340356E+03   0.906864E+02   0.925444E+02   0.204882E-01   0.945181E-05
0.180000E+00   0.             0.             0.             0.             0.             0.500000E+00   0.100000E+01
0.100000E+01   0.100000E+01   0.100000E+01   0.             0.             0.000000E-38   0.000000E-38
```

Next, NAMELIST data are again supplied to DYNGEN so that an off-design case is run. Since ITRAN is set equal to 1, the off-design point is also the initial condition for the transient. In this case the WFB is set equal to 1.486 kg/sec and the off-design point is run by specifying MODE and WFB (table IV). Also specified are DT, DTPRINT, and TF (table V).

```
$DATAIN MODE=2,ITRAN=1,DT=.100,DTPRNT=.100,TF=3.0,DELT1=17.2,WFB=1.486$/
```

The DYNGEN transient output is now given. The first point is the initial condition and is indicated by TIME=0. at the top of the printout. The fuel flow is 1.486 kg/sec as specified. Also DYNGEN again specifies that the output is in SI units.

```
                        TIME= 0.

OUTPUT                  AM=  0.          ALTP=      0.          T4= 1336.92                         ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                          PCNF           CNF            ZF             PRF            WAFC           WAF
                        0.935724E+02   0.935724E+00   0.826087E+00   0.135404E+01   0.258993E+03   0.251593E+03
                          PCNI           CNI            ZI             PRI            WACI           WAI
                        0.945018E+02   0.950729E+00   0.829649E+00   0.152179E+01   0.132555E+03   0.166145E+03
                          PCNC           CNC            ZC             PRC            WACC           WAC
                        0.947421E+02   0.958534E+00   0.793836E+00   0.663671E+01   0.449892E+02   0.802017E+02
                          T2             P2             T22            P22            T21            P21
                        0.305349E+03   0.101325E+06   0.336279E+03   0.137198E+06   0.384985E+03   0.208788E+06
                          T3             P3             PCBLF          BLF            PCBLC          BLC
                        0.699518E+03   0.138566E+07   0.             0.             0.             0.
                          PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
                        0.             0.             0.             0.             0.             0.
                          WA3            WFB            WG4            FAR4           T4             P4
                        0.802017E+02   0.148600E+01   0.816877E+02   0.185283E-01   0.133692E+04   0.131543E+07
                          TFFHP          CNHP           DHTCHP         DHTC           T50            P50
                        0.500680E+02   0.195436E+01   0.239087E+03   0.320899E+06   0.107253E+04   0.459903E+06
                          TFFIP          CNIP           DHTCIP         DHTI           T5             P5
                        0.120510E+03   0.214746E+01   0.928167E+02   0.997759E+05   0.988154E+03   0.315046E+06
                          TFFLP          CNLP           DHTCLP         DHTF           T55            P55
                        0.130926E+03   0.222468E+01   0.967787E+02   0.956015E+05   0.906063E+03   0.212977E+06
```

ETAB	PCBLDU	ETAD	DPDUC	T24	P24
C.983000E+00	0.	0.	0.483611E-01	0.336278E+03	0.130563E+06
WAD	WFD	WG24	FAR24	T25	P25
0.854474E+02	0.	0.854474E+02	0.	0.336278E+03	0.130563E+06
ETAF	ETAI	ETAC	ETATHP	ETATIP	ETATLP
0.892888E+00	0.879752E+00	0.843767E+00	0.897626E+00	0.895935E+00	0.902426E+00
T6	P6	PS6	AM6	V6	WG6
0.906063E+03	0.212977E+06	0.205461E+06	0.237785E+00	0.139343E+03	0.816877E+02
T7	WFA	WG7	FAR7	ETAA	DPAFT
C.906063E+03	0.	0.816877E+02	0.185283E-01	0.	0.
PS8	AM8	V8	PS9	AM9	V9
0.115430E+06	0.100000E+01	0.546833E+03	0.115430E+06	0.100000E+01	0.546833E+03
PS28	AM28	V28	PS29	AM29	V29
0.101325E+06	0.612208E+00	0.217096E+03	0.101325E+06	0.612208E+00	0.217096E+03
BPRINT	DPCOM	DPWING	PS38	AM38	V38
0.107159E+01	0.506851E-01	0.999821E-01	0.101325E+06	0.984277E+00	0.35447CE+03
BYPASS	HPEXT	WFT	WGT	VA	FRD
0.514293E+00	0.	0.148600E+01	0.253079E+03	0.	0.
PCBLI	WG37	VJW	PS39	AM39	V39
0.517280E+00	0.859436E+02	0.349153E+03	0.101325E+06	0.984277E+00	0.354470E+03
CVDWNG	FGMWNG	FGPWNG	FNWING	FNMAIN	P28
C.985000E+00	0.300074E+05	0.	0.300074E+05	0.663338E+05	0.130563E+06
FFOVFN	FWOVFN	FCOVFN	FMNOFN	FNOVFD	P38
0.189659E+00	0.311470E+00	0.498870E+00	0.688530E+00	0.833190E+00	0.187913E+06
CVMNOZ	VJM	CVDNOZ	VJD	FGM	FGP
C.985000E+00	0.538631E+03	0.985000E+00	0.213839E+03	0.922790E+05	0.406223E+04

MAIN SONIC CONVERGENT NOZZLE   FG= 96341.23   FN= 96341.23   SFC= 0.05553
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 12 LOOPS

After the initial time point is calculated, DYNGEN calls DISTRB. From DISTRB the fuel flow is stepped to 1.858 kg/sec. Note that this value is the design-point fuel flow (although it did not have to be). Also, in DYNGEN, subsequent calls are made to NOZCTR and FCNTRL to determine what controls are used on the main nozzle area and the fuel flow. For the case being presented, there are no controls. The next printout from DYNGEN, at TIME=.1 second indicates that the fuel flow is now 1.858 kg/sec, as specified by DISTRB.

TIME= 0.1000

OUTPUT   AM= 0.   ALTP= 0.   T4= 1480.23   ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

PCNF	CNF	ZF	PRF	WAFC	WAF
0.939401E+02	0.939401E+00	0.826768E+00	0.135677E+01	0.260183E+03	0.252747E+03
PCNI	CNI	ZI	PRI	WACI	WAI
0.947623E+02	0.953013E+00	0.828907E+00	0.152349E+01	0.132976E+03	0.166943E+03
PCNC	CNC	ZC	PRC	WACC	WAC
0.952465E+02	0.963095E+00	0.831634E+00	0.696022E+01	0.451836E+02	0.803957E+02
T2	P2	T22	P22	T21	P21
0.305349E+03	0.101325E+06	0.336517E+03	0.137475E+06	0.385419E+03	0.209441E+06
T3	P3	PCBLF	BLF	PCBLC	BLC
0.709963E+03	0.145775E+07	0.	0.	0.	0.
PCBLHP	BLHP	PCBLIP	BLIP	PCBLLP	BLLP
0.	0.	0.	0.	0.	0.
WA3	WFB	WG4	FAR4	T4	P4
0.803957E+02	0.185800E+01	0.820832E+02	0.231107E-01	0.148023E+04	0.138683E+07
TFFHP	CNHP	DHTCHP	DHTC	T50	P50
0.502356E+02	0.186723E+01	0.241456E+03	0.354798E+06	0.119406E+04	0.483147E+06
TFFIP	CNIP	DHTCIP	DHTI	T5	P5
0.121398E+03	0.204086E+01	0.921327E+02	0.110029E+06	0.110284E+04	0.331369E+06
TFFLP	CNLP	DHTCLP	DHTF	T55	P55
0.131845E+03	0.211411E+01	0.947642E+02	0.104510E+06	0.101513E+04	0.226184E+06
ETAB	PCBLDU	ETAD	DPDUC	T24	P24
0.983000E+00	0.	0.	0.484824E-01	0.336516E+03	0.130809E+06
WAD	WFD	WG24	FAR24	T25	P25
0.858036E+02	0.	0.857984E+02	0.	0.336516E+03	0.130809E+06
ETAF	ETAI	ETAC	ETATHP	ETATIP	ETATLP
0.892210E+00	0.879302E+00	0.843843E+00	0.891106E+00	0.889029E+00	0.903776E+00
T6	P6	PS6	AM6	V6	WG6
0.101513E+04	0.226184E+06	0.218181E+06	0.239097E+00	0.147660E+03	0.820161E+02
T7	WFA	WG7	FAR7	ETAA	DPAFT
0.101315E+04	0.	0.819242E+02	0.231107E-01	0.	0.
PS8	AM8	V8	PS9	AM9	V9
0.123329E+06	0.100000E+01	0.577103E+03	0.123329E+06	0.100000E+01	0.577103E+03
PS28	AM28	V28	PS29	AM29	V29
0.101325E+06	0.614761E+00	0.218014E+03	0.101325E+06	0.614761E+00	0.218014E+03
BPRINT	DPCOM	DPWING	PS38	AM38	V38
0.106729E+01	0.486544E-01	0.100010E+00	0.101325E+06	0.987067E+00	0.355514E+03

ORIGINAL PAGE IS
OF POOR QUALITY

BYPASS	HPEXT	WFT	WGT	VA	FRD
0.513969E+00	0.	0.185800E+01	0.254605E+03	0.	0.
PCBLI	WG37	VJW	PS39	AM39	V39
0.516274E+00	0.861776E+02	0.350181E+03	0.101325E+06	0.987067E+00	0.355514E+03
CVDWNG	FGMWNG	FGPWNG	FNWING	FNMAIN	P28
0.985000E+00	0.301778E+05	0.	0.301778E+05	0.713314E+05	0.130809E+06
FFOVFN	FWOVFN	FCOVFN	FMNOFN	FNOVFD	P38
0.181507E+00	0.297291E+00	0.521202E+00	0.702709E+00	0.877885E+00	0.188495E+06
CVMNOZ	VJM	CVDNOZ	VJD	FGM	FGP
C.985000E+00	0.568446E+03	0.985000E+00	0.214744E+03	0.951720E+05	0.633722E+04

MAIN SONIC CONVERGENT NOZZLE FG=101509.19 FN=101509.19 SFC= 0.06589
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 15 LOOPS

Next, the DYNGEN output is given for a 3-second transient.

```
                      TIME= 0.2000
OUTPUT                 AM=  0.          ALTP=      0.          T4= 1480.45                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                        PCNF           CNF            ZF             PRF            WAFC           WAF
                      0.943149E+02   0.943149E+00   0.827059E+00   0.135937E+01   0.261425E+03   0.253953E+03
                        PCNI           CNI            ZI             PRI            WACI           WAI
                      0.950307E+02   0.955383E+00   0.826160E+00   0.152399E+01   0.133480E+03   0.167841E+03
                        PCNC           CNC            ZC             PRC            WACC           WAC
                      0.957213E+02   0.967455E+00   0.835857E+00   0.704346E+01   0.455164E+02   0.813925E+02
                        T2             P2             T22            P22            T21            P21
                      0.305349E+03   0.101325E+06   0.336749E+03   0.137738E+06   0.385770E+03   0.209912E+06
                        T3             P3             PCBLF          BLF            PCBLC          BLC
                      0.713110E+03   0.147851E+07   0.             0.             0.             0.
                        PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
                      0.             0.             0.             0.             0.             0.
                        WA3            WFB            WG4            FAR4           T4             P4
                      0.813925E+02   0.185800E+01   0.832034E+02   0.228270E-01   0.148045E+04   0.140654E+07
                        TFFHP          CNHP           DHTCHP         DHTC           T50            P50
                      0.502072E+02   0.187640E+01   0.239770E+03   0.354794E+06   0.119499E+04   0.490942E+06
                        TFFIP          CNIP           DHTCIP         DHTI           T5             P5
                      0.121311E+03   0.204585E+01   0.919082E+02   0.109620E+06   0.110467E+04   0.337415E+06
                        TFFLP          CNLP           DHTCLP         DHTF           T55            P55
                      0.131585E+03   0.212078E+01   0.946886E+02   0.104413E+06   0.101745E+04   0.230517E+06
                        ETAB           PCBLDU         ETAD           DPDUC          T24            P24
                      0.983000E+00   0.             0.             0.485800E-01   0.336748E+03   0.131047E+06
                        WAD            WFD            WG24           FAR24          T25            P25
                      0.861119E+02   0.             0.861069E+02   0.             0.336748E+03   0.131047E+06
                        ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
                      0.891441E+00   0.878487E+00   0.844006E+00   0.892432E+00   0.889735E+00   0.903491E+00
                        T6             P6             PS6            AM6            V6             WG6
                      0.101745E+04   0.230517E+06   0.222426E+06   0.238139E+00   0.147241E+03   0.831803E+02
                        T7             WFA            WG7            FAR7           ETAA           DPAFT
                      0.101745E+04   0.             0.831503E+02   0.228270E-01   0.             0.
                        PS8            AM8            V8             PS9            AM9            V9
                      0.125452E+06   0.100000E+01   0.578307E+03   0.125452E+06   0.100000E+01   0.578307E+03
                        PS28           AM28           V28            PS29           AM29           V29
                      0.101325E+06   0.617023E+00   0.218834E+03   0.101325E+06   0.617023E+00   0.218834E+03
                        BPRINT         DPCOM          DPWING         PS38           AM38           V38
                      0.105952E+01   0.486737E-01   0.100014E+00   0.101325E+06   0.989038E+00   0.356271E+03
                        BYPASS         HPEXT          WFT            WGT            VA             FRD
                      0.513056E+00   0.             0.185800E+01   0.255811E+03   0.             0.
                        PCBLI          WG37           VJW            PS39           AM39           V39
                      0.514449E+00   0.863379E+02   0.350927E+03   0.101325E+06   0.989038E+00   0.356271E+03
                        CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
                      0.985000E+00   0.302983E+05   0.             0.302983E+05   0.728741E+05   0.131047E+06
                        FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
                      0.179898E+00   0.293667E+00   0.526435E+00   0.706333E+00   0.892269E+00   0.188918E+06
                        CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
                      0.985000E+00   0.569632E+03   0.985000E+00   0.215552E+03   0.962239E+05   0.694858E+04
MAIN SONIC CONVERGENT NOZZLE         FG=103172.46                 FN=103172.46                    SFC= 0.06483
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  12 LOOPS
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
                    TIME= 0.3000
OUTPUT              AM=  0.          ALTP=      0.          T4= 1475.36                         ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                 PCNF            CNF             ZF              PRF             WAFC            WAF
               C.946757E+02    0.946757E+00    0.827339E+00    0.136188E+01    0.262621E+03    0.255114E+03
                 PCNI            CNI             ZI              PRI             WACI            WAI
               C.952952E+02    0.957725E+00    0.823439E+00    0.152447E+01    0.133967E+03    0.168709E+03
                 PCNC            CNC             ZC              PRC             WACC            WAC
               0.961557E+02    0.971404E+00    0.835074E+00    0.708573E+01    0.458381E+02    0.821515E+02
                 T2              P2              T22             P22             T21             P21
               0.305349E+03    0.101325E+06    0.336972E+03    0.137993E+06    0.386121E+03    0.210365E+06
                 T3              P3              PCBLF           BLF             PCBLC           BLC
               0.714466E+03    0.149059E+07    0.              0.              0.              0.
                 PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
               0.              0.              0.              0.              0.              0.
                 WA3             WFB             WG4             FAR4            T4              P4
               0.821515E+02    0.185800E+01    0.839823E+02    0.226155E-01    0.147536E+04    0.141789E+07
                 TFFHP           CNHP            DHTCHP          DHTC            T50             P50
               0.501880E+02    0.188816E+01    0.239891E+03    0.353795E+06    0.119044E+04    0.494918E+06
                 TFFIP           CNIP            DHTCIP          DHTI            T5              P5
               0.121224E+03    0.205546E+01    0.919313E+02    0.109252E+06    0.110034E+04    0.340181E+06
                 TFFLP           CNLP            DHTCLP          DHTF            T55             P55
               0.131461E+03    0.213308E+01    0.948932E+02    0.104278E+06    0.101313E+04    0.232142E+06
                 ETAB            PCBLDU          ETAD            DPDUC           T24             P24
               C.983000E+00    0.              0.              0.486717E-01    0.336971E+03    0.131276E+06
                 WAD             WFD             WG24            FAR24           T25             P25
               0.864049E+02    0.              0.864001E+02    0.              0.336971E+03    0.131276E+06
                 ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
               0.890700E+00    0.877486E+00    0.845339E+00    0.893114E+00    C.890408E+00    0.903347E+00
                 T6              P6              PS6             AM6             V6              WG6
               0.101313E+04    0.232142E+06    0.223989E+06    0.238176E+00    0.146975E+03    0.839717E+02
                 T7              WFA             WG7             FAR7            ETAA            DPAFT
               0.101325E+04    0.              0.839604E+02    0.226155E-01    0.              0.
                 PS8             AM8             V8              PS9             AM9             V9
               0.126376E+06    0.100000E+01    0.577159E+03    0.126376E+06    0.100000E+01    0.577159E+03
                 PS28            AM28            V28             PS29            AM29            V29
               0.101325E+06    0.619176E+00    0.219616E+03    0.101325E+06    0.619176E+00    0.219616E+03
                 BPRINT          DPCOM           DPWING          PS38            AM38            V38
               0.105215E+01    0.487757E-01    0.100020E+00    0.101325E+06    0.990935E+00    0.357006E+03
                 BYPASS          HPEXT           WFT             WGT             VA              FRD
               0.512152E+00    0.              0.185800E+01    0.256972E+03    0.              0.
                 PCBLI           WG37            VJW             PS39            AM39            V39
               0.512705E+00    0.864908E+02    0.351651E+03    0.101325E+06    0.990935E+00    0.357006E+03
                 CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
               0.985000E+00    0.304145E+05    0.              0.304145E+05    0.736366E+05    0.131276E+06
                 FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
               0.179625E+00    0.292304E+00    0.528071E+00    0.707696E+00    0.899868E+00    0.189325E+06
                 CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
               C.985000E+00    0.568502E+03    0.985000E+00    0.216322E+03    0.968364E+05    0.721474E+04

MAIN SONIC CONVERGENT NOZZLE       FG=104051.11                    FN=104051.11                    SFC= 0.06428
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  12 LOOPS
```

```
                         TIME= 0.4000
OUTPUT                    AM=  0.          ALTP=      0.          T4= 1470.58                              ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                          PCNF            CNF             ZF              PRF             WAFC            WAF
                         0.950161E+02    0.950161E+00    0.827591E+00    0.136425E+01    0.263750E+03    0.256211E+03
                          PCNI            CNI             ZI              PRI             WACI            WAI
                         0.955516E+02    0.960002E+00    0.821173E+00    0.152516E+01    0.134428E+03    0.169531E+03
                          PCNC            CNC             ZC              PRC             WACC            WAC
                         0.965489E+02    0.974938E+00    0.833512E+00    0.711715E+01    0.461295E+02    0.828288E+02
                          T2              P2              T22             P22             T21             P21
                         0.305349E+03    0.101325E+06    0.337183E+03    0.138232E+06    0.386469E+03    0.210826E+06
                          T3              P3              PCBLF           BLF             PCBLC           BLC
                         0.715453E+03    0.150048E+07    0.              0.              0.              0.
                          PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
                         0.              0.              0.              0.              0.              0.
                          WA3             WFB             WG4             FAR4            T4              P4
                         0.828288E+02    0.185800E+01    0.846646E+02    0.224308E-01    0.147058E+04    0.142713E+07
                          TFFHP           CNHP            DHTCHP          DHTC            T50             P50
                         0.501693E+02    0.189896E+01    0.239869E+03    0.352596E+06    0.118639E+04    0.498628E+06
                          TFFIP           CNIP            DHTCIP          DHTI            T5              P5
                         0.121139E+03    0.206450E+01    0.919387E+02    0.108862E+06    0.109653E+04    0.342848E+06
                          TFFLP           CNLP            DHTCLP          DHTF            T55             P55
                         0.131360E+03    0.214446E+01    0.950931E+02    0.104075E+06    0.100941E+04    0.233803E+06
                          ETAB            PCBLDU          ETAD            DPDUC           T24             P24
                         0.983000E+00    0.              0.              0.487576E-01    0.337182E+03    0.131492E+06
                          WAD             WFD             WG24            FAR24           T25             P25
                         0.866806E+02    0.              0.866761E+02    0.              0.337182E+03    0.131492E+06
                          ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
                         0.889998E+00    0.876584E+00    0.846777E+00    0.893800E+00    0.891064E+00    0.903226E+00
                          T6              P6              PS6             AM6             V6              WG6
                         0.100941E+04    0.233803E+06    0.225607E+06    0.237917E+00    0.146568E+03    0.846544E+02
                          T7              WFA             WG7             FAR7            ETAA            DPAFT
                         0.100953E+04    0.              0.846428E+02    0.224308E-01    0.              0.
                          PS8             AM8             V8              PS9             AM9             V9
                         0.127136E+06    0.100000E+01    0.576136E+03    0.127136E+06    0.100000E+01    0.576136E+03
                          PS28            AM28            V28             PS29            AM29            V29
                         0.101325E+06    0.621202E+00    0.220351E+03    0.101325E+06    0.621202E+00    0.220351E+03
                          BPRINT          DPCOM           DPWING          PS38            AM38            V38
                         0.104555E+01    0.488875E-01    0.100025E+00    0.101325E+06    0.992847E+00    0.357744E+03
                          BYPASS          HPEXT           WFT             WGT             VA              FRD
                         0.511297E+00    0.              0.185800E+01    0.258069E+03    0.              0.
                          PCBLI           WG37            VJW             PS39            AM39            V39
                         0.511135E+00    0.866455E+02    0.352378E+03    0.101325E+06    0.992847E+00    0.357744E+03
                          CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
                         0.985000E+00    0.305320E+05    0.              0.305320E+05    0.742805E+05    0.131492E+06
                          FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
                         0.179489E+00    0.291301E+00    0.529210E+00    0.708699E+00    0.906453E+00    0.189738E+06
                          CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
                         0.985000E+00    0.567494E+03    0.985000E+00    0.217046E+03    0.973790E+05    0.743353E+04
MAIN SONIC CONVERGENT NOZZLE             FG=104812.52                     FN=104812.52                    SFC= 0.06382
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  12 LOOPS
```

```
                         TIME= 0.5000
OUTPUT                   AM=  0.        ALTP=      0.        T4= 1466.43                       ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
      PCNF          CNF           ZF            PRF           WAFC          WAF
  0.953155E+02  0.953155E+00  0.827730E+00  0.136629E+01  0.264749E+03  0.257182E+03
      PCNI          CNI           ZI            PRI           WACI          WAI
  0.957839E+02  0.962074E+00  0.819222E+00  0.152585E+01  0.134843E+03  0.170263E+03
      PCNC          CNC           ZC            PRC           WACC          WAC
  C.968994E+02  0.978084E+00  0.832122E+00  0.714499E+01  0.463886E+02  0.834290E+02
      T2            P2            T22           P22           T21           P21
  0.305349E+03  0.101325E+06  0.337366E+03  0.138439E+06  0.386779E+03  0.211238E+06
      T3            P3            PCBLF         BLF           PCBLC         BLC
  0.716322E+03  0.150929E+07  0.            0.            0.            0.
      PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
  0.            0.            0.            0.            0.            0.
      WA3           WFB           WG4           FAR4          T4            P4
  0.834290E+02  0.185800E+01  0.852671E+02  0.222704E-01  0.146643E+04  0.143536E+07
      TFFHP         CNHP          DHTCHP        DHTC          T50           P50
  0.501558E+02  0.190855E+01  0.240239E+03  0.351288E+06  0.118310E+04  0.502279E+06
      TFFIP         CNIP          DHTCIP        DHTI          T5            P5
  0.121086E+03  0.207240E+01  0.920615E+02  0.107913E+06  0.109395E+04  0.346220E+06
      TFFLP         CNLP          DHTCLP        DHTF          T55           P55
  0.131248E+03  0.215375E+01  0.952236E+02  0.103396E+06  0.100735E+04  0.236481E+06
      ETAB          PCBLDU        ETAD          DPDUC         T24           P24
  0.983000E+00  0.            0.            0.488316E-01  0.337365E+03  0.131679E+06
      WAD           WFD           WG24          FAR24         T25           P25
  0.869186E+02  0.            0.869147E+02  0.            0.337365E+03  0.131679E+06
      ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
  0.889365E+00  0.875787E+00  0.848071E+00  0.894240E+00  0.891465E+00  0.903092E+00
      T6            P6            PS6           AM6           V6            WG6
  0.100735E+04  0.236481E+06  0.228285E+06  0.236536E+00  0.145589E+03  0.852546E+02
      T7            WFA           WG7           FAR7          ETAA          DPAFT
  0.100745E+04  0.            0.852359E+02  0.222704E-01  0.            0.
      PS8           AM8           V8            PS9           AM9           V9
  0.127873E+06  0.100000E+01  0.575568E+03  0.127873E+06  0.100000E+01  0.575568E+03
      PS28          AM28          V28           PS29          AM29          V29
  0.101325E+06  0.622954E+00  0.220988E+03  0.101325E+06  0.622954E+00  0.220988E+03
      BPRINT        DPCOM         DPWING        PS38          AM38          V38
  0.103975E+01  0.489839E-01  0.100029E+00  0.101325E+06  0.994559E+00  0.358405E+03
      BYPASS        HPEXT         WFT           WGT           VA            FRD
  0.510495E+00  0.            0.185800E+01  0.259040E+03  0.            0.
      PCBLI         WG37          VJW           PS39          AM39          V39
  0.509745E+00  0.867841E+02  0.353029E+03  0.101325E+06  0.994559E+00  0.358405E+03
      CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
  0.985000E+00  0.306373E+05  0.            0.306373E+05  0.748881E+05  0.131679E+06
      FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
  0.179284E+00  0.290331E+00  0.530385E+00  0.709669E+00  0.912618E+00  0.190108E+06
      CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
  C.985000E+00  0.566935E+03  0.985000E+00  0.217673E+03  0.978795E+05  0.764592E+04

MAIN SONIC CONVERGENT NOZZLE      FG=105525.37              FN=105525.37                SFC= 0.06339
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                          TIME= 0.6000
OUTPUT                    AM=  0.            ALTP=      0.          T4= 1462.67                        ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                  PCNF          CNF           ZF            PRF           WAFC          WAF
                0.956018E+02  0.956018E+00  0.827894E+00  0.136826E+01  0.265701E+03  0.258108E+03
                  PCNI          CNI           ZI            PRI           WACI          WAI
                C.960105E+02  0.964099E+00  0.817668E+00  0.152674E+01  0.135237E+03  0.170962E+03
                  PCNC          CNC           ZC            PRC           WACC          WAC
                0.972195E+02  0.980915E+00  0.830965E+00  0.717065E+01  0.466214E+02  0.839854E+02
                  T2            P2            T22           P22           T21           P21
                0.305349E+03  0.101325E+06  0.337542E+03  0.138639E+06  0.387094E+03  0.211666E+06
                  T3            P3            PCBLF         BLF           PCBLC         BLC
                0.717185E+03  0.151778E+07  0.            0.            0.            0.
                  PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                0.            0.            0.            0.            0.            0.
                  WA3           WFB           WG4           FAR4          T4            P4
                0.839854E+02  0.185800E+01  0.858241E+02  0.221229E-01  0.146267E+04  0.144331E+07
                  TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                0.501410E+02  0.191732E+01  0.240261E+03  0.350546E+06  0.117975E+04  0.505107E+06
                  TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                0.121022E+03  0.208025E+01  0.921198E+02  0.107713E+06  0.109071E+04  0.348107E+06
                  TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                0.131162E+03  0.216343E+01  0.953898E+02  0.103337E+06  0.100408E+04  0.237526E+06
                  ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                0.983000E+00  0.            0.            0.489017E-01  0.337541E+03  0.131859E+06
                  WAD           WFD           WG24          FAR24         T25           P25
                0.871461E+02  0.            0.871423E+02  0.            0.337541E+03  0.131859E+06
                  ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                0.888765E+00  0.875074E+00  0.849220E+00  0.894780E+00  0.891959E+00  0.902985E+00
                  T6            P6            PS6           AM6           V6            WG6
                0.100408E+04  0.237526E+06  0.229285E+06  0.236639E+00  0.145434E+03  0.858168E+02
                  T7            WFA           WG7           FAR7          ETAA          DPAFT
                0.100417E+04  0.            0.858095E+02  0.221229E-01  0.            0.
                  PS8           AM8           V8            PS9           AM9           V9
                0.128496E+06  0.100000E+01  0.574667E+03  0.128496E+06  0.100000E+01  0.574667E+03
                  PS28          AM28          V28           PS29          AM29          V29
                0.101325E+06  0.624627E+00  0.221596E+03  0.101325E+06  0.624627E+00  0.221596E+03
                  BPRINT        DPCOM         DPWING        PS38          AM38          V38
                0.103460E+01  0.490643E-01  0.100032E+00  0.101325E+06  0.996321E+00  0.359082E+03
                  BYPASS        HPEXT         WFT           WGT           VA            FRD
                0.509741E+00  0.            0.185800E+01  0.259966E+03  0.            0.
                  PCBLI         WG37          VJW           PS39          AM39          V39
                0.508502E+00  0.869274E+02  0.353696E+03  0.101325E+06  0.996321E+00  0.359082E+03
                  CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                0.985000E+00  0.307459E+05  0.            0.307459E+05  0.754181E+05  0.131859E+06
                  FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                0.179164E+00  0.289607E+00  0.531229E+00  0.710393E+00  0.918141E+00  0.190492E+06
                  CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                0.985000E+00  0.566047E+03  0.985000E+00  0.218272E+03  0.983387E+05  0.782522E+04
MAIN SONIC CONVERGENT NOZZLE    FG=106163.96                FN=106163.96                SFC= 0.06300
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                    TIME= 3.0000
OUTPUT               AM=  0.          ALTP=     0.          T4= 1425.46                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                    PCNF          CNF           ZF            PRF           WAFC          WAF
                 0.993348E+02  0.993348E+00  0.831783E+00  0.139483E+01  0.278014E+03  0.270070E+03
                    PCNI          CNI           ZI            PRI           WACI          WAI
                 0.993467E+02  0.994119E+00  0.823817E+00  0.155895E+01  0.140106E+03  0.179928E+03
                    PCNC          CNC           ZC            PRC           WACC          WAC
                 0.999798E+02  0.100166E+01  0.817143E+00  0.731696E+01  0.483671E+02  0.900970E+02
                    T2            P2            T22           P22           T21           P21
                 0.305349E+03  0.101325E+06  0.339910E+03  0.141331E+06  0.392605E+03  0.220328E+06
                    T3            P3            PCBLF         BLF           PCBLC         BLC
                 0.727519E+03  0.161213E+07  0.            0.            0.            0.
                    PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                 0.            0.            0.            0.            0.            0.
                    WA3           WFB           WG4           FAR4          T4            P4
                 0.900970E+02  0.185800E+01  0.919527E+02  0.206205E-01  0.142546E+04  0.153167E+07
                    TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                 0.500064E+02  0.199732E+01  0.240593E+03  0.342951E+06  0.114680E+04  0.536552E+06
                    TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                 0.120149E+03  0.218324E+01  0.926810E+02  0.106226E+06  0.105833E+04  0.368763E+06
                    TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                 0.130179E+03  0.228204E+01  0.975721E+02  0.103256E+06  0.971061E+03  0.248309E+06
                    ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                 0.983000E+00  0.            0.            0.497929E-01  0.339909E+03  0.134294E+06
                    WAD           WFD           WG24          FAR24         T25           P25
                 0.901418E+02  0.            0.901408E+02  0.            0.339909E+03  0.134294E+06
                    ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                 0.881090E+00  0.869682E+00  0.859149E+00  0.899713E+00  0.898809E+00  0.900556E+00
                    T6            P6            PS6           AM6           V6            WG6
                 0.971061E+03  0.248309E+06  0.239550E+06  0.238310E+00  0.144211E+03  0.919510E+02
                    T7            WFA           WG7           FAR7          ETAA          DPAFT
                 0.971061E+03  0.            0.919489E+02  0.206205E-01  0.            0.
                    PS8           AM8           V8            PS9           AM9           V9
                 0.135091E+06  0.100000E+01  0.565458E+03  0.135091E+06  0.100000E+01  0.565458E+03
                    PS28          AM28          V28           PS29          AM29          V29
                 0.101325E+06  0.646694E+00  0.229624E+03  0.101325E+06  0.646694E+00  0.229624E+03
                    BPRINT        DPCOM         DPWING        PS38          AM38          V38
                 0.996946E+00  0.499101E-01  0.100001E+00  0.104996E+06  0.100000E+01  0.362716E+03
                    BYPASS        HPEXT         WFT           WGT           VA            FRD
                 0.500987E+00  0.            0.185800E+01  0.271928E+03  0.            0.
                    PCBLI         WG37          VJW           PS39          AM39          V39
                 0.499235E+00  0.898230E+02  0.357275E+03  0.104996E+06  0.100000E+01  0.362716E+03
                    CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                 0.985000E+00  0.320915E+05  0.813497E+03  0.329050E+05  0.813259E+05  0.134294E+06
                    FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                 0.178481E+00  0.288057E+00  0.533462E+00  0.711943E+00  0.987906E+00  0.198295E+06
                    CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                 0.985000E+00  0.556976E+03  0.985000E+00  0.226180E+03  0.103693E+06  0.105380E+05

MAIN SONIC CONVERGENT NOZZLE      FG=114230.88                  FN=114230.88                  SFC= 0.05856
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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ORIGINAL PAGE IS
OF POOR QUALITY

```
                          TIME= 0.8000
OUTPUT                     AM=  0.          ALTP=       0.          T4= 1456.01                      ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                            PCNF            CNF             ZF              PRF             WAFC            WAF
                          0.961356E+02    0.961356E+00    0.828203E+00    0.137193E+01    0.267475E+03    0.259831E+03
                            PCNI            CNI             ZI              PRI             WACI            WAI
                          0.964459E+02    0.967997E+00    0.815482E+00    0.152896E+01    0.135967E+03    0.172262E+03
                            PCNC            CNC             ZC              PRC             WACC            WAC
                          0.977814E+02    0.985785E+00    0.828857E+00    0.721365E+01    0.470218E+02    0.849944E+02
                            T2              P2              T22             P22             T21             P21
                          0.305349E+03    0.101325E+06    0.337872E+03    0.139011E+06    0.387723E+03    0.212543E+06
                            T3              P3              PCBLF           BLF             PCBLC           BLC
                          0.718761E+03    0.153321E+07    0.              0.              0.              0.
                            PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
                          0.              0.              0.              0.              0.              0.
                            WA3             WFB             WG4             FAR4            T4              P4
                          0.849944E+02    0.185800E+01    0.868354E+02    0.218603E-01    0.145601E+04    0.145777E+07
                            TFFHP           CNHP            DHTCHP          DHTC            T50             P50
                          0.501150E+02    0.193281E+01    0.240341E+03    0.349312E+06    0.117375E+04    0.510085E+06
                            TFFIP           CNIP            DHTCIP          DHTI            T5              P5
                          0.120903E+03    0.209501E+01    0.922404E+02    0.107411E+06    0.108484E+04    0.351355E+06
                            TFFLP           CNLP            DHTCLP          DHTF            T55             P55
                          0.131033E+03    0.218139E+01    0.957237E+02    0.103252E+06    0.998159E+03    0.239277E+06
                            ETAB            PCBLDU          ETAD            DPDUC           T24             P24
                          0.983000E+00    0.              0.              0.490312E-01    0.337871E+03    0.132195E+06
                            WAD             WFD             WG24            FAR24           T25             P25
                          0.875686E+02    0.              0.875652E+02    0.              0.337871E+03    0.132195E+06
                            ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
                          0.887608E+00    0.873850E+00    0.851256E+00    0.895719E+00    0.892874E+00    0.902817E+00
                            T6              P6              PS6             AM6             V6              WG6
                          0.998159E+03    0.239277E+06    0.230950E+06    0.236940E+00    0.145220E+03    0.868292E+02
                            T7              WFA             WG7             FAR7            ETAA            DPAFT
                          0.998159E+03    0.              0.868233E+02    0.218603E-01    0.              0.
                            PS8             AM8             V8              PS9             AM9             V9
                          0.129571E+06    0.100000E+01    0.573005E+03    0.129571E+06    0.100000E+01    0.573005E+03
                            PS28            AM28            V28             PS29            AM29            V29
                          0.101325E+06    0.627738E+00    0.222727E+03    0.101325E+06    0.627738E+00    0.222727E+03
                            BPRINT          DPCOM           DPWING          PS38            AM38            V38
                          0.102587E+01    0.492080E-01    0.100040E+00    0.101325E+06    0.999940E+00    0.360465E+03
                            BYPASS          HPEXT           WFT             WGT             VA              FRD
                          0.508346E+00    0.              0.185800E+01    0.261689E+03    0.              0.
                            PCBLI           WG37            VJW             PS39            AM39            V39
                          0.506385E+00    0.872236E+02    0.355058E+03    0.101325E+06    0.999940E+00    0.360465E+03
                            CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
                          0.985000E+00    0.309695E+05    0.              0.309695E+05    0.763495E+05    0.132195E+06
                            FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
                          0.179005E+00    0.288574E+00    0.532421E+00    0.711426E+00    0.928129E+00    0.191280E+06
                            CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
                          0.985000E+00    0.564410E+03    0.985000E+00    0.219386E+03    0.991840E+05    0.813493E+04
MAIN SONIC CONVERGENT NOZZLE              FG=107318.94                    FN=107318.94                    SFC= 0.06233
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                 TIME= 0.9000
OUTPUT            AM=  0.          ALTP=      0.          T4= 1453.27                           ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                    PCNF          CNF           ZF            PRF           WAFC          WAF
                 0.963847E+02  0.963848E+00  0.828064E+00  0.137352E+01  0.268326E+03  0.260657E+03
                    PCNI          CNI           ZI            PRI           WACI          WAI
                 0.966556E+02  0.969895E+00  0.813661E+00  0.152955E+01  0.136347E+03  0.172908E+03
                    PCNC          CNC           ZC            PRC           WACC          WAC
                 C.980289E+02  0.987955E+00  0.828139E+00  0.723438E+01  0.471992E+02  0.854219E+02
                    T2            P2            T22           P22           T21           P21
                 0.305349E+03  0.101325E+06  0.338017E+03  0.139172E+06  0.387978E+03  0.212870E+06
                    T3            P3            PCBLF         BLF           PCBLC         BLC
                 0.719482E+03  0.153998E+07  0.            0.            0.            0.
                    PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                 0.            0.            0.            0.            0.            0.
                    WA3           WFB           WG4           FAR4          T4            P4
                 0.854219E+02  0.185800E+01  0.872644E+02  0.217509E-01  0.145327E+04  0.146412E+07
                    TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                 0.501042E+02  0.193952E+01  0.240424E+03  0.348895E+06  0.117121E+04  0.512116E+06
                    TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                 0.120849E+03  0.210185E+01  0.923002E+02  0.107315E+06  0.108233E+04  0.352640E+06
                    TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                 C.130975E+03  0.218958E+01  0.958748E+02  0.103256E+06  0.995592E+03  0.239913E+06
                    ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                 0.983000E+00  0.            0.            0.490863E-01  0.338016E+03  0.132341E+06
                    WAD           WFD           WG24          FAR24         T25           P25
                 0.877498E+02  0.            0.877468E+02  0.            0.338016E+03  0.132341E+06
                    ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                 0.887061E+00  0.873122E+00  0.852108E+00  0.896105E+00  0.893292E+00  0.902739E+00
                    T6            P6            PS6           AM6           V6            WG6
                 C.995592E+03  0.239913E+06  0.231547E+06  0.237168E+00  0.145186E+03  0.872594E+02
                    T7            WFA           WG7           FAR7          ETAA          DPAFT
                 C.995592E+03  C.            0.872548E+02  0.217509E-01  0.            0.
                    PS8           AM8           V8            PS9           AM9           V9
                 0.130025E+06  0.100000E+01  0.572295E+03  0.130025E+06  0.100000E+01  0.572295E+03
                    PS28          AM28          V28           PS29          AM29          V29
                 0.101325E+06  0.629076E+00  0.223214E+03  0.101325E+06  0.629076E+00  0.223214E+03
                    BPRINT        DPCOM         DPWING        PS38          AM38          V38
                 0.102337E+01  0.492627E-01  0.100173E+00  0.101604E+06  0.100000E+01  0.360573E+03
                    BYPASS        HPEXT         WFT           WGT           VA            FRD
                 0.507496E+00  0.            0.185800E+01  0.262515E+03  0.            0.
                    PCBLI         WG37          VJW           PS39          AM39          V39
                 0.505775E+00  0.874475E+02  0.355165E+03  0.101604E+06  0.100000E+01  0.360573E+03
                    CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                 C.985000E+00  0.310583E+05  0.617632E+02  0.311200E+05  0.767447E+05  0.132341E+06
                    FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                 0.178859E+00  0.288510E+00  0.532632E+00  0.711490E+00  0.932849E+00  0.191546E+06
                    CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                 0.985000E+00  0.563710E+03  0.985000E+00  0.219866E+03  0.995373E+05  0.832746E+04

MAIN SONIC CONVERGENT NOZZLE    FG=107864.72                FN=107864.72                 SFC= 0.06201
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                              TIME= 1.0000
OUTPUT                        AM=  0.          ALTP=      0.            T4= 1450.47                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                                PCNF          CNF          ZF           PRF          WAFC         WAF
                              0.966201E+02  0.966201E+00  0.828621E+00  0.137533E+01  0.269073E+03  0.261383E+03
                                PCNI          CNI          ZI           PRI          WACI         WAI
                              0.968554E+02  0.971669E+00  0.814706E+00  0.153188E+01  0.136612E+03  0.173428E+03
                                PCNC          CNC          ZC           PRC          WACC         WAC
                              0.982515E+02  0.989707E+00  0.826868E+00  0.724588E+01  0.473452E+02  0.858869E+02
                                T2            P2           T22          P22          T21          P21
                              0.305349E+03  0.101325E+06  0.338177E+03  0.139356E+06  0.388364E+03  0.213476E+06
                                T3            P3           PCBLF        BLF          PCBLC        BLC
                              0.720398E+03  0.154682E+07  0.            0.            0.            0.
                                PCBLHP        BLHP         PCBLIP       BLIP         PCBLLP       BLLP
                              0.            0.            0.            0.            0.            0.
                                WA3           WFB          WG4          FAR4         T4           P4
                              0.858869E+02  0.185800E+01  0.877294E+02  0.216331E-01  0.145047E+C4  0.147049E+07
                                TFFHP         CNHP         DHTCHP       DHTC         T50          P50
                              0.500928E+02  0.194580E+01  0.240356E+03  0.348417E+06  0.116865E+04  0.514260E+06
                                TFFIP         CNIP         DHTCIP       DHTI         T5           P5
                              0.120793E+03  0.210849E+01  0.923392E+02  0.107155E+06  0.107985E+04  0.354084E+06
                                TFFLP         CNLP         DHTCLP       DHTF         T55          P55
                              0.130917E+03  0.219744E+01  0.960165E+02  0.103179E+06  0.993128E+03  0.240734E+06
                                ETAB          PCBLDU       ETAD         DPDUC        T24          P24
                              0.983000E+00  0.            0.            0.491481E-01  0.338176E+03  0.132507E+06
                                WAD           WFD          WG24         FAR24        T25          P25
                              0.879552E+02  0.            0.879518E+02  0.            0.338176E+03  0.132507E+06
                                ETAF          ETAI         ETAC         ETATHP       ETATIP       ETATLP
                              0.886553E+00  0.872929E+00  0.853005E+00  0.896535E+00  0.893729E+00  0.902661E+00
                                T6            P6           PS6          AM6          V6           WG6
                              0.993128E+03  0.240734E+06  0.232327E+06  0.237308E+00  0.145105E+03  0.877237E+02
                                T7            WFA          WG7          FAR7         ETAA         DPAFT
                              C.993128E+03  0.            0.877179E+02  0.216331E-01  0.            0.
                                PS8           AM8          V8           PS9          AM9          V9
                              0.130531E+06  0.100000E+01  0.571612E+03  0.130531E+06  0.100000E+01  0.571612E+03
                                PS28          AM28         V28          PS29         AM29         V29
                              0.101325E+06  0.630584E+00  0.223763E+03  0.101325E+06  0.630584E+00  0.223763E+03
                                BPRINT        DPCOM        DPWING       PS38         AM38         V38
                              0.101847E+01  0.493435E-01  0.100001E+00  0.101712E+06  0.100000E+01  0.360752E+03
                                BYPASS        HPEXT        WFT          WGT          VA           FRD
                              0.507158E+00  0.            0.185800E+01  0.263241E+03  0.            0.
                                PCBLI         WG37         VJW          PS39         AM39         V39
                              0.504575E+00  0.874966E+02  0.355341E+03  0.101712E+06  0.100000E+01  0.360752E+03
                                CVDWNG        FGMWNG       FGPWNG       FNWING       FNMAIN       P28
                              0.985000E+00  0.310911E+05  0.858038E+02  0.311769E+05  0.771850E+05  0.132507E+06
                                FFOVFN        FWOVFN       FCOVFN       FMNOFN       FNOVFD       P38
                              0.178892E+00  0.287711E+00  0.533396E+00  0.712289E+00  0.937149E+00  0.192128E+06
                                CVMNOZ        VJM          CVDNOZ       VJD          FGM          FGP
                              0.985000E+00  0.563038E+03  0.985000E+00  0.220406E+03  0.998648E+05  0.849714E+04

MAIN SONIC CONVERGENT NOZZLE              FG=108361.89                FN=108361.89                SFC= 0.06173
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                TIME= 1.1000
OUTPUT          AM=  0.          ALTP=      0.           T4= 1448.02                               ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
      PCNF            CNF             ZF              PRF             WAFC            WAF
  0.968443E+02    0.968443E+00    0.828809E+00    0.137690E+01    0.269814E+03    0.262103E+03
      PCNI            CNI             ZI              PRI             WACI            WAI
  C.970481E+02    0.973399E+00    0.814576E+00    0.153340E+01    0.136908E+03    0.173967E+03
      PCNC            CNC             ZC              PRC             WACC            WAC
  0.984504E+02    0.991317E+00    0.826128E+00    0.725961E+01    0.474774E+02    0.862799E+02
      T2              P2              T22             P22             T21             P21
  0.305349E+03    0.101325E+06    0.338319E+03    0.139515E+06    0.388673E+03    0.213932E+06
      T3              P3              PCBLF           BLF             PCBLC           BLC
  0.721070E+03    0.155307E+07    0.              0.              0.              0.
      PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
  0.              0.              0.              0.              0.              0.
      WA3             WFB             WG4             FAR4            T4              P4
  0.862799E+02    0.185800E+01    0.881236E+02    0.215346E-01    0.144802E+04    0.147636E+07
      TFFHP           CNHP            DHTCHP          DHTC            T50             P50
  0.500839E+02    0.195139E+01    0.240430E+03    0.347786E+06    0.116659E+04    0.516574E+06
      TFFIP           CNIP            DHTCIP          DHTI            T5              P5
  0.120742E+03    0.211455E+01    0.923740E+02    0.107081E+06    0.107781E+04    0.355587E+06
      TFFLP           CNLP            DHTCLP          DHTF            T55             P55
  0.130867E+03    0.220462E+01    0.961481E+02    ).103185E+06    0.991038E+03    0.241554E+06
      ETAB            PCBLDU          ETAD            DPDUC           T24             P24
  0.983000E+00    0.              0.              0.492030E-01    0.338317E+03    0.132650E+06
      WAD             WFD             WG24            FAR24           T25             P25
  0.881357E+02    0.              0.881327E+02    0.              0.338317E+03    0.132650E+06
      ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
  0.886071E+00    0.872538E+00    0.853707E+00    0.896855E+00    0.894128E+00    0.902592E+00
      T6              P6              PS6             AM6             V6              WG6
  0.991038E+03    0.241554E+06    0.233119E+06    0.237292E+00    0.144955E+03    0.881176E+02
      T7              WFA             WG7             FAR7            ETAA            DPAFT
  0.991038E+03    0.              0.881118E+02    0.215346E-01    0.              0.
      PS8             AM8             V8              PS9             AM9             V9
  0.130960E+06    0.100000E+01    0.571032E+03    0.130960E+06    0.100000E+01    0.571032E+03
      PS28            AM28            V28             PS29            AM29            V29
  0.101325E+06    0.631914E+00    0.224246E+03    0.101325E+06    0.631914E+00    0.224246E+03
      BPRINT          DPCOM           DPWING          PS38            AM38            V38
  0.101559E+01    0.493928E-01    0.999980E-01    0.101931E+06    0.100000E+01    0.360896E+03
      BYPASS          HPEXT           WFT             WGT             VA              FRD
  C.506623E+00    0.              0.185800E+01    0.263961E+03    0.              0.
      PCBLI           WG37            VJW             PS39            AM39            V39
  0.503869E+00    0.876491E+02    0.355482E+03    0.101931E+06    0.100000E+01    0.360896E+03
      CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
  0.985000E+00    0.311577E+05    0.134224E+03    0.312919E+05    0.775619E+05    0.132650E+06
      FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
  0.178836E+00    0.287467E+00    0.533697E+00    0.712533E+00    0.941403E+00    0.192540E+06
      CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
  0.985000E+00    0.562467E+03    0.985000E+00    0.220883E+03    0.100185E+06    0.866914E+04

MAIN SONIC CONVERGENT NOZZLE      FG=108853.78                    FN=108853.78                    SFC= 0.06145
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                    TIME= 1.2000

OUTPUT              AM=  0.          ALTP=      0.           T4= 1445.76                    ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                      PCNF          CNF           ZF            PRF           WAFC          WAF
                    0.970571E+02  0.970571E+00  0.828998E+00  0.137840E+01  0.270516E+03  0.262785E+03
                      PCNI          CNI           ZI            PRI           WACI          WAI
                    0.972334E+02  0.975065E+00  0.814551E+00  0.153493E+01  0.137189E+03  0.174480E+03
                      PCNC          CNC           ZC            PRC           WACC          WAC
                    0.986314E+02  0.992756E+00  0.825366E+00  0.727111E+01  0.475961E+02  0.866455E+02
                      T2            P2            T22           P22           T21           P21
                    0.305349E+03  0.101325E+06  0.338453E+03  0.139667E+06  0.388972E+03  0.214379E+06
                      T3            P3            PCBLF         BLF           PCBLC         BLC
                    0.721676E+03  0.155877E+07  0.            0.            0.            0.
                      PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                    0.            0.            0.            0.            0.            0.
                      WA3           WFB           WG4           FAR4          T4            P4
                    0.866455E+02  0.185800E+01  0.884904E+02  0.214437E-01  0.144576E+04  0.148171E+07
                      TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                    0.500753E+02  0.195650E+01  0.240462E+03  0.347353E+06  0.116456E+04  0.518432E+06
                      TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                    0.120695E+03  0.212043E+01  0.924205E+02  0.107009E+06  0.107580E+04  0.356772E+06
                      TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                    0.130816E+03  0.221153E+01  0.962779E+02  0.103178E+06  0.988991E+03  0.242168E+06
                      ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                    0.983000E+00  0.            0.            0.492539E-01  0.338452E+03  0.132787E+06
                      WAD           WFD           WG24          FAR24         T25           P25
                    0.883054E+02  0.            0.883026E+02  0.            0.338452E+03  0.132787E+06
                      ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                    0.885617E+00  0.872178E+00  0.854368E+00  0.897165E+00  0.894497E+00  0.902489E+00
                      T6            P6            PS6           AM6           V6            WG6
                    0.988991E+03  0.242168E+06  0.233700E+06  0.237423E+00  0.144896E+03  0.884857E+02
                      T7            WFA           WG7           FAR7          ETAA          DPAFT
                    0.988991E+03  0.            0.884814E+02  0.214437E-01  0.            0.
                      PS8           AM8           V8            PS9           AM9           V9
                    0.131355E+06  0.100000E+01  0.570464E+03  0.131355E+06  0.100000E+01  0.570464E+03
                      PS28          AM28          V28           PS29          AM29          V29
                    0.101325E+06  0.633164E+00  0.224701E+03  0.101325E+06  0.633164E+00  0.224701E+03
                      BPRINT        DPCOM         DPWING        PS38          AM38          V38
                    0.101307E+01  0.494413E-01  0.999989E-01  0.102145E+06  0.100000E+01  0.361035E+03
                      BYPASS        HPEXT         WFT           WGT           VA            FRD
                    0.506106E+00  0.            0.185800E+01  0.264643E+03  0.            0.
                      PCBLI         WG37          VJW           PS39          AM39          V39
                    0.503247E+00  0.877991E+02  0.355619E+03  0.102145E+06  0.100000E+01  0.361035E+03
                      CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                    0.985000E+00  0.312231E+05  0.181784E+03  0.314048E+05  0.779110E+05  0.132787E+06
                      FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                    0.178785E+00  0.287285E+00  0.533929E+00  0.712715E+00  0.945399E+00  0.192941E+06
                      CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                    0.985000E+00  0.561907E+03  0.985000E+00  0.221331E+03  0.100485E+06  0.883045E+04

MAIN SONIC CONVERGENT NOZZLE      FG=109315.86                FN=109315.86                SFC= 0.06119
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                 TIME= 1.3000
OUTPUT            AM=  0.          ALTP=      0.          T4= 1443.67                          ETAR= 1 0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                  PCNF            CNF              ZF              PRF             WAFC            WAF
               0.972583E+02    0.972583E+00    0.829181E+00    0.137982E+01    0.271181E+03    0.263431E+03
                  PCNI            CNI              ZI              PRI             WACI            WAI
               0.974110E+02    0.976662E+00    0.814657E+00    0.153649E+01    0.137455E+03    0.174965E+03
                  PCNC            CNC              ZC              PRC             WACC            WAC
               0.987962E+02    0.994042E+00    0.824618E+00    0.728084E+01    0.477023E+02    0.869860E+02
                  T2              P2               T22             P22             T21             P21
               0.305349E+03    0.101325E+06    0.338580E+03    0.139810E+06    0.389264E+03    0.214817E+06
                  T3              P3               PCBLF           BLF             PCBLC           BLC
               0.722233E+03    0.156405E+07    0.              0.              0.              0.
                  PCBLHP          BLHP             PCBLIP          BLIP            PCBLLP          BLLP
               0.              0.              0.              0.              0.              0.
                  WA3             WFB              WG4             FAR4            T4              P4
               0.869860E+02    0.185800E+01    0.888319E+02    0.213597E-01    0.144367E+04    0.148665E+07
                  TFFHP           CNHP             DHTCHP          DHTC            T50             P50
               0.500676E+02    0.196119E+01    0.240503E+03    0.346955E+06    0.116269E+04    0.520138E+06
                  TFFIP           CNIP             DHTCIP          DHTI            T5              P5
               0.120649E+03    0.212602E+01    0.924612E+02    0.106941E+06    0.107395E+04    0.357863E+06
                  TFFLP           CNLP             DHTCLP          DHTF            T55             P55
               0.130770E+03    0.221803E+01    0.964160E+02    0.103168E+06    0.987102E+03    0.242729E+06
                  ETAB            PCBLDU           ETAD            DPDUC           T24             P24
               0.983000E+00    0.              0.              0.493020E-01    0.338579E+03    0.132917E+06
                  WAD             WFD              WG24            FAR24           T25             P25
               0.884659E+02    0.              0.884632E+02    0.              0.338579E+03    0.132917E+06
                  ETAF            ETAI             ETAC            ETATHP          ETATIP          ETATLP
               0.885191E+00    0.871856E+00    0.854982E+00    0.897444E+00    0.894853E+00    0.902338E+00
                  T6              P6               PS6             AM6             V6              WG6
               0.987101E+03    0.242729E+06    0.234231E+06    0.237552E+00    0.144846E+C3    0.888276E+02
                  T7              WFA              WG7             FAR7            ETAA            DPAFT
               0.987101E+03    0.              0.888236E+02    0.213597E-01    0.              0.
                  PS8             AM8              V8              PS9             AM9             V9
               0.131720E+06    0.100000E+01    0.569938E+03    0.131720E+06    0.100000E+01    0.569938E+03
                  PS28            AM28             V28             PS29            AM29            V29
               0.101325E+06    0.634347E+00    0.225132E+03    0.101325E+06    0.634347E+00    0.225132E+03
                  BPRINT          DPCOM            DPWING          PS38            AM38            V38
               0.101082E+01    0.494873E-01    0.999993E-01    0.102355E+06    0.100000E+01    0.361170E+03
                  BYPASS          HPEXT            WFT             WGT             VA              FRD
               0.505620E+00    0.              0.185800E+01    0.265289E+03    0.              0.
                  PCBLI           WG37             VJW             PS39            AM39            V39
               0.502690E+00    0.879461E+02    0.355752E+03    0.102355E+06    0.100000E+01    0.361170E+03
                  CVDWNG          FGMWNG           FGPWNG          FNWING          FNMAIN          P28
               0.985000E+00    0.312870E+05    0.228337E+03    0.315154E+05    0.782355E+05    0.132917E+06
                  FFOVFN          FWOVFN           FCOVFN          FMNOFN          FNOVFD          P38
               0.178742E+00    0.287154E+00    0.534104E+00    0.712846E+00    0.949161E+00    0.193336E+06
                  CVMNOZ          VJM              CVDNOZ          VJD             FGM             FGP
               0.985000E+00    0.561389E+03    0.985000E+00    0.221755E+03    0.100769E+06    0.898210E+04

MAIN SONIC CONVERGENT NOZZLE       FG=109750.89                    FN=109750.89                    SFC= 0.06095
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                        TIME= 1.4000
OUTPUT                   AM=  0.          ALTP=     0.          T4= 1441.74                  ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
     PCNF              CNF              ZF               PRF              WAFC             WAF
 0.974485E+02     0.974485E+00     0.829362E+00     0.138116E+01     0.271809E+03     0.264041E+03
     PCNI              CNI              ZI               PRI              WACI             WAI
 0.975806E+02     0.978190E+00     0.814871E+00     0.153805E+01     0.137706E+03     0.175424E+03
     PCNC              CNC              ZC               PRC              WACC             WAC
 0.989457E+02     0.995186E+00     0.823907E+00     0.728911E+01     0.477969E+02     0.873025E+02
     T2                P2               T22              P22              T21              P21
 0.305349E+03     0.101325E+06     0.338700E+03     0.139947E+06     0.389546E+03     0.215245E+06
     T3                P3               PCBLF            BLF              PCBLC            BLC
 0.722752E+03     0.156895E+07     0.               0.               0.               0.
     PCBLHP            BLHP             PCBLIP           BLIP             PCBLLP           BLLP
 0.               0.               0.               ).               0.               0.
     WA3               WFB              WG4              FAR4             T4               P4
 0.873025E+02     0.185800E+01     0.891492E+02     0.212823E-01     0.144174E+04     0.149124E+07
     TFFHP             CNHP             DHTCHP           DHTC             T50              P50
 0.500605E+02     0.196547E+01     0.240525E+03     0.346571E+06     0.116097E+04     0.521757E+06
     TFFIP             CNIP             DHTCIP           DHTI             T5               P5
 C.120605E+03     0.213130E+01     0.924960E+02     0.106875E+06     0.107225E+04     0.358906E+06
     TFFLP             CNLP             DHTCLP           DHTF             T55              P55
 0.130724E+03     0.222412E+01     0.965408E+02     0.103160E+06     0.985376E+03     0.243269E+06
     ETAB              PCBLDU           ETAD             DPDUC            T24              P24
 0.983000E+00     0.               0.               0.493470E-01     0.338699E+03     0.133041E+06
     WAD               WFD              WG24             FAR24            T25              P25
 0.886172E+02     0.               0.886146E+02     0.               0.338699E+03     0.133041E+06
     ETAF              ETAI             ETAC             ETATHP           ETATIP           ETATLP
 0.884792E+00     0.871568E+00     0.855545E+00     0.897706E+00     0.895196E+00     0.902190E+00
     T6                P6               PS6              AM6              V6               WG6
 0.985376E+03     0.243269E+06     0.234744E+06     0.237654E+00     0.144791E+03     0.891451E+02
     T7                WFA              WG7              FAR7             ETAA             DPAFT
 0.985376E+03     0.               0.891412E+02     0.212823E-01     0.               0.
     PS8               AM8              V8               PS9              AM9              V9
 0.132060E+06     0.100000E+01     0.569458E+03     0.132060E+06     0.100000E+01     0.569458E+03
     PS28              AM28             V28              PS29             AM29             V29
 0.101325E+06     0.635461E+00     0.225537E+03     0.101325E+06     0.635461E+00     0.225537E+03
     BPRINT            DPCOM            DPWING           PS38             AM38             V38
 0.100883E+01     0.495300E-01     0.100000E+00     0.102561E+06     0.100000E+01     0.361301E+03
     BYPASS            HPEXT            WFT              WGT              VA               FRD
 0.505161E+00     0.               0.185800E+01     0.265899E+03     0.               0.
     PCBLI             WG37             VJW              PS39             AM39             V39
 0.502197E+00     0.880904E+02     0.355881E+03     0.102561E+06     0.100000E+01     0.361301E+03
     CVDWNG            FGMWNG           FGPWNG           FNWING           FNMAIN           P28
 0.985000E+00     0.313497E+05     0.273932E+03     0.316237E+05     0.785385E+05     0.133041E+06
     FFOVFN            FWOVFN           FCOVFN           FMNOFN           FNOVFD           P38
 0.178701E+00     0.287065E+00     0.534234E+00     0.712935E+00     0.952718E+00     0.193721E+06
     CVMNOZ            VJM              CVDNOZ           VJD              FGM              FGP
 0.985000E+00     0.560916E+03     0.985000E+00     0.222154E+03     0.101037E+06     0.912554E+04
MAIN SONIC CONVERGENT NOZZLE       FG=110162.15                FN=110162.15                 SFC= 0.06072
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

TIME= 1.5000

OUTPUT AM= 0. ALTP= 0. T4= 1439.97 ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

PCNF	CNF	ZF	PRF	WAFC	WAF
0.976296E+02	0.976296E+00	0.829559E+00	0.138246E+01	0.272405E+03	0.264620E+03
PCNI	CNI	ZI	PRI	WACI	WAI
0.977413E+02	0.979633E+00	0.815174E+00	0.153960E+01	0.137939E+03	0.175856E+03
PCNC	CNC	ZC	PRC	WACC	WAC
C.990811E+02	0.996198E+00	0.823255E+00	0.729624E+01	0.478807E+02	0.875961E+02
T2	P2	T22	P22	T21	P21
0.305349E+03	0.101325E+06	0.338815E+03	0.140078E+06	0.389820E+03	0.215663E+06
T3	P3	PCBLF	BLF	PCBLC	BLC
0.723243E+03	0.157353E+07	0.	0.	0.	0.
PCBLHP	BLHP	PCBLIP	BLIP	PCBLLP	BLLP
0.	0.	0.	0.	0.	0.
WA3	WFB	WG4	FAR4	T4	P4
0.875961E+02	0.185800E+01	0.894436E+02	0.212110E-01	0.143997E+04	0.149553E+07
TFFHP	CNHP	DHTCHP	DHTC	T50	P50
0.500540E+02	0.196937E+01	0.240551E+03	0.346216E+06	0.115940E+04	0.523274E+06
TFFIP	CNIP	DHTCIP	DHTI	T5	P5
0.120557E+03	0.213625E+01	0.924856E+02	0.106774E+06	0.107073E+04	0.359951E+06
TFFLP	CNLP	DHTCLP	DHTF	T55	P55
0.130653E+03	0.222984E+01	0.966260E+02	0.103196E+06	0.983795E+03	0.243780E+06
ETAB	PCBLDU	ETAD	DPDUC	T24	P24
0.983000E+00	0.	0.	0.493911E-01	0.338814E+03	0.133159E+06
WAD	WFD	WG24	FAR24	T25	P25
0.887644E+02	0.	0.887619E+02	0.	0.338814E+03	0.133159E+06
ETAF	ETAI	ETAC	ETATHP	ETATIP	ETATLP
0.884417E+00	0.871313E+00	0.856052E+00	0.897941E+00	0.895580E+00	0.902016E+00
T6	P6	PS6	AM6	V6	WG6
0.983795E+03	0.243780E+06	0.235230E+06	0.237739E+00	0.144735E+03	0.894396E+02
T7	WFA	WG7	FAR7	ETAA	DPAFT
0.983795E+03	0.	0.894360E+02	0.212110E-01	0.	0.
PS8	AM8	V8	PS9	AM9	V9
0.132376E+06	0.100000E+01	0.569018E+03	0.132376E+06	0.100000E+01	0.569018E+03
PS28	AM28	V28	PS29	AM29	V29
0.101325E+06	0.636544E+00	0.225931E+03	0.101325E+06	0.636544E+00	0.225931E+03
BPRINT	DPCOM	DPWING	PS38	AM38	V38
0.100706E+01	0.495687E-01	0.100000E+00	0.102761E+06	0.100000E+01	0.361428E+03
BYPASS	HPEXT	WFT	WGT	VA	FRD
0.504757E+00	0.	0.185800E+01	0.266478E+03	0.	0.
PCBLI	WG37	VJW	PS39	AM39	V39
0.501759E+00	0.882305E+02	0.356006E+03	0.102761E+06	0.100000E+01	0.361428E+03
CVDWNG	FGMWNG	FGPWNG	FNWING	FNMAIN	P28
0.985000E+00	0.314106E+05	0.318224E+03	0.317288E+05	0.788231E+05	0.133159E+06
FFOVFN	FWOVFN	FCOVFN	FMNOFN	FNOVFD	P38
0.178679E+00	0.287004E+00	0.534318E+00	0.712996E+00	0.956089E+00	0.194097E+06
CVMNOZ	VJM	CVDNOZ	VJD	FGM	FGP
C.985000E+00	0.560483E+03	0.985000E+00	0.222542E+03	0.101291E+06	0.926079E+04

MAIN SONIC CONVERGENT NOZZLE FG=110551.95 FN=110551.95 SFC= 0.06050
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 11 LOOPS

ORIGINAL PAGE IS
OF POOR QUALITY

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                         TIME= 1.6000
OUTPUT                   AM=  0.          ALTP=      0.          T4= 1438.22                       ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
      PCNF              CNF              ZF               PRF              WAFC             WAF
  0.978002E+02     0.978002E+00     0.829767E+00     0.138369E+01     0.272965E+03     0.265165E+03
      PCNI              CNI              ZI               PRI              WACI             WAI
  0.978937E+02     0.981003E+00     0.815550E+00     0.154112E+01     0.138158E+03     0.176263E+03
      PCNC              CNC              ZC               PRC              WACC             WAC
  0.992034E+02     0.997090E+00     0.822614E+00     0.730201E+01     0.479548E+02     0.878688E+02
      T2                P2               T22              P22              T21              P21
  0.305349E+03     0.101325E+06     0.338925E+03     0.140202E+06     0.390083E+03     0.216068E+06
      T3                P3               PCBLF            BLF              PCBLC            BLC
  0.723692E+03     0.157773E+07     0.               0.               0.               0.
      PCBLHP            BLHP             PCBLIP           BLIP             PCBLLP           BLLP
  0.               0.               0.               0.               0.               0.
      WA3               WFB              WG4              FAR4             T4               P4
  0.878688E+02     0.185800E+01     0.897171E+02     0.211452E-01     0.143822E+04     0.149947E+07
      TFFHP             CNHP             DHTCHP           DHTC             T50              P50
  0.500480E+02     0.197300E+01     0.240578E+03     0.345867E+06     0.115785E+04     0.524650E+06
      TFFIP             CNIP             DHTCIP           DHTI             T5               P5
  0.120515E+03     0.214101E+01     0.925047E+02     0.106706E+06     0.106921E+04     0.360848E+06
      TFFLP             CNLP             DHTCLP           DHTF             T55              P55
  0.130601E+03     0.223533E+01     0.967258E+02     0.103195E+06     0.982236E+03     0.244227E+06
      ETAB              PCBLDU           ETAD             DPDUC            T24              P24
  0.983000E+00     0.               0.               0.494316E-01     0.338923E+03     0.133272E+06
      WAD               WFD              WG24             FAR24            T25              P25
  0.889018E+02     0.               0.888995E+02     0.               0.338923E+03     0.133272E+06
      ETAF              ETAI             ETAC             ETATHP           ETATIP           ETATLP
  0.884068E+00     0.871086E+00     0.856521E+00     0.898160E+00     0.895908E+00     0.901867E+00
      T6                P6               PS6              AM6              V6               WG6
  0.982236E+03     0.244227E+06     0.235654E+06     0.237833E+00     0.144685E+03     0.897136E+02
      T7                WFA              WG7              FAR7             ETAA             DPAFT
  0.982236E+03     0.               0.897104E+02     0.211452E-01     0.               0.
      PS8               AM8              V8               PS9              AM9              V9
  0.132662E+06     0.100000E+01     0.568583E+03     0.132662E+06     0.100000E+01     0.568583E+03
      PS28              AM28             V28              PS29             AM29             V29
  0.101325E+06     0.637557E+00     0.226300E+03     0.101325E+06     0.637557E+00     0.226300E+03
      BPRINT            DPCOM            DPWING           PS38             AM38             V38
  0.100551E+01     0.496059E-01     0.100000E+00     0.102955E+06     0.100000E+01     0.361550E+03
      BYPASS            HPEXT            WFT              WGT              VA               FRD
  0.504371E+00     0.               0.185800E+01     0.267023E+03     0.               0.
      PCBLI             WG37             VJW              PS39             AM39             V39
  0.501373E+00     0.883669E+02     0.356126E+03     0.102955E+06     0.100000E+01     0.361550E+03
      CVDWNG            FGMWNG           FGPWNG           FNWING           FNMAIN           P28
  0.985000E+00     0.314698E+05     0.361275E+03     0.318311E+05     0.790840E+05     0.133272E+06
      FFOVFN            FWOVFN           FCOVFN           FMNOFN           FNOVFD           P38
  0.178661E+00     0.286986E+00     0.534354E+00     0.713014E+00     0.959230E+00     0.194461E+06
      CVMNOZ            VJM              CVDNOZ           VJD              FGM              FGP
  0.985000E+00     0.560054E+03     0.985000E+00     0.222905E+03     0.101529E+06     0.938646E+04
MAIN SONIC CONVERGENT NOZZLE   FG=110915.06                      FN=110915.06                      SFC= 0.06031
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                          TIME= 1.7000
CUTPUT                      AM=  0.          ALTP=      0.          T4= 1436.76                          ETAR= 1.0000

THREE SPOOL ENGINE
THE CUTPUT IS IN SI UNITS
                        PCNF           CNF            ZF             PRF            WAFC           WAF
                      0.979616E+02   0.979616E+00   0.829968E+00   0.138485E+01   0.273495E+03   0.265680E+03
                        PCNI           CNI            ZI             PRI            WACI           WAI
                      0.980387E+02   0.982306E+00   0.815992E+00   0.154263E+01   0.138363E+03   0.176646E+03
                        PCNC           CNC            ZC             PRC            WACC           WAC
                      0.993145E+02   0.997882E+00   0.822095E+00   0.730749E+01   0.480203E+02   0.881211E+02
                        T2             P2             T22            P22            T21            P21
                      0.305349E+03   0.101325E+06   0.339028E+03   0.140320E+06   0.390337E+03   0.216462E+06
                        T3             P3             PCBLF          BLF            PCBLC          BLC
                      0.724140E+03   0.158179E+07   0.             0.             0.             0.
                        PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
                      0.             0.             0.             0.             0.             0.
                        WA3            WFB            WG4            FAR4           T4             P4
                      0.881211E+02   0.185800E+01   0.899698E+02   0.210846E-01   0.143676E+04   0.150328E+07
                        TFFHP          CNHP           DHTCHP         DHTC           T50            P50
                      0.500429E+02   0.197621E+01   0.240631E+03   0.345622E+06   0.115651E+04   0.525895E+06
                        TFFIP          CNIP           DHTCIP         DHTI           T5             P5
                      0.120479E+03   0.214543E+01   0.925332E+02   0.106668E+06   0.106787E+04   0.361633E+06
                        TFFLP          CNLP           DHTCLP         DHTF           T55            P55
                      0.130559E+03   0.224042E+01   0.968245E+02   0.103216E+06   0.980851E+03   0.244596E+06
                        ETAB           PCBLDU         ETAD           DPDUC          T24            P24
                      0.983000E+00   0.             0.             0.494706E-01   0.339027E+03   0.133378E+06
                        WAD            WFD            WG24           FAR24          T25            P25
                      0.890331E+02   0.             0.890309E+02   0.             0.339027E+03   0.133378E+06
                        ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
                      0.883741E+00   0.870884E+00   0.856923E+00   0.898340E+00   0.896196E+00   0.901736E+00
                        T6             P6             PS6            AM6            V6             WG6
                      0.980851E+03   0.244596E+06   0.235999E+06   0.237972E+00   0.144675E+03   0.899667E+02
                        T7             WFA            WG7            FAR7           ETAA           DPAFT
                      0.980851E+03   0.             0.899640E+02   0.210846E-01   0.             0.
                        PS8            AM8            V8             PS9            AM9            V9
                      0.132931E+06   0.100000E+01   0.568196E+03   0.132931E+06   0.100000E+01   0.568196E+03
                        PS28           AM28           V28            PS29           AM29           V29
                      0.101325E+06   0.638524E+00   0.226651E+03   0.101325E+06   0.638524E+00   0.226651E+03
                        BPRINT         DPCOM          DPWING         PS38           AM38           V38
                      0.100414E+01   0.496361E-01   0.100000E+00   0.103144E+06   0.100000E+01   0.361667E+03
                        BYPASS         HPEXT          WFT            WGT            VA             FRD
                      0.504019E+00   0.             0.185800E+01   0.267538E+03   0.             0.
                        PCBLI          WG37           VJW            PS39           AM39           V39
                      0.501032E+00   0.884991E+02   0.356242E+03   0.103144E+06   0.100000E+01   0.361667E+03
                        CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
                      0.985000E+00   0.315271E+05   0.402998E+03   0.319301E+05   0.793293E+05   0.133378E+06
                        FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
                      0.178648E+00   0.286988E+00   0.534364E+00   0.713012E+00   0.962208E+00   0.194815E+06
                        CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
                      0.985000E+00   0.559673E+03   0.985000E+00   0.223252E+03   0.101754E+06   0.950553E+04
                                                                                               SFC= 0.06012
MAIN SONIC CONVERGENT NOZZLE         FG=111259.40                  FN=111259.40
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                          TIME= 1.8000
OUTPUT                    AM=  0.         ALTP=     0.         T4= 1435.38                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                 PCNF           CNF            ZF             PRF            WAFC           WAF
            0.981133E+02   0.981133E+00   0.830173E+00   0.138595E+01   0.273993E+03   0.266163E+03
                 PCNI           CNI            ZI             PRI            WACI           WAI
            0.981759E+02   0.983538E+00   0.816473E+00   0.154410E+01   0.138555E+03   0.177007E+03
                 PCNC           CNC            ZC             PRC            WACC           WAC
            0.994147E+02   0.998579E+00   0.821532E+00   0.731149E+01   0.480783E+02   0.883566E+02
                 T2             P2             T22            P22            T21            P21
            0.305349E+03   0.101325E+06   0.339126E+03   0.140432E+06   0.390580E+03   0.216840E+06
                 T3             P3             PCBLF          BLF            PCBLC          BLC
            0.724532E+03   0.158542E+07   0.             0.             0.             0.
                 PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
            0.             0.             0.             0.             0.             0.
                 WA3            WFB            WG4            FAR4           T4             P4
            0.883566E+02   0.185800E+01   0.902062E+02   0.210284E-01   0.143538E+04   0.150668E+07
                 TFFHP          CNHP           DHTCHP         DHTC           T50            P50
            0.500380E+02   0.197916E+01   0.240649E+03   0.345333E+06   0.115529E+04   0.527113E+06
                 TFFIP          CNIP           DHTCIP         DHTI           T5             P5
            0.120443E+03   0.214956E+01   0.925510E+02   0.106614E+06   0.106667E+04   0.362435E+06
                 TFFLP          CNLP           DHTCLP         DHTF           T55            P55
            0.130517E+03   0.224514E+01   0.969136E+02   0.103219E+06   0.979625E+03   0.245008E+06
                 ETAB           PCBLDU         ETAD           DPDUC          T24            P24
            0.983000E+00   0.             0.             0.495064E-01   0.339125E+03   0.133479E+06
                 WAD            WFD            WG24           FAR24          T25            P25
            0.891556E+02   0.             0.891535E+02   0.             0.339125E+03   0.133479E+06
                 ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
            0.883438E+00   0.870703E+00   0.857311E+00   0.898520E+00   0.896478E+00   0.901610E+00
                 T6             P6             PS6            AM6            V6             WG6
            0.979625E+03   0.245008E+06   0.236390E+06   0.238040E+00   0.144632E+03   0.902030E+02
                 T7             WFA            WG7            FAR7           ETAA           DPAFT
            0.979625E+03   0.             0.902001E+02   0.210284E-01   0.             0.
                 PS8            AM8            V8             PS9            AM9            V9
            0.133185E+06   0.100000E+01   0.567854E+03   0.133185E+06   0.100000E+01   0.567854E+03
                 PS28           AM28           V28            PS29           AM29           V29
            0.101325E+06   0.639427E+00   0.226980E+03   0.101325E+06   0.639427E+00   0.226980E+03
                 BPRINT         DPCOM          DPWING         PS38           AM38           V38
            0.100293E+01   0.496681E-01   0.100001E+00   0.103325E+06   0.100000E+01   0.361780E+03
                 BYPASS         HPEXT          WFT            WGT            VA             FRD
            0.503683E+00   0.             0.185800E+01   0.268021E+03   0.             0.
                 PCBLI          WG37           VJW            PS39           AM39           V39
            0.500731E+00   0.886269E+02   0.356353E+03   0.103325E+06   0.100000E+01   0.361780E+03
                 CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
            0.985000E+00   0.315825E+05   0.443263E+03   0.320257E+05   0.795604E+05   0.133479E+06
                 FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
            0.178629E+00   0.287004E+00   0.534366E+00   0.712996E+00   0.965034E+00   0.195156E+06
                 CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
            0.985000E+00   0.559336E+03   0.985000E+00   0.223575E+03   0.101967E+06   0.961898E+04
MAIN SONIC CONVERGENT NOZZLE   FG=111586.17                 FN=111586.17                 SFC= 0.05994
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                     TIME= 1.9000
OUTPUT                 AM=  0.          ALTP=      0.          T4= 1434.12                         ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                   PCNF          CNF           ZF            PRF           WAFC          WAF
                 0.982558E+02  0.982558E+00  0.830367E+00  0.138699E+01  0.274460E+03  0.266617E+03
                   PCNI          CNI           ZI            PRI           WACI          WAI
                 0.983054E+02  0.984702E+00  0.816998E+00  0.154553E+01  0.138735E+03  0.177345E+03
                   PCNC          CNC           ZC            PRC           WACC          WAC
                 0.995046E+02  0.999185E+00  0.821000E+00  0.731464E+01  0.481290E+02  0.885733E+02
                   T2            P2            T22           P22           T21           P21
                 0.305349E+03  0.101325E+06  0.339218E+03  0.140537E+06  0.390812E+03  0.217204E+06
                   T3            P3            PCBLF         BLF           PCBLC         BLC
                 0.724894E+03  0.158877E+07  0.            0.            0.            0.
                   PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                 0.            0.            0.            0.            0.            0.
                   WA3           WFB           WG4           FAR4          T4            P4
                 0.885733E+02  0.185800E+01  0.904236E+02  0.209770E-01  0.143412E+04  0.150981E+07
                   TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                 0.500334E+02  0.198182E+01  0.240652E+03  0.345051E+06  0.115419E+04  0.528270E+06
                   TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                 0.120409E+03  0.215342E+01  0.925647E+02  0.106564E+06  0.106559E+04  0.363203E+06
                   TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                 0.130477E+03  0.224954E+01  0.969941E+02  0.103225E+06  0.978518E+03  0.245404E+06
                   ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                 0.983000E+00  0.            0.            0.495407E-01  0.339217E+03  0.133574E+06
                   WAD           WFD           WG24          FAR24         T25           P25
                 0.892721E+02  0.            0.892701E+02  0.            0.339217E+03  0.133574E+06
                   ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                 0.883155E+00  0.870545E+00  0.857663E+00  0.898688E+00  0.896746E+00  0.901490E+00
                   T6            P6            PS6           AM6           V6            WG6
                 0.978518E+03  0.245404E+06  0.236768E+06  0.238086E+00  0.144585E+03  0.904205E+02
                   T7            WFA           WG7           FAR7          ETAA          DPAFT
                 0.978518E+03  0.            0.904177E+02  0.209770E-01  0.            0.
                   PS8           AM8           V8            PS9           AM9           V9
                 0.133421E+06  0.100000E+01  0.567545E+03  0.133421E+06  0.100000E+01  0.567545E+03
                   PS28          AM28          V28           PS29          AM29          V29
                 0.101325E+06  0.640285E+00  0.227292E+03  0.101325E+06  0.640285E+00  0.227292E+03
                   BPRINT        DPCOM         DPWING        PS38          AM38          V38
                 0.100187E+01  0.496975E-01  0.100001E+00  0.103500E+06  0.100000E+01  0.361887E+03
                   BYPASS        HPEXT         WFT           WGT           VA            FRD
                 0.503380E+00  0.            0.185800E+01  0.268475E+03  0.            0.
                   PCBLI         WG37          VJW           PS39          AM39          V39
                 0.500468E+00  0.887497E+02  0.356459E+03  0.103500E+06  0.100000E+01  0.361887E+03
                   CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                 0.985000E+00  0.316356E+05  0.481924E+03  0.321175E+05  0.797759E+05  0.133574E+06
                   FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                 0.178617E+00  0.287037E+00  0.534347E+00  0.712963E+00  0.967691E+00  0.195484E+06
                   CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                 0.985000E+00  0.559032E+03  0.985000E+00  0.223883E+03  0.102168E+06  0.972545E+04

MAIN SJNIC CONVERGENT NOZZLE       FG=111893.44                FN=111893.44                SFC= 0.05978
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                      TIME= 2.0000
OUTPUT                 AM=  0.          ALTP=      0.          T4= 1432.96                     ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                        PCNF          CNF           ZF            PRF           WAFC          WAF
                      0.983894E+02  0.983894E+00  0.830559E+00  0.138797E+01  0.274898E+03  0.267043E+03
                        PCNI          CNI           ZI            PRI           WACI          WAI
                      0.984274E+02  0.985799E+00  0.817550E+00  0.154693E+01  0.138902E+03  0.177662E+03
                        PCNC          CNC           ZC            PRC           WACC          WAC
                      0.995853E+02  0.999712E+00  0.820495E+00  0.731704E+01  0.481731E+02  0.887731E+02
                        T2            P2            T22           P22           T21           P21
                      0.305349E+03  0.101325E+06  0.339304E+03  0.140636E+06  0.391034E+03  0.217553E+06
                        T3            P3            PCBLF         BLF           PCBLC         BLC
                      0.725228E+03  0.159184E+07  0.            0.            0.            0.
                        PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                      0.            0.            0.            0.            0.            0.
                        WA3           WFB           WG4           FAR4          T4            P4
                      0.887731E+02  0.185800E+01  0.906240E+02  0.209298E-01  0.143296E+04  0.151269E+07
                        TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                      0.500294E+02  0.198423E+01  0.240657E+03  0.344792E+06  0.115319E+04  0.529330E+06
                        TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                      0.120377E+03  0.215703E+01  0.925776E+02  0.106520E+06  0.106460E+04  0.363905E+06
                        TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                      0.130441E+03  0.225365E+01  0.970700E+02  0.103230E+06  0.977501E+03  0.245765E+06
                        ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                      0.983000E+00  0.            0.            0.495727E-01  0.339303E+03  0.133664E+06
                        WAD           WFD           WG24          FAR24         T25           P25
                      0.893813E+02  0.            0.893794E+02  0.            0.339303E+03  0.133664E+06
                        ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                      0.882894E+00  0.870405E+00  0.857983E+00  0.898840E+00  0.896998E+00  0.901378E+00
                        T6            P6            PS6           AM6           V6            WG6
                      0.977501E+03  0.245765E+06  0.237113E+06  0.238133E+00  0.144544E+03  0.906213E+02
                        T7            WFA           WG7           FAR7          ETAA          DPAFT
                      0.977501E+03  0.            0.906187E+02  0.209298E-01  0.            0.
                        PS8           AM8           V8            PS9           AM9           V9
                      0.133638E+06  0.100000E+01  0.567260E+03  0.133638E+06  0.100000E+01  0.567260E+03
                        PS28          AM28          V28           PS29          AM29          V29
                      0.101325E+06  0.641089E+00  0.227585E+03  0.101325E+06  0.641089E+00  0.227585E+03
                        BPRINT        DPCOM         DPWING        PS38          AM38          V38
                      0.100096E+01  0.497249E-01  0.100001E+00  0.103668E+06  0.100000E+01  0.361990E+03
                        BYPASS        HPEXT         WFT           WGT           VA            FRD
                      0.503098E+00  0.            0.185800E+01  0.268901E+03  0.            0.
                        PCBLI         WG37          VJW           PS39          AM39          V39
                      0.500240E+00  0.888678E+02  0.356560E+03  0.103668E+06  0.100000E+01  0.361990E+03
                        CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                      0.985000E+00  0.316867E+05  0.519081E+03  0.322058E+05  0.799758E+05  0.133664E+06
                        FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                      0.178606E+00  0.287086E+00  0.534308E+00  0.712914E+00  0.970182E+00  0.195798E+06
                        CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                      0.985000E+00  0.558752E+03  0.985000E+00  0.224171E+03  0.102356E+06  0.982526E+04
MAIN SONIC CONVERGENT NOZZLE        FG=112181.53                FN=112181.53                SFC= 0.05962
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                 TIME= 2.1000
OUTPUT           AM=  0.          ALTP=     0.          T4= 1431.89                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                 PCNF           CNF            ZF             PRF            WAFC           WAF
                 0.985145E+02   0.985145E+00   0.830753E+00   0.138889E+01   0.275307E+03   0.267440E+03
                 PCNI           CNI            ZI             PRI            WACI           WAI
                 0.985421E+02   0.986829E+00   0.818136E+00   0.154828E+01   0.139057E+03   0.177957E+03
                 PCNC           CNC            ZC             PRC            WACC           WAC
                 C.996571E+02   0.100016E+01   0.820022E+00   0.731902E+01   0.482135E+02   0.889614E+02
                 T2             P2             T22            P22            T21            P21
                 0.305349E+03   0.101325E+06   0.339385E+03   0.140729E+06   0.391245E+03   0.217888E+06
                 T3             P3             PCBLF          BLF            PCBLC          BLC
                 0.725561E+03   0.159473E+07   0.             0.             0.             0.
                 PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
                 0.             0.             0.             0.             0.             0.
                 WA3            WFB            WG4            FAR4           T4             P4
                 0.889614E+02   0.185800E+01   0.908127E+02   0.208855E-01   0.143189E+04   0.151539E+07
                 TFFHP          CNHP           DHTCHP         DHTC           T50            P50
                 0.500256E+02   0.198640E+01   0.240654E+03   0.344567E+06   0.115225E+04   0.530300E+06
                 TFFIP          CNIP           DHTCIP         DHTI           T5             P5
                 0.120347E+03   0.216043E+01   0.925879E+02   0.106471E+06   0.106368E+04   0.364558E+06
                 TFFLP          CNLP           DHTCLP         DHTF           T55            P55
                 0.130406E+03   0.225749E+01   0.971403E+02   0.103228E+06   0.976562E+03   0.246107E+06
                 ETAB           PCBLDU         ETAD           DPDUC          T24            P24
                 0.983000E+00   0.             0.             0.496024E-01   0.339384E+03   0.133749E+06
                 WAD            WFD            WG24           FAR24          T25            P25
                 0.894836E+02   0.             0.894818E+02   0.             0.339384E+03   0.133749E+06
                 ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
                 0.882653E+00   0.870285E+00   0.858226E+00   0.898981E+00   0.897237E+00   0.901273E+00
                 T6             P6             PS6            AM6            V6             WG6
                 0.976562E+03   0.246107E+06   0.237439E+06   0.238178E+00   0.144506E+03   0.908102E+02
                 T7             WFA            WG7            FAR7           ETAA           DPAFT
                 0.976562E+03   0.             0.908077E+02   0.208855E-01   0.             0.
                 PS8            AM8            V8             PS9            AM9            V9
                 0.133844E+06   0.100000E+01   0.566998E+03   0.133844E+06   0.100000E+01   0.566998E+03
                 PS28           AM28           V28            PS29           AM29           V29
                 0.101325E+06   0.641843E+00   0.227859E+03   0.101325E+06   0.641843E+00   0.227859E+03
                 BPRINT         DPCOM          DPWING         PS38           AM38           V38
                 0.100007E+01   0.497516E-01   0.999956E-01   0.103822E+06   0.100000E+01   0.362087E+03
                 BYPASS         HPEXT          WFT            WGT            VA             FRD
                 0.502839E+00   0.             0.185800E+01   0.269298E+03   0.             0.
                 PCBLI          WG37           VJW            PS39           AM39           V39
                 0.500016E+00   0.889758E+02   0.356656E+03   0.103822E+06   0.100000E+01   0.362087E+03
                 CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
                 0.985000E+00   0.317338E+05   0.553328E+03   0.322871E+05   0.801643E+05   0.133749E+06
                 FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
                 0.178596E+00   0.287120E+00   0.534283E+00   0.712880E+00   0.972516E+00   0.196100E+06
                 CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
                 0.985000E+00   0.558493E+03   0.985000E+00   0.224441E+03   0.102533E+06   0.991872E+04

MAIN SONIC CONVERGENT NOZZLE   FG=112451.34                 FN=112451.34                SFC= 0.05948
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTEK  11 LOOPS
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```
                         TIME= 2.2000
OUTPUT                   AM=  0.          ALTP=      0.          T4= 1430.47                        ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                           PCNF          CNF           ZF            PRF           WAFC          WAF
                         0.986316E+02  0.986316E+00  0.830912E+00  0.138974E+01  0.275693E+03  0.267814E+03
                           PCNI          CNI           ZI            PRI           WACI          WAI
                         0.986501E+02  0.987801E+00  0.818621E+00  0.154951E+01  0.139205E+03  0.178236E+03
                           PCNC          CNC           ZC            PRC           WACC          WAC
                         0.997189E+02  0.100072E+01  0.819621E+00  0.732337E+01  0.482677E+02  0.891796E+02
                           T2            P2            T22           P22           T21           P21
                         0.305349E+03  0.101325E+06  0.339461E+03  0.140816E+06  0.391297E+03  0.218196E+06
                           T3            P3            PCBLF         BLF           PCBLC         BLC
                         0.725723E+03  0.159793E+07  0.            0.            0.            0.
                           PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                         0.            0.            0.            0.            0.            0.
                           WA3           WFB           WG4           FAR4          T4            P4
                         0.891796E+02  0.185800E+01  0.910302E+02  0.208344E-01  0.143047E+04  0.151838E+07
                           TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                         0.500223E+02  0.198862E+01  0.240719E+03  0.344280E+06  0.115099E+04  0.531304E+06
                           TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                         0.120319E+03  0.216398E+01  0.926175E+02  0.106101E+06  0.106271E+04  0.365623E+06
                           TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                         0.130373E+03  0.226121E+01  0.972083E+02  0.103183E+06  0.975604E+03  0.246765E+06
                           ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                         0.983000E+00  0.            0.            0.496298E-01  0.339460E+03  0.133827E+06
                           WAD           WFD           WG24          FAR24         T25           P25
                         0.895779E+02  0.            0.895763E+02  0.            0.339460E+03  0.133827E+06
                           ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                         0.882426E+00  0.870160E+00  0.858372E+00  0.899090E+00  0.897459E+00  0.901170E+00
                           T6            P6            PS6           AM6           V6            WG6
                         0.975604E+03  0.246765E+06  0.238088E+06  0.237968E+00  0.144315E+03  0.910266E+02
                           T7            WFA           WG7           FAR7          ETAA          DPAFT
                         0.975604E+03  0.            0.910218E+02  0.208344E-01  0.            0.
                           PS8           AM8           V8            PS9           AM9           V9
                         0.134084E+06  0.100000E+01  0.566730E+03  0.134084E+06  0.100000E+01  0.566730E+03
                           PS28          AM28          V28           PS29          AM29          V29
                         0.101325E+06  0.642538E+00  0.228112E+03  0.101325E+06  0.642538E+00  0.228112E+03
                           BPRINT        DPCOM         DPWING        PS38          AM38          V38
                         0.998275E+00  0.497794E-01  0.999288E-01  0.103899E+06  0.100000E+01  0.362112E+03
                           BYPASS        HPEXT         WFT           WGT           VA            FRD
                         0.502579E+00  0.            0.185800E+01  0.269672E+03  0.            0.
                           PCBLI         WG37          VJW           PS39          AM39          V39
                         0.499568E+00  0.890361E+02  0.356680E+03  0.103899E+06  0.100000E+01  0.362112E+03
                           CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                         0.985000E+00  0.317574E+05  0.570490E+03  0.323279E+05  0.803726E+05  0.133827E+06
                           FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                         0.178588E+00  0.286848E+00  0.534564E+00  0.713152E+00  0.974670E+00  0.196392E+06
                           CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                         0.985000E+00  0.558229E+03  0.985000E+00  0.224691E+03  0.102695E+06  0.100051E+05

MAIN SONIC CONVERGENT NOZZLE           FG=112700.48                FN=112700.48                SFC= 0.05935
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                    TIME= 2.3000
OUTPUT              AM=  0.         ALTP=     0.         T4= 1429.69                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
   PCNF           CNF            ZF             PRF            WAFC           WAF
0.987420E+02   0.987420E+00   0.830862E+00   0.139045E+01   0.276070E+03   0.268181E+03
   PCNI           CNI            ZI             PRI            WACI           WAI
0.987594E+02   0.988802E+00   0.818713E+00   0.155051E+01   0.139371E+03   0.178524E+03
   PCNC           CNC            ZC             PRC            WACC           WAC
0.997706E+02   0.100102E+01   0.819315E+00   0.732513E+01   0.482980E+02   0.893245E+02
   T2             P2             T22            P22            T21            P21
0.305349E+03   0.101325E+06   0.339525E+03   0.140888E+06   0.391464E+03   0.218448E+06
   T3             P3             PCBLF          BLF            PCBLC          BLC
0.726023E+03   0.160016E+07   0.             0.             0.             0.
   PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
0.             0.             0.             0.             0.             0.
   WA3            WFB            WG4            FAR4           T4             P4
0.893245E+02   0.185800E+01   0.911773E+02   0.208006E-01   0.142969E+04   0.152047E+07
   TFFHP          CNHP           DHTCHP         DHTC           T50            P50
0.500189E+02   0.199019E+01   0.240631E+03   0.343991E+06   0.115040E+04   0.532314E+06
   TFFIP          CNIP           DHTCIP         DHTI           T5             P5
C.120290E+03   0.216693E+01   0.926119E+02   0.106351E+06   0.106191E+04   0.365944E+06
   TFFLP          CNLP           DHTCLP         DHTF           T55            P55
0.130336E+03   0.226460E+01   0.972632E+02   0.103207E+06   0.974762E+03   0.246867E+06
   ETAB           PCBLDU         ETAD           DPDUC          T24            P24
0.983000E+00   0.             0.             0.496530E-01   0.339524E+03   0.133892E+06
   WAD            WFD            WG24           FAR24          T25            P25
0.896571E+02   0.             0.896558E+02   0.             0.339524E+03   0.133892E+06
   ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
0.882192E+00   0.869961E+00   0.858480E+00   0.899236E+00   0.897688E+00   0.901067E+00
   T6             P6             PS6            AM6            V6             WG6
0.974762E+03   0.246867E+06   0.238172E+06   0.238160E+00   0.144373E+03   0.911755E+02
   T7             WFA            WG7            FAR7           ETAA           DPAFT
0.974762E+03   C.             0.911748E+02   0.208006E-01   0.             0.
   PS8            AM8            V8             PS9            AM9            V9
0.134244E+06   0.100000E+01   0.566494E+03   0.134244E+06   0.100000E+01   0.566494E+03
   PS28           AM28           V28            PS29           AM29           V29
0.101325E+06   0.643125E+00   0.228326E+03   0.101325E+06   0.643125E+00   0.228326E+03
   BPRINT         DPCOM          DPWING         PS38           AM38           V38
C.998355E+00   0.498010E-01   0.999996E-01   0.104095E+06   0.100000E+01   0.362189E+03
   BYPASS         HPEXT          WFT            WGT            VA             FRD
0.502214E+00   0.             0.185800E+01   0.270039E+03   0.             0.
   PCBLI          WG37           VJW            PS39           AM39           V39
0.499589E+00   0.891846E+02   0.356756E+03   0.104095E+06   0.100000E+01   0.362189E+03
   CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
0.985000E+00   0.318172E+05   0.613921E+03   0.324311E+05   0.805196E+05   0.133892E+06
   FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
0.178518E+00   0.287126E+00   0.534356E+00   0.712874E+00   0.976834E+00   0.196603E+06
   CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
0.985000E+00   0.557997E+03   0.985000E+00   0.224901E+03   0.102856E+06   0.100945E+05

MAIN SONIC CONVERGENT NOZZLE   FG=112950.63                FN=112950.63                 SFC= 0.05922
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
                    TIME= 2.4000
OUTPUT              AM=  0.          ALTP=      0.          T4= 1428.92                         ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                      PCNF           CNF            ZF             PRF            WAFC           WAF
                    0.988456E+02   0.988456E+00   0.830983E+00   0.139120E+01   0.276412E+03   0.268513E+03
                      PCNI           CNI            ZI             PRI            WACI           WAI
                    0.988620E+02   0.989732E+00   0.819438E+00   0.155187E+01   0.139505E+03   0.178773E+03
                      PCNC           CNC            ZC             PRC            WACC           WAC
                    C.998156E+02   0.100123E+01   0.818966E+00   0.732523E+01   0.483192E+02   0.894678E+02
                      T2             P2             T22            P22            T21            P21
                    0.305349E+03   0.101325E+06   0.339591E+03   0.140963E+06   0.391654E+03   0.218756E+06
                      T3             P3             PCBLF          BLF            PCBLC          BLC
                    0.726313E+03   0.160244E+07   0.             0.             0.             0.
                      PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
                    0.             0.             0.             0.             0.             0.
                      WA3            WFB            WG4            FAR4           T4             P4
                    0.894678E+02   0.185800E+01   0.913205E+02   0.207672E-01   0.142892E+04   0.152261E+07
                      TFFHP          CNHP           DHTCHP         DHTC           T50            P50
                    0.500166E+02   0.199163E+01   0.240644E+03   0.343832E+06   0.114972E+04   0.533062E+06
                      TFFIP          CNIP           DHTCIP         DHTI           T5             P5
                    0.120266E+03   0.216982E+01   0.926295E+02   0.106335E+06   0.106122E+04   0.366424E+06
                      TFFLP          CNLP           DHTCLP         DHTF           T55            P55
                    0.130310E+03   0.226770E+01   0.973205E+02   0.103223E+06   0.974049E+03   0.247098E+06
                      ETAB           PCBLDU         ETAD           DPDUC          T24            P24
                    0.983000E+00   0.             0.             0.496771E-01   0.339590E+03   0.133960E+06
                      WAD            WFD            WG24           FAR24          T25            P25
                    0.897401E+02   0.             0.897387E+02   0.             0.339590E+03   0.133960E+06
                      ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
                    0.881991E+00   0.869885E+00   0.858597E+00   0.899321E+00   0.897879E+00   0.900979E+00
                      T6             P6             PS6            AM6            V6             WG6
                    0.974049E+03   0.247098E+06   0.238391E+06   0.238221E+00   0.144361E+03   0.913186E+02
                      T7             WFA            WG7            FAR7           ETAA           DPAFT
                    C.974049E+03   0.             0.913170E+02   0.207672E-01   0.             0.
                      PS8            AM8            V8             PS9            AM9            V9
                    0.134397E+06   0.100000E+01   0.566295E+03   0.134397E+06   0.100000E+01   0.566295E+03
                      PS28           AM28           V28            PS29           AM29           V29
                    0.101325E+06   0.643735E+00   0.228548E+03   0.101325E+06   0.643735E+00   0.228548E+03
                      BPRINT         DPCOM          DPWING         PS38           AM38           V38
                    0.997935E+00   0.498198E-01   0.100001E+00   0.104243E+06   0.100000E+01   0.362277E+03
                      BYPASS         HPEXT          WFT            WGT            VA             FRD
                    0.501978E+00   0.             0.185800E+01   0.270371E+03   0.             0.
                      PCBLI          WG37           VJW            PS39           AM39           V39
                    0.499483E+00   0.892892E+02   0.356843E+03   0.104243E+06   0.100000E+01   0.362277E+03
                      CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
                    C.985000E+00   0.318622E+05   0.646672E+03   0.325088E+05   0.806634E+05   0.133960E+06
                      FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
                    0.178506E+00   0.287251E+00   0.534243E+00   0.712749E+00   0.978750E+00   0.196881E+06
                      CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
                    C.985000E+00   0.557800E+03   0.985000E+00   0.225120E+03   0.103001E+06   0.101715E+05
MAIN SONIC CONVERGENT NOZZLE       FG=113172.22                 FN=113172.22                  SFC= 0.05910
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
             TIME= 2.5000
OUTPUT       AM=  0.          ALTP=      0.          T4= 1428.20                              ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
     PCNF            CNF             ZF              PRF             WAFC            WAF
0.989421E+02    0.989421E+00    0.831110E+00    0.139190E+01    0.276730E+03    0.268822E+03
     PCNI            CNI             ZI              PRI             WACI            WAI
0.989577E+02    0.990600E+00    0.820190E+00    0.155319E+01    0.139627E+03    0.179004E+03
     PCNC            CNC             ZC              PRC             WACC            WAC
0.998541E+02    0.100138E+01    0.818613E+00    0.732457E+01    0.483352E+02    0.895993E+02
     T2              P2              T22             P22             T21             P21
0.305349E+03    0.101325E+06    0.339653E+03    0.141034E+06    0.391836E+03    0.219053E+06
     T3              P3              PCBLF           BLF             PCBLC           BLC
0.726565E+03    0.160447E+07    0.              0.              0.              0.
     PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
0.              0.              0.              0.              0.              0.
     WA3             WFB             WG4             FAR4            T4              P4
0.895993E+02    0.185800E+01    0.914526E+02    0.207368E-01    0.142820E+04    0.152450E+07
     TFFHP           CNHP            DHTCHP          DHTC            T50             P50
0.500143E+02    0.199290E+01    0.240631E+03    0.343648E+06    0.114912E+04    0.533799E+06
     TFFIP           CNIP            DHTCIP          DHTI            T5              P5
0.120243E+03    0.217249E+01    0.926378E+02    0.106314E+06    0.106062E+04    0.366912E+06
     TFFLP           CNLP            DHTCLP          DHTF            T55             P55
0.130283E+03    0.227056E+01    0.973696E+02    0.103228E+06    0.973431E+03    0.247354E+06
     ETAB            PCBLDU          ETAD            DPDUC           T24             P24
0.983000E+00    0.              0.              0.496998E-01    0.339652E+03    0.134025E+06
     WAD             WFD             WG24            FAR24           T25             P25
0.898181E+02    0.              0.898168E+02    0.              0.339652E+C3    0.134025E+06
     ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
0.881807E+00    0.869826E+00    0.858714E+00    0.899409E+00    0.898067E+00    0.900894E+00
     T6              P6              PS6             AM6             V6              WG6
0.973431E+03    0.247354E+06    0.238635E+06    0.238238E+00    0.144329E+03    0.914507E+02
     T7              WFA             WG7             FAR7            ETAA            'DPAFT
0.973431E+03    0.              0.914488E+02    0.207368E-01    0.              0.
     PS8             AM8             V8              PS9             AM9             V9
0.134543E+06    0.100000E+01    0.566122E+03    0.134543E+06    0.100000E+01    0.566122E+03
     PS28            AM28            V28             PS29            AM29            V29
0.101325E+06    0.644310E+00    0.228757E+03    0.101325E+06    0.644310E+00    0.228757E+03
     BPRINT          DPCOM           DPWING          PS38            AM38            V38
C.997608E+00    0.498387E-01    0.100002E+00    0.104386E+06    0.100000E+01    0.362361E+03
     BYPASS          HPEXT           WFT             WGT             VA              FRD
0.501766E+00    0.              0.185800E+01    0.270680E+03    0.              0.
     PCBLI           WG37            VJW             PS39            AM39            V39
0.499401E+00    0.893900E+02    0.356925E+03    0.104386E+06    0.100000E+01    0.362361E+03
     CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
0.985000E+00    0.319055E+05    0.678226E+03    0.325838E+05    0.807993E+05    0.134025E+06
     FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
0.178493E+00    0.287378E+00    0.534130E+00    0.712622E+00    0.980574E+00    0.197147E+06
     CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
C.985000E+00    0.557630E+03    0.985000E+00    0.225326E+03    0.103138E+C6    0.102449E+05

MAIN SONIC CONVERGENT NOZZLE    FG=113383.11                    FN=113383.11                    SFC= 0.05899
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                 TIME= 2.6000
OUTPUT            AM=  0.          ALTP=      0.          T4= 1427.55                              ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                  PCNF            CNF             ZF              PRF             WAFC            WAF
                C.990318E+02    0.990318E+00    0.831245E+00    0.139256E+01    0.277024E+03    0.269108E+03
                  PCNI            CNI             ZI              PRI             WACI            WAI
                0.990467E+02    0.991407E+00    0.820945E+00    0.155445E+01    0.139739E+03    0.179217E+03
                  PCNC            CNC             ZC              PRC             WACC            WAC
                0.998872E+02    0.100150E+01    0.818277E+00    0.732349E+01    0.483472E+02    0.897183E+02
                  T2              P2              T22             P22             T21             P21
                0.305349E+03    0.101325E+06    0.339711E+03    0.141101E+06    0.392007E+03    0.219335E+06
                  T3              P3              PCBLF           BLF             PCBLC           BLC
                0.726794E+03    0.160630E+07    0.              0.              0.              0.
                  PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
                0.              0.              0.              0.              0.              0.
                  WA3             WFB             WG4             FAR4            T4              P4
                0.897183E+02    0.185800E+01    0.915721E+02    0.207093E-01    0.142755E+04    0.152622E+07
                  TFFHP           CNHP            DHTCHP          DHTC            T50             P50
                0.500123E+02    0.199401E+01    0.240627E+03    0.343495E+06    0.114856E+04    0.534436E+06
                  TFFIP           CNIP            DHTCIP          DHTI            T5              P5
                0.120221E+03    0.217497E+01    0.926480E+02    0.106290E+06    0.106007E+04    0.367339E+06
                  TFFLP           CNLP            DHTCLP          DHTF            T55             P55
                0.130259E+03    0.227321E+01    0.974170E+02    0.103231E+06    0.972869E+03    0.247577E+06
                  ETAB            PCBLDU          ETAD            DPDUC           T24             P24
                0.983000E+00    0.              0.              0.497207E-01    0.339710E+03    0.134085E+06
                  WAD             WFD             WG24            FAR24           T25             P25
                0.898908E+02    0.              0.898895E+02    0.              0.339710E+03    0.134085E+06
                  ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
                0.881639E+00    0.869781E+00    0.858818E+00    0.899483E+00    0.898238E+00    0.900817E+00
                  T6              P6              PS6             AM6             V6              WG6
                0.972869E+03    0.247577E+06    0.238848E+06    0.238262E+00    0.144305E+03    0.915704E+02
                  T7              WFA             WG7             FAR7            ETAA            DPAFT
                C.972869E+03    0.              0.915688E+02    0.207093E-01    0.              0.
                  PS8             AM8             V8              PS9             AM9             V9
                0.134675E+06    0.100000E+01    0.565964E+03    0.134675E+06    0.100000E+01    0.565964E+03
                  PS28            AM28            V28             PS29            AM29            V29
                0.101325E+06    0.644845E+00    0.228952E+03    0.101325E+06    0.644845E+00    0.228952E+03
                  BPRINT          DPCOM           DPWING          PS38            AM38            V38
                0.997357E+00    0.498558E-01    0.100001E+00    0.104521E+06    0.100000E+01    0.362440E+03
                  BYPASS          HPEXT           WFT             WGT             VA              FRD
                0.501574E+00    0.              0.185800E+01    0.270966E+03    0.              0.
                  PCBLI           WG37            VJW             PS39            AM39            V39
                0.499338E+00    0.894855E+02    0.357003E+03    0.104521E+06    0.100000E+01    0.362440E+03
                  CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
                C.985000E+00    0.319466E+05    0.708105E+03    0.326547E+05    0.809238E+05    0.134085E+06
                  FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
                0.178482E+00    0.287508E+00    0.534010E+00    0.712492E+00    0.982264E+00    0.197401E+06
                  CVMNOZ          VJM             CVONOZ          VJD             FGM             FGP
                0.985000E+00    0.557475E+03    0.985000E+00    0.225518E+03    0.103266E+06    0.103129E+05
MAIN SONIC CONVERGENT NOZZLE    FG=113578.48                    FN=113578.48                    SFC= 0.05889
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                    TIME= 2.7000

OUTPUT              AM=  0.          ALTP=     0.          T4= 1427.02                                ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                      PCNF            CNF             ZF              PRF             WAFC            WAF
                    0.991186E+02    0.991186E+00    0.831382E+00    0.139320E+01    0.277309E+03    0.269385E+03
                      PCNI            CNI             ZI              PRI             WACI            WAI
                    0.991321E+02    0.992179E+00    0.821674E+00    0.155567E+01    0.139847E+03    0.179423E+03
                      PCNC            CNC             ZC              PRC             WACC            WAC
                    C.999191E+02    0.100160E+01    0.818301E+00    0.732513E+01    0.483574E+02    0.898274E+02
                      T2              P2              T22             P22             T21             P21
                    0.305349E+03    0.101325E+06    0.339768E+03    0.141166E+06    0.392173E+03    0.219608E+06
                      T3              P3              PCBLF           BLF             PCBLC           BLC
                    0.727130E+03    0.160866E+07    0.              0.              0.              0.
                      PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
                    0.              0.              0.              0.              0.              0.
                      WA3             WFB             WG4             FAR4            T4              P4
                    C.898274E+02    0.185800E+01    0.916799E+02    0.206824E-01    0.142702E+04    0.152846E+07
                      TFFHP           CNHP            DHTCHP          DHTC            T50             P50
                    0.500121E+02    0.199502E+01    0.240809E+03    0.343657E+06    0.114786E+04    0.534655E+06
                      TFFIP           CNIP            DHTCIP          DHTI            T5              P5
                    0.120210E+03    0.217751E+01    0.927189E+02    0.106374E+06    0.105929E+04    0.367301E+06
                      TFFLP           CNLP            DHTCLP          DHTF            T55             P55
                    0.130245E+03    0.227604E+01    0.974800E+02    0.103320E+06    0.971992E+03    0.247377E+06
                      ETAB            PCBLDU          ETAD            DPDUC           T24             P24
                    0.983000E+00    0.              0.              0.497412E-01    0.339767E+03    0.134144E+06
                      WAD             WFD             WG24            FAR24           T25             P25
                    0.899619E+02    0.              0.899607E+02    0.              0.339767E+03    0.134144E+06
                      ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
                    0.881478E+00    0.869738E+00    0.858814E+00    0.899456E+00    0.898326E+00    0.900748E+00
                      T6              P6              PS6             AM6             V6              WG6
                    0.971992E+03    0.247377E+06    0.238627E+06    0.238649E+00    0.144477E+03    0.916799E+02
                      T7              WFA             WG7             FAR7            ETAA            DPAFT
                    C.971992E+03    0.              0.916814E+02    0.206824E-01    0.              0.
                      PS8             AM8             V8              PS9             AM9             V9
                    0.134772E+06    0.100000E+01    0.565718E+03    0.134772E+06    0.100000E+01    0.565718E+03
                      PS28            AM28            V28             PS29            AM29            V29
                    0.101325E+06    0.645369E+00    0.229143E+03    0.101325E+06    0.645369E+00    0.229143E+03
                      BPRINT          DPCOM           DPWING          PS38            AM38            V38
                    0.997160E+00    0.498548E-01    0.100003E+00    0.104653E+06    0.100000E+01    0.362516E+03
                      BYPASS          HPEXT           WFT             WGT             VA              FRD
                    0.501397E+00    0.              0.185800E+01    0.271243E+03    0.              0.
                      PCBLI           WG37            VJW             PS39            AM39            V39
                    0.499289E+00    0.895794E+02    0.357079E+03    0.104653E+06    0.100000E+01    0.362516E+03
                      CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
                    C.985000E+00    0.319869E+05    0.737400E+03    0.327243E+05    0.810252E+05    0.134144E+06
                      FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
                    0.178503E+00    0.287687E+00    0.533809E+00    0.712313E+00    0.983742E+00    0.197647E+06
                      CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
                    0.985000E+00    0.557232E+03    0.985000E+00    0.225706E+03    0.103379E+06    0.103702E+05

MAIN SONIC CONVERGENT NOZZLE        FG=113749.44                    FN=113749.44                    SFC= 0.05880
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                     TIME= 2.8000
OUTPUT                AM=  0.          ALTP=      0.          T4= 1426.43                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                       PCNF          CNF           ZF            PRF           WAFC          WAF
                     0.991968E+02  0.991968E+00  0.831520E+00  0.139379E+01  0.277564E+03  0.269633E+03
                       PCNI          CNI           ZI            PRI           WACI          WAI
                     0.992095E+02  0.992879E+00  0.822408E+00  0.155683E+01  0.139941E+03  0.179606E+03
                       PCNC          CNC           ZC            PRC           WACC          WAC
                     0.999433E+02  0.100165E+01  0.817775E+00  0.732170E+01  0.483638E+02  0.899321E+02
                       T2            P2            T22           P22           T21           P21
                     0.305349E+03  0.101325E+06  0.339819E+03  0.141225E+06  0.392327E+03  0.219863E+06
                       T3            P3            PCBLF         BLF           PCBLC         BLC
                     0.727241E+03  0.160977E+07  0.            0.            0.            0.
                       PCBLHP        BLHP          PCBLIP        BLIP          PCBLLP        BLLP
                     0.            0.            0.            0.            0.            0.
                       WA3           WFB           WG4           FAR4          T4            P4
                     0.899321E+02  0.185800E+01  0.917876E+02  0.206600E-01  0.142643E+04  0.152947E+07
                       TFFHP         CNHP          DHTCHP        DHTC          T50           P50
                     0.500093E+02  0.199592E+01  0.240655E+03  0.343275E+06  0.114756E+04  0.535543E+06
                       TFFIP         CNIP          DHTCIP        DHTI          T5            P5
                     0.120185E+03  0.217950E+01  0.926825E+02  0.106279E+06  0.105906E+04  0.368034E+06
                       TFFLP         CNLP          DHTCLP        DHTF          T55           P55
                     0.130221E+03  0.227809E+01  0.975100E+02  0.103266E+06  0.971799E+03  0.247894E+06
                       ETAB          PCBLDU        ETAD          DPDUC         T24           P24
                     0.983000E+00  0.            0.            0.497597E-01  0.339818E+03  0.134198E+06
                       WAD           WFD           WG24          FAR24         T25           P25
                     0.900264E+02  0.            0.900253E+02  0.            0.339818E+03  0.134198E+06
                       ETAF          ETAI          ETAC          ETATHP        ETATIP        ETATLP
                     0.881336E+00  0.869712E+00  0.858967E+00  0.899591E+00  0.898527E+00  0.900681E+00
                       T6            P6            PS6           AM6           V6            WG6
                     0.971799E+03  0.247894E+06  0.239145E+06  0.238380E+00  0.144303E+03  0.917847E+02
                       T7            WFA           WG7           FAR7          ETAA          DPAFT
                     0.971799E+03  0.            0.917810E+02  0.206600E-01  0.            0.
                       PS8           AM8           V8            PS9           AM9           V9
                     0.134902E+06  0.100000E+01  0.565664E+03  0.134902E+06  0.100000E+01  0.565664E+03
                       PS28          AM28          V28           PS29          AM29          V29
                     0.101325E+06  0.645844E+00  0.229316E+03  0.101325E+06  0.645844E+00  0.229316E+03
                       BPRINT        DPCOM         DPWING        PS38          AM38          V38
                     0.997012E+00  0.498821E-01  0.100001E+00  0.104773E+06  0.100000E+01  0.362587E+03
                       BYPASS        HPEXT         WFT           WGT           VA            FRD
                     0.501243E+00  0.            0.185800E+01  0.271491E+03  0.            0.
                       PCBLI         WG37          VJW           PS39          AM39          V39
                     0.499252E+00  0.896647E+02  0.357149E+03  0.104773E+06  0.100000E+01  0.362587E+03
                       CVDWNG        FGMWNG        FGPWNG        FNWING        FNMAIN        P28
                     0.985000E+00  0.320236E+05  0.764116E+03  0.327877E+05  0.811433E+05  0.134198E+06
                       FFOVFN        FWOVFN        FCOVFN        FMNOFN        FNOVFD        P38
                     0.178481E+00  0.287786E+00  0.533733E+00  0.712214E+00  0.985313E+00  0.197877E+06
                       CVMNOZ        VJM           CVDNOZ        VJD           FGM           FGP
                     0.985000E+00  0.557179E+03  0.985000E+00  0.225876E+03  0.103497E+06  0.104344E+05

MAIN SONIC CONVERGENT NOZZLE       FG=113931.04                FN=113931.04                SFC= 0.05871
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
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```
              TIME= 2.9000
OUTPUT         AM=  0.          ALTP=      0.          T4= 1425.92                        ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                 PCNF           CNF            ZF             PRF            WAFC           WAF
              0.992691E+02   0.992691E+00   0.831651E+00   0.139433E+01   0.277800E+03   0.269862E+03
                 PCNI           CNI            ZI             PRI            WACI           WAI
              0.992812E+02   0.993527E+00   0.823114E+00   0.155791E+01   0.140029E+03   0.179776E+03
                 PCNC           CNC            ZC             PRC            WACC           WAC
              C.999639E+02   0.100167E+01   0.817506E+00   0.731992E+01   0.483669E+02   0.900182E+02
                 T2             P2             T22            P22            T21            P21
              0.305349E+03   0.101325E+06   0.339867E+03   0.141280E+06   0.392471E+03   0.220103E+06
                 T3             P3             PCBLF          BLF            PCBLC          BLC
              0.727411E+03   0.161113E+07   0.             0.             0.             0.
                 PCBLHP         BLHP           PCBLIP         BLIP           PCBLLP         BLLP
              0.             0.             0.             0.             0.             0.
                 WA3            WFB            WG4            FAR4           T4             P4
              0.900182E+02   0.185800E+01   0.918730E+02   0.206385E-01   0.142592E+04   0.153075E+07
                 TFFHP          CNHP           DHTCHP         DHTC           T50            P50
              0.500080E+02   0.199669E+01   0.240664E+03   0.343169E+06   0.114710E+04   0.535982E+06
                 TFFIP          CNIP           DHTCIP         DHTI           T5             P5
              C.120168E+03   0.218151E+01   0.926929E+02   0.106272E+06   0.105860E+04   0.368324E+06
                 TFFLP          CNLP           DHTCLP         DHTF           T55            P55
              0.130199E+03   0.228024E+01   0.975448E+02   0.103276E+06   0.971323E+03   0.248027E+06
                 ETAB           PCBLDU         ETAD           DPDUC          T24            P24
              0.983000E+00   0.             0.             0.497771E-01   0.339865E+03   0.134248E+06
                 WAD            WFD            WG24           FAR24          T25            P25
              C.900866E+02   0.             0.900856E+02   0.             0.339865E+03   0.134248E+06
                 ETAF           ETAI           ETAC           ETATHP         ETATIP         ETATLP
              0.881206E+00   0.869691E+00   0.859045E+00   0.899636E+00   0.898663E+00   0.900614E+00
                 T6             P6             PS6            AM6            V6             WG6
              C.971323E+03   0.248027E+06   0.239270E+06   0.238418E+00   0.144293E+03   0.918719E+02
                 T7             WFA            WG7            FAR7           ETAA           DPAFT
              C.971323E+03   0.             0.918709E+02   0.206385E-01   0.             0.
                 PS8            AM8            V8             PS9            AM9            V9
              0.134997E+06   0.100000E+01   0.565531E+03   0.134997E+06   0.100000E+01   0.565531E+03
                 PS28           AM28           V28            PS29           AM29           V29
              0.101325E+06   0.646287E+00   0.229477E+03   0.101325E+06   0.646287E+00   0.229477E+03
                 BPRINT         DPCOM          DPWING         PS38           AM38           V38
              0.996958E+00   0.498935E-01   0.100002E+00   0.104889E+06   0.100000E+01   0.362654E+03
                 BYPASS         HPEXT          WFT            WGT            VA             FRD
              C.501105E+00   0.             0.185800E+01   0.271720E+03   0.             0.
                 PCBLI          WG37           VJW            PS39           AM39           V39
              0.499238E+00   0.897471E+02   0.357214E+03   0.104889E+06   0.100000E+01   0.362654E+03
                 CVDWNG         FGMWNG         FGPWNG         FNWING         FNMAIN         P28
              0.985000E+00   0.320589E+05   0.789797E+03   0.328487E+05   0.812365E+05   0.134248E+06
                 FFOVFN         FWOVFN         FCOVFN         FMNOFN         FNOVFD         P38
              0.178485E+00   0.287931E+00   0.533584E+00   0.712069E+00   0.986646E+00   0.198092E+06
                 CVMNOZ         VJM            CVDNOZ         VJD            FGM            FGP
              C.985000E+00   0.557048E+03   0.985000E+00   0.226035E+03   0.103598E+06   0.104874E+05

MAIN SONIC CONVERGENT NOZZLE        FG=114085.21                 FN=114085.21                SFC= 0.05863
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

```
                                TIME= 3.0000

OUTPUT                          AM=  0.          ALTP=      0.          T4= 1425.46                          ETAR= 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS
                                 PCNF            CNF             ZF              PRF             WAFC            WAF
                               0.993348E+02    0.993348E+00    0.831783E+00    0.139483E+01    0.278014E+03    0.270070E+03
                                 PCNI            CNI             ZI              PRI             WACI            WAI
                               0.993467E+02    0.994119E+00    0.823817E+00    0.155895E+01    0.140106E+03    0.179928E+03
                                 PCNC            CNC             ZC              PRC             WACC            WAC
                               0.999798E+02    0.100166E+01    0.817143E+00    0.731696E+01    0.483671E+02    0.900970E+02
                                 T2              P2              T22             P22             T21             P21
                               0.305349E+03    0.101325E+06    0.339910E+03    0.141331E+06    0.392605E+03    0.220328E+06
                                 T3              P3              PCBLF           BLF             PCBLC           BLC
                               0.727519E+03    0.161213E+07    0.              0.              0.              0.
                                 PCBLHP          BLHP            PCBLIP          BLIP            PCBLLP          BLLP
                               0.              0.              0.              0.              0.              0.
                                 WA3             WFB             WG4             FAR4            T4              P4
                               0.900970E+02    0.185800E+01    0.919527E+02    0.206205E-01    0.142546E+04    0.153167E+07
                                 TFFHP           CNHP            DHTCHP          DHTC            T50             P50
                               0.500064E+02    0.199732E+01    0.240593E+03    0.342951E+06    0.114680E+04    0.536552E+06
                                 TFFIP           CNIP            DHTCIP          DHTI            T5              P5
                               0.120149E+03    0.218324E+01    0.926810E+02    0.106226E+06    0.105833E+04    0.368763E+06
                                 TFFLP           CNLP            DHTCLP          DHTF            T55             P55
                               0.130179E+03    0.228204E+01    0.975721E+02    0.103256E+06    0.971061E+03    0.248309E+06
                                 ETAB            PCBLDU          ETAD            DPDUC           T24             P24
                               0.983000E+00    0.              0.              0.497929E-01    0.339909E+03    0.134294E+06
                                 WAD             WFD             WG24            FAR24           T25             P25
                               0.901418E+02    0.              0.901408E+02    0.              0.339909E+03    0.134294E+06
                                 ETAF            ETAI            ETAC            ETATHP          ETATIP          ETATLP
                               0.881090E+00    0.869682E+00    0.859149E+00    0.899713E+00    0.898809E+00    0.900556E+00
                                 T6              P6              PS6             AM6             V6              WG6
                               0.971061E+03    0.248309E+06    0.239550E+06    0.238310E+00    0.144211E+03    0.919510E+02
                                 T7              WFA             WG7             FAR7            ETAA            DPAFT
                               0.971061E+03    0.              0.919489E+02    0.206205E-01    0.              0.
                                 PS8             AM8             V8              PS9             AM9             V9
                               0.135091E+06    0.100000E+01    0.565458E+03    0.135091E+06    0.100000E+01    0.565458E+03
                                 PS28            AM28            V28             PS29            AM29            V29
                               0.101325E+06    0.646694E+00    0.229624E+03    0.101325E+06    0.646694E+00    0.229624E+03
                                 BPRINT          DPCOM           DPWING          PS38            AM38            V38
                               0.996946E+00    0.499101E-01    0.100001E+00    0.104996E+06    0.100000E+01    0.362716E+03
                                 BYPASS          HPEXT           WFT             WGT             VA              FRD
                               0.500987E+00    0.              0.185800E+01    0.271928E+03    0.              0.
                                 PCBLI           WG37            VJW             PS39            AM39            V39
                               0.499235E+00    0.898230E+02    0.357275E+03    0.104996E+06    0.100000E+01    0.362716E+03
                                 CVDWNG          FGMWNG          FGPWNG          FNWING          FNMAIN          P28
                               0.985000E+00    0.320915E+05    0.813497E+03    0.329050E+05    0.813259E+05    0.134294E+06
                                 FFOVFN          FWOVFN          FCOVFN          FMNOFN          FNOVFD          P38
                               0.178481E+00    0.288057E+00    0.533462E+00    0.711943E+00    0.987906E+00    0.198295E+06
                                 CVMNOZ          VJM             CVDNOZ          VJD             FGM             FGP
                               0.985000E+00    0.556976E+03    0.985000E+00    0.226180E+03    0.103693E+06    0.105380E+05
MAIN SONIC CONVERGENT NOZZLE                   FG=114230.88                    FN=114230.88                    SFC= 0.05856
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER  11 LOOPS
```

As indicated earlier, the step in fuel flow for this case is up to the design-flow. A comparison of the results at 3 seconds and at the design point shows that the transient has not quite settled out. However, the results from both cases are close. Time histories of the fan speed, middle spool speed, core speed, and turbine inlet temperature are given in figure 17.

APPENDIX C

CONTROL SYSTEM SIMULATION

A set of subroutines has been written to allow the DYNGEN user to simulate such common control functions as integrations, first-order lags, and hysteresis. These subroutines are discussed in this appendix, and examples are shown to illustrate their use. Most of the subroutines (ALFLAG, ALINTR, etc.) are linear transfer functions. They are solved by assuming that the input is a ramp from the past value to the current value; the output is then the exact solution assuming the ramp input. The accuracy of this method is consistent with the accuracy of the modified Euler method used by DYNGEN itself.

All general-purpose control subroutines are listed in this appendix, except for AFQUIR and DERIV, which are part of the main program and are listed in appendix B.

All subroutines, including AFQUIR and DERIV, are discussed in the following section. Subroutines DISTRB, FCNTRL, and NOZCTR for the two-spool turbofan and one-spool turbojet example cases are also listed.

General-Purpose Subroutines

SUBROUTINE AFQUIR(X, AIND, DEPEND, ANS, AJ, TOL, DIR, ANEW, ICON) solves implicit loops.

X(I)	storage array for previous values
AIND	independent variable
DEPEND	dependent variable
ANS	desired value of dependent variable
AJ	maximum number of iterations
TOL	percentage tolerance on answer
DIR	direction for first guess
ANEW	new guess for independent variable
ICON	control = 1, guess again
	= 2, answer reached
	= 3, exceeded maximum number of iterations

Given successive values of AIND and corresponding values of DEPEND, AFQUIR will calculate new values for ANEW in an attempt to make DEPEND equal to ANS (within tolerance TOL). An example of the use of AFQUIR is given in subroutine FCNTRL for the two-spool example.

FUNCTION ALFLAG(I, X, TAU, YMAX, YMIN) determines amplitude-limited first-order lag.

I integer constant used with all first-order functions to identify location of previous values of function input and output (For first use of ALFLAG (or any first-order function with I as an argument), value of I must be 24. (First 23 locations are used by the main program.) Subsequent first-order function calls should be numbered consecutively, e.g.,

X = ALFLAG (24, . . .)

Y = ALINTR (25, . . .)

Z = FIRLAG (26, . . .)

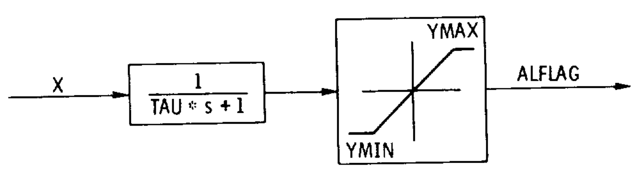
The maximum value for I is 50.)

X current input value

TAU time constant

YMAX maximum output value

YMIN minimum output value

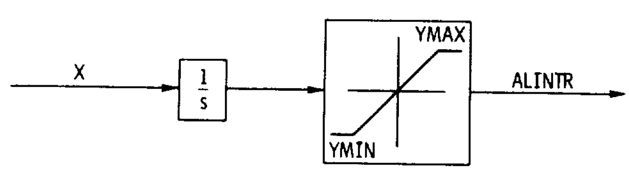


```
$IBFTC ALFLAG
      FUNCTION ALFLAG(I,X,TAU,YMAX,YMIN)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      ALFLAG=AMAX1(YMIN,AMIN1(YMAX,X))
      FO(I,1)= X
      FO(I,2)= X
      FO(I,3)=ALFLAG
      FO(I,4)=ALFLAG
      RETURN
    1 XO=FO(I,2)
      YO=FO(I,4)
      TEMP=-DT/TAU
      IF(ABS(TEMP)-75.)40,40,30
   30 EX1=0.0
      GO TO 50
   40 EX1=EXP(TEMP)
   50 EX2=TAU/DT*(1.0-EX1)
             Y=YO*EX1+X*(1.0-EX2)+XO*(EX2-EX1)
      ALTIMC=AMAX1(YMIN,AMIN1(YMAX,Y))
      FO(I,1) = X
      FO(I,3)=ALTIMC
      IF(ABS(ALTIMC-YMAX).LT.1.0E-5.OR.ABS(ALTIMC-YMIN).LT.1.0E-5)
     1FO(I,1)=ALTIMC
      ALFLAG=ALTIMC
      RETURN
      END
```

FUNCTION ALINTR(I, X, YIC, YMAX, YMIN) performs amplitude-limited integration.

I	integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)
X	current input value
YIC	initial condition
YMAX	maximum output value
YMIN	minimum output value

ALINTR



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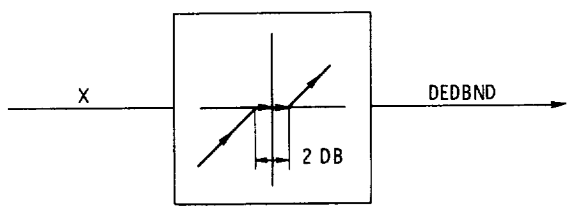
```
$IBFTC ALINTR
      FUNCTION ALINTR(I,X,YIC,YMAX,YMIN)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      ALINTR=YIC
      FO(I,1)= X
      FO(I,2)=X
      FO(I,3)=ALINTR
      FO(I,4)=ALINTR
      RETURN
    1 XO=FO(I,2)
      YO=FO(I,4)
      ALINTR=YO+.5*DT*(X+XO)
      ALINTR=AMAX1(YMIN,AMIN1(YMAX,ALINTR))
      FO(I,1)= X
      FO(I,3)=ALINTR
      RETURN
      END
```

FUNCTION DEDBND(X, DB) determines the dead band.

X current input value

DB width of dead band




```
$IBFTC DEDBND
      FUNCTION DEDBND(X,DB)
      Y=0.
      IF(X.GT.DB)Y=X-DB
      IF(X.LT.-DB)Y=X+DB
      DEDBND=Y
      RETURN
      END
```

FUNCTION DELAY(IDLAY, X, TDELAY, TCLOCK) determines the time delay.

IDLAY integer constant, similar to I, used only with DELAY (Calls to DELAY should be numbered consecutively from IDLAY=1 to IDLAY=5.)

X current input value

TDELAY length of delay (TDELAY should not exceed 49.×DT, where DT is the solution time step specified by user.)

TCLOCK current time

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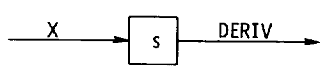
```
$IBFTC DELAY
      FUNCTION DELAY(IDLAY,X,TDELAY,TCLOCK)
      COMMON/CDELAY/PDATA(5,50),TIMEPT(50)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      IF(JTRAN.EQ.1) GO TO 20
      DO 10 I=1,50
      TIMEPT(I) = TCLOCK
   10 PDATA(IDLAY,I) = X
      DELAY   = X
      GO TO 50
   20 PDATA(IDLAY,1) = X
      TIMEPT(1)       = TCLOCK
      DO 30 I=1,50
      J       = I
      IF ((TCLOCK-TIMEPT(I)).GE.TDELAY) GO TO 40
   30 CONTINUE
   40 DELTA   = 0.0
      IF(ABS(TIMEPT(J-1)-TIMEPT(J)) .LT. 0.0001) GO TO 45
      IF (J.GT.1) DELTA = (PDATA(IDLAY,J-1)-PDATA(IDLAY,J))*(TCLOCK
     1                    -TIMEPT(J)-TDELAY)/(TIMEPT(J-1)-TIMEPT(J))
   45 CONTINUE
      DELAY   = PDATA(IDLAY,J) + DELTA
   50 RETURN
      END
```

FUNCTION DERIV(I, X) calculates the time derivative.

I integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

X current input value



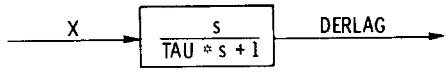
The listing for DERIV is given in appendix B.

FUNCTION DERLAG(I, X, TAU) calculates the derivative of first-order lag.

I integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

X current input value

TAU time constant



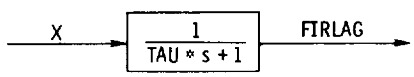

```
$IBFTC DERLAG
      FUNCTION DERLAG(I,X,TAU)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      DERLAG=(1.0/TAU)*(X-FIRLAG(I,X,TAU))
      RETURN
      END
```

FUNCTION FIRLAG(I, X, TAU) determines the first-order lag.

I — integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

X — current input value

TAU — time constant




```
$IBFTC FIRLAG
      FUNCTION FIRLAG(I,X,TAU)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      FIRLAG=X
      FO(I,1)= X
      FO(I,2)= X
      FO(I,3)=FIRLAG
      FO(I,4)=FIRLAG
      RETURN
    1 X0=FO(I,2)
      Y0=FO(I,4)
      TEMP=-DT/TAU
      IF(ABS(TEMP)-75.)40,40,30
   30 EX1=0.
      GO TO 50
   40 EX1=EXP(TEMP)
   50 EX2=TAU/DT*(1.0-EX1)
      FIRLAG=Y0*EX1+X*(1.0-EX2)+X0*(EX2-EX1)
      FO(I,1) = X
      FO(I,3)=FIRLAG
      RETURN
      END
```

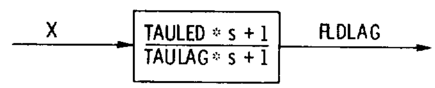
FUNCTION FLDLAG(I, X, TAULED, TAULAG) determines the first-order lead-lag.

I integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

TAULED lead-time constant

TAULAG lag-time constant

X current input value



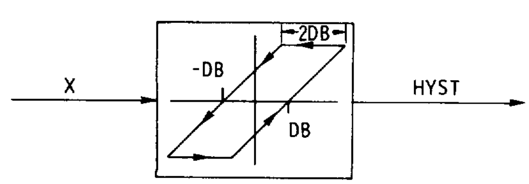

```
$IBFTC FLDLAG
      FUNCTION FLDLAG(I,X,TAULED,TAULAG)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      Y=FIRLAG(I,X,TAULAG)
      FLDLAG=(TAULED/TAULAG)*X+(1.0-TAULED/TAULAG)*Y
      RETURN
      END
```

FUNCTION HYST(I, X, DB) calculates the hysteresis.

I integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

X current input value

DB width of dead band



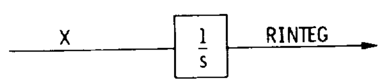
```
$IBFTC HYST
      FUNCTION HYST(I,X,DB)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      FO(I,1)=X
      FO(I,2)=X
      FO(I,3)=X
      FO(I,4)=X
      HYST=X
      RETURN
    1 XO=FO(I,2)
      YO=FO(I,4)
      HYST=YO
      IF(X-DB.GT.YO.AND.X.GT.XO) HYST=X-DB
      IF(X+DB.LT.YO.AND.X.LT.XO) HYST=X+DB
      FO(I,1)=X
      FO(I,3)=HYST
      RETURN
      END
```

FUNCTION RINTEG(I, X, YIC) performs integration.

I — integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

X — current input value

YIC — initial condition




```
$IBFTC RINTEG
      FUNCTION RINTEG(I,X,YIC)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      RINTEG=YIC
      FO(I,1)= X
      FO(I,2)=X
      FO(I,3)=RINTEG
      FO(I,4)=RINTEG
      RETURN
    1 XO=FO(I,2)
      YO=FO(I,4)
      RINTEG=YO+.5*DT*(X+XO)
      FO(I,1)= X
      FO(I,3)=RINTEG
      RETURN
      END
```

FUNCTION RFLAG(I, X, TAU, RLH, RLL) determines the rate-limited first-order lag.

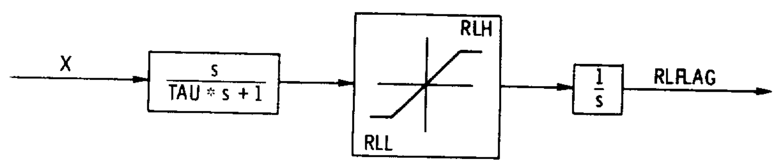
I integer constant used to identify storage location of previous function values (See ALFLAG for further discussion.)

X current input value

TAU time constant

RLH upper rate limit

RLL lower rate limit




```
$IBFTC RLFLAG
      FUNCTION RLFLAG(I,X,TAU,RLH,RLL)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /FOC/ FO(50,4)
      IF(JTRAN.EQ.1) GO TO 1
      RLFLAG=X
      FO(I,1)= X
      FO(I,2)= X
      FO(I,3)=RLFLAG
      FO(I,4)=RLFLAG
      RETURN
    1 XO=FO(I,2)
      YO=FO(I,4)
      TEMP=-DT/TAU
      IF(ABS(TEMP)-75.)40,40,30
   30 EX1=0.0
      GO TO 50
   40 EX1=EXP(TEMP)
   50 EX2=TAU/DT*(1.0-EX1)
      RLFLAG=YO*EX1+X*(1.0-EX2)+XO*(EX2-EX1)
      RLFLAG=YO+AMIN1(RLH,AMAX1(RLL,(RLFLAG-YO)/DT))*DT
      FO(I,1)= X
      FO(I,3)=RLFLAG
      RETURN
      END
```

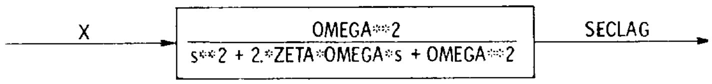
FUNCTION SECLAG(J, X, OMEGA, ZETA) determines the second-order lag.

J integer constant, similar to I, used only with second-order functions SECLAG and SLDLAG (Calls to SECLAG and SLDLAG should be numbered consecutively from J=1 to J=10.)

X current input value

OMEGA natural frequency

ZETA damping ratio




```
$IBFTC SECLAG
      FUNCTION SECLAG(J,X,OMEGA,ZETA)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON/SOC/SO(10,6)
      IF(JTRAN.EQ.1) GO TO 1
      SO(J,1)=X
      SO(J,2)=X
      SO(J,3)=X
      SO(J,4)=X
      SO(J,5)=X
      SO(J,6)=X
      SECLAG=X
      RETURN
    1 X0=SO(J,2)
      X00=SO(J,3)
      Y0=SO(J,5)
      Y00=SO(J,6)
      A=-ZETA*OMEGA
      OM1=OMEGA*SQRT(1.0-ZETA**2)
      YD=(Y0-Y00)/DT
      XD=(X-X00)/DT/2.0
      XDD=(X-2.0*X0+X00)/DT/DT
      A1=X0-XDD/OMEGA/OMEGA*(1.0-4.0*ZETA*ZETA)-2.0*ZETA*XD/OMEGA
      B1=XD-2.0*ZETA*XDD/OMEGA
      SECLAG=(Y0-A1)*EXP(A*DT)*COS(OM1*DT)+A1+B1*DT+XDD*DT*DT/2.0
     1+(YD+ZETA*OMEGA*Y0-XD*(1.0-2.0*ZETA*ZETA)+ZETA*XDD/OMEGA*
     2(3.0-4.0*ZETA*ZETA)-ZETA*OMEGA*X0)*EXP(A*DT)/OM1*SIN(OM1*DT)
      SO(J,1)=X
      SO(J,4)=SECLAG
      RETURN
      END
```

FUNCTION SLDLAG(J, X, OMEGA, ZETA, AA, BB) determines the second-order lead-lag.

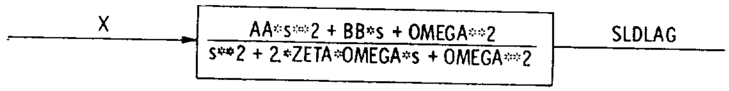
J integer constant, similar to I, used with second-order functions (See SECLAG for discussion.)

X current input value

OMEGA denominator natural frequency

ZETA denominator damping ratio

AA, BB numerator coefficients



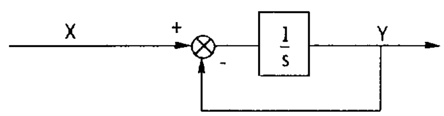

```
$IBFTC SLDLAG
      FUNCTION SLDLAG(J,X,OMEGA,ZETA,AA,BB)
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON/SOC/SO(10,6)
      IF(JTRAN.EQ.1) GO TO 1
      SO(J,1)=X
      SO(J,2)=X
      SO(J,3)=X
      SO(J,4)=X
      SO(J,5)=X
      SO(J,6)=X
      SLDLAG=X
      RETURN
    1 XO=SO(J,2)
      XOO=SO(J,3)
      YO=SO(J,5)
      YOO=SO(J,6)
      A=-ZETA*OMEGA
      OM1=OMEGA*SQRT(1.0-ZETA**2)
      YD=(YO-YOO)/DT
      XD=(X-XOO)/DT/2.0
      XDD=(X-2.0*XO+XOO)/DT/DT
      XOTEMP=XO
      XO=XO+(AA*XDD+BB*XD)/OMEGA/OMEGA
      XD=XD+BB*XDD/OMEGA/OMEGA
      A1=XO-XDD/OMEGA/OMEGA*(1.0-4.0*ZETA*ZETA)-2.0*ZETA*XD/OMEGA
      B1=XD-2.0*ZETA*XDD/OMEGA
      SECLAG=(YO-A1)*EXP(A*DT)*COS(OM1*DT)+A1+B1*DT+XDD*DT*DT/2.0
     1+(YD+ZETA*OMEGA*YO-XD*(1.0-2.0*ZETA*ZETA)+ZETA*XDD/OMEGA*
     2(3.0-4.0*ZETA*ZETA)-ZETA*OMEGA*XO)*EXP(A*DT)/OM1*SIN(OM1*DT)
      XO=XOTEMP
      SO(J,1)=X
      SLDLAG=SECLAG
      SO(J,4)=SLDLAG
      RETURN
      END
```

Use of Control Subroutines

For any engine he wishes to simulate, the user must write three subroutines: FCNTRL, NOZCTR, and DISTRB. Subroutine FCNTRL is called by COCOMB and is used to calculate main fuel flow WFB. Subroutine NOZCTR is called by COMNOZ and is used to calculate nozzle area. Subroutine DISTRB is called by ENGBAL and supplies a time-varying transient input to the simulation. Listings of subroutines FCNTRL, NOZCTR, and DISTRB for the two-spool and one-spool example cases used in this report are given at the end of this appendix. If one of these subroutines is not needed for a particular engine, it should consist of a RETURN statement, as shown in the listings.

The fuel control system for the two-spool turbofan is given in figure 18, and the fuel and nozzle control systems for the afterburning turbojet are shown in figure 20.

The fuel control system for the two-spool turbofan (fig. 18) is used as an example to illustrate programming techniques. Certain problems arise from the fact that DYNGEN can use a large time step DT in obtaining solutions to differential equations. For example, consider a simple block diagram, as shown in the following sketch:



A programmer could use function RINTEG, with X-Y as input, to calculate the output of the integrator. For maximum accuracy, RINTEG requires that the current value of X-Y be used as input; however, only the past value of Y is available (unless iterative methods are used). Use of the past value of Y can lead to appreciable errors if the value of DT is large. Hence, to ensure maximum accuracy, the programmer must sometimes resort to iterative methods when writing control subroutines for DYNGEN. This technique is illustrated in subroutine FCNTRL for the control system of figure 18. In order to begin the iterative process, a value for integrator output YF is assumed. By using function DERIV, a value for integrator input YFDOT is then calculated. Also EXNL and EACL, the inputs to the MIN function, can be calculated by using the assumed value of YF. The lesser of these inputs is the output of the MIN function YFDOTX. For a consistent solution, YFDOT and YFDOTX should be equal. This fact is used to generate an error variable ERRW. Subroutine AFQUIR is then used to generate a new guess for YF, and the process continues until ERRW is less than a desired tolerance.

Example Case - Two-Spool Turbofan

An example of DISTRB, FCNTRL, and NOZCTR are given for the two-spool turbofan case. In this example a throttle step is accomplished by starting the transient at a specified low-pressure-rotor speed. DISTRB is called by DYNGEN and the demanded speed for the low-pressure rotor is set higher (at the design-point value). The difference between the actual speed and the demanded speed is used to generate a fuel flow (fig. 18).

Subroutine DISTRB is now shown. COMMON blocks DYN, RPMS, and CNTRL are shown. In DISTRB the demanded speed XNLDEM is set equal to the low-pressure-rotor design speed XNLPDS (table V), which is set in the NAMELIST input (not presented).

XNLDEM is transferred to the fuel control subroutine FCNTRL through COMMON block CNTRL.

```
$IBFTC DISTRB
      SUBROUTINE DISTRB
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
      COMMON /CNTRL/ XNHM,XNLM,T21M,P3M,YF,YFDOT,YFB,EXNL,PHI,WFBACL,
     1 YFACL,EACL,XNLDEM,XNHP,XNLP
      XNLDEM=XNLPDS
      RETURN
      END
```

Subroutine FCNTRL is now presented. COMMON blocks ALL1 to ALL5 are used as previously described in the three-spool example. In this subroutine,

DATA AWORD/6HFCNTRL/

WORD=AWORD

is set so that the name FCNTRL is sent to subroutine ERROR if an error is found. The other commons are used to transmit data to and from FCNTRL as needed.

```
$IBFTC FCNTRL
      SUBROUTINE FCNTRL
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TCLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,CELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,CPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,CPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAACS,WG6CDS,CPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
```

```
     7CNHP   ,ETATHP,DHTCHP,DHTC   ,BLHP   ,WG5    ,FAR5   ,CS     ,
     8CNLP   ,ETATLP,DHTCLP,DHTF   ,BLLP   ,WG55   ,FAR55  ,HPEXT  ,
     9AM     ,ALTP  ,ETAR  ,ZF     ,PCNF   ,ZC     ,PCNC   ,WFB    ,
     $TFFHP  ,TFFLP ,PCBLF ,PCBLC  ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1    ,XWAF  ,XWAC  ,XBLF   ,XBLDU  ,XH3    ,DUMS1  ,DUMS2  ,
     2XT21   ,XP21  ,XH21  ,XS21   ,T23    ,P23    ,H23    ,S23    ,
     3T24    ,P24   ,H24   ,S24    ,T25    ,P25    ,H25    ,S25    ,
     4T28    ,P28   ,H28   ,S28    ,T29    ,P29    ,H29    ,S29    ,
     5WAD    ,WFD   ,WG24  ,FAR24  ,ETAD   ,DPDUC  ,BYPASS,DUMS3   ,
     6TS28   ,PS28  ,V28   ,AM28   ,TS29   ,PS29   ,V29    ,AM29   ,
     7XT55   ,XP55  ,XH55  ,XS55   ,XT25   ,XP25   ,XH25   ,XS25   ,
     8XWFB   ,XWG55 ,XFAR55,XWFD   ,XWG24  ,XFAR24,XXP1    ,DUMB   ,
     9T6     ,P6    ,H6    ,S6     ,T7     ,P7     ,H7     ,S7     ,
     $T8     ,P8    ,H8    ,S8     ,T9     ,P9     ,H9     ,S9
      COMMON /ALL4/
     1WG6    ,WFA   ,WG7   ,FAR7   ,ETAA   ,DPAFT  ,V55    ,V25    ,
     2PS6    ,V6    ,AM6   ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
     3TS8    ,PS8   ,V8    ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
     4VA     ,FRD   ,VJD   ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
     5FGM    ,FGP   ,WFT   ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
     6WA32   ,DPWGDS,DPWING,WA32DS,A38     ,AM38   ,V38    ,T38    ,
     7H38    ,P38   ,TS38  ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
     8V39    ,AM39  ,A39   ,BPRINT,WG37    ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39   ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW    ,T22   ,P22   ,H22    ,S22    ,T50    ,P50    ,H50
      COMMON /ALL5/
     1S50    ,WA22  ,ZI    ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
     2TFFIP  ,CNIP  ,ETATIP,DHTCIP,DHTI    ,BLIP   ,PCBLIP,PCNIGU,
     3ZIDS   ,PCNIDS,PRIDS ,ETAIDS,WAIDS  ,PRICF  ,ETAICF,WAICF  ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI    ,PCBLI ,BLI   ,T22DS ,WA21   ,WG50   ,FAR50  ,A24    ,
     6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41     ,FAN    ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
      COMMON /CNTRL/ XNHM,XNLM,T21M,P3M,YF,YFDOT,YFB,EXNL,PHI,WFBACL,
     1 YFACL,EACL,XNLDEM,XNHP,XNLP
      DIMENSION Q(9)
      DATA AWORD /6HFCNTRL/
      WORD=AWORD
      XNHP=XNHPDS*PCNC/100.
      XNLP=XNLPDS*PCNF/100.
      IF(ITRAN.EQ.1.AND.JTRAN.EQ.0) XNLDEM=XNLP
      XNHM=FIRLAG(24,XNHP,.01)
      XNLM=FIRLAG(25,XNLP,.01)
      T21M=FIRLAG(26,T21,.50)
      P3M=FIRLAG(27,P3,.02)
      YF=SQRT(WFB/4.653)-.0846
      Q(2)=0.0
      Q(3)=0.0
18    YFDOT=DERIV(28,YF)
      YFB=14.978*FIRLAG(29,YFDOT,.50)
      EXNL=25.91*(XNLDEM-XNLM)/XNLPDS-YFB
      PHI=(-9.4+(33.*XNHM/XNHPDS)*SQRT(518.67/T21M))*(.3124+.6895*T21M
     1 /518.67)
      WFBACL=14.696*PHI*P3M/3600.
      YFACL=SQRT(WFBACL/4.653)
      EACL=33.*(YFACL-YF)
```

```
      YFDOTX=EXNL
      IF(EACL.LT.EXNL) YFDOTX=EACL
      ERRW=YFDOT-YFDOTX
      DIR=0.0
      IF(YFDOTX.NE.0.0) DIR=SQRT(ABS(YFDOT/YFDOTX))
      CALL AFQUIR(Q(1),YF,ERRW,C.,20.,1.E-4,DIR,YFT,IGO)
      GO TO (19,21,20),IGO
19    YF=YFT
      GO TO 18
20    CALL ERROR
21    CONTINUE
      WFB=4.653*(YF+.0846)**2
      RETURN
      END
```

There is no main nozzle control required for this case, and subroutine NOZCTR contains only a return.

```
$IBFTC NOZCTR
      SUBROUTINE NOZCTR
      RETURN
      END
```

Example Case - One-Spool Turbojet

For this example a throttle slam from idle (60 percent corrected speed) to full afterburning for a one-spool turbojet is simulated. Subroutine DISTRB sets the demanded speed at 60 percent at TIME=0.0. If TIME is greater than 0.1 second, the demanded speed (PCNFDM) is set equal to 101.5 percent. PCNFDM is transferred to subroutine FCNTRL through COMMON block XXPCNF. Also when the speed equals 100 percent, the fuel flow to the afterburner (WFA) is ramped. Note here that IAFTBN must now be set equal to 2 so that this can be accomplished (table III). The change in IAFTBN is transferred into DYNGEN through COMMON block DESIGN. WFA is transferred into DYNGEN through COMMON block ALL4.

```
$IBFTC DISTRB
      SUBROUTINE DISTRB
      COMMON /WORDS/ WORD
      COMMON /DESIGN/
     1IDES  ,JDES  ,KDES  ,MODE  ,INIT  ,IDUMP ,IAMTP ,IGASMX,
     2IDBURN,IAFTBN,IDCD  ,IMCD  ,IDSHOC,IMSHOC,NOZFLT,ITRYS ,
     3LOOPER,NOMAP ,NUMMAP,MAPEDG,TCLALL,ERR(9)
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
```

```
2ZFDS   ,PCNFDS,PRFDS ,ETAFCS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
3ZCDS   ,PCNCDS,PRCDS ,ETACCS,WACDS ,PRCCF ,ETACCF,WACCF ,
4T4DS   ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
7T24DS  ,WFDCS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
8T7DS   ,WFACS ,DTAFDS,ETAACS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
9A55    ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
$PS55   ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
 COMMON /ALL2/
1T1     ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
2T21    ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
3T4     ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
4T55    ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
5CNF    ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
6CNC    ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
7CNHP   ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
8CNLP   ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
9AM     ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
$TFFHP  ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
 COMMON /ALL3/
1XP1    ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
2XT21   ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
3T24    ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
4T28    ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
5WAD    ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
6TS28   ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
7XT55   ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
8XWFB   ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
9T6     ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
$T8     ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
 COMMON /ALL4/
1WG6    ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
2PS6    ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
3TS8    ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
4VA     ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
5FGM    ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
6WA32   ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
7H38    ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
8V39    ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
$VJW    ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
 COMMON /ALL5/
1S50    ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
2TFFIP  ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
3ZIDS   ,PCNIDS,PRIDS ,ETAICS,WAIDS ,PRICF ,ETAICF,WAICF ,
4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
5WAI    ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
  COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
  COMMON /RPMS/ XNHPDS,XNIPDS,XNLPDS,PMIHP,PMIIP,PMILP
  COMMON/XXPCNF/PCNFDM
  IF (ITIME .EQ. 1) GO TO 1
  TIMEA=0.0
  ITIME=0
1 CONTINUE
  PCNFDM=60.0
  IF (TIME .GE. .1) PCNFDM=101.5
```

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```
      IF (PCNF .GE. 100.0) ITIME=1
      IF (ITIME .EQ. 0) GO TO 3
      IF (TIMEA .GT. 0.0) GO TO 2
      IF (ITIME .EQ. 1) TIMEA=TIME
    2 CONTINUE
      IF (TIME .GT. TIMEA) IAFTBN=2
      IF (TIME .GT. TIMEA) WFA=2.5/2.0*(TIME-TIMEA)
      IF (WFA .GE. 2.5) WFA=2.5
    3 CONTINUE
      RETURN
      END
```

Subroutine FCNTRL calculates main burner fuel flow from the speed error. The fuel flow (WFB) is transferred into DYNGEN through COMMON block ALL2.

```
$IBFTC FCNTRL
      SUBROUTINE FCNTRL
      COMMON /ALL1/
     1PCNFGU,PCNCGU,T4GU  ,DUMD1 ,DUMD2 ,DELFG ,DELFN ,DELSFC,
     2ZFDS  ,PCNFDS,PRFDS ,ETAFDS,WAFDS ,PRFCF ,ETAFCF,WAFCF ,
     3ZCDS  ,PCNCDS,PRCDS ,ETACDS,WACDS ,PRCCF ,ETACCF,WACCF ,
     4T4DS  ,WFBDS ,DTCODS,ETABDS,WA3CDS,DPCODS,DTCOCF,ETABCF,
     5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS  ,
     6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS ,
     7T24DS ,WFDDS ,DTDUDS,ETADDS,WA23DS,DPDUDS,DTDUCF,ETADCF,
     8T7DS  ,WFADS ,DTAFDS,ETAADS,WG6CDS,DPAFDS,DTAFCF,ETAACF,
     9A55   ,A25   ,A6    ,A7    ,A8    ,A9    ,A28   ,A29   ,
     $PS55  ,AM55  ,CVDNOZ,CVMNOZ,A8SAV ,A9SAV ,A28SAV,A29SAV
      COMMON /ALL2/
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
```

```
2PS6    ,V6     ,AM6    ,TS7    ,PS7    ,V7     ,AM7    ,AM25   ,
3TS8    ,PS8    ,V8     ,AM8    ,TS9    ,PS9    ,V9     ,AM9    ,
4VA     ,FRD    ,VJD    ,FGMD   ,VJM    ,FGMM   ,FGPD   ,FGPM   ,
5FGM    ,FGP    ,WFT    ,WGT    ,FART   ,FG     ,FN     ,SFC    ,
6WA32   ,DPWGDS,DPWING,WA32DS,A38    ,AM38   ,V38    ,T38    ,
7H38    ,P38    ,TS38   ,PS38   ,T39    ,H39    ,P39    ,TS39   ,
8V39    ,AM39   ,A39    ,BPRINT,WG37   ,CVDWNG,FGMWNG,FGPWNG,
9FNWING,FNMAIN,FWOVFN,PS39   ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
$VJW    ,T22    ,P22    ,H22    ,S22    ,T50    ,P50    ,H50
 COMMON /ALL5/
1S50    ,WA22   ,ZI     ,PCNI   ,CNI    ,PRI    ,ETAI   ,WACI   ,
2TFFIP  ,CNIP   ,ETATIP,DHTCIP,DHTI   ,BLIP   ,PCBLIP,PCNIGU,
3ZIDS   ,PCNIDS,PRIDS  ,ETAIDS,WAIDS  ,PRICF  ,ETAICF,WAICF  ,
4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
5WAI    ,PCBLI  ,BLI    ,T22DS  ,WA21   ,WG50   ,FAR50  ,A24    ,
6AM23   ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT   ,PCBLID,P6DSAV,
7AM6DSV,ETAASV,FAR7SV,T4PBL  ,T41    ,FAN    ,ISPCOL
 COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
 COMMON/XXPCNF/PCNFDM
 XKP=.0006351
 IF (ITRAN .EQ. 1 .AND. JTRAN .EQ. 0) PCNFDM=60.0
 ERPCNF=PCNFDM-PCNF
 ALIM=.005501
 BLIM=.008806
 WFOP3U=(ALIM-BLIM)*(PCNF-105.C)/(-45.0)+BLIM
 WFOP3L=WFOP3U/3.
 WFPB=.005833+XKP*ERPCNF
 IF(WFPB.GT.WFOP3U) WFPB=WFOP3U
 IF(WFPB.LT.WFOP3L) WFPB=WFOP3L
 WFB=WFPB*P3*14.696
 RETURN
 END
```

Subroutine NOZCTR calculates the afterburner nozzle area (A8) as a function of pressure ratio error. Values needed for this error are P3 and P2 and are transferred to NOZCTR from DYNGEN through COMMON block ALL2. The nozzle area (A8) is transferred out of NOZCTR through COMMON block ALL1.

```
$IBFTC NOZCTR
       SUBROUTINE NOZCTR
       COMMON /ALL1/
      1PCNFGU,PCNCGU,T4GU   ,DUMD1  ,DUMD2  ,DELFG  ,DELFN  ,DELSFC,
      2ZFDS   ,PCNFDS,PRFDS  ,ETAFDS,WAFDS  ,PRFCF  ,ETAFCF,WAFCF  ,
      3ZCDS   ,PCNCDS,PRCDS  ,ETACDS,WACDS  ,PRCCF  ,ETACCF,WACCF  ,
      4T4DS   ,WFBDS  ,DTCODS,ETABDS,WA3CDS,CPCODS,DTCOCF,ETABCF,
      5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCF,T2DS   ,
      6TFLPDS,CNLPDS,ETLPDS,TFLPCF,CNLPCF,ETLPCF,DHLPCF,T21DS  ,
      7T24DS  ,WFDCS  ,DTDUDS,ETADCS,WA23DS,CPDUDS,DTDUCF,ETADCF,
      8T7DS   ,WFACS  ,DTAFDS,ETAACS,WG6CDS,CPAFDS,DTAFCF,ETAACF,
      9A55    ,A25    ,A6     ,A7     ,A8     ,A9     ,A28    ,A29    ,
      $PS55   ,AM55   ,CVDNOZ,CVMNOZ,A8SAV  ,A9SAV  ,A28SAV,A29SAV
       COMMON /ALL2/
```

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```
     1T1    ,P1    ,H1    ,S1    ,T2    ,P2    ,H2    ,S2    ,
     2T21   ,P21   ,H21   ,S21   ,T3    ,P3    ,H3    ,S3    ,
     3T4    ,P4    ,H4    ,S4    ,T5    ,P5    ,H5    ,S5    ,
     4T55   ,P55   ,H55   ,S55   ,BLF   ,BLC   ,BLDU  ,BLOB  ,
     5CNF   ,PRF   ,ETAF  ,WAFC  ,WAF   ,WA3   ,WG4   ,FAR4  ,
     6CNC   ,PRC   ,ETAC  ,WACC  ,WAC   ,ETAB  ,DPCOM ,DUMP  ,
     7CNHP  ,ETATHP,DHTCHP,DHTC  ,BLHP  ,WG5   ,FAR5  ,CS    ,
     8CNLP  ,ETATLP,DHTCLP,DHTF  ,BLLP  ,WG55  ,FAR55 ,HPEXT ,
     9AM    ,ALTP  ,ETAR  ,ZF    ,PCNF  ,ZC    ,PCNC  ,WFB   ,
     $TFFHP ,TFFLP ,PCBLF ,PCBLC ,PCBLDU,PCBLOB,PCBLHP,PCBLLP
      COMMON /ALL3/
     1XP1   ,XWAF  ,XWAC  ,XBLF  ,XBLDU ,XH3   ,DUMS1 ,DUMS2 ,
     2XT21  ,XP21  ,XH21  ,XS21  ,T23   ,P23   ,H23   ,S23   ,
     3T24   ,P24   ,H24   ,S24   ,T25   ,P25   ,H25   ,S25   ,
     4T28   ,P28   ,H28   ,S28   ,T29   ,P29   ,H29   ,S29   ,
     5WAD   ,WFD   ,WG24  ,FAR24 ,ETAD  ,DPDUC ,BYPASS,DUMS3 ,
     6TS28  ,PS28  ,V28   ,AM28  ,TS29  ,PS29  ,V29   ,AM29  ,
     7XT55  ,XP55  ,XH55  ,XS55  ,XT25  ,XP25  ,XH25  ,XS25  ,
     8XWFB  ,XWG55 ,XFAR55,XWFD  ,XWG24 ,XFAR24,XXP1  ,DUMB  ,
     9T6    ,P6    ,H6    ,S6    ,T7    ,P7    ,H7    ,S7    ,
     $T8    ,P8    ,H8    ,S8    ,T9    ,P9    ,H9    ,S9
      COMMON /ALL4/
     1WG6   ,WFA   ,WG7   ,FAR7  ,ETAA  ,DPAFT ,V55   ,V25   ,
     2PS6   ,V6    ,AM6   ,TS7   ,PS7   ,V7    ,AM7   ,AM25  ,
     3TS8   ,PS8   ,V8    ,AM8   ,TS9   ,PS9   ,V9    ,AM9   ,
     4VA    ,FRD   ,VJD   ,FGMD  ,VJM   ,FGMM  ,FGPD  ,FGPM  ,
     5FGM   ,FGP   ,WFT   ,WGT   ,FART  ,FG    ,FN    ,SFC   ,
     6WA32  ,DPWGDS,DPWING,WA32DS,A38   ,AM38  ,V38   ,T38   ,
     7H38   ,P38   ,TS38  ,PS38  ,T39   ,H39   ,P39   ,TS39  ,
     8V39   ,AM39  ,A39   ,BPRINT,WG37  ,CVDWNG,FGMWNG,FGPWNG,
     9FNWING,FNMAIN,FWOVFN,PS39  ,FFOVFN,FCOVFN,FMNOFN,FNOVFD,
     $VJW   ,T22   ,P22   ,H22   ,S22   ,T50   ,P50   ,H50
      COMMON /ALL5/
     1S50   ,WA22  ,ZI    ,PCNI  ,CNI   ,PRI   ,ETAI  ,WACI  ,
     2TFFIP ,CNIP  ,ETATIP,DHTCIP,DHTI  ,BLIP  ,PCBLIP,PCNIGU,
     3ZIDS  ,PCNIDS,PRIDS ,ETAICS,WAIDS ,PRICF ,ETAICF,WAICF ,
     4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAICDS,
     5WAI   ,PCBLI ,BLI   ,T22DS ,WA21  ,WG50  ,FAR50 ,A24   ,
     6AM23  ,DUMSPL,FXFN2M,FXM2CP,AFTFAN,PUNT  ,PCBLID,P6DSAV,
     7AM6DSV,ETAASV,FAR7SV,T4PBL ,T41   ,FAN   ,ISPOOL
      COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRNT
      A8MIN=.790078
      P3QP2D=14.07
      XKI=1.0
      XKP=.1
      YICC=0.0
      DERV=P3/P2-P3QP2D
      IF (ABS(DERV) .LE. 1.0E-5) DERV=0.0
      A8INT=ALINTR(24,DERV,YICC,10000.0,-10000.0)*XKI
      A8PROP=XKP*DERV
    2 A8=A8MIN+A8INT+A8PROP
      IF (A8 .GE. A8MIN.AND. WFA .GT. 0.0) GO TO 3
      XERV=0.0
      A8INT=ALINTR(24,XERV,YICC,0.0,0.0)*XKI
      A8=A8MIN
    3 CONTINUE
      IF (WFA .LE. 1.0E-3) WFA=0.0
      RETURN
      END
```

APPENDIX D

DEBUGGING PROCEDURES

This appendix is intended to give the DYNGEN user some hints for debugging problems which may occur in running the program. If the proper input variables are provided by the user, trouble will usually not occur in running the design point (IDES=1) case. However, problems will often arise in obtaining solutions for off-design cases. One frequent source of trouble is going out of range on the component maps, usually the turbine. If this occurs, an appropriate error message will be printed out, for example,

***** CNHP OFF MAP

which indicates that the high-pressure-turbine speed parameter is out of range for the map supplied. The most obvious, and effective, way of remedying this problem is to extend the range of the maps. However, the user should take note if the engine is operating beyond the performance limits of a component.

Occasionally, trouble will occur in COMIX, CODUCT, or COAFBN when the program tries to calculate Mach numbers less than zero or greater than 0.700. The error listing will contain COMMON blocks ALL1, ALL2, etc., and the user should check variables such as AM55, AM6, AM7, AM23, and AM24 to see if they are negative or equal to 0.700. If they are and if the problem was not initiated by a map-out-of-range, it may be possible to solve the problem by changing Mach numbers at the design point. For example, if AM55 goes negative for some off-design case, increasing AM55 at the design point will tend to raise the value of AM55 for all cases and help to avoid the problem.

The Newton-Raphson method of solving simultaneous equations (appendix A) requires a matrix of approximate partial derivatives $\Delta E_i/\Delta V_j$, where ΔV_j is an incremental change in the j^{th} variable and ΔE_i is the resulting change in the i^{th} error. The size of ΔV_j can be changed by the DYNGEN user, and this often is effective in solving convergence problems. In order to change the size of ΔV_j, the user should change variables VDELTA and DELSAV from their nominal values of 1.E-4. These values are set by DATA statements in subroutine ENGBAL.

The variable VRATIO, also found in ENGBAL, may sometimes help to solve convergence problems if it is set to some value less than its nominal value of 1.0. VRATIO controls the maximum step size in changing the iteration variables.

The basic version of DYNGEN uses slightly less than 32 000 words of computer storage. If the user has a computer with a maximum storage capacity of 32 000 words, he will exceed that limit when attempting to add control system subroutines. Certain subroutines in the basic program can be omitted to save space. For example, if the engine to be simulated has only a converging exhaust nozzle, subroutine CONDIV can be eliminated. Similarly, if the engine has only a converging-diverging nozzle, subroutine CONVRG can be eliminated. In all cases, a dummy subroutine, consisting only of a RETURN statement, must replace the omitted subroutine. Also, storage space can be omitted by deleting component maps which are not used, along with their associated storage locations (table I).

A list of error messages in DYNGEN is given in the following table:

Error message	Subroutine found in
AN ERROR HAS BEEN FOUND IN (SUBROUTINE NAME)	ERROR
CHANGE TOO SMALL	ENGBAL
CNC OFF MAP	COCOMP
CNC WAS = ____, AND NOW = ____, CHECK PCNC INPUT	COCOMP
CNF OFF MAP	COFAN
CNF WAS = ____, AND NOW = ____, CHECK PCNF INPUT	COFAN
CNHP OFF MAP	COHPTB
CNI OFF MAP	COINTC
CNI WAS = ____, AND NOW = ____, CHECK PCNI INPUT	COINTC
CNIP OFF MAP	COIPTB
CNLP OFF MAP	COLPTB
COLUMN IS ZERO IN EMAT	ENGBAL
ERROR IN CONOUT INPUT	CONOUT
ERROR IN SYG	SYG
FAILED TO CONVERGE AFTER (NUMBER) LOOPS	ERROR
NO CONVERGENCE IN THERMO	THERMO
ROW IS ZERO IN EMAT	ENGBAL
TFFHP OFF MAP	COHPTB
TFFIP OFF MAP	COIPTB
TFFLP OFF MAP	COLPTB
THE ERROR IN (SUBROUTINE NAME) IS AT (NUMBER)	ERROR[1]
THE WORD ____NOT FOUND IN COMMON ARRAY	CONOUT

[1]For subroutines COAFBN, COMIX, and CODUCT.

The list contains the error messages in alphabetical order and also the subroutine in which the error message is generated. Most messages are self-explanatory; thus, the determination of the actual cause for the error message printout is left to the user.

In the subroutines COAFBN, COMIX, and CODUCT, there are many implicit loops and as a result many calls to the ERROR routine. Therefore, as shown in the previous table, a special error message is given if an error occurs in one of these subroutines. The number given in this error message corresponds to a number which has been set into the subroutine in error. For example, before each call to ERROR in subroutine COAFBN, ICOAFB=1, 2, 3, . . . is set; then, if the error message in ERROR says, THE

ERROR IN COAFBN IS AT 2, the user need only look in subroutine COAFBN for the implicit loop at which ICOAFB=2 was set. The same procedure can be followed in subroutines COMIX and CODUCT, where the error indicators are ICOMIX and ICODUC, respectively.

APPENDIX E

COMPARISON WITH GENENG AND GENENG II

In addition to having transient capability, DYNGEN combines in one program the steady-state capabilities of GENENG and GENENG II. The following list summarizes the differences (apart from transient capability) between DYNGEN and those programs:

(1) In order to conserve storage, DYNGEN uses NAMELIST input rather than Huff input. Only subroutine PUTIN needs to be modified to allow use of Huff input.

(2) Subroutine MAPBAC, which changes the independent variable, has been deleted. Instead, subroutine SEARCH is used to extrapolate if values of CNHP, CNIP, or CNLP are out of range for the turbine maps. Error messages are still printed on UNIT08 if this occurs.

(3) Additional error messages have been added to COAFBN, CODUCT, and COMIX (appendix D).

(4) Calculations may be performed in SI units.

(5) Unlike GENENG (but not GENENG II), IAFTBN=1 will not automatically result in IMCD=1. Similarly, IDBURN=1 will not automatically result in IDCD=1.

(6) Unlike GENENG (but not GENENG II), subroutine FRATIO has been deleted. The user must supply his own values of CVMNOZ and CVDNOZ. These values are single-point inputs and not table lookups as in GENENG.

APPENDIX F

SYMBOLS

A	state matrix
A_8	main nozzle throat area, m^2 (ft^2)
a	coefficient
E	error variable
ΔE	change in error variable
f( )	function
$(HP)_{ext}$	power extracted, W (Btu/sec)
h	enthalpy, J/kg (Btu/lbm)
Δh	change in enthalpy, J/kg (Btu/lbm)
I	polar moment of inertia, kg-m^2 (Btu-sec^2)
M	matrix of $\partial E_i/\partial V_j$
N	rotor speed, rpm
ΔN	change in rotor speed, rpm
P	pressure, N/m^2 (atm)
R	gas constant, J/kg-K (atm-ft^3/lbm-^oR)
s	Laplace transform variable, 1/sec
T	temperature, K (^oR)
ΔT	change in temperature, K (^oR)
t	time, sec
Δt	time step, sec
u	specific internal energy, J/kg (Btu/lbm)
V	independent variable in Newton-Raphson iteration
ΔV	change in independent variable
$\tilde{V}$	component volume, m^3 (ft^3)
$\dot{w}$	mass flow rate, kg/sec (lbm/sec)
X	independent variable

Y	dependent variable
y	difference equation variable
ϵ	parameter in difference equation
λ	eigenvalue of differential equation
μ	eigenvalue of difference equation
Φ	state matrix

Subscripts:

C	compressor
f	fuel flow
i	integer
in	into control volume
j	integer
max	maximum
min	minimum
n	integer
out	out of control volume
r	reference
T	turbine
0	base value

Superscripts:

'	denotes calculated quantity
*	denotes quantity modified by dynamic terms

General symbols internal to program: Variables in program are formed by combining these symbols.

Station numbers: See figures 1 to 11 for each type of engine.

Thermodynamic property symbols:

AM	Mach number
FAR	fuel-air ratio
H	enthalpy, J/kg (Btu/lbm)
P	total pressure, N/m^2 (atm)

PS	static pressure, N/m^2 (atm)
S	entropy, J/kg-K (Btu/lbm-^{o}R)
T	total temperature, K (^{o}R)
TS	static temperature, K (^{o}R)
U	internal energy, J/kg (Btu/lbm)
V	velocity, m/sec (ft/sec)

Component symbols:

A, AFT	afterburner
B	burner
C	inner compressor
COM	combustor
D	fan duct
F	first or fan compressor
I	intermediate (middle) compressor
M	core nozzle
MAIN	all but wing
NOZ	nozzle
OB	overboard
T	total
THP	inner (high pressure) turbine
TIP	middle (intermediate pressure) turbine
TLP	outer (low pressure) turbine
WDUCT	wing (third stream) duct
WING, WNG	wing (third stream)

Engine symbols:

BL	bleed, kg/sec (lbm/sec)
CN	ratio of corrected speed to design corrected speed
DHT	turbine delta enthalpy, J/kg (Btu/lbm)
DHTC	turbine delta enthalpy (temperature corrected), $(H_{in} - H_{out})/T_{in}$, J/kg-K (Btu/lbm-^{o}R)

DP	pressure drop, $\Delta P/P$
ETA	efficiency
ETAR	ram recovery, P_2/P_1
HPEXT	power extracted, W (hp)
PCBL	fractional bleed
PCN	percent of design shaft speed
PR	pressure ratio
TFF	turbine flow function, $\text{kg-}\sqrt{\text{K}}\text{-m}^2/\text{N-sec}$ $\left(\text{lbm-}\sqrt{^{\text{o}}\text{R}}\text{-in.}^2/\text{lbf-sec}\right)$
WA	airflow, kg/sec (lbm/sec)
WF	fuel flow, kg/sec (lbm/sec)
WG	gas flow, kg/sec (lbm/sec)
Z	ratio of pressure ratios

Miscellaneous symbols:

A	area, m^2 (ft^2)
ALTP	altitude, m (ft)
AM	Mach number of aircraft
BPRINT	bypass ratio (wing duct air/core air)
BYPASS	bypass ratio (fan duct air/air entering intermediate compressor)
C	when following component symbol, signifies "corrected"
CF	when following component symbol, signifies "correction factor"
CS	ambient speed of sound, m/sec (ft/sec)
CV	nozzle velocity coefficient
DEL	delta degradation coefficient
DOT	time derivative
DS	design value
DUM	dummy value
FCOVFN	ratio of core thrust to net thrust
FFOVFN	ratio of fan thrust to net thrust
FG	gross thrust, N (lbf)

FGM	momentum thrust, N (lbf)
FGP	pressure thrust, N (lbf)
FMOVFN	ratio of fan plus core thrust to net thrust
FN	net thrust, N (lbf)
FNOVFD	ratio of net thrust to design-point net thrust
FRD	ram drag, N (lbf)
GU	initial or guessed values
ITRYS	number of loops through engine before quitting
LOOP	variable counter
LOOPER	number of loops through engine counter
P1	standard pressure, N/m^2 (atm)
SFC	specific fuel consumption, kg/N-hr (lbm/lbf-hr)
TOLALL	tolerance on convergence
T1	standard temperature, K (^oR)
VA	velocity of aircraft, m/sec (ft/sec)
VJ	jet velocity, m/sec (ft/sec)

Input symbols:

AFTFAN	logical control for an aft-fan engine
ALTP	altitude, m (ft)
AM	Mach number of aircraft
AM6	design afterburner entrance Mach number
AM23	design ductburner entrance Mach number
AM55	design low-pressure-turbine exit Mach number
A6	area of afterburner entrance (calculated from AM6), m^2 (ft^2)
A8	main nozzle throat area (can be changed at off design), m^2 (ft^2)
A28	fan duct nozzle throat area (see A8), m^2 (ft^2)
A38	wing duct nozzle throat area (see A8), m^2 (ft^2)
CNHPDS	design corrected speed - inner turbine
CNIPDS	design corrected speed - middle turbine
CNLPDS	design corrected speed - outer turbine

CVDNOZ	nozzle thrust coefficient (duct)
CVDWNG	nozzle thrust coefficient (wing)
CVMNOZ	nozzle thrust coefficient (core)
DELFG	gross-thrust delta degradation multiplier
DELFN	net-thrust delta degradation multiplier
DELSFC	specific-fuel-consumption delta degradation multiplier
DELT1	correction to standard-day temperature, K (^{o}R)
DPAFDS	afterburner design pressure drop, $\Delta P/P$
DPCODS	combustor design pressure drop, $\Delta P/P$
DPDUDS	duct design pressure drop, $\Delta P/P$
DPWGDS	wing duct design pressure drop, $\Delta P/P$
DT	solution time step for transients, sec
DTPRNT	time step for output listings, sec
DUMSPL	logical control for spool which does not change temperature or pressure of air
ETAA	afterburner efficiency (not required)
ETAADS	afterburner efficiency at design
ETABDS	combustor efficiency at design
ETACDS	inner-compressor adiabatic efficiency at design
ETAD	ductburner combustor efficiency
ETAFDS	front (outer) compressor adiabatic efficiency at design
ETAIDS	intermediate (middle) compressor adiabatic efficiency at design
ETAR	inlet pressure recovery (ram recovery), P2/P1
ETHPDS	high-pressure-(inner) turbine design adiabatic efficiency
ETIPDS	intermediate-pressure-(middle) turbine design adiabatic efficiency
ETLPDS	low-pressure-(outer) turbine design adiabatic efficiency
FAN	logical control which indicates fan or turbojet
FXFN2M	logical control for boosted fan
FXM2CP	logical control for supercharged compressor
HPEXT	power extraction, W (hp)

IAFTBN	index on afterburning desired
IAMTP	index on ram or inlet operation desired
IDBURN	index on ductburning desired
IDCD	duct nozzle convergent-divergent when IDCD=1 (design or off design)
IDES	index for design point; must be set equal to 1 to design engine; zeroed automatically
IDUMP	index for dumping of error matrix
IGASMX	index for mixed-flow or non-mixed-flow turbofans
IMCD	main nozzle convergent-divergent when IMCD=1 (design or off design)
INIT	index for initializing guesses
ISPOOL	number of engine rotors
ITRAN	index for initiating transients
ITRYS	index for maximum number of iterations
JTRAN	index which indicates a transient is in process
MODE	independent variable designator for engine operation
NOZFLT	index for floating main or duct nozzle
PCBLC	ratio of compressor bleed to turbines to compressor airflow
PCBLDU	ratio of compressor bleed leaked into fan duct to total compressor bleed flow
PCBLF	ratio of bleed from outer compressor to fan airflow dumped overboard (i.e., leakage)
PCBLHP	fraction of PCBLC used for high-pressure (inner) turbine (cooling)
PCBLID	ratio of design value of air into wing to air into core; zero for two-stream engine
PCBLIP	fraction of PCBLC used for intermediate-pressure turbine (cooling)
PCBLLP	fraction of PCBLC used for low-pressure (outer) turbine (cooling)
PCBLOB	inner-compressor bleed compressor airflow (overboard for customer use)
PCNC	inner-compressor shaft speed as a percent of design
PCNCDS	design inner-compressor corrected speed as a percent of design
PCNF	outer-compressor shaft speed as a percent of design
PCNFDS	design outer-compressor corrected speed as a percent of design

PCNI	intermediate-compressor shaft speed as a percent of design
PCNIDS	design intermediate-compressor corrected speed as a percent of design
PMIHP	high-pressure-rotor polar moment of inertia, kg-m^2 (slug-ft^2)
PMIIP	intermediate-pressure-rotor polar moment of inertia, kg-m^2 (slug-ft^2)
PMILP	low-pressure-rotor polar moment of inertia, kg-m^2 (slug-ft^2)
PRCDS	design inner-compressor pressure ratio
PRFDS	design outer-compressor pressure ratio
PS55	static pressure at low-pressure-turbine exit, N/m^2 (atm)
P2	fan inlet total pressure, N/m^2 (atm)
SI	logical control for SI or U.S. customary (English) units
TF	final time for transient, sec
TFHPDS	design inner-turbine flow function, kg-$\sqrt{K}$-m^2/N-sec (lbm-$\sqrt{^oR}$-in.^{2}/lbf-sec)
TFIPDS	design intermediate-turbine flow function, kg-$\sqrt{K}$-m^2/N-sec (lbm-$\sqrt{^oR}$-in.^{2}/lbf-sec)
TFLPDS	design outer-turbine flow function, kg-$\sqrt{K}$-m^2/N-sec (lbm-$\sqrt{^oR}$-in.^{2}/lbf-sec)
TOLALL	tolerance on error matrix
T2	fan inlet total temperature, K (^oR)
T4	combustor exit temperature, K (^oR)
T7	afterburner exit temperature, K (^oR)
T24	ductburner exit temperature, K (^oR)
T4DS	design combustor exit temperature, K (^oR)
T7DS	design afterburner exit temperature, K (^oR)
VAFTBN	control volume associated with afterburner, m^3 (ft^3)
VCOMB	control volume associated with combustor, m^3 (ft^3)
VCOMP	control volume associated with high-pressure compressor, m^3 (ft^3)
VFAN	control volume associated with fan, m^3 (ft^3)
VFDUCT	control volume associated with fan duct, m^3 (ft^3)
VHPTRB	control volume associated with high-pressure turbine, m^3 (ft^3)
VINTC	control volume associated with intermediate compressor, m^3 (ft^3)
VIPTRB	control volume associated with intermediate-pressure turbine, m^3 (ft^3)

VLPTRB control volume associated with low-pressure turbine, m^3 (ft^3)

VWDUCT control volume associated with wing duct, m^3 (ft^3)

WACCDS design inner-compressor corrected airflow, kg/sec (lbm/sec)

WAFCDS design outer-compressor corrected airflow, kg/sec (lbm/sec)

WAICDS design intermediate-compressor corrected airflow, kg/sec (lbm/sec)

WFA fuel flow rate to afterburner (IAFTBN=2 only), kg/sec (lbm/sec)

WFB fuel flow rate to main burner (MODE=2 only), kg/sec (lbm/sec)

WFBDS design fuel flow rate to main burner (MODE=2 only), kg/sec (lbm/sec)

XNHPDS high-pressure-rotor design speed, rpm

XNIPDS intermediate-pressure-rotor design speed, rpm

XNLPDS low-pressure-rotor design speed, rpm

ZCDS, ZFDS, ZIDS design ratio of inner-compressor, fan-compressor, and middle-compressor pressure ratios, respectively; equals pressure ratio at design point on design speed line minus value of pressure ratio at lowest point on speed line, divided by high (surge) value minus low value of pressure ratio on design speed line

Output symbols:[1]

A area, m^2 (ft^2)

ALTP altitude, m (ft)

AM Mach number

BLC bleed flow out of compressor, kg/sec (lbm/sec)

BLDU bleed flow into fan duct, kg/sec (lbm/sec)

BLF bleed flow out of fan (dumped overboard), kg/sec (lbm/sec)

BLHP bleed flow into high-pressure turbine, kg/sec (lbm/sec)

BLI airflow into third stream, kg/sec (lbm/sec)

BLIP bleed flow into intermediate-pressure turbine, kg/sec (lbm/sec)

BLLP bleed flow into low-pressure turbine, kg/sec (lbm/sec)

BLOB bleed flow lost overboard (customer bleed), kg/sec (lbm/sec)

BPRINT ratio of airflow into wing duct to airflow into core

[1]Some symbols, such as T4, are followed by station numbers; see appropriate figure for each engine in order to determine station locations.

BYPASS	ratio of airflow into fan duct to airflow into intermediate compressor
CNC	corrected shaft speed - inner compressor
CNF	corrected shaft speed - fan
CNHP	corrected shaft speed - high-pressure turbine
CNHPCF	corrected speed - high-pressure-turbine correction factor
CNI	corrected shaft speed - intermediate compressor
CNIP	corrected shaft speed - intermediate-pressure turbine
CNIPCF	corrected speed - intermediate-pressure-turbine correction factor
CNLP	corrected speed - low-pressure turbine
CNLPCF	corrected speed - low-pressure-turbine correction factor
CVDNOZ	velocity coefficient of fan nozzle
CVDWNG	velocity coefficient of wing nozzle
CVMNOZ	velocity coefficient of core nozzle
DHHPCF	high-pressure-turbine delta enthalpy correction factor
DHIPCF	intermediate-pressure-turbine delta enthalpy correction factor
DHLPCF	low-pressure-turbine delta enthalpy correction factor
DHTC	work done by high-pressure turbine, J/kg (Btu/lbm)
DHTCHP	enthalpy change temperature corrected - high-pressure turbine, J/kg-K (Btu/lbm-^{o}R)
DHTCIP	enthalpy change temperature corrected - intermediate-pressure turbine, J/kg-K (Btu/lbm-^{o}R)
DHTCLP	enthalpy change temperature corrected - low-pressure turbine, J/kg-K (Btu/lbm-^{o}R)
DHTF	work done by low-pressure turbine, J/kg (Btu/lbm)
DHTI	work done by intermediate-pressure turbine, J/kg (Btu/lbm)
DPAFT	$(\Delta P/P)_{afterburner}$
DPCOM	$(\Delta P/P)_{combustor}$
DPDUC	$(\Delta P/P)_{fan\ duct}$
DPWING	$(\Delta P/P)_{wing\ duct}$
ETAA	afterburner efficiency

ETAB	combustor efficiency
ETABCF	combustor efficiency correction factor
ETAC	inner-compressor adiabatic efficiency
ETACCF	inner-compressor efficiency correction factor
ETAD	ductburner efficiency
ETAF	fan adiabatic efficiency
ETAFCF	fan efficiency correction factor
ETAI	intermediate-compressor adiabatic efficiency
ETAICF	intermediate-compressor efficiency correction factor
ETATHP	high-pressure-turbine adiabatic efficiency
ETATIP	intermediate-pressure-turbine adiabatic efficiency
ETATLP	low-pressure-turbine adiabatic efficiency
ETHPCF	high-pressure-turbine efficiency correction factor
ETIPCF	intermediate-pressure-turbine efficiency correction factor
ETLPCF	low-pressure-turbine efficiency correction factor
FAR	fuel-air ratio
FCOVFN	ratio of core thrust to net thrust
FFOVFN	ratio of fan thrust to net thrust
FG	gross thrust, N (lbf)
FGM	momentum thrust of all but wing, N (lbf)
FGMWNG	momentum thrust of wing, N (lbf)
FGP	pressure thrust of all but wing, N (lbf)
FGPWNG	pressure thrust of wing, N (lbf)
FMNOFN	ratio fan thrust plus core thrust to net thrust
FN	net thrust, N (lbf)
FNMAIN	net thrust of all but wing, N (lbf)
FNOVFD	ratio of net thrust to design-point net thrust
FNWING	net thrust of wing, N (lbf)
FRD	ram drag, N (lbf)
FWOVFN	ratio of net wing thrust to net thrust

HPEXT	power extracted, W (hp)
P	total pressure, N/m^2 (atm)
PCBLC	fraction of compressor exit air bled for cooling or lost to cycle
PCBLDU	fraction of bleed air out of compressor which leaks into fan duct
PCBLF	fraction of fan exit airflow lost overboard
PCBLHP	fraction of compressor bleed air put into high-pressure turbine
PCBLI	fraction of intermediate-compressor air which goes into third stream
PCBLIP	fraction of compressor bleed air put into intermediate-pressure turbine
PCBLLP	fraction of compressor bleed air put into low-pressure turbine
PCBLOB	fraction of bleed air out of compressor lost overboard
PCNC	inner-compressor shaft speed as percent of design
PCNF	fan-compressor shaft speed as percent of design
PCNI	intermediate-compressor shaft speed as percent of design
PRC	pressure ratio of inner compressor
PRCCF	pressure-ratio-of-inner-compressor correction factor
PRF	pressure ratio of fan
PRFCF	pressure-ratio-of-fan correction factor
PRI	pressure ratio of intermediate compressor
PRICF	pressure-ratio-of-intermediate-compressor correction factor
PS	static pressure, N/m^2 (atm)
SFC	specific fuel consumption, kg/N-hr (lbm/lbf-hr)
T	total temperature, K (^{o}R)
T3DS	design exit temperature of inner compressor, K (^{o}R)
T21DS	design exit temperature of intermediate compressor, K (^{o}R)
T22DS	design exit temperature of fan, K (^{o}R)
TFFHP	high-pressure-turbine flow function, $kg\text{-}\sqrt{K}\text{-}m^2/sec\text{-}N$ $\left(lbm\text{-}\sqrt{^{o}R}\text{-}in.^2/sec\text{-}lbf\right)$
TFFIP	intermediate-pressure-turbine flow function, $kg\text{-}\sqrt{K}\text{-}m^2/sec\text{-}N$ $\left(lbm\text{-}\sqrt{^{o}R}\text{-}in.^2/sec\text{-}lbf\right)$
TFFLP	low-pressure-turbine flow function, $kg\text{-}\sqrt{K}\text{-}m^2/sec\text{-}N$ $\left(lbm\text{-}\sqrt{^{o}R}\text{-}in.^2/sec\text{-}lbf\right)$

TFHPCF	high-pressure-turbine flow function correction factor
TFIPCF	intermediate-pressure-turbine flow function correction factor
TFLPCF	low-pressure-turbine flow function correction factor
TIME	time, sec
V	velocity, m/sec (ft/sec)
VA	velocity of aircraft, m/sec (ft/sec)
VJD	fan duct exhaust velocity, m/sec (ft/sec)
VJM	core exhaust velocity, m/sec (ft/sec)
VJW	wing duct exhaust velocity, m/sec (ft/sec)
WA	airflow, kg/sec (lbm/sec)
WAC	inner-compressor airflow, kg/sec (lbm/sec)
WACC	inner-compressor corrected airflow, kg/sec (lbm/sec)
WACCF	inner-compressor corrected airflow correction factor
WA3CDS	corrected airflow in combustor at design, kg/sec (lbm/sec)
WACI	intermediate-compressor corrected airflow, kg/sec (lbm/sec)
WAD	fan duct airflow, kg/sec (lbm/sec)
WAF	fan airflow, kg/sec (lbm/sec)
WAFC	fan corrected airflow, kg/sec (lbm/sec)
WAFCF	fan corrected airflow correction factor
WAI	intermediate-compressor airflow, kg/sec (lbm/sec)
WAICF	intermediate-compressor corrected airflow correction factor
WFA	fuel flow rate to afterburner, kg/sec (lbm/sec)
WFB	fuel flow rate to combustor, kg/sec (lbm/sec)
WFD	fuel flow rate to ductburner, kg/sec (lbm/sec)
WFT	total fuel flow rate, kg/sec (lbm/sec)
WG	gas flow rate, kg/sec (lbm/sec)
WGT	total gas flow rate, kg/sec (lbm/sec)
ZC	ratio of inner-compressor pressure ratios
ZF	ratio of fan pressure ratios
ZI	ratio of intermediate-compressor pressure ratios

Control system symbols (figs. 18 and 20):

A8MIN	minimum main nozzle throat area, m^2 (ft^2)
EACL	acceleration error
EXNL	speed error
MAX	function whose output is equal to largest input
MIN	function whose output is equal to smallest input
PCNFDM	commanded rotor speed, percent
PHI	output of acceleration schedule, kg-m^2/N-sec (lbm-in.^{2}/lbf-sec)
P3M	sensed P3, N/m^2 (atm)
P3QP2D	commanded compressor pressure ratio
T21M	sensed T21, K (^{o}R)
WFBACL	acceleration fuel flow, kg/sec (lbm/sec)
WFOP3L	lower limit on WFB/P3, kg-m^2/N-sec (lbm-in.^{2}/lbf-sec)
WFOP3U	upper limit on WFB/P3, kg-m^2/N-sec (lbm-in.^{2}/lbf-sec)
XNHM	sensed core speed, rpm
XNHP	core speed, rpm
XNLDEM	commanded fan speed, rpm
XNLM	sensed fan speed, rpm
XNLP	fan speed, rpm
YF	metering valve position
YFACL	metering valve position for accelerations
YFB	metering valve position feedback
YFDOT	time derivative of metering valve position

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TABLE I. - COMPONENT MAP SPECIFICATION

[DYNGEN is supplied with storage locations and dummy maps for all components. The user may supply maps for a particular engine and leave the maps for unused components in the simulation.]

Engine configuration	Component map[1]						
	BLKFAN	BLKINT	BLKCMP	CMBDAT	HPTDAT	IPTDAT	LPTDAT
a	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b	↓	↓	↓	↓	↓	No	↓
c[2]	↓	↓	↓	↓	↓	No	↓
d	↓	↓	↓	↓	↓	Yes	↓
e	↓	No	↓	↓	↓	No	↓
f	↓	Yes	↓	↓	↓	Yes	↓
g[2]	↓	Yes	↓	↓	↓	No	↓
h	↓	No	↓	↓	↓	No	↓
i	↓	Yes	↓	↓	↓	Yes	↓
j	↓	No	↓	↓	↓	No	↓
k	↓	No	No	↓	No	No	↓

[1]A "Yes" entry means that component map must be specified. A "No" entry means that component map need not be specified and storage space may be deleted. However, if storage space is not deleted and BLOCK DATA are supplied for components which are not used, calculations are not affected.

[2]Engine configurations c and g (figs. 3 and 7) have intermediate and core compressors physically attached. Combination is driven by intermediate-pressure turbine. Calculation bypasses routine which calculates high-pressure-turbine performance but transfers turbine performance data from this routine into that of intermediate-pressure turbine to represent turbine performance. Since intermediate-pressure turbine speed is set by speed of intermediate compressor, which also sets speed of combined compressors, this procedure is necessary. In these cases, COIPTB uses COMMON/HTUR13/, which is high-pressure-turbine data.

TABLE II. - INPUTS FOR DESIGN POINTS

Variable[1]	Units or type	Definition	Default value	a	b	c	d	e	f	g	h	i	j	k
				Engine configuration										
				a	b	c	d	e	f	g	h	i	j	k
				Number of spools										
				3	2	2	3	2	3	2	2	3	2	1
				Number of streams										
				3	3	3	2	2	3	3	2	2	1	1
				Turbo-fan	Boosted fan	Super-charged com-pressor	Turbofan		Aft fan	Super-charged com-pressor	Aft fan		Turbojet	
Variables that specify engine configuration and should be input only when IDES=1														
PRFDS		Fan pressure ratio	0.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WAFCDS	kg sec (lbm sec)	Fan corrected airflow												
ETAFDS		Fan efficiency												
ZFDS		Ratio of pressure ratios of fan												
PCNFDS		Fan corrected speed												
PRIDS		Intermediate pressure ratio	1.5					No			No		No	No
WAICDS	kg sec (lbm sec)	Intermediate corrected airflow	0.											
ETAIDS		Intermediate efficiency	1.0											
ZIDS		Ratio of pressure ratios of intermediate compressor	.75											
PCNIDS		Intermediate compressor corrected speed	100.		No									
PRCDS		Compressor pressure ratio	0.		No			Yes			Yes		Yes	
WACCDS	kg sec (lbm sec)	Compressor corrected airflow		No	No	No	No	Yes	No	No	Yes	No	No	
PCBLID		Fraction of air into wing duct		Yes	Yes	Yes	0.	0.	Yes	Yes	0.	0.	0.	0.
ETACDS		Compressor efficiency				Yes	Yes	Yes		Yes	Yes	Yes	Yes	No
ZCDS		Ratio of pressure ratios of compressor				Yes				Yes				No
PCNCDS		Compressor corrected speed	100.			No				No				No
ETABDS		Combustor efficiency	0.			Yes				Yes				Yes
DPCODS		Combustor pressure drop, ΔP P				Yes				Yes				Yes
T4DS	K (^oR)	Turbine inlet temperature		T4DS or WFBDS, but not both, should be specified by user for all engine types. If MODE=0, supply T4DS; if MODE=2, supply WFBDS. MODE=1 and MODE=3 cannot be used when IDES=1.										
WFBDS	kg sec (lbm sec)	Combustor fuel flow												
TFHPDS	$kg\sqrt{K}$-m^2/N-sec (lbm-$\sqrt{^oR}$-in.^{2}/lbf-sec)	High-pressure-turbine flow function		Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
CNHPDS	percent/$\sqrt{K}$ (percent/$\sqrt{^oR}$)	High-pressure turbine corrected speed			Yes	No		Yes		No	Yes		Yes	
ETHPDS		High-pressure turbine efficiency			Yes	No		Yes		No	Yes		Yes	
TFIPDS	kg-$\sqrt{K}$-m^2/N-sec (lbm-$\sqrt{^oR}$-in.^{2}/lbf-sec)	Intermediate-pressure-turbine flow function			No	Yes		No		Yes	No		No	
CNIPDS	percent/$\sqrt{K}$ (percent/$\sqrt{^oR}$)	Intermediate-pressure-turbine corrected speed			No			No			No		No	
ETIPDS		Intermediate-pressure-turbine efficiency			No			No			No		No	
TFLPDS	kg-$\sqrt{K}$-m^2/N-sec (lbm-$\sqrt{^oR}$-in.^{2}/lbf-sec)	Low-pressure-turbine flow function			Yes			Yes			Yes		Yes	Yes
CNLPDS	percent/$\sqrt{K}$ (percent/$\sqrt{^oR}$)	Low-pressure-turbine corrected speed			Yes			Yes			Yes		Yes	Yes
ETLPDS		Low-pressure-turbine efficiency			Yes			Yes			Yes		Yes	Yes
DPDUDS		Fan duct pressure drop, ΔP P		Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	No	No
DPWGDS		Wing duct pressure drop, ΔP P		Optional	Optional	Optional	No	No	Optional	Optional	No	No	No	No
DPAFDS		Afterburner pressure drop, ΔP P		Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
T7DS	K (^oR)	Afterburner exit temperature		T7DS and ETAADS must be supplied only if afterburning operation will be requested for some off-design case. Afterburning should not be requested when IDES=1.										
ETAADS		Afterburner efficiency												
AM55		Low-pressure-turbine exit Mach number		AM55 or PS55, but not both, should be specified by the user for all engine types. Unless a particular value for AM55 is desired, 0.300 is a reasonable number to use.										
PS55	N m^2 (atm)	Low-pressure-turbine exit static pressure												
AM23		Ductburner entrance Mach number		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No

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Variable	Units	Description	Default											
IGASMX		Index for mixed or unmixed flow	0	IGASMX determines whether fan and core streams will be mixed. Available options: =-1 Streams will be separate; A6 will be calculated to give user-specified value of AM6. .0 Streams will be separate; A6 will be set equal to A55; AM6 should not be supplied as input. .1 Streams will be mixed; A25 will be calculated to obtain PS25=PS55; A6 will be set equal to A55+A25; AM6 should not be supplied as input. =2 Streams will be mixed; A25 will be calculated to obtain PS25=PS55; A6 will be calculated to give user-specified value of AM6.										
AM6		Afterburner entrance Mach number	0.											
ISPOOL		Index for number of spools	0	3	2	2	3	2	3	2	2	3	2	1
SI	Logical	Logical control for SI units	0.	T or F	T or F	T or F	T or F	T or F	T or F	T or F	T or F	T or F	T or F	T or F
FXFN2M	↓	Logical control for boosted fan	↓	F	T	F	F	F	F	F	F	F	F	F
FXM2CP	↓	Logical control for supercharged compressor	↓	↓	F	T	↓	F	F	T	F	F	↓	↓
DUMSPL	↓	Logical control for dummy spool	↓	↓	F	F	↓	T	F	F	T	F	↓	↓
AFTFAN	↓	Logical control for aft-fan engine	↓	↓	F	F	↓	F	T	T	T	T	↓	↓
FAN	↓	Logical control for turbofan or turbojet	↓	T	T	T	T	T	T	T	T	T	↓	↓
Variables that should be input at the design point but that may be changed for off-design operation														
IDES		Index to indicate design point	0	1	1	1	1	1	1	1	1	1	1	1
ITRYS		Index for maximum number of iterations	0	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TOLALL		Tolerance on error vector	0.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IAMTP		Index on ram or inlet operation	0	IAMTP determines which inlet variables are to be calculated. Available options: 0 User specifies ALTP and AM; standard-day T1 and P1 and military-specification ETAR will be calculated. -1 User specifies ALTP, AM, and ETAR; standard-day T1 and P1 will be calculated. =2 User specifies ALTP, AM, and DELTI; military-specification ETAR will be calculated; standard-day P1 will be used; DELTI will be added to standard-day T1. .3 User specifies ALTP, AM, and P2; ETAR and standard-day T1 will be calculated. 4 User specifies T2 and P2. .5 User specifies ALTP and AM; ETAR is calculated from a user-supplied table of ETAR as a function of AM located in subroutine RAM2; standard T1 and P1 are calculated.										
ALTP	m (ft)	Altitude	0.											
AM		Mach number of aircraft	↓											
ETAR		Inlet pressure recovery	↓											
DELTI	K (°R)	Correction to standard-day temperature	↓											
P2	N/m² (atm)	Fan inlet total pressure	↓											
T2	K (°R)	Fan inlet total temperature	↓											
MODE		Independent variable designator	0	T4DS or WFBDS, but not both, should be specified by user for all engine types. If MODE=0, supply T4DS; if MODE=2, supply WFBDS. MODE=1 and MODE=3 cannot be used when IDES=1.										
IDUMP		Index for dumping program messages	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
INIT		Index for initializing point	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
IDBURN		Index for ductburning	↓	0	0	0	0	0	0	0	0	0	0	0
IAFTBN		Index for afterburning	↓	0	0	0	0	0	0	0	0	0	0	0
IDCD		Index for converging-diverging duct nozzle	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
IMCD		Index for converging-diverging main nozzle	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
NOZFLT		Index for floating nozzle exit area	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
DELFG		Correction factor on gross thrust	0.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DELFN		Correction factor on net thrust	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
DELSFC		Correction factor on specific fuel consumption	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
CVMNOZ		Main nozzle thrust coefficient	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
CVDNOZ		Duct nozzle thrust coefficient	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	No	No
CVDWNG		Wing nozzle thrust coefficient	↓	↓	↓	↓	No	No	↓	↓	No	No	No	No
PCBLC		Fraction of compressor flow removed as bleed	↓	Bleed distribution in an engine is governed by BLF = PCBLF•WAF, where BLF is fan flow lost overboard, and BLC = PCBLC•WAC, where BLC is compressor bleed flow, which is distributed as follows: BLDU = PCBLDU•BLC; BLOB = PCBLOB•BLC; BLHP = PCBLHP•BLC; BLIP = PCBLIP•BLC; BLLP = PCBLLP•BLC, where PCBLDU + PCBLOB + PCBLHP + PCBLIP + PCBLLP must equal 1 to maintain conservation of flow.										
PCBLDU		Fraction of bleed going to fan duct	↓											
PCBLOB		Fraction of bleed lost overboard	↓											
PCBLF		Fraction of fan airflow lost to cycle	↓											
PCBLHP		Fraction of bleed going to high-pressure turbine	↓											
PCBLIP		Fraction of bleed going to intermediate-pressure turbine	↓											
PCBLLP		Fraction of bleed going to low-pressure turbine	↓											
HPEXT	W (hp)	Power extracted from high-pressure turbine	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional

[1]A "Yes" entry in the columns on the right means that the user must supply a value for variable in question; default value should not be used. A "No" entry means the user must not supply a value; default value should be used. "Optional" means that the user may supply a value, but default value can be used if desired. If table entry is a specific value such as T, F, 0, or 0., that value should be used.

TABLE III. - PROGRAM INDICES

Name	Value	Features[1]				Purpose
		1	2	3	4	
IDES	0	X				Off-design case
	1	X				Design-point case
MODE	0		X	X		Specify T4
	1			X		Specify PCNC
	2		X	X		Specify WFB
	3			X		Specify PCNF
INIT	0	X	X			Will call GUESS
	1	X	X			Will not call GUESS
IDUMP	0		X	X		Will not print stored messages
	1		X	X		Will print stored messages after errors
	2		X	X		Will print stored messages after every point
IAMTP	0		X	X		Input AM, ALTP; military-specification ETAR will be used
	1		X	X		Input AM, ALTP, ETAR
	2		X	X		Input AM, ALTP, DELT1; military-specification ETAR will be used
	3		X	X		Input AM, ALTP, P2
	4		X	X		Input P2, T2
	5		X	X		Input AM, ALTP; ETAR schedule stored in RAM2
IGASMX	-1			X		Separate flow, input AM6
	0			X		Separate flow, A6 = A55
	1			X		Mixed flow, A6 = A25 + A55
	2			X		Mixed flow, input AM6
IDBURN	0	X				No ductburning
	1	X			X	Ductburning, input T24
	2	X			X	Ductburning, input WFD
IAFTBN	0	X				No afterburning
	1	X			X	Afterburning, input T7
	2	X			X	Afterburning, input WFA
IDCD	0		X	X		Convergent duct nozzle
	1		X	X		Convergent-divergent duct nozzle
IMCD	0		X	X		Convergent main nozzle
	1		X	X		Convergent-divergent main nozzle
NOZFLT	0	X				A9 and A29 are held constant
	1	X			X	A9 will be set for fully expanded flow
	2	X			X	A29 will be set for fully expanded flow
	3	X			X	A9 and A29 will be set for fully expanded flow
ITRYS	N[2]			X		Number of iterations before calling ERROR
TOLALL	X[3]			X		Tolerance which errors must satisfy for convergence
SI	T			X		Input and output in SI units
	F			X		Input and output in English units
ITRAN	0		X	X		A steady-state point
	1			X		The initial condition for a transient

[1] 1 - Automatically returns to zero after each point.
2 - Can be used for design or off design.
3 - Value remains as input unless changed by new input.
4 - A setup case must be run where all components are matched; then the identical case can be run using these options.

[2] User-specified value; default value is 0

[3] User-specified value; default value is 0.

TABLE IV. - INPUTS FOR OFF-DESIGN POINTS

Variable	Units or type	Definition
ITRYS	---------------	Index for maximum number of iterations
TOLALL	---------------	Tolerance on error vector
INIT	---------------	Index for initializing point
MODE	---------------	Independent variable designator[1]
T4	K (°R)	Turbine inlet temperature[1]
PCNC	---------------	Compressor speed[1]
WFB	kg/sec (lbm/sec)	Combustor fuel flow[1]
PCNF	---------------	Fan speed[1]
IDUMP	---------------	Index for dumping program messages
IAMTP	---------------	Index on ram or inlet operation[2]
ALTP	m (ft)	Altitude[2]
AM	---------------	Mach number[2]
ETAR	---------------	Inlet pressure recovery[2]
DELT1	---------------	Correction to standard-day temperature[2]
P2	N/m^2 (atm)	Fan inlet total pressure[2]
T2	K (°R)	Fan inlet total temperature[2]
IDCD	---------------	Index for converging-diverging duct nozzle[3]
IMCD	---------------	Index for converging-diverging main nozzle[3]
NOZFLT	---------------	Index for floating nozzle exit area[3]
IDBURN	---------------	Index for ductburning[4]
T24	K (°R)	Ductburner exit temperature[4]
WFD	kg/sec (lbm/sec)	Ductburner fuel flow[4]
ETAD	---------------	Ductburner efficiency[4]
IAFTBN	---------------	Index for afterburning[5]
T7	K (°R)	Afterburner exit temperature[5]
WFA	kg/sec (lbm/sec)	Afterburner fuel flow[5]
DELFG	---------------	Correction factor on gross thrust
DELFN	---------------	Correction factor on net thrust
DELSFC	---------------	Correction factor on specific fuel consumption
CVDNOZ	---------------	Duct nozzle thrust coefficient
CVMNOZ	---------------	Main nozzle thrust coefficient
CVDWNG	---------------	Wing nozzle thrust coefficient
A6	m^2 (ft^2)	Afterburner entrance area
A38	m^2 (ft^2)	Wing nozzle throat area
A8	m^2 (ft^2)	Main nozzle throat area
A28	m^2 (ft^2)	Duct nozzle throat area
HPEXT	W (hp)	Power extracted from high-pressure turbine
PCBLC	---------------	Fraction of compressor airflow removed as bleed[6]
PCBLDU	---------------	Fraction of bleed going to fan duct[6]
PCBLOB	---------------	Fraction of bleed lost overboard[6]
PCBLHP	---------------	Fraction of bleed going to high-pressure turbine[6]
PCBLIP	---------------	Fraction of bleed going to intermediate-pressure turbine[6]
PCBLLP	---------------	Fraction of bleed going to low-pressure turbine[6]
PCBLF	---------------	Fraction of fan airflow lost to cycle[6]

[1]Four basic options are available for specifying off-design operating points: MODE=0, specify T4; MODE=1, specify PCNC; MODE=2, specify WFB; MODE=3, specify PCNF.

[2]IAMTP determines which inlet variables are to be specified. The following options are available: IAMTP=0 - User specifies ALTP and AM; standard-day T1 and P1 and military-specification ETAR will be calculated. IAMTP=1 - User specifies ALTP, AM, and ETAR; standard-day T1 and P1 will be calculated. IAMTP=2 - User specifies ALTP, AM, and DELT1; military-specification ETAR will be calculated; standard-day P1 will be used; DELT1 will be added to standard-day T1. IAMTP=3 - User specifies ALTP, AM, and P2; ETAR and standard-day T1 will be calculated. IAMTP=4 - User specifies T2 and P2. IAMTP=5 - User specifies ALTP and AM; ETAR is calculated from user-supplied table of ETAR as a function of AM located in subroutine RAM2; standard-day P1 and T1 are calculated.

[3]If IDCD=1 at design point, A29 will automatically be calculated to obtain fully expanded flow. However, to recalculate A29 for an off-design point, NOZFLT must be set equal to 2 or 3 in addition to specifying IDCD=1. Similarly, IMCD=1 at design point means A9 will be calculated to obtain fully expanded flow; but to recalculate A9 for an off-design case, NOZFLT must be set equal to 1 or 3 in addition to specifying IMCD=1. If NOZFLT=0, A9 and A29 will retain their previous values.

[4]The following options are available for ductburning: IDBURN=0, no ductburning; IDBURN=1, specify T24; IDBURN=2, specify WFD. If IDBURN=1 or IDBURN=2 is to be used, the user must also specify a value for ETAD. No parameters other than T24, WFD, and ETAD may be changed while running a ductburning case, unless program is in transient (ITRAN=1) mode. This restriction is necessary because, in steady-state mode, DYNGEN recalculates A28 to maintain operating point which was established in case immediately previous to ductburning case.

[5]The following options are available for afterburning: IAFTBN=0, no afterburning; IAFTBN=1, specify T7; IAFTBN=2, specify WFA. The user need not specify a value for ETAA since it is calculated automatically. No parameters other than T7 or WFA may be changed while running an afterburning case, unless program is in transient (ITRAN=1) mode. This restriction is necessary because, in steady-state mode, DYNGEN recalculates A8 to maintain operating point which was established in case immediately previous to afterburning case.

[6]Bleed distribution in engine is governed by following equations:

BLF = PCBLF*WAF

where BLF is fan flow lost overboard.

BLC = PCBLC*WAC

where BLC is compressor bleed flow, which is distributed as follows:

BLDU = PCBLDU*BLC

BLOB = PCBLOB*BLC

BLHP = PCBLHP*BLC

BLIP = PCBLIP*BLC

BLLP = PCBLLP*BLC

PCBLDU + PCBLOB + PCBLHP + PCBLIP + PCBLLP must equal 1 to maintain conservation of flow.

TABLE V. - TRANSIENT INPUTS

Variable[1]	Units or type	Definition	Default value	Engine configuration										
				a	b	c	d	e	f	g	h	i	j	k
				Number of spools										
				3	2	2	3	2	3	2	2	3	2	1
				Number of streams										
				3	3	3	2	2	3	3	2	2	1	1
				Turbo-fan	Boosted fan	Super-charged com-pressor	Turbofan		Aft fan	Super-charged com-pressor	Aft fan		Turbojet	
ITRAN	---------------	Index to begin transient[2]	0	1	1	1	1	1	1	1	1	1	1	1
DT	sec	Time step for modified Euler method	0.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DTPRNT	sec	Time interval between printouts	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
TF	sec	Final time for transient	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
PMILP	$kg\text{-}m^2$ ($slug\text{-}ft^2$)	Low-pressure-rotor polar moment of inertia	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
PMIIP	$kg\text{-}m^2$ ($slug\text{-}ft^2$)	Intermediate-pressure-rotor polar moment of inertia	↓	↓	No	↓	↓	No	↓	↓	No	↓	No	No
PMIHP	$kg\text{-}m^2$ ($slug\text{-}ft^2$)	High-pressure-rotor polar moment of inertia	↓	↓	Yes	No	↓	Yes	↓	No	Yes	↓	Yes	No
XNLPDS	rpm	Low-pressure-rotor design speed[3]	↓	↓	Yes	Yes	↓	Yes	↓	Yes	Yes	↓	Yes	Yes
XNIPDS	rpm	Intermediate-pressure-rotor design speed[3]	↓	↓	No	Yes	↓	No	↓	Yes	No	↓	No	No
XNHPDS	rpm	High-pressure-rotor design speed[3]	↓	↓	Yes	No	↓	Yes	↓	No	Yes	↓	Yes	No
VFAN	m^3 (ft^3)	Fan volume	↓	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
VINTC	↓	Intermediate-pressure-compressor volume	↓	↓	↓	↓	↓	No	↓	↓	No	↓	No	No
VCOMP	↓	High-pressure-compressor volume	↓	↓	↓	↓	↓	Optional	↓	↓	Optional	↓	Optional	No
VCOMB	↓	Combustor volume	↓	↓	↓	↓	↓	Optional	↓	↓	Optional	↓	Optional	Optional
VHPTRB	↓	High-pressure-turbine volume	↓	↓	↓	No	↓	Optional	↓	No	Optional	↓	Optional	No
VIPTRB	↓	Intermediate-pressure-turbine volume	↓	↓	No	Optional	↓	No	↓	Optional	No	↓	No	No
VLPTRB	↓	Low-pressure-turbine volume	↓	↓	Optional	↓	↓	Optional	↓	↓	Optional	↓	Optional	Optional
VAFTBN	↓	Afterburner volume	↓	↓	↓	↓	↓	Optional	↓	↓	Optional	↓	Optional	Optional
VFDUCT	↓	Fan duct volume	↓	↓	↓	↓	↓	Optional	↓	↓	Optional	↓	No	No
VWDUCT	↓	Wing duct volume	↓	↓	↓	↓	No	No	↓	↓	No	No	No	No

[1]A "Yes" entry in the columns on the right means that the user must supply a value for the variable in question; the default value should not be used. A "No" entry means the user must not supply a value; the default value should be used. "Optional" means that the user may supply a value, but the default value can be used if desired.

[2]Setting ITRAN equal to 1 has the following effects: (1) The next point calculated will be for TIME = 0.0. For each succeeding time point, subroutine DISTRB will be called by ENGBAL to obtain transient input. (2) If MODE = 2, subroutine FCNTRL will be called by COCOMB to obtain a controlled value of WFB. (3) If IAFTBN = 1 or 2, A8 will not be automatically recalculated. If the user wants controlled A8, he should write subroutine NOZCTR, which is called by COMNOZ. (4) If IDBURN=1 or 2, A28 will not be automatically recalculated. The user can easily add a subroutine similar to NOZCTR to be called by CODUCT if he wishes to have controlled A28.

[3]Rotor design speed is defined as the rpm corresponding to 100 percent PCNF, PCNI, or PCNC. DYNGEN assumes that rotor mechanical speed (in percent) is equal to corrected speed (in percent) at the design point. For example, if PCNCDS = 80.0 and the user wants high-pressure-rotor speed to be 10 000 rpm at the design point, he should input XNHPDS = 10 000/0.80 = 12 500.

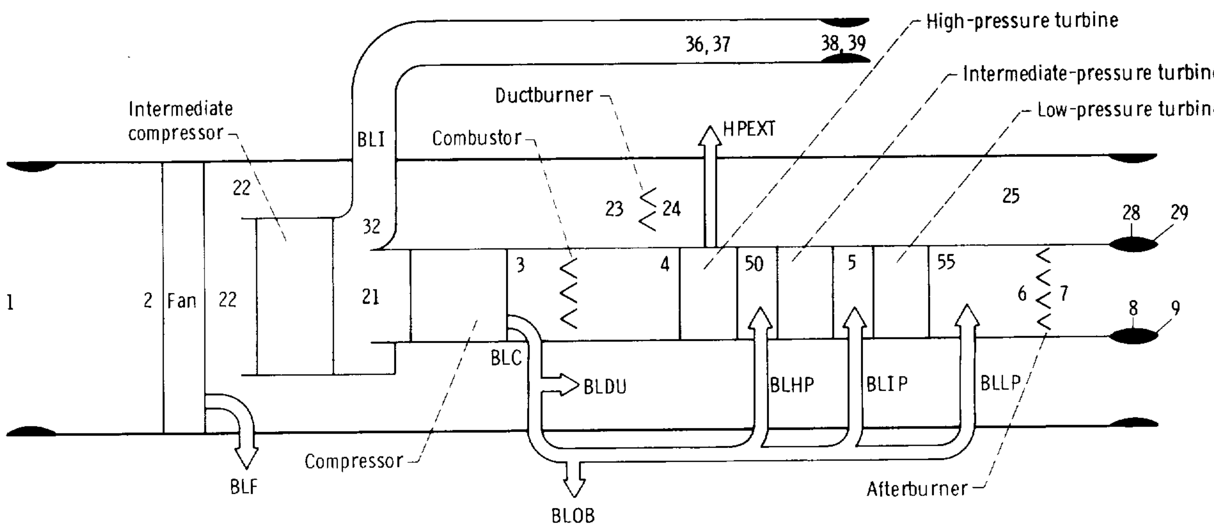


Figure 1. - Three-spool, three-stream turbofan engine (type a).

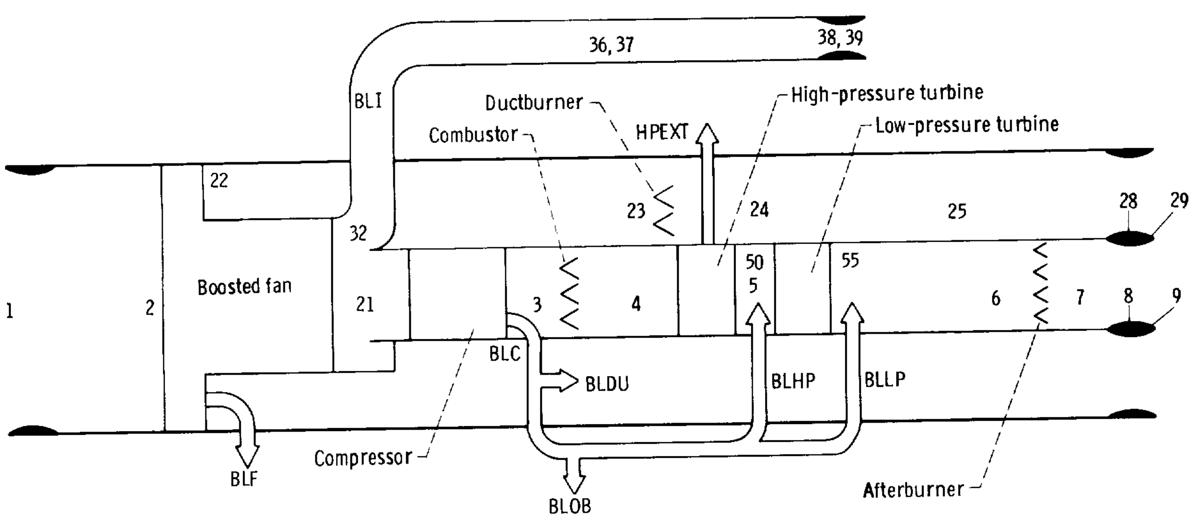


Figure 2. - Two-spool, three-stream boosted-fan engine (type b).

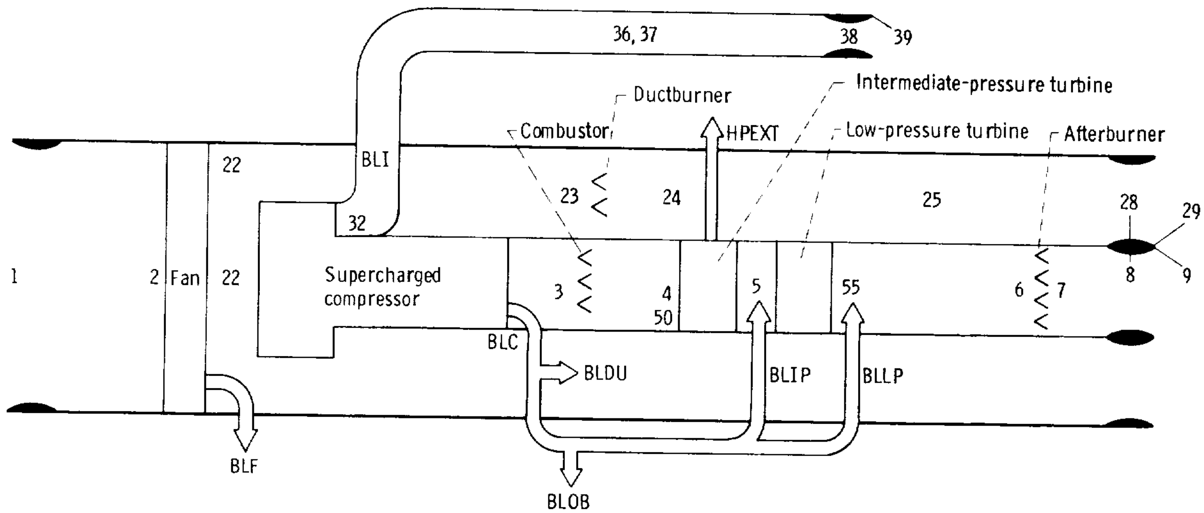


Figure 3. - Two-spool, three-stream, supercharged-compressor engine (type c).

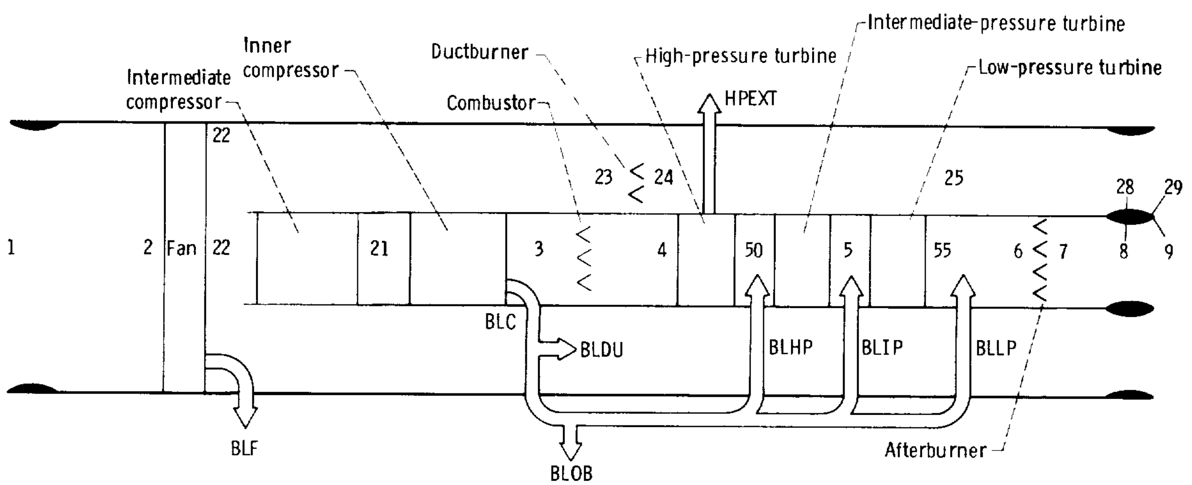


Figure 4. - Three-spool, two-stream engine (type d).

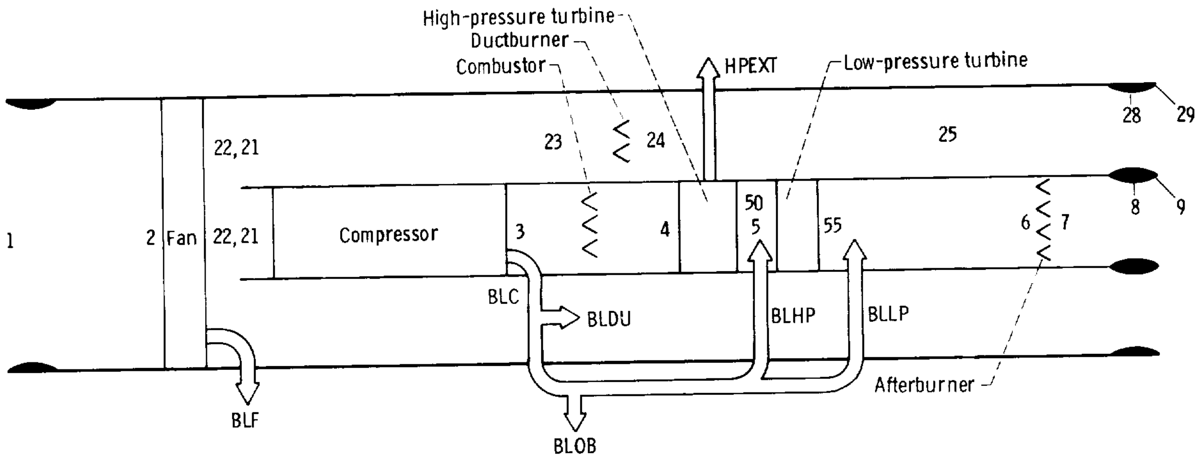


Figure 5. - Two-spool, two-stream turbofan engine (type e).

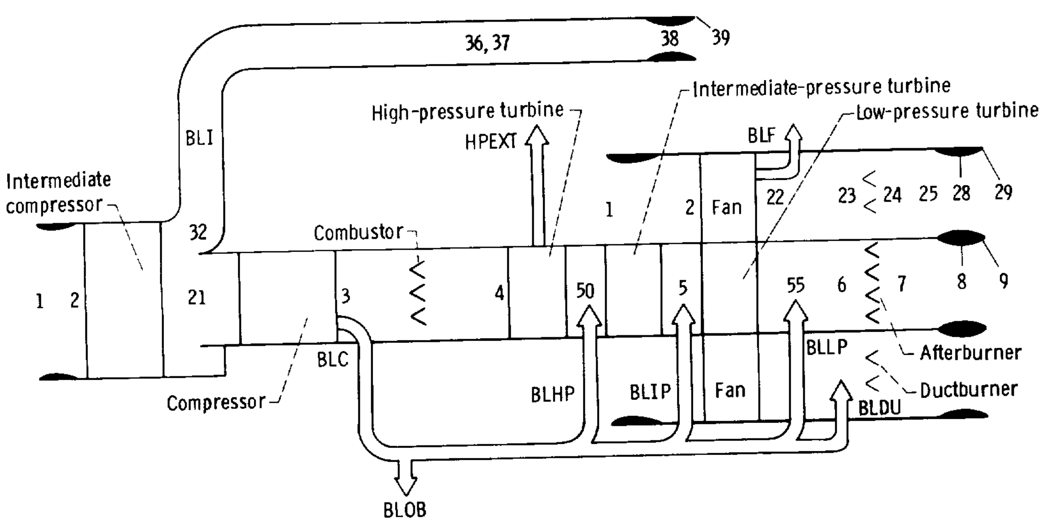


Figure 6. - Three-spool, three-stream, aft-fan engine (type f).

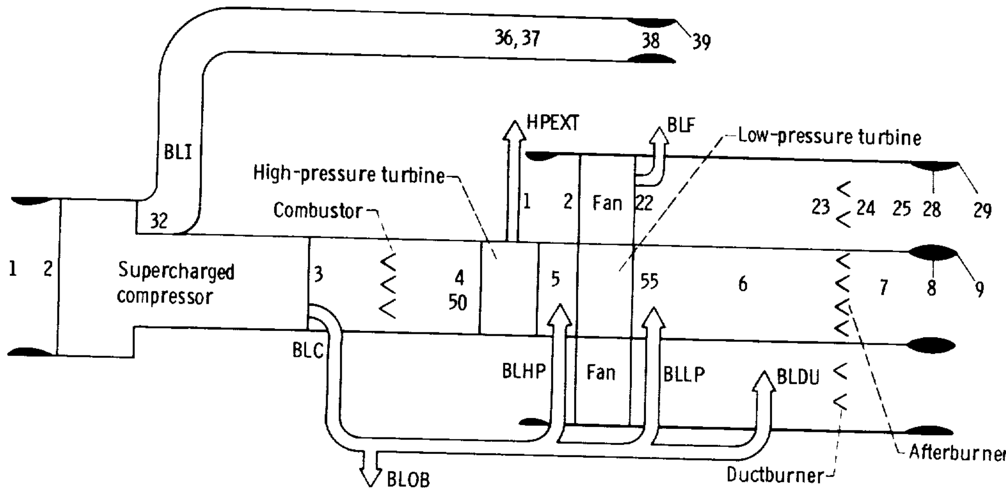


Figure 7. - Two-spool, three-stream, aft-fan engine (type g).

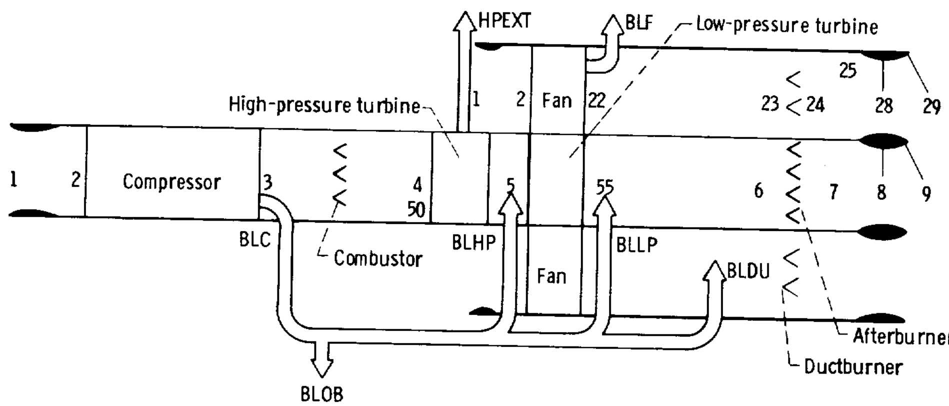


Figure 8. - Two-spool, two-stream aft-fan engine (type h).

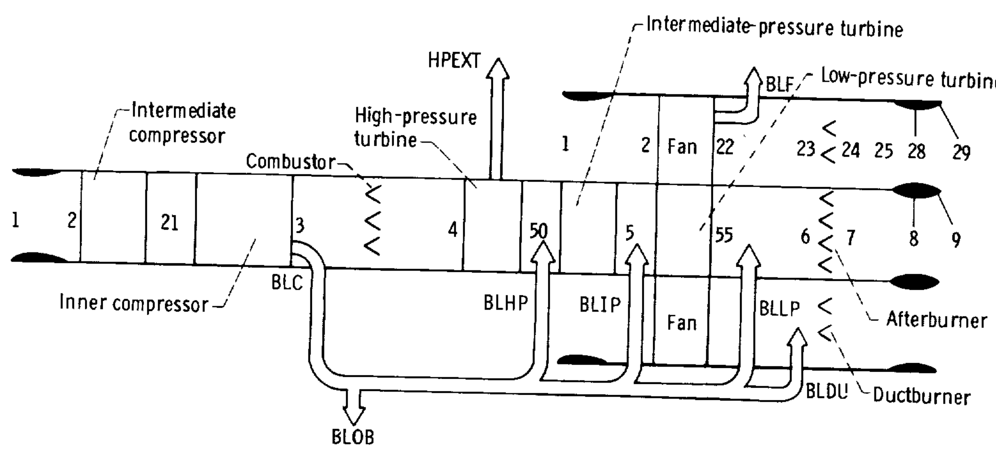


Figure 9. - Three-spool, two-stream aft-fan engine (type i).

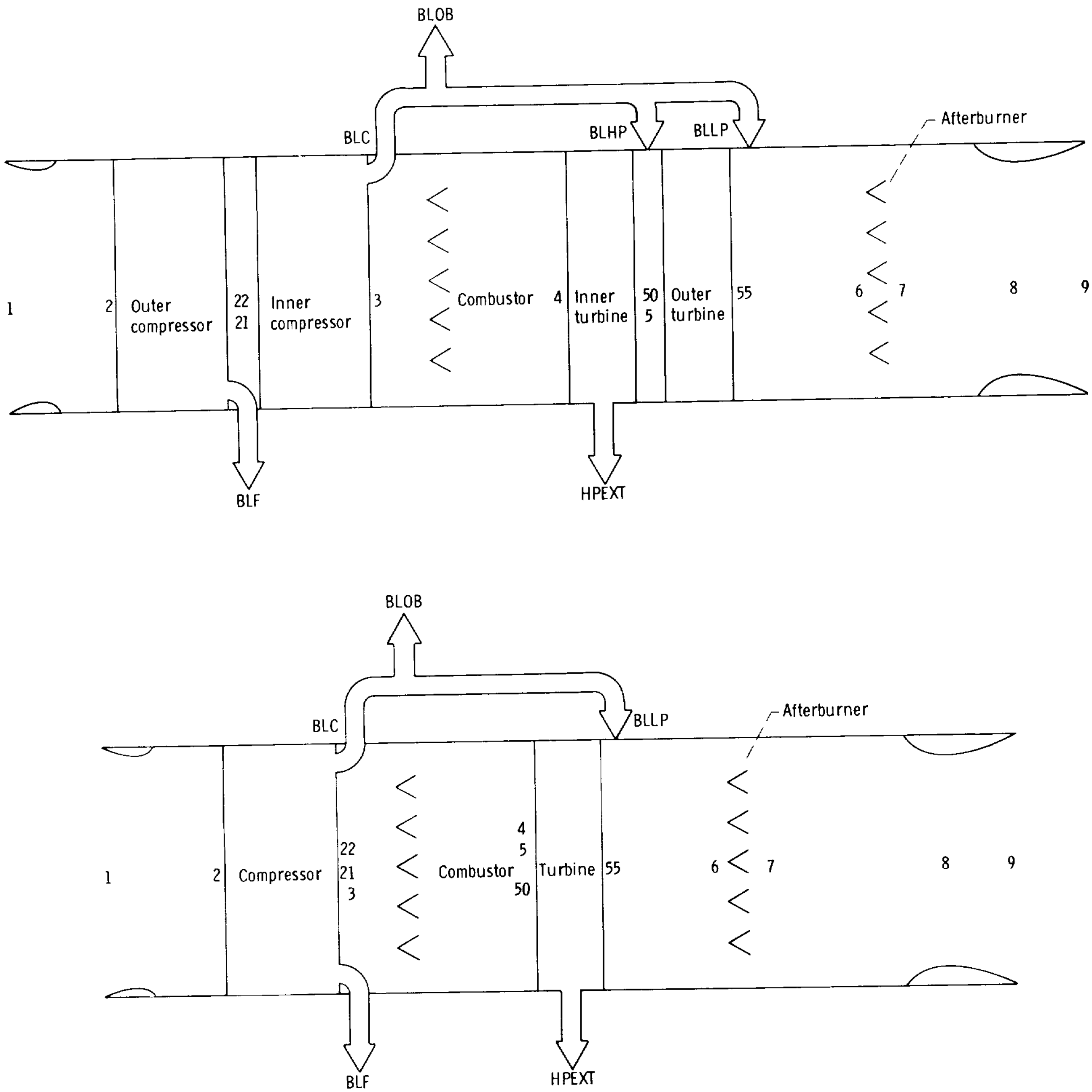
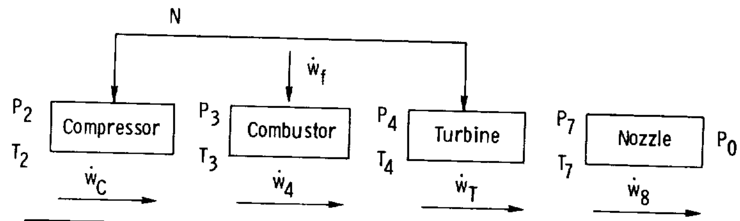


Figure 11. - One-spool turbojet (type k).



Guessed variables, V_i	Error variables, E_i
Speed, N	Power, $\dot{w}_C \Delta h_C - \dot{w}_T \Delta h_T$
Compressor pressure ratio, P_3/P_2	Turbine flow function, $\left(\dot{w}_4\sqrt{T_4}/P_4\right) - \left(\dot{w}_4\sqrt{T_4}/P_4\right)$
Turbine flow function, $\dot{w}_4\sqrt{T_4}/P_4$	Nozzle pressure, $P_7 - P_7'$

Figure 12. - Steady-state engine calculations for a turbojet.

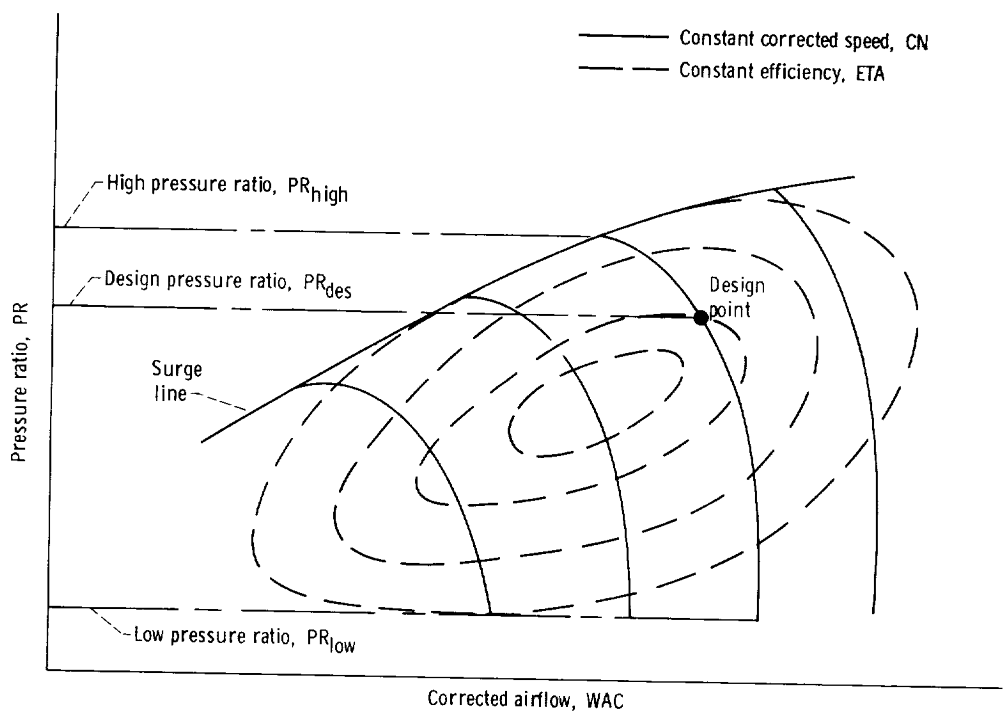


Figure 13. Example of specific fan-compressor map. $Z = (PR_x - PR_{low})/(PR_{high} - PR_{low})$.

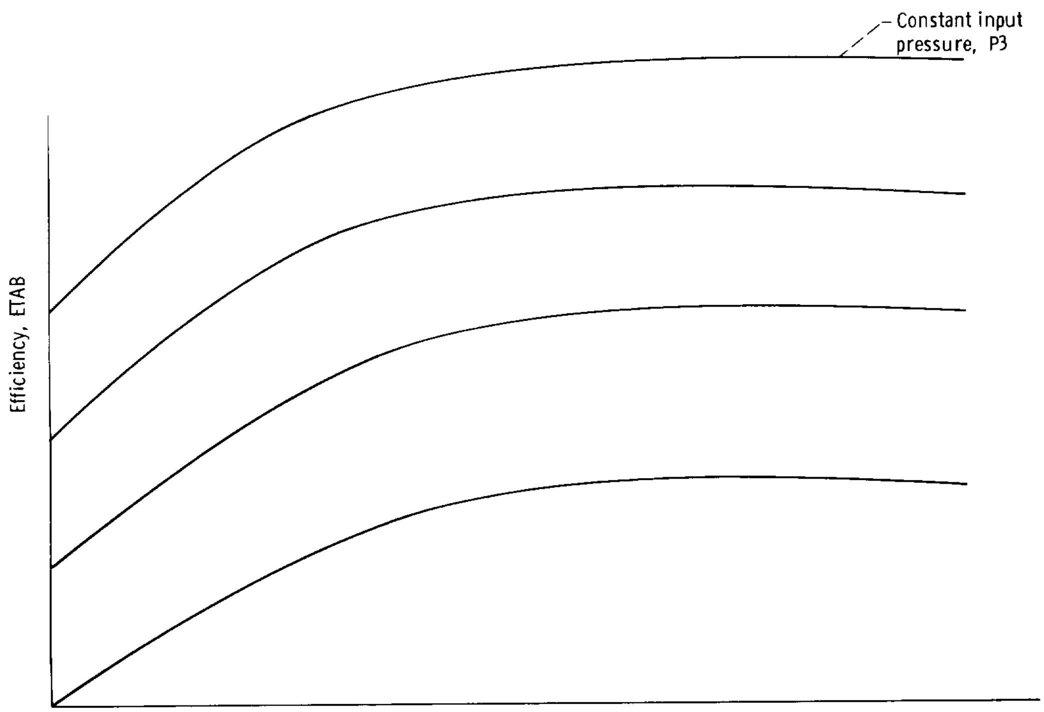


Figure 14. - Example of combustor map.

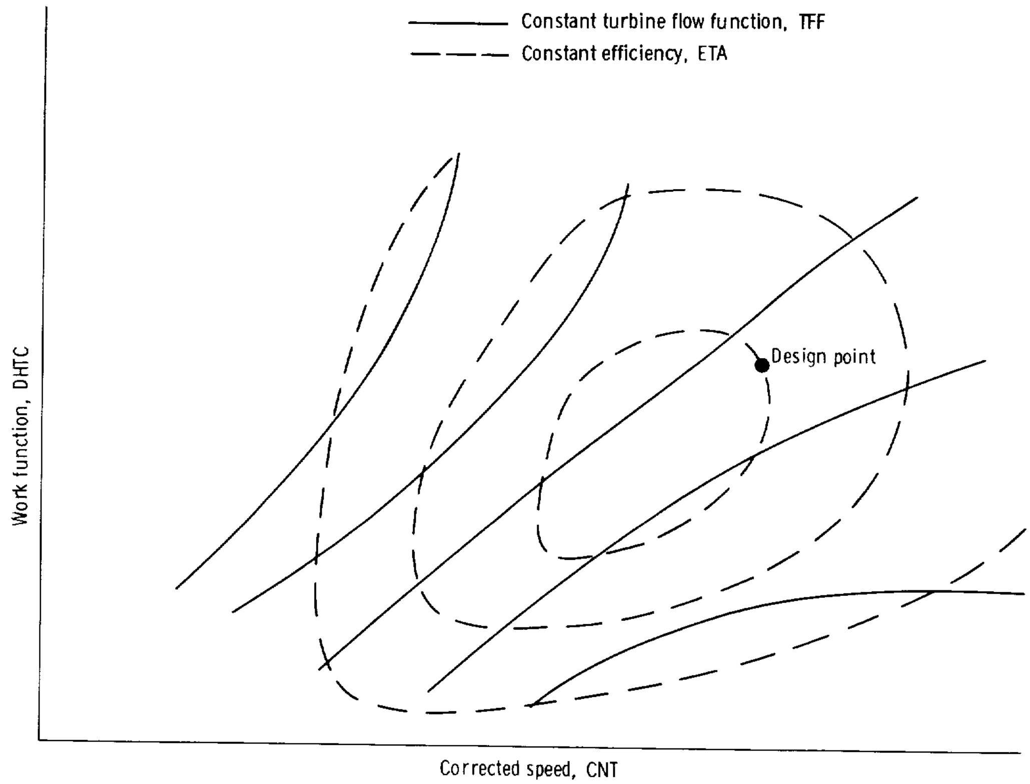
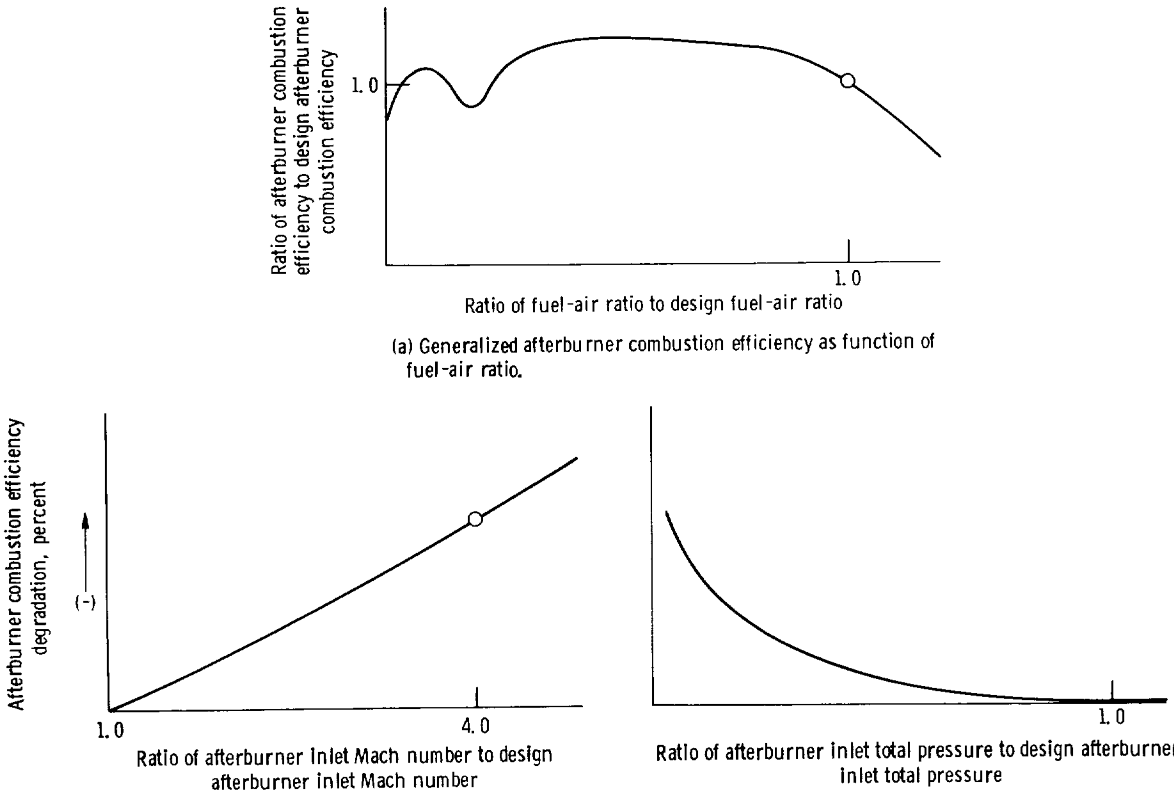


Figure 15. - Example of specific turbine map.



(a) Generalized afterburner combustion efficiency as function of fuel-air ratio.

(b) Efficiency correction factor as function of afterburner inlet Mach number.

(c) Efficiency correction factor as function of afterburner inlet total pressure.

Figure 16. - Example of generalized afterburner combustion efficiency performance map.

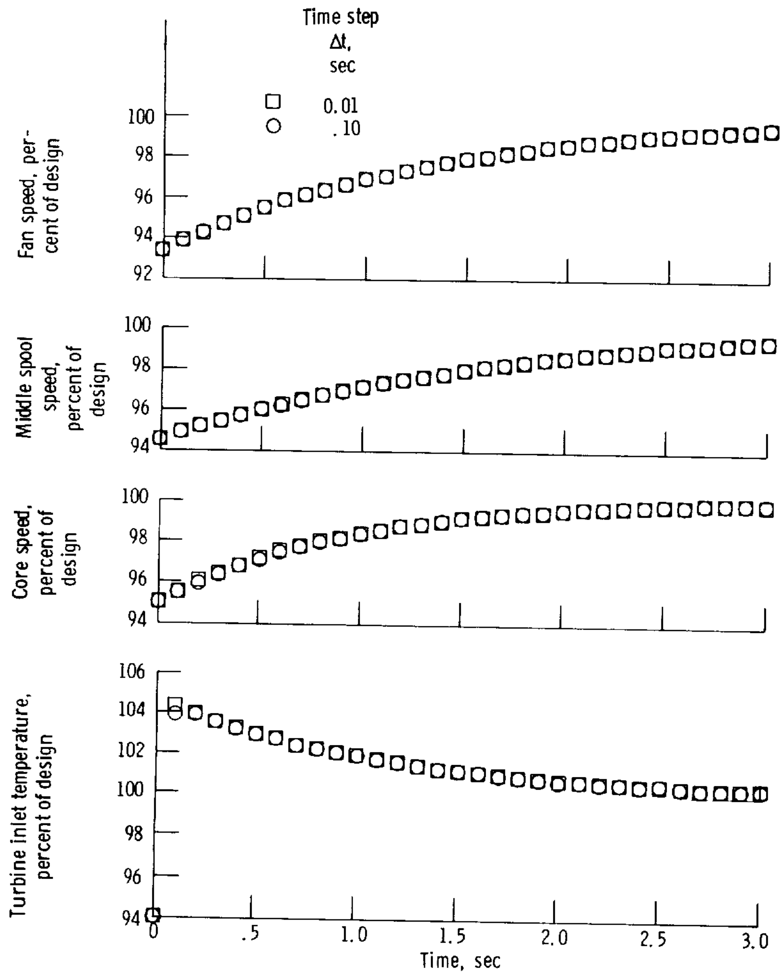


Figure 17. - Response of three-spool turbofan to fuel flow step.

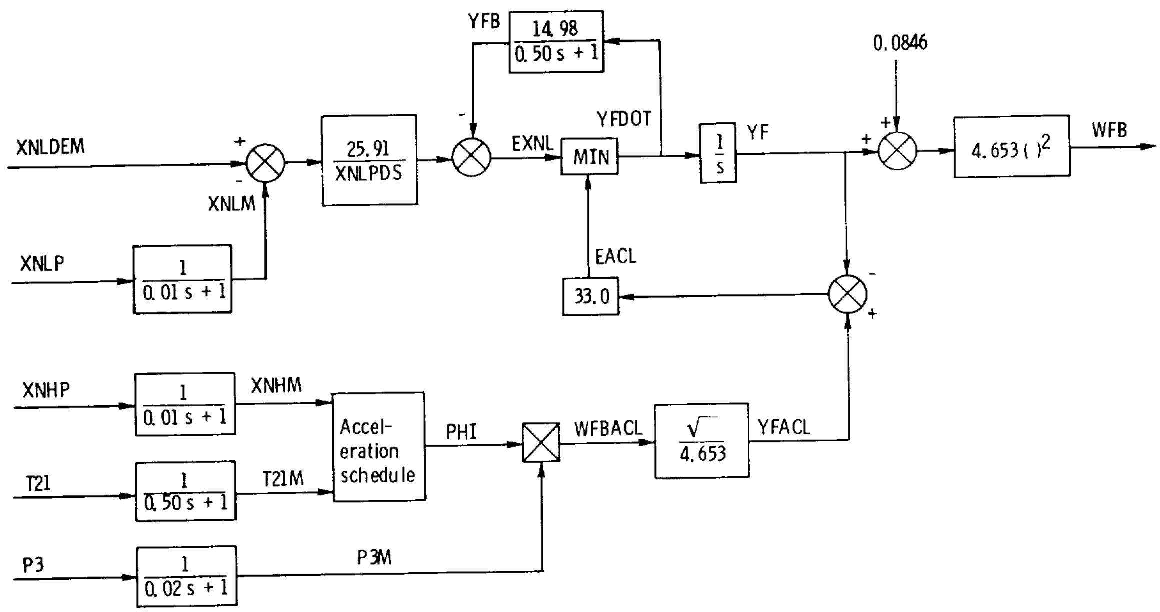


Figure 18. - Two-spool turbofan speed control.

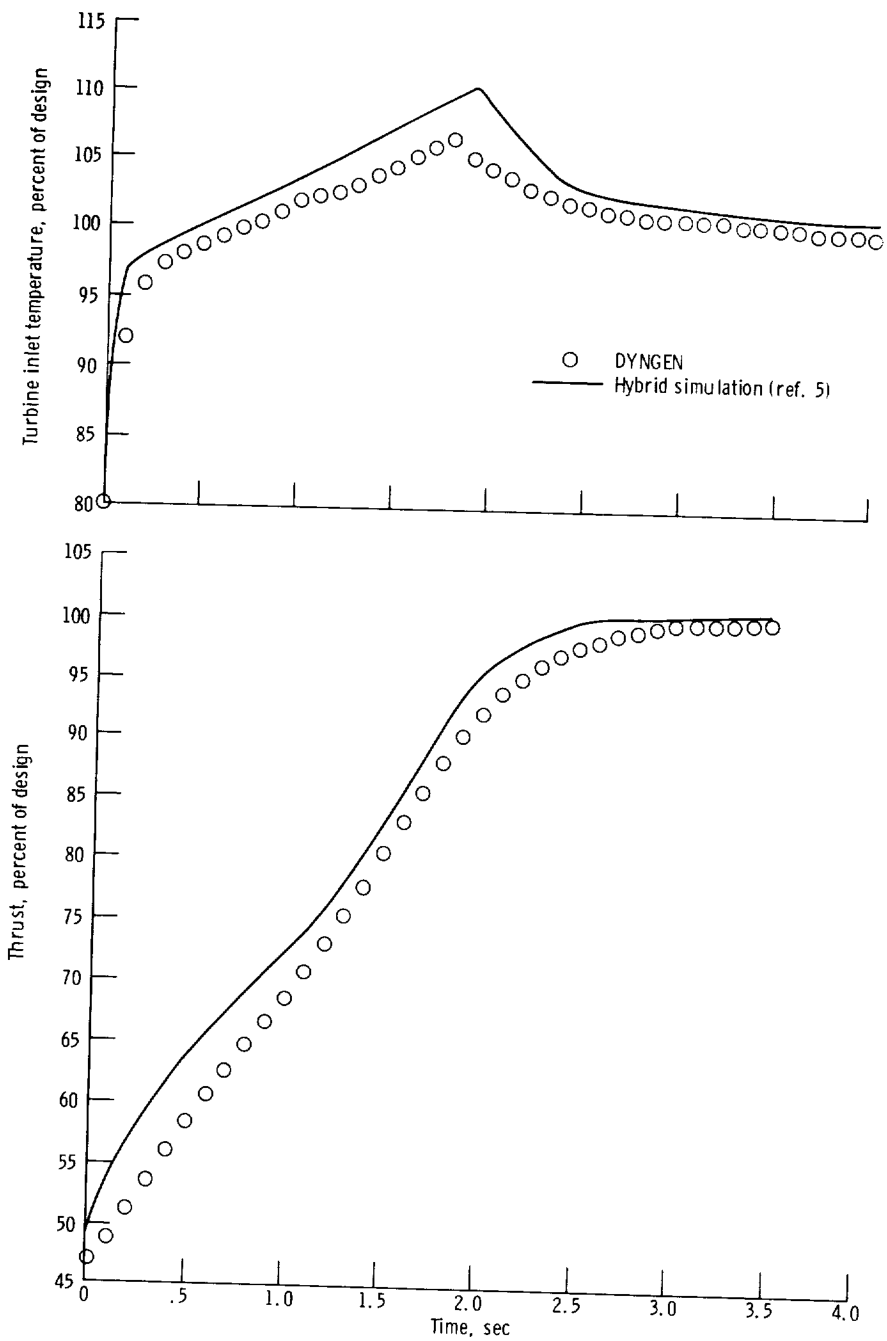
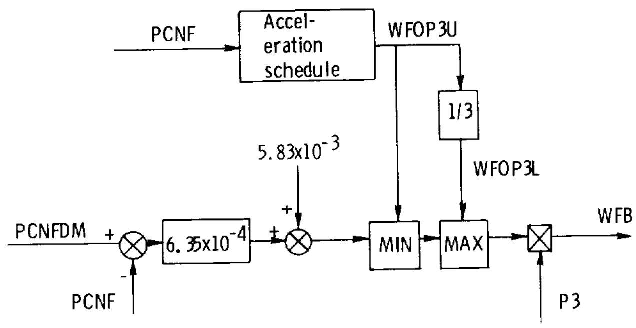
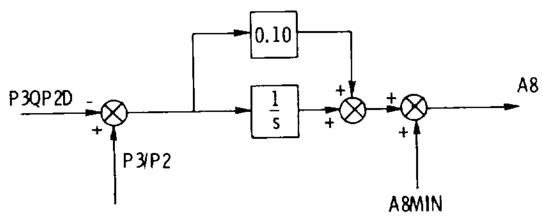


Figure 19. - Response of two-spool turbofan to throttle step.



(a) Fuel control.



(b) Nozzle control.

Figure 20. - Afterburning turbojet control system.

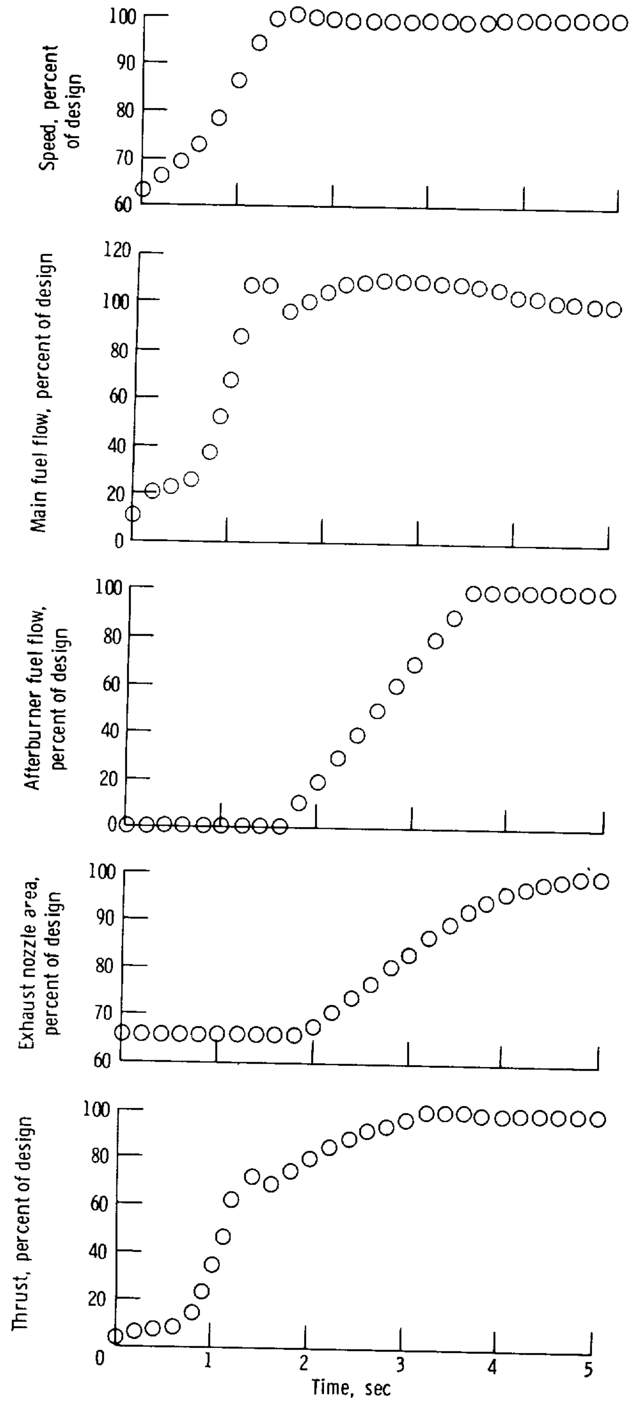


Figure 21. - Response of afterburning turbojet to throttle slam.

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