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

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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 re-
ferred to references 3 and 4 for a detailed discussion of thermodynamic and component
equations. The discussion in this report concentrates on how the programming tech-
niques 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 differen-
tial 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 en-
gine is used in the example, but similar methods are used for more complicated config-
urations. Figure 12 shows a turbojet engine with its major components labeled. Pres-
sures P, temperatures T, and flows w are also labeled with appropriate station num-
bbers. The example illustrates how the calculation of variables proceeds through the en-
gine. DYNGEN is written so that the user can select off-design points by specifying
speed N, turbine inlet temperature T4, 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
P2 and T2 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 thermo-
dynamic 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 calcula-
tions for \(\dot{w}_4\), \(P_4\), and \(T_4\) can be made by using the thermodynamic relations, the com-
bustor 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 \( \dot{w}_4 \sqrt{\frac{T_4}{P_4}} \). Then, from the known value of \( \sqrt{\frac{N}{\sqrt{T_4}}} \), the turbine map (fig. 15) is used to calculate turbine work \( \Delta h \) 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 \( \dot{w}_4 \sqrt{\frac{T_4}{P_4}} \). 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 \( \dot{w}_4 \sqrt{\frac{T_4}{P_4}} \) based only on the first two guesses, but for a consistent solution the calculated value must equal the guessed value. Hence, the difference \( \dot{w}_4 \sqrt{\frac{T_4}{P_4}} - \dot{w}_4 \sqrt{\frac{T_4}{P_4}} \) 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.
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

\[ \dot{w}_T \Delta h_T = \dot{w}_C \Delta h_C + (HP)_{ext} \]  

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

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

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.
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 \( \frac{dP}{dt} \)

\[
\dot{w}_{\text{out}} = \dot{w}_{\text{in}} - \frac{\dot{V}}{\gamma RT} \frac{dP}{dt}
\]

If \( \frac{dP}{dt} \) 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

\[
\dot{w}_{\text{out}} h_{\text{out}} = \dot{w}_{\text{in}} h_{\text{in}}
\]

In unsteady flow, energy storage is accounted for by two terms: one reflecting the rate of change of specific internal energy \( \frac{du}{dt} \), and another reflecting energy storage caused by mass storage

\[
\dot{w}_{\text{out}} h_{\text{out}} = \dot{w}_{\text{in}} h_{\text{in}} - (\dot{w}_{\text{in}} - \dot{w}_{\text{out}})u - \frac{P\dot{V}}{RT} \frac{du}{dt}
\]

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

\[
E_1 = \dot{w}_C \Delta h_C - \dot{w}_T \Delta h_T + (\text{HP})_{\text{ext}}
\]

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

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

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 enter-
The combustor will be given by $\dot{w}_C^*$ and $h_3^*$, where
\[ \dot{w}_C^* = \dot{w}_C - \frac{\dot{V}_3}{\gamma RT_3} \frac{dP_3}{dt} \]
\[ h_3^* = \frac{\dot{w}_C^* - (\dot{w}_C - \dot{w}_C^*)u_3 - \frac{P_3 \dot{V}_3}{RT_3} \frac{du_3}{dt}}{\dot{w}_C^*} \]

The derivatives are calculated by the simplest possible approximation
\[ \frac{dy}{dt} \approx \frac{y_i - y_{i-1}}{\Delta t} \]

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 $\Delta t$ 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 $\Delta t$ no greater than 0.10 second. In selecting a value of $\Delta t$ for a given engine simulation, some trial and error may be necessary to determine the optimum value of $\Delta t$. As mentioned earlier, $\Delta t$'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

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

\[
WA = \frac{(WA)_{\text{design}}}{(WA)_{\text{map, design}}} \times (WA)_{\text{map}}
\]

\[
ETA = \frac{(ETA)_{\text{design}}}{(ETA)_{\text{map, design}}} \times (ETA)_{\text{map}}
\]
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 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).
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 ηB 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 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 \( \Delta \text{ETAA} \) 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 \( \Delta \text{ETAA} \) is not a generalized value. Also input in ETAAB are the following:

1. The change in efficiency as a function of \( \text{EM6T} \) is input as \( \text{DELM6} \) (which is really \( \Delta \text{ETAA} = f(\text{AM6}) \)).

2. The change in efficiency as a function of \( \text{P6T} \) is input as \( \text{DELP6} \) (which is really \( \Delta \text{ETTA} = f(\text{P6}) \)).

At execution time for the design point, afterburner combustion efficiency ETAADS, exit total temperature T7DS, and entrance Mach number AM6DS design values are in-
put. 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 1 msec) 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

\[
E_i(V_j) = 0 \quad i = 1, 2, \ldots, n
\]

\[
j = 1, 2, \ldots, n
\]

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 \( \Delta V \) and \( \Delta E \) 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
jth case. Then for the jth case,

\[ M_{ij} \approx \frac{\Delta E_i}{\Delta V_j} \quad i = 1, 2, \ldots, n \]

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

\[ \frac{dy}{dt} = f(y, t) \quad (A1) \]

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

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

where

\[ y_j \Delta y(t_0 + j \Delta t) \]
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 \([t_j, t_{j+1}]\). For \( \epsilon = 1 \), equation (A2) becomes

\[ y_{j+1} = y_j + \Delta t f(y_j, t_j) \quad (A3) \]

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

\[ \frac{dy}{dt} = ay \quad (A4) \]

For this equation, equation (A2) becomes

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

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

\[ y_{j+1} = \left( \frac{1 + a\epsilon \Delta t}{1 + a\epsilon \Delta t - a \Delta t} \right) y_j \quad (A6) \]

the general solution for \( y_j \) can be written

\[ y_j = r^j y_0 \quad (A7) \]

where

\[ r = \frac{1 + a\epsilon \Delta t}{1 + a\epsilon \Delta t - a \Delta t} \quad (A8) \]
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 \( \Delta t \). Solving equation (A8) for \( \Delta t \) yields

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

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

\[
\Delta t < \frac{2}{a(1 - 2\epsilon)} \quad \epsilon > \frac{1}{2} \tag{A10a}
\]

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

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

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

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 \( \Phi \) have magnitudes less than unity.

It will now be proved that if \( \lambda \) is an eigenvalue of \( A \),
$\mu = \frac{1 + \lambda \epsilon \Delta t}{1 + \lambda \epsilon \Delta t - \lambda \Delta t}$ \hfill (A14)

is an eigenvalue of $\Phi$. Proof: Let $\lambda$ be an eigenvalue of $A$. Then

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

If $\mu$ is an eigenvalue of $\Phi$,

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

But

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

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

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

But from equation (A14),

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

so that

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

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

$$= 0$$

which completes the proof.

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

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

$\Delta t$ is unconstrained for $\epsilon < \frac{1}{2}$ \hfill (A15b)
where \( \lambda_{\text{max}} \) is the eigenvalue of \( A \) having the greatest magnitude. In particular, for the Euler method the step size is restricted by

\[
\Delta t < \frac{2}{\lambda_{\text{max}}}
\]

(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 \( \lambda \) 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 \( (e < 1/2) \), 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

\[
\frac{dy}{dt} = f(y)
\]

(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 configura-
tion 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

$$y_{j+1} = y_j + \Delta t f(y_{j+1})$$  \hspace{1cm} (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

```fortran
$IBFTC AFQUIR
SUBROUTINE AFQUIR (X,AIND,DEPEND,ANS,AJ,TOL,DIR,ANEW,ICON)

DIMENSION X(9)

C XI)=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 XI)=COUNTER STORAGE
C XI)=CHOSES METHOD OF CONVERGENCE
C XI)=THIRD DEPEND VAR
C XI)=THIRD IND VAR
C XI)=SECOND DEPEND VAR
C XI)=SECOND IND VAR
C XI)=FIRST DEPEND VAR
C XI)=FIRST IND VAR
C XI)=MUST BE ZERO UPON FIRST ENTRY TO ROUTINE

Y=O
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)=O
ICON=2
RETURN
6 ANEW=Y
X(2)=X(2)+1
ICON=1
RETURN
7 ANEW=Y
X(2)=O
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
```

25
IF (X(8)-X(6)) > 14,9,14
15 IF (X(9)-X(7)) > 15,9,15
16 A=(X(9)-X(7))/(X(8)-X(6))
17 Y=X(9)-A*X(8)
18 IF (ABS(10+X(9))-ABS(Y)) > 9,9,6

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

26
SUBROUTINE ATHOS (ZFT, TM, SIGMA, RHO, THETA, DELTA, CA, AMU, K)

THIS IS A SUBROUTINE TO COMPUTE CERTAIN ELEMENTS OF THE 1962 U.S. STANDARD ATMOSPHERE UP TO 90 KILOMETERS.

CALLING SEQUENCE...

CALL ATHOS (ZFT, TM, SIGMA, RHO, THETA, DELTA, CA, AMU, K)

ZFT = GEOMETRIC ALTITUDE (FEET)
TM = MOLECULAR SCALE TEMPERATURE (DEGREES RANKINE)
SIGMA = RATIO OF DENSITY TO THAT AT SEA LEVEL
RHO = DENSITY (LB-SEC**2-FT**(-4)) OR SLUG-FT**(-3)
THETA = RATIO OF TEMPERATURE TO THAT AT SEA LEVEL
DELTA = RATIO OF PRESSURE TO THAT AT SEA LEVEL
CA = SPEED OF SOUND (FT/SEC)
AMU = VISCOSITY COEFFICIENT (LB-SEC/FT**2)
K = 1 NORMAL

= 2 ALITUDE LESS THAN -5000 METERS OR GREATER THAN 90 KM
= 3 FLOATING POINT OVERFLOW

ALL DATA AND FUNDAMENTAL CONSTANTS ARE IN THE METRIC SYSTEM AS THESE QUANTITIES ARE DEFINED AS EXACT IN THIS SYSTEM.

THE RADIUS OF THE EARTH (REFT59) IS THE VALUE ASSOCIATED WITH THE 1959 ARDC ATMOSPHERE SO THAT PROGRAMS CURRENTLY USING THE LIBRARY 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, 288.16, 1.000000E 00, -6.5,
3 11.0, 216.65, 2.23361E-01, 0.0,
4 20.0, 216.65, 5.40328E-02, 0.0,
5 32.0, 228.65, 8.56633E-03, 0.0,
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,
S 88.743, 180.65, 1.6223 E-06, 0.0,
DATA REFT59/2.0855531E 07, G2 /9.80665/,
1 AMZ /28.9644 //, RSTAR /8.31432/,
2 FTTOKM/3.048E-04 //, S /110.4 //,
3 AMUZ /1.2024E-03 //, CAZ /1116.45/,
4 RHOTZ /0.76474 //, GZENG /32.174/,
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(1)
IF (H=LT.5.0 OR ZGT.90.0) GO TO 7
DO 1 M=1,10
IF (H=HB(M)) 2,3,1
1 CONTINUE
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 NOT ZERO, PAGE 10, EQUATION 1.2+10-(3)
DIMENSION Q(9)
DATA AWORD/CHCOAFBN/
ORD=A_ORD
Q(2)=0.
Q(3)=0
IF (S[N] .EQ. 1) GO TO 100
AJ=T78e2b
AJX‘=Z.719
CAPSF=211b,2170
G=32,174049
PRATH=14.696
TDEL=2000.0
TMAX=4000.0
RA=-.0252
GO TO 101
100 AJ=1.0
AJX=1.0
CAPSF=101325.0
G=1.0
PRATH=14.696/101325+6
TDEL=1111.0
TMAX=2222.0
RA=286.9
CONTINUE
101 CONTINUE
ICOAFA=0
C***
P6DS AND AM6DS ARE SET FOR GENERALIZATION OF AFTERBURNER
C*** EFFICIENCY MAP GENERALIZATION
IF (IDES .EQ. 1) P6DS=P6+PRATH
IF (IDES=Eq.1) AM6DS=AM6
WF6 = FAR55*WG55/(FAR55+1.)
IF (GASMX<GT=0.) WF6 = WF6 + FAR24*WG24/(FAR24+1.)
WA6=WF6+W6
C*** DRY LOSS
WF6C=WG6*SORTT(T61)+P6
IF (IDES=Eq.1) WG6CDS=WG6C
DPAFT=DPAFTDS*(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)
WA=WG6/A7
C1=75SORTG/(T6*A7)*CAPSF
AM7=AM6
TS7=0.875*16
1 DO 2 =1:15
CALL PROC6M (FAR6,TS7,CS7,AK7,CP7,REX7,PHIS7,HS7)
V7=AM7*CS7
HSCAL=H6-V7*2/12*GMAJ)
DELHS=HSCAL-HS7
IF (ABS(DELS)+LE=0.0005*HSCALE GO TO 3
2 TS7=TS7+DELHS/CP7
ICOAFB=1
GO TO 14
3 WQAT=C1254RT(AK7/REX7)*AM7/(1+1(AK7-1)*AM7**2/2)**((AK7+1)/(2*1)
V(AM7-1))
DIR=WQA/WQAT
E6=(WQA-WQAT)/WQA
CALL AFQUIR (Q1I,AM7,E6,0.0,5001,DIR,AM7,IGO)
ICOAFB=2
GO TO 4,5,14,IGO
4 AM7=AM7T
IF (AM7GE=0.9) AM7=0.9
GO TO 1
5 PS7=PT/EXP((PHI6-PHISH)/REX7)
IF (IAFTBNGT=0) GO TO 7
C *** NON-AFTERBURNING
6 T7=T6
WFA=0.0
FART=FAR6
WG7=WG6
IF (IDES=EQ=1*AND*+T7DS*NE=0.0) GO TO 7
GO TO 20
C *** AFTERBURNING
7 IF (IAFTBN=EQ=2) T7=T6+TDEL
IF (IDES=EQ=1) T7=T7DS
IF (T7LE=T6) GO TO 6
RHO65=CAPSF=PS7/(AK7*REX7)*AM7/(
L+1AK7-1.0)*AM7=W=2/20)
=(AK7-
1°)
(I2*2763643E-11)*T7**2051
150E-07)*T7-2453116E-03)*T7-9433296E-01)*T7-865537E+05
IF (SI) T7=T7*5.0/9.0
IF (SI) HV=HV*2325.4295
CALL THERMO (PT,PHAP,T7,XX1,XX2,1,FAR6,1)
C *** TO ALTER DESIGN ABETA MAP FROM GENERAL TO SPECIFIC MAP
IF (IDES=NE=1) GO TO 9
FARTDS=(HA-H6)/(HV*ETAADS)
CALL ETAAB (1.2,3,0,0,00,ETAADS,ETAASV,P6DS,P6DSAV,AM6S,AM6DSV,IDE
E,5,FAR7DS,FARTSV)
T7=T6
GO TO 20
9 P6DS=P6*PRATM
FARTGS=(HA-H6)/(HV*ETAADS)
DO 10 II=1:15
CALL ETAAB (FART7S,AM0,P6GS,ETAADS,ETAASV,P6DS,P6DSAV,AM6S,AM6DSV,IDE
E,5,FAR7DS,FARTSV)
FART=(HA-H6)/(HV*ETAADS)
FART7S=(FAR7,FARTGS)
IF (DELFA7+LE=0.01=FIT) GO TO 11
10 FARTGS=FART
10 CONTINUE
IF (FARTGTGT) GO TO 12
ICOAFB=3
CALL ERROR
12 WFA=FART*WG6
IF (IAFTBN=EQ=1) GO TO 15
ERRW=(WFA-WFA*WFA)
DIR=SQRT(WFA*WFA)!
CALL AFQUIR (Q1I,T7,ERRW,0.0,30000051,DIR,T7T,IGO)
ICOAFB=4
GO TO 13,16,14,IGO
13 T7=T7T
130
GO TO 8
14 CALL ERROR
15 WFA=WFX
16 FAR7=(WF6+WFA)/WA6
17 WGT=WG6+WFA
18
C *** MOMENTUM LOSS
19 CALL PROCOM (FART,T7,XX1,XX2,XX3,XX7,PH7,H7)
20 RHO7=CAPSF*P7/AJ*REX7*T7
21 V7=VGT/(RHO7*T7)
22 Q(2)=0.
23 Q(5)=0.
24 PST=P56=0.O1
25 H7=H7-V7*G7/2(SG+GAJ)
26 CALL THERMO (1,0,H7,T7,PH7,XX2,1,FAR7,1)
27 IF (T7.GE.301) GO TO 18
28 CALL THERMO (1,0,H7,H7,PH7,XX2,1,FAR7,0)
29 V7=Sqrt(T7*G+GAJ*(H7-H7))
30 GO TO 17
31
32 PST=H07*AJ*REX7*T7/CAPSF
33 PSTA=P565+(H06555+2-H07*V7**2)/(G+CAPSF)
34 DIR=Sqrt(ABS(P7/PSTA))
35 EP=(P7-PSTA)/PST
36 CALL AFQUIR (Q11,V7,E0,50.0,0.001,DIR,V7,IGO)
37 V7=V7T
38 IF (V7LT=100.0) V7=100.0
39 ICOAFB=5
40 GO TO (17,19,14), IGO
41
42 P7=PST*EXP3(PH7-PHIST)/REX7
43 CALL PROCOM (FART,T7;C7,XX2,XX3,XX4,XX5,XX7)
44 AMT7=V7T/C7
45
46 CALL THERMO (P7,H7,T7,XX2,1,FAR7,0)
47 IF (IVAFTN=EQ+0.0) GO TO 31
48 Q(2)=0.0
49 Q(3)=0.0
50 PST=P7
51 P7DOT=DERIV(18,P7)
52
53 CONTINUE
54 CALL THERMO(P7,H7,T7,T7,XX2,1,FAR7,0)
55 WGT=WG7=W7DOT*VAFTBN/T7/(1+4*RA)
56 UT=H7-AJX*RA*77
57 UTDOT=DERIV(19,UT)
58 H7X=(WGT*H7-(W7P-W7G7)*UT-UTDOT*P7*VAFTBN/T7/RA)/WGT
59 ERRW=(H7-H7X)/H7
60 DIR=Sqrt(ABS(H7-H7X))
61 CALL AFQUIR (Q11,T7,ERRW,0.0,20.0,0.0001,DIR,T7T,IGO)
62 ICOAFB=6
63 GO TO (29,31,30), IGO
64
65 T7=T7T
66 GO TO 28
67
68 CALL ERROR
69
70 CONTINUE
71 ICOAFB=0
72 CALL COMMNO
73 RETURN
74
75 C
76 C END
77

$IBFTC COCOMB

SUBROUTINE COCOMB

COMMON /WORDS/ WORD
COMMON /DESIGN/
I1DES , I2DES , I3DES , MODE , INIT , IDUMP , IAMTP , IAGSNX ,
2IDBURN , IAFTBNO , IODC , IMCD , IDSHOC , IMSHOC , NOZFLT , ITRY ,
3LOOPER , NOMAP , NUMMAP , MAPEGD , TOLLALL , ERR(9)
COMMON /ALL/
IPCNFGU , PCNGU , T4GU , DUMD1 , DUMD2 , DELEG , Delyn , DELSGF ,
310
WA3C=W3A*S QRT(T3)/P3PSI
IF (SI) WA3C=W3A*S QRT(T3)/P3
IF (IDES=EQ.+1) WA3CDS=W3A3C
DPDCOM=DPDCDS*(WA3C/WA3CDS)
IF (DPDCOM=GT+1.) DPDCOM=1.
IFS=EPS(1.-DPDCOM)
IFS=EPS(1.*MODE+EQ.2) T4=(TMAX+TMIN)/2
IFS=TRAN(EQ.1.*MODE+EQ.2) CALL FCNTRL
IF (T4=GT+TMAX) T4=TMAX
IFS=TRAN(GE+TMIN) GO TO 2
T4=TMIN
IFS=MODE+EQ.1) MAPEDG=1
DTCO=T4-T3
IFS=SI) DTCO=DOTC0+9.0+5.0
IFS=SI) DTCO=DOTC0+9.0+5.0
IFS=SI) HV=(((((−454317E−19*T4)−2034116E−15)*T4+1.783643E−11)*T4+1.849337E+05
IFS=SI) HV=HV+2325.4295
CALL THERMO (P4,H4,T4,XX1,XX2,0.0,0.0,0)
IFS=SI) T4=T4+9.0+5.0
IFS=SI) HV=HV+2325.4295
IFS=SI) FAR4=(HA-H4)/HV*ETAB)
IFS=SI) IF (FAR4+LT.0.) FAR4=0.0
IFS=SI) WFBX=FWB+MA3
IFS=SI) IF (MODE+NE.2) GO TO 7
IFS=SI) ERRM=SQRT(WFB/WFBX)
IFS=SI) CALL APQDIR (Q(1),T4,ERRW,0.,20.,+0.0001,DIR,T4,IG0)
IFS=SI) GO TO (5,8,6,10,17)
IFS=SI) T4=T4
IFS=SI) GO TO 1
IFS=SI) CALL ERROR
IFS=SI) WFB=WFBX
IFS=SI) IF (IDES=EQ.+1) WFBOS=WFB
IFS=SI) CALL THERNO (P4,H4,T4,XX1,XX2,1,FAR4,0)
IFS=SI) MG4=WFB+WA3
IFS=SI) IF (VCOMB+EQ.0.0) GO TO 21
IFS=SI) Q(1)=0.0
IFS=SI) Q(3)=0.0
IFS=SI) MG4P=MG4
IFS=SI) H4P=H4
IFS=SI) P4DOT=DERIV(10.,P4)
IFS=SI) CALL THERNO (P4,H4,T4,XX1,XX2,1,FAR4,0)
IFS=SI) MG4P=P4DOT*VCOMB/T4+1.0+RA
IFS=SI) U4=H4-AFR4/T4
IFS=SI) U4DOT=DERIV(11.,U4)
IFS=SI) H4X=(MG4P+H4)-U4-U4DOT*P4*VCOMB/T4+RA)/MG4
IFS=SI) ERRW=(H4-H4X)/H4X
IFS=SI) DIR=SQRTABS(H4/H4X)
IFS=SI) CALL APQDIR (Q(1),T4,ERRW,0.,20.,+0.0001,DIR,T4,IG0)
IFS=SI) GO TO (19,21,20,17)
IFS=SI) T4=T4
IFS=SI) GO TO 18
IFS=SI) CALL ERROR
IFS=SI) CALL CONTINUE
IFS=SI) IF (IDES=EQ.+1) WRITE(6,10) WA3CDS,ETABC
IFS=SI) IF (FXMCP+OR.1*SPool+EQ.1) GO TO 9
IFS=SI) CALL COMPTB
IFS=SI) RETURN
IFS=SI) P50=P4
IFS=SI) H50=HA
IFS=SI) T50=T4
IFS=SI) S50=SA
IFS=SI) FAR50=FAR4
IFS=SI) WOS=W4
IFS=SI) SET HIGH PRESSURE TURBINE PARAMETERS TO ZERO, NOT USED

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$IBFTC COCOMP

SUBROUTINE COCOMP

COMMON /WORDS/ WORD

COMMON /DESIGN/

IIDES, JDES, KDES, MODE, INIT, IDUMP, IAMTP, IASMX,

2IDBURN, IATBN, IODC, IMCD, IDSHOC, IMSHOC, IDZFL, ITRYS,

3LDTRES, INUMMAP, IMAPEDG, ITOLALL, ERR(1), ERR(2)

COMMON /ALL1/

1PCNFPGU, PCNGC, T4GU, DUMD1, DUMD2, DELFG, DELFN, DELSFC,

2ZFD, PCNFDS, PRFD, ETFADS, WAFDS, PRFC, ETACF, WAFPC,

3ZCD, PCNCDS, PRCDS, ETTACD, WACD, PRCCD, ETACCD, WACCD,

4ZTDS, WFTDS, DTODS, ETABDS, WA3CDS, EPDCODS, DTDFCD, ETAFCF,

5FFPDS, CFTPDS, ETFTPS, TFHPKF, CFNHPF, CTFTP, DHTCP, T2DS,

6TFTPDS, CNLTPDS, ETLTPS, TLTPKF, CNLTPF, ETLPKF, ETLTPF, DHTLPF, T21DS,

7T240DS, DT240DS, ET240DS, WA230DS, DTDFD, ETA2C, ETAFCF,

8T7DS, WFT7DS, DT77DS, ETAB7, WA7CDS, EPD7DS, DTDF7, ETA7CF,

9T855, A25, A9, A28, A29, A35, A48, A55, A65, A75, A86, A95,

$TFFP, TFFLP, PCBLF, PCBL, PCBLTD, PCBLC, PCBLLP, PCBLP,

COMMON /ALL2/

10T1, P1, H1, S1, T2, P2, H2, S2, T3, P3, H3, S3, T4, P4, H4, S4,

5T5, P5, H5, S5, T6, P6, H6, S6, T7, P7, H7, S7, T8, P8, H8, S8,

$T8, P8, H8, S8, T9, P9, H9, S9, T10, P10, H10, S10,

COMMON /ALL4/

11G6, WFA, AMG7, FAR7, ETA, DPAFT, V55, V25, 2P56, V6, AM6, T57, P57, V7, AM7, AM25,

3T38, P38, H38, S38, T39, P39, H39, S39, T40, P40, H40, S40,

4V4, AMV4, V8, AMB, T59, P59, V9, AM9, AM59,

5V5, AMV5, WFT, AMF, T59, P59, V9, AM9, AM59,

6W6A32, OMPW6DS, OMPW6NG, WA632DS, A63, AM38, V38, T38, AM38,

7T38, P38, H38, S38, T39, P39, H39, S39, T539,

8V39, AM39, A39, BPRINT, W37, CVNDM, GFMWNG, FGMWN, GFMWNG,

9FNWNG, FMN, FNWNG, FNWNG, FNWNG, FNWNG, FNWNG, FNWNG,

$VNW, T22, P22, H22, S22, T59, P59, H59, S59,

COMMON /ALL5/

10S50, WAZ, AM22, T2, PCNI, CPNI, PRI, ETA, WACI,

$TFFIP, CNIP, ETATIP, DHTCIP, DHTI, BLIP, PCBLIP, PCNIGU,
COMMON /PCNL, NPT(15)
! INCN, NPT(15)
! COMMON /FLSWS/ WAF, WAIW, WACP
COMMON /UNITS/ SI
! LOGICAL FXFNM2, FXM2CP, DUMSPL, FAN, SI
COMMON /COMP/CNX(15), PRX(15, 15), WACX(15, 15), ETA(15, 15), MAC(15, 15), MAC(15, 15)
DATA AMORO, MLH/6HCOCQNPtbH ILO)
jbH (H|)
/ MORDA AWORD
1 IF {SI) GO TO 100
TSTD=, SI 8, 668
PSTD= 1, 0
RA:,.0252
AJ=2, 719
GO TO 101
TSTD=288, 168
PSTD=101325,
RA=286, 9
AJ=1, 0
GO TO 101
THETA=SORT(T21/TSTD)
DELTA=P21/PSTD
! IF (IDES NE I) GO TO 1
THETAD=THETA
WACX=MAC
WAC=MAC-THETA/Delta
! IF (*NOTFXM2CP) PCNC=PCNCDS
1 IF (*NOTFXM2CP) PCNC=PCNCDS
2 IF (ZC, LT 0) CZ=0
! IF (ZC, GT 1) ZC=1
CNC=CNCS IF (ISPOOL = EQ 1) GO TO 12
CALL SEARCH (ZC, CNC, PRC, MAC, ETA, CNX(1), NCPX(1), MACX(1, 1), ETA(1, 1), MAC(1, 1), MAC(1, 1))
GO TO 13
PRC=1
ETAC=1
MAC=MA21
WAC=MAC-THETA/Delta
CNC=1
PRCCF=1
IF (MODE EQ 1) GO TO 4
IF ((CNCS-CNCS) GT 0.0005*CNCS) MAPPED=1
4 IF (IDO EQ 1 OR IDO EQ 2) WRITE (8, 9) CNCS, WLM(IGO)
WAC=MAC-THETA/Delta
IF (IDES NE 1) GO TO 5
T21DS=T21
IF (ISPOOL EQ 2) PRCCF=(PRCCF-1)/{PRC-1}
ETA(1)=ETA(1)
IF (T21DS EQ 1) ETACCF=1
WAC=MACF=WAC
! IF (*NOTDUMSPL OR PCBLID NE 0) OR (*NOTFAN) GO TO 6
WA22=WAC
WA1=WA22
WA1=WAC
WA22=WAC
WA1=WAC
WA22=WAC
BIL=MA32
WA1=WA21
$IBFTG CDUCT

SUBROUTINE CDUCT
COMMON /WORDS/ WORD
COMMON /DESIGN/
1IDES, JDES, KDES, MODE, INIT, IDUMP, IAMTP, IGASMX, 1
2IDBURN, IAFTBN, IODC, IMCD, I10SMOC, I1MHOC, NO2FLT, ITrys, 2
3LDOPER, QOMAP, NOMAP, NOMP, MAPEDG, TOLALL, ERR(9), 3
COMMON /ALL11
1PCNFGU, PCNCGU, TGU, DUQ1, DUQ2, DELFG, DELFN, DELSFC, 1
22FDS, PCNFD, PRFDS, ETAFDS, WAFFDS, PRFCC, ETAFCF, WAFFCF, 2
3ZCCS, PCNCDS, PRCDS, ETAADOs, WACCCS, PRCFCC, ETAACCF, WACCCF, 3
4TAFCF, ETAADC, ETAADS, WACCCS, DPCOOS, DTCCCF, ETABCF, 4
5TFHPCD, CHNPDFS, ETYPDFS, TFPFPC, CNHPFPC, ETYFPFPC, 5
6TLPFPC, CLNLPS, TDPFD, TLPFPC, CLNLPS, TLPFPC, DLPFPC, TLPFPC, 6
7T2DOS, T2FDS, T2TODS, T2TODS, T2TODS, T2TODS, T2TODS, T2TODS, 7
8T7DOS, W2FDS, DT2DOS, ET2ADOs, WA2FDS, D2PUDOS, DT2UCF, ET2UCF, 8
97T7DOS, W2FDS, DT7TODS, ETA7TODS, W2GACOS, D7APFDS, DT7TODS, ET7TODS, 9
COMMON /ALL2/
111  P1  H1  S1  T2  P2  H2  S2  
212  P1  H1  S1  T2  P2  H2  S2  
313  P1  H1  S1  T2  P2  H2  S2  
414  P1  H1  S1  T2  P2  H2  S2  
515  P1  H1  S1  T2  P2  H2  S2  
616  P1  H1  S1  T2  P2  H2  S2  
717  P1  H1  S1  T2  P2  H2  S2  
818  P1  H1  S1  T2  P2  H2  S2  
919  P1  H1  S1  T2  P2  H2  S2  

COMMON /ALL3/

1XP1  XWAF  xWAC  xXBF  xXBLD  xXH3  DUMS1  DUMS2  
2XP2  XH21  XH2  XH21  XH2  XH21  XH2  XH21  XH2
3XP3  XH3  XH3  XH3  XH3  XH3  XH3  XH3  XH3  XH3
4XP4  XH4  XH4  XH4  XH4  XH4  XH4  XH4  XH4  XH4
5XP5  XH5  XH5  XH5  XH5  XH5  XH5  XH5  XH5  XH5
6XP6  XH6  XH6  XH6  XH6  XH6  XH6  XH6  XH6  XH6

COMMON /ALLA/

1WG6  XWAFA  WM7  XR7  ETA  DPA  V55  V25  
2WG7  XWAFA  WM7  XR7  ETA  DPA  V55  V25  
3WG8  XWAFA  WM7  XR7  ETA  DPA  V55  V25  
4WG9  XWAFA  WM7  XR7  ETA  DPA  V55  V25  
5WG10 XWAFA  WM7  XR7  ETA  DPA  V55  V25  

COMMON /ALL5/

1S15  MA22  ZI  PCN1  CNI  PRI  ETA  WAI  
2S16  MA22  ZI  PCN1  CNI  PRI  ETA  WAI  
3S17  MA22  ZI  PCN1  CNI  PRI  ETA  WAI  
4S18  MA22  ZI  PCN1  CNI  PRI  ETA  WAI  
5S19  MA22  ZI  PCN1  CNI  PRI  ETA  WAI  

COMMON /UNITS/SI

LOGICAL SI
LOGICAL AFTFAN
DIMENSION Q150
DATA AMORD1,AMORD2,6HCODUCT,6HDN0Z2L/
WORO=AMORD1
Q(1)=0. 
Q(3)=0. 
GOD0=0.0
IF (S1) 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=222.0
RA=28.6
101 CONTINUE
ICODUC=0
WAX=WAF=WAI-FLF

ORIGINAL PAGE IS OF POOR QUALITY
IF (PCBLIO.EQ.0.) WA$4=WAF=WAC-BLF
IF (AFTFAN) WAX=WAF=BLF
WAD=MAX+BLDU
P23= Parse the code here...
MOMENTUM LOSS

CALL THERMO (P24, H24, T24, S24, XXI, XX2, XX3, XX4, XX5, XX6)

AMZ6=V24/C$24

IF (VZ4EQ0.0) GO TO 31

WHZ=WHZ+DER|V4)

IF (|GASNXGT*O) GO TO 1

MORD-A_RDZ

AZOSAV=AZB

AZgSAV=A;_9

NOZD=O

DNOZ=O

1 GO TO 31

P24=MG24*DER|V4)

AMZ6=AMZ6

IF (|GASNXGT*O) GO TO 1

MORD-A_RDZ

AZOSAV=AZB

AZgSAV=A;_9

NOZD=O

DNOZ=O

1 GO TO 31

WHZ=WHZ+DER|V4)

IF (VZ4EQ0.0) GO TO 31

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

WHZ=WHZ+DER|V4)

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WHZ=WHZ+DER|V4)
IF (INOZFLT.EQ.2.OR.NOZFLT.EQ.3) IDNOZ=1
241
IF (IDES.EQ.1.OR.IDBURN.EQ.0 OR NOZD.EQ.0) IDNOZ=1  
242
IF (ITRYS.EQ.1) IDNOZ=0
243
IF (IDOC.EQ.0) GO TO 18
244
CALL CONVRG (T25,H25,P25,S25,FAR24,WF24,P1,IDNOZ,A28,P25R,T25,H28) 
245
1P28,S28,T28,S28,P28,V28,AM28,ICON)
246
GO TO (19,19,19,11),ICON
247
10 CALL CONDIV (T25,H25,P25,S25,FAR24,WF24,P1,IDNOZ,A28,A29,P25R,T28) ,
248
1H28,P28,S28,T29,H29,P29,S29,TS29,TS29,PS29,PS29,V28,V28,AM28,AM29
249
12ICON)
250
IDSHOC=ICON
251
IIDCUC=6
252
GO TO (20,20,20,11),ICON
253
19 T29=T28
254
H29=H28
255
P29=P28
256
S29=S28
257
TS29=TS28
258
PS29=PS28
259
V29=V28
260
AM29=AM28
261
A29=A28
262
IDSHOC=ICON+3
263
20 ERR5=(P25R-P25)/P25R
264
IF (IDNOZ.EQ.1) WRITE (6,22) A28,AM28,A29,AM29
265
21 ICDUC=6
266
CALL FASTBK
267
RETURN
268
END
269
C
270
$IBFTC COFAN
271
SUBROUTINE COFAN
272
COMMON /WORDS/ WORD
273
COMMON /DESIGN/ IDDES,MODE,INIT,IDUMP,IANTP,IGASMX,
274
2IDBURN,IAFTBN,ICO,IMCD,IDSOC,IMSHOC,NOZFLT,ITRYS,  
275
3LOOPER,NOMAP,TOLALL,ERR(9)
276
COMMON /ALL1/ 
277
1PCNFU,PCNCGU,TAGU,DOMDI,DUMD2,DELFG,DELHN,DELSCF,
278
2FDOS,PCNFDOS,PRFDOS,ETAFDOS,WAEDOS,PRFCF,ETACF,WACF,  
279
3COS,PCNCDS,PRCDS,ETACDS,WACDS,PRCCF,ETACCF,WACC,  
280
4T4DOS,WF4DOS,DT4DOS,ET4DOS,WA4DOS,DP4DOS,DT4CFC,ETABCF,  
281
5TFHPDS,CMHPDS,ETHPDS,THPFC,CMHFC,ETHPFC,OMHPFC,T25D,  
282
6TFPDS,CPNFDPS,ETLPDS,FLPFC,CLPFC,ETLPCF,OLHPFC,T25DOS,
283
7TFD4DS,WD4DOS,DT4DAD,WA23DOS,DP4DUS,DT4DCF,ETADCF,  
284
8TFDOS,WF4DOS,DT4FAED,ET4AED,WA6DOS,DP4FDS,DT4FCF,ETACF,  
285
9A5S,A25,AN6,AP7,AP8,AN9,AN2,AN29,AN29
286
$PS55,AM55,CDVMNOZ,CMVMNOZ,BS5AV,AKS5AV,AE25AV,AE25AV
287
COMMON /ALL2/ 
288
1LT1,P1,H1,S1,T2,P2,H2,S2,  
289
1T21,P21,H21,S21,T3,P3,H3,S3,  
290
3T4,P4,H4,S4,T5,P5,H5,S5,  
291
4TF5,S5,H55,S55,BLF,BLC,BLU,BLOB,  
292
5T55,PRF,ETAF,WAF,WAF,WAF,WAF,WAF,  
293
6CN,PRC,EATC,MAC,MAC,YAEE,DP4CM,DP4CM,  
294
7CNHP,ETANTHP,DTANTHP,THLHP,WHG5,FRX5,CS,  
295
8CNLP,ETATLP,DTATLP,THF,BLP,W65,FRX5,HPEXT,  
296
9AL,F,ETAR,AZF,PCNF,ZC,PCNC,WF8,  
297
$TFPHF,TFPHF,PCBLF,PCBLC,PCBLDU,PCBLOB,PCBLOP,PCBLOP,PCBLOP
298
COMMON /ALL3/ 
299
1XP1,XYMAG,XYMC,XYLC,XYBED,XYBED,XYMD,XYMD,  
300
2XT21,XP21,XH21,XS21,T23,P23,H23,S23,  
301
3T24,P24,H24,S24,T25,P25,H25,S25,  
302
4T28,P28,H28,S28,T29,P29,H29,S29,  
303
5MAD,WF0,WFG2,FAR24,ETAD,DPDUC,BYPASS,DM53,  
304
6TS28,P28,V28,AM28,TS29,PS29,V29,AM29,  
305
241
COMMON /ALL4/
1NG6 ,WFA ,MG7 ,FAR7 ,ETAA ,DPAFT ,V55 ,V25 ,  
2P5S ,C6 ,AM6 ,TST ,PS7 ,VT ,AMT ,AM25 ,  
3T5B ,PS8 ,V5 ,AMG ,TS9 ,PS9 ,V9 ,AM9 ,  
4V5D ,VJD ,FGM ,VJM ,FGGM ,FGPD ,FGPM ,  
5FGM ,FGP ,WFT ,WGT ,FAR7 ,FST ,FG ,FN ,SFC ,  
6NA32 ,DPWGDS,DPWING,MA32OS,A38 ,AM38 ,V38 ,T38 ,  
7H38 ,P38 ,T38 ,PS38 ,T39 ,H39 ,PS39 ,T39 ,  
8V39 ,AM39 ,V39 ,VPRINT,AM38 ,V38 ,AM38 ,  
9SWING,FMAIN,FVDFN,PS39 ,FFOVF,FOVF,N,FVDFN,  
0VJJ ,T22 ,P22 ,H22 ,S22 ,T50 ,P50 ,H50 ,  
1COMMON /ALL5/
1LS50 ,MA22 ,ZI ,PCN1 ,CNI ,PRI ,ETAI ,WACI ,  
2FFIP ,LCNP ,ETAPI ,DHTCIP ,DHTI ,BLIP ,PCB1P ,PC1NGU ,  
3ZLDS ,PCNIDS,PRIDS ,ETAIDS ,MAIDS ,PRICF ,ETAPIF ,WACF ,  
4TFIPDS ,CNIPDS ,ETIPDS ,TFIPC ,CNPCF ,ETIPCF ,DHCIP ,WACDS ,  
5MAI ,PCBLI ,BLI ,T22OS ,MA2I ,W650 ,FAR50 ,A24 ,  
6AM23 ,DUMS ,FXF2M ,FM2CP ,AFIF ,PUN ,PCBLI0 ,P6OSAV ,  
7AM6OSV ,ETAASV ,FM2CP ,AFIF ,PUN ,PCBLI0 ,P6OSAV ,  
8AM6OSV ,ETAASV ,FM2CP ,AFIF ,PUN ,PCBLI0 ,P6OSAV ,  
9COMMON /DYN/ ,TRAN,TIME,DT,TF,TRAN,NSTEP,TPRINT,TPRINT ,  
0COMMON /VOLS/ ,VFAN,VINC,TCOMP,VCOMP,COMB,VPTRB ,VPRTB ,VPLTRB ,VAFTB ,  
1VFDOUCT,VFUDUCT
2COMMON /FLOWS/ ,WAFP,WAIF,WACP
3COMMON /UNITS/ ,SI
4LOGICAL SI
5LOGICAL FXM2CP
6COMMON /FAN,CNX(15),PRX(15,15),MACX(15,15),ETAX(15,15),
71NCN,NT(15)
8DIMENSION (Q(1,WLH(2)
9DATA AWOROtMLH/bH COFANebH (LO)
10MORO=A_ORD
11IF (SI) GO TO 100
12TSTO_518.b68
13PSTD_I.0
14RA=.0252
15AJ=Z.T[9
16GO TO 101
17TSTO=288oI69
18PSTD=101325.
19_6=286.9
20AJ=I.O
21THETA=SQRT|T2/TSTD)
22DELTA-P2/PSTD
23IF (IOESeNE°I) GO TO 1
24THETAD=THETA
25WAFDS-_AFC_DELTA/THETA
26CNF=PCNF_THETAO/(IOO**THETA)
27IF (ZFO*LT*O.I ZF=O*
28IF (ZFO.GT.I.) ZF=I.
29CNF=CNF
30CALL SEARCH (ZF_CNFtPRFeNAFC_ETAF,CNXIL)_NCN_PRX|I_II_MACX(I_I)_ET
31IAX(I,I),NPTII),IS_IS,IGO)
32IF ((CNF-CNFS).GT_O.OOOS_CNF)
33MAPEDG=I
34IF (IGO.EQ.I.0R.|GO.EQ.2) MR[TE (8t12)
35CNFS_LH(IGO)
36NAF=MAFC_OELTA/THETA
37IF (IOESeNE°I) GO TO 2
38PRFCF=(PRFDS-I.I/IPRF-I.;
39ETAFCF=ETAFDS/ETAF
40MAFCF=MAFDS/MAF
41WRIT(6,13) PRFCF,ETAF,MAFCF,T20S
42PRF=PRFCF(PRF-1)+1,
43ETAF=ETAFCF*ETA
44WAF=MAFCF*WAF
45WAF=MAFCF*WAF
46PCNF=100*THETA*CNF/THETAD
47DUMB=PRF
48CALL THCOMP (PRF,ETAF,T22H2S2,P2T22,T22,H2S2,P22)
49IF (VFAN,EQ.O=O) GO TO 20
50Q(2)=O=0

ORIGINAL PAGE IS
OF POOR QUALITY
Q(13)=0.0
H2P=H22
P22DOT=DERIV(4,22)
CONTINUE
CALL THERMO(P22,H22,T22,S22,XX2,0,0,0,0)
WAF=WAFP-P22DOT*VFAN/T22/4/RA
U22=H22-RA*U22
U22DOT=DERIV(5,22)
H22X=(MAFP*H22)-P2200T*VFAN/T22/RA
U22=U22DOT*VFAN/T22/RA
CONTINUE
IF (PCRLF.GT.0.) 8LF=PCBLF*WAF
IF (JDES.EQ.0) GO TO 9
JDES=I
IF (NIT.EQ.1) GO TO 8
IF (IOES*EQ.0) GO TO 6
IF (FINTRAN.EQ.1) GO TO 8
IF (MOOE*NE.2) GO TO 3
T6=GUESS(3,Y1,Y2,PCN,PCNF,SY,SB,Y12)*TDOA)
PCNI=GUESS(8,T4,TDOA,Y3,Y4,Y5,Y6,T22,T2DOA,PCNID)
PCNC=GUESS(4,Y1,Y2,PCNI,PCNID,SY,SB,Y12)*PCNCD)
CONTINUE
PCNC=PCNCS(DS)
PCNI=PCNID(S)
T4=TDOA
WFB=WFBDS
T2DS=T23
ZC=ZCDS
ZI=ZIDS
PCNIIG=PCNI
PCNC=(PCNC)
CONTINUE
IF (MODE.EQ.1) GO TO 7
IF (MODE.EQ.0) GO TO 8
T4=GUESS(T7,Y1,Y2,PCNF,PCNFD,SY,SB,Y12,T22,S22)
CONTINUE
PCNC=GUESS(5,T4,TDOA,Y3,Y4,Y5,Y6,T22,T2DOA,PCNCD)
IF (FMZC2P) PCNC=PCNCD(9.9)
PCNG1=PCNC
PCNG2=PCNCD
PCNI=GUESS(9,Y1,Y2,PCNC2,PCNC2,Y5,Y6,T22,T2DOA,PCNID)
CONTINUE
T4=GUESST(6,Y1,Y2,PCNC,PCNCD,SY,SB,Y12,T22,T2DOA,TDOA)
PCNI=GUESST(8,T4,TDOA,Y3,Y4,Y5,Y6,T22,T2DOA,PCNID)
CONTINUE
PCNC=PCNID(S)
PCNI=PCNID(S)
T4=TDOA
WFB=WFBDS
T2DS=T23
ZC=ZCDS
ZI=ZIDS
PCNIIG=PCNI
PCNC=PCNC
T4GU=T4
CONTINUE
IF (MODE.EQ.3) GO TO 10
IF (ABS(CNF-CNFS)*LE.0.001*CNFS) GO TO 11
WRITE (8,14) CNFS,CNF
CONTINUE
IF (PCNF.EQ.0) 100=THETA*CNF/THETAD
CONTINUE
IF (PCNF.EQ.100) 100=THETA*CNF/THETAD
CONTINUE
RETURN
SUBROUTINE COMPTB
COMMON /WORDS/ WORD
COMMON /DESIGN/
1IDES,JDES,KDES,MODE,INIT,IDUMP,IAMP,EGASMX
2IBURN,IAFTBN,ICO,IMCD,IDSCHOC,INSHOC,NOZFL,TRY
3LORDER,NOMAP,NUMMAP,MAPEOG,TOLLALL,ERR(19)
COMMON /ALL1/
1PCNF0,PCNP,PCNBU,TAGU,DUM01,DUM02,DELFG,DELFS,DELSSFC
22FDS,PCNFDS,PRDFS,ETAFDS,WAFDS,PRFCF,ETAFCF,WAFCF
32CDS,PCNCDS,PRCDS,ETACDS,WACDS,PRCCF,ETAHCF,WACCF
47IADS,WFBIOS,DCIODS,ETADO,WAIDS,PRDCF,ETADCF,WAICF
57IFPDS,CNHPDS,EFHPDS,ETHPDF,ENHPCF,ETHCF,ENHACF,TFDS
6TLPDS,CNLPS,ETLPS,TLPCF,CLNPFC,ETLPCF,DHLPCF,TDS
7TLS24DS,WFDOS,DTDOUS,ETAIDS,MA23DS,OPD0US,DTDOUC,ETADCF
8TDS,WFADS,DTFAADS,ETADS,MG6CDS,DPADAS,DTAFCF,ETAACF
9A55,A25,A6,A7,A8,A9,A28,A29
 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,FLF,BLC,BLDU,BLOB
5CNF,PRF,ETAF,WAF,WAF,MA3,WS4,FA4
6NCNPR,ETAC,WACC,WAC,ETAB,DPCOM,DUMP
7CNHP,WATAHP,ATHTCH,ATHTC,ATLHP,WG5,FARGS,CS
8CNHP,ATLAT,ATLCH,ATLHF,ATLHP,FG55,FARGS,HPXT
9CNHP,ALTP,ETAR,ZF,PCNF,ZNPC,WF8
$TFHFP,TFILP,PCLFL,PCBL,PCBLDU,PCBLBD,PCBLHP,PCBLLP
 COMMON /ALL3/
1XPF,XWAF,XWAC,XBLF,XBLDU,XH3,DUMS1,DUMS2
2XPF2,XPF1,XH2,XS21,T23,P23,H23,S23
3T24,P24,H24,S24,T25,P25,H25,S25
4T28,P28,H28,S28,T29,P29,H29,S29
5NAD,WFD,WG24,FAR2,ETAD,DPDAC,BYPASS,DUMS3
6TS28,PS28,V28,AM28,T529,WS29,AM29
7TS25,PS25,V25,AM25,T525,WS25,AM25
8WXW,FSG55,FXFAR55,WXFO,FXG24,FXFAR24,XP1,DUMB
9R6,P6,H6,T7,P7,H7,S7
$R6,P8,H8,S8,T9,P9,H9,S9
 COMMON /ALL4/
1W6FA,WGT,FAR,TET,F,DPAFT,V55,V55
2PS6,V6,AM6,T57,P57,V7,AM7,AM25
3TS8,P58,V8,AM8,T59,P59,V9,AM9
4VA,FRD,VJU,FGMD,VJH,FGMM,FGPD,FGPM
5PFM,FGP,F6,FMT,FG6,FN,SCF
6WAM,DPMDI,DPMNG,NA32DS,AM38,MA38,T38
7HA38,TS38,PS38,T39,H39,ZS39
8V38,AM39,A39,PRINT,WGT,CSV,CSV,CSW,CSW,CSW
9FWN,FWMAIN,FWVFN,P339,FWVFN,FCWVN,FMNDFN,FWDFV
0VJW,IZ22,P22,H22,S22,T30,P50,H30
 COMMON /ALL5/
15S40,MA22,ZI,PCN,CNI,PRI,ETA,MACI
2TFFP,CNP,ETATIP,HTCHPI,HTHI,BLIP,PCBCLI,PCNIIU
3ID,PCNID,PRID,ETAI,A,WAIDS,PRICF,ETAI,WAIFC
4TFPDS,CNPIDS,ETFDS,ETPFDF,ETPFCF,ETIFPCF,ETIFPCF,ETIFPCF
55AI,PCBLI,BLII,T2205,M21,WG50,FA52,A24
6MA32,DUMSPL,FOX2M,FZX2P,FATAN,PR,FCLBI,P50S,PSAV
7AM6D5V,ETAASS,FAT75,Y4P8,4T41,FAN2,FPOOL
COMMON /RMTS/ XHNDPS,ZNZDPDS,DXNPS,PRIMPS,PRWPS,PMIPS,PMIPS,PMIPS
1VFDT,VDVDT,VDVDT
COMMON /FLOWS/ WAPF,WAIP,WAPC
COMMON /UNITS/ SI
LOGICAL SI
DIMENSION Q(9)
LOGICAL FXXW2M,FXXZ2P,DSMPS
COMMON /HTURB/TF1515,CDX(15,15),DTCX(15,15),ETATX(15,15)
1NTFFS,PTFF1159
DATA A0W,WDG,W1H/6HCOMPTB,6H(LO)/6H(HI)/
WORD=AWORD
IF(1)=GOTO 100
RA=-0.252
A3=2.719
CONFAC=1.4091E-5  
GO TO 101  
100  
RA=286.9  
AJ=1.0  
CONFAC=1.0966E-2  
101  
CONTINUE  
IF (ISPOLID=EQ.1) GO TO 8  
IF (IDES=EQ.0) GO TO 1  
CNHP=CNHP+SQRT(T4)/PCNL  
CNHPS-CNHP  
TFHPS=TFHPC  
CALL SEARCH (-1.,TFHPC,CNHP,DHTCHP,ETATHP,TFFX(1),NTFFS,CNX(1,1),0  
HTCX(1,1),ETATX(1,1),NPTFFF(1),15,15,1GO)  
IF (IGO-EQ.1.OR.IGO=EQ.11.OR.IGO=EQ.21) WRITE (8,9) TFFHPS,WLO  
IF (IGO=EQ.12.OR.IGO=EQ.10.OR.IGO=EQ.22) WRITE (8,9) TFFHPS,WHI  
IF (IGO=EQ.20.OR.IGO=EQ.21.OR.IGO=EQ.22) WRITE (8,10) CNHPS,WHI  
IF (IGO=EQ.7) GO TO 2  
CALL ERROR  
RETURN  
2  
NONAP=O  
TFHCAL=WG6*SQRT(T6)/P6)  
BTUEXT=0.76705*HPEXT  
IF(S1) TFHCAL=WG6*SQRT(T4)/P4  
IF(S1) BTUEXT*HPEXT  
XNHP=XNHPD*PCNC/100  
XNHDOT=DERIV(1,XNHP)  
DHTCC=(BTUEXT+WAGP*(H3-H21)+CONFAC*PM1HP*XNHP*XNHDOT)/(WG4*T4)  
IF (IDES=EQ.0) GO TO 5  
TFHPCF=TFHPS/TFHCAL  
DHHPCF=DHTCC/DHTCHP  
ETHPCF=ETHPDS/ETATHP  
WRITE (6,11) CNHP,TFHPCF,ETHPCF,DHHPCF  
5  
TFHCAL=TFHPCF*TFHCAL  
DHHPCF=DHHPCF*DHTCHP  
ETATHP=ETHPCF*ETATHP  
DHTC=DHTCC*T4  
ERR(1)=(TFHCAL-TFHCAL)/TFHCAL  
ERR(2)=DHTCC-DHTCHP/DHTCC  
CALL THERMB (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(WHPTB=EQ.0.0) GO TO 21  
Q(2)=0.0  
Q(3)=0.0  
WG50=WG500  
H500=H50  
P500=DERIV(12,P50)  
18  
CONTINUE  
CALL THERMO(P50,H50,T50,S50,XX2,1,FAR50,0)  
WG50=WG50+P500*WHPTB/T50/1.4/RA  
USO=H50-RA*AJ*T50  
USO0=DERIV(13,USO)  
H50=USO+USO0*WHPTB/T50/1.4/RA  
ERRW=(H50-H50X)/H50X  
DIR=SORT(ABS(H50/H50X))  
CALL AFQ + UQI(Q(1),T50,ERRW,0.,20.,0.0001,DIR,T50,1GO)  
GO TO (19,21,20),1GO  
19  
T50=T50  
GO TO 18  
20  
CALL ERROR  
21  
CONTINUE  
IF (FPFXN2M+OR+DUMSPL) GO TO 8  
CALL COPTB  
RETURN  
8  
P5=P50  
GO TO 101
SUBROUTINE COINLT

COMMON /WORDS/ WORD
COMMON /DESIGN/
1DES , JDES , KDES , MDES , INIT , IDUMP , IAMTP , IGAMX,
21DJBURN , IAFTSN , ICOD , IMCD , IDSHOC , IMSHOC , IQZPLT , ITIYR,
3LOOPER , NMAP , NUMMAP , MAPEDO , TDLALL , ERR19

COMMON /ALLI/
1PCNFGU , PCNCGU , T4GU , DUM1 , DUM2 , DELGF , DELFN , DELSF,
2FFDS , PCNFD , PFODS , ETAFDS , WAPDS , PRF , ETACFT , WACF,
3CDOS , PCNCD , PCOS , ETAOS , WACOS , PROCF , ETACCF , WACCF,
4TFDOS , WFPDS , DTCDOS , ETAPOS , WAPPOS , DOPCOS , DTCCOF , ETAFCF,
5TFHPDS , CNHPDS , ETHPOS , TEPHPF , CNHPCF , ETHPHCF , DHHPCH , TDKOS,
6TFPLDS , CNLPS , ETLPDS , TFLPCF , CNLPCF , ETLPHF , DHLPCF , TDKOS,
7TF2DOS , WFDOS , DTDOS , ETAPOS , WAPPOS , DOPDOS , DTDCOF , ETAOCF,
8TFDS , WFDAS , DTAPOS , ETAPOS , WAPPOS , DOPDAS , DTAFCF , ETAACF,
9A59 , DA55 , AM55 , CVNDQZ , CMNZQZ , A85AV , A95AV , A285AV , A295AV

COMMON /ALL2/
11I , P1 , H1 , S1 , T2 , P2 , H2 , S2,
221 , P21 , H21 , S21 , T3 , P3 , H3 , S3,
34 , P4 , H4 , S4 , T5 , P5 , H5 , S5,
4755 , P55 , H55 , S55 , LBF , BLQ , BLDU , BLOG,
55CF , PRF , ETAF , WAFC , WAF , MA3 , MG4 , FAF,
6NC , PAC , ETAC , WAC , ETA , DOPCOM , DUMP,
7CHNP , ETAFCF , DTCFCH , DHT , BLDC , WG5 , FARP , CS,
8CNLP , ETAFTLP , DHTLP , DHTF , BLLP , WG55 , FARP5 , HPEX,
9AM , ALTP , ETAR , ZF , PCNCF , ZC , PCNC , WFB,
$TFHPF , TFLFP , PCLFL , PCLBL , PCDL , PCLBDU , PCBLBP , PCLBLP

COMMON /ALL3/
1XP1 , XWAF , XWAC , XBLF , XBLD , XH3 , DUMS1 , DUMS2,
242 , XP21 , XH21 , XS21 , T23 , P23 , H23 , S23,
374 , P24 , H24 , S24 , T25 , P25 , H25 , S25,
4758 , P28 , H28 , S28 , T29 , P29 , H29 , S29,
59AD , WFD , WG24 , FAR24 , ETA , DPUCC , BYPASS , DUH3S3,
6TS28 , P28 , V28 , AH28 , TS29 , P29 , V29 , AM29,
7XT55 , XP55 , XH55 , XM55 , XT5 , XPS2 , XS25 , XS25,
8IXMF , XWG55 , XFRAR55 , XWFD , XW24 , FXAR24 , XP1 , DUMB,
9T6 , P6 , H6 , S6 , T7 , P7 , H7 , S7,
$T8 , P8 , H8 , S8 , T9 , P9 , H9 , S9,

COMMON /ALL4/
1LG6 , WFA , MG7 , FAK7 , ETA , DPAFT , V55 , V25,
2PS6 , V6 , AM6 , TS7 , P57 , VT , AM7 , AM25,
3TS8 , PS8 , V8 , AM8 , T59 , P59 , V9 , AM9,
4VA3 , PVD , WJD , FGM , V5M , FGM , FGMD , FGMN,
5FEGM , FGP , WFT , WG , FART , FG , FN , SFC,
6WAM32 , DPGDS , DPGN , WAM32 , AS38 , AM38 , V38 , T38,
738 , P38 , TS38 , P338 , T39 , M39 , P39 , T39
CONTINUE
IF (.NOT.AFTFAN) GO TO 1
T22S=T22
HZS=H2
S2Z=S22
P22S=P22
TZZ=T2
H2ZS=H2
S2Z=S2
P2Z=P2

1
THETA=SQRT(T22/TSTD)
DELTA=P22/PSTD
IF (.NOT.FAN) WAIF=WAIF-BLF
IF (IDES=NE+1) GO TO 2
PRI=PRI0S
PCBI=PCBI0D
IF (.NOT.FAN) WACDWS=WAI*THETA/Delta
IF (.NOT.FAN) DUMSPL=.TRUE.
WACI=WACDS
THETAD=THETA
WACDS=WAI*DELTA/THETA
ETAI=ETAI0S

2
IF (.NOT.FAN) GO TO 3
IF (FAN AND MIDDLE SPool ROTATE AT SAME SPEED)
SPDFAN=CNF*SQRT(T2/TSTD)
CNF=SPDFAN/THETA
PCNI=100.*CNI*THETA/THETAD
IF (IDES=EQ.1) PCNI0S=PCNI

3
CNI=PCNI*/THETAD/100.*THETA)
ZI=AMAX1(Z1,0.)
Z1=AMIN1(Z1,1.)
CNI=CN1
IF (.NOT.FAN) WACI=WAI*THETA/Delta
CALL INDUMY (CN1,ZI,WAICDS,IDES)
CALL SEARCH (Z1,CNI,PR1,WACI,ETAI,CN1,CN1,PRX,WAICX,ETAXX,NPTX,
115,15,IGO)
GO TO 5

4
CONTINUE
CALL SEARCH (Z1,CNI,PR1,WAC1,ETAI,CN1,CN1,PRX(1,1),WAICX(1,1),ETAXX(1,1),NPTX(1,1),NPTX(1,1,15),IGO)

5
CONTINUE
IF ((CNI-CNI1)*GT.*0.005 CN1 MAPEDG=1
IF (IGO=EQ 1.) OR (IGO=EQ 2) WRITE (8,12) CN1,WLH(IGO)
IF (.NOT.FAN) WACI=WAI*THETA/Delta
WAI=WACI*Delta/THETA
W22=WAI
IF (IDES=NE+1) GO TO 7
T220S=T22

6
IF (AFTFAN) T220S=T22
IF (.NOT.FAN) DUMSPL) PRICF=(PRI0S-1.)/(PRI-1.)
ETAI0C=ETAIDS/ETAI
WAI=WAICF=WAI
IF (.NOT. DUMSPL) GO TO 6
PRICF=1.
ETAI0C=1.
WAI=1.

7
WRITE (6,13) PRICF,ETAI0C,WAI,PR1,T22DS
PRI=PRI0F*PRI-1.*1.
ETAI=ETAI0F*ETAI
WAI=WAICF=WAI
WAI=WAI
WACI=WACI*WAIF
WAI=WAI
CALL THCONP (PR1,ETAI,T22,H2,2,22,P22,T21,H21,21,21,21)
IF (VINTC=EQ.0.0) GO TO 21
Q(2)=0.0
Q(3)=0.0
H2P=H21

8
P21DOT=DERIV1 (6,P21)

9
CONTINUE
CALL THERMO(P21,H21,T21,21,XXZ,0.,0.,0.,0.)
WAI=WAI-P21DOT*VINTC/T21/1.4/RA
U21=H21-AJ*RA*T21
U2100T=DERIV(T7,U21)
H2IX=(RAI+H2IP-(RAI=WAI)*U21-U2100T*P21*VINTC/T21/RAI)/WAI
ERRW=SQR(H2I-H2IX/H2I)
DIR=SQR(ABS(H2I/H2IX))
CALL #OUTRIG(I1)*T21,ERRW,0.,20.,0.,0.0001,DIR,21T,1GO)
19 T21=T2IT
GO TO 18
20 CALL ERROR
21 CONTINUE
IF (<NOT-DUMPSL>) GO TO 8
PRI=1.
ETAI=1.
T21=T22
H21=H22
S21=S22
P21=P22
IF (ISPOOL-EQ.1) WA21=WAI
CONTINUE
IF (IDES-NE.1) GO TO 9
BLI=PCBLI*WAI
WA21=WA22-BLI
WA32=BLI
T22-T22S
H22=H22S
S22=S22S
P22=P22S
11 CALL COCUMP
RETURN
C
C
C
12 FORMAT (19H0=* * * CNI OFFMAP,F10.4,2xA6,11H0 * * *$$$$$$)
13 FORMAT (20H/MIDDLE SPOOL DESIGN,F4X8H PRICF=,E15.8,E15.8 ETAICF=,E15.8)
18.8H WAICF=E15.8,E8H T22DS=,E15.8)
14 FORMAT (10HCNI WAS=,E15.8,11H AND NOW=,E15.8,24H CHECK PCNI I)
INPUT$$$$$$)
END

SUBROUTINE COIPTB
COMMON /WORDS/ WORD
COMMON /DESIGN/
IDES ,IDES ,KDES ,MODE ,INIT ,IDUMP ,IAMTP ,IGASMM,
2IDBURN ,IAFTB ,IOCD ,IMCD ,1DSHDG,IMSHDG,NOZFLT,ITRYS,
3LDOPER ,NONAP ,NUMMAP,MAPEDG,YDALL,ERR(9)
COMMON /ALL1/
1PCNFU ,PCNCUG ,TAGAV ,DUMD1 ,DUMD2 ,DELFV ,DELFN ,DELSFC,
2ZFDOS ,PCNFDOS ,PRFDS ,ETAFOOS ,WAFDOOS ,PRKCF ,ETAFCF ,WAFCF,
3ZCDS ,PCNCDS ,PRCD ,ETAACDS ,WACDS ,PRCCF ,ETACCF ,WAACF,
4TFDOS ,MFBDOS ,TDCCDS ,ETABDS ,WACDS ,DPCDS ,DTACC ,ETACC ,TAACC,
5TFHPDOS ,CNHFDOS ,TFHPCF ,CNHPF ,ETHPF ,OMHPF ,T2DS,
6TFLPFDOS ,CNLPDOS ,TFLPCI ,CNLPCF ,ETLPCF ,DHLPF ,T21DS,
7T72DS ,MFADS ,TDUDDS ,ETADDOS ,W23DS ,DPUDS ,DTDCF ,ETADC,
8T77DS ,MFADS ,TDADS ,ETADDOS ,WGCDS ,DPADOOS ,DTCACF ,ETACCF,
94AS ,AG ,A25 ,AT ,A9 ,A8 ,A28 ,A29
4PS55 ,AM55 ,CVNDZ,CVNOZ,BSAV,CU55,CU55,CU55,CU55,CU55,CU55,
COMMON /ALL2/
111 ,P1 ,H1 ,S1 ,T2 ,P2 ,H2 ,S2
2T21 ,P21 ,H21 ,S21 ,T3 ,P3 ,H3 ,S3
3T6 ,P6 ,H6 ,S6 ,T7 ,P7 ,H7 ,S7
4T55 ,P55 ,H55 ,S55 ,BLF ,BLC ,BLD ,BLOB,
5CNF, PRF, ETAF, WAF, WAI, WA3, WG4, FAR4, 23
6NC, PRC, ETAC, MAC, WAC, ETAB, DPACOM, DUMP, 24
7CNLP, ETATLP, DHTCLP, DHTF, BLLP, WG5, FAR5, CS, 25
9AM, ALTP, ETAR, ZF, PCNF, ZC, PCNC, WFA, 26
$TFFHP, TFFLP, PCBLF, PCBLC, PCLBDU, PCBLD9, PCBLHP, PCBLLP, 27
COMMON /ALL3/ 28
1KP1, XMAF, XWAC, XBLF, XBLDU, XH3, DUMS1, DUMS2, 29
2XT21, XP21, XH21, X521, T23, H23, S23, 30
3T24, P24, H24, S24, T25, P25, H25, S25, 31
4T28, P28, H28, S28, T29, P29, H29, S29, 32
5WAD, WG2, FAR24, ETAC, DPUOC, BYPASS, DUMS3, 33
6T28, PS28, V28, AM28, TS29, PS29, V29, AM29, 34
7XT55, XP55, XH55, X555, TS25, X25, X525, 35
8XWFB, XWG55, XWAR5, XWFD, XWG24, XWAR24, 36
9T6, T6, P6, H6, S6, T7, P7, H7, S7, 37
$T8, P8, H8, S8, T9, P9, H9, S9, 38
COMMON /ALL4/ 39
1WG6, WFA, WG7, FAR7, ETA9, DPAFT, V55, V25, 40
2PS6, V6, AM6, T57, PS7, V7, AM7, 41
3TS6, PS8, V8, AM8, T59, PS9, V9, AM9, 42
4WA, FGD, V9, AM9, 43
5FGM, FGFT, FGT, WGT, FAR5, W55, H55, 44
6WA32, WPWGDS, WPWING, WA32DS, A3B, AM38, V3B, 45
7XT25, XP55, XH55, X555, TS25, X25, X525, 46
8XWFB, XWG55, XWAR5, XWFD, XWG24, XWAR24, 47
9TNWNING, FNAIN, FOWOFN, PW59, PWCFVN, PWCFDF, PW59FD, 48
5JVW, T22, P22, H22, S22, T50, P50, H50, 49
COMMON /ALL5/ 50
1550, WA22, Z1, PCNI, CN1, PRI, ETA1, MACI, 51
2TFFI, CNIP, ETATIP, DHTCIP, DHTI, BLIP, PCBLIP, PCNI, 52
3TIPS, PCNIDPS, PRIDS, ETAPIDS, WAIDS, PCPIF, ETAICF, WAICF, 53
4TFIPDS, CNIPDS, ETIPDS, TFIPCF, CNIPCF, ETAICF, PCNI, 54
5WAI, PCBLI, PLS, T2205, WA21, W50, FR50, A25, 55
6AM32, WPWGDS, WPWING, WA32DS, A3B, AM38, V3B, 56
7XT25, XP55, XH55, X555, TS25, X25, X525, 57
8XWFB, XWG55, XWAR5, XWFD, XWG24, XWAR24, 58
9TNWNING, FNAIN, FOWOFN, PW59, PWCFVN, PWCFDF, PW59FD, 59
5JVW, T22, P22, H22, S22, T50, P50, H50, 60
COMMON /ALL6/ 61
1VFOUT, TVDOUT, 62
COMMONT /FLDWS/ WAFP, WAIW, WACP, 63
COMMON /UNITS/ SI, DIMENSION (9), 64
COMMON /ITURB/TFFX(15), CNX(15,15), DHTCX(15,15), ETA(15,15), 65
1NTFFS, NPTTFF(15), 66
LOGICAL AFTFAN, FXFNZM, FXMZCP, SI, 67
COMMON /HTURB/TFFY(15), CNY(15,15), DHTCY(15,15), ETAY(15,15), 68
1NTFTYS(15), 69
DATA AWORD, WLO, WH, WH1, 70
6H, LO, HI, / 71
1 IF (SI) GO TO 100 72
RA = 0252 73
AJ = 719 74
CONFAC = 1.4091E-5 75
GO TO 101 76
RA = 286.9 77
AJ = 0 78
CONFAC = 0.9666E-2 79
CONTINUE 80
100 H22SAV = H22 81
IF (AFTFAN) H22 = H2 82
WORD = AWORD 83
IF (IDES.EQ.0) GO TO 1 84
CNIPCF = CNIPDS*SORTIT50/PCNI 85
IF (FXM2CP) CNIPCF = CNIPDS*SORTIT50/PCNI 86
1 CNIP = CNIPCF*PCNI/SORTIT50 87
CNIPS = CNIP 88
TFFIPS = TFFIP 89
IF (FXM2CP) GO TO 2 90
CALL SEARCH (-1, TFFIP, CNIP, DHTCIP, ETATIP, TFFX(1), NTFFS, CNX(1,1), 91
DHTCX(1,1), ETA(1,1), NPTTFF(1), 15,15, 92
1G0) 93
IF (FXM2CP) CALL SEARCH (1, TFFIP, CNIP, DHTCIP, ETATIP, TFFY(1), NTFY 94
15, CNY(1,1), DHTCY(1,1), ETA(1,1), NPTTTSF(1), 15,15, 95
1G0) 96
IF (IG0.EQ.1) OR IG0.EQ.11 OR IG0.EQ.21 WRITE (8,9) TFFIPS, WLO 97
IF (IG0.EQ.2) OR IG0.EQ.12 OR IG0.EQ.22 WRITE (8,9) TFFIPS, WLO 98
IF (IG0.EQ.10) OR IG0.EQ.11 OR IG0.EQ.12) WRITE (8,9) CNIPS, WLO 99
IF (IGO.EQ.20.OR.IGO.EQ.21) WRITE (8,10) CNIPS,WHI 97
IF (IGO.NE.7) GO TO 3 98
CALL ERROR 99
RETURN 100
NOMAP=0 101
TFCAL=WG50*SQRT(T50)/(14.696*P50) 102
IF(SI) TFCAL=WG50*SQRT(T50)/P50 103
XNIP=XNIPDS*PCNI/100.* 104
XNIDOT=DERIV(XNIP) 105
BTUEXT=.706705*HEXT 106
IF(SI) BTUEXT=HEXT 107
DHICAL=CONFAC*PNI*XNIP*XNIDOT 108
DHTIC=(WAIP*(H21-H22)+DHACEL)/(WG50*T50) 109
IF(FXM2CP) DHTIC=(BTUEXT+16.8*(H3-H21)+WAIP*(H21-H22)+DHACEL)/ 110
(1706505) 111
IF(WG50*T50) 112
IF (IDES.EQ.0) GO TO 6 113
TFICAL=TFICAL+TFICAL 114
DHPICF=DHTIC/DHTIC 115
ETICF=ETICAL+ETICAL 116
IF (FHMCP) TFICAL=TFICAL 117
WRITE (6,11) CNIPCFF,TFICAL,ETICAL 118
6 119
TFICAL=TFICAL+TFICAL 120
DHTICD=ETIC/DHTIC 121
ETICAL=ETICAL+ETICAL 122
IF (IDES.EQ.0) GO TO 6 123
TFICAL=TFICAL+TFICAL 124
ERR(N1)=TFICAL+TFICAL 125
ERR(N2)=TFICAL+TFICAL 126
CALL THTURB(DHTIC,ETICAL+FAR50,H50,S50,P50,T5,H5,S5,P5) 127
IF(BLIP.LE.0.0) GO TO 7 128
FAR5=FAR50+WG50/(1+WG50*BLIP*FAR50+1.0)) 129
WGS=WG50+BLIP 130
XN(IP=BLIP*H3+WG50*H5)/WG5 131
CALL THERMO(P5,H5,T5,S5,XX2,1,FAR5,1) 132
GO TO 8 133
7 134
FAR5=FAR50 135
WGS=WG50 136
8 137
CONTINUE 138
IF (V2PR8+E0.0) GO TO 21 139
Q(2)=0.0 140
Q(3)=0.0 141
WGS=WG5 142
H5P=H5 143
P50=DERIV(14.5) 144
18 145
CONTINUE 146
CALL THERMO(P5,H5,T5,S5,XX2,1,FAR5,0) 147
WGS=WG5-P50=VPR8/T5/1.4/RA 148
U5=H5-R=AJ+T5 149
U5D0=DERIV(15.0) 150
H5X=(WGS=H5P=16.8*WGS-P5)*V2PR8/T5/RA)/WGS 151
ERR=(H5-H5X)/H5 152
DIR=SQRT(AHS(H5/H5)) 153
CALL AFQUIR(11,T5,ERRW,0.0,20.0,0.0001,DIR,T5,IGO) 154
GO TO (19,21,20),IGO 155
19 156
T5=T5 157
GO TO 18 158
20 159
CALL ERROR 160
21 161
CONTINUE 162
H22=H22SAV 163
CAF NTPTB 164
RETURN 165
C 166
C 167
C 168
9 169
FORMAT (19H0,2F16.6,11H0,2F16.6) 165
10 166
FORM M (20H0,2F16.6,11H0,2F16.6) 167
11 168
END 169
52

$IBFTC COLPTB
SUBROUTINE COLPTB
COMMON /WORDS/ WORD
COMMON /DESIGN/
IODES, JODES, KDES, MODE, INIT, IDUMP, IAMTP, IGAEXM,
2DBURN, IAFTHN, IDCD, IDCH, IDSHOC, IDSHOC, N2FZLT, ITRYS,
3LOOPER, NOMAP, NUMAP, MAPED, COLPTB, ERL(19)
COMMON /ALL1/
1PC1G0, PC1C0G0, TACG0, TACG1, TACG2, TACG3, TACG4
2FDOS, PCFDOS, PRFDOS, ETA1FDOS, WADFS, PRFCF, ETA1FCF, WAFCF
3COS, PCNCDOS, PRCDOS, ETA1CDOS, WADS, PRCCF, ETA1CCF, WACCF
4T4DFS, WF4DFS, DTF4DFS, ETA14DFS, WAD4DFS, V4DFS, ETA14CF, ETA4CF
5TF1PDOS, CNTF1PDOS, ET1FDOS, TF1PDOS, CNLTPDOS, ET1FCDOS, TF1PCF, ETA1FCDOS
6TF2PDOS, CNTF2PDOS, ET2FDOS, TF2PDOS, CNLTF2PDOS, ET2FCDOS, TF2PCF, ETA2FCDOS
7TF24DFS, WF24DFS, DTF24DFS, ETA124DFS, WAD24DFS, V24DFS, ETA12CF, ETA24CF
8T4DFS, WF4DFS, DTF4DFS, ETA4DFS, WAD4DFS, V4DFS, ETA4CF, ETA4CF
9A5S, $A25, A7, A8, A9, A28, A29
1PS55, CVNO24, CVHNO24, A6SAV, A9SAV, A28SAV, A29SAV
COMMON /ALL2/
1T1, S1, T2, P2, H2, S2
2T21, H21, S21, T3, P3, H3, S3
3T4, H4, S4, T5, P5, H5, S5
4T55, S55, B5, OLC, BLOU, BLOB
5CNF, PFR, ETA1F, WMFC, WMF, WMG, WMF
6NC, PRC, ETA1C, WACC, WAF, WCF, WAF
7CNH, ETA1HP, DHT1CH, DHT1C, BL1HP, W1G5, FA1R5, CS
8CNLP, ETA1LP, DHT1LP, DHT1P, BL1LP, W1G5, FA1R5, HP1XT
9AM, LATP, ETA1AR, ZL, PCNF, ZC, PCNC, WFB
$FFFFHP, TFLFL, PCBLF, PBCLC, PCCL0U, PCLB0U, PCBL0H, PCBLLP
COMMON /ALL3/
1X1F, XWAF, XMAC, XBLF, XBLD0U, XH3, DUM51, DUM52
2XT21, XP21, X21, X521, T23, H23, S23
3T24, P24, H24, S24, T25, P25, H25, S25
4T28, P28, H28, S28, T29, P29, H29, S29
5MNAD, WFD, W24F, FAR24, ETA1D, PD1UC, BYPASS, DUM53
6T528, PS28, V28, AM28, TS29, PS29, V29, AM29
7TX5P0, CNX5P0, X55P0, TX25, XP25, TX25, X525, S525
8BF8P, XW55, FX55P, WFXD, XMG24, FX24P, XP21, DUM57
9T6, P6, H6, S6, T7, P7, H7, S7
8T8, P8, H8, S8, T9, P9, H9, S9
COMMON /ALL4/
1XG5, WFA, W7, FAR7, ETA1A, DPAFT, V55, V25
2P56, V6, AM6, TS7, PS7, V7, AM7, AM25
3T58, PS8, V8, AM8, TS9, PS9, V9, AM9
4VADA, FRD, VJO, FGM0, VG1M, FGM1, FGM2, FGM3
5FGM, FGP, WFT, WFT, FART, V6, FNC, FNC
6WAM32, DPMGDS, DPMLNG, WAG32DS, A38, AM38, V38, T38
7XH3, P38, TS38, PS38, T39, P39, TS39
8V39, AM39, A39, BPRINT, MC37, CVNO24, FGMWNG, FGMWNG
9FWN1NG, FHMNA1, FNOVF0M, PS39, FFOVF1M, FCOVF1, FNOFPN, FNOF0D
8JVM, T22, P22, H22, $22, X50, P50, H50
COMMON /ALL5/
15S50, WA22, 11, PCN, CN1, PRI, ETA1, WACI
2TEFFP, CNIP, EAT1IP, EHTC1P, DHTI, BL1P, PCBLIP, PCNIGU
3ZI5OS, PCNIOS, PRIOS, ETA1IOS, WAI5OS, PRICF, ETA1ICF, WACIF
4TP12OS, CNPIOS, ETIPOS, TFI1PCF, CN1PCF, ET1PCF, W1PCF
5W51, PCBL1, BL1, T22OS, WA21, HN50, FAM50, A24
6AN23, DUMSPL, FXP2M, FXM2CP, AFT1AN, PUNT, PCB1L0, PDSAV
7AM6DSV, ETA1ASV, FART5V, T4B1L, T41, FAN, ISP0U
COMMON /RPSMS/ XNHPODS, XNHPODS, XNHPODS, PMP1HP, PMP1HP, PMP1HP
COMMON /VOLS/ WFA, VINTC, VC0MD, VC0M, VHPTRB, V1P8TRB, VLPTRB, VAFTBN, 1
VFOUT, VFOUT
COMMON /FLS/ WA1F, MA1P, WACP
COMMON /UNITS/ S1
COMMON /LOGI1/ AFTFAN, FXP2M, FXM2CP, S1
COMMON /LTURB/ TFFX(15), CNX(15, 15), DHTC1X(15, 15), ETA1TX(15, 15)
COMMON /NTFTS, NPTTFF(15)
DIMENSION Q19
DATA AWORD, WLO, WHI, 6HCOLPTB, 6H (LO), 6H (HI) /
WORD=AWORD
IF(S1) GO TO 100
RA=-0252
AJ=2.719
52
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=CNLPS*SQR(T5)/PCNF
CNLPS=CNLP
TFLPS=TFLP
CALL SEARCH (-1.,TFFLP,CNLP,DHTCLP,ETATLP,TFFX(11),NTFFS,CNX(1,1),D
HTCX(1,1),ETATX(1,1),NTFFX(1,1,15,15,15,15,IGO)
IF (IGO.EQ.1) WRITE (8,8) TFFLP,WLO
IF (IGO.EQ.2) WRITE (8,8) TFFLP,WHI
IF (IGO.EQ.12) WRITE (8,9) CNLPS,WLO
IF (IGO.EQ.22) WRITE (8,9) CNLPS,WHI
IF (IGO.NE.7) GO TO 2
CALL ERROR
RETURN
2 undergo=0
IF(IGO.EQ.2) GO TO 11
IF(IGO.EQ.1) WRITE (8,8) TFFLP,WLO
IF(IGO.EQ.11) WRITE (8,8) TFFLP,WHI
11 IF (IDO.EQ.0) GO TO 5
TFLPCF=TFLPS/TFLCAL
DMLPCF=DHTCF/DHTCLP
ETLPCF=ETLPS/ETATLP
WRITE (6,10) CNLPCF,TFLPCF,DMLPCF,ETLPCF
5 TFLCAL=TFLPCF*TFLCAL
DHTCLP=DMLPCF*DHTCLP
ETATLP=ETLPCF*ETATLP
DHTF=DHTCF*T5
I2=4
IF (ISPOOL=1) I2=1
IF (ISPOOL=1) I2=2
ERR11=(TFLCAL-TFFLP)/TFLCAL
ERR12=(DHTCF-DHTCLP)/DHTCF
CALL THTURB (DHTF,ETATLP,FAR5,H55,S55,P5,T55,H575,S55,P55)
IF (BLLP=LE.0) GO TO 6
FAR55 = FAR5*W5/(W55+BLLP*(1.+FAR5))
W55=W5+BLLP
H55=(BLLP+H5+H55)/W55
CALL THERMO(P55,H55,T55,S55,X2,1,FAR55,1)
GO TO 7
6 FAR55=FAR5
W55=W5
7 CONTINUE
IF (WLPLTRB=EQ.0.0) GO TO 21
Q(2)=0.0
Q(3)=0.0
W55P=W55
H55P=H55
P55DOT=DERIV16,P55)
18 CONTINUE
CALL THERMO(P55,H55,T55,S55,X2,1,FAR55,0)
W55=W55P-P55DOT*WLPLTRB/T55/1.+RA
U55=H55-RA-AJ+T55
U55DOT=DERIV17,U55)
H55X=(W55P+H55P-W55P)*U55-U55DOT*P55*WLPLTRB/T55/RA+W55
ERRW=(H55-H55X)/H55
DIR=SQR(ABS(H55/H55X))
CALL AGFORI(Q1),TS5,ERRW,0*,20*,0.0001,D1R,TS5,T1G)
GO TO (19,21,22,1G0)
19 T55=T5T
GO TO 18
20 CALL ERROR
21 CONTINUE
CALL FRTOSD
RETURN

C

8 FORMAT (19H0****TFLP OFF MAP,FIG,4*2X46.1H0****88****)

C

9 FORMAT (19H0**** CNLP OFF MAP,FIG,4*2X46.1H0****88****)

C

10 FORMAT (20HOL, TURBINE DESIGN,5X7MCNLPCF=,E15.8,8H TFLPCF=,E15.8
END
1,8 TFLPCF=,E15.8,8H DMLPCF=,E15.8)

$IBFTC COMIX
SUBROUTINE COMIX
COMMON /WORDS/ WORD
COMMON /DESIGN/
10IDES . ,JDES ,KDES ,MODE ,INIT ,IDUMP ,IAMTP ,IGASMX,
210BURN,IAFBN, TIODC ,IMC ,IODSHC, IOMHOC,NQZFLI,ITRYS
31LIPUT,KNMAP,NUMMAP,MAPEDG, TOLALL,ERR(9)
COMMON /ALL1/
1PCNFG,HPCNCGU,TAGU,DUDM1 ,DUDM2 ,DELFG ,DELFN ,DELSF,
2FPDS ,PCNFDS,PRFDS ,ETAIFS,WAFDS ,PRRCF ,ETAFCC,WAFCF,
32CDS ,PCNCDS,PRCDS,ETAADC,WAADC,PRRCC,ETACCF,WAACF,
4TADS ,WAFDS ,DTDCDS,ETAADS,WADCD,DPCADS,DTCOFC,ETABCF,
5TFHPDS,CHMHDPS,ETHPDS,THPCF,CMHPCF,ETHPCF,ETHPCF,T2DS,
6TFLPDS,CNLPDS,ETLPS,TLFPCF,CLNPCF,ETLPCF,DLNPCF,T1LDS,
7T240S ,WFDOS ,TDTDOS,ETAADS,WAD203,DPODUS,DOTUCF,ETADCF,
8TDS ,WFDOS ,DTAFDS,ETAADS,WADG60S,DPAFDS,DTAFCF,ETACCF,
9A55 ,A25 ,A6 , A7 , A8 , A9 , A10
15P55 ,A55 ,AM55 ,CVNDZ, CVMDZ, A58AV , A95AV, A58AV, A95AV
COMMON /ALL2/

1 IT , P1 , P1 , H1 , S1 , T2 , P2 , H2 , S2
19 2 T21 , P21 , H21 , S21 , T21 , P21 , H21 , S21
20 3 T74 , P4 , H4 , S4 , T54 , P4 , H5 , S5
21 4 T55 , P55 , H55 , S55 , T55 , P55 , H55 , S55
22 5 CNF , PRF , ETAF , WAF , WAF , MA3 , M3 , W4
23 6 CNC , PRC , ETAE , WAC , WAC , ETA , WP3 , WP3
24 7 CHP , ETATMP , DHTCHP , DHTC , BLHP , W55 , F55 , CS
25 8 CMLP , ETATLP , DHTLCL , DHTT , BLLP , W55 , F55 , HPXT
26 9 AM , ALTP , ETAR , ZF , PCN , ZC , PCNC , WFE
27 10 TFFNP , TFFLP , PCBLF , PCBLF , PCBLD , PCBLD , PCBL, PCBL
COMMON /ALL3/
1 XP1 , XMAP , XMWP , XBLF , XBLUO , XH3 , DUM51 , DUM52
29 2 X21 , XP21 , XM21 , XS21 , T23 , P23 , H23 , S23
30 3 T24 , P24 , H24 , S24 , T25 , P25 , H25 , S25
31 4 T28 , P28 , H28 , S28 , T29 , P29 , H29 , S29
32 5 NAD , WFD , WGD2 , WFD , ETAD , DPSUC , BYPASS , DUM53
33 6 T28 , P28 , H28 , S28 , T29 , P29 , H29 , S29
34 7 TX55 , XP55 , XMS5 , X55 , T25 , X25 , X52 , X52
35 8 WKB , XM55 , XE55 , WXM , XM24 , XF24 , XSM , XSM
36 96 , P6 , H6 , S6 , T7 , P7 , H7 , S7
37 108 , P8 , H8 , S8 , T9 , P9 , H9 , S9
38 COMMON /ALL4/
1 LMG6 , WFA , WGD , FAR7 , ETA , CPA , CVPS , CVPS
40 2 P56 , Y6 , AM6 , TS7 , PS7 , V7 , AM7 , AM7
41 3 TS8 , P8 , V8 , AMI , TS8 , PS9 , V9 , AM9
42 4 VAD , FRED , VJD , FNGD , VJF , VM , FGM
43 5 FGM , FGSP , VWT , VGT , FCP , FCP
44 6 MAP32 , DPMGDS, DPMG , IMA32 , A38 , AM38 , V38
45 7 H38 , P38 , TS38 , P38 , T39 , H39 , P39
46 8 V59 , AM39 , A39 , BPR , N93 , CVNWDG, FGWNDG, FGPMG
47 9 MNW , FMAM , FMVFN , PS39 , FPV , PCV , VMFPD, FMDVFD
48 10 WJ , T22 , P22 , H22 , S22 , T50 , P50 , H50
50 COMMON /ALL5/
1550 , MA22 , ZI , PCN , CNI , PRI , ETAI , MACI
51 2 TFFLP , CNLP , ETAI , DHTCIP , DHTI , BLIP , PCBLIP , PCNIGU
COMMON/WRERR/ICODAFB, ICODUG, ICOMIX
COMMON/UNITS/SI
LOGICAL SI

DIMENSION QA*(15), PSB(15), PSS(15), PZS(15)
DIMENSION QA*(15), PSB(15), PSS(15), PZS(15)

DATA AWORD/6H COMIX/
DATA AWORD/6H COMIX/

IF SJ) GO TO 100
AJ=778.2b
CAPSF-211be2170
G-32.17069
GD=1.986375
GO TO 101
AJ=1.0
CAPSF=1.0
G-1.0
RDEM=8316.61
CONTINUE
ICOMIX=0
CALL PROCON (FAR55, T55, XX1, XX2, XX3, XX4, PHI55, XX5)
CALL PROCON (FAR25, T25, XX1, XX2, XX3, XX4, PHI25, XX5)
IF (DES.EQ.O) GO TO 12
CALCULATE A55 AND A25 WITH PS25=P55
IF (P55.EQ.0.0) GO TO 3
TS55=TS55*(P55/P55)**0.286
DO 1 I=1,15
CALL PROCON (FAR55, T55, CS55, AK55, CP55, REX55, PHI55, HS55)
PHIS=PHI55-REX55*ALOG(P55/P55)
DELPHI=PHIS-PHI55
IF (ABS(DELPHI) .LE. 0.0001*PHI55) GO TO 6
TS55=TS55*EXP(4.0*DELPHI)
ICOMIX=1
2 CALL ERROR
RETURN
3 TS55=0.875*T55
DO 4 I=1,15
CALL PROCON (FAR55, T55, CS55, AK55, CP55, REX55, PHI55, HS55)
V55=AM55*CS55
HSCAL=H55-V55**2/(2.*G_AJ)
DELHS=HSCAL-H55
IF (ABS(DELHS) .LE. 0.0005*HSCAL) GO TO 5
TS55=TS55+DELHS/CP55
ICOMIX=2
GO TO 2
5 PS55=PS55/EXP(1.PHI55-PHI55/REX55)
IF (PS55.GT.PZ55) GO TO 45
6 IF (HS55.GT.HS55) GO TO 7
WRITE (8,46) P55, PSS55, T55, T55, HS55
ICOMIX=3
CALL ERROR
7 V55=SQRT(2.*G_AJ*HS55-HS55))
RHO=CAPSF*PS55/(AJ*REX55*T55)
A55=W55/PHI55
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=T55*(PS25/P25)**0.286
DO 9 I=1,15
CALL PROCON (FAR25, T25, CS25, AK25, CP25, REX25, PHI25, HS25)
PHIS=PHI25-REX25*ALOG(P25/P25)
DELPHI=PHIS-PHI25
IF (ABS(DELPHI) .LE. 0.0001*PHI25) GO TO 10
TS25=TS25*EXP(4.0*DELPHI)
ICOMIX=4
GO TO 2
9 TS25=TS25*EXP(4.0*DELPHI)
GO TO 2

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10 IF (H25 GT HS25) GO TO 11
WRITE (8,48) P25,PS25,T25,T525,H25,HS25
ICOMIX=5
CALL ERROR
11 V25=SQRTI2*GAJ*(H25-HS25))
RHO=CAPSF*PS25/(AJ*REX25*TS25)
A25=MG24/(RHO*V25)
AM25=V25/C525
WRITE (6,49) A55,AM55,A25,AM25
GO TO 27
C *** CALCULATE PS55 AND PS25
12 WQA=WG55/AM55
**=SQRT(G/(T55*AJ))*CAPSF
MCON=0
QQ(2)=0.
QQ(3)=0.
AM55=0.50
TS55=0.875*TS55
13 DO 14 I=1,15
CALL PROCOM (FARS55,TS55,CS55,AK55,CP55,REX55,PHI55,HS55)
V55=AM55*CS55
HSCAL=H55-V55**2/(2*GAJ)
DELHS=HSCAL-HS55
IF (ABSDELHS LE 0.0005*HSCAL) GO TO 15
14 TS55=TS55+DELHS/CP55
ICOMIX=6
GO TO 2
15 WQA=C1*SQRT(AK55/REX55)*AM55/(1+(AK55-1.0)*AM55**2/2.0)**((AK55+1.0)/(2.0*(AK55-1.0)))/1.2*(AK55-1.0))
AMX=AM55
IGOGO=0
16 DIR=WQA/WQA
E=VQA-WQAT/WQA
CALL AFQUIR (QQ(1),AMX,EW,0.,300.,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=DUM01
WRITE (8,50) PCNF,AMX,PS55,PSS55,P25,PS25
PCNF=1.01*PCNF
DUM01=PCNF
18 NOMAP=7
ICOMIX=0
RETURN
19 WRITE (8,51) IF,AMX,PS55,PSS55,P25,PS25
ZF=0.9992Z
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=PSS55/EXP1(PHI55-PHI55)/REX55)
IF (IGASMX +EQ 0) GO TO 41
IF (IGASMX -EQ -1) GO TO 35
WQA=MG24/A25
C1=P25*SQRT(G/(T25*AJ))*CAPSF
MCON=0
QQ(2)=0.
QQ(3)=0.
AM25=0.25
TS25=0.875*TS25
23 DO 24 I=1,15
CALL PROCOM (FARS25,TS25,CS25,AK25,CP25,REX25,PHI2S55,HS25)
V25=AM25*CS25
HSCAL=H25-V25**2/(2*GAJ)
DELHS=HSCAL-HS25
IF (ABSDELHS LE 0.0005*HSCAL) GO TO 25
24 TS25=TS25+DELHS/CP25
200
ICOMIX=8
GO TO 2
25 WQT=C1*SQRT(AK25/REX25)*AM25/(1.0*(AK25-1.0)*AM25**2/2.0)*(1.0*(AK25-1.0))
AMX=AM25
IGOQ=1
GO TO 16
27 WGS=W24+W55
ERRS1=(PS25-PS55)/PS25
WF55=FA55*WGS/(FAR55+1.0)
WA55=W55/(FAR55+1.0)
WF24=FA24*W24/(FAR24+1.0)
WA24=W24/(FAR24+1.0)
FA6=(WF55+WF24)/(WA55+WA24)
H6=(W24*H25+W55*H55)/W6
CALL THERNO (1,PH6,T6,H6,AMX,1,FAR6,1)
C1=PS55*AM55*(1.0+AK55*AM55**2)+PS25*(A25+AK25*AM25**2)
TS6=0.833*T6
DO 32 I=1,15
30 AM62G=SQRT(C6)/C4
GO TO 31
31 IF (AM62G>LE0) GO TO 28
AM6G=SQRT(AH62G)
V6=AM6G*CS6
HSCAL=H6-V6**2/(I.0+(((AK6-1.0)/Z.0)**2))
32 TS6=TS6+DELHS/CP6
ICOMIX=10
CALL ERROR
33 AM6G=A25*A55
C7=SQRT(1.0*(AK6-1.0)*AM6G/2.0)
PS6=C7/(CAPSF*AM6G*C7)
P6=PS6*EXP((PHI6-PHIS6)/REX6)
CALL THERNO (P6,H6,T6,661,1,FAR6,0)
S6AVE=(MG2*TS55+MG55)/MG6
IF (S6+GE-S6AVE) GO TO 35
S6=S6AVE
P6=EXP(AHM6*(PHI6-S6)/FD6E)
CALL THERNO (P6,H6,T6,661,1,FAR6,0)
IF (1.0<ENG<1.0) GO TO 36
IF (IGASMX .EQ. 2) GO TO 37
36 T6 = TS5
P6 = P55
H6 = H55
S6 = S55
WG6 = WG55
PS6 = PS55
FAR6 = FAR55
AK6 = AK55
37 IF (IDES .EQ. 0) GO TO 38
C** CALLS A6 AS A FUNCTION OF INPUT AM6
TS6=T6/(1.0+((AK6-1.0)/Z.0)*AM6**21))
DO 34 JJ=1,15
AK6=AK6
CALL THERNO (FAR6,TS6,CS6,AK6,CP6,REX6,PHIS6,HS6)
V6=AM6*C6
DELAK6=AK6P-AK6
IF (ABS(DELAK6) .LE. 0.0005*AK6) GO TO 34
34 TS6=T6/(1.0+((AK6-1.0)/Z.0)*AM6**21))
ICOMIX=11
CALL ERROR

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54 PS6=PS6/(1+O+((AK6-1.0)/2.0)*AM6**2))**(AK6/(AK6-1.0)))

AM6ABD=AM6
RHO6=CAPSF*PS6/(AJ+REX6+TS6)
A6=W66/(RHO6*V6)
WRITE (6,52) A6
GO TO 44

C CALCULATES M6=F(A6DESIGN)

DO 39 I=1,15
CALL PROCOM (FAR6,TS6,P,C6,A6,C6,PS6,PHIS6,HS6)
PS6=PS6/(TS6/TS6)**((AK6/IAK6-1)**)
RHO6=CAPSF*PS6/(AJ+REX6+TS6)
V6=SQR((2.0*GAM*(H6-H66))/)
IF ((H6-HS6)+LT+O+0) GO TO 42
A6=W66/(RHO6*V6)
DEL6=A6-P6
V6=W66/(RHO6*A6)
AM6=V6/C65
AM62=AM6**2
IF (ABS(DEL6)-LE-0.002*A6) GO TO 42
T56=P56/(1+O+((AK6-1.0)/2.0)*AM6**2))

39 ICOMIX=12
CALL ERROR
GO TO 44

T6=TS6
P6=PS6
GO TO 44

T6=TS6
P6=PS6
GO TO 44

T6=TS6
P6=PS6
GO TO 44

T6=TS6
P6=PS6
GO TO 44

T6=TS6
P6=PS6
GO TO 44

T6=TS6
P6=PS6
GO TO 44

C WRITE (6,53) H6,HS6
ICOMIX=13
CALL ERROR
AM62=AM62G
AM6=AM6G
A6=A25*A55
ICOMIX=0
CALL COAF8N
RETURN

KKGO=1
DPRDS=DPRFDS*PRCFDS
PRFCF=PRFDS*PS55*PS25*1.02
PRCFD=PRDS*PRFCF
ICOMIX=0
CALL ENGBAL
RETURN

C

FORMAT (22HOSQRT OF H55-H55 NEG ,6E15+6,6H$$$$$$)

FORMAT (20HOTURBINE AREA DESIGN,6X6H A55=E15+8,8H AM55=E15+8)

FORMAT (22HOSQRT OF H55-H55 NEG ,6E15+6,6H$$$$$$)

FORMAT (25HOTURBINE/DUCT AREA DESIGN,7H A55=E15+8,8H AM55=E15+8)

FORMAT (12HCOMIC PCNF=F7+4,4H AM6=F8+6,5H P55=F9+5,6H P555,F9)

FORMAT (10HCOMIC XZ=F7+4,4H AM6=F8+6,5H P55=F9+5,6H P555,F9)

FORMAT (3X,2THAFTERBURNER DESIGN AREA A6 F8.3)

FORMAT (3X,18HNEG+HS6 FACTOR H6 F9+4,3X,4HHS6 F9+4)

END
SUBROUTINE CONNOZ
COMMON /WORDS/ WORD
COMMON /DESIGN/
110DES, JDES, KDES, MODE, INIT, IDUMP, IAMTP, IGASMX,
210DUMB, IAFTBN, IDOC, IMCD, IDSHOC, IMSHOC, NOZFLT, ITRY,
330LOOPER, NOMP, NUNMAP, MAPEDG, TOLALL, ERR(9)
COMMON /ALL/
1PCNF, PCNCGU, TAGU, DUMO, DUMOZ, DELDF, DELSF, DELFS,
2FFDS, FNDFFS, FFDOS, ETAFPS, WAPF, PRCF, ETAFCF, WACF,
3CGOS, PCNCDS, PCRCDS, ETAUCDS, WCACDS, PRUCF, ETAUCF, WACCF,
4T4OS, WBFDS, DTOSDS, ETAUDS, WCADS, DPCOS, DTCCOF, ETAUCF,
5TIDPS, CNHPS, ETIPDS, THPCF, CNHPCF, ETIPCF, DNPCCF, DNPCCF,
6TIFPS, CNLPS, ETPLDS, THLPCF, CNLPCF, ETPLCF, DNLPCCF, DNLPCCF,
7T2OS, WFDODS, DTODDS, ETAODDS, WCADCDS, DPDUSODS, DTUCCDF, ETAUDCF,
8TOS, WADPS, DTAPS, ETAAPS, WGA6DS, DPDAPS, DTAFCF, ETAACF,
9IA55, A255, A6, A7, A8, A9, A26, A27
COMMON /ALL2/
171, 2T21, P21, H21, S21, T3, P3, H3, S3, T4, P4, H4, S4, T5, P5, H5, S5,
184, 2T55, P55, H55, S55, BLF, WAC, WAZ, W4, W4, W4,
195, 6NC, PR, ETA, WAC, WLAC, ETA, DPCDF, DUMP,
207CNMP, ETAHPS, DHTHPS, DHTPS, BAHPS, WGS, FARS, CS,
218CNLP, ETAHLPS, DHTLPS, DHTLPS, BAHLP, WOS, FARS, HPX,
229AM, AFT, ETAR, ZF, PCNF, WFB,
230$FHP, TPFPL, PCBLC, PCBLO, PCBLO, PCBLO, PCBLO,
241COMMON /ALL3/
1XP1, XWAF, XWAC, XBLF, XBLDU, XHZ, DUMS1, DUMS2,
22XT21, P21, XH21, XZ21, T23, P23, H23, S23, T24, P24, H24, S24,
324, 2T26, P26, H26, S26, T29, P29, H29, S29,
345WAD, WMO, WGF4, FAR4, ETA, DPDUC, BYPAS, DUMS3,
356TS28, P28, V28, T29, P29, V29, T29, P29, V29,
367TK35, XH35, XZ35, T25, X25, X25, T25, X25,
378WFB, XW59, XAR59, XWDF, XWDF, FAR42, X4, DUMP,
389T6, P6, H6, S6, T7, P7, H7, S7,
390T8, P8, H8, S8, T9, P9, H9, S9,
COMMON /ALL4/
11MG, WFT, WGT, FAR7, ETA, UPNF, V55, V55,
20P56, V6, AM6, TS7, PS7, V7, AM7, AM7,
213TS8, P8, H8, TS9, PS9, V9, AM9,
224VFA, FRD, VJD, FGM, FGM, FGM, FGM,
235FGM, PGG, NGT, FRT, F, FN, F,
246MA32, DPWDS, DPWNS, WAZ2DS, AMI, AMI, AMI,
257T36, P36, TS3, T39, H39, T39, T39,
268V93, AM39, A39, BPRINT, WGM3, CVDFG, WGM, WGM,
279FNWN, FNMAI, FNQVF, P39, FOFQF, FCVFQ, FMMDF, FNQFD,
280JDW, T2Z, P22, H22, S22, T50, P50, H50,
COMMON /ALL5/
155S50, WAZ2Z, Z1, CP1, CN1, PRI, ETAI, WACI,
20FFIP, CNI, ETAIP, DHTCIP, DHTI, BLP, PCBLIP, PCNIU,
212ZOS, PCNIDS, PRIDS, ETADS, WADS, PRICF, ETAICF, WACF,
224TIFPS, CNIPS, ETIPS, TIPFCF, CNIPCF, ETIPCF, DNPCCF, WACO
235WAI, PCBL1, BL1, T22DS, W221, H250, FAR50, A24,
246AD23, DUMSPS, XMN2, XM2CP, AFTN, PUNT, PCBLID, PDSAV,
257TAD5DS, ETAASS, FAR7SV, T4BPL, T41, FAN, IPDQ
COMMON /DYN/ ITRAI, ITIME, DT, DTF, DTRAN, NSSTEP, DTPRINT, DTPRINT
DATA AMORD/6HMNOZ/,
WORD=AMORD
A95A9=A9
A95A9=A9
NOZM=0
NOZM=0
IF ITRAN = EQ. 1) CALL NOZCTR
IF (NOZFLT.EQ.1 AND NOZFLT.EQ.1) NOZM=1
IF (IDES.EQ.1 OR IAFTBN.GT.0 OR NOZM.EQ.1) IINOZ=1
IF (ITRA6.EQ.1) IINOZ=0
IF (ITRA6.EQ.1) GO TO 1
CALL CONWRG (TT, HT, PT, M7, FAR7, W7, P7, MMNOZ, A8, PTR, T8, HT, P8, S8, TS8,
207PO, PS8, AM8, ICON
GO TO (1, 3, 3, 2, 3)
ORIGINAL PAGE IS
OF POOR QUALITY
CALL CONDIV (TT,HT,PT;$_FRT,MGTtPI,IMNOZ,A8,A9,PTR,T8,H8,P8,58,T)

19,H9,P9,S9,T58,T59,PS8,PS9,V8,V9,AM8,AM9,ICON)
IMSHOC=ICON
GO TO (4,4,4,2),ICON

2 CALL ERROR
3 T9=T8
H9=H8
99=98
S9=S8
T9=T58
PS9=PS8
V9=V8
AM9=AM8
A9=A8
IMSHOC=ICON+3

4 ERR(3)=(PTR-PT)/PTR
IF(ISPOOL*EQ.1) ERR(3)=ERR(6)
IF (IMNOZ*EQ.1) WRITE (6,5) A8,AM8,A9,AM9
RETURN
C
C
5 FORMAT (14HONDOZZLE DESIGN,10X8H A8*,E15.8,8H AM8*,E15.8,8H A9*,E15.8,8H
1 AM9*,E15.8,8H)
END

$IRFTC CONDIV
SUBROUTINE CONDIV (TI,HI,PI,SI,FAR,WG,PA,IDES,AT,AO,PIR,TT,HT,PT,S
1 TT,T0,H0,PO,SO,TST,T05,PST,P50,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 ICON=4 ERROR
COMMON/UNITS/ZI
LOGICAL ZI
DIMENSION Q(9)
Q(2)=0.
Q(3)=0.
IF (ZI) GO TO 100
AJ=T78+26
CAPSF=2116+170
G=32.17+9
GO TO 110
100 AJ=1.0
CAPSF=101325+0
G=1.0
101 CONTINUE
CALL PROCOM (FAR,TI,XX1,XX2,XX3,XX4,PHII,XX6)
C
J=0
TSS=0.833*TI
J=J+1
CALL PROCOM (FAR,TSS,CSS,AK,CP,REXS,PHISS,HSS)
HSCAL=HI-CSS**2/12*G*AJ)
DELHS=HSCAL-HSS
IF (ABS(DELHS)-0.0005*HSCAL) 4,4,2
TSS=TSS+DELHS/CP
IF (J-15) 1,1,3
3 ICON=4
RETURN
4 IF (IDES) 11,1,5
C
VT=CSS
TST=TSS
PST=P1/(TST/HT) ** (AK/(AK-1))
RHO=CAPSF*PST/(AJ*REXS*TST)
AT=MG/(RHO*VT)
AMT=1.0
C
C
C
3 IDEAL EXPANSION DESIGN, CALCULATE AO
PS8=PA

60
J=0
TSO=TI*(PSO/PI)**286
6 J=J+1
CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
PHICAL=PHI-REX*LOG(PI/PSO)
DELPHI=PHICAL-PHISO
IF (ABS(DELPHI)) 8,8,7
7 TSO=TSO*EXP(4.*DELPHI)
IF (J=15) 6,6,3
8 V0=SQR(T2*PI/A(HI-HSO))
AMO=V0/CSO
AO=(AT/AMO)**(1++(AK-1.)*AMO**2/2.)/(AK+1.))**((AK+1.)/(2.*(AK-1.)))
P=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=RH/G*(AT*VT)
PST=RHO*AJ*REX*TS/TST/CAPSF
P=PI*(TIT/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=SQR(T2*(TIT/TSO)-1)/(AK-1.))
AOCAL=(AT/AMO)**2.0*(1++(AK-1.)*AMO**2/2.)/(AK+1.))**((AK+1.)/(2.*(AK-1.)))
EA=(AO-AOCAL)/AO
DIR=SQRT(AO/AOCAL)
14 CALL AFQUIR (QI,TST,SS,EA,0.00,100.0,0.0001,DIR,TSOT,JCON)
15 GO TO (14,18,3),JCON
16 TSO=TSOT
IF (TSO-TS) 15,13,16
17 TSC=2.*TI/(AK+1.)
18 IF (TSO-TS) GO TO 17
19 TSO=0.98*TI
GO TO 13
20 IF (Q(2)<LT.30.0 OR QMD.LT.0.95 OR MAM.EQ.1) GO TO 13
TSO=2.*TI/(2++.0.98*(AK-1.))
MAM=1
21 GO TO 13
22 P=PI*(TIT/TSO)**(AK/(AK-1.))
IF (PST-PA) 20,19,27
C *** CRITICAL FLOW, ISENTROPIC EXPANSION TO PA
19 V0=AMO-CSO
ICON=1
GO TO 9
C *** SUBSONIC FLOW
20 P=PA
Q(2)=0.0
Q(3)=0.0
J=0
21 TSO=0.833*TI
J=J+1
CALL PROCOM (FAR,TSO,CSO,AK,CP,REX,PHISO,HSO)
RHO=CAPSFS/PSO/(AJ*REX*TSO)
VO=RHO*AM/A
HSCL=H-VO**2/2.0*AG
DELH=SCL-HSO
IF (ABS(DELH)) 23,23,22
TSO=TSODELH/CP
IF (J=15) 21,21,3
116
C *** SUPERCRITICAL FLOW, ISENTROPIC EXPANSION TO PA

PSD=PA
J=0
TSD=TI*(PSD/PIR)**.286
J=J+1
CALL PROCOM (FAR,TSD,CSO,AK,CP,REX,PHISO,HSO)
PHICAL=PHI-REX=ALOG(PIR/PSO)
DELPHI=PHICAL-PHISO
IF (ABS(DELPHI)-0.0001*PHICAL) 30,30,20
TSD=TSD*EXP(44.9*DELPHI)
IF (J-15) 28,28,3
VO=SQR(T(2.4*GAJ*(HI-HSO))
AMO=VO/CSO
ADID=(AT/AMO)*(2.4+1+(AK-1.)*AMO**2/2.)/(AK+1.))*((AK+1.)/(2.*A
IK-1.)))
ICON=3
N=0
IF (AO-ADID) 31,9,32
C *** SUPERCRITICAL FLOW, ISENTROPIC EXPANSION TO AO

N=1
TSD=0.833*TI
J=0
J=J+1
CALL PROCOM (FAR,TSD,CSO,AK,CP,REX,PHISO,HSO)
AMO=SQR(T((TI/TSD)-1.)/(AK-1.))
AOCAL=(AT/AMO)*(2.4+1+(AK-1.)*AMO**2/2.)/(AK+1.))*((AK+1.)/(2.*A
IK-1.)))
DELHA=AO-AOCAL
IF (ABS(DELHA)-0.0001*AO) 35,35,34
TSD=TSD*SQRT(ADICAL/AO)
IF (J-50) 33,33,3
IF (N) 37,37,36
C *** UNDEREXPANDED, SHOCK OUTSIDE NOZZLE
PSD=PIR*(TSD/TI)**(AK/(AK-1.))
VO=AMO/CSO
GO TO 9
C *** OVEREXPANDED, FIND SHOCK POSITION
PSW=PWR*(TSD/TI)**(AK/(AK-1.))
PSY=PSW*2.4*AMO**2/(AK+1.)-(AK-1.)/(AK+1.))
IF (PA-PSY) 38,39,39
C *** OVEREXPANDED, SHOCK OUTSIDE NOZZLE
PSO=PSW
VO=AMO/CSO
GO TO 9
C *** OVEREXPANDED, SHOCK INSIDE NOZZLE
PSO=PA
J=0
J=J+1
CALL PROCOM (FAR,TSD,CSO,AK,CP,REX,PHISO,HSO)
RHO=CAPSF/PSO/(2.*G*AJ)
VO=MG/(RHO*AD)
HSCAL=HI-VQ**2/(2.*G*AJ)
DELHS=HSCAL-HSO
IF (ABS(DELHS)-0.0005*HSCAL) 42,42,41
TSD=TSD+DELHS/CP
SUBROUTINE CONOUT (ICON)

COMMON /WORDS/ WORD
COMMON /DESIGN/

I1DES, JDES, KDES, MODE, INIT, IDUMP, IAMTP, IGMASX,
2IBURN, IAFTN, IODC, IMCD, IDSHOC, IMSHOC, NOZFLT, ITRYS,
3LOOPER, NMAP, NMAP, MAPEDG, TOLDALL, ERR(9)

COMMON /ALL1/

PCNFU, PCNFUG, T4GU, DUMD1, DUMD2, DELFG, DELFN, DELSF,
2FFDS, PCNFDS, PRFD, EATAFS, WAFDS, RRAFC, ETAFCF, WACF,
32CDS, PCNCDS, PRCD, ETAAC, WCADS, PRACCF, ETAACF, WACCF,
4TFDS, WAFDS, DTDCCDS, ETABDS, WADDS, DPDCCDS, DTDCCF, ETAABCF,
5TFAPS, CINHPS, ENHPS, TFHCP, CNHPCF, ETHPCF, DHIPCF, T20S,
6TFLPDS, CNLPS, ETLPDS, TFPFLC, CNLPCF, ETLPCF, DLIPCF, T21DS,
7TF4DS, WFDPS, DTODDS, ETDADS, W23DS, DPDODS, DTODCF, ETAACF,
8TFDS, WFDPS, DTDODS, ETAADS, W26CD, DPDAPDS, DTAACF, ETAACF,
9TFAPS, CINPDS, FNHPDS, ETAADDS, W27DS, DPDADS, ETAACF, ETAACF,
$TF4PS, AM55, CVDNZT, CVMNZT, A5BSAV, A9SAV, A28SAV, A29SAV

COMMON /ALL2/

ITI, P1, H1, S1, T2, P2, H2, S2,
2T21, P21, H21, S21, T3, P3, H3, S3,
3T4, P4, H4, S4, T5, P5, H5, S5,
4T5, P55, H55, S55, BFL, BLC, BLDU, BLOB,
5CNF, PRF, ETAF, WACF, MAC, MA3, MG4, FAR4,
6CN, PRC, ETAAC, WAC, WCAC, ETAACF, DPCOM, DUMP,
7CNHP, ETAHF, DHTCHP, HHTC, BLHP, W65, FAR5, CS,
8CNLP, ETEATL, DHTCLP, HHTF, BLLP, W655, FAR55, HPEXT,
9AM, ALTP, ETAR, ZF, PCNF, ZC, PCNC, MF8,
$TFHP, TFFLP, PBLF, PCBL, PCBLU, PCBLOB, PCBLHP, PCBLLP

COMMON /ALL3/

1XP1, XWAF, XWAC, XBLF, XBLDU, X3H, DUMS1, DUMS2,
2XT21, XP21, HX21, XS21, T23, P23, H23, S23,
3T24, P24, H24, S24, T25, P25, H25, S25,
4T28, P28, H28, S28, T29, P29, H29, S29,
5W40, WF0, W24, FARZ, ETAO, DPCUC, BYPASS, DUMS3,
6T28, P28, H28, S28, T529, P529, V29, AM29,
7XT5, XP55, HX55, XS55, XT529, XP529, XK25, XS25,
8XWBF, XWGB, XFAW, XWDF, XGMB, XFAW24, XPA1, DUMB,
9T6, P6, H6, S6, T7, P7, H7, S7,
10T8, P8, H8, S8, T9, P9, H9, S9

COMMON /ALL4/

1W6, NFA, HG7, FAR7, ETA, DPAFT, V55, V25,
2P55, V6, AM6, TS7, PST, V7, AM7, AR25,
3TS8, P58, V8, AM8, TS9, P59, V9, AM9,
4VA, P80, VNO, FGM, VFJM, FGMN, FGMN, FGMN,
5FG, FGP, WFT, NGT, FART, FG, FN, SFC,
6MA32, DWMD, WDMG, WM32DS, AM38, AM38, V38, T38,
7N38, P38, T38, PS38, T39, NH39, P39, TS39,
8NV59, AN39, A59, BPMNTXG37, CVDMNG, FGMNG, FGMNG,
9CASING, FINMPN, FNMPN, PF39, FFCFV, FCVFN, FMNPN, FMNPN,
10SVJW, T22, P22, H22, S22, T50, P50, H50

COMMON /ALL5/

1550, W22, Z1, PCNI, CN1, PRI, ETAI, WAC1,
2TF1FIP, CN1P, ETA1P, DHTCIP, DHTI, BLIP, PCBLIP, PCNI1P,
3ZID, PCNIDS, PRIDS, ETAIDS, WAIDS, PRIPC, ETAICF, WACF,
4TFIPOPS, CNPIS, ETAIPS, TFPFCF, CNIPCF, ETIPCF, DMPFCF, MADC3,
5MA1, PCB1, BLI, T220S, W22, W250, F250, Z246,
6AZ23, DUMBPL, FXMN2M, FXMN2CF, AFTFAN, FINT, PCBLID, PADSAV,
7A3DSF, ETA2AF, FARTSV, T4PBL, T41, FAN, ISPOOL
```
* FORMAT (IX.25, WRITE)
* LOGICAL SI
* DATA THEEND, LINIT, THEEND, THEEND
* GO TO (I, ICON)
* IF (SI) GO TO 22
* INPUT SECTION
* e6HCNC tbHPRC
* e6HTC tbHETOSt6HETADSt
* w6HTACCF.6HMACCF .6HT6DS e6HWFSOS 16HDTCOSe6HETABDSt
* 61"1P3
* IF (SI) GO TO 22
```

C *** NUM=1,150
DO 4 N=1,150
NUM=N
READ I5,11|AIN,CHANGE
IF (AIN.EQ.THEEND) GO TO 5
DO 2 J=1,LIMIT
JJ=J
IF (AIN.EQ.WORDY(J)) GO TO 3
CONTINUE
WRITE (6,12) AIN
GO TO 4
10 OUT(NUM)=JJ
IF (CHANGE.NE.BLANK) WORDY(JJ)=CHANGE
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
9 N=N-6
DO 8 K=1,J
L=I+K-1
M=IOUT(L)
WOUT(K)=WORDY(M)
WRITE (6,14) (WOUT(K),K=1,J)
WRITE (6,15) (AOUT(K),K=1,J)
IF (N.LE.3) GO TO 10
CONTINUE
10 RETURN
C
C
C
11 FORMAT (A6,6X,A6)
12 FORMAT (100THE WORD ,A6,26H NOT FOUND IN COMMON ARRAY)
13 FORMAT (22HOERROR IN COMMON INPUT)
14 FORMAT (26X,A6,5(9X,A6))
15 FORMAT (1H ,20X6E15.6)
END

$18FC CONVRG
SUBROUTINE CONVRG (TI,HI,PI,S1,FAR,KG,PA,IDES,A0,PR,TO,H0,PO,S0,T)
C ICON=1 SUBSONIC, COMPARE PI WITH PR
C ICON=2 SONIC, COMPARE PI WITH PR
C ICON=4 ERROR
COMMON/UNITSIZI/LOGICAL ZI
IF (ZI) GO TO 100
AJ=778.26
CAPSF=0.0716°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*T
J=J+1
CALL PROCOM (FAR,TSS,CSS,AKS,CP,REXS,PHII,SS,HS)
HSCAL = HI - CSS * 2 / (2 * G * AJ)
DELHS = HSCAL - HSO
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 CALCULATIONS
5 J = 0
TSI = TI * (PA / PI) ** 0.286
6 J = J + 1
CALL THERMO (PA, HSI, TSI, SS, XX, 1, FAR, 0)
IF (ABS(SSI - SS) = 0.0001 * SS) 8, 8, 7
7 TSI = TSI / EXP(SSI - SS / 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, AKO, CP, REX, PHISO, HSO)
RHO = CAPSF * PSO / (AJ * REX * TSO)
ADO = WG / (RHO * VO)
AMO = VO / CSO
PR = PA
ICON = 1
TO = TI
MO = HI
PO = PI
SO = SI
RETURN
C *** SONIC DESIGN, CALCULATE AO
10 VO = CSS
TSS = TSS
PSO = PI * (TSO / TI) ** (AKO / (AKS - 1))
RHO = CAPSF * PSO / (AJ * REX * TSO)
ADO = WG / (RHO * VO)
AMO = 1.0
PR = PA
ICON = 2
GO TO 10
C *** NON-DESIGN, CALCULATE CRITICAL CONDITIONS
11 VO = CSS
TSS = TSS
PSO = PA
RHO = CAPSF * PSO / (AJ * REX * TSO)
AOCRIT = WG / (RHO * VO)
AMO = 1.0
PR = PSO * (TI / TSO) ** (AKO / (AKS - 1))
IF (AO = AOCRIT) 13, 13, 14
C *** NON-DESIGN, CRITICAL AND SUPERCritical CONDITIONS
13 PSO = PSO * AOCRIT / AO
PR = PR / AOCRIT / AO
ICON = 2
GO TO 10
C *** NON-DESIGN, SUBSONIC CALCULATIONS
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
TSS = TSS + DELHS / CP
IF (J - 15) 15, 15, 3
16 PSO = PSO * (TI / TSO) ** (AKO / (AKO - 1))
PR = VO / CSO
ICON = 1
RETURN
FUNCTION DERIV(I,X)
COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRINT
COMMON /FOC/ FO(150,4+)
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
END

SUBROUTINE ENGBAL
COMMON /WORDS/ MGRD
COMMON /DESIGN/
1IDES,KDES,MODE,INIT,IDUMP,IAMTP,IGASMX
2IDBURN,IAFTBN,IOCD,IMCD,IXSMOC,IXSHOC,NOZFLT,ITRYS
5LODPER,NUMMAP,MAPEDG,TLALL,ERR19)
COMMON /ALL2/
1PCNFAG,PCNFAG,T4G4,DUM01,DUM02,DELFG,DELFN,DELSFC,
2FDOS,PCIFDOS,PRFDS,ETA4DS,WAFDS,PRFCF,ETA4CF,WACF,
3CDOS,PCNCOS,PRCDOS,ETA4CD,WACOS,PRCCF,ETA4CC,WACCF,
4FDOS,MPFDOS,DPFDOS,ETA4DOS,WA3CDOS,DPCCDOS,DPCCDF,ETA4CCF,
5TFHPOE,CMHPDOS,ETHPDOS,THPDCF,CNHPDCF,ETHPCF,ETHPCF,THPDOS,T2DOS
6TFPDOS,CMPDOS,ETLPDS,TFLPCF,CNLPDCF,ETLPCF,DHLPCF,T2LDS
7TFD4DS,FDFDS,DTDUDS,ETADDS,WA2DOS,DPDUDS,DTDUDC,ETADCC
8TFDOS,WFDAS,DTADDFS,ETAADAS,WA6G6DOS,DPAFDOS,DTAFCC,ETAACF,
9A55,A25,A6,A7,A8,A9,A29,A29,
$PS55,AM55,CVMD02,CVMD02,ABSAV,A9SAV,A29SAV,A29SAV
COMMON /ALL3/
1TG1,P1,H1,S1,T2,P2',H2,S2
2TG1,P2,H2,S2,T3,P3,H3,S3
3TG1,P4,H4,S4,T5,P5,H5,S5
4TG1,P55,H55,S55,BLF,BLC,BLDU,BLDB
5CNF,PPF,ETA4F,MAFC,MAF,WA3,WM4,FAR4
6NC,PRC,ETAC,MAC,MAC,ETAB,DPCCD,DUMP
7CNHP,ETAPMD,DTCHP,HTCP,BLHP,WM5,FAR5,CS
8CNLP,ETAPLP,DTCLP,HTFL,BLLP,WM55,PAR55,HPX7
9AM,ALT,ETAR,AF,PCNF,ALC,PCNY,WFB
$TF9HF,TFFLP,PCFLF,PCFLC,PCBLUD,PCBLUD,PCBLHP,PCBLLP
COMMON /ALL/3/
1XP1,WMAT,WMAC,XBLF,XBLDU,XH3,DUMS1,DUMS2
2XP1,WMAT,WMAC,X521,X23,T23,H23,S23
3XP1,PRP4,H24,S24,T25,P25,H25,S25
4XP1,H28,S28,T29,P29,H29,S29
5WAD,WFD,WG24,FAR24,ETAD,DPDUC,BYPASS,DUM35
6T28,PS28,V28,AM28,T29,P29,V29,AM29
7T55,XP55,X555,X555,XT25,X255,XT25
8WFB,WM55,XFAR55,XWFD,XG24,XFAR24,XP1,DUMB
9T6,P6,H6,S6,T7,P7,H7,S7
TT8,P8,H8,S8,T9,P9,H9,S9
COMMON /ALL4/
1WG5,WFA,WM7,FAR7,ETAA,DPAFT,V55,V25
2PS6,PS6,AM6,TS7,PS7,V7,AM7,AM25

COMMON /ALL2/
1TG1,P1,H1,S1,T2,P2',H2,S2
2TG1,P2,H2,S2,T3,P3,H3,S3
3TG1,P4,H4,S4,T5,P5,H5,S5
4TG1,P55,H55,S55,BLF,BLC,BLDU,BLDB
5CNF,PPF,ETA4F,MAFC,MAF,WA3,WM4,FAR4
6NC,PRC,ETAC,MAC,MAC,ETAB,DPCCD,DUMP
7CNHP,ETAPMD,DTCHP,HTCP,BLHP,WM5,FAR5,CS
8CNLP,ETAPLP,DTCLP,HTFL,BLLP,WM55,PAR55,HPX7
9AM,ALT,ETAR,AF,PCNF,ALC,PCNY,WFB
$TF9HF,TFFLP,PCFLF,PCFLC,PCBLUD,PCBLUD,PCBLHP,PCBLLP
COMMON /ALL/3/
1XP1,WMAT,WMAC,XBLF,XBLDU,XH3,DUMS1,DUMS2
2XP1,WMAT,WMAC,X521,X23,T23,H23,S23
3XP1,PRP4,H24,S24,T25,P25,H25,S25
4XP1,H28,S28,T29,P29,H29,S29
5WAD,WFD,WG24,FAR24,ETAD,DPDUC,BYPASS,DUM35
6T28,PS28,V28,AM28,T29,P29,V29,AM29
7T55,XP55,X555,X555,XT25,X255,XT25
8WFB,WM55,XFAR55,XWFD,XG24,XFAR24,XP1,DUMB
9T6,P6,H6,S6,T7,P7,H7,S7
TT8,P8,H8,S8,T9,P9,H9,S9
COMMON /ALL4/
1WG5,WFA,WM7,FAR7,ETAA,DPAFT,V55,V25
2PS6,PS6,AM6,TS7,PS7,V7,AM7,AM25

COMMON /ALL2/
1TG1,P1,H1,S1,T2,P2',H2,S2
2TG1,P2,H2,S2,T3,P3,H3,S3
3TG1,P4,H4,S4,T5,P5,H5,S5
4TG1,P55,H55,S55,BLF,BLC,BLDU,BLDB
5CNF,PPF,ETA4F,MAFC,MAF,WA3,WM4,FAR4
6NC,PRC,ETAC,MAC,MAC,ETAB,DPCCD,DUMP
7CNHP,ETAPMD,DTCHP,HTCP,BLHP,WM5,FAR5,CS
8CNLP,ETAPLP,DTCLP,HTFL,BLLP,WM55,PAR55,HPX7
9AM,ALT,ETAR,AF,PCNF,ALC,PCNY,WFB
$TF9HF,TFFLP,PCFLF,PCFLC,PCBLUD,PCBLUD,PCBLHP,PCBLLP
COMMON /ALL/
1TG1,P1,H1,S1,T2,P2',H2,S2
2TG1,P2,H2,S2,T3,P3,H3,S3
3TG1,P4,H4,S4,T5,P5,H5,S5
4TG1,P55,H55,S55,BLF,BLC,BLDU,BLDB
5CNF,PPF,ETA4F,MAFC,MAF,WA3,WM4,FAR4
6NC,PRC,ETAC,MAC,MAC,ETAB,DPCCD,DUMP
7CNHP,ETAPMD,DTCHP,HTCP,BLHP,WM5,FAR5,CS
8CNLP,ETAPLP,DTCLP,HTFL,BLLP,WM55,PAR55,HPX7
9AM,ALT,ETAR,AF,PCNF,ALC,PCNY,WFB
$TF9HF,TFFLP,PCFLF,PCFLC,PCBLUD,PCBLUD,PCBLHP,PCBLLP

FUNCTION DERIV(I,X)
COMMON /DYN/ ITRAN,TIME,DT,TF,JTRAN,NSTEP,TPRINT,DTPRINT
COMMON /FOC/ FO(150,4+)
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
END
3TS8 ,PS8 ,V8 ,AM8 ,TS9 ,PS9 ,V9 ,AM9 ,
4YA ,FRD ,VJD ,FGMD ,VJM ,FGMM ,FGPD ,FGPM ,
5FGH ,FGP ,WFT ,WGT ,FART ,FG ,FN ,SFC ,
6M3A2 ,PGWOS,DPWNG,MA320S,A38 ,AM38 ,V38 ,T38 ,
7M36 ,P38 ,TS38 ,PS38 ,T39 ,H39 ,P39 ,T39 ,
8V39 ,AM39 ,A39 ,BPRINT,WG37 ,GDWNG,FPMNG,FGMG ,
9FMNW,FMPNW,FMDV,FMDV ,FMDV,FMDV ,FMDV,FMDV ,
VJM ,T22 ,P22 ,H22 ,S22 ,T50 ,P50 ,H50 ,
COMMON FALS5/
15S50 ,M22 ,Z1 ,PCNI ,CNI ,PRI ,ETAI ,MAC1 ,
2TFIPP ,CNIP ,ETATIP,DNTCIP,DHTI ,BLIP ,PCBLIP,PCNIUG ,
3TIDS ,PCNIDS,PRIDS ,ETAIDS,WAIDS ,PRICF ,ETAI CF ,MAICF ,
4TIPDS,CPNPOS,ETIPDS,TIPCPCNIPCF,ETIPCF,DMIPCF,WAICDS ,
5WAI ,PCBLI ,BLI ,T220S ,WA2L ,MG50 ,FAR50 ,A24 ,
6AM23 ,DUMSPL,FXFMNZ,FXMZCP,AFTFAN,FUNT ,PCBLID,P6DSAV ,
7AM6DSV,ETASSV,FAR75V,T4PB1 ,T41 ,FAN ,ISPOOL ,
COMMON /DYNT,TRAN,TIME,DT,TF,JTRAN,NSTEP,PRTN,DTPRNT ,
LOGICAL ERER,FXFNZM,FXMZCP,DUMSPL,FAN ,
DIMENSION DELSAV(9) ,
DATA AWORD,AHENGBAL ,
DATA VDELTA,VLMGCHNGE,NOMISXI ,
1 1=0.100,0.850,4/ ,
DATA DEL/9*0./ ,
DATA DELSAP/9*I.E-6/ ,
IF (ITRAN+NE=1) GO TO 100 ,
CALL SYG(1) ,
JTRAN=1 ,
INIT=1 ,
NSTEP=NSTEP+1 ,
TIME=TIME+TDLT(NSTEP) ,
IF (TIME+GT+TF) GO TO 100 ,
CALL DISTRB ,
CALL COINLT ,
GO TO 101 ,
CALL PUTIN ,
100 CONTINUE ,
IF (INIT+EQ+1) GO TO 1 ,
TFFHP=TFFHPOS ,
TFFIP=TFFIPDS ,
IF (FXM2CP+TFFP=TFHPDS ,
TFFLP=TFFLPDS ,
1 LOOP=0 ,
NUMMAP=0 ,
NOMISS=0 ,
2 LOOP=0 ,
MISMAT=0 ,
NOMAP=0 ,
IGD=2 ,
DO 3 I=1,9 ,
VMAT(I)=0 ,
AMAT(I)=0 ,
DELVAR(I)=0 ,
DO 3 L=1,9 ,
3 EMAT(L,L)=0 ,
4 LOOP=LOOP+1 ,
CALL COFAN ,
WORD=AWORD ,
IF (+NOT+FAN) DUMSPL=True ,
IF (LOOPER,GT+ITRYS) ERER=True ,
IF (LOOPER,GT+ITRYS) GO TO 26 ,
IF (NOMAP+GT+0) GO TO 2 ,
NUMMAP=0 ,
5 VAR(1)=ZC=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
VAR(9)=TFFIP
NMAX=9
IF(FAN) GO TO 39
NMAX=6
IF(ISPOOL.EQ.2) GO TO 7
NMAX=3
VAR(3)=TFFIP
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
CONTINUE
7 DO 8 I=1,NMAX
IF(ABS(ERR(I)).GT.TOLALL) GO TO 9
CONTINUE
8 IF(ITRAN.EQ.1) CALL ROLL
CALL PERF
CALL ERROR
9 IF (LOOP.GT.0) GO TO 11
MAPEGD=0
MAPSST=0
DO 10 I=1,NMAX
ERRB(I)=ERR(I)
DEL(I)=VDELTA*VAR(I)
GO TO 14
10 IF (MISMAT.GT.0) GO TO 29
IF (MAPEGD.EQ.0) GO TO 12
MAPEGD=0
MASSST=1
VAR(LOOP)=VAR(LOOP)+2*DEL(LOOP)
GO TO 15
12 IF (MAPSST.EQ.0) VAR(LOOP)=VAR(LOOP)+DEL(LOOP)
IF (MAPSST.EQ.1) VAR(LOOP)=VAR(LOOP)-DEL(LOOP)
MASSST=0
DO 13 I=1,NMAX
IF (DEL(LOOP).GE.0.0) DELSAV(LOOP)=DEL(LOOP)
IF (DEL(LOOP).LT.0.0) DELSAV(LOOP)=DEL(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(I)/100.
IF (MODE.NE.3) PCNF=VAR(2)
IF (MODE.EQ.3) T4=VAR(2)*10.
ZC=VAR(3)/100.
IF (MODE.NE.1) PCN=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.0.0) ZI=0.005
IF (ZF.LT.0.0) ZF=0.005
IF (ZC.LT.0.0) ZC=0.005
GO TO 18
17 DO 18 I=1,NMAX
AMAT(I)=ERRB(I)
18 DO 20 I=1,NMAX
IZERO=0
DO 19 LOOP=1,NMAX
IF (AMAT(I,LOOP).EQ.0.0) IZERO=IZERO+1
IF (IZERO.LT.NMAX) GO TO 20
WRITE (6,32) I

ORIGINAL PAGE IS OF POOR QUALITY
DO 21 I=1,NMAX
IF (EMAT(I,LOOP) .EQ. 0.) IZERO = IZERO + 1
IF (IZERO .LT. NMAX) GO TO 21
WRITE (6,33) LOOP
LOOPER=ITRYS+100
GO TO 26
CONTINUE
DO 21 I=1,NMAX
IF (EMAT(I,LOOP) .EQ. 0.) IZERO = IZERO + 1
IF (IZERO .EQ. NMAX) GO TO 22
WRITE (6,33) LOOP
LOOPER=ITRYS+100
GO TO 26
CONTINUE
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
CONTINUE
VRATIO=0.
IF (LBIG .EQ. 0) VRATIO=VLIM*VAR(LBIG)/VARBIG
ERRAVE=0.
VMAVE=0.
DELAVE=0.
DO 25 L=1,NMAX
DELVAR(L)=VRATIO*VMAT(L)
ERRAVE=ERRAVE+ABS(AMAT(L))/FLOAT(NMAX)
VMAVE=VMAVE+ABS(VMAT(L))/FLOAT(NMAX)
DELAVE=DELAVE+ABS(DELVAR(L))/FLOAT(NMAX)
IF (MISMAT .GT. 0) GO TO 31
IF (INOMISS .EQ. 0) MISMAT=0
IF (MISMAT .EQ. 0) LOOP=0
GO TO 2
WRITE (6,34) LOOP
CONTINUE
WRITE (6,35) AMAT(I),EMAT(I,L),L=1,NMAX
WRITE (6,36) ERRAVE,VMAVE,DELAVE
IF (LOOP .LT. ITRYS) GO TO 15
CALL ERROR
RETURN
VMAVE=VMAVE
DO 30 I=1,NMAX
AMAT(I)=ERR(I)
GO TO 23
WRITE (6,37) AMAT,ERRAVE,DELVAR,DELVAR,VMAT,VMAVE,WAR
MISMAT=MISMAT+1
IF (VMAVE .LT. VCHNGE*VMAVE) GO TO 28
WRITE (6,38) MISMAT,INOMISS
INOMISS=1
LOOP=0
IGO=2
GO TO 5
C
C
FORMAT (4HOROM_I2,t16H IS ZERO IN EMAT)
FORMAT (7HOCOLUMN_I2,t16H IS ZERO IN EMAT)
FORMAT (8HB ERROR,28XZ3HEROR MATRIX AFTER LOOP_I4,29XHVMAT,6XH)
FORMAT (7H1AHVARIABLES$$$$$)
FORMAT (1H0,F8.4,10F9.3,3.2F11.4,6H$$$$$)
FORMAT (1H0,F8.4,32XH1AVERAGE VALUES,31X,2F11.4,6H$$$$$)
FORMAT (12HO----- AMAT,10F11.6,6H$$$$$$,/,12H ------DELVAR,10F11.6
1:6H$$$$$:/,12H ----- VMAT,10F11.6,6H$$$$$$,/,12H ------ VAR,9F1
21:6,6H$$$$$$)
FORMAT (1H0,50XZ2HXCHANGE TOO SMALL$$$$$$)
END
DATA AWORD/6HCOMMON/
ERRER=TRUE.
WRITE (6,2) WORD
WRITE AWORD/6HWORD
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=1,55)
WRITE (6,4)
WRITE (6,7) LOOPER
IF (IDUMP.EQ.O) GO TO 0
WRITE (6,6)
CALL SYG (2)
RETURN
C
C
C
2 FORMAT (28HOAN ERROR HAS BEEN FOUND IN ,A6)
3 FORMAT (1HO,A6,9X,TE15,6,14)
4 FORMAT (2HO)
5 FORMAT (1H,8E15,6)
6 FORMAT (1H1)
7 FORMAT (25HOFAILEO TO CONVERGE AFTER,14,6H LOOPS)
8 FORMAT (1H+,30X,6E15,6|(1H,8E15,6))
END

$SIBFTC ETAAB

SUBROUTINE ETAAB (FAR,EM6,P6,ETA,ETAAVS,ETADD,ETADS,P6DS,P6DAYS,AM6DS,AM6DSV,AM6DSV,EM6T,DELM6,DELm,ETASV,ETADS)
DIMENSION FART(25),ETABRT(25),EM6T(7),DELM6(7),P6T(14),DELP6(14)
DIMENSION X(3),Y(3)
DATA FART/0.390,0.585,0.732,0.878,0.970,1.171,1.268,1.463,1.619,
1.834,1.951,2.195,2.439,2.927,3.415,4.146,4.634,5.366,6.341,7.317,
2.029,2.968,1.000,1.063,1.77/
DATA ETABRT/9.400,9.987,1.019,1.036,1.027,9.672,9.377,9.207,
1.935,9.626,9.773,1.019,1.053,1.071,1.071,1.074,1.066,1.058,
2.057,1.051,1.037,1.019,1.000,9.626,9.151/
DATA EM6T/0.000,0.190,1.309,1.428,1.547,1.666/
DATA DELM6/0.0,0.041,0.073,0.110,0.147,0.187/
DATA P6T/0.220,0.226,7.250,3.300,3.333,3.376,4.167,5.000,5.833,6.667,
1.75,8.333,9.167,1.0/
DATA DELP6/-1.142,-1.25,-1.075,-0.626,-0.05,-0.041,-0.027,-0.019,
1.013,-0.008,-0.004,-0.0021,0.0/
IF (IDES.NE.1) GO TO 5
DO 1 K=1,25
1 ETABRT(K)=ETABRT(K)*ETAAVS/ETADS
DO 2 K=1,25
2 FART(K)=FART(K)*FARTDS/FARTSV
DO 3 K=1,7
3 EM6T(K)=EM6T(K)*AM6DS/AM6DSV
DO 4 M=1,14
4 P6T(K)=P6T(K)*P6DS/P6DAYS
ETADS=ETADD
P6DAYS=P6DS
FARTSV=FARTDS
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

72
IF (N+EQ.0) N=1
IF (N+GE.24) N=23
DO 7 I=1,3
40 NN=N+1+1
7 X(I)=FART(NN)
41 Y(I)=ETABRT(NN)
CALL PARABO (X,Y,FAR1)
GO TO 9
8 ETA1=.2*FAR+.148
9 M=0
DO 10 J=1,7
10 IF (EM6+EQ.EM6T(J)) M=J-1
IF (M+EQ.0) M=1
IF (M+GE.6) M=5
DO 11 I=1,3
11 M=M+1+1
X(I)=EM6T(MM)
Y(I)=DELM6IMM)
CALL PARABO (X,Y,EM6_COR1)
L=0
DO 12 J=L+L6
12 IF (P6+EQ.0) L=1
IF (L+GE.13) L=12
DO 13 I=I-3
13 I=I-3+I
X(I)=P6T(JL)
Y(I)=OPEL(P6T(L)
CALL PARABO (X,Y,P6_COR2)
ETA=ETA1*(1+-COR1)*II+-COR2)
RETURN
END

$IBFTC FASTBK
SUBROUTINE FASTBK
 COMMON /WORDS/ WORD
 COMMON /DESIGN/
 COMMON /MP/DES tJDES tKDES tMOOE t[NIT tIDUMP tIAMTP tIGASMX t
21DBURNelAFTNeIDCD
eIDSHOCeIMSHOCeNOZFLTelTRYS
e NIJMKAPIMAPEDGeTOLALL_ERR(_)
COMMON /ALL1/
 ITI ePl _H1 •SI 
2TZ1 •P21 _H21 •SI
3T6 •P6 mH4 _$6 •T5 •P5 mH5 mS5 •
5CNF mPRF eETAF mWAFC •DPDUC ,BYPASS_DUMS3
 COMMON /ALL2/
 1X10 .P1 •H1 •S1 •T2 •P2 •H2 •S2 •
19 2T21 •P21 •H21 •S21 •T3 •P3 •H3 •S3 •
20 3T4 •P4 •H4 •S4 •T5 •P5 •H5 •S5 •
21 4T55 •P55 •H55 •S55 •BLF •BLC •BLU •BLB •
22 5CNF •PRF •ETAF •WAFC •WAFC •WAFC •WAF •WAF •
23 6CNC •PRC •ETAC •MAC •MAC •ETAB •DPCOM •DUMP •
24 7CNHP eETATHP eDHTCHP eDHTC •BLHP •MG5 •FAR5 •CS •
25 8CNLP •ETATLP •DHTCLP •DHTF •BLLP •MG55 •FAR55 •HPEXT •
26 9ALM •ALMP eETAR eZF •PCNF •ZC •PCNC •WFB •
27 9FFHP •TFLP •PCBLF •PCBLF •PCBLF •PCBLF •PCBLF •
28 COMMON /ALL3/
 1XP •XMAF •XWC •XBLF •XLDU •XH3 •DUMS1 •DUMS2 •
29 2XT21 •XP21 •XH21 •X21 •T23 •P23 •H23 •S23 •
30 3T24 •P24 •H24 •S24 •T25 •P25 •H25 •S25 •
31 4T28 •P28 •H28 •S28 •T29 •P29 •H29 •S29 •
32 5WAD •WFD •MG24 •FAR24 •ETAC •DPCUC •BYPASS •DUMS3 •
<table>
<thead>
<tr>
<th>COMMON /ALL4/</th>
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<tr>
<td>1WG6 = WFA</td>
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<td>1XP55 = XP55</td>
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<tr>
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<tr>
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<tr>
<td>2TFIPS = 2TFIPS</td>
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<tr>
<td>0TFIDPS = 0TFIDPS</td>
</tr>
</tbody>
</table>

SIBFTC FRTOSD

SUBROUTINE FRTOSD
COMMON /WRODS/ WORD
COMMON /DESIGN/
I1DES = 1DES, I1DES = 1DES, I1DES = 1DES, I1DES = 1DES, I1DES = 1DES
I2IDURN = 2IDURN, I2IDURN = 2IDURN, I2IDURN = 2IDURN, I2IDURN = 2IDURN, I2IDURN = 2IDURN
I3LOOPER,NOMAP,NUMMAP,MAPEDG,TCLALL,ERR(9)
COMMON /ALL2/
I1PNCNFU,PNCNUC,F4UG,DU40,DU90,DELFN,DELFN,DELFN,DELFN,DELFN
2FDFS = P2CFNS,PRFD,ETAADF,WFADFS,PRPCF,TANDCF,WADCF
3ZCDS = PCNCDS,PRCDS,ETAADS,WA6CD,PRCCF,ETCCCF,WA6CCF
4T4DS = MFBDOS,DTCODS,ETAADS,WA3CDS,DCPCDS,DTCOCCF,ETABCF
5TFHPS,CNPMPS,TFHPS,TFHPCF,CNPMPCF,ETFPCF,DCMPCF,T2OFS
6TFPS = CNLPS,ETLPS,TFLPWF,CNLP,ELPCLF,DMPCLF,TFNLF
7T2OFS = MFBDOS,DTCODS,ETAADS,WA3CDS,DCPCDS,DTCOCCF,ETABCF
8TDFS = MFADS,DATFDS,ETAADS,WA6CDS,DPAFDS,DTAFPCF,ETAAFCF
9A55 = A25,A6,A7,A8,A9,A28,A29
0PS55 = A55,CVONCZ,CVONCZ,A9SAV,A9SAV,A9SAV
COMMON /ALL3/
"
DIMENSION Xll)
EQUIVALENCE IX•IDES)
LOGICAL ERRER\CLEAR
DATA (ERRER=eTRUE_, RSTART=.TRUE.,
ITRAN-O, JTRAN=O, NSTEP = 0, TIME = O, TPRINT = O, DTPRNT = O,
IF (.NOT.eCLEAR) CALL ENGBAL
CLEAR=.FALSEo
DO
I
J=1,615
X(J)'O-
SET ARBITRARY
VALUES FOR
INTERMEDIATE
SPOOL DESIGN PARAMETERS TO
AVOID
ERROR WHEN
RUNNING A DUMNYSPOOL ENGINE
PRIDS'1-5
ETAIOS=I,O
PCNIOS=LO0.
/*8
78
79
80
81
82
83
84
85

76
$IBFTC GUESS

FUNCTION GUESS(M, T, TD, P, PD, W, WD, D, DD, VD)

IF (M.EQ.0) GUESS = ((T/TD)**1.60)*((V/D)**0.50)
IF (M.EQ.1) GUESS = ((P/PD)**1.80)*((V/D)**0.50)
IF (M.EQ.2) GUESS = ((W/WD)**0.33)*((V/D)**1.00)
IF (M.EQ.3) GUESS = ((W/WD)**1.00)*((P/PD)**0.50)
IF (M.EQ.4) GUESS = ((W/WD)**0.001)*((P/PD)**0.50)
IF (M.EQ.5) GUESS = ((V/TD)**1.1)*((V/D)**0.7)
IF (M.EQ.6) GUESS = ((V/TD)**1.00)*((V/D)**0.25)
IF (M.EQ.7) GUESS = ((V/TD)**0.82)*((V/D)**0.31)
IF (M.EQ.8) GUESS = ((V/TD)**1.2)*V/D
IF (M.EQ.9) GUESS = V/D*(P/PD)**1.5
RETURN
END

$IBFTC INDUMY

SUBROUTINE INDUMY (CNI, NI, VACI, IDES)

COMMON/DUM/NTX(15), PRX(15,15), MACX(15,15), ETAXX(15,15),
INCXX, NPTX(15)

DIMENSION WACAR(15), XCXX(15)

DATA XCXX/)001, 2, 3, 4, 5, 6, 7, 8, 1, 2, 3, 4, 5, 6, 7, 8, 9/,
DATA WACAR/5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5/,
IF (IDES.NE.1) GO TO 1
WAIDS=WACAR
CNIDS=CNI
1
I = 2, 3, 5
NCXX = 15
DO 2 I = 1, 15
NPTX(I) = 1
2
CNXX(I) = XCXX(I)*CNIDS
DO 2 J = 1, 15
PRX(I,J) = -FLOAT(J+1)/4
2
ETAXX(I,J) = 1
WACXX(I,J) = 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)

N = N+1
M = N+1
DO 1 I = 1, N
T(I,I) = A(I)
1
DO 1 J = 1, N
T(I,J) = E(I,J)
DO 7 I = 1, N
TEMP = 0.
7

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

$IBFTC OUTPUT
SUBROUTINE OUTPUT
COMMON /WORDS/ WORD
COMMON /DESIGN/
1/DES
_1DES _JDES _TDES _MDES _INIT _IDUMP _IAMTP _IGAMNX
2/DES
_BURN _IAFTB _IDCD _IMCD _IDSCHC _MIN, _MOZLFL _ITRYS
3/DES
3LOOPER _NOMAP _NUMMAP _MAPEDG _TOLALL _ERR(9)
COMMON /ALL1/
1/PCNGU _PCNGU _TACU _DUMD1 _DUMD2 _DELFN _DELSFC
2/PCNGU _PCNGU _PRDPS _ETAFO _WAFPS _PRFCF _ETACCF _WAPCF
3/PCNGU _PCNGU _PRCDS _ETACPS _WACDS _PRCCF _ETACCF _MWCFS
4/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
5/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
6/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
7/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
8/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
9/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
10/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
11/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
12/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
13/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
14/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
15/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
16/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
17/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
18/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
19/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
20/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
21/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
22/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
23/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
24/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
25/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
26/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
27/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
28/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
29/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
30/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
31/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
32/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
33/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
34/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
35/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
36/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
37/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS
38/PCNGU _PCNGU _TACDS _DETAOS _WACDS _PRCCF _ETACCF _MWCFS

78
COMMON /ALL4/
1WG6 / WF, W7, FAR7, ETA, DPAFT, V55, V25:
2PS6 / V6, AM6, PS7, V7, V25, VAM9:
3TS8 / P58, AM8, T59, P59, V9, AM9:
4FDR / VJD, FGM, VJM, FGM, FGP:
5FGM / WFT, WGT, FART, VG, FN, SFC:
6AWA3 / DPWDS, DPWING, MA32DS, AM38, V38, T38:
7TH38 / P38, TS38, PS38, T39, H39, P39, TS39:
8V39 / AM39, T39, P39, TP39, WPS39, FFWV:
9F39 / FP39, MFWV, PMS39, FFDV:
11438 / P38, TS3B, EFT38, V38, T38, ,P38:
9FNWING / FFWV, FFWV, FFWV, FFWV:
11438 / P38, TS3B, EFT38, V38, T38, ,P38:
9F39 / FP39, MFWV, PMS39, FFDV:
11438 / P38, TS3B, EFT38, V38, T38, ,P38:
9F39 / FP39, MFWV, PMS39, FFDV:
DIMENSION W(5,6), ANSI(80), ANS2(80), ANS3(80), ANS4(80), ANS5(80)
EQUIVALENCE (AND(1,1), WGT, ETA, WACI):
2TFIPP / AN(1,2), ETA(1,2), DTA(1,2), W(1,2), W(2,1), W(2,2), W(2,3):
2ID5 / AN(1,3), ETA(1,3), DTA(1,3), W(1,3), W(3,1), W(3,2), W(3,3):
4TIPPS / AN(1,4), ETA(1,4), DTA(1,4), W(1,4), W(4,1), W(4,2), W(4,3):
5WAI / PCBL, BLI, T22DS, MAZ, W50, FAR50, A24:
6AM23 / DUSMPL, FXF2NM, FXM2CP, AFTFAN, PINT, PCBLIP, PGSAV:
7AM6D5SG, ETAAS, FARTSG, T4BP, T4, T4, T4, T4:
COMMON / ALL5/
LSA0 / A22, ZL, PCNI, CNI, PRI, ETA, WACI:
ZTFIIP / CNI, ETA, DTA(1,1), DTA(1,2), DTA(1,3), DTA(1,4):
ZIIDS / PCNI, PRD, ETA(1,1), ETA(1,2), ETA(1,3), ETA(1,4):
4TIPPS / CNI, ETA, DTA(1,1), DTA(1,2), DTA(1,3), DTA(1,4):
5WAI / PCBL, BLI, T22DS, MAZ, W50, FAR50, A24:
6AM23 / DUSMPL, FXF2NM, FXM2CP, AFTFAN, PINT, PCBLIP, PGSAV:
7AM6D5SG, ETAAS, FARTSG, T4BP, T4, T4, T4, T4:
COMMON / ALL6/
IF(I3AN+EQ.1) WRITE(6,29) TIME:
2FORMAT(H18,20X TIME=F7.4):
WORD=AMORD1:
IF (IDBURN.GT.0) GO TO 2:
WRITE (6,7) WORD, AM, ALTP, T4, ETA:
GO TO 3:
1 WRITE (6,8) WORD, AM, ALTP, T4, T7, ETA:
GO TO 3:
1 WRITE (6,9) WORD, AM, ALTP, T4, T7, ETA:
GO TO 3:
3 IF (FXF2NM) WRITE (6,17):
IF (FXM2CP) WRITE (6,18): 1 IF (FAN) GO TO 25:
WRITE (6,26) ISPOOL:
26 FORMAT(H0,14,5H SPOOL TURBOJET):
GO TO 27:
IF (NOT+FXF2NM+AND+NOT+FXM2CP+AND+NOT+DUSMPL) WRITE(6,19):
1 IF (DUSMPL) WRITE (6,23):
IF (PCBLIP+EQ.0) WRITE (6,20):
1 IF (PCBLIP+EQ.0+AND+AFTFAN) WRITE (6,21):
1 IF (PCBLIP+EQ.0+AND+AFTFAN) WRITE (6,22):
27 CALL CONOUT(2):
WRITE (6,10) (MISHOC(I), I=1,4), FG, FN, SFC:
IF (IGASMX+GT.0+OR+NOT+FAN) GO TO 4:
WRITE (6,11) (MISHOC(I), I=1,4):
4 WRITE (6,12) LOOPER:
IF (IDES+NE.+1) GO TO 5:
WORD=AMORD2:
WRITE (6,13) WORD, ZF, PCNF, Z1, PCNI, ZC, PCNC, T4, MODE:
WRITE (6,14):
WRITE (6,15) (ANS1(I), I=1,80):
WRITE (6,16) (ANS2(I), I=1,80):
WRITE (6,17) (ANS3(I), I=1,80):
WRITE (6,18) (ANS4(I), I=1,80):
WRITE (6,19) (ANS5(I), I=1,55):
5 CONTINUE
AB=ABSAV
A9=AOSAV
A28=AZ8SAV
A29_A2qSAV
IF (IDUMP+NE=2) GO TO 6
WRITE (6,16)
CALL SYG
CALL ENGBAL
RETURN

FORMAT (1HB,6,9X3HFG*eFO.2eF0.2tIBBHSFAC=eF0.2)

FORMAT (21HOMIDOLE SPOOL IS DUMMY)
END

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

SUBROUTINE PERF
COMMON /WORDS/ WORD
COMMON /DESIGN/
1DES, JDES, JDEN, INIT, IDUMP, IA8MT, IGASHM, 4
2IDBURN, IDTFLN, IDCD, IDHOC, IMSHOC, IMZFLT, ITTRYS, 5
3LOOPER, NUMMAP, MAPEDG, TOLLAL, ERR(9)
COMMON /ALL/ 6
1PRCG, PRCNCG, TACG, DUMC1, DUMC2, DELFG, DELFN, DELSFC, 8
2CFDS, PRPFD, ETAFDS, WAFDS, PRFCF, ETATCF, WACP, 9
3C2DS, PRNCD, PRNCD, ETACDS, WACDS, PRCCF, ETATCF, WACP, 10
4T4DS, WFBDS, DTOSDS, ETABDS, WACDS, DPACDS, DTODS, ETABCF, 11
5TFHPSD, CNHPDS, ETPOS, TFHPCF, CNHPDF, ETAPCF, DNHPS, T2DS, 12
6TPFDS, CNLPS, ETLPS, TFLPCF, CNLPCF, ETILCF, DMLPCF, T2DS, 13
7T24DS, WFDOS, DTUDOS, ETADD, WAC2DS, DPDUS, DTUDCF, ETABCF, 14
87DS, SFADS, DTAADS, ETAADS, MG6CDS, DPADF, DTAFCF, ETAACF,  
9A55, A25, A6, A7, A8, A9, A28, A29,  
$PS55, AM55, CVNO2C, CVMNOZ, ABOAV, A57AV, A28AV, A29AV  
COMMON /ALL/  
1T1, P1, S1, T1, P2, H1, S2  
2T2, P2, S2, T2, P3, H2, S3  
3T4, P4, H4, T4, P5, S4, H5  
4T55, P55, S55, BLF, BLC, BLDU, BLOB,  
5CNF, PRF, EATAF, MACF, WAF, MA5, WG4, FAR4,  
6NCF, PRC, ETAC, MACC, WAC, ETAB, DPCOM, DUMP,  
7CNHF, EATAHP, DHTCHP, DHTC, BLHD, WG5, FAR5, CS,  
8CNLP, EATATLP, DHTCLP, DHTF, BLLP, WGG5, FAR5H, HEPT,  
9AM, ALTP, EATAR, ZF, PCNF, ZC, PCNC, MBF,  
$FFHP, TFFLP, PCCBLF, PCCBL, PCCBLB, PCCBLP,  
2TFON /ALL3/  
1XPF, XWAF, XWAC, XBLF, XBLDU, XH3, DUMS1, DUMS2,  
2XT2, XPF2, XH2, XS2, T2, P2, H2, S2  
3T2, P2, H2, T2, P2, H2, S2  
4T2, P2, H2, T2, P2, H2, S2  
5WAD, WFD, WGD, FAR24, EATAD, DPDU, BYPASS, DUMS3,  
6TS2, P52, V2, AM2, TS29, PS29, S29, V29, A2M9,  
7XT25, XP55, XH5, X55, XT25, XP25, XH25, S25,  
8XMFB, XMG5, XFAR5, XPFD, XMG24, XFAR24, XXP1, DUMB,  
9T6, P6, H6, S6, T7, P7, H7, S7  
0T8, P8, H8, S8, T9, P9, H9, S9  
COMMON /ALL4/  
1WGF, WFA, WGT, FAR7, ETAA, DPAFT, V55, V25  
2PS6, V6, AM6, TS7, P57, V7, AM7, S25  
3TS8, P58, V8, AM8, TS9, P59, V9, AM9  
4V4, FRD, VJD, FGM, VJM, FGMM, FPAD, GPDM,  
5FGM, FGP, WFT, GFM, VFG, FANT, GFT, FNC, FSC,  
6MA32, DPMDG5, DPMING, MA32D5, A38, AM38, V38, T38,  
7T3S, P38, TS38, PS39, T39, H39, P34, TS39  
8MS39, A39, SPRINT, W37, CYDWO, FGMWGW, FPWGW,  
9FNWNG, FMNAIN, FMWVFN, PS39, FFHVFN, FCOVFN, FNDFVT,  
0VWJ, T22, P22, H22, S22, T50, PSO, T50  
COMMON /ALL5/  
1550, A22, ZI, PCNI, CNI, PRI, ETAI, WAC,  
2TFTP, CNIP, EFAITP, DHTCIP, DHTL, BBLP, PCBLIP, PCNIGU,  
3ZIDS, PCNIDS, PRIDS, ETAIS, WAIDS, PRICF, ETAIFIC, WAF,  
4TIPDS, CNIPDS, EFTDS, TIFPCF, CNIPCF, ETIPCF, DHIPCF, WAIDO5,  
5MAI, PCBL1, BLI, T22DS, WA2I, WGD, FAR5, A26,  
6AM23, DUMSPL, FXP2N, FM2CP, AFHFL, PUNT, PCBLD, PEOAV,  
7AM6DVS, ETAASY, FAR75V, T4PBL, T41, FAN, ISPPOQ,  
8COMMON /DYN/, ITRAN, TIME, DT, TF, JTRAN, NSTEP, TPRT, TPRINT,  
9COMMON/UNITS/SI  
LOGICAL SI  
LOGICAL AFTFAN, DUMSPL, FAN,  
DATA AMORO/6H PERF/  
WORD=AWRD  
IF (SI) GO TO 100  
G=32, 174049  
CAPSF=216=2170  
GO TO 101  
100 G=1=0  
CAPSF=1=0  
101 CONTINUE  
WTF=WFB=MPD=WFA  
WAT=WAF=BLOB  
IF (AFHFL) WAT=WAT+WAI  
WAT=WAT+WAT  
WAT=WAT+WAT  
WAT=WAT+WAT  
WAT=WAT+WAT  
FRD=VA=WAT/G  
IF (AFHFL) FRD=VA*(WAF+WAI)/G  
VJM=CVNO2C#V9  
FGM=VJM#W7/G  
FGP=CAPSF*(PS9-PL)*A9  
IF (IFASMXGT0=OR.+NOT.+FAN) GO TO 1  
VJD=CVNO2C#V9  
FGD=VJD=WG24/G  
FGD=CAPSF*(PS9-PL)*A29  
1  
VJM=0. 
SUBROUTINE PRDCOM
COMMON/UNIT5/31
LOGICAL SI
C IF SI UNITS ARE USED, CONVERT TEX TO DEGREES RANKINE
IF (SI) TEX=TEX*9.0/5.0
IF (FARX.LE.0.0) GO TO 1
FARX=0.06723
1 IF (TEX.GE.300.) GO TO 2
TEX=300.
2 IF (TEX.LE.4000.) GO TO 3
TEX=4000.
3 IF (FARX.GE.4.0) GO TO 4
FARX=0.0
4 CPA=((1.0+15.546E-19)*TEX-1.4526770E-12)*TEX-1.512859E-14)*TEX-6.7178376E-12)*TEX+6.5919468E-08)*TEX-5.1536879E-05)*TEX+5.020051E-01)
HEA=((1.0+26.4425E-26)*TEX-2.0752522E-22)*TEX+1.0274330E-18)*TEX-1.026561E-15)*TEX-1.0679459E-12)*TEX+2.0839266E-08)*TEX-2.576844E-05)*TEX+2.052051E-01)*TEX-1.7556886E+00)
SEA=((1.0+50.0051E-01)*ALOG(TEX)+((1.0+45.08076E-16)*TEX-2.0752522E-22)*TEX-2.4112888E-22)
1)*TEX-1.5243135E-18)*TEX-3.0826048E-15)*TEX-2.392790E-12)*TEX+3.2275943E-08)*TEX-5.1576897E-05)*TEX+4.5432300E-02)
IF (FARX.LE.0.0) GO TO 5
5 C FUEL/AIR PATH
CPF=((1.0+15.546E-19)*TEX-1.4526770E-12)*TEX-1.512859E-14)*TEX+2.051104E-11)*TEX-9.9686793E-10)*TEX-1.0271901E-06)*TEX+2.258630E-03)*TEX+7.3816638E-02)
ENDIF
C AIR PATH
CPA=((1.0+15.546E-19)*TEX-1.4526770E-12)*TEX-1.512859E-14)*TEX+2.051104E-11)*TEX-9.9686793E-10)*TEX-1.0271901E-06)*TEX+2.258630E-03)*TEX+7.3816638E-02)
ENDIF
C FUEL/AIR PATH
CPF=((1.0+15.546E-19)*TEX-1.4526770E-12)*TEX-1.512859E-14)*TEX+2.051104E-11)*TEX-9.9686793E-10)*TEX-1.0271901E-06)*TEX+2.258630E-03)*TEX+7.3816638E-02)
SEF=+7.381663BE-02*ALOG(TEX1+11111111+01326870E-25*TEX-2+22226118E-21+121*TEX-2+0425826E-17*TEX-1+0512776E+13*TEX+3+3289278E-10)*TEX-6+8+2859505OE-07)*TEX+1+225843OE-03)*TEX+6+483398E-01

5
CPFX=CPEX*CPFX/(1+FARX)
HEX=(HEA+FARX*HEFX/(1+FARX))
PHI=(SEA+FARX*SEF/(1+FARX))
AMN=28.9+7-946186E*FARX
REX=1+986375/AMN
AKEX=CPEX/CPEX+REX
CSEX=SQT(AKEX*REX*TEX+25031.37)
IF (SIG GO TO 100
GO TO 101
100 CPFX=CPEX*4.185+7.666
HEX=HEX-2325.4+299
PHI=PHI*4.185+7.666
REX=REX*4.185+7.666
CSEX=CSEX*3.3048
TEX+TEX*1+5.0/9.0
CONT
INUE
RETURN
END

SUBROUTINE PUTIN
COMMON /WORS/ WORD
COMMON /DESIGN/
IDAD, IGE*, IDES, KDES, PNOOE, INET, 1DUMP, TMAP, TIGASHX,
T3LOOPER, NORMAP, NUMHAP, NUMAP, TMAPEDG, TOLALL, TERR(9)
COMMON /ALL1/
1PCNFGU, PCNCGU, T4GU, TUMDI, TUMDO, DELFG, DELFN, DELSGC,
2TDO, PCFNDS, PRFDS, TAFDS, WAFDS, PRFCF, ETAFCF, WAPCF,
3ZCDS, PCNDCS, PRDCS, TADCS, WACS, PRCCF, ETAFCF, WACC,
4T4DS, MFDS, DTCDS, ETADDS, WACS, DACDS, DPDCDS, DTCGCF, ETAFCB,
5TTFPDS, CNHPPDS, ETHPFS, CNHPCF, ETHPCF, DHPPCF, TDPFS,
6TFLFDS, CNLPODS, EBDPPS, TFLPCF, CNLPCF, ETLPCF, DHPPCF, T21DS,
7T21DS, MFDDS, DTPDDS, ETADDS, W6G6DS, DPAFDS, DTAFCF, ETAFCF,
8TAS, A2S, A6, AT, A7, A8, A9, A2B, A29
*PS55, A55, CVDNZ, CVNMOZ, A8SAY, A9SAY, A2BAS, A29SAY
COMMON /ALL2/
11T1, P1, H1, S1, T2, P2, H2, S2
2T1, P2, H2, S2, T3, P3, H3, S3
3T4, P4, H4, S4, T5, P5, H5, S5
4T5, P5, H5, S5, BLF, BLC, BLU, BLO
5CCH, PRF, ETAF, WAPC, WAF, WAM, WAG, WAF
6CNC, PRC, ETA, WAPC, WAC, ETAB, DPCM, DUMP
7CNP, ETAFA, DHTC, HTP, BLP, WM5, FAR5, CS
8BNL, ETAFA, DHTC, HTP, BLP, WM5, FAR5, HPST
9AM, ALTP, ETA, ZF, PCNF, PNC
10TFHH, PCBLF, PCLBL, PCLBLD, PCBLB, PCLBLP
COMMON /ALL3/
1XP1, XWAF, XWAC, XBLF, XBLU, XH3, DUMS1, DUMS2
2XT21, XP21, H21, S21, T23, P23, H23, S23
3XT, P24, H24, S24, T25, P25, H25, S25
4T28, P28, H28, S28, T29, P29, H29, S29
5WAD, WFD, WDF, FAR24, ETAD, DPDUC, BYPASS, DUMS3
6TS28, PS28, V28, AM28, T529, P529, V29, AM29
7TS75, XP55, H55, X555, T275, XP25, H275, X255
8BMW, WGM55, AX555, XWGM5, XWFD, XARF24, XP1, DUMB
9THB, P6, H6, S6, T7, P7, H7, S7
ST8, P8, H8, S8, T9, P9, H9, S9
COMMON /ALL4/
1L66, WFA, WDG, FART, ETAFA, DPAFT, V55, V25
2PS6, V6, AM6, T57, P57, V7, AM7, AM5
3TS8, PS8, V8, AM8, T59, P59, V9, AM9
4VA, FRD, VJD, FGM, VJM, FGM, FPGD, FPGP
5F6M, WFG, WFT, WGT, FART, WFG, WH, SFC
6W32, DPMGD5, DPMINT, WAM32DS, A38, A38, V38, T38

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COMMON / ALL5/

COMMON / DYN/ ITTRAN, TIME, DT, TF, JTRAN, NSTEP, TPRINT, DTPRNT

COMMON / RPSMS/ XNIPDS, XNPOS, XNLPOS, PMIHP, PMIIP, PMIPL

COMMON / VOL5/ VFAN, VINTC, VCOMP, VMCOMP, VHPRTR, VPTRB, VLPTRB, VAFTBN,

1 VFDU5C, VWDU5C

COMMON // UNITS/ SI

LOGICAL ERRER, FXNP2M, FXM2CP, DUNSPL, AFTFAN, FAN, SI

DATA AWORD/ 6HPUTIN /

COMMON/ LOOPPR/ KGKS0, PRFNEW, PCRENEW

DIMENSION XSAVE(6DS), XFILL(1)

EQUIVALENCE (XFILL, IDES)

COMMON/ ERER/ ERRER

IDES = 1 FOR CALCULATING DESIGN POINT

ITRAN = 1 THIS POINT IS THE IC FOR A TRANSIENT MODE

MODE = 0 FOR CONSTANT T4

MODE = 1 FOR PCNC

MODE = 2 FOR CONSTANT WFB

MODE = 3 FOR CONSTANT PCNF

INIT = 1 WILL NOT INITIALIZE POINT

IDUMP = 1 WILL DUMP LOOPING WRITE-OUTS IF ERROR OCCURS

IDUMP = 2 WILL DUMP LOOPING WRITE-OUTS AFTER EVERY POINT

IAMTP = 0 WILL USE INPUT AM AND MIL SPEC ETAR

IAMTP = 1 WILL USE INPUT AM AND INPUT ETAR

IAMTP = 2 WILL USE T1 = T1+ DELT1 AND STANDARD P1

IAMTP = 3 WILL USE T2 AND STANDARD P2

IAMTP = 4 WILL USE T2 AND P2

IAMTP = 5 WILL USE RAM2 FOR SPECIAL RECOVERY

IGASMX = 1 SEPARATE FLOW, INPUT AM6

IGASMX = 0 SEPARATE FLOW, A6=A55

IGASMX = 1 WILL MIX DUCT AND MAIN STREAMS, A6=A25+ A55

IGASMX = 2 WILL MIX DUCT AND MAIN STREAMS, INPUT AM6

IDURN = 1 FOR DUCT BURNING, INPUT T24

IDURN = 2 FOR DUCT BURNING, INPUT WFD

IAFTBN = 1 FOR AFTERBURNING, INPUT T7

IAFTBN = 2 FOR AFTERBURNING, INPUT WFA

IDCD = 1 DUCT NOZZLE WILL BE C-D

IMCD = 1 MAIN NOZZLE WILL BE C-D

NOZFLT1 = 1 FOR FLOAT MAIN NOZZLE

NOZFLT2 = 2 FOR FLOAT DUCT NOZZLE

NOZFLT3 = 3 FOR FLOAT MAIN AND DUCT NOZZLES

ITRYS = N NUMBER OF PASSES THRU ENGINE BEFORE QUITTING

NAMELIST //DATAIN/ ISPOLL, FAN, SI, DELT1,

IDES, MODE, IDUMP, IAMTP, IGASMX, IDURN, IAFTBN, IDCD, IMCD, NOZFLT1, ITRYS,

2, EAFDS, FXHF, AFTFAN, DUNSPL, TOLALL, DELF, DELF, DELF, DELF, DELF, DELF,

3, ETAFDS, PCNCDS, PCPCS, EATCDS, T40S, WFDOS, ETAROS, DPPCDS, ETHPOS, ETLOPS

4, PDUDOS, T70S, ETAADS, DPAFDS, A6, A8, A28, PS55, AM55, CVNOD, CVNODZ, T2, P2

5, T4, WAPCDS, WCACDS, HPFEXT, AM, ALTP, ETAR, PCNF, PCNC, WFD, PCBLF, PCBLC

6, PCBLOP, PCBLOP, PCBLOP, PCBLOP, T24, ETA0, T7, WFA, ETA, AM6, AM23, DPMGOS

7A38, PCNCDS, PCBLIP, PCBLIP, PCBLIP, PCBLIP, PCBLIP, PCBLIP, PCBLIP, PCBLIP, PCBLIP

8CNP0S, TFLPOS, CNLPOS, PRIDS, ETAIDS, ETIPS, ETAIDS, ETAIDS, ETAIDS, ETAIDS, ETAIDS

9, ITTRAN, DTPRNT, TF, INIT, DT, XNIPDS, XNPOS, XNLPOS, PMIHP, PMIIP, PMIPL

VFAN, VINTC, VCOMP, VMCOMP, VHPRTR, VPTRB, VLPTRB, VAFTBN, VFDU5, VWDU5C

WORD=AWORD

ITRAN=0

JTRAN=0

TIME = 0.0

NSTEP=0

TPRINT=0.0

DTPRNT=0.0

CALL ZERO

IF (KGKS0.EQ.1) GO TO 5

IDES=0

110
READ (S,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.
TABLE IS REFERENCED TO COMMON/ALL/FIRST ENTRY
IF (IDES.EQ.0) GO TO 7
IF (KKGO.EQ.2) GO TO 3
DO 1 I=1,397
XFILL(I)=XSAVE(I)
READ (S,DATAIN)
CONTINUE
SAVE INPUT IN CASE OF LOOP ON PRESSURE RATIOS
DO 6 I=1,397
XFILL(I)=XSAVE(I)
WRITE (6,9) PRFD=PRFNEW,PRCDS,PRCNEW
PRCDS=PRCNEW
PRFDS=PRFNEW
CONTINUE
1 KKD$=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,PRCNC,T24,T7
IF (MODE.EQ.2) WRITE (8,11) IDES,AM,ALTP,HPB,T24,T7
IF (MODE.EQ.3) WAFC=WAFCD
IF (DUMSPPL) WACD=WACDS
IF (IDES.EQ.1) WACI=WACDS
IF (IDES.EQ.2) WACI=WACDS
CALL CO[NLT
RETURN
FORMAT (18HCHANGE PRFDS FROM F9.3,F4.4 TO F9.3,F16.4 AND PRCDS FROM
1 F10.3,F4.4 TO F10.3)
9 FORMAT (18H 0.3,F4.4 TO F9.3,F16.4 AND PRCDS FROM
1 F10.3,F4.4 TO F10.3)
10 FORMAT (18H0.3,F4.4 TO F9.3,F16.4 AND PRCDS FROM
1 F10.3,F4.4 TO F10.3)
11 FORMAT (18H0.3,F4.4 TO F9.3,F16.4 AND PRCDS FROM
1 F10.3,F4.4 TO F10.3)
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 PRINLTI15),FMN(15)
DIMENSION Y(3),X(3)
DATA FMN/0.,1.,2.,3.,4.,5.,6.,7.,8.,9.,0.,1.,2.,3.,4.,5./
DATA PRINT/9.,932.,95.,961.,968.,97.,970.,97.,968.,97.,958.,94.,
1.,918.,858.,8201.,75/
\[ M = 0 \]
\[ \text{DO 1 J=1,15} \]
\[ 1 \text{ IF (AM \geq FHM(J)) M = J-1} \]
\[ \text{IF (M = EQ 0) M = 1} \]
\[ \text{IF (M \geq 14) M = 13} \]
\[ \text{DO 2 I=1,3} \]
\[ \text{MM=M-1} \]
\[ \text{XI(I)=FHM(MM)} \]
\[ 2 \text{ Y(I)=PRNTL(MM)} \]
\[ \text{CALL PARABO (X, Y, AM, ETAR)} \]
\[ \text{RETURN} \]
\[ \text{END} \]

\$IBFTC ROLL

SUBROUTINE ROLL
COMMON/FO/FO(SO, 4)
COMMON/SCD/SCD(10, 6)
COMMON/CDATA/PDATA(5, 50), TIMEPT(50)
DO 1 I=1,50
1 FO(I, 2)=FO(I, 1)
2 FO(I, 4)=FO(I, 3)
DO 2 I=1,10
3 FO(I, 6)=SOI(I, 5)
4 SOI(I, 5)=SOI(I, 4)
5 SOI(I, 3)=SOI(I, 2)
6 SOI(I, 2)=SOI(I, 1)
C DO 3 J=1,49
7 NI=51-I
8 NO=50-I
9 TIMEPT(NI)=TIMEPT(NO)
10 DO 3 J=1,5
11 PDATA(J, NI)=PDATA(J, NO)
12 RETURN
13 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 AFQUR
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 C NCODE=01 A LO
C C NCODE=02 A HI
C NCODE=07 ERROR
C C NCODE=10 B LO
C NCODE=20 B HI
C NCODE=0 C=0
C NCODE=1 D=0
C *** FIND A
C DO 1 I=1, NA
1 IF (A=LT.AX(I)) GO TO 2
C C CONTINUE
C IF (A=GT.AX(I)) NCODE=2
C A=AX(I)
2 C GO TO 3
3 C NCODE=1
C C NCODE=2
C A=AX(1)
C C NCODE=3
C I=I-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

GO TO 5

NCODE=NCODE+20
BH=BX(IL,LIML)+PRM*(BX(IH,LIMH)-BX(IL,LIML))
CH=BX(IL,LIML)+PRM*(CX(IH,LIMH)-CX(IL,LIML))
DH=DX(IL,LIML)+PRM*(DX(IH,LIMH)-DX(IL,LIML))
CSLOPE=(CH-CSL)/BH-BH)
DSLOPE=(DH-DSL)/BH-BH)
RETURN

PP=O.5
Q(1)=O.
Q(2)=O.

6 IF (BL+LE+BH) GO TO 5
NCODE=NCODE+20
BH=BX(IL,LIML)+PRM*(BX(IH,LIMH)-BX(IL,LIML))
CH=BX(IL,LIML)+PRM*(CX(IH,LIMH)-CX(IL,LIML))
DH=DX(IL,LIML)+PRM*(DX(IH,LIMH)-DX(IL,LIML))
CSLOPE=(CH-CSL)/BH-BH)
DSLOPE=(DH-DSL)/BH-BH)
RETURN

IF (PP+GT+O.5) PP=O.
GO TO 6

NCODE=7
B=BT
C=CT
D=DT
RETURN

SUBROUTINE SYG (ICON)
DIMENSION I(132)
DATA ONEDOL,6H$ /
GO TO (1,2,ICON)
SUBROUTINE THCOMP (PR, ETA, T, H, S, P, TO, HO, SO, PO)
COMMON /UNITS/ SI
LOGICAL SI
CPG=.250
IF(SI) CPG=1048.
P0=P*PR
TP=TP*P**0.28572
DO 1 I=1,25
CALL THERMO (PO, HP, TP, SP, X1, O, X2, O)
DELS=SP-SP
IF (ABS(DELS)>LE.0.00005*SP) GO TO 2
1 TP=TP/EXP(DELS/CPG)
CALL ERROR
2 HO=H+((HP-H)*ETA)
CALL THERMO (PO, HC, TO, SO, X1, O, X2, O)
RETURN
END

SUBROUTINE THERNO (Px, Mx, Tx, SX, AMX, L, FAR, K)
COMMON/UNITS/SI
LOGICAL SI
IF (SI) GO TO 100
DEH=1.986375
CPG=.250
PSTD=1.0
GO TO 101
100 DEM=B316+41
CPG=1048
PSTD=101325.
101 CONTINUE
FX=FX
IF (L.EQ.1) FX=FAR
IF (K.EQ.1) GO TO 1
CALL PROCOM (FX,TX,CS,AK,CP,R,PHI,H)
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))ELE.000001*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 (31HOMO CONVERGENCE IN THERMO$ $ $ $ $ $)
END

SUBROUTINE THTURB (DH,ETA,FAR,H,S,P,TO,H0,SO,PO)
COMMON /UNITS/ZI
LOGICAL ZI
IF (ZI) GO TO 100
DEM=1.986375
GO TO 101
100 DEM=B316+41
101 CONTINUE
HO=H-DH
HOP=H-ETA
PT=P/2°
00 I 1=1.25
CALL THERMO (PT,HOP,TT,ST,AMWT,1,FAR,1)
DELSS=ST-S
IF (ABS(DELSS))ELE.0000005*ST) GO TO 2
1 PT=P*EXP(DELSS/AMWT/DEM+ALOG(PT/P))
CALL ERROR
2 PD=PT
CALL THERMO (PO,HO,TO,SO,X1,1,FAR,1)
RETURN
END

SUBROUTINE WDUCTI
COMMON /WORDS/ WORD
COMMON /DESIGN/
1DES ,JOES ,KDES ,MODE ,INIT ,IDUMP ,IAMTP ,IGASMX ,
1DBURN, IAFDBN, IDCD, IMCD, IDSHOC, IMSHOC, NOZFLT, ITRY ,3
SLOOPER, NONMAP, NUMMAP, MAPEDG, TOLLALL, ERR(9)
COMMON /ALLI/ 7
1PCNFGU, PNCGU, TAGU ,DUMO1 ,DUMO2 ,DELFG ,DELFN ,DELSFC ,
2FDFS ,PCNDFS, PPDFS, ETADFS, WAFDS, PRFCF, ETAFCF, MAPCF ,
3CDS ,PCNCDS, PRCS, ETAEDS, WACDS, PRCCF, ETAACF, WACCF ,
4TADS ,WFADS ,DTACS, ETAACS, WAACS, DPDUDS, DTDUCF, ETADC, 
5TFHPS ,CMHPSDS, TFHPS, CNTFHC, ETPHC, OHMPCF, T2DS , 8
6TFLPS, CNLPS, ETLPFS, TFLPCF, CLNPCF, ETLPFCF, DHLPCF, T2IDS ,
7T24DS ,WFADS ,DTUDS, ETAEDS, WA23DS, DPDUDS, DTDUCF, ETADC ,
8T10S ,WFADS ,DTAFDS, ETAADS, W24CDs, DP, DAFDS, ETAFCF, ETAACF ,

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COMMON ALL2/
1T1 = P1, H1, S1, T2, P2, H2, S2
2T2 = P2, H2, S2, T3, P3, H3, S3
3T4 = P4, H4, S4, T5, P5, H5, S5
4T5 = P5, H5, S5, BLF, BLC, BLDU, BLOB
5CNF = PRF, EFAF, MAF, WA3, H4, FAI
6CNCF = ETAC, WAC, EFA8, DPWNG, DUP
7CNHP = ETATHP, DHTCIP, DHTC, BLIP, MG5, FARS
8CNLP = ETATLP, DHTCLP, DHTF, BLLP, MG55, FARS5, HPEXT
9AM = ALTP, ETA8, LF, PCNF, ZC, PCNC, WFB
$T$7 = TFPFL, PCBFL, PCBLC, PCLU, PCBLDU, PCBLHP, PCBLLP
COMMON ALL3/
1XP1 = XMAF, XNAT, XNATL, XBLDU, XH3, DUMS1, DUMS2
2XT2 = XP2, XH21, XS21, T23, P23, H23, S23
3T4 = P4, H4, S4, T5, P5, H5, S5
4T5 = P5, H5, S5, BLF, BLC, BLDU, BLOB
5CNF = PRF, EFAF, MAF, WA3, H4, FAI
6CNCF = ETAC, WAC, EFA8, DPWNG, DUP
7CNHP = ETATHP, DHTCIP, DHTC, BLIP, MG5, FARS
8CNLP = ETATLP, DHTCLP, DHTF, BLLP, MG55, FARS5, HPEXT
9AM = ALTP, ETA8, LF, PCNF, ZC, PCNC, WFB
$T$7 = TFPFL, PCBFL, PCBLC, PCLU, PCBLDU, PCBLHP, PCBLLP
COMMON ALL4/
1WG6 = WFA, WG7, FAR7, ETA, DPAFT, V55, V25
2PS6 = V6, AM6, TS7, PST, V7, AM7, AM25
3TS8 = P8, H8, T9, P9, H9, S9
4TS9 = P9, H9, S9, T10, P10, H10, S10
5WAD = WFD, WG24, FAR24, ETAD, DPWNG, BYPASS, DUMS3
6TS2 = PS26, V26, AM28, T72, PS28, V28, AM29
7XWFB = XWG55, XWFAR55, XWFD
8T6 = P6, H6, S6, T7, P7, H7, S7
$T$8 = PB, H8, S8, T9, P9, H9, S9
COMMON ALL5/
1550 = WA22, ZI, PCI1, CNI, PRI, ETAI, MAC1
2TFF1P = CNP1, ETATIP, DHTCIP, DHT1, BLP, PCLU, PNCLG
3TIDS = PCN10, PRIDS, ETAIDS, WAIDS, PRICF, ETAICF, WAICF
4TFIPDS = CNPIDS, ETIPDS, TIPCF, CNPFCF, ETIPCF, DHCIP, WAICDS
5XW2 = PCBL1, BL1, T22DS, W21, MG50, FARS0, A24
6AM23 = DUMPSL, FXFG2M, F2M2CP, AFTFAN, PUNT, PCBL10, DPDADS
7M6 = CFAG6, ETASAV, FAR75V, TAPBL, T44, FAN, ISPOOL
COMMON /VOLS/ VFAN, VINTC, VCOMP, VCMOB, VHPTRB, VLPTRB, VLTPRB, VARTBN
1 VDUCT, WMUDT/C
COMMON UNIT3/ SI
LOGICAL SI
DATA AWORD/6H16DUT1/1
DIMENSION Q(91
DIMENSION XZERO(26)
EQUIVALENCE (XZERO, DPWNG)
WORD = AWORD
IF (SI_ EQ 0) GO TO 100
RA = 0252
AJ = 2, 719
GO TO 101
RA = 286, 9
AJ = 1, 0
CONTINUE
IF (PCBL1 = GT 0) GO TO 3
XZERS = CVWNG
DO 1 = 1, 26
1 XZERO(1) = 0, 0
CVWNG = XZERS
RETURN
3 CONTINUE
P32 = P21
H32 = H21
T32 = T21
BPRINT = WA32, WAT, WA32 = SQRT(T32)/P32
IF (IDES EQ 1) WA32 = WA32
DOWNG = DPWNG, WA32 = WA32

90
DPWNG=AMINII,O,DPWNG) 89
P36=P3211,DPWNG) 90
T36=T32 91
H36=H32 92
CALL THERMO (P36,H36,T36,S36,XX2,1,0,0,0) 93
WG37=WG32 94
T37=T36 95
P37=P36 96
H37=H36 97
S37=S36 98
IF(VMDUCT=EQ.0.0) GO TO 20 99
Q(2)=Q.0 100
Q(3)=Q.0 101
WG37=WG37 102
H37=H37 103
P37=P37 104
CONTINUE 105
CALL THERMO(P37,H37,T37,S37,XX2,1,0,0,0) 106
WG37=WG37-P370T*VMDUCT/T37/1.4/RA 107
U37=H37-RAlAJ*T37 108
U370T=DERIV12,P37) 109
H3X=(WG37*H37-(WG37-WG37)*U37-U370T*P370VMDUCT/T37/RA)/WG37 110
ERRW=(H37-H37)/(H37) 111
DIR=SQRT(ABS(H37X/H37)) 112
CALL AIFQURIQ(1),T37,ERRW,0.,20.,0.0001,DIR,T37,IGO) 113
GO TO (19,21,20),IGO) 114
T37=T37T 115
GO TO 18 116
CALL ERROR 117
CONTINUE 118
NOZD=O 119
CALL CONVRG (T37,H37,P37,T37,0.,1.,W37,P1,IDES,A38,P38R,T38,H38,P38 120
1,S38,T38,P38,V38,AM38,ICON) 121
GO TO (15,5,49),ICON) 122
CALL ERRORR 123
T39=T38 124
H39=H38 125
P39=P38 126
S39=S38 127
T39=T38 128
V39=V38 129
AM39=AM38 130
A39=A38 131
P39=P38 132
IDSHOC=ICON+3 133
ERR(T)=(P38R-P38)/P38R 134
IF (IDES=EQ.1) WRITE (6,6) A38,AM38,A39,AM39 135
RETURN 136
C 137
C 138
FORMAT (18,INTER DUCT DESIGN,5X,8H A38=,E15.8,8H AM38=,E15.8 139
1,8H A39=,E15.8,8H AM39=,E15.8) 140
END 141

SUBFTC ZERO 1
SUBROUTINE ZERO 2
COMMON /WORDS/ WORD 3
COMMON /DESIGN/ 4
IDES,JOE,KDES,MODE,INIT,JDUMP,IAMTP,IGASMX, 5
2DBC,IAFTBN,IMDC,IMN,MHOC,NOZFL,ITRYS, 6
3LOPER,NOMAP,NUMMAP,MAPEDG,TOLLALL,ERR(9) 7
COMMON /ALL/ 8
1PCNGU,PCNCGU,T4GU,DUM0,DUM2,DELF,DELFN,DELSFC, 9
ZFD,S,PCNFDS,PRFDST,ETADSF,WAFDS,PRFCE,ETACCF,WACCF, 10
3ZCS,PCNCOE,PRCDS,ETACS,WACS,PRCCF,ETACC,WACCF, 11
4T4DS,WFBDST,DTCDS,ETABDS,WADCS,DPCDS,DTGCEF,ETABCF, 12
5TFHPDS,CHNPDST,ETHPDS,ETHPDS,CHNPECF,ETHPCEF,OMHPCEF,TZDS, 13
6TLPDS,CLNPDS,ETLPDF,TFLPCF,CLNPCF,ETLPCEF,OMLPCF,TZLDS, 14
7T24DS,WFDDS,DTCDDS,ETADDSD,WADDDS,DPDDDS,DTDDCF,ETADCF,
DIMENSION Z1(63), Z2(63), Z3(10), Z4(62)

EQUIVALENCE (Z1: T1), (Z2: X1), (Z3: X55), (Z4: X55)

!DEDE=O
!JDEES=O
!INIT=O
!IDBURN=O
!IAFTB=O
!IDSHOC=3
!IMSHOC=3
!NOZFT=O
!T2Q=T2
!P2P=P2
!T4Q=T4
!DO 1 I=1,63

1 Z1(I)=0.
!DO 2 I=1,148
!DO 3 I=1,10
!DO 4 I=1,62
!Z4(I)=0.
!T2=T2
!P2=P2
!T4=T4
CALL SYG (1)
RETURN
END
### A Generalized Fan Map for Unrealistic Supersonic Engine

**BLOCK DATA**

```plaintext
DATA N,NP/10,3,7,29,6,0,6,2,980,960,.590/,
DATA (PRI (J),MAC (J),ETA (J),J=1,8)/
DATA (PR (J),WAC (J),ETA (J),J=1,8)/
DATA (PR (J),WAC (J),ETA (J),J=1,8)/
DATA (PRI (J),MAC (J),ETA (J),J=1,8)/
```

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The text appears to be a data table with numerical values, possibly related to a scientific or technical context. The data is presented in a tabular format with columns and rows, suggesting it could be part of a larger dataset or report. The specific content and context of the data are not clear from the image alone. The table includes numerical values, possibly representing measurements or calculations, but without additional context, the exact nature of the data cannot be determined.
$IBFTC IPTDAT

BLOCK DATA
COMM / ITURB / TFF(15),CN(15,15),DH(15,15),ETA(15,15),N,NPI(15)
DATA N,NPI,11,9,15,12,9,4,15,101
DATA TFF,70,776,82,236,93,468,103,464,112,836,130,536,440
DATA CN(1,1,15),DH(1,1,15),ETA(1,1,15),J=1,1
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 1.0618, 0.0045, 0.7140, 1.3556, 0.0049, 0.7300
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, 2.8173, 0.0031, 0.5000
8 3.1698, 0.0031, 0.4350, 3.1850, 0.0031, 0.4350
DATA CN(2,1,15),DH(2,1,15),ETA(2,1,15),J=1,1
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, 1.3810, 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 3.2422, 0.0068, 0.5900, 3.4650
DATA CN(3,1,15),DH(3,1,15),ETA(3,1,15),J=1,1
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 1.3197, 0.0087, 0.8670, 1.3730, 0.0098, 0.8700
4 1.7649, 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 3.2422, 0.0149, 0.7600
DATA CN(4,1,15),DH(4,1,15),ETA(4,1,15),J=1,1
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
END
$IBFTC LTPTDAT

BLOCK DATA

COMMON / LTURB/TFF(15),CN(5,15),DH(15,15),ETA(15,15),N,NP(15)

DATA N,NP(11,9*15),12,9*4,0/
<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
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<td>1</td>
<td>0.3682</td>
<td>0.0054</td>
<td>0.6780</td>
<td>0.5518</td>
<td>0.0080</td>
</tr>
<tr>
<td>2</td>
<td>0.6629</td>
<td>0.0096</td>
<td>0.7125</td>
<td>0.8282</td>
<td>0.0119</td>
</tr>
<tr>
<td>3</td>
<td>1.0129</td>
<td>0.0141</td>
<td>0.7690</td>
<td>1.0169</td>
<td>0.0160</td>
</tr>
<tr>
<td>4</td>
<td>1.2337</td>
<td>0.0169</td>
<td>0.8060</td>
<td>1.3009</td>
<td>0.0188</td>
</tr>
<tr>
<td>5</td>
<td>1.5283</td>
<td>0.0209</td>
<td>0.8395</td>
<td>1.6201</td>
<td>0.0223</td>
</tr>
<tr>
<td>6</td>
<td>1.7482</td>
<td>0.0244</td>
<td>0.8470</td>
<td>1.8409</td>
<td>0.0263</td>
</tr>
<tr>
<td>7</td>
<td>1.8954</td>
<td>0.0279</td>
<td>0.8330</td>
<td>1.9147</td>
<td>0.0289</td>
</tr>
<tr>
<td>8</td>
<td>1.9237</td>
<td>0.0303</td>
<td>0.7000</td>
<td>1.8225</td>
<td>0.0303</td>
</tr>
</tbody>
</table>

DATA (CN(10,J),DH(10,J),ETA(10,J),J=1,12)/

|   |   |   |   |   |
|---|---|---|---|
| 1 | 0.3682 | 0.0054 | 0.6780 |
| 2 | 0.6629 | 0.0096 | 0.7125 |
| 3 | 1.0129 | 0.0141 | 0.7690 |
| 4 | 1.2337 | 0.0169 | 0.8060 |
| 5 | 1.5283 | 0.0209 | 0.8395 |
| 6 | 1.7482 | 0.0244 | 0.8470 |
| 7 | 1.8954 | 0.0279 | 0.8330 |
| 8 | 1.9237 | 0.0303 | 0.7000 |

DATA (CN(11,J),DH(11,J),ETA(11,J),J=1,9)/

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3682</td>
<td>0.0054</td>
</tr>
<tr>
<td>2</td>
<td>0.6629</td>
<td>0.0096</td>
</tr>
<tr>
<td>3</td>
<td>1.0129</td>
<td>0.0141</td>
</tr>
<tr>
<td>4</td>
<td>1.2337</td>
<td>0.0169</td>
</tr>
<tr>
<td>5</td>
<td>1.5283</td>
<td>0.0209</td>
</tr>
<tr>
<td>6</td>
<td>1.7482</td>
<td>0.0244</td>
</tr>
<tr>
<td>7</td>
<td>1.8954</td>
<td>0.0279</td>
</tr>
<tr>
<td>8</td>
<td>1.9237</td>
<td>0.0303</td>
</tr>
</tbody>
</table>

END
Flow Chart of DYNGEN

ORIGINAL PAGE IS OF POOR QUALITY
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 T₄ 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 intermediate-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
calculates performance after engine is balanced

calculates thermodynamic gas properties for either air or a fuel-air mixture based on JP-4

reads input data; controls loop on static pressures for mixed-flow turbofan

calculates ram recovery defined by MIL-E-5008B specifications

calculates special cases of input ram recovery as a function of flight Mach number

saves past values of dynamic variables needed for calculating derivatives, etc.

general table lookup and interpolation routine to obtain data from BLOCK DATA subroutines

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.)

provides thermodynamic conditions using PROCOM

performs isentropic calculations for compressors

performs isentropic calculations for turbines

performs third-stream (wing) duct calculations (not used in two-stream engines)

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 DISTR
SUBROUTINE DISTR
COMMON /WORDS/ WORD
COMMON /DECE/ 10FS, JDES, KDES, MODE, INIT, IDUMP, IAMTP, IGASMX,
2IDURN, IAFTB, IDCD, IMCD, IDSHOC, IMSHOC, NOZFLT, ITRYS,
3LOOPER, NOMAP, NUMMAP, MAPEOG, TOLALL, EPR(9)
COMMON /ALL1/
1PCNFGU, PCNCGU, T4GU, DUMD1, DUMD2, CELFG, DELFO, DELSFC,
2ZDFS, PCFNDS, PRRFS, ETADFS, WAFTS, PRCFC, ETAFCF, WAFCF,
3ZCDS, PCNCDS, PRRCDS, ETAECDS, WACDS, PRCCF, ETAACF, WACCF,
4T4DS, WAFTDS, DTCODS, ETAODS, WA3CDS, CPCODS, DTCOCC, ETAOCF,
5TFHPS, CNDHPS, ETHHPS, TFHPCF, CNHPCF, ETHPCF, DHHPCF, T2DS,
6TFLPDS, CLNPS, TFLPCF, CNLPCF, TFLPCF, DHLPCF, T21DS,
7T24DS, WAFTDS, DTDUDS, ETAADS, WA23DS, DPDUDS, DTDUCC, ETAACF,
8T7DS, WAFTDS, ETAADS, WAVDS, CPAFDs, ETAFCF, EAACF,
9A55, A25, A6, A7, A8, A9, A28, A29,
$PS55, AM55, CVNOCZ, CVNOCZ, A8SA, A9SA, A28SA, A29SA
COMMON /ALL2/
1I1, 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,
5CIFS, PCIFS, ETAI, WAFT, WA3, WG, TARA,
6CIFS, PRRC, ETAI, MAC, ETA, DPOC, DUMS3,
7CIFS, ETAIP, DHTCIP, DHTC, BLHP, WG5, FAR5, CS,
8CIFS, ETAIP, DHTCIP, DHTC, BLHP, WG5, FAR5, HPS,
9AM, ALTAP, ETAIP, ETAIP, PCNF, ZC, PCNC, WFB,
$TFFIHP, TFFLP, PCBLF, PCBLC, PCBLD, PCBLD, PCBLH, PCBLIP
COMMON /ALL3/
1XI, P1, XWAF, XWAC, XBLF, XBLDU, XH3, DUMS1, DUMS2,
2XI, P21, 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, ETAI, DPOC, BYPASS, DUMS3,
6T28, PS28, V28, AM28, TS29, M29, V29, AM29,
7X55, XP55, XH55, X55, XT25, XP25, XH25, X25,
8XWF, XWG55, XWAF, XWAC, XBLF, XBLDU, XH3, DUMS1, DUMS2,
9T6, P6, H6, S6, T7, P7, H7, S7,
$T8, P8, H8, S8, T9, P9, H9, S9
COMMON /ALL4/
1WG6, WFA, WG7, FAR7, ETAA, CPAFT, V55, V25,
2PS6, V6, AM6, TS7, PS7, V7, AM7, AM25,
3T5, PS8, V8, AM8, TS9, P9, V9, AM9,
4V4A, VRD, VJD, FGMD, VJMM, FGM, FGP, FGPM,
5FGM, FGP, WFT, WGT, FRT, FG, FN, SFC,
6WAKS, DWWDS, DWWING, WACCDS, A38, AM38, V38, T38,
7H38, T38, P38, HS38, T39, H39, P39, T39,
8V39, AM39, A39, BPR, W37, CVNO, FGM, FGP, WGP,
9FNW, FWM, FWM, FWM, FWM, FWM, FWM, FWM,
$WJ2, T2, P22, H22, S22, T50, P50, H50
COMMON /ALL5/
1550, W22, ZL, PNCI, CNI, PRI, ETAI, WACI,
2TFFIP, CNI, ETAI, DHTCIP, DHTI, BLP, PCBLIP, PCNIGU,
3I1DS, PCMI, PRDS, ETAICS, WAIDS, PRICF, ETAICF, WAICF,
4T1IPDS, CNI, ETAI, DHTCIP, DHTI, BLP, PCBLIP, PCNIGU,
5WAY, PCBLI, BLP, T220S, WA21, WG50, FAR50, A24,
6AM23, DUMSPL, FXF2M, FXM2CP, AFTFA, PUNI, PCBLID, P6D5A,
7AM6DSV, ETAASV, FAS5V, T48L, T41, FAN, ISPOOL

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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.

```
$18FTC FCNTRL
   SUBROUTINE FCNTRL
   RETURN
   END

$18FTC 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.

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(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.

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.")
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.
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).

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 0.935724E+02 0.935724E+00 0.935724E+00 0.935724E+00
PCNF 0.945018E+02 0.945018E+00 0.945018E+00 0.945018E+00
PCNF 0.947421E+02 0.947421E+00 0.947421E+00 0.947421E+00
T2 0.303349E+03 0.303349E+00 0.303349E+00 0.303349E+00
T3 0.699518E+03 0.699518E+00 0.699518E+00 0.699518E+00
PCBLHP 0.138566E+07 0.138566E+00 0.138566E+00 0.138566E+00

MA3 0.802017E+00 0.802017E+00 0.802017E+00 0.802017E+00
MA3 0.956680E+02 0.956680E+00 0.956680E+00 0.956680E+00
MA3 0.130926E+03 0.130926E+00 0.130926E+00 0.130926E+00

RAW TEXT END
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.
Next, the DYNGEN output is given for a 3-second transient.
<table>
<thead>
<tr>
<th>TIME = 0.0000</th>
<th>OUTPUT</th>
<th>AM = 0.0</th>
<th>ALTP = 0.0</th>
<th>T4 = 1480.45</th>
<th>ETAP = 1.0000</th>
</tr>
</thead>
</table>

**THREE SPOOL ENGINE**

**THE OUTPUT IS IN SI UNITS**

**PCNF**

| C = 943149E+02 | CNF = 0.963149E+00 | ZF = 0.827059E+00 | PRF = 0.135937E+01 | WAF = 0.261245E+03 |
| CNI = 0.9553E+00 | Z1 = 0.826160E+00 | P1R = 0.152399E+01 | WAI = 0.253953E+03 |
| PCNC = 0.975213E+02 | CNC = 0.835857E+00 | PRC = 0.704346E+01 | WAC = 0.133480E+03 |
| P2 = 0.305349E+03 | T2 = 0.336749E+03 | P22 = 0.137738E+06 | WAC = 0.818292E+02 |
| T3 = 0.310310E+03 | P3 = 0.147518E+07 | T21 = 0.385770E+03 | P21 = 0.209912E+06 |
| PCBLHP = 0.0 | P3 = 0.0 | PCBLF = 0.0 | BLP = 0.0 |
| C = 0.0 | WAF = 0.0 | PCBLIP = 0.0 | BLIP = 0.0 |

**C. WAD = 0.813925E+02**

| WF = 0.185800E+00 | WGD = 0.832034E+00 | WAF = 0.228273E+00 | T4 = 0.148045E+04 |
| CNHP = 0.187640E+00 | DMTCHP = 0.354794E+00 | FAR = 0.104949E+00 | P90 = 0.140654E+07 |
| TFFIP = 0.121316E+00 | DHTCIP = 0.150629E+00 | T5 = 0.134715E+00 | P85 = 0.337415E+00 |
| TFLLP = 0.415858E+00 | DHTCLP = 0.104413E+00 | DTF = 0.101745E+06 | P85 = 0.230517E+06 |
| ETAB = 0.983000E+00 | T24 = 0.485803E-01 | DPDCU = 0.336748E+03 | P25 = 0.363047E+00 |
| WAD = 0.861119E+02 | WGD = 0.861096E+02 | T25 = 0.363047E+03 | V6 = 0.337415E+00 |
| ETAF = 0.884800E+00 | ETAC = 0.844000E+00 | DTF = 0.227421E+03 | MW6 = 0.831803E+02 |
| T6 = 0.101356E+04 | WS6 = 0.224225E+03 | WAF = 0.281939E+03 | DEPAF = 0.931803E+02 |
| T7 = 0.101454E+04 | WAD = 0.831503E+02 | WAF = 0.282705E+00 | T9 = 0.0 |
| PSB = 0.125452E+06 | AM8 = 0.100000E+01 | V9 = 0.578376E+03 | V9 = 0.218834E+03 |
| PS28 = 0.101356E+06 | AM28 = 0.578376E+03 | V28 = 0.218834E+00 | V28 = 0.218834E+03 |
| BPP = 0.105955E+01 | V28 = 0.101356E+06 | P85 = 0.365271E+03 | V99 = 0.218834E+03 |
| BYPASS = 0.858737E+02 | V28 = 0.101356E+06 | PS28 = 0.365271E+03 | P99 = 0.218834E+03 |
| PCRL = 0.531306E+00 | WAD = 0.101356E+06 | V28 = 0.101356E+06 | P99 = 0.218834E+03 |
| CVDN = 0.531449E+00 | V28 = 0.101356E+06 | V99 = 0.218834E+03 | V99 = 0.218834E+03 |
| CVN = 0.985030E+00 | V9 = 0.985030E+00 | V9 = 0.985030E+00 | V9 = 0.985030E+00 |

**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERG+ NOZZLE**

**CONVERGED AFTER 12 LOOPS**

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THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

| ORIGINAL PAGE IS OF POOR QUALITY |

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MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 12 LOOPS

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FN=104051.11
SFC=9.06428
**OLPUT**

**AM** = 3.

**ALTP** = 0.

**T4** = 147056

**ETA** = 1.0000

---

**TIME = 0.4000**

**THREE SPool ENgINE**

**The Output is in SI Units**

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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERG. NOZZLE**

**CONVERGED AFTER 12 LOOPS**

**FG=104812.52**

**FN=104812.52**

**SFC=3.06382**
THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

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MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 11 LOOPS

TIME = 0.5000

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SFC = 0.06339
### THREE SPOOL ENGINE

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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERGENT NOZZLE**

**CONVERGED AFTER 11 LOOPS**

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### THREE SPOOL ENGINE

THE OUTPUT IS IN SI UNITS

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MAIN SONIC CONVERGENT NOZZLE

DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 11 LOOPS

FG = 114230.88
FN = 114230.88
SFC = 0.95856
### Three Spool Engine

The output is in SI units.

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**Main Sonic Convergent Nozzle**

**Duct Subsonic Convergent Nozzle**

**Converged after 11 loops**

**Output Values**

- FG: 107318.94
- FN: 107318.94
- SFC: 0.06233
TIME = 0.9000

OUTPUT
AM = 0
ALTP = 0
T4 = 1453.27
ETAR = 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

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<th>PRF</th>
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MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERGENT NOZZLE

CONVERGED AFTER 11 LOOPS
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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERGENT NOZZLE**

CONVERGED AFTER 11 LOOPS
**TIME = 1.2000**

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**THREE SPOOL ENGINE**

THE OUTPUT IS IN SI UNITS

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| C1.00095E+03 | 0.212043E+01 | 0.294205E+02 | 0.107009E+06 | 0.107580E+04 | 0.356772E+06 |

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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERG. NOZZLE**

CONVERGED AFTER 11 LOOPS

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THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

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<td>0.0*</td>
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MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERG. NOZZLE
CONVERGED AFTER 11 LOOPS

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SFC = 0.06072
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<td>0.138246E+01</td>
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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERG. NOZZLE**

**CONVERGED AFTER 11 LOOPS**

**FG = 110551.95**

**FN = 110551.95**

**SFC = 0.06050**

**TIME = 1.5000**

**AM = 0.0**

**ALTP = 0.0**

**T4 = 1439.97**

**ETAR = 1.0000**
## THREE SPOOL ENGINE

The output is in SI units.

### TIME = 1.6000

**OUTPUT**

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### E0

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### MAIN SONIC CONVERGENT NOZZLE

Duct Subsonic Convergent Nozzle

Converged after 11 loops.
### Output of Three Spool Engine

The output is in SI units.

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### Main Sonic Convergent Nozzle

Duct Subsonic Convergent Nozzle

Converged after 11 loops.
## TIME = 2.0000

### THREE SPOOL ENGINE

The output is in SI units

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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERGENT NOZZLE**

Converged after 11 loops
| TIME = 2.1000 |
| OUTPUT | AM = 0.0 | ALTP = 0.0 | T4 = 1431.09 | ETAR = 1.0000 |

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

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MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERG. NOZZLE

CONVERGED AFTER 11 LOOPS
### Three Spool Engine

The output is in SI units.

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**Main Sonic Convergent Nozzle**

**Duct Subsonic Convergent Nozzle**

Converged after 11 loops.

- **Time:** $2 \times 10^3$
- **Output:** $a = 0.0$
- **ALTP:** $0.0$
- **T4:** $1430 \pm 47$
- **ETAR:** $1.0000$
- **FG:** $112700 \pm 48$
- **FN:** $112700 \pm 48$
- **SFC:** $0.09535$
**THREE SPOOL ENGINE**

THE OUTPUT IS IN SI UNITS

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**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERG. NOZZLE**

CONVERGED AFTER 11 LOOPS

**TIME = 2.4000**

**OUTPUT**

**AM = 0.**

**ALTP = 0.**

**T4 = 142892**

**ETAR = 1.0000**

**FG = 113172.22**

**FN = 113172.22**

**SFC = 0.05910**
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THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

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| TFFHP | TFFHP | TFFHP | TFFHP | TFFHP | TFFHP | TFFHP |
| 0.50143E+02 | 0.50143E+02 | 0.50143E+02 | 0.50143E+02 | 0.50143E+02 | 0.50143E+02 | 0.50143E+02 |

ETAB | ETAB | ETAB | ETAB | ETAB | ETAB | ETAB |
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ETAB | ETAB | ETAB | ETAB | ETAB | ETAB | ETAB |
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MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERGENT NOZZLE
CONVERGED AFTER 11 LOOPS

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<td>0+565964E+03</td>
<td>0+134675E+06</td>
<td>0+100000E+01</td>
<td>0+565964E+03</td>
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</tbody>
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<table>
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<th>PS28</th>
<th>AM28</th>
<th>V28</th>
<th>V9</th>
<th>AM9</th>
<th>V9</th>
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<td>0+644845E+00</td>
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<td>0+644845E+00</td>
<td>0+228952E+03</td>
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<tr>
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<th>DPCON</th>
<th>DPWING</th>
<th>P53</th>
<th>AM39</th>
<th>V38</th>
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<tbody>
<tr>
<td>0+997357E+00</td>
<td>0+498558E+01</td>
<td>0+100000E+01</td>
<td>0+104528E+06</td>
<td>0+100000E+01</td>
<td>0+362440E+03</td>
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<th>HPEXT</th>
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<th>WA</th>
<th>FRD</th>
<th>VA</th>
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<tr>
<td>0+501574E+00</td>
<td>0+0</td>
<td>0+0</td>
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<td>0+0</td>
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<th>V39</th>
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<td>0+499338E+00</td>
<td>0+894855E+02</td>
<td>0+357030E+03</td>
<td>0+104528E+06</td>
<td>0+100000E+01</td>
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<table>
<thead>
<tr>
<th>CDWNG</th>
<th>FGWNG</th>
<th>FNWING</th>
<th>FMW [F39]</th>
<th>FNW</th>
<th>FMW</th>
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<td>0+985000E+00</td>
<td>0+319466E+05</td>
<td>0+708105E+03</td>
<td>0+326547E+05</td>
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<table>
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<th>FMFDF</th>
<th>P38</th>
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<tbody>
<tr>
<td>0+178482E+00</td>
<td>0+287508E+00</td>
<td>0+534010E+00</td>
<td>0+712492E+00</td>
<td>0+982264E+00</td>
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<table>
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<tr>
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<th>VJN</th>
<th>VD</th>
<th>FGM</th>
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<td>0+985000E+00</td>
<td>0+557475E+03</td>
<td>0+985000E+00</td>
<td>0+229518E+03</td>
<td>0+103266E+06</td>
</tr>
</tbody>
</table>

MAIN SONIC CONVERGENT NOZZLE
DUCT SUBSONIC CONVERGENT NOZZLE

CONVERGED AFTER 11 LOOPS

MAIN SONIC CONVERGENT NOZZLE
FG=113578.48

DUCT SUBSONIC CONVERGENT NOZZLE
FN=113578.48

SFC= 0.05889
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<th>TIME = 2.7000</th>
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<tr>
<td>OUTPUT</td>
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<tr>
<td>AM = 0*</td>
</tr>
<tr>
<td>ALTP = 0*</td>
</tr>
<tr>
<td>T4 = 1427.02</td>
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<tr>
<td>ETAR = 1.0000</td>
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</tbody>
</table>

**THREE SPOOL ENGINE**

THE OUTPUT IS IN SI UNITS

<table>
<thead>
<tr>
<th>PCNF</th>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.991186E+02</td>
<td>0.991186E+00</td>
<td>0.831382E+00</td>
<td>0.139320E+01</td>
<td>0.277309E+03</td>
<td>0.269385E+03</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>PCNF</th>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.991321E+02</td>
<td>0.991279E+00</td>
<td>0.821674E+00</td>
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<td>0.194847E+03</td>
<td>0.179423E+03</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
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</thead>
<tbody>
<tr>
<td>0.999191E+02</td>
<td>0.100160E+01</td>
<td>0.818301E+00</td>
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<td>0.89274E+02</td>
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<table>
<thead>
<tr>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.101325E+06</td>
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<td>0.1166E+06</td>
<td>0.219608E+06</td>
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<table>
<thead>
<tr>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
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</thead>
<tbody>
<tr>
<td>0.727130E+03</td>
<td>0.160866E+07</td>
<td>0.0*</td>
<td>0.0*</td>
<td>0.0*</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>PCNF</th>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.983000E+00</td>
<td>0.0*</td>
<td>0.0*</td>
<td>0.497412E+01</td>
<td>0.339767E+03</td>
<td>0.134144E+06</td>
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</tbody>
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<table>
<thead>
<tr>
<th>PCNF</th>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.899619E+02</td>
<td>0.185800E+01</td>
<td>0.916799E+02</td>
<td>0.206824E-01</td>
<td>0.142702E+04</td>
<td>0.152646E+07</td>
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</table>

**ORIGINAL PAGE IS OF POOR QUALITY**

**MAIN SONIC CONVERGENT NOZZLE**

DUCT SUBSONIC CONVERG. NOZZLE

**CONVERGED AFTER 11 LOOPS**

FG = 113749.44
FN = 113749.44
SFC = 0.05880
### Output

#### Time = 2.8000

<table>
<thead>
<tr>
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<th>AM = 0.9</th>
<th>ALTP = 0.9</th>
<th>T4 = 1426.43</th>
<th>ETAR = 1.0000</th>
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### THREE SPOOL ENGINE

**The Output is in SI Units**

<table>
<thead>
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<th>PCNF</th>
<th>CNF</th>
<th>ZF</th>
<th>PRF</th>
<th>WAFC</th>
<th>WAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9919E+02</td>
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<td>0.9920E+02</td>
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<td>0.9944E+02</td>
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<td>0.4993E+02</td>
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<tr>
<td>0.1013E+00</td>
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<td>0.1609E+00</td>
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<td>0.0000E+00</td>
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<th>PCBLIP</th>
<th>BLIP</th>
<th>PCBLTP</th>
<th>BLP</th>
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<table>
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<th>WFB</th>
<th>WGD</th>
<th>FAR</th>
<th>T4</th>
<th>P4</th>
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<tr>
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<td>0.1858E+01</td>
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<tr>
<td>0.5009E+02</td>
<td>0.1995E+01</td>
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<td>0.3432E+06</td>
<td>0.1147E+04</td>
<td>0.5355E+06</td>
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<td>0.1208E+00</td>
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<td>0.1302E+00</td>
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<th>ETA TP</th>
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<tr>
<td>0.8509E+00</td>
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<th>PSB</th>
<th>PB</th>
<th>PSB</th>
<th>PSB</th>
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<td>0.4992E+02</td>
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<table>
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<tr>
<th>CVW</th>
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<th>WFN</th>
<th>FN W</th>
<th>FNB</th>
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<table>
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<tr>
<th>CVNMD</th>
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<th>CVND</th>
<th>VJD</th>
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<th>FGP</th>
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</tr>
</tbody>
</table>

### MAIN SONIC CONVERGENT NOZZLE

**DUCT SUBSONIC CONVERG. NOZZLE**

**CONVERGED AFTER 11 LOOPS**

- FG = 1.1931E+04
- FN = 1.1931E+04
- SFC = 0.5871
<table>
<thead>
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<th>AM = 0</th>
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<th>T4 = 1425.92</th>
<th>ETAR = 1.0000</th>
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</thead>
<tbody>
<tr>
<td>THREE SPOOL ENGINE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THE OUTPUT IS IN SI UNITS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCNF</td>
<td>0.992691E+02</td>
<td>0.992691E+00</td>
<td>0.831651E+00</td>
<td>0.139433E+01</td>
<td>0.277800E+03</td>
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<tr>
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<td>0.993527E+00</td>
<td>0.823114E+00</td>
<td>0.155791E+01</td>
<td>0.140029E+03</td>
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<td>PCNC</td>
<td>0.999693E+02</td>
<td>0.100167E+01</td>
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<td>0.731992E+01</td>
<td>0.483669E+02</td>
</tr>
<tr>
<td>T2</td>
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<td>0.339867E+03</td>
<td>0.141208E+06</td>
<td>0.392471E+03</td>
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<tr>
<td>T3</td>
<td>0.727611E+03</td>
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<td>0.244321E+07</td>
<td>0.244321E+07</td>
<td>0.244321E+07</td>
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<tr>
<td>W3</td>
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<td>0.142592E+04</td>
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<tr>
<td>TFFHP</td>
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<td>0.240664E+03</td>
<td>0.343169E+06</td>
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<tr>
<td>TFFIP</td>
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<td>0.239270E+06</td>
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<tr>
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</table>

**MAIN SONIC CONVERGENT NOZZLE**

**DUCT SUBSONIC CONVERG. NOZZLE**

**CONVERGED AFTER 11 LOOPS**
TIME = 3.0000
OUTPUT
AM = 0.0
ALTP = 0.0
T4 = 1425.46
ETAR = 1.0000

THREE SPOOL ENGINE
THE OUTPUT IS IN SI UNITS

<table>
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MAINS ONIC CONVERGENT NOZZLE
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


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.,

\[
X = \text{ALFLAG} (24, \ldots) \\
Y = \text{ALINTR} (25, \ldots) \\
Z = \text{FIRLAG} (26, \ldots)
\]

The maximum value for I is 50.)

X current input value

TAU time constant

YMAX maximum output value

YMIN minimum output value
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, AMINI(YMAX, X))
FO(I, 1)= X
FO(I, 2)= X
FO(I, 3)= ALFLAG
FO(I, 4)= ALFLAG
RETURN
1 X0=FO(I, 2)
   Y0=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)+X0*(EX2-EX1)
   ALTIMC=AMAX1(YMIN, AMINI(YMAX, Y))
   FO(I, 1)= X
   FO(I, 3)= ALTIMC
   IF(ABS(ALTIMC-YMAX)·LT·1·CE-5 OR ABS(ALTIMC-YMIN)·LT·1·CE-5)
1 FO(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

ORIGINAL PAGE IS
OF POOR QUALITY
FUNCTION ALINTR(I, X, YIC, YMAX, YMIN)
  COMMON /DYN/ ITRAN, TIME, DT, TF, JTRAN, NSTEP, TPRINT, DTPRNT
  COMMON /FOC/ F0(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 X0=FO(I,2)
  Y0=FO(I,4)
  ALINTR=Y0+.5*DT*(X+X0)
  ALINTR=AMAX1(YMIN, AMIN1(YMAX, ALINTR))
  FO(I, 1)=X
  FC(I, 3)=ALINTR
  RETURN
END

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

X current input value
DB width of dead band

\[
\begin{align*}
X & \quad \text{current input value} \\
DB & \quad \text{width of dead band}
\end{align*}
\]

\[
\begin{align*}
& X \quad \text{current input value} \\
& DB \quad \text{width of dead band}
\end{align*}
\]

\[
\begin{align*}
X & \quad \text{current input value} \\
DB & \quad \text{width of dead band}
\end{align*}
\]

\[
\begin{align*}
& X \quad \text{current input value} \\
& DB \quad \text{width of dead band}
\end{align*}
\]

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

ORIGINAL PAGE IS OF POOR QUALITY
$IBFTC$ DELAY

FUNCTION DELAY(IDLAY, X, TDELAY, TCLK)
COMMON/CDELAY/PDATA(5,50), TIMEPT(50)
COMMON/DYN/ JTRAN, TIME, DT, TF, JTRAN, NSTEP, TPRINT, DPRINT
IF(JTRAN.EQ.1) GO TO 20
DO 10 I=1,50
       TIMEPT(I) = TCLK
10  PDATA(IDLAY, I) = X
       DELAY = X
       GO TO 50
20  PDATA(IDLAY, I) = X
       TIMEPT(I) = TCLK
       DO 30 I=1,50
           J = I
           IF ((TCLK-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))*(TCLK
           - 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
FUNCTION DERLAG(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

FUNCTION FIRLAG(I, X, TAU)

DERLAG = TAU * (X - FIRLAG(I, X, TAU))

RETURN
END

FIRLAG = TAU * (X - FIRLAG(I, X, TAU))

RETURN
END

ORIGINAL PAGE IS OF POOR QUALITY
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

\[ \text{TFLAG} = \frac{\text{TAULED}}{\text{TAULAG}} \]

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

[Diagram of hysteresis curve]
FUNCTION HYST(I, X, DB)
COMMON /DYN/ ITTRAN, 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 XD = FO(I, 2)
YD = FO(I, 4)
HYST = YD
IF(X-DB.GT.YD.AND.X.GT.XD) HYST = X-DB
IF(X+DB.LT.YD.AND.X.LT.XD) 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

RINTEG = YIC
FO(I, 1) = X
FO(I, 2) = X
FO(I, 3) = RINTEG
FO(I, 4) = RINTEG
RETURN
1 XD = FO(I, 2)
YD = FO(I, 4)
RINTEG = YD + 5*DT*(X*XD)
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

\[
\begin{align*}
&X \\
&\frac{s}{\tau + s + 1} \\
&\frac{1}{s} \\
&\text{RLH} \\
&\text{RLL} \\
&\text{RLLAG}
\end{align*}
\]

FUNCTION RFLAG(I, X, TAU, RLH, RLL)

COMMON /DYN/ ITRAN_TIME, DT, TF, JTRAN, NSTEP, TPRINT, DTPRINT
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 X0=FO(I, 2)
Y0=FO(I, 4)
TEMP=-DT/TAU
IF(ABS(TEMP)-75.40, 30)
30 EX1=0.1
GO TO 50
40 EX1=EXP(TEMP)
50 EX2=TAU/DT*(1.0-EX1)
RLFLAG=Y0*EX1+X*(1.0-EX2)+X0*(EX2-EX1)
RLFLAG=Y0+AMIN1(RLH, AMAX1(RLL, (RLFLAG-Y0)/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.)
$18FTC$ SECLAG

FUNCTION SECLAG(J, X, OMEGA, ZETA)
COMMON /DYN/ ITRAN, TIME, DT, TF, JTRAN, NSTEP, TPRINT, DTPRT
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
CM1=OMEGA*SQRT(1.0-ZETA**2)
YO=(Y0-Y00)/DT
XD=(X-X0)/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*X0/OMEGA
B1=XD-2.0*ZETA*XDD/OMEGA
SECLAG=(YO-A1)*EXP(A*DT)*COS(OM1*DT)+A1+B1*DT+XDD*DT/2.0
1+1.0*ZETA*OMEGA*YO-XD*(1.0+2.0*ZETA*ZETA)*ZETA*XDD/OMEGA*
2*ZETA*(ZETA+1.0)*ZETA*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
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:

\[
\begin{array}{c}
X \\
+ \\
\downarrow \\
\int \\
\uparrow \\
Y \\
\end{array}
\]

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.

$S8FTC DISTRB
SUBROUTINE DISTRB
COMMON /DYN/ ITTRAN, TIME, DT, TF, JTTRAN, NSTEP, TPRINT, DTPRNT
COMMON /PPMS/ XNHPDS, XNIPCS, XNLPS, PMIH, PMILP, PMILP
COMMON /CNTRL/ XNMM, XNLM, T21M, P3M, YF, YFOOT, YFB, EXNL, PHI, WFBACL,
1 YFACL, SC, XNLDEM, XMHP, XNLP
XNLDEM=XNLPS
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.

$S8FTC FCNTRL
SUBROUTINE FCNTRL
COMMON /WORDS/ WORD
COMMON /DESIGN/
1 IDES, JOES, KDES, MODE, INIT, IDUMP, IAMTP, IGASMX,
2 IDDBURN, IAFTBN, IDCD, IMCD, IDSHOC, IMSHOC, NOZFLT, ITrys,
3 LOOPER, NOMAP, NUMMAP, MAPEDG, TCLALL, ERR(9)
COMMON /ALL1/
1 IPCNFGU, PNCNCG, T4GU, DUMC1, DUMC2, CEFGL, CENF, DELSFC,
2 ZFODS, PCNFS, PRDODS, ETAFOS, WAFOS, WAEF, ETAFCF, WAEFC,
3 ZCDS, PCNCS, PRDCS, ETAICS, WACDS, WAECC, ETAACC, WAECC,
4 IT4DS, WTFDOS, TDCOS, ETAEBS, WAE3DS, EPDCDS, DTPCOS, ETAABC,
5 TFCPHPS, CNHDPDS, TEPHPCF, CNHPCF, TEPHCF, DTHPCF, T20S,
6 TFLPDOS, CNTLPDS, TFLPCF, CNTLPF, TFLPCF, DTLPCF, T21DS,
7 TT24DS, WFDOS, TODUDS, ETA2DS, WA23DS, DPOUDS, DTUCEF, ETAADC,
8 TT7DS, MFADS, OTA2DS, EACDS, WACDS, DPAFDS, OTAFCF, ETAADC,
9 T55, A25, A6, A7, A8, A9, A28, A29,
$PS55, AM55, CVDNOZ, CVMNCZ, AB5SAV, A9SAV, A28SAV, A29SAV
COMMON /ALL2/
1 IT1, P1, H1, S1, T2, P2, H2, S2,
2 T21, P21, H21, S21, T3, P3, H3, S3,
3 T4, P4, H4, S4, T5, P5, H5, S5,
4 T55, P55, H55, S55, BLF, BLC, BLDU, BLOB,
5 SCNF, PPF, ETAF, WAFC, WAF, WA3, WGC, FA4,
6 6CNPC, PPP, ETAC, WACC, WAC, ETAB, DPCOM, DUMP,
COMMON / ALL3/
1 XP1 , XHAF , XWAC , XBLF , XBLDU , XH3 , DUMS1 , DUMS2 
2 XT21 , XP21 , XH21 , T23 , P23 , H23 , S23 
3 T24 , P24 , H24 , S24 , T25 , P25 , H25 , S25 
4 T28 , P28 , H28 , S28 , T29 , P29 , H29 , S29 
5 WAD , WFD , WG24 , FAR24 , ETAD , DP0UC , BYPASS , DUMS3 
6 TS28 , PS28 , V28 , AM28 , TS29 , PS29 , V29 , AM29 
7 XT55 , XP55 , XS55 , XT25 , XP25 , XH25 , XS25 
8 XWFB , XW55 , XWFD , XFR24 , XW24 , XH24 , XS24 
9 T6 , P6 , H6 , S6 , T7 , P7 , H7 , S7 
T8 , P8 , H8 , S8 , T9 , P9 , H9 , S9 
COMMON / ALL4/
1 WG6 , WFA , WG7 , FAR7 , ETAA , DPAFT , V55 , V25 
2 PS6 , V6 , AM6 , TS7 , PS7 , V7 , AM7 , AM25 
3 TS8 , PS8 , V8 , AM8 , TS9 , PS9 , V9 , AM9 
4 VA , FRD , TS7 , PS7 , AM6 , AM7 , AM25 
5 FGM , FGP , WGT , FART , FG , FN , SFC 
6 WA32 , DPGDS , DPWING , WA32DS , A38 , AM38 , V38 , T38 
7 H38 , P38 , TS38 , PS38 , T39 , H39 , P39 , T39 
8 V39 , AM39 , A38 , P38 , F38 , V38 , AM38 , V38 
COMMON / ALL5/
1 S50 , WA22 , T , PCNI , CNI , PRI , ETAI , WACI 
2 TFFIP , CNIP , ETATIP , DHTCIP , DHTI , BLIP , PCBLIP , PCNIU 
3 ZIDS , PCNIDS , PRIDS , ETAICS , WAIDS , PRICF , ETAICF , WACIF 
4 TFIPDS , CNIPDS , ETIPDS , TIPDCF , CNIPCF , ETIPCF , DHIPCFS , WACDS 
5 WA1 , PCBLI , BLI , T22DS , WA2I , T22S , H22S , T22S 
6 AM23 , XNMP , FXN2M , FXM2CP , ATFFAN , PUNT , PCBLID , PESAV 
7 AM6DSV , ETAASV , FAPTSV , T4PBL , T41 , FAN , ISPOLL 
COMMON / DYN/ ITRAN , TIME , DT , TF , JTRAN , NSP , TPRINT , DTRNT 
COMMON / FRCM / XNHPDS , XNIPDS , XNLPS , PMTIP , PMIIP , PMILP 
COMMON / CNTRL / XNH4 , XNL4 , T21M , P3M , YF , YFDOT , YFB , EXNL , PHI , WFBACL 
1 YFACL , EACL , XNLDEM , XNHP , XNLP 
DIMENSION QI (9) 
DATA AWORD / 6HFCNTRL/ 
WORD=AWORD 
XNH=PXMHPDS*PCNC/100. 
XNL=XPnlPDSC*PCNF/100. 
IF (ITRAN.EQ.1 AND JTRAN.EQ.0) XNLDEM=XNLP 
XNHM=FIRLAG(24,XNH,*01) 
XNLM=FIRLAG(25,XNL,*01) 
T21M=FIRLAG(26,T21,*50) 
P3M=FIRLAG(27,P3,*02) 
YF=SQRT(WFB/4.653)-0.0846 
Q(12)=0.0 
Q(13)=0.0 
YFDOT=DERIV(YF,YF) 
YFB=4.978*FIRLAG(29,YFDOT,*50) 
EXNL=25.*XNLM/XNLPS*YFB 
PHI=(-9.4*13.*XNHM/XNHPS)*SQRT(518.67/T21M)*)((3124+.6895*T21M)151.8.67 
1 /518.67) 
WFBACL=14.696*PHI*P3M/3600. 
YFACL=SQRT(WFBACL/4.653) 
EACL=33.*YFACL*YF
There is no main nozzle control required for this case, and subroutine NOZCTR contains only a return.

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.

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2ZFDS,PCNFDS,PRFDS,ETAFCF,WAFDS,PRFCF,ETAFCF,WAFCF,
32CDS,PCNCDS,PRCDS,ETAACDS,WACDS,PRCCF,ETAACF,WACCF,
4T4DS,WFBDS,DTCODS,ETADBDS,WAD3DS,DPCODS,DTCODF,ETABCF,
5TFHPDS,CNHPDS,ETHPDS,TFHPCF,CNHPCF,ETHPCF,DHHPCE,T2DS,
6TFLPDS,CLNLPS,ETFPCF,TLFLPCF,CLNPFCF,ETLPFCF,DLPLPCF,T1DS,
7T24DS,WFDOS,DTUDOS,ETADDOS,WAD23DS,DPUDOS,DTUDCF,ETADD
8T7DS,WFACDS,DTADCF,ETAACS,WG6CDS,DPADCS,DTADCF,ETAAC
9A55,A25,A7,A8,A28A29,A9
$PS55,AM55,CVDNOZ,CVMNOZ,A8SAV,A9SAV,A8SAV,A9SAV

COMMON /ALL2/

1P1,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,W4,FAR4
6CNCF,PRCF,ETACF,WACF,WAC,ETAF,WAFC
7CNHP,ETATHP,DHTCHP,DHCT,WG5,FAR5,F5,CS
8CNLP,ETATLP,DHTCLP,DHTL,WLLP,WG55,FAR55,HPEXT
9AM,ALTP,ETAR,ZC,PCNC,WFB

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
5WAAD,WFD,WG24,FAR24,ETAD,DPDUC,BYPASS,DUMS3
6TS28,PS28,V28,AM28,TS29,PS29,V29,AM29
7T55,PS55,XH55,XS55,XT25,XP25,XH25,XS25
8XWF6,XNG55,XFAR55,XWFD,XG24,XFAR24,XP1,DUMB
9T6,P6,H6,S6,T7,P7,H7,S7
$T8,P8,H8,S8,T9,P9,H9,S9

COMMON /ALL4/

1W466,WFA,WG7,FAR7,ETA,A,DAFT,V55,V5,V5
2PS6,P6,AM6,TS7,PS7,V7,AM7,AM25
3T58,P8,V8,AM8,TS9,PS9,V9,AM9
4VA,F3,FDJ,FGMD,VJM,FGMM,FGPD,FGPM
5FGM,FGP,WFT,WG,FART,WG,FN,SFC
6W432,DPWGS,DPKING,WG32DS,AM38,AM38,AM38,V38,T38
7H38,P38,TS38,PS38,T39,P39,TS39
8V39,AM39,A39,DPRTN,WG37,CVDWNG,FGMWNG,FGPMNG
9FNWING,FMAIN,FWOVFN,PS39,FFOVFN,FCOVFN,FMDNDFN,FNDFD
$WJ,W22,H22,S22,T50,P50,H50

COMMON /ALL5/

1550,WA22,ZI,PCN,CDN,PRI,ETA,MAC1
2TFIP,CLNP,ETATIP,DHTCIP,DHTIL,BLIP,PCBLL,PCIVNIGU
3ZIOS,PCNIDS,PRIDS,ETAIDS,WAIJDS,PRICF,ETAICF,WAIJCF
4TFIPDS,CNIPDS,ETIPDS,TFIPCF,CNIPCF,ETIPCF,DHIPCF,WAIJDS
5WA1,PCALI,BL1,T22DS,WA21,WG50,FAR50,A24
6AM23,DMUSPL,FXZN2M,FXM2CP,AFATN,PUNT,PCBL1,PDOSAV
7AM6DSV,ETAASV,FAR72,V4,P4BL,TA1,FAN,ISPDO

COMMON /DYN/ITRAN,TIME,DT,TF,ITRAN,NSTEP,TPRTN,DTPRINT
COMMON /PPMS/XNHPDS,XNIPDS,XNLPS,PMIHP,PMII,PMILP
COMMON/XPCNF/PCNFDM
IF (ITIME.EQ.1) GO TO 1
TIMEA=0.0
CONTINUE
PCNFDM=60.0
IF (TIME.GE.1) PCNFDM=101.5

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

$IBFC FCNTRL
SUBROUTINE FCNTRL
COMMON /ALL1/
1PCNFGU, PCNFGU, T4GU, DUMD1, DUMD2, CELFG, DELFN, DELSFC,
2ZFD0, PCNFD0, PRFD0, ETAFD0, WA0D0, PRFCF, ETAFCF, WAFCF,
3ZCDS, PCNCD5, PRCD5, ETACCD5, WACD5, PRCCF, ETACCF, WACC5,
4T4DS, WFDOS, DTCD05, ETA5D5, WA3D5, CPCD5, DTC05, ETA5C5,
5TFHPDS, CNHPDS, ETHPDS, TFHPCF, CNHPCF, ETHP05, DHHP05, T2DS,
6TFLPDS, CNLPDS, ETLPDS, TFLP5C5, CNLP05, ETLPC5, DHLPC5, T1DS,
7T24DS, WFD0S, DTDD05, ETA0DS, WA23DS, DPDODS, DTDD05, ETD0CF,
8T7DS, WFD05, ETA0DS, ETAADS, W6G0DS, DPA0DS, DTA0CF, ETAACF,
9A55, A25, A6, A7, A8, A9, A28, A29,
$PS55, AM55, CVNDOZ, CVMN0Z, A8SAV, A9SAV, A28SAV, A29SAV
COMMON /ALL2/
1TI, PI, H1, S1, T2, P2, H2, S2,
2TI, P21, H21, S21, T3, P3, H3, S3,
3TI, P4, H4, S4, T5, P5, H5, S5,
4TI, P55, H55, S55, BFL, BL5, BLU, BLOB,
5CNF, PRF, ETA0F, WAF0C, WA5, W5G, FAR4,
6CNC, PRC, ETA5C, WACC, WAC, ETA0B, DPCOM, DUMP,
7CN0HP, ETA0THP, DHTCHP, DHTC, BL5HP, W5G, FAR5, CS,
8CNLP, ETA0LP, DHTCLP, DHTF, BL5LP, W5G5, FAR55, HP5XT,
9AM, ALTP, ETA5, ZF, PCA5F, ZC, PCNC, WFB,
$TF0HP, TF0LP, PCLBLF, PCBL0C, PCBL0DU, PCBL0B, PCBL0HP, PCBL0LP
COMMON /ALL3/
1XP1, XWAF, XWAC, XLBF, XBL0D, XH3, DUM51, DUM52,
2XT21, XP21, XH21, XS21, T23, P23, H23, S23,
3T24, P24, H24, S24, T25, P25, H25, S25,
4TT28, P28, H28, S28, T29, P29, H29, S29,
5W0D, WFD, W24, FAR24, ETA2D, DPD05, BYPASS, DUM53,
6TS28, PS28, V28, AM28, TS29, PS29, V29, AM29,
7XT55, XP55, XH55, XS55, XT25, XP25, XH25, XS25,
8XWFB, XWG55, XFA5R55, XWFD, XWG24, XFA5R24, XXP1, DUMB,
9T6, P6, H6, S6, T7, P7, H7, S7,
5T8, P8, H8, S8, T9, P9, H9, S9,
COMMON /ALL4/
1WG6, WFA, WG7, FAR7, ETA5, DPA5T, V55, V25,
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.
1T1  P1  H1  S1  T2  P2  H2  S2  
2T2  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  WAF  WAS  WGS  FAR  
6CNC  PRC  ETAC  WAC  WATB  DPCOM  DUMP  
7CNHP  ETATHP  DHTCHP  DHTC  BLHP  WGS  FAR  CS  
8CNLP  ETALP  DHTCLP  DHTF  BLLP  WGS  FAR  HPEXT  
9AM  ALTP  ETAR  ZF  PCNF  ZC  PCNC  WFB  
* TFFHP  TFFLP  PCBLF  PCBLNC  PCBLDU  PCBLC  PCBLHP  PCBLLP  
COMMON /ALL3/  
1XP1  XWAF  XWAC  XBLF  XBLDU  XH3  DUMS1  DUMS2  
2XT2  XP21  XH21  XS21  T23  P23  H23  S23  
4T28  P28  H28  S28  T29  P29  H29  S29  
5WAD  WFD  WG24  FAR24  ETAD  DPDUC  BYPASS  DUMS3  
6TS28  PS28  V28  AM28  TS29  PS29  V29  AM29  
7TX55  XP55  XH55  XS55  XT25  XP25  XH25  XS25  
8XWFB  XWG55  XFAR55  XWFD  XWG24  XP21  DUM8  
9T6  P6  H6  S6  T7  P7  H7  S7  
* T8  P8  H8  S8  T9  P9  H9  S9  
COMMON /ALL4/  
1WG6  WFA  WG7  FAR7  ETAA  CPAFT  V55  V25  
2PS6  V6  AM6  TS7  PS7  V7  AM7  AM25  
3TS8  PS8  V8  AM8  TS9  PS9  V9  AM9  
4VA  FRD  VJO  FGM  VJMM  FGMM  FGP  FP  
5FGM  FGP  WFT  FGT  FART  FG  FN  FSC  
6WA32  DPGD5  DPGWNG  WA32DS  A38  AM38  W38  T38  
7H38  P38  TS38  PS38  T39  H39  P39  TS39  
8V39  AM39  A39  BPRINT  WG37  CVDWNG  FGMWNG  FPWNG  
9FNgwNg  FNmain  FWDVFN  PS39  FFDVFN  FCDFVFN  FMNDFN  FNQVD  
* TVJ  T22  P22  H22  S22  T50  P50  H50  
COMMON /ALL5/  
1S50  WA22  ZI  PCNL  CNI  PRI  ETAI  WACI  
2TFFIP  CNIP  ETATIP  DHTClP  DHTI  BLIP  PCBCLIP  PCNLIGU  
3ZID5  PCNIDZ  PRDS  ETAICS  WAIDS  PRICF  ETAICF  WACGF  
4TFIPDS  CNIPDS  ETIPDS  TFIPCF  CNIPCF  ETIPCF  DHPICF  WAICDG  
5WAI  PCBLI  BLI  T22DS  WA21  WGS  FAR50  A24  
6AM23  DUMSPIL  FXF294  FXM2CP  AFTFAN  PUNT  PCBLID  PDOSAV  
7AMOSV  ETAASV  FARM75V  T4PBL  T41  FAN  ISPPOOL  
COMMON /DYN/  ITRAN  TIME  OT  TF  JTRAN  NSTEP  TPRINT  DTPRNT  
A8MIN=793078  
P3QP2D=14.07  
XKI =1.0  
XKP=1.0  
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 \( \Delta V_j \) is an incremental change in the \( j \)th variable and \( \Delta E_i \) is the resulting change in the \( i \)th error. The size of \( \Delta V_j \) can be changed by the DYNGEN user, and this often is effective in solving convergence problems. In order to change the size of \( \Delta V_j \), the user should change variables VDELTA and DELSAV from their nominal values of 1.0E-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:

<table>
<thead>
<tr>
<th>Error message</th>
<th>Subroutine found in</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN ERROR HAS BEEN FOUND IN (SUBROUTINE NAME)</td>
<td>ERROR</td>
</tr>
<tr>
<td>CHANGE TOO SMALL</td>
<td>ENGBAL</td>
</tr>
<tr>
<td>CNC OFF MAP</td>
<td>COCOMP</td>
</tr>
<tr>
<td>CNC WAS = _____, AND NOW = _____, CHECK PCNC INPUT</td>
<td>COCOMP</td>
</tr>
<tr>
<td>CNF OFF MAP</td>
<td>COFAN</td>
</tr>
<tr>
<td>CNF WAS = _____, AND NOW = _____, CHECK PCNF INPUT</td>
<td>COFAN</td>
</tr>
<tr>
<td>CNHP OFF MAP</td>
<td>COHPTB</td>
</tr>
<tr>
<td>CNI OFF MAP</td>
<td>CINTC</td>
</tr>
<tr>
<td>CNI WAS = _____, AND NOW = _____, CHECK PCNI INPUT</td>
<td>CINTC</td>
</tr>
<tr>
<td>CNIP OFF MAP</td>
<td>COPTB</td>
</tr>
<tr>
<td>CNLP OFF MAP</td>
<td>COLPTB</td>
</tr>
<tr>
<td>COLUMN IS ZERO IN EMAT</td>
<td>CONOUT</td>
</tr>
<tr>
<td>ERROR IN CONOUT INPUT</td>
<td>SYG</td>
</tr>
<tr>
<td>ERROR IN SYG</td>
<td>SYG</td>
</tr>
<tr>
<td>FAILED TO CONVERGE AFTER (NUMBER) LOOPS</td>
<td>SYG</td>
</tr>
<tr>
<td>NO CONVERGENCE IN THERMO</td>
<td>THERMO</td>
</tr>
<tr>
<td>ROW IS ZERO IN EMAT</td>
<td>ENGBAL</td>
</tr>
<tr>
<td>TFFIP OFF MAP</td>
<td>COHPTB</td>
</tr>
<tr>
<td>TFFIP OFF MAP</td>
<td>COPTB</td>
</tr>
<tr>
<td>TFFLP OFF MAP</td>
<td>COLPTB</td>
</tr>
<tr>
<td>THE ERROR IN (SUBROUTINE NAME) IS AT (NUMBER)</td>
<td>ERROR</td>
</tr>
<tr>
<td>THE WORD ______ NOT FOUND IN COMMON ARRAY</td>
<td>CONOUT</td>
</tr>
</tbody>
</table>

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.
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

$A_\theta$  main nozzle throat area, $m^2$ (ft$^2$)

a  coefficient

E  error variable

$\Delta E$  change in error variable

$f(\ )$  function

$(HP)_{ext}$  power extracted, W (Btu/sec)

h  enthalpy, J/kg (Btu/lbm)

$\Delta h$  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

$\Delta N$  change in rotor speed, rpm

P  pressure, N/m$^2$ (atm)

R  gas constant, J/kg-K (atm-ft$^3$/lbm-°R)

s  Laplace transform variable, 1/sec

T  temperature, K (°R)

$\Delta T$  change in temperature, K (°R)

$\tau$  time, sec

$\Delta \tau$  time step, sec

u  specific internal energy, J/kg (Btu/lbm)

V  independent variable in Newton-Raphson iteration

$\Delta V$  change in independent variable

$\bar{V}$  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
c  parameter in difference equation
\lambda  eigenvalue of differential equation
\mu  eigenvalue of difference equation
\Phi  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/m² (atm)
PS static pressure, N/m$^2$ (atm)
S entropy, J/kg-K (Btu/lbm-°R)
T total temperature, K (°R)
TS static temperature, K (°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-°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, kg/\( \sqrt{K \cdot m^2} / N \cdot \text{sec} \) (lbm/\( \sqrt{R \cdot \text{in.}^2} / \text{lbf} \cdot \text{sec} \))
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/m² (atm)
SFC  specific fuel consumption, kg/N-hr (lbm/lbf-hr)
TOLALL  tolerance on convergence
T1  standard temperature, K (°C)
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), m² (ft²)
A8  main nozzle throat area (can be changed at off design), m² (ft²)
A28  fan duct nozzle throat area (see A8), m² (ft²)
A38  wing duct nozzle throat area (see A8), m² (ft²)
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
DELTI    correction to standard-day temperature, K (°R)
DPAFDS   afterburner design pressure drop, ΔP/P
DPCODS   combustor design pressure drop, ΔP/P
DPDUDS   duct design pressure drop, ΔP/P
DPWGDS   wing duct design pressure drop, ΔP/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)
ETAAADS  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·m² (slug-ft²)
PMIIP intermediate-pressure-rotor polar moment of inertia, kg·m² (slug-ft²)
PMILP low-pressure-rotor polar moment of inertia, kg·m² (slug-ft²)
PRCDS design inner-compressor pressure ratio
PRFDS design outer-compressor pressure ratio
PS55 static pressure at low-pressure-turbine exit, N/m² (atm)
P2 fan inlet total pressure, N/m² (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·√K·m²/N·sec (lbm·√R·in.²/lbf·sec)
TFIPDS design intermediate-turbine flow function, kg·√K·m²/N·sec (lbm·√R·in.²/lbf·sec)
TFLPDS design outer-turbine flow function, kg·√K·m²/N·sec (lbm·√R·in.²/lbf·sec)
TOLALL tolerance on error matrix
T2 fan inlet total temperature, K (°R)
T4 combustor exit temperature, K (°R)
T7 afterburner exit temperature, K (°R)
T24 ductburner exit temperature, K (°R)
T4DS design combustor exit temperature, K (°R)
T7DS design afterburner exit temperature, K (°R)
VAFTBN control volume associated with afterburner, m³ (ft³)
VCOMB control volume associated with combustor, m³ (ft³)
VCOMP control volume associated with high-pressure compressor, m³ (ft³)
VFAN control volume associated with fan, m³ (ft³)
VFDUCT control volume associated with fan duct, m³ (ft³)
VHPTRB control volume associated with high-pressure turbine, m³ (ft³)
VINTE control volume associated with intermediate compressor, m³ (ft³)
VIPTRB control volume associated with intermediate-pressure turbine, m³ (ft³)
VLPTRB    control volume associated with low-pressure turbine, m³ (ft³)
VWDUCT    control volume associated with wing duct, m³ (ft³)
WACCDSD    design inner-compressor corrected airflow, kg/sec (lbm/sec)
WAFCDSD    design outer-compressor corrected airflow, kg/sec (lbm/sec)
WAICDSD    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)
XNHPSD     high-pressure-rotor design speed, rpm
XNHIPS     intermediate-pressure-rotor design speed, rpm
XNLPDS     low-pressure-rotor design speed, rpm
ZCDSD,     design ratio of inner-compressor, fan-compressor, and middle-
ZFDSD,     compressor pressure ratios, respectively; equals pressure ratio at de-
ZIDS       sign 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, m² (ft²)
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

¹Some 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
CNLP CF  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-°R)
DHTCIP   enthalpy change temperature corrected - intermediate-pressure turbine, J/kg-K (Btu/lbm-°R)
DHTCLP   enthalpy change temperature corrected - low-pressure turbine, J/kg-K (Btu/lbm-°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

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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
ETAI CF  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
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPEXT</td>
<td>power extracted, W (hp)</td>
</tr>
<tr>
<td>P</td>
<td>total pressure, N/m² (atm)</td>
</tr>
<tr>
<td>PCBLC</td>
<td>fraction of compressor exit air bled for cooling or lost to cycle</td>
</tr>
<tr>
<td>PCBLDU</td>
<td>fraction of bleed air out of compressor which leaks into fan duct</td>
</tr>
<tr>
<td>PCBLF</td>
<td>fraction of fan exit airflow lost overboard</td>
</tr>
<tr>
<td>PCBLHP</td>
<td>fraction of compressor bleed air put into high-pressure turbine</td>
</tr>
<tr>
<td>PCBLI</td>
<td>fraction of intermediate-compressor air which goes into third stream</td>
</tr>
<tr>
<td>PCBLIP</td>
<td>fraction of compressor bleed air put into intermediate-pressure turbine</td>
</tr>
<tr>
<td>PCBLLP</td>
<td>fraction of compressor bleed air put into low-pressure turbine</td>
</tr>
<tr>
<td>PCBLOB</td>
<td>fraction of bleed air out of compressor lost overboard</td>
</tr>
<tr>
<td>PCNC</td>
<td>inner-compressor shaft speed as percent of design</td>
</tr>
<tr>
<td>PCNF</td>
<td>fan-compressor shaft speed as percent of design</td>
</tr>
<tr>
<td>PCNI</td>
<td>intermediate-compressor shaft speed as percent of design</td>
</tr>
<tr>
<td>PRC</td>
<td>pressure ratio of inner compressor</td>
</tr>
<tr>
<td>PRCCF</td>
<td>pressure-ratio-of-inner-compressor correction factor</td>
</tr>
<tr>
<td>PRF</td>
<td>pressure ratio of fan</td>
</tr>
<tr>
<td>PRFCF</td>
<td>pressure-ratio-of-fan correction factor</td>
</tr>
<tr>
<td>PRI</td>
<td>pressure ratio of intermediate compressor</td>
</tr>
<tr>
<td>PRICF</td>
<td>pressure-ratio-of-intermediate-compressor correction factor</td>
</tr>
<tr>
<td>PS</td>
<td>static pressure, N/m² (atm)</td>
</tr>
<tr>
<td>SFC</td>
<td>specific fuel consumption, kg/N-hr (lbm/lbf-hr)</td>
</tr>
<tr>
<td>T</td>
<td>total temperature, K (°R)</td>
</tr>
<tr>
<td>T3DS</td>
<td>design exit temperature of inner compressor, K (°R)</td>
</tr>
<tr>
<td>T21DS</td>
<td>design exit temperature of intermediate compressor, K (°R)</td>
</tr>
<tr>
<td>T22DS</td>
<td>design exit temperature of fan, K (°R)</td>
</tr>
<tr>
<td>TFFHP</td>
<td>high-pressure-turbine flow function, kg·√K·m²/sec·N (lbm·√°R·in.²/sec·lbf)</td>
</tr>
<tr>
<td>TFFIP</td>
<td>intermediate-pressure-turbine flow function, kg·√K·m²/sec·N (lbm·√°R·in.²/sec·lbf)</td>
</tr>
<tr>
<td>TFFLP</td>
<td>low-pressure-turbine flow function, kg·√K·m²/sec·N (lbm·√°R·in.²/sec·lbf)</td>
</tr>
</tbody>
</table>

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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):

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A8MIN</td>
<td>minimum main nozzle throat area, ( m^2 (ft^2) )</td>
</tr>
<tr>
<td>EACL</td>
<td>acceleration error</td>
</tr>
<tr>
<td>EXNL</td>
<td>speed error</td>
</tr>
<tr>
<td>MAX</td>
<td>function whose output is equal to largest input</td>
</tr>
<tr>
<td>MIN</td>
<td>function whose output is equal to smallest input</td>
</tr>
<tr>
<td>PCNFDM</td>
<td>commanded rotor speed, percent</td>
</tr>
<tr>
<td>PHI</td>
<td>output of acceleration schedule, ( kg\cdot m^2/N\cdot sec ) (lbm-in.(^2)/lbf-sec)</td>
</tr>
<tr>
<td>P3M</td>
<td>sensed ( P_3 ), ( N/m^2 ) (atm)</td>
</tr>
<tr>
<td>P3QP2D</td>
<td>commanded compressor pressure ratio</td>
</tr>
<tr>
<td>T21M</td>
<td>sensed ( T_{21} ), ( K (^\circ R) )</td>
</tr>
<tr>
<td>WFBACL</td>
<td>acceleration fuel flow, ( kg/sec ) (lbm/sec)</td>
</tr>
<tr>
<td>WFOP3L</td>
<td>lower limit on ( WFB/P_3 ), ( kg\cdot m^2/N\cdot sec ) (lbm-in.(^2)/lbf-sec)</td>
</tr>
<tr>
<td>WFOP3U</td>
<td>upper limit on ( WFB/P_3 ), ( kg\cdot m^2/N\cdot sec ) (lbm-in.(^2)/lbf-sec)</td>
</tr>
<tr>
<td>XNHM</td>
<td>sensed core speed, rpm</td>
</tr>
<tr>
<td>XNHP</td>
<td>core speed, rpm</td>
</tr>
<tr>
<td>XNLDEM</td>
<td>commanded fan speed, rpm</td>
</tr>
<tr>
<td>XNLM</td>
<td>sensed fan speed, rpm</td>
</tr>
<tr>
<td>XNLP</td>
<td>fan speed, rpm</td>
</tr>
<tr>
<td>YF</td>
<td>metering valve position</td>
</tr>
<tr>
<td>YFACL</td>
<td>metering valve position for accelerations</td>
</tr>
<tr>
<td>YFB</td>
<td>metering valve position feedback</td>
</tr>
<tr>
<td>YFDO T</td>
<td>time derivative of metering valve position</td>
</tr>
</tbody>
</table>
REFERENCES


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.

<table>
<thead>
<tr>
<th>Engine configuration</th>
<th>Component map</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BLKFAN</td>
</tr>
<tr>
<td>a</td>
<td>Yes</td>
</tr>
<tr>
<td>b</td>
<td>Yes</td>
</tr>
<tr>
<td>c</td>
<td>Yes</td>
</tr>
<tr>
<td>d</td>
<td>Yes</td>
</tr>
<tr>
<td>e</td>
<td>Yes</td>
</tr>
<tr>
<td>f</td>
<td>Yes</td>
</tr>
<tr>
<td>g</td>
<td>Yes</td>
</tr>
<tr>
<td>h</td>
<td>Yes</td>
</tr>
<tr>
<td>i</td>
<td>Yes</td>
</tr>
<tr>
<td>j</td>
<td>Yes</td>
</tr>
<tr>
<td>k</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variables</th>
<th>Units or type</th>
<th>Definition</th>
<th>Default value</th>
<th>Engine configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAFDS</td>
<td>ft/sec (in/sec)</td>
<td>Fan corrected airspeed</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>ETADS</td>
<td>ft/sec (in/sec)</td>
<td>Intermediate corrected airflow</td>
<td>1.0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>ZIIS</td>
<td></td>
<td>Intermediate efficiency</td>
<td>0.9</td>
<td>No No No No No No No No No No</td>
</tr>
<tr>
<td>PCHDS</td>
<td></td>
<td>Ratio of pressure ratios of intermediate compressor</td>
<td>75</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>WACDS</td>
<td>ft/sec (in/sec)</td>
<td>Compressor corrected airflow</td>
<td>0</td>
<td>No No No No No No No No No No</td>
</tr>
<tr>
<td>ZIUM</td>
<td></td>
<td>Compressor corrected airflow</td>
<td>0</td>
<td>No No No No No No No No No No</td>
</tr>
<tr>
<td>ETASH</td>
<td>ft/sec (in/sec)</td>
<td>Compressor corrected airflow</td>
<td>100</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>TITB</td>
<td>0°F (°C)</td>
<td>Turbine inlet temperature</td>
<td>0</td>
<td>No No No No No No No No No No</td>
</tr>
<tr>
<td>WRBDS</td>
<td>ft/sec (in/sec)</td>
<td>Turbine inlet pressure</td>
<td>0</td>
<td>No No No No No No No No No No</td>
</tr>
<tr>
<td>THIPDS</td>
<td>ft/sec (in/sec)</td>
<td>High-pressure turbine flow function</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>CNHPDS</td>
<td>percent/°N (percent/°R)</td>
<td>High-pressure turbine corrected speed</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>TFIPDS</td>
<td>ft/sec (in/sec)</td>
<td>High-pressure turbine corrected speed</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>THIPS</td>
<td>ft/sec (in/sec)</td>
<td>Intermediate-pressure turbine flow function</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>CNIPDS</td>
<td>percent/°N (percent/°R)</td>
<td>Intermediate-pressure turbine corrected speed</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>TILIPDS</td>
<td>ft/sec (in/sec)</td>
<td>Intermediate-pressure turbine corrected speed</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>CNLPDS</td>
<td>percent/°N (percent/°R)</td>
<td>Low-pressure turbine flow function</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>TELLPDS</td>
<td>ft/sec (in/sec)</td>
<td>Low-pressure turbine corrected speed</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>DHDPS</td>
<td>ft/sec (in/sec)</td>
<td>Duct duct pressure drop, 3P P</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>DPPDS</td>
<td>ft/sec (in/sec)</td>
<td>Duct duct pressure drop, 3P P</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>DFAPDS</td>
<td>ft/sec (in/sec)</td>
<td>Afterburner pressure drop, 3P P</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>TTD5</td>
<td>°F (°C)</td>
<td>Afterburner exit temperature</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>ETASS</td>
<td></td>
<td>Afterburner efficiency</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>AMD5</td>
<td></td>
<td>Low-pressure turbine exit Mach number</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>PSS5</td>
<td>ft-lb/ft-lb</td>
<td>Low-pressure turbine exit static pressure</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>AMD5</td>
<td></td>
<td>Low-pressure turbine exit Mach number</td>
<td>0</td>
<td>Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes</td>
</tr>
</tbody>
</table>

**Variables that specify engine configuration and should be input only when BDD препарат:**

- AMD5
- PSS5
- AMD5

The values above are applicable when BDD препарат is used.

For AMD5 or PSS5, but not both, should be specified by the user for all engine types. If MODEL-0, supply TTD5, if MODEL-2, supply WFBDS. MODEL-1 and MODEL-3 cannot be used when BDD препарат.
1 A "Yes" entry in the column on the left 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, P, or 0, that value should be used.
<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Features</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDES</td>
<td>0</td>
<td>X</td>
<td>Off-design case</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Design-point case</td>
</tr>
<tr>
<td>MODE</td>
<td>0</td>
<td>X</td>
<td>Specify T4</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Specify PCNC</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>Specify WFB</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>X</td>
<td>Specify PCNF</td>
</tr>
<tr>
<td>INIT</td>
<td>0</td>
<td>X</td>
<td>Will call GUESS</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Will not call GUESS</td>
</tr>
<tr>
<td>IDUMP</td>
<td>0</td>
<td>X</td>
<td>Will not print stored messages</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Will print stored messages after errors</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>Will print stored messages every point</td>
</tr>
<tr>
<td>IAMTP</td>
<td>0</td>
<td>X</td>
<td>Input AM, ALTP; military-specification ETAR will be used</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Input AM, ALTP, ETAR</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>Input AM, ALTP, DELT1; military-specification ETAR will be used</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>X</td>
<td>Input AM, ALTP, P2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>X</td>
<td>Input P2, T2</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>X</td>
<td>Input AM, ALTP; ETAR schedule stored in RAM2</td>
</tr>
<tr>
<td>IGASMX</td>
<td>-1</td>
<td>X</td>
<td>Separate flow, input AM6</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>X</td>
<td>Separate flow, AM - A55</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Mixed flow, AM - A25 + A55</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>Mixed flow, input AM6</td>
</tr>
<tr>
<td>IDBURN</td>
<td>0</td>
<td>X</td>
<td>No ductburning</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Ductburning, input T24</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>Ductburning, input WFD</td>
</tr>
<tr>
<td>IAFBTBN</td>
<td>0</td>
<td>X</td>
<td>No afterburning</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Afterburning, input T7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>Afterburning, input WFA</td>
</tr>
<tr>
<td>IDCMD</td>
<td>0</td>
<td>X</td>
<td>Convergent duct nozzle</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Convergent-divergent duct nozzle</td>
</tr>
<tr>
<td>IMCD</td>
<td>0</td>
<td>X</td>
<td>Convergent main nozzle</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>Convergent-divergent main nozzle</td>
</tr>
<tr>
<td>NOZFLT</td>
<td>0</td>
<td>X</td>
<td>A9 and A29 are held constant</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>A9 will be set for fully expanded flow</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X</td>
<td>A29 will be set for fully expanded flow</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>X</td>
<td>A9 and A29 will be set for fully expanded flow</td>
</tr>
<tr>
<td>ITRYS</td>
<td>N^2</td>
<td>X</td>
<td>Number of iterations before calling ERROR</td>
</tr>
<tr>
<td>TOLALL</td>
<td>X^3</td>
<td>X</td>
<td>Tolerance which errors must satisfy for convergence</td>
</tr>
<tr>
<td>SI</td>
<td>T</td>
<td>X</td>
<td>Input and output in SI units</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>X</td>
<td>Input and output in English units</td>
</tr>
<tr>
<td>ITRAN</td>
<td>0</td>
<td>X</td>
<td>A steady-state point</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>X</td>
<td>The initial condition for a transient</td>
</tr>
</tbody>
</table>

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.

User-specified value; default value is 0

User-specified value; default value is 0.
### TABLE IV - INPUTS FOR OFF-DESIGN POINTS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units or type</th>
<th>Definition</th>
<th>Variable</th>
<th>Units or type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITRYS</td>
<td></td>
<td>Index for maximum number of iterations</td>
<td>ETAD</td>
<td></td>
<td>Ductburner efficiency&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>TOLALL</td>
<td></td>
<td>Tolerance on error vector</td>
<td>LAFTBN</td>
<td></td>
<td>Index for afterburning&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>INIT</td>
<td></td>
<td>Index for initializing point</td>
<td>T7</td>
<td>K (°R)</td>
<td>Afterburner exit temperature&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>MODE</td>
<td></td>
<td>Independent variable designator&lt;sup&gt;1&lt;/sup&gt;</td>
<td>TFDG</td>
<td></td>
<td>Afterburner fuel flow&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>K (°R)</td>
<td>Turbine inlet temperature&lt;sup&gt;1&lt;/sup&gt;</td>
<td>DELFG</td>
<td></td>
<td>Correction factor on gross thrust</td>
</tr>
<tr>
<td>PCCH</td>
<td></td>
<td>Compressor speed&lt;sup&gt;1&lt;/sup&gt;</td>
<td>DELFN</td>
<td></td>
<td>Correction factor on net thrust</td>
</tr>
<tr>
<td>WFD</td>
<td>kg/sec (lbm/sec)</td>
<td>Fan speed&lt;sup&gt;1&lt;/sup&gt;</td>
<td>DELFIC</td>
<td></td>
<td>Correction factor on specific fuel consumption</td>
</tr>
<tr>
<td>PCNF</td>
<td></td>
<td>Fan speed&lt;sup&gt;1&lt;/sup&gt;</td>
<td>CVNSOS</td>
<td></td>
<td>Duct nozzle thrust coefficient</td>
</tr>
<tr>
<td>EDMUP</td>
<td></td>
<td>Index for dumping program messages</td>
<td>CVNONE</td>
<td></td>
<td>Main nozzle thrust coefficient</td>
</tr>
<tr>
<td>IAMTP</td>
<td>m (ft)</td>
<td>Altitude&lt;sup&gt;2&lt;/sup&gt;</td>
<td>CYDNG</td>
<td></td>
<td>Wing nozzle throat coefficient</td>
</tr>
<tr>
<td>AM</td>
<td>m&lt;sup&gt;2&lt;/sup&gt; (ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Mach number&lt;sup&gt;2&lt;/sup&gt;</td>
<td>A6</td>
<td>mj&lt;sup&gt;2&lt;/sup&gt; (ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Afterburner entrance area</td>
</tr>
<tr>
<td>ETAR</td>
<td></td>
<td>Correction to standard-day temperature&lt;sup&gt;2&lt;/sup&gt;</td>
<td>A28</td>
<td>mj&lt;sup&gt;2&lt;/sup&gt; (ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Wing nozzle thrust area</td>
</tr>
<tr>
<td>DELT1</td>
<td>N&lt;sup&gt;2&lt;/sup&gt; (atm)</td>
<td>Fan inlet total pressure&lt;sup&gt;2&lt;/sup&gt;</td>
<td>A29</td>
<td>mj&lt;sup&gt;2&lt;/sup&gt; (ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Main nozzle thrust area</td>
</tr>
<tr>
<td>P2</td>
<td>m&lt;sup&gt;2&lt;/sup&gt; (atm)</td>
<td>Fan inlet total temperature&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td>Duct nozzle throat area</td>
</tr>
<tr>
<td>T2</td>
<td>K (°R)</td>
<td>Fan inlet temperature&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDCO</td>
<td></td>
<td>Index for converging-diverging duct nozzle&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMCO</td>
<td></td>
<td>Index for converging-diverging main nozzle&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOZFLT</td>
<td></td>
<td>Index for floating nozzle exit area&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBDURN</td>
<td></td>
<td>Index for ductburning&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T24</td>
<td>K (°R)</td>
<td>Ductburner exit temperature&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFD</td>
<td>kg/sec (lbm/sec)</td>
<td>Ductburner fuel flow&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBF</td>
<td>kg/sec (lbm/sec)</td>
<td>Ductburner efficiency&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Your basic options are available for specifying off-design operating points: MODE: 0, specify T4; MODE: 1, specify PCNF; MODE: 2, specify WFD; MODE 3, specify PCBF.
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; IAMTP: 1 - User specifies ALTP, AM, and ETAR; IAMTP: 2 - User specifies ALTP, AM, DELT1; IAMTP: 3 - User specifies ALTP, AM, P2, ETAR and standard-day T1 will be calculated. IAMTP: 4 - User specifies T2 and P2.
3. DELT1 - 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.
4. If EDCO<sub>1</sub>: 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 EDCO<sub>1</sub>. Similarly, IMCO<sub>1</sub> and standard day P1 must be set equal to 2 or 3 in addition to specifying IMCO<sub>1</sub>. If NOZFLT<sub>0</sub>, A9 and A29 will retain their previous values.
5. The following options are available for afterburning: IBDURN<sub>0</sub>, no afterburning; IBDURN<sub>1</sub>, specify T4; IBDURN<sub>2</sub>, specify WFD. If IBDURN<sub>0</sub> or IBDURN<sub>2</sub> is to be used, the user must also specify a value for ETAD. No parameters other than T4, WFD, and ETAD may be changed while running an afterburning case, unless program is in transient (ITRAN<sub>1</sub>) 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 afterburning case.
6. Bleed distribution in engine is governed by following equations:

\[ \text{BLF} = \text{PCBF} \times \text{WAF} \]

\[ \text{BLC} = \text{PCBF} \times \text{WAC} \]

where BLF is fan flow loss overboard.

\[ \text{BLFD} = \text{PCBF} \times \text{WAF} \]

\[ \text{BLOW} = \text{PCBF} \times \text{WAC} \]

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

\[ \text{BLFD} = \text{PCBF} \times \text{WAF} \]

\[ \text{BLOW} = \text{PCBF} \times \text{WAC} \]

\[ \text{BL} = \text{PCBF} \times \text{WAC} \]

\[ \text{BL} = \text{PCBF} \times \text{WAC} \]

\[ \text{PCBF} = \text{PCBF} \times \text{WAC} \]

PCBF, PCBF, PCBF, PCBF, PCBF must equal 1 to maintain conservation of flow.

ORIGINAL PAGE IS OF POOR QUALITY.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Units or type</th>
<th>Definition</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTTRAN</td>
<td>sec</td>
<td>Time step for modified Euler method</td>
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</tr>
<tr>
<td>DT</td>
<td>sec</td>
<td>Time interval between printouts</td>
<td>1</td>
</tr>
<tr>
<td>DTXPRNT</td>
<td>sec</td>
<td>Final time for transient</td>
<td>1</td>
</tr>
<tr>
<td>TMLP</td>
<td>kg m^-2 (slug ft)^2</td>
<td>Low-pressure-rotor polar moment of inertia</td>
<td>1</td>
</tr>
<tr>
<td>TMLP</td>
<td>kg m^-2 (slug ft)^2</td>
<td>Intermediate-pressure-rotor polar moment of inertia</td>
<td>1</td>
</tr>
<tr>
<td>HMLP</td>
<td>kg m^-2 (slug ft)^2</td>
<td>High-pressure-rotor polar moment of inertia</td>
<td>1</td>
</tr>
<tr>
<td>XNLPDS</td>
<td>rpm</td>
<td>Low-pressure-rotor design speed</td>
<td>1</td>
</tr>
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<td>XNLPS</td>
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<td>XNHLPDS</td>
<td>rpm</td>
<td>High-pressure-rotor design speed</td>
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</tr>
<tr>
<td>YEAN</td>
<td>m^3 (ft^3)</td>
<td>Fan volume</td>
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</tr>
<tr>
<td>VINTC</td>
<td></td>
<td>Intermediate-pressure-compressor volume</td>
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<tr>
<td>VCOMP</td>
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<tr>
<td>VCOMB</td>
<td></td>
<td>Combustor volume</td>
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<td>VHIPTB</td>
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<td>VIPTB</td>
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<td>Intermediate-pressure-turbine volume</td>
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<tr>
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<td>Afterburner volume</td>
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<tr>
<td>VAFTC</td>
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<td>Fan duct volume</td>
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</tr>
<tr>
<td>VADUCT</td>
<td></td>
<td>Wine duct volume</td>
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</tr>
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</table>

1. A "No" entry means that the user must supply a value for the variable in question; the default value should not be used. A "Yes" entry means that the user must 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 TTTRAN equal to 1 has the following effects: (1) The next point calculated will be for TDXP 1.0. For each successive time point, subroutine DTXPRNT will be called by ENHIAL to obtain transient input. (2) If MODE 2, subroutine FCXTRL will be called by COCOMB to obtain a controlled value of WAX. (3) If AFTBN I or 2, A8 will not be automatically recalculated. If the user wants controlled A8, he should write subroutine NOZCTR, which is called by CONNOX. (4) If IMBDDN I or 2, A8 will not be automatically recalculated. The user can easily add a subroutine similar to NOZCTR to be called by CONDOCUT if he wishes to have controlled A8.

3. Rotor design speed is defined as the rpm corresponding to 100 percent PCNF, PCNL, or PCNC. DYNEE assumes that rotor mechanical speed (in percent) is equal to corrected speed in percent at the design point. For example, if PCCMDI = 80.0 and the user wants high-pressure-rotor speed to be 10,000 rpm at the design point, he should input XNHLPDS 10 000 0.80 12 300.
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).
<table>
<thead>
<tr>
<th>Guessed variables, $V_i$</th>
<th>Error variables, $E_i$</th>
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<tbody>
<tr>
<td>Speed, $N$</td>
<td>Power, $\dot{W}_C \Delta h_C - \dot{w}_T \Delta h_T$</td>
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<tr>
<td>Compressor pressure ratio, $P_3/P_2$</td>
<td>Turbine flow function, $\left(\frac{\dot{w}_4 T_4}{P_4}\right) - \left(\frac{\dot{w}_4 T_4}{P_4}\right)$</td>
</tr>
<tr>
<td>Turbine flow function, $\frac{\dot{w}_4 T_4}{P_4}$</td>
<td>Nozzle pressure, $P_T - P_7$</td>
</tr>
</tbody>
</table>

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

Figure 13. Example of specific fan-compressor map. $Z = \left| P_{R_x} - P_{R_{low}} \right| \left(\frac{P_{R_{high}}}{P_{R_{low}}} - 1\right)$.
Figure 14. Example of combustor map.
Figure 15. - Example of specific turbine map.
Ratio of fuel-air ratio to design fuel-air ratio

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

Ratio of afterburner inlet Mach number to design afterburner inlet Mach number

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

Ratio of afterburner inlet total pressure to design afterburner inlet total pressure

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

Figure 16. - Example of generalized afterburner combustion efficiency performance map.
Figure 11. - 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.
Figure 20. - Afterburning turbojet control system.

(a) Fuel control.

(b) Nozzle control.
Figure 21. - Response of afterburning turbojet to throttle slam.