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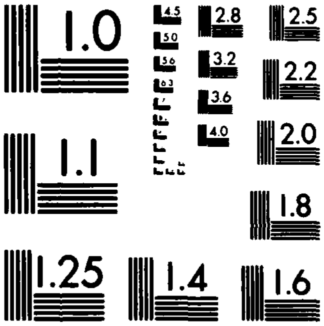

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ANALYTIC MODEL OF GAS TURBINE ENGINE INSTALLATIONS

by

Stephen M. Ezzell

September 1984

Thesis Advisor: P. F. Pucci

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An Analytic Model
of
Gas Turbine Engine Installations

by

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Lieutenant Commander, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

An interactive computer simulation of marine gas turbine installations including intake and exhaust ducting for the engine and module cooling has been developed. A one-dimensional analysis was used in determining the pressure losses of the ducting. The pressure losses along with the ambient conditions and desired power setting define a unique operating point for the system. The computer model predicts operating parameters for this point by an iterative matching technique.

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LIST OF SYMBOLS

A	Area, ft^2
AC	Area, cooling flow passage
AM	Area, mixed flow passage
AP	Area, primary flow passage (exhaust)
a b	Duct cross section dimensions, ft
D	Diameter, ft
ϵ	Absolute roughness factor, ft
f	Friction factor, dimensionless
g	Acceleration due to gravity, ft/sec^2
g_c	Gravitational constant, 32.174 $ft\text{-}lbm/lbf\text{-}sec^2$
L	Length, ft
p	Pressure, lbf/ft^2
p_t	Total pressure, lbf/ft^2
Δp_t	Change in total pressure, lbf/ft^2
PS	Static pressure, lbf/ft^2
PT	Total pressure, lbf/ft^2
PV	Velocity pressure, lbf/ft^2
P0	Ambient pressure, lbf/ft^2 or PSIA
P8	Engine back pressure, lbf/ft^2 or PSIA
Q	Volumetric flow rate, ft^3/sec
Re	Reynolds Number, dimensionless
V,v	Velocity, ft/sec
WC	Cooling mass flow rate, lbm/sec
W8	Exhaust mass flow rate, lbm/sec
z	Potential height, ft
ρ	Density, lbm/ft^3

I. INTRODUCTION

The installation of gas turbine engines in a ship raises several problem areas in the design of the intake and exhaust ducting. The problems relate mainly with the large volume of combustion air required and the properties of the exhaust gases rejected to the atmosphere at high temperatures and velocity. For comparison, a boiler's combustion air requirement is nearly stoichiometric but the gas turbine operates at about 400 percent of stoichiometric. The boiler's exhaust is about 400 degrees F after leaving the last rows of the economizer, but gas turbine exhaust temperatures are frequently as high as 950 degrees F.

In addition to the air that passes through the gas turbine engine there is also a requirement to ventilate the engine enclosure. An adequate and uniformly distributed cooling airflow is required around the engine to maintain engine-mounted components at their proper operating temperatures and to minimize the heat rejected to the engine room thereby reducing the heat exposure of operating personnel. Many current designs branch the engine cooling airflow off the main intakes and/or join heated enclosure cooling air into the engine exhaust ducting. Figure 1.1 shows a typical layout of inlet and exhaust ducting. Since the enclosure cooling airflow is on the order of 20 percent of the engine's full power airflow rate, it is an important part of the ducting design.

The fundamental requirement of an intake design is to provide air to the engine compressor with the minimum total pressure loss and with a minimum of total pressure distortion. The loss of total pressure in the intakes leads to a loss of engine power and an increase in specific fuel

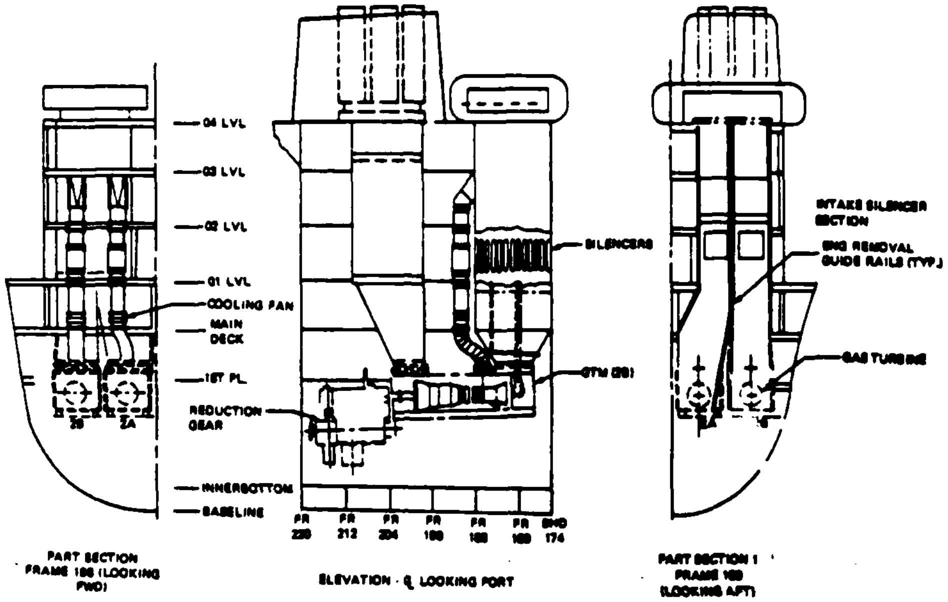


Figure 1.1 Typical Shipboard Inlet and Exhaust Ducting.

consumption. Schwieger reports "Typical exchange rates are that a one percent loss in intake pressure is equivalent to a 2.2 percent loss in power and a 1.2 percent increase in specific fuel consumption" [Ref. 1]. Additionally, total pressure distortion at the compressor face can lead to a risk of compressor blade failure.

Exhaust ducts must also operate with a minimum pressure loss. "The exchange rate is 1.1 percent loss in power and 1.1 percent increase in specific fuel consumption for the one percent increase in total pressure at the power turbine exit" [Ref. 1].

Conflicting with the design objective to reduce losses in the ducting system are several possible requirements to install components in the ducting system which contribute to the losses but not directly to engine performance. Filters are installed to increase engine life. Silencers are installed to reduce noise. Machinery arrangements dictate the use of certain elbows, contractions, and transitions. The infared signature of the ship's exhaust plume can be reduced by the installation of an eductor system at the exhaust exit. The eductor also improves the environment of mast mounted equipment and may contribute to flight safety when operating helicopters. Some systems use an eductor arrangement installed at the exhaust plane of the engine to pump cooling air through the engine enclosure. A waste heat recovery boiler may be installed in the exhaust to improve overall efficiency. To reduce pressure losses every attempt should be made to reduce the velocity in the duct. Lower velocities requires larger ducts. Part of the design compromise must balance the large volume of the ship occupied with inlet and exhaust ducts and the volume for other uses such as weapons and habitibility. In summary there are many different components that can be utilized within the ducting system and have various effects on the system performance. The effects also vary with the operating point of the system.

It is not a straight forward problem to predict how components in the ducting system will perform. It is an interacting or matching type of problem. Furthermore, it is a dynamic problem as parameters affecting performance can vary over a wide range. For example, one power setting of the gas turbine requires a different mass flow rate of air than another. The variable mass flow rate through the ducting system creats a variable inlet and exhaust duct pressure loss. The variation in exhaust temperature affects the losses in the exhaust duct. Ultimately all losses affect the performance of the gas turbine engine.

One approach to the analysis of ducting system performance is to separate the problem into two areas of concern. The first area should deal with a one-dimensional analysis of the ducting system to determine how pressure losses affect engine performance and how the various components of the system contribute to the sum total of these losses. The second area should deal with the distortion of total pressure across any section of the duct. This area becomes a three-dimensional problem where interest is directed to performance not just at any section of the duct but to within that section to the variation of velocity across the cutting plane. The one-dimensional and three-dimensional areas of the analysis are of course related.

The relationship between the one-dimensional and the three-dimensional aspect of the problem is understood and is dealt with in an empirical manner. The method is to apply a correction factor to the loss developed in the one-dimensional analysis of a particular system component, based on the distortion of the flow assumed to be presented to the component. If the assumptions about flow distortion are made and are accurate much valuable information results from the one-dimensional analysis.

The three-dimensional analysis of a duct system is possible only for a very simple system and requires very large computer assets. It is current practice to deal with three-dimensional analysis of complex systems through model studies. One-dimensional analysis on the other hand is well suited for analysis on a computer.

It is the intent of this study to develop the methodology for a one-dimensional analysis of a gas turbine engine's inlet and exhaust ducting as might be installed on a ship. Then to implement the method in an interactive computer program which allows rapid input of the duct geometry, desired operating point and ambient conditions to obtain an accurate estimate of performance. The designer can then decide to make changes to components to achieve design objectives and make those changes to the duct geometry through an editing routine and rerun the problem. Once the designer is satisfied with the one dimensional analysis a firm basis exists to provide a design for model studies.

II. THEORY AND ANALYSIS

A. GENERAL

A one dimensional analysis of the flow in duct sections utilizes the Bernoulli Equation modified to account for losses. The term one-dimensional is an adjective often applied to flow situations. The whole flow is considered to be one large streamtube with average velocity V at each cross section. Thus the one dimension is the location down the duct. Losses refers to the pressure loss caused by frictional stresses in the airflow boundary layer and by turbulence. A thorough understanding of these terms and concepts is required to convey the meaning of the results of the duct system analysis.

B. THE BERNOULLI EQUATION

The Bernoulli Equation is discussed in any basic text on fluid mechanics. It was developed to describe the flow work of an ideal incompressible fluid in steady flow through a streamtube. In words it states that the mechanical energy per unit mass along a streamline is conserved. The Bernoulli Equation is:

$$V^2/2g_c + p/\rho + (g/g_c)z = \text{constant.} \qquad \text{(eqn 2.1)}$$

It relates velocity, pressure, and potential height. The constant may have a different value for each streamline, but for the purposes of duct flow certain simplifying assumptions are valid which make the constant valid for any streamline. The assumptions are that the static pressure is constant at any point in a cross section of the duct. The next assumption is that because the system uses gases, the effect of variation in potential height at a duct section is so small relative to the other terms that its effect is neglected. This assumption is extended further to include the change in elevation effect at any section relative to any other section.

Alternate forms of the Bernoulli Equation are obtained by multiplying through by either g_c/g or ρ. Of interest to gas flow and duct design is the form obtained by multiplying through by ρ. Applying the above assumptions the resulting equation is:

$$\rho v^2/2g_c + p = \text{constant} \qquad \text{(eqn 2.2)}$$

In this form the constant has units of foot-pound force/feet^3 and expresses the energy per unit volume flow rate. It reduces to pound force/feet^2 or pressure. Each term in the expression is given a name. The velocity term is the velocity presure, p is the static pressure, and the constant is the total pressure. In words, the total pressure at a point is the sum of the velocity pressure and the static pressure.

C. MODIFIED BERNOULLI EQUATION

Although equation 2.2 was derived for flow along a streamtube of an ideal frictionless flow it can be extended to analyze flow through ducts in real systems by applying the First Law of Thermodynamics. A good development of the application of the First Law of Thermodynamics to pipe flow is found in [Ref. 2]. It results in the modified Bernoulli Equation (2.3). Equation (2.3) incorporates all the assumptions so far and includes the term Δp_t. The flow resistance in a system with a real fluid between stations 1 and 2 is represented by the total pressure loss, Δp_t.

$$\rho v_1^2/2g_c + p_1 = \rho v_2^2/2g_c + p_2 + \Delta p_t \qquad \text{(eqn 2.3)}$$

The velocity used in the modified Bernoulli Equation will be taken as the mean velocity and then this equation will be assumed valid for any streamline in the duct. Analytically this is not correct because there is a variation of velocity at a duct section from the walls to the center of the duct. The error introduced by this assumption is offset by two circumstances. First, with turbulent flow the velocity profile is nearly uniform which makes the mean velocity a good approximation of the velocity at any point in the cross section. Second, experimentally determined loss coefficients are utilized in computations and this coefficient is applied using the mean velocity. Then if the velocity profile in the system matches the profile of the experiment, the loss will be correctly computed using the mean velocity.

The computer program uses the mean velocity and computes it based on mass flow rates. The mean velocity is computed from the mass flow through a sectional area and the density of the fluid at the section using equation 2.4. Density is computed by the perfect gas law equation (2.5) and is a function of the absolute temperature of the gas and the static pressure of the gas.

$$V_{mean} = \frac{W}{\rho A} \qquad \text{(eqn 2.4)}$$

$$\rho = p/RT \qquad \text{(eqn 2.5)}$$

where p = static pressure
R = gas constant
T = absolute temperature

D. PRESSURE LOSSES

There are two types of fluid losses in the ducting system, frictional and dynamic losses. Frictional losses occur along the walls of the entire duct length and are due to fluid viscosity. Dynamic losses result from disturbing the flow such as a change of direction, contraction, or expansion.

The Darcy-Weisbach equation (2.6) calculates the friction loss for straight ducts.

Darcy-Wiesbach equation $\Delta p_t = f\,(L/D)\frac{\rho V^2}{2g_c}$ (eqn 2.6)

where Δp_t = frictions loss
in terms of total pressure
f = friction factor
L = duct length
D = duct diameter or
equivalent hydraulic diameter
$\frac{\rho V^2}{2g_c}$ = velocity pressure

The friction factor, f, used in computing duct losses is taken from a correlation by Swamee and Jain presented in [Ref. 2].

$$f = \frac{0.25}{\left[LOG\left(\frac{e}{3.7\,D} + \frac{5.74}{R_e^{.9}}\right. \right]^2} \qquad 10^{-6} \le \frac{e}{D} \le 10^{-2} \qquad 5000 \le R_e \le 10^8 \qquad \text{(eqn 2.7)}$$

The absolute roughness factor, e, is taken to be 0.00015 feet for all air duct components. For rectangular straight duct sections the equivalent hydraulic diameter, D_e, is calculated by equation (2.8) presented in [Ref. 3]. Equations 2.6, 2.7, and 2.8 are utilized in the program for computing friction losses in the straight sections of the duct.

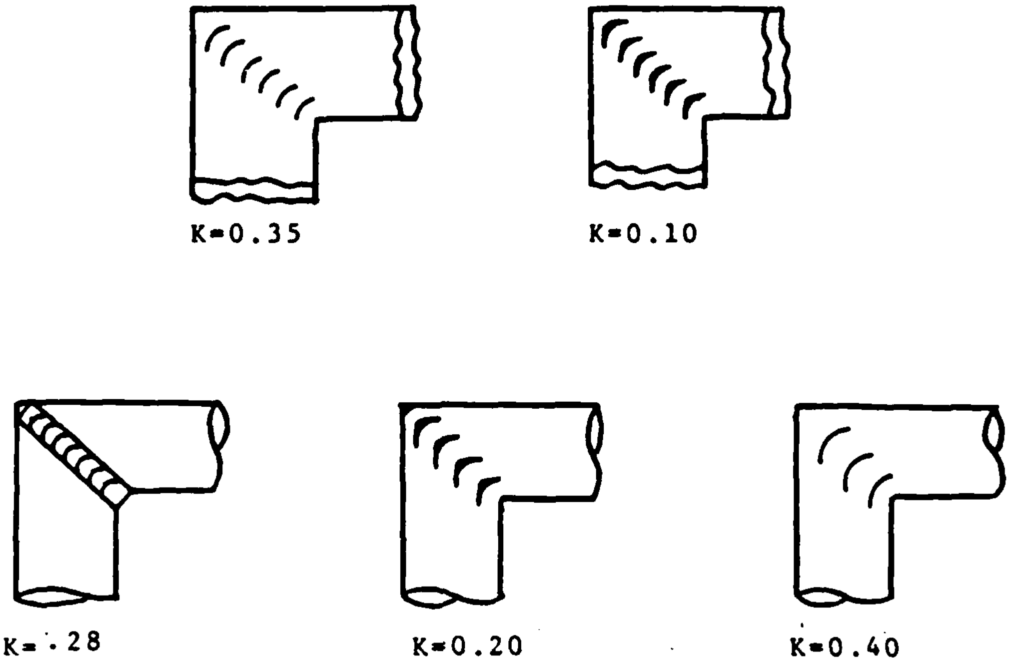
$$D_e = 1.30 \frac{(ab)^{0.625}}{(a+b)^{0.250}} \qquad \text{(eqn 2.8)}$$

Friction losses occur in all fittings not just in straight duct. There are two techniques to arrive at the friction losses in these other fittings. The decision about which technique to use depends on the whether the fitting is short or long. In short fittings friction is accounted for by measuring the connecting sections of straight duct to the center of the fitting. No attempt is made to include friction in the calculation of fluid resistance for a short fitting. Elbows are short fittings. For long fittings such as diffusers and contractions, friction is included in the computation of the flow resistance coefficient. Therefore, a connecting straight duct length should be measured to the center of an elbow or to the start or end of a diffuser or contraction.

Dynamic losses are sometimes called local or minor losses. In piping systems, losses due to the local disturbances of the flow are often called minor losses. In very long piping systems these losses are usually insignificant in comparison with the friction in the length considered. In the duct used for a gas turbine installation these so-called minor losses actually become major losses because of the short lengths usually encountered. Experimental results are almost always used to account for pressure losses through the duct fittings. Such information is usually given in the form of equation 2.9.

$$\Delta p_t = K\rho v^2/2g_c \qquad \text{(eqn 2.9)}$$

The coefficient K is given for the fitting in numerous handbooks. Figure 2.1 shows some typical representations of the information available.



The drawings were reproduced from [Ref. 6].

Figure 2.1 Typical K Values for Fittings.

One of the purposes of the program is to provide K coefficients for various fittings selected to represent duct components. K values can vary with the geometry of a fitting. For example, a long smooth radius rectangular elbow has a lower K value than a short smooth radius rectangular elbow. The program takes this into account and is the reason for the various questions about a fitting's geometry in the area of the program where the user is inputing the duct system.

Two fittings in the program's menu do not require geometry inputs to obtain resistance information. The two fittings are filters and the gas turbine module. The reason for the lack of questions is that the losses are based on manufacturer's data. Filter manufacturers provide pressure loss data based on face velocity and the module is based on the mass flow rate of cooling air. A power curve fits the data and the program uses the curve to model pressure losses for these fittings.

Table I sumarizes the fittings available from the program's menu. The fluid resistance coefficients are computed by the program upon input of the required geometry factors for the fitting. Input of the duct fittings is accomplished interactively. The source of the model for each fitting is noted in the program listing in the title block of the fitting subroutine. The program subroutines FIT01 through FIT29 correspond to the fittings listed in table I . A sketch of each fitting is provided in the user's manual for the program. The user's manual is Appendix C.

E. GAS TURBINE/SYSTEM INTERFACE

General Electric Company, the manufacturer of the LM2500 marine gas turbine, publishes performance data for its engine under variable operating conditions. [Ref. 4]. It is important to understand how the shipboard engine is operated under variable operating conditions such as duct losses and ambient temperature , pressure and humidity so that the proper corrections may be applied to the engine performance parameters for these variables.

TABLE I

Fittings Available From Program Menu

Fitting Number	Description
01	Intake shaft, rectangular cross section, side orifices, with or without louvers
02	Straight duct, round or rectangular
03	Smooth radius round elbow
04	Round 90 degree segmented elbow with 3,4, or 5 pieces
05	Mitered round elbow with or without concentric vanes
06	Mitered rectangular elbow
07	Smooth radius rectangular elbow
08	Smooth radius rectangular elbow with splitters
09	Mitered rectangular elbow with vanes
10	Rectangular elbow with converging or diverging flow
11	90 degree rectangular elbows in a Z-shaped configuration
12	90 degree rectangular elbows in different planes
13	Branch section of a diverging wye
14	Main section of a diverging wye
15	Branch section of a convergent wye
16	Main section of a convergent wye
17	Conical round diffuser
18	Plane in-line diffuser
19	Pyramidial in-line diffuser
20	Transitional diffuser
21	Round contraction
22	Rectangular contraction
23	Screen obstruction in duct
24	Louver entrance

continued next page

25	Filter element
26	Multi-baffle type silencer
27	Gas turbine module enclosure
28	Waste heat recovery boiler
29	Abrupt exit
30	Fitting not listed

From the shipboard operator's point of view the engine should drive the ship at the desired speed whether it is a hot day or a cold day, or if the inlet duct losses are four inches of water or eight. The engine is operating differently under such conditions to produce the same horsepower and speed. The proper correction factor set to be applied to the tabulated data is the set for constant speed and horsepower. The corrections are applied in the program with each iteration of the duct system performance calculations using the current values of the inlet and exhaust duct losses and ambient conditions. The corrections are very small (less than two percent) and the convergence of the correct engine operating point and duct losses created by the mass flow of air required at the operating point is quite stable.

F. FAN/SYSTEM INTERFACE

The operating point of the fan installed in a duct system is the point where the fan characteristic curve intersects the system characteristic curve. The fan curve shows pressure rise vs. flow rate. With increasing flow the pressure rise across the fan is reduced. The system curve is the opposite, increasing flow in the system increases the resistance to flow. Figure 2.2 represents this situation graphically.

In the iteration process the system curve is estimated as a quadratic fitted to the origin as a minimum point and the other point at the assumed flow and the resulting pressure loss. Similiarily the fan curve is also represented as a quadratic with a maximum at maximum pressure attainable and the corresponding flow and another point at zero pressure and maximum flow. The representation of the fan performance for the default condition, the Spruance class destroyer module cooling fan, is excellent. With an equation for both curves the point of intersection can be obtained. The resulting flow is used in the next iteration until the resistance of the system and the pressure rise across the fan is the same for the assumed flow.

G. JUNCTIONS OR WYES

An excellent discussion of the mixing of two streams moving at different velocities was written by Idel'chik and is presented here to develop the background for the eductor/system interface discussion.

> The junction of two parallel streams moving at different velocities is characterized by turbulent mixing of the streams, accompanied by pressure losses. In the course of this mixing an exchange of the momentum takes place between the particles moving at different velocities, finally resulting in the equilization of the velocity distributions in the common stream. The jet with higher velocity loses a part of its kinetic energy by transmitting it to the slower jet.
>
> The loss in total pressure before and after mixing is always large and positive for the higher-velocity jet, and increases with an increase in the amount of energy transmitted to the lower velocity jet. Consequently, the resistance coefficient, which is defined as the ratio of the difference of total pressure to the mean dynamic pressure in the given section, will likewise always be positive. As to the lower-velocity jet, the energy stored in it increases as a result of mixing. The loss in total pressure and the resistance coefficient can, therefore, also have negative values for the lower-velocity jet [Ref. 5].

The program incorporates this concept at the junction of the module cooling air and the engine exhaust (if the system is so configured). The program assumes the lower velocity jet

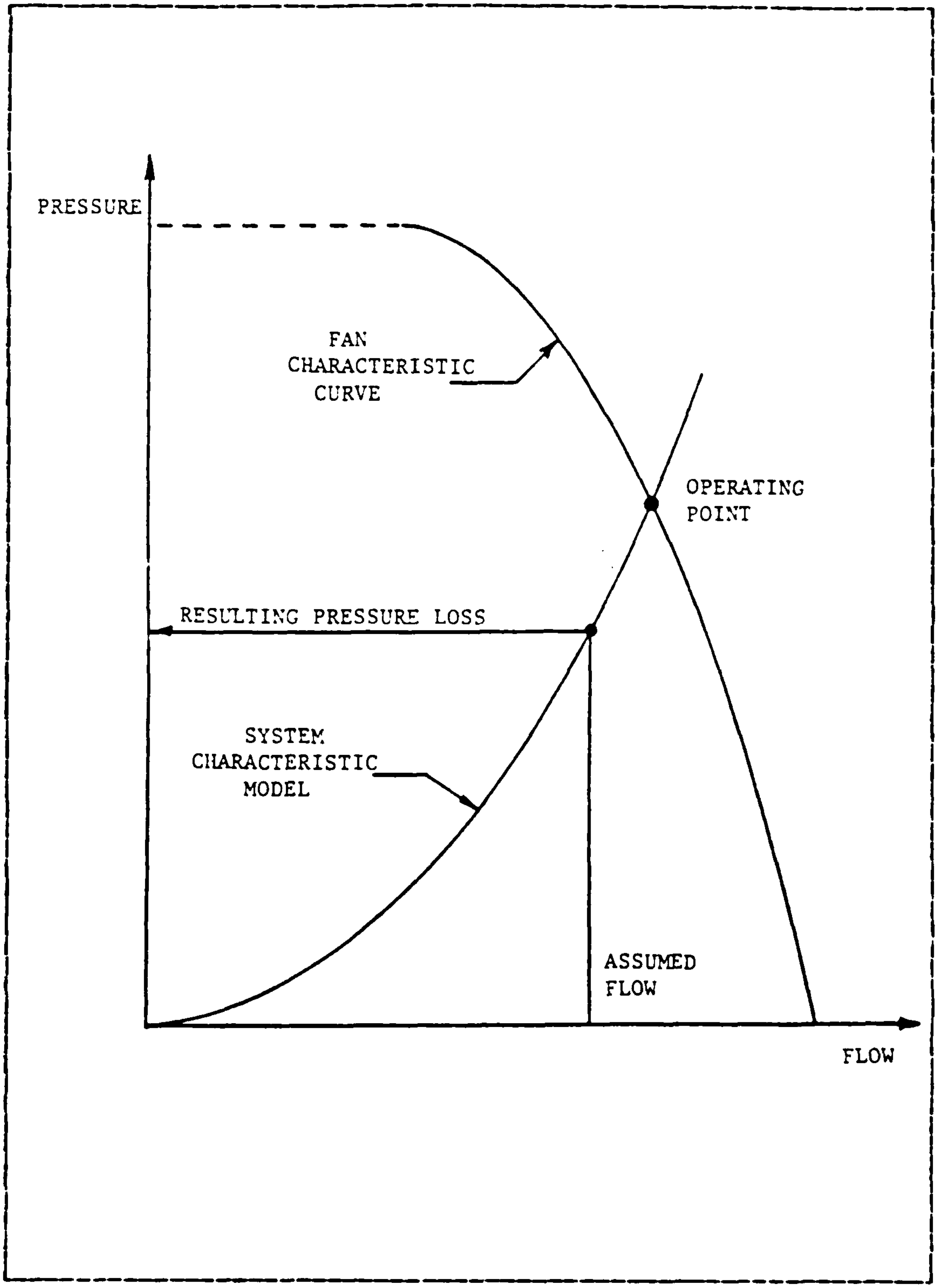


Figure 2.2 Fan/System Interface.

to be the cooling flow and the higher velocity jet to be the exhaust flow.

H. EDUCTOR/SYSTEM INTERFACE

The eductor discussed in this section is used in the engine's exhaust to move cooling air through the cooling ducting and engine enclosure. There is a mixing of the cooling flow and exhaust before it is discharged to the atmosphere. This section does not discuss the eductor installed at the exhaust duct exit. The only component of interest there is the nozzle as a dynamic loss. The effect of the external mixing tube is small and can be neglected.

The module cooling eductor is used on the Oliver Hazard Perry class frigate. It is shown schematically in figure 2.3. The eductor system is illustrated in figure 2.4. This figure shows the geometry and pressure distribution during the mixing of primary flow, engine exhaust, and the secondary flow, module cooling flow. A match point concept can be developed for the eductor much like the fan and system interface concept shown in figure 2.2. One curve is called the gain required and the other the gain available. These curves are shown in figure 2.5. Given the geometry of the mixing area the gain available can be computed by varying the cooling flow while the primary flow, the engine exhaust, remains nearly constant for the desired power setting. The gain available is a maximum at zero cooling flow.

The gain required is computed by dividing the system at the eductor and is analogous to the system characteristic model in figure 2.2. On the downstream side cooling and engine exhaust flows move through the exhaust duct. The cooling flow moves through the upstream duct. Total pressure losses can be computed for both and the sum is the gain required. Since these computations are taking place at nearly constant primary flow, engine exhaust, the gain required at an operating point is a function of the cooling flow. The gain required at zero cooling flow is the exhaust duct pressure loss under the flow condition represented by the engine exhaust alone. Increasing the cooling flow increases the losses in the exhaust duct and also brings to bear losses in the cooling duct. Therefore the required gain is a minimum at zero cooling flow and increases with increasing cooling flow.

There must be an intersection of the gain required curve and the gain available curve if the system is to operate. This condition occurs if the gain available at zero cooling flow is greater than the gain required at zero cooling flow. The intersection must also be far enough to the right to provide the minimum cooling requirement for the load on the engine. The matching technique is to begin with some minimum cooling flow as specified by the engine manufacturer and march to the right adding a small increment to the cooling flow until gain required equals gain available.

I. SYSTEM ANALYSIS

Sections of the intake and exhaust ductwork will be analyzed from node to node resulting in the pressure loss for the section. The sections will be called branches. A node is the starting or ending point of a branch. The fittings of a branch will be entered into the program in the sequence encountered by the flow along a branch. A node is an entry, diverging wye, fan, the gas turbine engine (not to be confused with the engine enclosure), convergent wye, or an exit. Figure 2.6 shows the six resulting schematic representations of a gas turbine installation and the variations of cooling flow available. The numbered dots are the nodes. Node 1 is always the main inlet entrance. Node 3 is

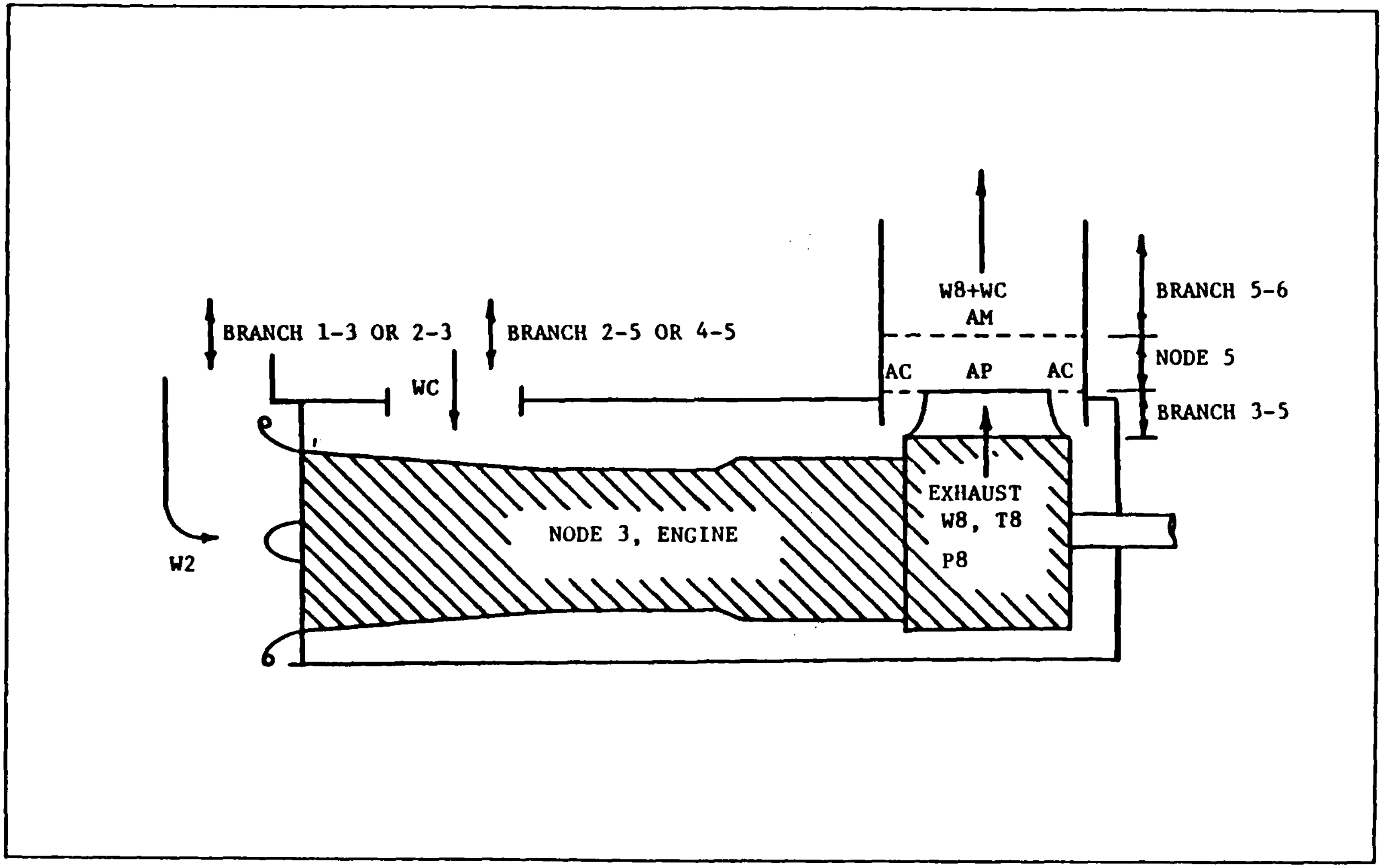


Figure 2.3 Module Cooling Eductor Schematic.

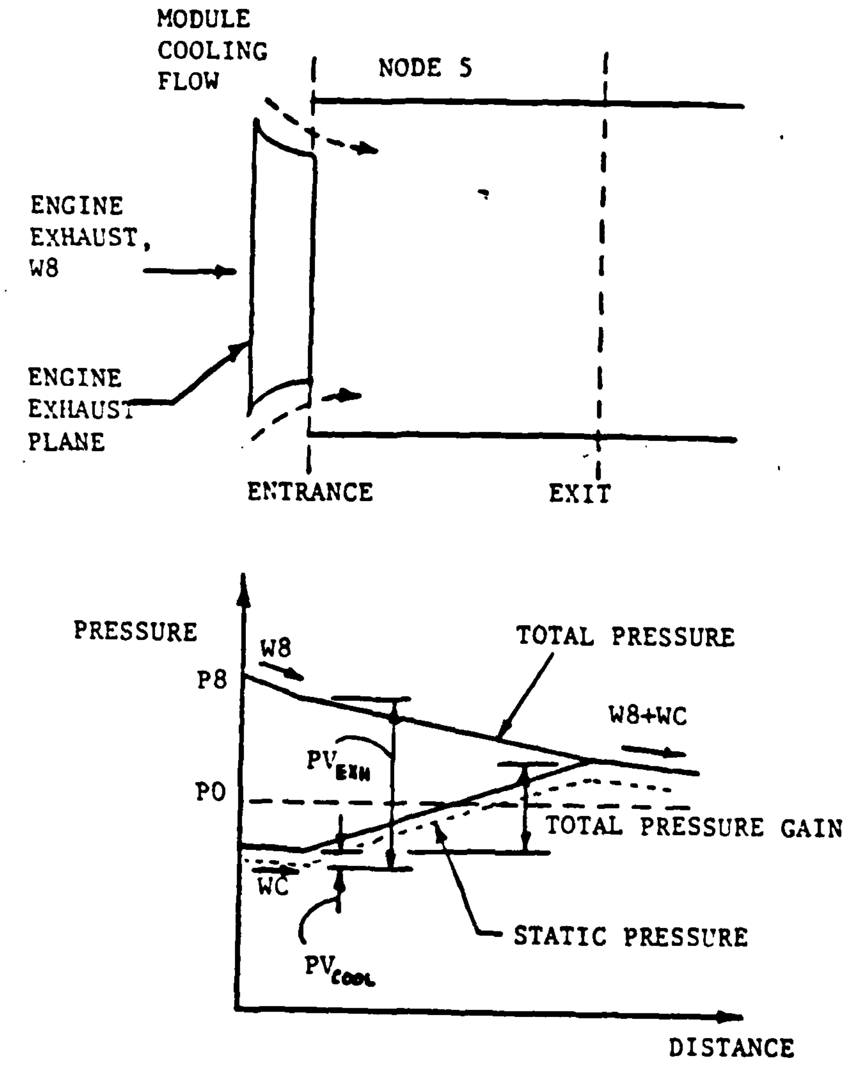


Figure 2.4 Module Eductor Performance.

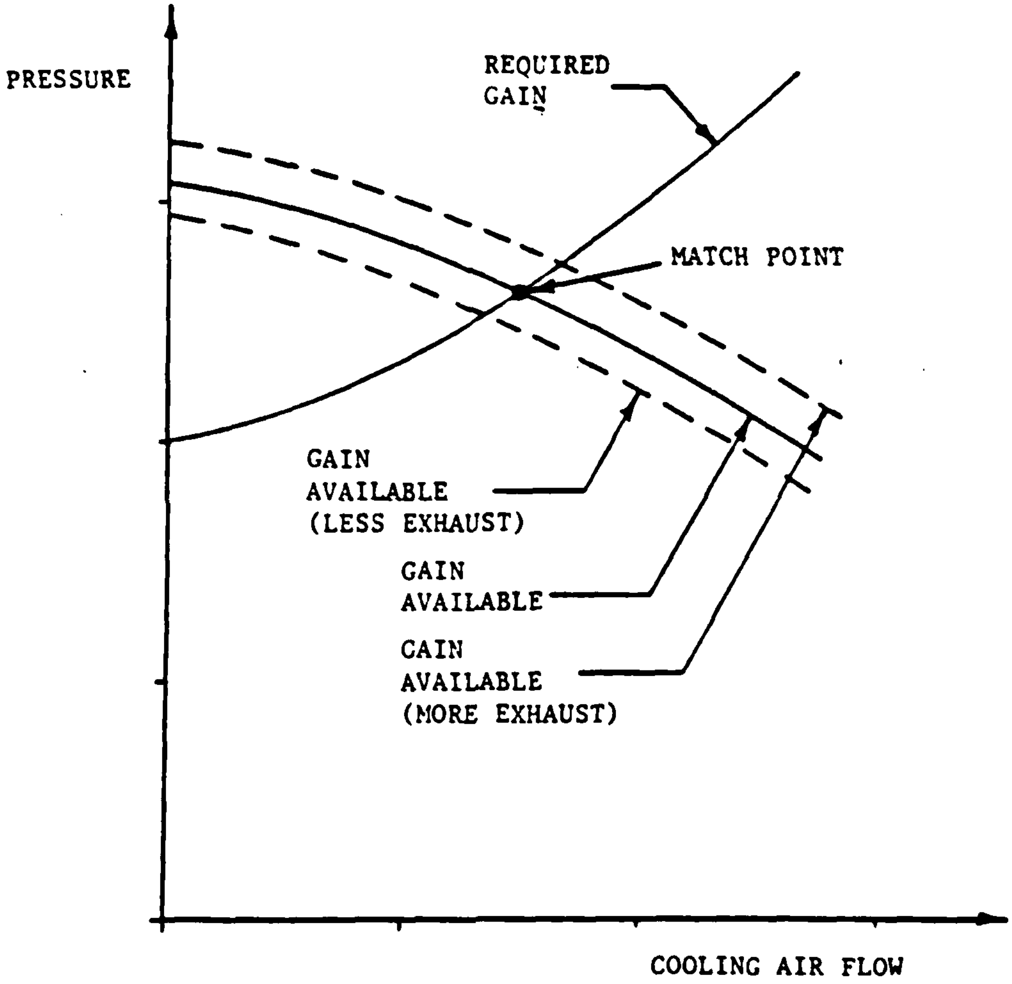


Figure 2.5 Eductor/System Interface.

always the engine. Node 4 is always the cooling fan. Node 6 is always the main exhaust exit. Node 2 may be either an independent entry for the cooling flow or the branch location where the cooling flow diverges from the combined inlet. Node 5 may be either an independent exit for the cooling flow or the junction of cooling flow with the engine exhaust. The hashed area is the engine and the larger rectangle represents the engine module which surrounds the engine and is a fitting in the cooling flow branch. The branches are designated by the node number at the begining and end of the branch. The reader should refer to the user's manual for a complete description of entry of the fittings into the program.

The system in figure 1.1 would be a class three system. It has the cooling flow branching off the main inlet (divergent wye) and joining the main exhaust near the exhaust exit plane of the engine (convergent wye). It also has a fan installed which differentiates it from the class five system.

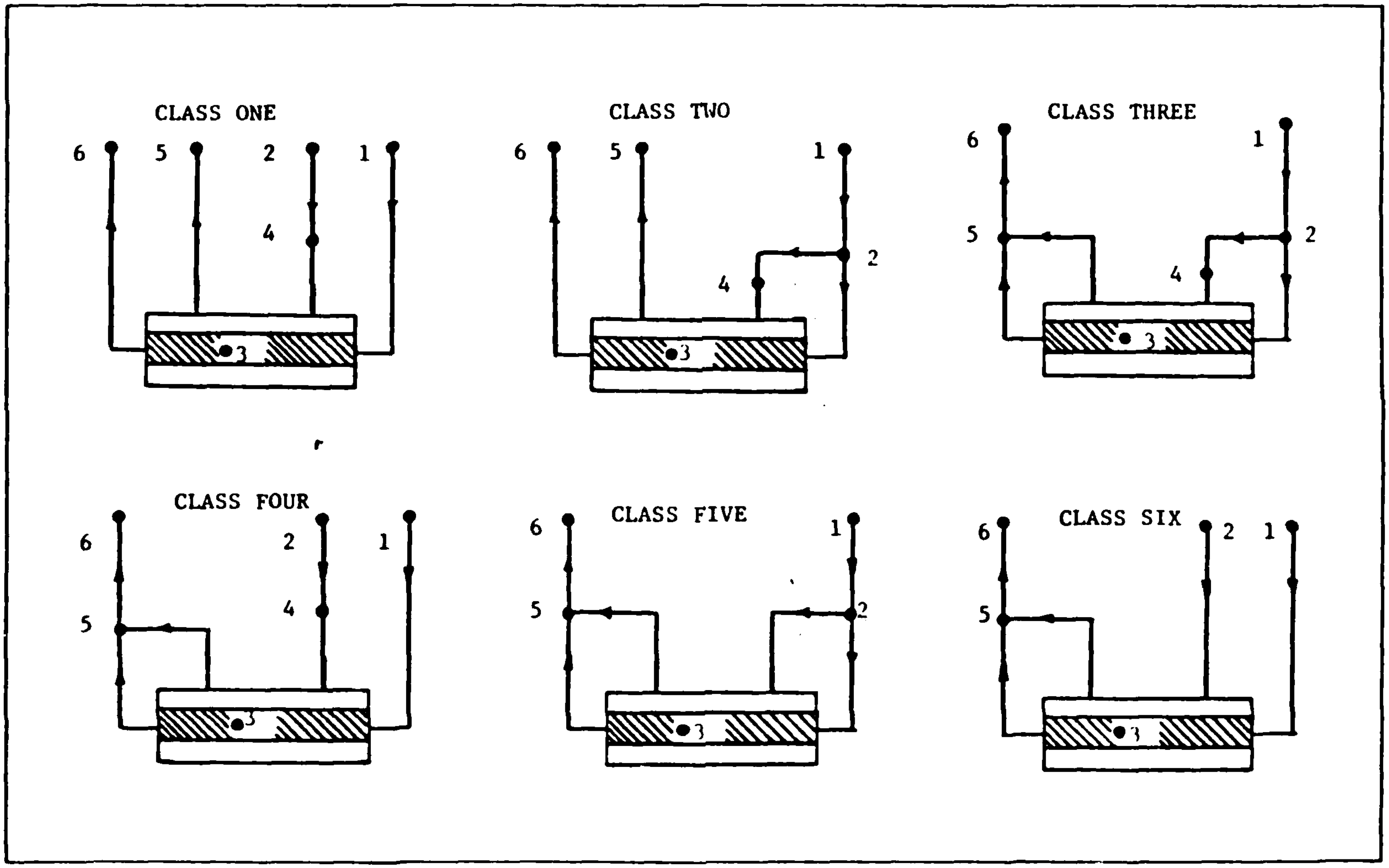


Figure 2.6 System Arrangements and Their Classification.

The basic procedure for system analysis is to assume enough flow and loss information to proceed with the analysis and check the assumptions with continuity of pressure at the nodes with each iteration. If the pressures do not match, new assumptions are made based on the current performance and the iteration is continued until convergence is achieved.

With six different types of systems to match, six different schemes must be implemented in the computer code to handle overall system matching. Each scheme must be tailored to handle the expected components that make it different from any other system. For example, system six has no cooling fan and system one does. System one needs to consider the fan and system interface but system six does not. Appendix A is the complete program listing. Appendix B contains a flow chart of the most complex system in the program, system three, and incorporates all possible component/system interfaces.

J. TOTAL PRESSURE GRADIENT

The total pressure changes represent the energy requirements of the system. Total pressure losses in the intake and exhaust ducts are inputs to the engine performance subroutine in the program and are used to determine the operating parameters of the engine. Fan and system matching is accomplished with the total pressure requirement. Therefore total pressure gradients in the ductwork are most important to analysis. Measurement on the other hand usually produces the static pressure gradient. The static pressure at a point is less than the total pressure at the point. Figure 2.7 shows a typical representation of the pressure changes during flow in a simple duct. Losses in a duct are due to the irreversible transformations of mechanical energy into heat and the losses are used to plot the total pressure grade line. Note that some fittings such as diffusers and contractions cause a change in the static pressure quite different from the change in total pressure. This is a result of a change in the velocity pressure through a variable area fitting. The sample program output presented in the user's manual, appendix C, can be used to produce similar plots of the pressure grade line.

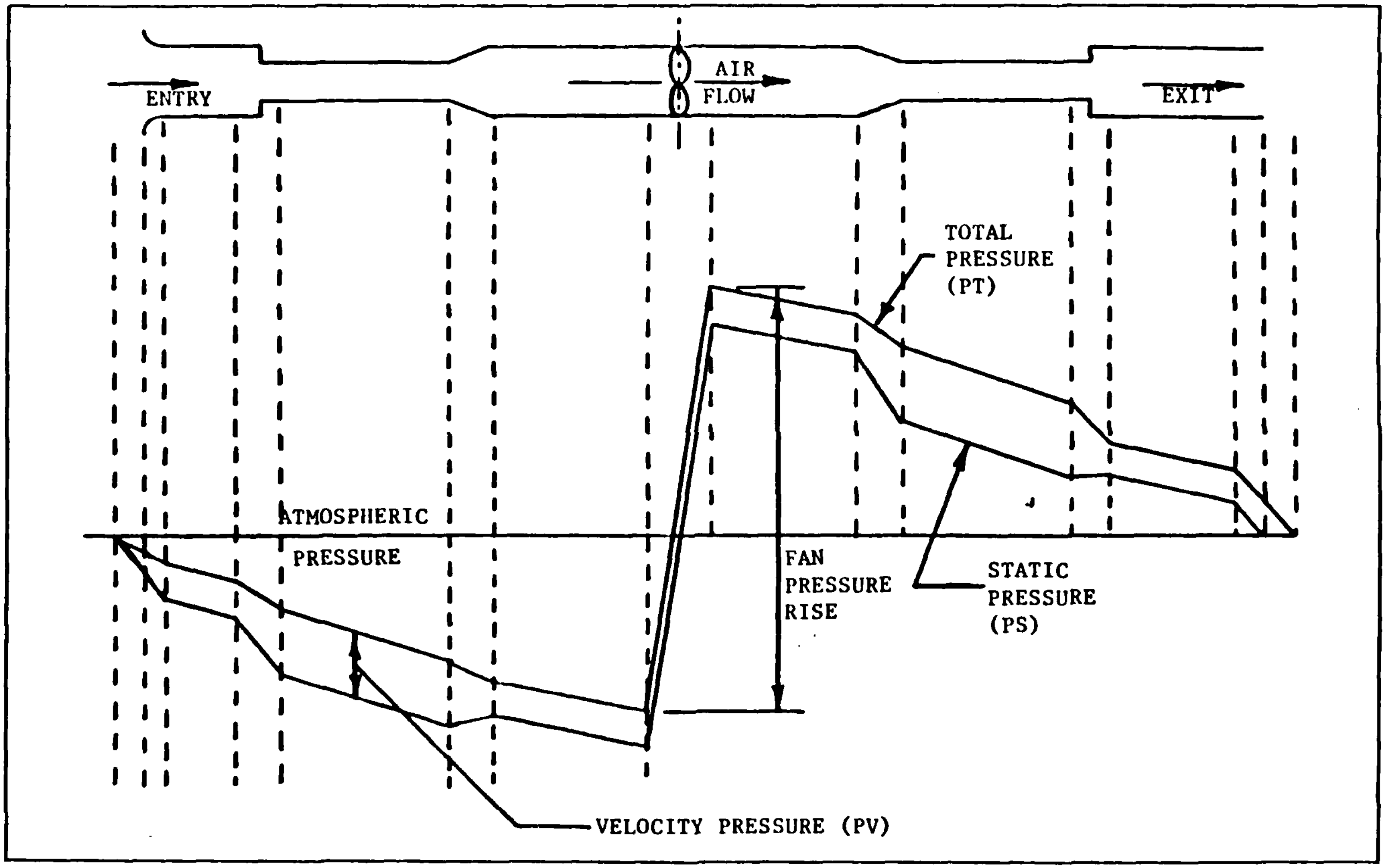


Figure 2.7 Typical Duct Pressure Changes.

III. PROGRAM PROCEDURES

A. GENERAL

The purpose of the program prepared for this study is to translate the geometry of a gas turbine installation including inlet, exhaust, and cooling ducting into a one-dimensional problem to calculate the system's frictional and dynamic resistance to air flow and solve the problem for various operating conditions. The solution will include engine performance parameters such as specific fuel consumption, turbine inlet temperature, and mass flow rates. Additionally a summary of the duct system performance is given by pressure losses for each component and a summary of branch losses. Cooling air flow is predicted by matching the system and the installed fan or module eductor.

Interactive code is utilized for all program inputs. Any number of fittings and combinations of fittings may be selected to represent the user's current design. The system in figure 1.1 can be represented by fittings chosen from the menu. About 30 selections from the menu would be required to model the system. The type and number of selections depends on the system's configuration and complexity. Each fitting may have from one to seven questions posed interactively to establish the required geometry inputs. With the geometry known the program computes areas and coefficients necessary to perform the analysis. This data is stored in a file called duct data and may be saved for future program runs where geometry input is not required. The operating point is defined upon input of ambient temperature and pressure, humidity, horsepower, and power turbine speed. When combined with the duct data file the problem may be solved.

B. INTERACTIVE CODE

Interactive code allows the user to sit at a computer terminal, access a desired program, specify inputs by typing at the terminal keyboard, and execute the program. All inputs are requested by statements appearing on the terminal screen. Resulting output is written to the user's files which may be viewed at the terminal or sent to the printer. The interactive mode of operation is especially valuable because it allows the user, by modifying selected input values, to quickly evaluate the effects of changes to an existing or contemplated design. Modification of a system is accomplished interactively within the editor portion of the program. The editor offers the ability to change a fitting. For example, a mitered round elbow could be modified to add cascaded turning vanes or a different elbow substituted entirely. Also offered is the ability to add or delete a fitting. The addition option does not allow the user to add a new first fitting to a branch, however one may be added anywhere else.

The most important consideration in writing an interactive computer program is what appears on the screen and how it appears. Requests for inputs are in English rather than engineering jargon. Units are all in the English system. All lengths are in feet, etc. All logical choices are accomplished by entry of one letter, the first letter of the choice. For example, "Y" is the reply for yes. All logical choice replies are indicated within parenthesis at the end of the question. Should the user not use one of the choices indicated, the question will be repeated until a proper response is given. Default values are available for many circumstances to minimize the input effort. A default is not available by simply depressing the return key. The user must elect default values by a logical choice. For example the Hamilton Standard filter system installed on the Spruance class destroyer is available as a default for the filter fitting. The user selects this by answering affirmatively to a question asking if the user would like to use the default filter system.

C. OTHER PROGRAM FEATURES

Another consideration in interactive computer programs is the practice of "user proofing" the inputs. In other words, an interactive computer program should not terminate execution (i.e.,"crash") if an improper input value is inadvertently defined by the user. On numerical and logical input two features are incorporated to protect input to the program. First, read statements are protected with error and end of file detection. A problem with input here is handled by asking the user to re-enter the value. On numerical input if it happens again on the same question the program stops execution. Secondly, if an incorrect number is properly defined to the program in the geometry input phase, the user is offered one last chance to re-enter correct fitting data if the user realizes his mistake before he is asked if he wants to load the data for the fitting. The user is assisted here by a check for area continuity from one fitting to the next. A warning is provided if continuity is not maintained. Electing not to load a fitting brings the user back to the menu with the program ready to accept a choice of fittings for use instead of the erroneously entered fitting.

The program is modularized by the extensive use of subroutines. Modularization facilitates program improvements by allowing the upgrade and replacement of individual subroutines. This is a difficult procedure to do if common blocks are used. Therefore common blocks have been eliminated from the program. The user may decide to change the fittings available in the menu, for example. Internal code documentation shows the areas that must be changed to accomplish this task.

Appendix C is a user's manual and completes the external program documentation. The manual explains how to execute the program as installed on the Naval Postgraduate School's IBM 3033 main frame computer and a smaller VAX computer. A sample case is described and sample output provided. A terminal session is also recorded to show typical screen displays.

IV. RESULTS AND RECOMMENDATIONS

A. GENERAL

It is now possible to analyze system performance of an ordinary marine gas turbine installation. Prior to the development of this program subsections of the system were analyzed and their interaction was neglected. This did not provide serious errors in the estimation of engine performance but it did not provide complete information on system performance. In particular, the prediction of cooling flow was not accurate. This was particularily acute when the system utilized a module eductor.

The process of manually assigning a resistance coefficient to a fitting has been eliminated. Now it is possible for the computer program to analyze the geometry of most fittings rapidly and apply the correct resistance coefficients for the one-dimensional analysis without the user looking up any correlations.

The program flexibility is demonstrated by the ability to quickly change input parameters and analyze a system at any operating point. Previous methods analyzed components at full power and then used a proportionality model where losses were proportional to the square of the engine air mass flow rate. This method consistently under-estimates duct losses at low power because it does not take into account the variation of cooling flow provided with an installed fan or module eductor. At low power the cooling flow can be a significant contributor to duct losses and the previous method can not predict this contribution.

B. LIMITATIONS

It should be emphasized that any one-dimensional analysis does not handle flow distortion well. Suspected problems in this area are still best dealt with by the use of model studies. The limitation of a one-dimensional model is that a fitting's pressure loss may be known for uniform flow distribution, but is is difficult to predict the loss with distorted flow. It is known however that the distorted flow situation will have a larger pressure loss, but how much is not easily determined. A one-dimensional analysis may point to problems with flow distortion. The program recognizes the potential for flow distortion on certain fittings such as diffusers and points out this potential. If a fitting's pressure loss can vary significantly with distortion of flow and the one-dimensional analysis has computed a large pressure loss, the user should flag the fitting for futher study by model testing as the pressure loss has probably been underestimated.

Not all possible duct designs can have their fittings modeled by the program. Some fittings will be available from the program menu and others will be similar to fittings listed, but not exactly. Then there are some which may not be listed at all. If the fitting is close, it may be used and expected to give reasonable results. If the fitting is not listed then the user must provide the resistance coefficient by using the "fitting not listed" choice. The data for this entry may come from a published correlation or from tests performed on similiar installations. It is in the area of correlations where most benefit can be gained by program modification.

C. RECOMMENDATIONS

The program currently runs as a stand alone program, but some increased utility may be realized by incorporating some of the subroutines in other programs which would then input a ship's horsepower and RPM requirements for an operating profile instead of point by point user input.

The General Electric LM2500 engine is currently the engine within the program. The engine performance in the program is built by table interpolation of the published performance data. General Electric also offers a program which provides performance data and it is recommended that this program be substituted for the engine subroutine currently in the program. This will eliminate any doubts about engine performance predictions and make the parameters more offical. Also the General Electric program covers the complete performance map of the engine whereas the engine subroutine used in this analysis was limited to 22,500 horsepower maximum. There is still a little power left beyond this value and the program can not currently operate there. Another modification concerning the engine is improving the module temperature out model used in the FIIDP subroutine. The model used produces reasonable results but is not based on test data but on operator experience.

The biggest improvement in program performance and utility can be made by the incorporation of improved fitting flow resistance correlations of test data. Models and full scale systems should be instrumented to provide duct pressure loss data to check the program's analysis. Where the program prediction is not accurate new fitting correlations should be developed. Potential fittings for improved models are louvers, silencers, diffusers with distorted flow, junctions and wyes (especially where eductor action is desired), and boiler tube bundles. With sufficient data these fittings could be modeled better and more simply. The overall objective is to increase both the utility and accuracy of the program analysis.

APPENDIX A

PROGRAM LISTING

```
C*******************************************************************C
C*******************************************************************C
C   ANALYTIC MODEL OF A GAS TURBINE INSTALLATION ON BOARD A SHIP     C
C                                                                    C
C   PROGRAM WRITTEN BY STEPHEN M. EZZELL, LCDR, USN                  C
C   VERSION 1.0  DATE MARCH 30, 1984                                 C
C   PURPOSE:  TO ANALYZE THE DUCTING AND GAS TURBINE INSTALLATION    C
C             AS MIGHT BE INSTALLED ON A SHIP.  INPUT DUCT GEOMETRY, C
C             AMBIENT CONDITIONS, AND POWER SETTING TO GET PERFORMANCE C
C             PARAMETERS.                                            C
C                                                                    C
C*******************************************************************C
C*******************************************************************C
C   THIS IS THE MAIN CONTROL PROGRAM.  ITS SOLE PURPOSE IS TO BRANCH C
C   TO THE AREA OF THE PROGRAM YOU NEED.  IF YOU ARE ANALYZING A NEW C
C   SYSTEM YOU WILL NEED TO BUILD A DATA FILE FOR THE SYSTEM.  YOU   C
C   WILL BE DIRECTED TO THE BUILD SUBROUTINE.  IF YOU WANT TO MAKE   C
C   SOME CHANGES TO A SYSTEM YOU WILL GO TO THE EDIT SUBROUTINE.     C
C   WHEN YOU HAVE A DATA FILE YOU LIKE YOU WILL NEED TO GO TO        C
C   THE COMPUTE SUBROUTINE.  IN THE COMPUTE SUBROUTINE YOUR DATA FILE C
C   WILL BE READ AND THEN YOU WILL BE ASKED QUESTIONS TO ESTABLISH   C
C   THE OPERATING POINT.  THEN THE PROGRAM WILL COMPUTE THE OPERATING C
C   PARAMETERS YOU NEED AND OUTPUT THEM TO THE OUTPUT FILE.          C
C                                                                    C
C   NO COMPUTATIONS ARE DONE IN THE MAIN CONTROL PROGRAM.            C
C                                                                    C
C   SUBROUTINES CALLED: BUILD, EDIT, COMPUT, AND FRTCMS              C
C                                                                    C
C   A NOTE ABOUT FRTCMS, YOU WILL NOT FIND IT IN THE LISTING.  IT IS C
C   LIBRARY SUBROUTINE AVAILABLE AT NPS AND IS USED TO CALL THE      C
C   OPERATING SYSTEM FROM WITHIN THE FORTRAN PROGRAM.  I USE IT FOR  C
C   TWO PURPOSES.  FIRST TO DEFINE MY FILES.  SECOND TO CLEAR THE    C
C   SCREEN AT YOUR TERMINAL SO THE WRITE FORMATS DON'T GET CHOPPED   C
C   UP.  IF YOUR SYSTEM DOES NOT HAVE THIS CAPABILITY YOU WILL HAVE  C
C   TO SUBSTITUTE AN APPROPRIATE CODE TO ACCOMPLISH THE SAME THINGS. C
C   THIS NOTE APPLIES TO THE IBM 3033 COMPUTER.                      C
C ******************************************************************C
      INTEGER ANS,YES,NO,COMPUT,EDIT,QUIT
      DATA YES/'Y'/,NO/'N'/,COMPUT/'C'/,EDIT/'E'/,QUIT/'Q'/
C
C
C
C     NPS IBM 3033 MAIN FRAME COMPUTER PROGRAM REQUIREMENTS
C
C
C
C     HERE IS WHERE I SET UP THE FILE DEFINITIONS USING THE LIBRARY
C     SUBROUTINE "FRTCMS".  THERE ARE NO OTHER FILEDEF'S REQUIRED.
C
C     READING TERMINAL INPUT
      CALL FRTCMS ('FILEDEF ','05       ','TERMINAL')
C     WRITING TO THE TERMINAL
      CALL FRTCMS ('FILEDEF ','06       ','TERMINAL')
C     STORAGE FILE FOR THE DUCT GEOMETRY DEPENDENT VARIABLES
      CALL FRTCMS ('FILEDEF ','08       ','DISK     ','DUCT     ',
     +             'DATA    ')
C     STORAGE FILE FOR THE PERFORMANCE DATA OUTPUT
      CALL FRTCMS ('FILEDEF ','04       ','DISK     ','OUTPUT   ',
     +             'DATA    ')
C
      CALL FRTCMS ('CLRSCRN ')
C     INTRODUCTION.      IS THERE A DUCT DATA FILE ???
 10   WRITE (6,600)
C
C     EVERY READ IS PROTECTED AGAINST A NULL ENTRY AND AN ERROR IN
C     INPUT.  THIS IS ACCOMPLISHED WITH "END=XX,ERR=XX".  YOUR SYSTEM
C     MAY NOT HAVE THIS CAPABILITY, IN WHICH CASE DELETE IT OR
C     SUBSTITUTE AND EQUIVALENT CODE.
C
      READ (5,601,END=12,ERR=12) ANS
      CALL FRTCMS ('CLRSCRN ')
```

```
C
C     EVERY QUESTION REPLY IS CHECKED TO MAKE SURE ONE OF THE ALLOWED
C     RESPONSES WAS USED, IF NOT THE USER IS WARNED AND ASKED TO
C     ANSWER WITH ONE OF THE CORRECT RESPONSES.
C
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 20
 12      REWIND 5
         WRITE (6,602)
         GO TO 10
 20   CONTINUE
      IF (ANS.EQ.YES) GO TO 30
      IF (ANS.EQ.NO) GO TO 50
C
C     DO YOU WANT TO COMPUTE OR EDIT THE DATA FILE ?????
C
 30   WRITE (6,603)
      READ (5,601,END=32,ERR=32) ANS
      IF ((ANS.EQ.COMPUT).OR.(ANS.EQ.EDIT)) GO TO 40
 32      REWIND 5
         WRITE (6,602)
         GO TO 30
 40   CONTINUE
      IF (ANS.EQ.COMPUT) GO TO 80
      IF (ANS.EQ.EDIT) GO TO 110
C
 50   CALL BUILD
C
 60   WRITE (6,604)
      READ (5,601,END=62,ERR=62) ANS
      CALL FRTCMS ('CLRSCRN ')
      IF ((ANS.EQ.COMPUT).OR.(ANS.EQ.QUIT)) GO TO 70
 62      REWIND 5
         WRITE (6,602)
         GO TO 60
 70   CONTINUE
      IF (ANS.EQ.COMPUT) GO TO 80
      IF (ANS.EQ.QUIT) GO TO 999
C
 80   CALL COMP
C
 90   WRITE (6,605)
      READ (5,601,END=92,ERR=92) ANS
      IF ((ANS.EQ.EDIT).OR.(ANS.EQ.QUIT)) GO TO 100
 92      REWIND 5
         WRITE (6,602)
         GO TO 90
 100  CONTINUE
      IF (ANS.EQ.EDIT) GO TO 110
      IF (ANS.EQ.QUIT) GO TO 999
C
 110  CALL ED
C
      GO TO 60
 999  CONTINUE
 600  FORMAT ('  A ONE-DIMENSIONAL MODEL FOR THE SYSTEM PERFORMANCE'/
     +  '            OF A MARINE GAS TURBINE INSTALLATION'//
     +  '                 BY LCDR. STEPHEN M. EZZELL'//
     +  '                VERSION 1.0   MARCH 30, 1984'/
     +     '   OPTIONS: BUILD A DATA FILE REPRESENTING THE DUCT SYSTEM'/
     +     '            EDIT OR CHANGE THE DUCT DATA FILE '/
     +     '            COMPUTE SYSTEM PERFORMANCE '/
     +     '   METHOD:  INTERACTIVE INPUT OF DATA, BRANCHING TO DESIRED'/
     +     '            OPTION BY ANSWERING QUESTIONS'//
     +     ' *** WARNING, TWO NULL ENTRIES ON NUMERICAL INPUT WILL ***'/
     +     '                *** KILL THE PROGRAM. ***'///
     +'  FIRST QUESTION:'/
     +'  DO YOU HAVE A DATA FILE OF DUCT FITTINGS  (Y/N)?')
 601  FORMAT (A1)
 602  FORMAT ('  YOU MUST ENTER THE LETTER INDICATED IN THE BRACKETS'/
```

```
     +          '  FOR A PROPER ANSWER !!!!!!')
 603  FORMAT (/'  DO YOU WANT TO EDIT THE FILE OR USE IT FOR COMPUTATION
     +(E/C) ?')
 604  FORMAT ('  DO YOU WANT TO COMPUTE WITH THE FILE OR QUIT (C/Q) ?')
 605  FORMAT ('  DO YOU WANT TO EDIT THE DUCT DATA FILE OR QUIT (E/Q)?')
      STOP
      END
```

```
C*********************************************************************C
C    BUILD SUBROUTINE: INPUTS GEOMETRY OF DUCT, OUTPUTS DUCT DATA     C
C*********************************************************************C
C    TO GET THIS GOING THE DUCT SYSTEM YOU ARE WORKING WITH NEEDS TO  C
C    BE CLASSIFIED.  SYSTEM SUBROUTINE DOES THIS.  WITH THE CLASS OF  C
C    THE SYSTEM KNOWN, IDENTIFICATION NUMBERS ARE ASSIGNED.  THE MENU C
C    IS CALLED UP AND FITTINGS ARE ENTERED FOR THE SYSTEM TO A FILE   C
C    NAMED DUCT DATA.  THE DUCT DATA FILE WILL BE SERIALIZED BY THE   C
C    USER WITH A SIX DIGIT NUMBER OF THE USER'S CHOICE.               C
C                                                                     C
C    VARIABLES:  WKI AND WKR ARE TRANSPORT ARRAYS USED TO FILL THE    C
C                SYSTEM ARRAYS WORKI AND WORKR.  WORKI(NNN,1) IS THE  C
C                ID NUMBER, AND WORKI(NNN,2) IS THE FITTING TYPE.     C
C                WORKR STORES FITTING DATA SUCH AS LENGTHS, AREAS, AND C
C                RATIOS.                                              C
C                                                                     C
C*********************************************************************C
      SUBROUTINE BUILD
      REAL WKR,WORKR
      INTEGER SORL,WKI,WORKI,TERM,TYPE,BRANCH,FITID,GEOM,DUMMY,M,CLASS
      DIMENSION GEOM(6),WKI(2),WKR(4),WORKI(200,2),WORKR(200,4)
C
C     INST FINDS OUT IF YOU WANT LONG OR SHORT INSTRUCTIONS
C
      CALL INST(SORL,TERM)
C
C     SYSTEM CLASSIFIES THE SYSTEM TO ONE OF SIX POSSIBLE SYSTEMS
C
      CALL SYSTEM(SORL,CLASS)
      GO TO (1,2,3,4,5,6),CLASS
C
C     GEOM IS THE IDENTIFICATION NUMBER TO BE USED WITH THE FITTING.
C     IT IS BROKEN UP INTO FOUR PARTS.  THE FIRST DIGIT IS THE SYSTEM
C     CLASSIFICATION, 1,2,3,4,5, OR 6.  THE NEXT TWO DIGITS ARE THE
C     STARTING NODE AND THE FINISHING NODE OF THE BRANCH.  THE NEXT
C     DIGIT IS THE FLOW IN THE BRANCH, ZERO IS COOLING FLOW, ONE IS
C     ENGINE FLOW, TWO IS COMBINED COOLING AND ENGINE FLOW.  THE LAST
C     TWO DIGITS ARE FOR THE ORDER NUMBER OF THE FITTING IN THE BRANCH.
C
C     EXAMPLE: 113101  SYSTEM ONE, NODE ONE TO THREE, ENGINE FLOW,
C                      FIRST FITTING IN BRANCH
C
 1    GEOM(1)=113101
      GEOM(2)=124001
      GEOM(3)=136101
      GEOM(4)=145001
      BRANCH=4
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,600)
      GO TO 10
 2    GEOM(1)=212201
      GEOM(2)=223101
      GEOM(3)=224001
      GEOM(4)=236101
      GEOM(5)=245001
      BRANCH=5
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,601)
      GO TO 10
 3    GEOM(1)=312201
      GEOM(2)=323101
      GEOM(3)=324001
      GEOM(4)=335101
      GEOM(5)=345001
      GEOM(6)=356201
      BRANCH=6
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,602)
      GO TO 10
```

```
 4    GEOM(1)=413101
      GEOM(2)=424001
      GEOM(3)=435101
      GEOM(4)=445001
      GEOM(5)=456201
      BRANCH=5
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,603)
      GO TO 10
 5    GEOM(1)=512201
      GEOM(2)=523101
      GEOM(3)=525001
      GEOM(4)=535101
      GEOM(5)=556201
      BRANCH=5
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,604)
      GO TO 10
 6    GEOM(1)=613101
      GEOM(2)=625001
      GEOM(3)=635101
      GEOM(4)=656201
      BRANCH=4
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,605)
 10   CONTINUE
      M=0
      WRITE (6,606)
C
C     READI IS AN INTEGER READ SUBROUTINE TO PROTECT THE PROGRAM FROM
C     CRASHING ON NULL INPUT OR ERROR INPUT.  IT ALSO ALLOWS FREE
C     FORMAT INPUT.
C
      CALL READI(DUMMY,5)
      CALL FRTCMS('CLRSCRN ')
C
C     NOW EACH BRANCH WILL BE FILLED UP WITH THE FITTINGS.  BRANCHES
C     ARE TAKEN IN NUMERICALLY ASCENDING ORDER.
C
      DO 40 I=1,BRANCH
 20      CALL MENU (M,TERM,TYPE,GEOM(I))
C        THE MENU CHOICES ARE 0 THRU 30, CHANGE THE NUMBER OF FITTINGS
C        AND YOU MUST CHANGE THE FOLLOWING IF CONDITION ACCORDINGLY
         IF((TYPE.GE.0).AND.(TYPE.LT.31)) GO TO 30
            CALL FRTCMS('CLRSCRN ')
            WRITE(6,607)
            GO TO 20
C        ZERO MEANS NO MORE FITTINGS THIS BRANCH
 30      IF (TYPE.EQ.0) GO TO 40
         M=M+1
C
C        A FITTING HAS BEEN SELECTED, NOW GO TO THE BRANCHING SUBROUTINE
C        TO ENTER THE FITTING.
C
         CALL SELECT (M,SORI,GEOM(I),TYPE,WORKI,WORKR)
         CALL FRTCMS ('CLASCRN ')
         GEOM(I)=GEOM(I)+1
         GO TO 20
 40   CONTINUE
C
C     ALL THE FITTINGS HAVE BEEN ENTERED AND THE DATA FILE IS ABOUT
C     TO BE WRITTEN.
      CALL SUMOUT(WORKI,WORKR,M)
 600  FORMAT('  SYSTEM IS CLASS ONE, SEPARATE ENGINE/COOLING FLOWS.'/
     +'  YOU WILL BE ENTERING FITTINGS FOR FOUR BRANCHES.'/
     +'     1.  ENGINE INLET TO THE ENGINE.'/
     +'     2.  COOLING INLET TO THE COOLING FAN.'/
     +'     3.  ENGINE EXHAUST TO THE ATMOSPHERE.'/
     +'     4.  COOLING FAN EXHAUST TO THE ATMOSPHERE, VIA GT MODULE.')
```

```
601  FORMAT(' SYSTEM IS CLASS TWO, COMBINED INLET FOR ENGINE AND '/
    +'  COOLING FLOW AND SEPARATE FLOWS FOR ENGINE EXHAUST AND MODULE'/
    +'  COOLING HOT EXHAUST.  YOU WILL BE ENTERING FITTINGS FOR FIVE'/
    +'  BRANCHES.'/
    +'      1.  COMBINED INLET TO THE COMBINED SECTION OF A DIVERGENT WYE
    +.'/'     2.  MAIN SECTION OF A DIVERGENT WYE TO THE ENGINE.'/
    +'      3.  BRANCH SECTION OF THE DIVERGENT WYE TO THE COOLING FAN.'/
    +'      4.  ENGINE EXHAUST TO ATMOSPHERE. '/
    +'      5.  COOLING FAN EXHAUST TO THE ATMOSPHERE VIA GT MODULE.')
602  FORMAT('   SYSTEM IS CLASS THREE, COMBINED INLETS AND EXHAUST '/
    +'  FLOWS FOR THE ENGINE AND MODULE COOLING.  A COOLING FAN IS'/
    +'  INSTALLED.  YOU WILL BE ENTERING FITTINGS FOR SIX BRANCHES.'/
    +'      1.  COMBINED INLET TO THE COMBINED SECTION OF A DIVERGENT WYE
    +.'/'     2.  MAIN SECTION OF THE DIVERGENT WYE TO THE ENGINE.'/
    +'      3.  BRANCH SECTION OF THE DIVERGENT WYE TO THE COOLING FAN.'/
    +'      4.  ENGINE EXHAUST TO MAIN SECTION OF A CONVERGENT WYE.'/
    +'          AN EDUCTOR INSTALLED AT THE EXHAUST PLANE OF THE ENGINE'/
    +'          IS CONSIDERED TO BE A CONTRACTION FOLLOWED BY THE MAIN'/
    +'          SECTION OF A CONVERGING WYE FOR THE PURPOSES OF THIS '/
    +'          PROGRAM.'/
    +'      5.  COOLING FAN EXHAUST TO THE BRANCH SECTION OF A CONVERGENT
    + WYE.'/
    +'      6.  COMBINED SECTION OF A CONVERGENT WYE TO THE ATMOSPHERE.')
603  FORMAT('   SYSTEM IS CLASS FOUR; SEPARATE INLETS FOR THE ENGINE'/
    +'  AND COOLING FLOWS, COMBINED FLOWS FOR THE ENGINE EXHAUST AND'/
    +'  HOT MODULE COOLING.  A COOLING FAN IS INSTALLED.'/
    +'  ENTER FITTINGS FOR FIVE BRANCHES.'/
    +'      1.  ENGINE INLET TO THE ENGINE.'/
    +'      2.  COOLING INLET TO THE COOLING FAN.'/
    +'      3.  ENGINE EXHAUST TO MAIN SECTION OF A CONVERGENT WYE.'/
    +'          AN EDUCTOR INSTALLED AT THE EXHAUST PLANE OF THE ENGINE'/
    +'          IS CONSIDERED TO BE A CONTRACTION FOLLOWED BY THE MAIN'/
    +'          SECTION OF A CONVERGENT WYE FOR THE PURPOSES OF THIS'/
    +'          PROGRAM.  '/
    +'      4.  COOLING FAN EXHAUST TO THE BRANCH SECTION OF A CONVERGENT
    + WYE.'/
    +'      5.  COMBINED SECTION OF A CONVERGENT WYE TO THE ATMOSPHERE.')
604  FORMAT('   SYSTEM IS CLASS FIVE, COMBINED INLET AND EXHAUST FLOW.'/
    +'  AN EDUCTOR SYSTEM IS USED TO PUMP COOLING AIR.'/
    +'  ENTER FITTINGS FOR FIVE BRANCHES.'/
    +'      1.  COMBINED INLET TO THE COMBINED SECTION OF A DIVERGENT WYE
    +.'/'     2.  MAIN SECTION OF THE DIVERGENT WYE TO THE ENGINE.'/
    +'      3.  THE EDUCTOR ONLY, THIS PROGRAM CONSIDERS THIS BRANCH TO'/
    +'          CONSIST OF ONLY TWO COMPONENTS, A CONTRACTION AND THE'/
    +'          MAIN SECTION OF A CONVERGENT WYE INSTALLED AT THE EXHAUST
    +'/'          PLANE OF THE ENGINE.'/
    +'      4.  BRANCH SECTION OF A DIVERGENT WYE VIA THE GT MODULE TO'/
    +'          THE EDUCTOR.  THE PROGRAM CONSIDERS THIS PART OF THE'/
    +'          EDUCTOR TO BE THE BRANCH SECTION OF A CONVERGENT WYE.'/
    +'      5.  COMBINED SECTION OF A CONVERGING WYE TO THE ATMOSPHERE.'/
    +'          INSTALLATION OF A WASTE HEAT BOILER IS NOT RECOMENDED.')
605  FORMAT('   SYSTEM IS CLASS SIX; SEPARATE INLETS FOR THE ENGINE'/
    +'  AND COOLING FLOWS, COMBINED FLOWS FOR THE ENGINE EXHAUST AND'/
    +'  HOT MODULE COOLING.  AN EDUCTOR IS INSTALLED.'/
    +'  ENTER FITTINGS FOR FOUR BRANCHES.'/
    +'      1.  ENGINE INLET TO THE ENGINE.'/
    +'      2.  COOLING INLET TO THE EDUCTOR VIA THE GT MODULE.'/
    +'          THE PROGRAM CONSIDERS THIS PART OF THE EDUCTOR TO BE'/
    +'          THE BRANCH SECTION OF A CONVERGENT WYE.'/
    +'      3.  THE EDUCTOR ONLY, THIS PROGRAM CONSIDERS THIS BRANCH TO'/
    +'          CONSIST OF ONLY TWO COMPONENTS, A CONTRACTION AND THE'/
    +'          MAIN SECTION OF A CONVERGENT WYE INSTALLED AT THE EXHAUST
    +'/'          PLANE OF THE ENGINE.'/
    +'      4.  THE COMBINED SECTION OF A CONVERGENT WYE TO THE ATMOSPHER
    +E.')
606  FORMAT(///'  ENTER ZERO TO CONTINUE')
607  FORMAT('   YOU DID NOT ENTER A CORRECT FITTING ID NUMBER.')
     RETURN
     END
```

```
C**********************************************************************C
C      EDITING SUBROUTINE:  USED TO ALTER THE DUCT DATA FILE           C
C**********************************************************************C
C      WITH THIS PART OF THE PROGRAM YOU CAN CHANGE, DELETE, OR ADD A  C
C      FITTING TO THE DATA FILE.  IT WOULD BE HANDY TO HAVE A COPY OF  C
C      IT WITH YOU WHEN YOU MAKE THE CHANGES.  ALSO THE DATA FILE IS   C
C      IS PERMANENTLY CHANGED, TO SAVE A COPY, MAKE A COPY OF IT UNDER C
C      A DIFFERENT FILE NAME.  YOU STILL MUST HAVE A FILE NAMED "DUCT  C
C      DATA" TO EDIT.  EACH DUCT DATA FILE IS SERIALIZED BY THE USER   C
C      AND A NEW SERIAL NUMBER CAN BE ASSIGNED TO THE CHANGED FILE.    C
C      THE SERIAL NUMBER APPEARS OF THE COMPUTED OUTPUT FILE OF SYSTEM C
C      PERFORMANCE.  CHANGES ARE MADE BY THE INDEX NUMBER OF THE FITTINGC
C      IN THE DUCT DATA FILE.  THE INDEX NUMBER IS THE NUMBER IN THE   C
C      FIRST COLUMN.                                                   C
C                                                                      C
C      THIS SUBROUTINE DOES NOT CHANGE THE SYSTEM CLASSIFICATION.      C
C      TO GET A DIFFERENT SYSTEM YOU MUST BUILD IT WITH THE BUILD      C
C      PART OF THE PROGRAM.                                            C
C                                                                      C
C**********************************************************************C
      SUBROUTINE ED
      REAL A,WORKR
      INTEGER N,INDEX,ANS,CHANGE,DELETE,ADD,L,M,S,YES,NC,WORKI,P,Z,
     +        FITID
      DIMENSION INDEX(200),WORKR(200,4),WORKI(200,2)
      DATA CHANGE/'C'/,DELETE/'D'/,ADD/'A'/,YES/'Y'/,NO/'N'/
      READ (8,600) SERIAL,N
      DO 10 I=1,N
         READ (8,601) INDEX(I),WORKI(I,1),WORKI(I,2),WORKR(I,1),
     +                WORKR(I,2),WORKR(I,3),WORKR(I,4)
 10   CONTINUE
      REWIND 8
 20   WRITE (6,602)
      READ (5,603,END=22,ERR=22) ANS
      IF((ANS.EQ.CHANGE).OR.(ANS.EQ.DELETE).OR.(ANS.EQ.ADD)) GO TO 30
 22      REWIND 5
         WRITE (6,604)
         GO TO 20
 30   IF(ANS.EQ.CHANGE) GO TO 40
      IF(ANS.EQ.DELETE) GO TO 80
      IF(ANS.EQ.ADD) GO TO 150
C
C      FITTING IS TO BE CHANGED, A NEW FITTING SUBSTITUTED FOR THE OLD
C
C      WHAT INDEX NUMBER, M ???
C
 40   WRITE (6,605)
      CALL READI(M,5)
C     DO YOU NEED A MENU ???
 50   WRITE (6,606)
      READ (5,603,END=52,ERR=52) ANS
      CALL FRTCMS ('CLRSCRN ')
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 60
 52      REWIND 5
         WRITE (6,604)
         GO TO 50
 60   CONTINUE
      IF(ANS.EQ.YES) GO TO 62
      WRITE (6,607)
      CALL READI(TYPE,5)
      GO TO 64
C
C      CALL THE MENU AND MAKE THE CHANGE
C
 62   CALL MENU (0,0,TYPE,WORKI(M,1))
 64   CALL SELECT(M,1,WORKI (M,1),TYPE,WORKI,WORKR)
C     ANY MORE CHANGES ???
 66   WRITE (6,608)
      READ (5,603,END=68,ERR=68) ANS
```

```
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 70
 68       REWIND 5
          WRITE (6,604)
          GO TO 66
 70   CONTINUE
      IF (ANS.EQ.YES) GO TO 40
      GO TO 250
C
C     A FITTING IS TO BE DELETED
C
 80   WRITE (6,605)
      CALL READI(M,5)
      IF(M.EQ.N) GO TO 120
      N=N-1
      Z=0
C     REWORK THE ID NUMBERS AND RELOAD THE FILE
      DO 110 I=M,N
          TEST=WORKI(I+1,1)-WORKI(I,1)
          IF(TEST.GT.1) Z=Z+1
          IF((TEST.EQ.1).AND.(Z.EQ.0)) GO TO 90
              WORKI(I,1)=WORKI(I+1,1)
              GO TO 100
 90       CONTINUE
 100      WORKI(I,2)=WORKI(I+1,2)
          WORKR(I,1)=WORKR(I+1,1)
          WORKR(I,2)=WORKR(I+1,2)
          WORKR(I,3)=WORKR(I+1,3)
          WORKR(I,4)=WORKR(I+1,4)
 110  CONTINUE
 120  CONTINUE
      WRITE (6,609)
C     ANY MORE DELETIONS ???
 130  WRITE (6,610)
      READ (5,603,END=132,ERR=132) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 140
 132      REWIND 5
          WRITE (6,604)
          GO TO 130
 140  CONTINUE
      IF (ANS.EQ.YES) GO TO 80
      GO TO 250
C
C     A FITTING IS TO BE ADDED
C
 150  WRITE (6,611)
      CALL READI(M,5)
      FITID=WORKI(M,1)+1
      S=N-M
      N=N+1
      P=M+1
C     OPEN UP THE DATA FILE TO ADD THE NEW FITTING
      DO 160 I=1,S
          WORKI(N+1-I,1)=WORKI(N-I,1)
          WORKI(N+1-I,2)=WORKI(N-I,2)
          WORKR(N+1-I,1)=WORKR(N-I,1)
          WORKR(N+1-I,2)=WORKR(N-I,2)
          WORKR(N+1-I,3)=WORKR(N-I,3)
          WORKR(N+1-I,4)=WORKR(N-I,4)
 160  CONTINUE
      Z=0
C     REWORK THE ID NUMBERS
      DO 180 I=P,N
          TEST=WORKI(I,1)-WORKI(I-1,1)
          IF((TEST.LT.100).AND.(Z.EQ.0)) GO TO 170
              Z=Z+1
              GO TO 180
 170          WORKI(I,1)=WORKI(I,1)+1
 180  CONTINUE
C     DO YOU NEED A MENU ???
```

```
  190   WRITE (6,606)
        READ (5,603,END=192,ERR=192) ANS
        CALL FRICMS ('CIRSCAN ')
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 200
  192      REWIND 5
           WRITE (6,604)
           GO TO 190
  200   CONTINUE
        IF(ANS.EQ.YES) GO TO 210
        WRITE (6,607)
        CALL READI(TYPE,5)
        GO TO 220
C       GET THE NEW FITTING
  210   CALL MENU (0,0,TYPE,FITID)
  220   CALL SELECT(P,1,FITID,TYPE,WORKI,WORKR)
C       DO YOU WANT TO ADD ANOTHER FITTING ???
  230   WRITE (6,612)
        READ (5,603,END=232,ERR=232) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 240
  232      REWIND 5
           WRITE (6,604)
           GO TO 230
  240   CONTINUE
        IF (ANS.EQ.YES) GO TO 150
C       DO YOU WANT TO MAKE ANY OTHER CHANGES ???
  250   WRITE (6,613)
        READ (5,603,END=252,ERR=252) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 260
  252      REWIND 5
           WRITE (6,609)
           GO TO 250
  260   CONTINUE
        IF (ANS.EQ.YES) GO TO 20
           CALL SUMOUT(WORKI,WORKR,N)
        REWIND 8
  600   FORMAT(I6,/,I3)
  601   FORMAT(I3,3X,I6,3X,I2,3X,F10.4,3X,F10.4,3X,F10.4,3X,F10.4)
  602   FORMAT('   DO YOU WANT TO CHANGE, DELETE, OR ADD (C/D/A)?'/
     +         '   YOUR OLD FILE WILL BE PERMANENTLY CHANGED, DID YOU'/
     +         '   COPY THE OLD FILE UNDER A NEW NAME IF YOU WANTED TO'/
     +         '   SAVE IT?  IF NOT, ENTER TWO NULL STRINGS TO KILL THE'/
     +         '   PROGRAM.')
  603   FORMAT(A1)
  604   FORMAT('   YOU MUST ENTER A LETTER INDICATED IN THE BRACKETS.')
  605   FORMAT('   WHAT LINE DO YOU WANT TO EDIT?')
  606   FORMAT('   DO YOU NEED A MENU (Y/N)?')
  607   FORMAT('   WHAT IS THE FITTING TYPE NUMBER?')
  608   FORMAT('   WANT TO CHANGE ANOTHER FITTING (Y/N)?')
  609   FORMAT('   DELETION COMPLETE.')
  610   FORMAT('   WANT TO DELETE ANOTHER FITTING (Y/N)?')
  611   FORMAT('   AFTER WHAT LINE DO YOU WANT TO ADD ANOTHER FITTING?')
  612   FORMAT('   WANT TO ADD ANOTHER FITTING (Y/N)?')
  613   FORMAT('   WANT TO MAKE ANY OTHER CHANGES (Y/N)?')
        RETURN
        END
```

```
C*****************************************************************
C      COMPUTE SUBROUTINE: PRODUCES PERFORMANCE DATA OF SYSTEM
C****************************************************************C
C      THE DUCT DATA FILE IS READ AND THEN THE USER MUST INPUT THE    C
C      DESIRED OPERATING POINT.  INPUT THE AMBIENT TEMPERATURE       C
C      (DEGREES F), THE AMBIENT PRESSURE (PSIA), AND HUMIDITY (GRAINS), C
C      HORSEPOWER, AND POWER TURBINE SPEED.  OUTPUT IS THE ENGINE     C
C      PERFORMANCE AND DUCT RESISTANCES.  THE OUTPUT GOES TO YOUR DISK C
C      UNDER FILE OUTPUT DATA.                                         C
C****************************************************************C
      SUBROUTINE COMP
      REAL WORKR,TO,PO,HUMID,HP,NPT,ACWB,ACWM,ACWC,ADWB,ADWC,
     +     ADWM,ALFAD,ALFAC,RHOSTD,CMFD,CFMMAX,DPMAX,K
      INTEGER N,INDEX,WORKI,CLASS,BRANCH,FIT1ST,M,TEST,NBR,OFF,SERIAL,
     +     ANS,YES,NC
      DIMENSION INDEX(200),WORKI(200,2),WORKR(200,4),FIT1ST(7),NBR(6)
      DATA YES/'Y'/,NC/'N'/
      CALL FRTCMS ('CLRSCRN ')
C     READ FILE SERIAL NUMBER AND HOW MANY FITTINGS ARE IN THE FILE
      READ (8,600) SERIAL,N
C     READ INDEX,ID NUMBER,FITTING TYPE,AND FOUR ELEMENTS OF DATA
C     FOR EACH FITTING
      DO 10 I=1,N
         READ (8,601) INDEX(I),WORKI(I,1),WORKI(I,2),WORKR(I,1),
     +               WORKR(I,2),WORKR(I,3),WORKR(I,4)
 10   CONTINUE
      REWIND 8
C     FIND OUT WHAT CLASS SYSTEM IS IN THE DUCT DATA FILE
      CLASS=WORKI(1,1)/100000
C     SET UP FOR THE CORRECT NUMBER OF BRANCHES FOR THE SYSTEM
      IF(CLASS.EQ.1)  BRANCH=4
      IF(CLASS.EQ.2)  BRANCH=5
      IF(CLASS.EQ.3)  BRANCH=6
      IF(CLASS.EQ.4)  BRANCH=5
      IF(CLASS.EQ.5)  BRANCH=5
      IF(CLASS.EQ.6)  BRANCH=4
      IF(CLASS.EQ.1)  GO TO 80
C     SEARCH FOR WYE AREAS.  MUST BE KNOWN FOR MATCHING.  SEARCH IS
C     DONE BY LOOKING FOR THE "WYE" FITTING TYPES, 13,14,15,16.
 20   DO 70 I=1,N
         IF(WORKI(I,2).EQ.13)  GO TO 30
         IF(WORKI(I,2).EQ.14)  GO TO 40
         IF(WORKI(I,2).EQ.15)  GO TO 50
         IF(WORKI(I,2).EQ.16)  GO TO 60
         GO TO 70
 30      ADWC=WORKR(I,1)
         ADWB=WORKR(I,2)
         ALFAD=WORKR(I,3)
         GO TO 70
 40      ADWM=WORKR(I,1)
         GO TO 70
 50      ACWC=WORKR(I,1)
         ACWB=WORKR(I,2)
         ALFAC=WORKR(I,3)
         GO TO 70
 60      ACWM=WORKR(I,1)
 70   CONTINUE
 80   CONTINUE
      M=2
C     THE INDEX NUMBER OF THE FIRST FITTING OF THE BRANCH MUST BE KNOWN.
C     IT IS USED IN THE DO LOOPS OF THE SYSTEM ANALYSIS TO FIND BRANCH
C     PRESSURE DROPS.  NEXT LOOP SEARCHES FOR THESE INDEXES.  LOOP WILL
C     FIND THE INDEX WHEN ID NUMBERS DIFFER BY MORE THAN ONE.
      FIT1ST(1)=1
      DO 90 I=1,N
         TEST=WORKI(I+1,1)-WORKI(I,1)
         IF(TEST.EQ.1) GO TO 90
            FIT1ST(M)=INDEX(I+1)
            M=M+1
```

```
   90 CONTINUE
C     GET THE OPERATING CONDITIONS AND POWER REQUIREMENTS.
      CALL OPCOND(TO,PO,HUMID)
C     IF A FAN IS INSTALLED GET FAN CHARACTERISTICS
      IF (CLASS.GT.4) GO TO 98
      CALL FAN (RHOSTD,CFMO,CFMMAX,DPMAX,K)
   95 CALL PWRPT (HP,NPT,TO,PO)
C     GO TO THE SYSTEM SUBROUTINE TAILORED FOR THE SYSTEM
   98 GO TO (100,150,200,250,300,350) ,CLASS
  100 CALL SYS1(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +            RHOSTD,CFMO,CFMMAX,DPMAX,K)
      GO TO 400
  150 CALL SYS2(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +            ALFAD,ADWB,ADWC,ADWM,
     +            RHOSTD,CFMO,CFMMAX,DPMAX,K)
      GO TO 400
  200 CALL SYS3(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +            ALFAD,ADWB,ADWC,ADWM,ALFAC,ACWB,ACWC,ACWM,
     +            RHOSTD,CFMO,CFMMAX,DPMAX,K)
      GO TO 400
  250 CALL SYS4(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +            ALFAC,ACWB,ACWC,ACWM,
     +            RHOSTD,CFMO,CFMMAX,DPMAX,K)
      GO TO 400
  300 CALL SYS5(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +            ALFAD,ADWB,ADWC,ADWM,ALFAC,ACWB,ACWC,ACWM)
      GO TO 400
  350 CALL SYS6(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +            ALFAC,ACWB,ACWC,ACWM)
  400 CONTINUE
C     DO YOU WANT TO COMPUTE WITH DIFFERENT OPERATING CONDITIONS ???
  410 WRITE (6,602)
      READ (5,603,END=420,ERR=420) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 430
  420     REWIND 5
          WRITE (6,604)
          GO TO 410
  430 CONTINUE
      IF (ANS.EQ.YES) GO TO 95
  600 FORMAT(I6,/,I3)
  601 FORMAT(I3,3X,I6,3X,I2,3X,F10.4,3X,F10.4,3X,F10.4,3X,F10.4)
  602 FORMAT('  DO YOU WANT TO COMPUTE WITH DIFFERENT OPERATING CONDITIO
     +NS (Y/N)?')
  603 FORMAT(A1)
  604 FORMAT('  YOU MUST ENTER A LETTER INDICATED IN THE BRACKETS.')
      RETURN
      END
```

```
C**********************************************************************C
C     INSTRUCTIONS SUBROUTINE: LONG OR SHORT, CRT OR TYPEWRITER       C
C**********************************************************************C
C     THIS SUBROUTINE IS CALLED IN THE BUILD SUBROUTINE.  IT DOES NOT C
C     COMPUTE ANYTHING.  IT IS AN ADMINISTRATIVE PART OF THE PROGRAM   C
C     TO SEE IF THE USER WANTS LONG OR SHORT INSTRUCTIONS, AND IF      C
C     THE USER IS USING A CRT TERMINAL OR TYPEWRITER TERMINAL.         C
C     TYPEWRITER TERMINALS DO NOT GET THE MENUS OVER AND OVER.         C
C**********************************************************************C
      SUBROUTINE INST(SORL,TERM)
      INTEGER SORL,TERM,ANS,LONG,SHORT,CRT,TYPE
      DATA LONG,SHORT,CRT,TYPE/'L','S','C','T'/
 5    WRITE(6,600)
      READ  (5,601,END=7,ERR=7) ANS
      IF((ANS.EQ.LONG).OR.(ANS.EQ.SHORT)) GO TO 10
 7       REWIND 5
         WRITE(6,602)
         GO TO 5
 10   IF(ANS.EQ.SHORT)GO TO 20
         SORL=1
         WRITE(6,603)
         GO TO 30
 20   SORL=0
 30   CONTINUE
 40   WRITE(6,604)
      READ  (5,601,END=42,ERR=42) ANS
      IF((ANS.EQ.CRT).OR.(ANS.EQ.TYPE)) GO TO 50
 42      REWIND 5
         WRITE(6,602)
         GO TO 40
 50   IF(ANS.EQ.CRT) GO TO 60
         TERM=0
         WRITE(6,605)
         GO TO 70
 60   TERM=1
      WRITE(6,606)
 70   CONTINUE
 600  FORMAT('  DO YOU WANT LONG OR SHORT INSTRUCTIONS (L/S)?')
 601  FORMAT(A1)
 602  FORMAT('  YOU MUST ENTER THE LETTER INDICATED IN THE BRACKETS.')
 603  FORMAT('  YOU HAVE SELECTED THE LONG INSTRUCTIONS.')
 604  FORMAT('  ARE YOU WORKING ON A CRT OR TYPEWRITER TERMINAL (C/T)?')
 605  FORMAT('  YOU ARE WORKING ON A TYPEWRITER TERMINAL.')
 606  FORMAT('  YOU ARE WORKING ON A CRT TERMINAL.')
      RETURN
      END
```

```
C*********************************************************************C
C     SYSTEM SUBROUTINE: DETERMINES WHICH SYSTEM, 1,2,3,4,5,OR 6      C
C*********************************************************************C
C     CALLED BY THE BUILD SUBROUTINE.  USED TO SET UP THE PROGRAM FOR C
C     THE VARIATIONS IN DUCT SYSTEMS AVAILABLE.  THE EDITING SUBROUTINEC
C     CAN NOT CHANGE THE SYSTEM TYPE.  ONCE SET UP HERE ANOTHER RUN OF C
C     THE BUILD SUBROUTINE IS REQUIRED TO GET A DIFFERENT SYSTEM.     C
C*********************************************************************C
      SUBROUTINE SYSTEM(SORL,CLASS)
      INTEGER,SORL,CLASS,ANS1,ANS2,ANS3,YES,NO,SHORT
      DATA YES/'Y'/,NO/'N'/,SHORT/3/
      IF(SORL.EQ.SHORT)GO TO 30
C     DOES THE COOLING AIR BRANCH OFF THE MAIN INLET ???
 5    WRITE(6,600)
      READ(5,601,END=7,ERR=7)ANS1
      IF((ANS1.EQ.YES).OR.(ANS1.EQ.NO))GO TO 10
 7       REWIND 5
         WRITE(6,602)
         GO TO 5
C     DOES THE COOLING AIR JOIN THE MAIN EXHAUST ???
 10   WRITE(6,603)
      READ(5,601,END=12,ERR=12)ANS2
      IF((ANS2.EQ.YES).OR.(ANS2.EQ.NO)) GO TO 15
 12      WRITE(6,602)
         GO TO 10
 15   IF(ANS2.EQ.YES) GO TO 20
         ANS3=YES
         GO TO 25
C     IS THERE A COOLING FAN INSTALLED ???
 20   WRITE(6,604)
      READ(5,601,END=22,ERR=22)ANS3
      IF((ANS3.EQ.YES).OR.(ANS3.EQ.NO))GO TO 25
 22      REWIND 5
         WRITE(6,602)
         GO TO 20
C     SYSTEM CLASSIFICATION DEPENDS ON THE CONFIGURATION OF THE SYSTEM
C     AND IF A COOLING FAN IS INSTALLED.  CONFIGURATION MEANS HOW THE
C     DUCT ARE JOINED TOGETHER IN THE SYSTEM.
 25   IF((ANS1.EQ.NO ).AND. (ANS2.EQ.NO ))CLASS=1
      IF((ANS1.EQ.YES).AND. (ANS2.EQ.NO ))CLASS=2
      IF((ANS1.EQ.YES).AND. (ANS2.EQ.YES).AND. (ANS3.EQ.YES))CLASS=3
      IF((ANS1.EQ.NO ).AND. (ANS2.EQ.YES).AND. (ANS3.EQ.YES))CLASS=4
      IF((ANS1.EQ.YES).AND. (ANS2.EQ.YES).AND. (ANS3.EQ.NO ))CLASS=5
      IF((ANS1.EQ.NO ).AND. (ANS2.EQ.YES).AND. (ANS3.EQ.NO ))CLASS=6
      GO TO 40
C     SHORT INSTRUCTIONS...JUST ENTER THE SYSTEM CLASSIFICATION NUMBER
 30   WRITE(6,605)
      CALL READI(CLASS,5)
      IF((CLASS.GT.0).AND.(CLASS.LT.7))  GO TO 40
         WRITE(6,606)
         GO TO 30
 40   CONTINUE
 600  FORMAT('  DOES THE MODULE COOLING AIR BRANCH OFF THE MAIN INLET?
     +(Y,N)')
 601  FORMAT(A1)
 602  FORMAT('  YOU MUST ENTER A LETTER IN THE BRACKETS.')
 603  FORMAT('  DOES THE MODULE COOLING AIR JOIN THE MAIN ENGINE EXHAUST
     +?  (Y,N)')
 604  FORMAT('  IS THERE A COOLING FAN INSTALLED?')
 605  FORMAT('  ENTER THE SYSTEM CLASSIFICATION: 1, 2, 3, 4, 5, OR 6')
 606  FORMAT('  YOU MUST ENTER A 1, 2, 3, 4, 5, OR 6')
      RETURN
      END
```

```
C*********************************************************************C
C      MENU SUBROUTINE: PRINTS MENU AND FINDS OUT WHICH FITTING TO USE  C
C*********************************************************************C
C      CALLED BY BUILD AND EDIT SUBROUTINES.                           C
C      CHANGING THE NUMBER OF FITTINGS REQUIRES CHANGING THE MENU.     C
C      JUST REVISE THE FORMAT STATEMENTS, WATCH THAT IT DOES NOT       C
C      OVERFLOW THE SCREEN.                                            C
C*********************************************************************C
       SUBROUTINE MENU(M,TERM,TYPE,FITID)
       INTEGER FITID,M,TERM,TYPE,CRT,TYPWRT
       DATA TYPWRT/0/
C      IF USER IS ON A TYPEWRITER TERMINAL, THE MENU IS PRINTED ONLY ONCE
       IF((M.GT.0).AND.(TERM.EQ.TYPWRT)) GO TO 10
       WRITE(6,600)
       WRITE(6,601)
       WRITE(6,602)
       WRITE(6,603)
       WRITE(6,604)
       WRITE(6,605) FITID
       CALL READI(TYPE,5)
       GO TO 20
 10    WRITE(6,606)
       CALL READI(TYPE,5)
 20    CONTINUE
       CALL FRTCMS('CLRSCRN ')
 600   FORMAT (     '  00 NO MORE FITTINGS THIS BRANCH',6X,  '* 14 DIVERGI
      +NG WYE, MAIN SECTION   '/'  01 INTAKE SHAFT, RECT SECTION, SIDE  *
      +15 CONVERGENT WYE, BRANCH SECTION '/'     .    ORIFACES, WITH(OUT) LO
      +UVERS       * 16 CONVERGENT WYE, MAIN SECTION'/'  02 STRAIGHT DUCT',
      +21X,'* 17 DIFFUSER, CONICAL ROUND SECTION'/'  03 ELBOW, SMOOTH RAD
      +IUS ROUND',8X,'* 18 DIFFUSER, PLANE, IN-LINE'/'  04 ELBOW: 90 DEG:
      + 3,4,5 PCS: ROUND    * 19 DIFFUSER PYRAMIDAL, IN-LINE  '/'  05 ELBO
      +W, MITERED, ROUND, W&W/O VANES* 20 DIFFUSER, TRANSITIONAL (ROUND T
      +O'/
      +'  06 ELBOW, MITERED, RECTANGULAR         *          RECT OR RECT TO RO
      +UND')
 601   FORMAT('  07 ELBOW, SMOOTH RADIUS, RECTANGULAR * 21 CONTRACTION RO
      +UND'/'  08 ELBOW, SMOOTH RADIUS, WITH          * 22 CONTRACTION RECT
      +ANGULAR'/'          SPLITTERS, RECTANGULAR          * 23 OBSTRUCTION,
      +SCREEN IN DUCT'/'  09 ELBOW, MITERED WITH VANES, RECT    * 24 LOUVE
      +R ENTRANCE')
 602   FORMAT('  10 ELBOW, CONVERGING OR DIVERGING     * 25 FILTER'/
      +'          FLOW, RECTANGULAR',14X,'* 26 MULTI-BAFFLE SILENCER'/
      +'  11 ELBOWS, 90 DEG, Z-SHAPED, RECT     * 27 GT MODULE ')
 603   FORMAT('  12 ELBOWS, 90 DEG, IN DIFFERENT        * 28 WASTE HEAT BOI
      +LER'/'          PLANES, RECTANGULAR ',11X,'* 29 EXIT ABRUPT'/
      +'  13 DIVERGING WYE, BRANCH SECTION      * 30 FITTING NOT LISTED')
 604   FORMAT('  /   *************USE TWO DIGIT NUMBER, PRESS ENTER*******
      +*****')
 605   FORMAT('  >> YOU ARE WORKING ON FITTING NUMBER >> ',I6)
 606   FORMAT('  ENTER THE FITTING TYPE NUMBER FROM THE MENU.')
       RETURN
       END
```

```
C************************************************************************C
C     SELECT SUBROUTINE: BRANCHES TO FITTING SELECTED IN MENU            C
C************************************************************************C
C     CALLED BY BUILD AND EDIT SUBROUTINES                               C
C     THIS SUBROUTINE CALLS LOAD A SUBROUTINE THAT TRANSFERS THE         C
C     DATA OF A FITTING TO THE SYSTEM STORAGE ARRAYS WORKI AND WORKR     C
C************************************************************************C
      SUBROUTINE SELECT (M, SORL,GEOM,TYPE,WORKI,WORKR)
      REAL WORKR,WKR
      INTEGER M,WKI,WORKI,SORL,GEOM,TYPE
      DIMENSION WORKI(200,2),WORKR(200,4),WKI(2),WKR(3)
C     CHANGING THE NUMBER OF FITTINGS REQUIRES A CHANGE TO THE FOLLOWING
C     GO TO STATEMENT AND THE ADDITION OF A CALL TO THE SUBROUTINE
C     THAT HANDLES THE NEW FITTING.
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
     +       21,22,23,24,25,26,27,28,29),TYPE
 1    CALL FIT01 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 2    CALL FIT02 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 3    CALL FIT03 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 4    CALL FIT04 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 5    CALL FIT05 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 6    CALL FIT06 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 7    CALL FIT07 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 8    CALL FIT08 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 9    CALL FIT09 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 10   CALL FIT10 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 11   CALL FIT11 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 12   CALL FIT12 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 13   CALL FIT13 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 14   CALL FIT14 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 15   CALL FIT15 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 16   CALL FIT16 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 17   CALL FIT17 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
 18   CALL FIT18 (SORL,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
```

```
      GO TO 40
19    CALL FIT19 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
20    CALL FIT20 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
21    CALL FIT21 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
22    CALL FIT22 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
23    CALL FIT23 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
24    CALL FIT24 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
25    CALL FIT25 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
26    CALL FIT26 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
27    CALL FIT27 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
28    CALL FIT28 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
29    CALL FIT29 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
      GO TO 40
30    CALL FIT30 (SORI,GEOM,WKI,WKR)
      CALL LOAD (M,GEOM,WKI,WKR,WORKI,WORKR)
C     A NEW FITTING WOULD REQUIRE ANOTHER CALL STATEMENT HERE
40    CONTINUE
      RETURN
      END
```

```
C***********************************************************************
C      FITTING 01: VERT. INTAKE SHAFT, SIDE ORIFACES, WITH(OUT) LOUVERS
C**********************************************************************C
C      REF. HANDBOOK OF HYDRAULIC RESISTANCE, I.E. IDEL'CHIK, PAGE 103  C
C      THE TABULATED VALUES ARE LISTED IN AN ARRAY "A", THE PROPER VALUEC
C      IS EXTRACTED BY ANSWERING CERTAIN QUESTIONS ABOUT CONFIGURATION. C
C      THE REFERENCE AREA IS THE SHAFT AREA.  THIS FITTING IS FOR       C
C      DYNAMIC RESISTANCE, THE DUCT CONNECTED TO IT SHOULD START JUST   C
C      BELOW THE ORIFACES.                                              C
C**********************************************************************C
       SUBROUTINE FIT01(SORL,GEOM,WKI,WKR)
       REAL WKR,A,AREA
       INTEGER N,M,ANS1,ANS2,YES,NO,GEOM,SORL,WKI,OPP,ADJ
       DIMENSION WKI(2),WKR(4),A(2,5)
       DATA YES/'Y'/,NO/'N'/,OPP/'O'/,ADJ/'A'/
C      HOW MANY ORIFACES ???
  2    WRITE(6,600)
       CALL READI(N,5)
       IF((N.LT.1).OR.(N.GT.4)) GO TO 2
       IF(N.NE.2) GO TO 10
C      IF TWO, OPPOSITE OR ADJACENT ???
  5    WRITE(6,602)
       READ(5,603,END=7,ERR=7) ANS1
       IF((ANS1.EQ.OPP).OR.(ANS1.EQ.ADJ))GO TO 10
  7       REWIND 5
          WRITE(6,604)
          GO TO 5
C      ARE THERE LOUVERS INSTALLED ???
 10    WRITE(6,601)
       CALL READR(AREA,5)
 15    WRITE(6,605)
       READ(5,603,END=17,ERR=17) ANS2
       IF((ANS2.EQ.YES).OR.(ANS2.EQ.NO)) GO TO 18
 17       REWIND 5
          WRITE(6,604)
          GO TO 15
 18    IF((N.EQ.2).AND.(ANS1.EQ.OPP)) N=2
       IF((N.EQ.2).AND.(ANS1.EQ.ADJ)) N=3
       IF(N.EQ.3) N=4
       IF(N.EQ.4) N=5
       IF(ANS2.EQ.YES) GO TO 20
       M=1
       GO TO 30
 20    M=2
 30    CONTINUE
C      DATA FROM IDEL'CHIK'S HANDBOOK
       A(1,1)=12.6
       A(1,2)=3.6
       A(1,3)=4.2
       A(1,4)=1.8
       A(1,5)=1.2
       A(2,1)=17.5
       A(2,2)=5.4
       A(2,3)=6.3
       A(2,4)=3.2
       A(2,5)=2.5
C      ENTER DATA INTO TRANSFER ARRAYS WKI,WKR
       WKI(1)=GEOM
       WKI(2)=1
       WKR(1)=AREA
       WKR(2)=0.0
       WKR(3)=A(M,N)
       WKR(4)=AREA
 600   FORMAT('   YOU HAVE SELECTED A VERTICAL INTAKE SHAFT OF '/
      +        '  RECTANGULAR SECTION WITH SIDE ORIFACES AT THE TOP.'/
      +        '  IT MAY OR MAY NOT HAVE LOUVERS OVER THE ORIFACES.'/
      +        '  FILTERS ARE A SEPARATE FITTING.'//'***FIRST, ENTER THE NU
      +MBER OF ORIFACES. (1,2,3,OR 4)***')
 601   FORMAT('   ENTER THE CROSS SECTIONAL AREA OF THE VERTICAL SHAFT.')
```

```
602   FORMAT('   SINCE THERE ARE TO BE TWO ORIFACES, ARE THE ORIFACES OPP
     +OSITE OR ADJACENT (O/A)?')
603   FORMAT(A1)
604   FORMAT('   YOU MUST ENTER A LETTER IN THE BRACKETS.')
605   FORMAT('   LAST QUESTION, ARE LOUVERS MOUNTED ON THE ORIFACES?  (Y/
     +N)')
      RETURN
      END
```

```
C**********************************************************************C
C     FITTING 02: STRAIGHT DUCT, ROUND OR RECTANGULAR                  C
C**********************************************************************C
C     NO REFERENCE, ONLY THE DUCT GEOMETRY IS INPUT HERE.  LATER ON IN C
C     THE COMPUTE PART OF THE PROGRAM A COEFFICENT BASED ON F*L/D WILL C
C     BE DEVELOPED TO DETERMINE THE RESISTANCE OF THE DUCT.  F IS THE  C
C     FRICTION FACTOR.  SEE FITDP FOR THE CORRELATION USED.            C
C**********************************************************************C
      SUBROUTINE FIT02 (SORL,GEOM,WKI,WKR)
      REAL A,B,L,D,WKR
      INTEGER SORL,GEOM,WKI,ANS1,CIR,REC,SHORT
      DIMENSION WKI(2),WKR(4)
      DATA CIR/'C'/,REC/'R'/,SHORT/0/
C     IS DUCT CIRCULAR OR RECTANGULAR ???
    5 WRITE(6,600)
      READ(5,601,END=6,ERR=6) ANS1
      IF((ANS1.EQ.CIR).OR.(ANS1.EQ.REC))GO TO 7
    6    REWIND 5
         WRITE(6,608)
         GO TO 5
    7 IF(ANS1.EQ.CIR) GO TO 30
      IF(SORL.EQ.SHORT) GO TO 10
      WRITE(6,602)
      CALL READR(A,5)
      WRITE(6,603)
      CALL READR(B,5)
      WRITE(6,604)
      CALL READR(L,5)
      GO TO 20
   10 WRITE(6,605)
      CALL READR(A,5)
      CALL READR(B,5)
      CALL READR(L,5)
   20 CONTINUE
      AREA=A*B
C     SINCE THE DUCT IS RECTANGULAR, THE EQUIVALENT CIRCULAR DIAMETER
C     IS REQUIRED.  THIS IS FROM THE ASHRAE HANDBOOK, CHAPTER 33, DUCTS
      D=1.3*((A*B)**0.625)/(A+B)**0.250
      R=L/D
      GO TO 100
   30 IF(SORL.EQ.0) GO TO 40
      WRITE(6,606)
      CALL READR(D,5)
      WRITE(6,604)
      CALL READR(L,5)
      GO TO 50
   40 WRITE(6,607)
      CALL READR(D,5)
      CALL READR(L,5)
   50 AREA=3.14*(D**2/4.0)
  100 WKI(1)=GEOM
      WKI(2)=2
      WKR(1)=AREA
      WKR(2)=D
      WKR(3)=L
      WKR(4)=AREA
  600 FORMAT('  YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND OR REC
     +TANGULAR.'/'****FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULA
     +R  (C/R)  ?')
  601 FORMAT(A1)
  602 FORMAT('  THE DUCT IS RECTANGULAR, ENTER FIRST CROSS-SECTIONAL DIM
     +ENSION.  (FEET)')
  603 FORMAT('  SECOND DIMENSION (FEET)')
  604 FORMAT('  ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)')
  605 FORMAT('  ENTER THE RECTANGUAR DUCT DIMENSIONS.  (FEET)'/
     +'   FORMAT:  FIRST DIMENSION        SAMPLE:  10  '/
     +'            SECOND DIMENSION                 8.35 '/
     +'            LENGTH                          18.5')
  606 FORMAT('  THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)')
```

```
607  FORMAT('  ENTER THE DIMENSIONS (FEET) OF THE CIRCULAR DUCT.'/
    +'     FORMAT:  DIAMETER                SAMPLE:  5.65 '/
    +'              LENGTH                          20')
608  FORMAT('  YOU MUST ENTER A LETTER IN THE BRACKETS.')
     RETURN
     END
```

```
C*********************************************************************C
C     FITTING 03: ELBOW, SMOOTH RADIUS, ROUND CROSS-SECTION           C
C*********************************************************************C
C     REF. ASHRAE HANDBOOK, PAGE 33.33, TABLE B-[illegible], FITTING 3-1              C
C     CURVE FIT TO THE TABULATED DATA                                 C
C     SHORT FITTING, FRICTION LOSSES NOT INCLUDED, CONNECTING DUCTS   C
C     TO THE CENTER OF THIS FITTING.                                  C
C*********************************************************************C
      SUBROUTINE FIT03(SCRL,GEOM,WKI,WKR)
      REAL R,D,THETA,KTHETA,C,AREA,CPRIME,WKR
      INTEGER GEOM,SCRL,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(D,5)
      WRITE(6,601)
      CALL READR(R,5)
      WRITE(6,602)
      CALL READR(THETA,5)
      AREA=0.7854*D**2
      KTHETA=0.0306*THETA**0.7825
      CPRIME=0.02946*EXP(2.5627*(1.57138-(R/D)))+0.11746
      C=KTHETA*CPRIME
      WKI(1)=GEOM
      WKI(2)=3
      WKR(1)=AREA
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=AREA
 600  FORMAT('  YOU HAVE SELECTED A SMOOTH RADIUS ROUND CROSS-SECTION'/
     +'  ELBOW.'/'  **FIRST QUESTION, WHAT IS THE CROSS-SECTION DIAMETER
     +'  (FEET)**')
 601  FORMAT('  ENTER THE RADIUS OF THE TURN OF THE ELBOW MEASURED TO'/
     +'  THE CENTERLINE OF THE DUCT.')
 602  FORMAT('  LAST QUESTION, ENTER THE ANGLE OF THE ELBOW TURN.  (DEGR
     +EES)')
      RETURN
      END
```

```
C**********************************************************************C
C     FITTING 04: ELBOW, SEGMENTED ROUND CROSS-SECTION, 90 DEGREE      C
C**********************************************************************C
C     REF.  ASHRAE HANDBOOK, PAGE 33.33, TABLE 3-3, FITTING 3-2        C
C     CURVE FIT TO THE TABULATED DATA FOR EACH NUMBER OF SEGMENTS.     C
C     THIS IS A SHORT FITTING, FRICTION LOSSES NOT INCLUDED, MEASURE   C
C     CONNECTING DUCTS TO THE CENTER OF THIS FITTING.                  C
C**********************************************************************C
      SUBROUTINE FIT04(SORL,GEOM,WKI,WKR)
      REAL D,R,WKR
      INTEGER SORL,GEOM,WKI,N,M
      DIMENSION WKI(2),WKR(4)
 5    WRITE(6,600)
      CALL READR(N,5)
      IF((N.LT.3).OR.(N.GT.5)) GO TO 5
      WRITE(6,601)
      CALL READR(D,5)
      WRITE(6,602)
      CALL READR(R,5)
      AREA=0.7854*D**2
      M=N-2
      GO TO (10,20,30),M
 10   C=4.4022*EXP(3.9394*(0.00282-R/D))+0.32829
      GO TO 40
 20   C=1.8428*EXP(2.4861*(-0.02393-R/D))+0.22798
      GO TO 40
 30   C=1.0456*EXP(1.74313*(0.01219-R/D))+0.15776
 40   CONTINUE
      WKI(1)=GEOM
      WKI(2)=4
      WKR(1)=AREA
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=AREA
 600  FORMAT('  YOU HAVE SELECTED A SEGMENTED ROUND CROSS-SECTION 90 DEG
     +REE ELBOW.'/'  **FIRST QUESTION, HOW MANY SEGMENTS, INCLUDE ENTRY
     +AND EXIT?   (3,4,OR 5) **')
 601  FORMAT('  ENTER THE CROSS-SECTIONAL DIAMETER.')
 602  FORMAT('  LAST QUESTION, WHAT IS THE RADIUS OF THE TURN OF THE ELB
     +OW,'/'  MEASURED TO THE CENTERLINE OF THE DUCT?')
      RETURN
      END
```

```
C**********************************************************************C
C       FITTING 05:  ELBOW MITERED CIRCULAR CROSS-SECTION              C
C**********************************************************************C
C       REF. ASHRAE HANDBOOK, PAGE 33.33, TABLE 8-3. FITTING 3-3       C
C       CURVE FIT TO DATA.                                             C
C       THIS IS A SHORT FITTING.  CONNECTING DUCTS SHOULD BE MEASURED  C
C       TO THE CENTER OF THIS FITTING.                                 C
C**********************************************************************C
        SUBROUTINE FIT05 (SORL,GEOM,WKI,WKR)
        REAL D,THETA,CPRIME,AREA,WKR,K
        INTEGER SORL,GEOM,WKI,ANS,YES,NO
        DIMENSION WKI(2),WKR(4)
        DATA YES/'Y'/,NO/'N'/
        WRITE(6,600)
        CALL READR(D,5)
        WRITE(6,601)
        CALL READR(THETA,5)
        K=1.0
 10     WRITE (6,602)
        READ (5,603,END=12,ERR=12) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 20
 12        REWIND 5
           WRITE (6,604)
           GO TO 10
 20     CONTINUE
        IF (ANS.EQ.YES) K=0.27
        CPRIME=(3.74E-4)*(THETA**1.7852)*K
        AREA=0.7854*D**2
        WKI(1)=GEOM
        WKI(2)=5
        WKR(1)=AREA
        WKR(2)=D
        WKR(3)=CPRIME
        WKR(4)=AREA
 600    FORMAT('  YOU HAVE SELECTED A MITERED ROUND ELBOW.'/
      + '   **FIRST QUESTION, WHAT IS THE CROSS-SECTIONAL DIAMETER?')
 601    FORMAT('  WHAT IS THE ANGLE OF THE ELBOW TURN?')
 602    FORMAT('  LAST QUESTION, ARE OPTIMUM NUMBER OF CONCENTRIC VANES'/
      + '       INSTALLED TO REDUCE RESISTANCE AND TURBULANCE (Y/N)?')
 603    FORMAT(A1)
 604    FORMAT('  YOU MUST ENTER A LETTER IN THE BRACKETS.')
        RETURN
        END
```

```
C*********************************************************************C
C     FITTING 06:  ELBOW MITERED RECTANGULAR CROSS-SECTION            C
C*********************************************************************C
C     REF. ASHRAE HANDBOOK, PAGE 33.33, TABLE B-3, FITTING 3-6 AND    C
C     THE HANDBOOK OF HYDRAULIC RESISTANCE, IDEL'CHIK.                C
C     CURVE FITS TO THE DATA.  THIS IS A SHORT FITTING, MEASURE DUCT  C
C     CONNECTED TO IT TO THE CENTER OF THIS FITTING.                  C
C*********************************************************************C
      SUBROUTINE FIT06(SORL,GEOM,WKI,WKR)
      REAL H,W,THETA,C1,A,PHI,CPRIME,RAD,AREA,DH,WKR
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(H,5)
      WRITE(6,601)
      CALL READR(W,5)
 10   WRITE(6,602)
      CALL READR(THETA,5)
      IF (THETA.LE.90.0) GO TO 20
      WRITE(6,603)
      GO TO 10
 20   RAD=THETA*3.1416/180.0
      DH=2.0*(H*W)/(H+W)
      AREA=H*W
      C1=0.23097*EXP(0.38896*(1.87338-(H/W)))+0.67819
      A=1.2+1.0381*((1.5708-RAD)/1.0472)**1.8233
      PHI=0.95*((SIN(RAD/2.0))**2)+2.05*((SIN(RAD/2.0))**4.0)
      CPRIME=C1*A*PHI
      WKI(1)=GEOM
      WKI(2)=6
      WKR(1)=AREA
      WKR(2)=DH
      WKR(3)=CPRIME
      WKR(4)=AREA
 600  FORMAT('  YOU HAVE SELECTED A MITERED, RECTANGULAR CROSS-SECTION,
     +ELBOW.'/'  **FIRST QUESTION, WHAT IS THE HEIGHT OF THE ELBOW?'/
     +'       (THE DIMENSION PARALLEL TO THE TURN AXIS)')
 601  FORMAT('  WHAT IS THE WIDTH OF THE ELBOW CROSS-SECTION?'/
     +'     (THE DIMENSION IN THE PLANE OF THE TURN)')
 602  FORMAT('  LAST QUESTION, WHAT IS THE ANGLE OF THE ELBOW TURN (0 -
     +90 DEGREES)?')
 603  FORMAT('  ELBOW TURN ANGLE MUST NOT BE GREATER THAN 90 DEGREES.')
      RETURN
      END
```

```
C**********************************************************************C
C     FITTING 07:  ELBOW SMOOTH RADIUS RECTANGULAR WITHOUT VANES        C
C**********************************************************************C
C     REF. ASHRAE HANDBOOK, PAGE 33.31, TABLE 3-3, FITTING 3-5          C
C     USES TWO DIMENSIONAL TABLE TO PROVIDE COEFFICIENT.  CALL TABLE    C
C     SUBROUTINE, A TABLE LOOKUP AND INTERPOLATION SUBROUTINE.          C
C     SHORT FITTING, MEASURE CONNECTING DUCTS TO THE CENTER OF FITTING C
C**********************************************************************C
      SUBROUTINE FIT07 (SORL,GEOM,WKI,WKR)
      REAL WKR,H,W,R,THETA,T,X,KTHETA,C,CPRIME,DH,AREA
      INTEGER WKI,SORL,GEOM,XOUT
      DIMENSION WKI(2),WKR(4),T(61),X(2)
C     TABLE IS LISTED AS FOLLOWS, NUMBER OF X'S, NUMBER OF Y'S, THE X'S
      DATA T/ 9.00,5.00,  0.25,0.50,0.75,1.00,1.50,2.00,3.00,4.00,5.00,
C                         THE Y'S
     +                    0.50,0.75,1.00,1.50,2.00,
C              THE TABLE INCREASING X TO THE RIGHT, INCREASING Y DOWN
     +           1.30,1.30,1.20,1.20,1.10,1.10,0.98,0.92,0.89,
     +           0.57,0.52,0.48,0.44,0.40,0.39,0.39,0.40,0.42,
     +           0.27,0.25,0.23,0.21,0.19,0.18,0.18,0.19,0.20,
     +           0.22,0.20,0.19,0.17,0.15,0.14,0.14,0.15,0.16,
     +           0.20,0.18,0.16,0.15,0.14,0.13,0.13,0.14,0.14/
      WRITE(6,600)
 10   WRITE(6,601)
      CALL READR(H,5)
      WRITE(6,602)
      CALL READR(W,5)
      WRITE(6,603)
      CALL READR(R,5)
      WRITE(6,604)
      CALL READR(THETA,5)
      X(1)=H/W
      X(2)=R/W
      CALL TABLE (T,X,XOUT,C)
      IF(XOUT.GT.0) GO TO 20
      WRITE(6,605)
      GO TO 10
 20   KTHETA=0.0306*THETA**0.7825
      DH=2.0*(H*W)/(H+W)
      CPRIME=C*KTHETA
      AREA=H*W
      WKI(1)=GEOM
      WKI(2)=7
      WKR(1)=AREA
      WKR(2)=DH
      WKR(3)=CPRIME
      WKR(4)=R/W
 600  FORMAT('  YOU HAVE SELECTED A SMOOTH RADIUS RECTANGULAR ELBOW WITH
     +OUT VANES.')
 601  FORMAT('  **FIRST QUESTION, WHAT IS THE HEIGHT OF THE ELBOW?'/
     +'      (THE CROSS-SECTIONAL DIMENSION PARALLEL TO THE TURN AXIS)')
 602  FORMAT('  WHAT IS THE WIDTH OF THE ELBOW (THE CROSS-SECTIONAL'/
     +'       DIMENSION IN THE PLANE OF THE TURN)?')
 603  FORMAT('  WHAT IS THE RADIUS OF THE ELBOW, MEASURED TO THE CENTER'
     +/'      OF THE ELBOW CROSS-SECTION?')
 604  FORMAT('  LAST QUESTION, WHAT IS THE ANGLE OF THE TURN (0-90 DEGR
     +EES)?')
 605  FORMAT('  CROSS-SECTION EXTREMELY NARROW, RE-ENTER BETTER DATA.')
      RETURN
      END
```

```
C*****************************************************************C
C     FITTING 08:  ELBOW SMOOTH RADIUS RECTANGULAR WITH SPLITTERS C
C*****************************************************************C
C     REF. ASHRAE HANDBOOK, PAGE 33.32 & 33.33, TABLE B-3, FITTING 3-7 C
C     USES TABLE INTERPOLATION SCHEME                             C
C     THIS IS A SHORT FITTING, MEASURE CONNECTING DUCT TO THE CENTER C
C     OF THIS FITTING TO INCLUDE FRICTION.                        C
C*****************************************************************C
      SUBROUTINE FIT08 (SORL,GEOM,WKI,WKR)
      REAL WKR,H,W,R,THETA,KTHETA,AREA,X,C,CPRIME,T1,T2,T3
      INTEGER WKI,N,XOUT,SORL,GEOM
      DIMENSION WKI(2),WKR(4),X(2),T1(100),T2(100),T3(100),XOUT(2)
C     ONE SPLITTER
      DATA T1/8.00,10.00, 0.25,0.50,1.00,1.50,2.00,3.00,4.00,5.00,
     +             0.55,0.60,0.65,0.70,0.75,0.80,0.85,0.90,0.95,1.00,
     +             0.52,0.40,0.43,0.49,0.55,0.66,0.75,0.84,
     +             0.36,0.27,0.25,0.28,0.30,0.35,0.39,0.42,
     +             0.28,0.21,0.18,0.19,0.20,0.22,0.25,0.26,
     +             0.22,0.16,0.14,0.14,0.15,0.16,0.17,0.18,
     +             0.18,0.13,0.11,0.11,0.11,0.12,0.13,0.14,
     +             0.15,0.11,0.09,0.09,0.09,0.09,0.10,0.10,
     +             0.13,0.09,0.08,0.07,0.07,0.08,0.08,0.08,
     +             0.11,0.08,0.07,0.06,0.06,0.06,0.06,0.07,
     +             0.10,0.07,0.06,0.05,0.05,0.05,0.05,0.05,
     +             0.09,0.06,0.05,0.05,0.04,0.04,0.04,0.05/
C     TWO SPLITTERS
      DATA T2/8.00,10.00, 0.25,0.50,1.00,1.50,2.00,3.00,4.00,5.00,
     +             0.55,0.60,0.65,0.70,0.75,0.80,0.85,0.90,0.95,1.00,
     +             0.26,0.20,0.22,0.25,0.28,0.33,0.37,0.41,
     +             0.17,0.13,0.11,0.12,0.13,0.15,0.16,0.17,
     +             0.12,0.09,0.08,0.08,0.08,0.09,0.10,0.10,
     +             0.09,0.07,0.06,0.05,0.06,0.06,0.06,0.06,
     +             0.08,0.05,0.04,0.40,0.04,0.04,0.05,0.05,
     +             0.06,0.04,0.03,0.03,0.03,0.03,0.03,0.03,
     +             0.05,0.04,0.03,0.03,0.03,0.03,0.03,0.03,
     +             0.05,0.03,0.03,0.02,0.02,0.02,0.02,0.02,
     +             0.04,0.03,0.03,0.02,0.02,0.02,0.02,0.02,
     +             0.03,0.02,0.02,0.02,0.02,0.01,0.01,0.01/
C     THREE SPLITTERS
      DATA T3/8.00,10.00, 0.25,0.50,1.00,1.50,2.00,3.00,4.00,5.00,
     +             0.55,0.60,0.65,0.70,0.75,0.80,0.85,0.90,0.95,1.00,
     +             0.11,0.10,0.12,0.13,0.14,0.16,0.18,0.19,
     +             0.07,0.05,0.06,0.06,0.06,0.07,0.07,0.08,
     +             0.05,0.04,0.04,0.04,0.04,0.04,0.04,0.04,
     +             0.03,0.03,0.03,0.03,0.03,0.03,0.03,0.03,
     +             0.03,0.02,0.02,0.02,0.02,0.02,0.02,0.02,
     +             0.03,0.02,0.02,0.02,0.02,0.01,0.01,0.01,
     +             0.02,0.02,0.01,0.01,0.01,0.01,0.01,0.01,
     +             0.02,0.01,0.01,0.01,0.01,0.01,0.01,0.01,
     +             0.01,0.01,0.01,0.01,0.01,0.01,0.01,0.01,
     +             0.01,0.01,0.01,0.01,0.01,0.01,0.01,0.01/
      WRITE(6,600)
C     HOW MANY SPLITTERS ???
10    WRITE(6,601)
      CALL READI(N,5)
      IF((N.LT.1).OR.(N.GT.3)) GO TO 10
      WRITE(6,602)
      CALL READR(H,5)
      WRITE(6,603)
      CALL READR(W,5)
      WRITE(6,604)
      CALL READR(R,5)
      WRITE(6,605)
      CALL READR(THETA,5)
      KTHETA=0.0306*THETA**0.7825
      X(1)=H/W
      X(2)=R/W
      AREA=H*W
      GO TO (20,30,40),N
```

```
20    CALL TABLE (T1,X,XOUT,CPRIME)
      GO TO 50
30    CALL TABLE (T2,X,XOUT,CPRIME)
      GO TO 50
40    CALL TABLE (T3,X,XOUT,CPRIME)
50    CONTINUE
      IF((XOUT(1).GT.0).OR.(XOUT(2).GT.0)) GO TO 60
      WRITE(6,606)
      GO TO 10
60    C=CPRIME*KTHETA
      WKI(1)=GEOM
      WKI(2)=3
      WKR(1)=AREA
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=AREA
600   FORMAT('  YOU HAVE SELECTED A SMOOTH RADIUS RECTANGULAR ELBOW WITH
     + SPLITTERS.'/'  IT MAY HAVE 1, 2, OR 3 SPLITTERS.')
601   FORMAT('  **FIRST QUESTION, HOW MANY SPLITTERS ARE IS THE ELBOW (1
     +,2,OR 3)?')
602   FORMAT('  WHAT IS THE HEIGHT OF THE ELBOW?'/
     +'      (THE CROSS-SECTIONAL DIMENSION PARALLEL TO THE TURN AXIS)')
603   FORMAT('  WHAT IS THE WIDTH OF THE ELBOW (THE CROSS-SECTIONAL'/
     +'      DIMENSION IN THE PLANE OF THE TURN)?')
604   FORMAT('  WHAT IS THE RADIUS OF THE ELBOW, MEASURED TO THE CENTER'
     +/'      OF THE ELBOW CROSS-SECTION?')
605   FORMAT('  LAST QUESTION, WHAT IS THE ANGLE OF THE TURN (0-90 DEGR
     +EES)?')
606   FORMAT('  CROSS-SECTION EXTREMELY NARROW, RE-ENTER BETTER DATA.')
      RETURN
      END
```

```
C********************************************************************C
C     FITTING 09:  ELBOW MITERED RECTANGULAR WITH VANES              C
C********************************************************************C
C     REF. ASHRAE HANDBOOK, PAGE 33.32, TABLE 3-3, FITTING 3-8       C
C     GIVES COEFFICIENT AS A FUNCTION OF NUMBER OF VANES             C
C     SHORT FITTING, DYNAMIC LOSSES ONLY.  MEASURE CONNECTING DUCTS  C
C     TO THE CENTER OF THIS FITTING TO INCLUDE FRICTION.             C
C********************************************************************C
      SUBROUTINE FIT09 (SORL,GEOM,WKI,WKR)
      REAL WKR,C,AREA
      INTEGER SORL,GEOM,WKI,N
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READI(N,5)
      GO TO (10,20,30),N
 10   C=0.12
      GO TO 40
 20   C=0.15
      GO TO 40
 30   C=0.18
 40   CONTINUE
      WRITE(6,601)
      CALL READR(AREA,5)
      WKI(1)=GEOM
      WKI(2)=9
      WKR(1)=AREA
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=AREA
 600  FORMAT('  YOU HAVE SELECTED A MITERED RECTANGULAR ELBOW WITH'/
     +'  SINGLE THICKNESS VANES.  THERE MAY BE 1, 2, OR 3 VANES.'/
     +'  **FIRST QUESTION, HOW MANY VANES (1,2,OR 3)?')
 601  FORMAT('  LAST QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE E
     +LBOW?')
      RETURN
      END
```

```
C*********************************************************************C
C      FITTING 10: ELBOW RECTANGULAR WITH CONVERGING OR DIVERGING FLOW  C
C*********************************************************************C
C      REF. ASHRAE HANDBOOK, PAGE 33.32, TABLE B-3, FITTING 3-10       C
C      TABLE INTERPOLATION                                             C
C      SHORT FITTING, DYNAMIC LOSSES ONLY. MEASURE CONNECTING DUCT TO  C
C      THE CENTER OF THIS FITTING TO INCLUDE FRICTION.                 C
C*********************************************************************C
       SUBROUTINE FIT10 (SORL,GEOM,WKI,WKR)
       REAL WKR,C,AREA,DH,X,CPRIME,W0,W1,H0
       INTEGER WKI,SORI,GEOM,N
       DIMENSION WKI(2),WKR(4),T(36),X(2),XOUT(2)
       DATA T/6.00,4.00,   0.60,0.80,1.20,1.40,1.60,2.00,
      +                    0.25,1.00,4.00,1000.00,
      +                    1.80,1.40,1.10,1.10,1.10,1.10,
      +                    1.70,1.40,1.00,0.95,0.90,0.84,
      +                    1.50,1.10,0.81,0.76,0.72,0.66,
      +                    1.50,1.00,0.69,0.63,0.60,0.55/
       WRITE(6,600)
 10    WRITE(6,601)
       CALL READR(H0,5)
       WRITE(6,602)
       CALL READR(W0,5)
       WRITE(6,603)
       CALL READR(W1,5)
       X(1)=W1/W0
       X(2)=H0/W0
       CALL TABLE(T,X,XOUT,CPRIME)
       IF((XOUT(1).GT.0).OR.(XOUT(2).GT.0)) GO TO 20
       WRITE(6,604)
       GO TO 10
 20    DH=2.0*(H0*W0)/(H0+W0)
       AREA=H0*W0
       WKI(1)=GEOM
       WKI(2)=10
       WKR(1)=AREA
       WKR(2)=DH
       WKR(3)=CPRIME
       WKR(4)=W1*H0
 600   FORMAT('  YOU HAVE SELECTED A 90 DEGREE RECTANGULAR ELBOW WITH'/
      +'   EITHER CONVERGING OR DIVERGING FLOW.  THE HEIGHT (DIMENSION'/
      +'   PARALLEL TO THE TURN AXIS) SHOULD REMAIN CONSTANT.')
 601   FORMAT('  **FIRST QUESTION, WHAT IS THE CROSS-SECTIONAL INLET HEIG
      +HT?')
 602   FORMAT('  WHAT IS THE CROSS-SECTIONAL OUTLET HEIGHT (DIMENSION IN
      +THE PLANE OF THE TURN)?')
 603   FORMAT('  LAST QUESTION, WHAT IS THE CROSS-SECTIONAL EXIT WIDTH?')
 604   FORMAT('  CROSS-SECTION EXTREMELY NARROW, RE-ENTER BETTER DATA.')
       RETURN
       END
```

```
C**********************************************************************C
C      FITTING 11:  ELBOWS 90 DEGREE RECTANGULAR IN Z-SHAPED CONFIG.   C
C**********************************************************************C
C      REF. ASHRAE HANDBOOK, PAGE 33.32, TABLE B-3, FITTING 3-11       C
C      CURVE FIT TO THE TABLE DATA                                     C
C                                                                      C
C                                                                      C
C**********************************************************************C
       SUBROUTINE FIT11 (SORL,GEOM,WKI,WKR)
       REAL WKR,C,AREA,DH,L,W,H,CPRIME,X,Y,K
       INTEGER SORL,GEOM,WKI
       DIMENSION WKI(2),WKR(4)
       WRITE(6,600)
       CALL READR(H,5)
       WRITE(6,601)
       CALL READR(W,5)
       WRITE(6,602)
       CALL READR(L,5)
       X=L/H
       Y=W/H
       IF((X.GT.0.0).AND.(X.LT.2.8)) GO TO 10
       C=3.4547-0.0992*X
       GO TO 20
10     C=(((0.85045*X)-5.21052)*X+9.1399)*X-2.168)*X+0.0545
20     CONTINUE
       K=0.4704*EXP(-0.3558*Y)+0.67
       CPRIME=C*K
       DH=2.0*(H*W)/(H+W)
       AREA=H*W
       WKI(1)=GEOM
       WKI(2)=11
       WKR(1)=AREA
       WKR(2)=DH
       WKR(3)=CPRIME
       WKR(4)=AREA
600    FORMAT('  YOU HAVE SELECTED A SERIES 90 DEGREE RECTANGULAR ELBOW'/
      +'  SET IN A Z-SHAPED CONFIGURATION.'/'  **FIRST QUESTION, WHAT IS
      +THE HEIGHT OF THE ELBOW CROSS-SECTION?'/'    (DIMENSION IN THE PLA
      +NE OF THE TURN)')
601    FORMAT('  WHAT IS THE WIDTH OF THE ELBOW CROSS-SECTION?'/
      +'    (THE DIMENSION PARALLEL TO THE TURN AXIS)')
602    FORMAT('  LAST QUESTION, WHAT IS THE LENGTH BETWEEN CENTERLINES'/
      +'  OF THE "Z" ENTRANCE AND "Z" EXIT?')
       RETURN
       END
```

```
C**********************************************************************C
C      FITTING 12: ELBOWS 90 DEGREE IN DIFFERENT PLANES                C
C**********************************************************************C
C      REF. ASHRAE HANDBOOK, PAGE 33.33, TABLE B-3, FITTING 3-12       C
C      CURVE FIT TO THE TABULATED DATA                                 C
C                                                                      C
C                                                                      C
C**********************************************************************C
      SUBROUTINE FIT12 (SORL,GEOM,WKI,WKR)
      REAL WKR,C,AREA,DH,L,W,H,CPRIME,X,Y,K
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(H,5)
      WRITE(6,601)
      CALL READR(W,5)
      WRITE(6,602)
      CALL READR(L,5)
      X=L/H
      Y=W/H
      IF((X.GT.0.0).AND.(X.LT.1.4)) GO TO 10
      IF((X.GE.1.4).AND.(X.LT.2.0)) GO TO 20
      IF((X.GE.2.0).AND.(X.LT.4.0)) GO TO 30
      C=3.4-0.10*X
      GO TO 40
10    C=((((1.79343*X)-5.47366)*X+3.5957)*X+2.29846)*X+1.20
      GO TO 40
20    C=(((1.04166*X)-5.35713)*X+8.60118)*X-1.0057
      GO TO 40
30    C=(((0.00983*X)-0.246799)*X+1.154425)*X+1.702965
40    CONTINUE
      K=0.4704*EXP(-0.3558*Y)+0.67
      CPRIME=C*K
      DH=2.0*(H*W)/(H+W)
      AREA=H*W
      WKI(1)=GEOM
      WKI(2)=12
      WKR(1)=AREA
      WKR(2)=DH
      WKR(3)=CPRIME
      WKR(4)=AREA
600   FORMAT('  YOU HAVE SELECTED A SET OF 90 DEGREE RECTANGULAR ELBOWS
     +IN DIFFERENT PLANES.'/'  **FIRST QUESTION, WHAT IS THE HEIGHT OF T
     +HE ELBOW CROSS-SECTION?'/'    (DIMENSION IN THE PLANE OF THE TURN
     +)')
601   FORMAT('  WHAT IS THE WIDTH OF THE ELBOW CROSS-SECTION?'/
     +'    (THE DIMENSION PARALLEL TO THE TURN AXIS)')
602   FORMAT('  LAST QUESTION, WHAT IS THE LENGTH BETWEEN CENTERLINES'/
     +'  OF THE "Z" ENTRANCE AND "Z" EXIT?')
      RETURN
      END
```

```
C**************************************************************C
C     FITTING 13:  BRANCH SECTION DIVERGING WYE                C
C**************************************************************C
C     REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN  C
C     PAGES 247-253                                            C
C                                                              C
C                                                              C
C                                                              C
C**************************************************************C
      SUBROUTINE FIT13(SORL,GEOM,WKI,WKR)
      REAL WKR,ALFAD,AC,AB
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(ALFAD,5)
      WRITE(6,601)
      CALL READR(AC,5)
      WRITE(6,602)
      CALL READR(AB,5)
      WKI(1)=GEOM
      WKI(2)=13
      WKR(1)=AC
      WKR(2)=AB
      WKR(3)=ALFAD
      WKR(4)=AB
 600  FORMAT('  YOU HAVE SELECTED THE BRANCH SECTION OF A DIVERGENT WYE.
     +'/'  THE MODULE COOLING AIR SHOULD BE BRANCHING OFF THE MAIN'/
     +'  INLET AND FLOWING THROUGH THIS SECTION.  THIS SHOULD BE THE '/
     +'  FIRST FITTING OF THIS BRANCH.'/
     +'  **FIRST QUESTION, WHAT IS THE ANGLE BETWEEN THE MAIN FLOW '/
     +'  AXIS AND THE BRANCH FLOW AXIS (DEGREES) ?')
 601  FORMAT('  WHAT IS THE CROSS-SECTIONAL AREA OF THE COMBINED FLOW'/
     +'  SECTION?  THIS IS WHERE BOTH ENGINE AIR AND COOLING AIR FLOW'/
     +'  JUST UPSTREAM OF THE BRANCH.')
 602  FORMAT('  LAST QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE B
     +RANCH?')
      RETURN
      END
```

```
C**********************************************************************C
C     FITTING 14:  MAIN SECTION DIVERGING WYE                          C
C**********************************************************************C
C     REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN  C
C     PAGES 247-253                                                    C
C                                                                      C
C                                                                      C
C**********************************************************************C
      SUBROUTINE FIT14(SORL,GEOM,WKI,WKR)
      REAL WKR,AM
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(AM,5)
      WKI(1)=GEOM
      WKI(2)=14
      WKR(1)=AM
      WKR(2)=0.0
      WKR(3)=0.0
      WKR(4)=AM
  600 FORMAT('  YOU HAVE SELECTED THE MAIN SECTION OF A DIVERGING WYE.'/
     +'  THE AIR TO THE ENGINE SHOULD BE FLOWING THROUGH THIS SECTION.'/
     +'  JUST ONE QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE '/
     +'  MAIN SECTION?  THIS SHOULD BE THE AREA JUST DOWNSTREAM OF THE'/
     +'  JUNCTION AND DIRECTS FLOW TO THE ENGINE.  IT ALSO SHOULD BE'/
     +'  THE FIRST FITTING OF THE BRANCH.')
      RETURN
      END
```

```
C*****************************************************************C
C     FITTING 15:  BRANCH SECTION CONVERGING WYE                  C
C*****************************************************************C
C     REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN  C
C     PAGES 247-253                                               C
C                                                                 C
C                                                                 C
C                                                                 C
C*****************************************************************C
      SUBROUTINE FIT15(SORL,GEOM,WKI,WKR)
      REAL WKR,ALFAC,AC,AB
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(ALFAC,5)
      WRITE(6,601)
      CALL READR(AC,5)
      WRITE(6,602)
      CALL READR(AB,5)
      WKI(1)=GEOM
      WKI(2)=15
      WKR(1)=AC
      WKR(2)=AB
      WKR(3)=ALFAC
      WKR(4)=AB
600   FORMAT('  YOU HAVE SELECTED THE BRANCH SECTION OF A CONVERGENT '/
     +'  WYE.  THE HOT MODULE CCOLING AIR SHOULD BE JOINING THE MAIN'/
     +'  ENGINE EXHAUST IN THIS WYE.  THIS FITTING SHOULD BE THE LAST'/
     +'  FITTING IN THE BRANCH.'/
     +'  **FIRST QUESTION, WHAT IS THE ANGLE BETWEEN THE MAIN FLOW '/
     +'     AXIS AND THE BRANCH AXIS (DEGREES)?')
601   FORMAT('  WHAT IS THE CROSS-SECTIONAL AREA OF THE COMBINED FLOW'/
     +'  SECTION?  THIS IS WHERE ENGINE EXHAUST AND MODULE COOLING AIR'/
     +'  FLOW JUST DOWNSTREAM OF THEBRANCH.')
602   FORMAT('  LAST QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE'/
     +'  BRANCH?')
      RETURN
      END
```

```
C************************************************************************C
C     FITTING 16: MAIN SECTION CONVERGING WYE                            C
C************************************************************************C
C     REF.  IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN   C
C     PAGES 247-253                                                      C
C                                                                        C
C                                                                        C
C************************************************************************C
      SUBROUTINE FIT16(SORL,GEOM,WKI,WKR)
      REAL WKR,AM
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(AM,5)
      WKI(1)=GEOM
      WKI(2)=16
      WKR(1)=AM
      WKR(2)=0.0
      WKR(3)=0.0
      WKR(4)=AM
 600  FORMAT('   YOU HAVE SELECTED THE MAIN SECTION OF A CONVERGING'/
     +'     WYE.  THE ENGINE EXHAUST ALONE SHOULD BE FLOWING THROUGH '/
     +'   THIS SECTION.  IT SHOULD BE THE LAST FITTING OF THE BRANCH.'/
     +'   **JUST ONE QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE'/
     +'     MAIN BRANCH?')
      RETURN
      END
```

```
C*****************************************************************C
C      FITTING 17: CONCIAL DIFFUSER                               C
C*****************************************************************C
C      REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE,  C
C      PAGE 167                                                   C
C                                                                 C
C                                                                 C
C*****************************************************************C
       SUBROUTINE FIT17(SORL,GEOM,WKI,WKR)
       REAL WKR,L,D0,D1,K1,K2,A0,A1,THETA,CEXP,CFRPRI
       INTEGER GEOM,SORL,WKI,ANS,YES,NO
       DIMENSION WKI(2),WKR(4)
       DATA YES/'Y'/,NO/'N'/
       WRITE(6,600)
       CALL READR(L,5)
 10    WRITE(6,601)
       CALL READR(D0,5)
       WRITE(6,602)
       CALL READR(D1,5)
 12    WRITE(6,603)
       READ(5,604,END=14,ERR=14) ANS
       IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 16
 14       REWIND 5
          WRITE (6,608)
          GO TO 12
 16    CONTINUE
       K1=1.0
       IF(ANS.EQ.YES) K1=6.8
       A0=0.7854*D0**2
       A1=0.7854*D1**2
       IF(A1.GT.A0) GO TO 20
       WRITE(6,605)
       GO TO 10
 20    THETA=2.0*ATAN((D1-D0)/(2.0*L))
       IF(THETA.LT.0.524) GO TO 30
 22    WRITE(6,606)
       READ(5,604,ERR=24,END=24) ANS
       IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 26
 24       REWIND 5
          WRITE (6,608)
          GO TO 22
 26    CONTINUE
       K2=1.0
       IF(ANS.EQ.YES) K2=0.65
 30    IF(THETA.GT.0.7) GO TO 40
       CEXP=1.3454*(THETA**1.2)*(1.0-A0/A1)**2
       GO TO 60
 40    IF(THETA.GT.1.05) GO TO 50
       CEXP=((((-0.3637*THETA)-0.8715)*THETA+3.0218)*THETA-0.6410)*
      +     (1.0-A0/A1)**2
       GO TO 60
 50    CEXP=((((-0.0061*THETA)-0.0139)*THETA-0.09293)*THETA+1.2623)*
      +     (1.0-A0/A1)**2
 60    CONTINUE
       WRITE(6,607)
       CFRPRI=(1.0-(A0/A1)**2)/(8.0*SIN(THETA/2.0))
       WKI(1)=GEOM
       WKI(2)=17
       WKR(1)=A0
       WKR(2)=CFRPRI*K2
       WKR(3)=CEXP*K1*K2
       WKR(4)=A1
 600   FORMAT('   YOU HAVE SELECTED A CONICAL DIFFUSER WITH CIRCULAR '/
      +       '   INLET AND OUTLET SECTIONS.'/
      +       '   **FIRST QUESTION, WHAT IS THE LENGTH OF THE DIFUSER?')
 601   FORMAT('   WHAT IS THE INLET DIAMETER?')
 602   FORMAT('   WHAT IS THE OUTLET DIAMETER?')
 603   FORMAT('   IS THERE A NON-UNIFORM VELOCITY DISTRIBUTION AT THE INLE
      +T (Y/N)?')
```

```
604   FORMAT(A1)
605   FORMAT('    DOWNSTREAM AREA IS NOT GREATER THAN UPSTREAM AREA.'/
     +'     FITTING IS NOT A DIFFUSER.  RE-ENTER DIAMETERS.')
606   FORMAT('    SINCE THERE IS A WIDE DIVERGING ANGLE, THE PROPER'/
     +'     INSTALLATION OF DIVIDING WALLS OR BAFFLES CAN REDUCE'/
     +      '  THE RESISTANCE OF THIS FITTING.  DO YOU WANT TO INSTALL'/
     +      '  DIVIDING WALLS OR BAFFLES (Y/N)?')
607   FORMAT('    NO MORE QUESTIONS THIS FITTING.')
608   FORMAT('    YOU MUST ENTER A LETTER IN THE BRACKETS.')
      RETURN
      END
```

```
C***********************************************************************C
C       FITTING 18: PLANE IN-LINE DIFFUSER                              C
C***********************************************************************C
C       REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE, C
C       PAGE 171                                                        C
C                                                                       C
C                                                                       C
C***********************************************************************C
        SUBROUTINE FIT18(SCRL,GEOM,WKI,WKR)
        REAL WKR,L,H,W0,W1,K1,K2,A0,A1,THETA,CEXP,CPRPRI
        INTEGER GEOM,SCRL,WKI,ANS,YES,NO
        DIMENSION WKI(2),WKR(4)
        DATA YES/'Y'/,NO/'N'/
        WRITE(6,600)
        CALL READR(L,5)
        WRITE(6,601)
        CALL READR(H,5)
 10     WRITE(6,602)
        CALL READR(W0,5)
        WRITE(6,603)
        CALL READR(W1,5)
 12     WRITE(6,604)
        READ(5,605,END=14,ERR=14) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 16
 14        REWIND 5
           WRITE (6,609)
           GO TO 12
 16     CONTINUE
        K1=1.0
        IF(ANS.EQ.YES) K1=6.8
        A0=W0*H
        A1=W1*H
        IF(A1.GT.A0) GO TO 20
        WRITE(6,606)
        GO TO 10
 20     THETA=2.0*ATAN((W1-W0)/(2.0*L))
        IF(THETA.LT.0.524) GO TO 30
 22     WRITE(6,607)
        READ(5,605,END=24,ERR=24) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 26
 24        REWIND 5
           WRITE (6,609)
           GO TO 22
 26     CONTINUE
        K2=1.0
        IF(ANS.EQ.YES) K2=0.65
 30     IF(THETA.GT.0.7) GO TO 40
        CEXP=1.3454*(THETA**1.2)*(1.0-A0/A1)**2
        GO TO 60
 40     IF(THETA.GT.1.05) GO TO 50
        CEXP=((((0.3637*THETA)-0.8715)*THETA+3.0218)*THETA-0.5410)*
     +        (1.0-A0/A1)**2
        GO TO 60
 50     CEXP=((((-0.0061*THETA)-0.0139)*THETA-0.0929)*THETA+1.2623)*
     +        (1.0-A0/A1)**2
 60     CONTINUE
        CPRPRI=((W0/H)*(1.0-A0/A1)+0.5*(1.0-(A0/A1)**2))/
     +         (4.0*SIN(THETA/2.0))
        WRITE(6,608)
        WKI(1)=GEOM
        WKI(2)=18
        WKR(1)=A0
        WKR(2)=CPRPRI*K2
        WKR(3)=CEXP*K1*K2
        WKR(4)=A1
 600    FORMAT('   YOU HAVE SELECTED A PLANE INLINE DIFFUSER WITH ONE'/
     +         '   DIMENSION CONSTANT THROUGHOUT AND RECTANGULAR INLET'/
     +         '   AND OUTLET.'/
     +         '   **FIRST QUESTION, WHAT IS THE LENGTH OF THE DIFFUSER?')
```

```
601  FORMAT('   WHAT IS THE CONSTANT HEIGHT OF THE INLET AND OUTLET '/
    +       '   CROSS-SECTIONAL AREAS?')
602  FORMAT('   WHAT IS THE WIDTH OF THE INLET CROSS-SECTIONAL AREA?')
603  FORMAT('   WHAT IS THE WIDTH OF THE OUTLET CROSS-SECTIONAL AREA?')
604  FORMAT('   IS THERE A NCN-UNIFORM VELOCITY DISTRIBUTION AT THE INLE
    +T (Y/N)?')
605  FORMAT(A1)
606  FORMAT('   DOWNSTREAM AREA IS NOT GREATER THAN UPSTREAM AREA.'/
    +       '   FITTING IS NOT A DIFFUSER.  RE-ENTER DATA.')
607  FORMAT('   SINCE THERE IS A WIDE DIVERGING ANGLE, THE PROPER'/
    +       '   INSTALLATIONS OF DIVIDING WALLS OR BAFFLES CAN REDUCE'/
    +       '  THE RESISTANCE OF THIS FITTING.  DO YOU WANT TO INSTALL'/
    +       '  DIVIDING WALLS OR BAFFLES (Y/N)?')
608  FORMAT('   NO MORE QUESTIONS THIS FITTING.')
609  FORMAT('   YOU MUST ENTER A LETTER IN THE BRACKETS.')
     RETURN
     END
```

```
C*****************************************************************C
C     FITTING 19:  PYRAMIDAL DIFFUSER, IN LINE                    C
C*****************************************************************C
C     REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE,  C
C     PAGE 169                                                    C
C                                                                 C
C                                                                 C
C*****************************************************************C
      SUBROUTINE FIT19(SORL,GEOM,WKI,WKR)
      REAL WKR,L,H0,W0,H1,W1,K1,K2,A0,A1,ALFA,BETA,THETA,CEXP,CFRPRI
      INTEGER GEOM,SORL,WKI,ANS,YES,NO
      DIMENSION WKI(2),WKR(4)
      DATA YES/'Y'/,NO/'N'/
      WRITE(6,600)
      CALL READR(L,5)
10    WRITE(6,601)
      CALL READR(H0,5)
      WRITE(6,602)
      CALL READR(W0,5)
      WRITE(6,603)
      CALL READR(H1,5)
      WRITE(6,604)
      CALL READR(W1,5)
12    WRITE(6,605)
      READ(5,606,END=14,ERR=14) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 16
14       REWIND 5
         WRITE (6,610)
         GO TO 12
16    CONTINUE
      K1=1.0
      IF(ANS.EQ.YES) K1=6.8
      A0=W0*H0
      A1=W1*H1
      IF(A1.GT.A0) GO TO 20
      WRITE(6,607)
      GO TO 10
20    ALFA=2.0*ATAN((W1-W0)/(2.0*L))
      BETA=2.0*ATAN((H1-H0)/(2.0*L))
      THETA=AMAX1(ALFA,BETA)
      IF(THETA.LT.0.524) GO TO 30
22    WRITE(6,608)
      READ(5,606,END=24,ERR=24) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 26
24       REWIND 5
         WRITE (6,610)
         GO TO 22
26    CONTINUE
      K2=1.0
      IF(ANS.EQ.YES) K2=0.65
30    IF(THETA.GT.0.44) GO TO 40
      CEXP=1.6818*(THETA**1.2)*(1.0-A0/A1)**2
      GO TO 60
40    IF(THETA.GT.1.05) GO TO 50
      CEXP=((((3.3598*THETA)-9.7924)*THETA+9.4559)*THETA-1.9220)*
     +     (1.0-A0/A1)**2
      GO TO 60
50    CEXP=1.1*(1.0-A0/A1)**2
60    CONTINUE
      CFRPRI=(1.0-(A0/A1)**2)/(8.0*SIN(THETA/2.0))
      WRITE(6,609)
      WKI(1)=GEOM
      WKI(2)=19
      WKR(1)=A0
      WKR(2)=CFRPRI*K2
      WKR(3)=CEXP*K1*K2
      WKR(4)=A1
600   FORMAT('  YOU HAVE SELECTED A PYRAMIDAL INLINE RECTANGULAR DIFFUSE
     +R.'/'  **FIRST QUESTION, WHAT IS THE LENGTH OF THE DIFFUSER/')
```

```
601   FORMAT('   WHAT IS THE SMALLER DIMENSION OF THE INLET AREA?')
602   FORMAT('   WHAT IS THE LARGER DIMENSION OF THE INLET AREA?')
603   FORMAT('   WHAT IS THE DIMENSION OF THE OUTLET AREA PARALLEL'/
     +       '   TO THE SMALLER INLET AREA DIMENSION?')
604   FORMAT('   WHAT IS THE DIMENSION OF THE OUTLET AREA PARALLEL'/
     +       '   TO THE LARGER INLET AREA DIMENSION?')
605   FORMAT('   IS THERE A NON-UNIFORM VELOCITY DISTRIBUTION AT THE INLE
     +T (Y/N)?')
606   FORMAT(A1)
607   FORMAT('   DOWNSTREAM AREA IS NOT GREATER THAN UPSTREAM AREA.'/
     +       '   FITTING IS NOT A DIFFUSER.  RE-ENTER DATA.')
608   FORMAT('   SINCE THERE IS A WIDE DIVERGING ANGLE, THE PROPER'/
     +       '   INSTALLATIONS OF DIVIDING WALLS OR BAFFLES CAN REDUCE'/
     +       '  THE RESISTANCE OF THIS FITTING.  DO YOU WANT TO INSTALL'/
     +       '  DIVIDING WALLS OR BAFFLES (Y/N)?')
609   FORMAT('   NO MORE QUESTIONS THIS FITTING.')
610   FORMAT('   YOU MUST ENTER A LETTER IN THE BRACKETS.')
      RETURN
      END
```

```
C*********************************************************************C
C         FITTING 20:  TRANSITIONAL DIFFUSER                          C
C*********************************************************************C
C         REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE, C
C         PAGE 174                                                    C
C                                                                     C
C                                                                     C
C*********************************************************************C
      SUBROUTINE FIT20(SORL,GEOM,WKI,WKR)
      REAL WKR,L,H,W,D,THETA,A0,A1,K1,K2,CEXP,CPRPRI
      INTEGER SORL,GEOM,WKI,ANS,YES,NO
      DIMENSION WKI(2),WKR(4)
      DATA YES/'Y'/,NO/'N'/
      WRITE(6,600)
 10   WRITE(6,601)
      READ(5,602,END=14,ERR=14) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 16
 14      REWIND 5
         WRITE (6,611)
         GO TO 10
 16   CONTINUE
      WRITE(6,603)
      CALL READR(L,5)
      WRITE(6,604)
      CALL READR(H,5)
      WRITE(6,605)
      CALL READR(W,5)
      WRITE(6,606)
      CALL READR(D,5)
      IF(ANS.EQ.YES) GO TO 30
      A0=H*W
      A1=0.7854*D**2
      IF(A1.GT.A0) GO TO 20
      WRITE(6,607)
      GO TO 10
 20   THETA=(D-2.0*SQRT(H*W/3.1416))/L
      GO TO 50
 30   A1=H*W
      A0=0.7854*D**2
      IF(A1.GT.A0) GO TO 40
      WRITE(6,607)
      GO TO 10
 40   THETA=(2.0*SQRT(H*W/3.1416-D))/L
 50   CONTINUE
 52   WRITE(6,608)
      READ(5,602,END=54,ERR=54) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 56
 54      WRITE (6,611)
         GO TO 52
 56   CONTINUE
      K1=1.0
      IF(ANS.EQ.YES) K1=6.8
      IF(THETA.LT.0.524) GO TO 60
      WRITE(6,609)
      READ(5,602) ANS
      K2=1.0
      IF(ANS.EQ.YES) K2=0.65
 60   IF(THETA.GT.0.44) GO TO 70
      CEXP=1.5818*(THETA**1.2)*(1.0-A0/A1)**2
      GO TO 90
 70   IF(THETA.GT.1.05) GO TO 80
      CEXP=((((3.3598*THETA)-9.7924)*THETA+9.4559)*THETA-1.9220)*
     +     (1.0-A0/A1)**2
      GO TO 90
 80   CEXP=1.1*(1.0-A0/A1)**2
 90   CONTINUE
      WRITE(6,610)
      CPRPRI=(1.0-(A0/A1)**2)/(8.0*SIN(THETA/2.0))
      WKI(1)=GEOM
```

```
      WKR(0)=20
      WKR(1)=A0
      WKR(2)=CPRPRI*K0
      WKR(3)=CEXP*K1*K2
      WKR(4)=A1
600   FORMAT('   YOU HAVE SELECTED A TRANSITIONAL DIFFUSER.  IT MAY BE'/
     +'     ROUND TO RECTANGULAR OR RECTANGULAR TO ROUND CROSS-SECTION.')
601   FORMAT('   **FIRST QUESTION, IS THIS FITTING ROUND TO RECTANGULAR?
     +'/'            (Y/N....NO MEANS RECTANGULAR TO ROUND)')
602   FORMAT(A1)
603   FORMAT('   WHAT IS THE LENGTH OF THE DIFFUSER?')
604   FORMAT('   WHAT IS THE HEIGHT OF THE RECTANGULAR CROSS-SECTIONAL AR
     +EA?')
605   FORMAT('   WHAT IS THE WIDTH OF THE RECTANGULAR CROSS-SECTIONAL ARE
     +A?')
606   FORMAT('   WHAT IS THE DIAMETER OF THE ROUND CROSS-SECTIONAL AREA?'
     +)
607   FORMAT('   DOWNSTREAM AREA IS NOT GREATER THAN THE UPSTREAM AREA.'/
     +      '   FITTING IS NOT A DIFFUSER.  RE-ENTER DATA.')
608   FORMAT('   IS THERE A NON-UNIFORM VELOCITY DISTRIBUTION AT THE INLE
     +T (Y/N)?')
609   FORMAT('   SINCE THERE IS A WIDE DIVERGING ANGLE, THE PROPER'/
     +      '   INSTALLATIONS OF DIVIDING WALLS OR BAFFLES CAN REDUCE'/
     +      '  THE RESISTANCE OF THIS FITTING.  DO YOU WANT TO INSTALL'/
     +      '  DIVIDING WALLS OR BAFFLES (Y/N)?')
610   FORMAT('   NO MORE QUESTIONS THIS FITTING.')
611   FORMAT('   YOU MUST ENTER A LETTER IN THE BRACKETS.')
      RETURN
      END
```

```
C*********************************************************************C
C      FITTING 21:  CIRCULAR CONTRACTION                              C
C*********************************************************************C
C      REF. ASHRAE HANDBOOK, PAGE 33.34, TABLE 8-5, FITTING 5-1       C
C      TABLE INTERPOLATION                                            C
C                                                                     C
C                                                                     C
C*********************************************************************C
      SUBROUTINE FIT21(SORL,GEOM,WKI,WKR)
      REAL WKR,D0,D1,L,THETA,T,C,A1,A0,X
      INTEGER SORL,GEOM,WKI,XOUT
      DIMENSION WKI(2),WKR(4),T(55),X(2),XOUT(2)
      DATA T/8.0,5.0,
     +       0.0,10.0,30.0,55.0,90.0,120.0,150.0,180.0,
     +        1.0,2.0,4.0,6.0,10.0,
     +       0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
     +       0.0,0.05,0.05,0.06,0.12,0.18,0.24,0.26,
     +       0.0,0.05,0.04,0.07,0.17,0.27,0.35,0.41,
     +       0.0,0.05,0.04,0.07,0.18,0.28,0.36,0.42,
     +       0.0,0.05,0.05,0.08,0.19,0.29,0.37,0.43/
      WRITE(6,600)
      CALL READR(L,5)
      IF(L.LT.0.05) L=0.05
      WRITE(6,601)
      CALL READR(D1,5)
      WRITE(6,602)
      CALL READR(D0,5)
      THETA=114.59156*ATAN((D1-D0)/(2.0*L))
      A1=0.7854*D1**2
      A0=0.7854*D0**2
      X(1)=THETA
      X(2)=A1/A0
      CALL TABLE(T,X,XOUT,C)
      WKI(1)=GEOM
      WKI(2)=21
      WKR(1)=A1
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=A0
600   FORMAT('  YOU HAVE SELECTED A CIRCULAR CONTRACTION.'/
     +     '  **FIRST QUESTION, WHAT IS THE LENGTH OF THE CONTRACTION?')
601   FORMAT('  WHAT IS THE UPSTREAM DIAMETER?')
602   FORMAT('  WHAT IS THE DOWNSTREAM DIAMETER?')
      RETURN
      END
```

```
C***********************************************************************C
C       FITTING 22:  RECTANGULAR CONTRACTION                            C
C***********************************************************************C
C       REF. ASHRAE HANDBOOK, PAGE 33.34, TABLE 3-5, FITTING 5-1        C
C       TABLE INTERPOLATION                                             C
C                                                                       C
C                                                                       C
C***********************************************************************C
        SUBROUTINE FIT22(SCRL,GEOM,WKI,WKR)
        REAL WKR,X,T,A1,B1,A0,B0,AREA1,AREA0,C,L,THETA1,THETA2,THETA
        INTEGER SCRL,GEOM,WKI,XOUT
        DIMENSION WKI(2),WKR(4),T(55),X(2),XOUT(2)
        DATA T/8.0,5.0,
     +         0.0,10.0,30.0,55.0,90.0,120.0,150.0,180.0,
     +         1.0,2.0,4.0,6.0,10.0,
     +         0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
     +         0.0,0.05,0.05,0.06,0.12,0.18,0.24,0.26,
     +         0.0,0.05,0.04,0.07,0.17,0.27,0.35,0.41,
     +         0.0,0.05,0.04,0.07,0.18,0.28,0.36,0.42,
     +         0.0,0.05,0.05,0.08,0.19,0.29,0.37,0.43/
        WRITE(6,600)
        CALL READR(L,5)
        IF(L.LT.0.05) L=0.05
        WRITE(6,601)
        CALL READR(A1,5)
        WRITE(6,602)
        CALL READR(B1,5)
        WRITE(6,603)
        CALL READR(A0,5)
        WRITE(6,604)
        CALL READR(B0,5)
        THETA1=114.59156*ATAN((A1-A0)/(2.0*L))
        THETA2=114.59156*ATAN((B1-B0)/(2.0*L))
        THETA=AMAX1(THETA1,THETA2)
        AREA1=A1*B1
        AREA0=A0*B0
        X(1)=THETA
        X(2)=AREA1/AREA0
        CALL TABLE(T,X,XOUT,C)
        WKI(1)=GEOM
        WKI(2)=22
        WKR(1)=AREA1
        WKR(2)=0.0
        WKR(3)=C
        WKR(4)=AREA0
  600   FORMAT('  YOU HAVE SELECTED A RECTANGULAR CONTRACTION.'/
     +  '  **FIRST QUESTION, WHAT IS THE LENGTH OF THE CONTRACTION?')
  601   FORMAT('  WHAT IS THE LEAST UPSTREAM CROSS-SECTION DIMENSION?')
  602   FORMAT('  WHAT IS THE GREATER UPSTREAM CROSS-SECTION DIMENSION?')
  603   FORMAT('  WHAT IS THE LEAST DOWNSTREAM CROSS-SECTION DIMENSION?')
  604   FORMAT('  LAST QUESTION, WHAT IS THE GREATER DOWNSTREAM'/
     +'  CROSS-SECTION DIMENSION?')
        RETURN
        END
```

```
C******************************************************************C
C     FITTING 23: SCREEN                                           C
C******************************************************************C
C     REF. ASHRAE HANDBOOK, PAGE 33.42, TABLE 8-7, FITTING 7-8     C
C     CURVE FIT TO TABULATED DATA, BASED ON DUCT AREA AND SCREEN   C
C     FREE FLOW AREA.                                              C
C                                                                  C
C******************************************************************C
      SUBROUTINE FIT23 (SORL,GEOM,WKI,WKR)
      REAL WKR,DUCTA,SCRNA,N,C
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      CALL READR(DUCTA,5)
      WRITE(6,601)
      CALL READR(SCRNA,5)
      N=SCRNA/DUCTA
      C=((((97.9021*N)-92.445)*N+32.066)*N-1.9557)*N+0.025
      WKI(1)=GEOM
      WKI(2)=23
      WKR(1)=DUCTA
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=DUCTA
600   FORMAT('  YOU HAVE SELECTED A SCREEN OBSTRUCTION IN THE DUCT.'/
     +       '  **FIRST QUESTION, WHAT IS THE DUCT CROSS-SECTIONAL AREA?')
601   FORMAT('  LAST QUESTION, WHAT IS THE FREE FLOW AREA OF THE SCREEN?
     +')
      RETURN
      END
```

```
C*******************************************************************C
C     FITTING 24: LOUVER ENTRANCE                                   C
C*******************************************************************C
C     REF. HANDBOOK OF HYDRAULIC RESISTANCE, IDEL'CHIK              C
C     CURVE FIT TO DYNAMIC LOSS INFORMATION, NO FRICTION INLUDED    C
C                                                                   C
C                                                                   C
C*******************************************************************C
      SUBROUTINE FIT24(SORL,GEOM,WKI,WKR)
      REAL DX,DB,N,DUCTA,F,C
      INTEGER WKI,SORL,GEOM
      DIMENSION WKI(2),WKR(4)
      WRITE (6,600)
      CALL READR(DX,5)
      WRITE (6,601)
      CALL READR(DB,5)
      WRITE (6,602)
      CALL READR(N,5)
      WRITE (6,603)
      CALL READR(DUCTA,5)
      F=N*DB/DX
      C=62.144*EXP(-4.47543*F)
      WKI(1)=GEOM
      WKI(2)=24
      WKR(1)=DUCTA
      WKR(2)=0.0
      WKR(3)=C
      WKR(4)=DUCTA
600   FORMAT('   YOU HAVE SELECTED A LOUVERED ENTRANCE.'/
     +       '   **FIRST QUESTION, WHAT IS THE DISTANCE ACROSS THE '/
     +       '   LOUVER OPENINGS?')
601   FORMAT('   WHAT IS THE DISTANCE BETWEEN THE LOUVERS, USE THE '/
     +       '   CLOSEST DISTANCE.')
602   FORMAT('   HOW MANY OPENINGS ARE THERE BETWEEN THE LOUVERS?')
603   FORMAT('   LAST QUESTION, WHAT IS THE AREA OF THE DUCT JUST'/
     +       '   INSIDE THE LOUVER ENTRANCE?')
      RETURN
      END
```

```
C**************************************************************C
C       FITTING 25:  INLET FILTER                              C
C**************************************************************C
C       REF. NAVSEA INLET DESIGN HANDBOOK                      C
C       DEFAULT SYSTEM, DD963 TYPE FILTER, CURVE FIT TO DATA   C
C       OPTIONAL FILTER, POWER CURVE FIT IS MADE TO PRESSURE LOSS DATA  C
C       BASED ON FACE VELOCITY ON FILTER.  DATA SUPPLIED BY USER.       C
C**************************************************************C
        SUBROUTINE FIT25(SCRL,GEOM,WKI,WKR)
        REAL WKR,AREA,VEL,DELP,XX,YY,SUMX,SUMY,SUMX2,SUMY2,SUMXY,A,B
        INTEGER SCRL,GEOM,WKI,N,ANS,YES,I,NPTS,NO
        DIMENSION WKI(2),WKR(4),VEL(10),DELP(10),XX(10),YY(10)
        DATA YES/'Y'/,NO/'N'/
        WRITE(6,600)
        CALL READR(AREA,5)
 2      WRITE(6,601)
        READ(5,602,END=4,ERR=4) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 6
 4          REWIND 5
            WRITE (6,607)
            GO TO 2
 6      CONTINUE
        IF(ANS.EQ.YES) GO TO 30
        WRITE(6,603)
        CALL READI(NPTS,5)
        DO 10 I=1,NPTS
            WRITE(6,604) I
            CALL READR(VEL(I),5)
            WRITE(6,605) I
            CALL READR(DELP(I),5)
            XX(I)=ALOG(VEL(I))
            YY(I)=ALOG(DELP(I))
 10     CONTINUE
        SUMX=0.0
        SUMY=0.0
        SUMX2=0.0
        SUMY2=0.0
        SUMXY=0.0
        DO 20 I=1,NPTS
            SUMX=SUMX+XX(I)
            SUMY=SUMY+YY(I)
            SUMX2=SUMX2+XX(I)**2
            SUMY2=SUMY2+YY(I)**2
            SUMXY=SUMXY+XX(I)*YY(I)
 20     CONTINUE
        N=FLOAT(NPTS)
        B=(N*SUMXY-SUMX*SUMY)/(N*SUMX2-(SUMX**2))
        A=EXP(SUMY/N-B*SUMX/N)
        WRITE(6,606)
        GO TO 40
 30     A=0.0167
        B=1.6287
        WRITE(6,606)
 40     CONTINUE
        WKI(1)=GEOM
        WKI(2)=25
        WKR(1)=AREA
        WKR(2)=A
        WKR(3)=B
        WKR(4)=AREA
 600    FORMAT('  YOU HAVE SELECTED THE INLET FILTER .'/
       +'   **FIRST QUESTION, WHAT IS THE TOTAL FACE AREA OF THE FILTER?')
 601    FORMAT('  DO YOU WANT TO USE THE DD963 TYPE FILTER IN THE DRY COND
       +ITION (Y/N)?')
 602    FORMAT(A1)
 603    FORMAT('  THE OPERATING CHARACTERISTICS OF YOUR FILTER WILL BE'/
       +'   DEFINED BY A  POWER CURVE FIT OF THE FORM:'//
       +'        DELTA PRESSURE = COEFA * FACE VELOCITY ** COEFB '//
       +'   APPLIED TO PERFORMANCE DATA TO BE INPUT BY THE USER.'/
```

```
     +'   ** HOW MANY DATA POINTS DO YOU HAVE (1 TO 9)?'/
     +'      DO NOT PUT IN THE POINT (0.0,0.0).')
604   FORMAT('   FACE VELOCITY (',I1,')=? (FEET PER SECOND)')
605   FORMAT('   DELTA PRESSURE (',I1,')=? (INCHES H2O)')
606   FORMAT('   NO MORE QUESTIONS.')
607   FORMAT('   YOU MUST ENTER A LETTER IN THE BRACKETS.')
      RETURN
      END
```

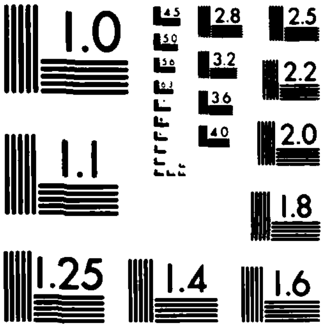
```
C***************************************************************************C
C       FITTING 26: SILENCER MULTI-BAFFLE TYPE                              C
C***************************************************************************C
C       REF. NAVSEA INLET DESIGN HANDBOOK                                   C
C       COMPOSITE LOSS COEFICIENT BASED ON A SUDDEN CONTRACTION,            C
C       FRICTION AND A SUDDEN EXPANSION                                     C
C                                                                           C
C***************************************************************************C
        SUBROUTINE FIT26(SORL,GEOM,WKI,WKR)
        REAL WKR,G,T,L,H,CX,A0,A1,DH,R,C1,C2,C3,C,N
        INTEGER SORL,GEOM,WKI
        DIMENSION WKI(2),WKR(4)
        WRITE(6,600)
        CALL READR(G,5)
        WRITE(6,601)
        CALL READR(T,5)
        WRITE(6,602)
        CALL READR(L,5)
        WRITE(6,603)
        CALL READR(H,5)
        WRITE(6,604)
        CALL READR(CX,5)
        WRITE(6,605)
        CALL READR(N,5)
        A0=CX*H
        A1=N*G*H
        DH=2.0*G*H/(G+H)
        R=(CX-N*G)/(2.0*N)
C       SUDDEN CONTRACTION
        C1=0.1141*((R/DH+0.1)**14.4405)*(1.0-A1/A0)
C       FRICTION
        C2=0.05*L/DH
C       SUDDEN EXPANSION
        C3=0.47*(1.0-N*G/CX)**2+0.02
C       COMPOSITE COEFICIENT
        C=C1+C2+C3
        WKI(1)=GEOM
        WKI(2)=26
        WKR(1)=A0
        WKR(2)=0.0
        WKR(3)=C
        WKR(4)=A0
  600   FORMAT('   YOU HAVE SELECTED A MULTI-BAFFLE TYPE SILENCER.'/
     +         '   EACH BAFFLE HAS A STREAMLINED SHAPE.  IT IS THE TYPE'/
     +         '   USED IN THE INLETS OF THE DD963.'/
     +         '   **FIRST QUESTION, WHAT IS THE GAP BETWEEN THE BAFFLES?')
  601   FORMAT('   WHAT IS THE THICKNESS OF THE BAFFLES?')
  602   FORMAT('   WHAT IS THE LENGTH OF THE BAFFLES?')
  603   FORMAT('   WHAT IS THE DIMENSION OF THE BAFFLES PARALLEL TO THE GAP
     +?')
  604   FORMAT('   WHAT IS THE DIMENSION OF THE MAIN DUCT ACROSS THE GAPS?'
     +)
  605   FORMAT('   LAST QUESTION, HOW MANY GAPS ARE THERE?')
        RETURN
        END
```

```
C***********************************************************************C
C     FITTING 27:  GAS TURBINE MODULE                                   C
C***********************************************************************C
C     REF. GENERAL ELECTRIC DATA, LOSSES IN THE MODULE BASED ON THE     C
C     MASS FLOW THROUGH THE MODULE.  NO QUESTIONS ASKED HERE.  THIS     C
C     SUBROUTINE JUST LOCATES THE MODULE.  NOTE THAT THE MODULE IS      C
C     THE FLOW PATH NOT THE ENGINE.  LOSSES WILL BE IN THE COOLING FLOW.
C***********************************************************************C
      SUBROUTINE FIT27(SORL,GEOM,WKI,WKR)
      REAL WKR,A0
      INTEGER SORL,GEOM,WKI
      DIMENSION WKI(2),WKR(4)
      WRITE(6,600)
      WKI(1)=GEOM
      WKI(2)=27
      WKR(1)=1.0
      WKR(2)=1.0
      WKR(3)=1.0
      WKR(4)=1.0
  600 FORMAT('   YOU HAVE SELECTED THE GAS TURBINE MODULE AS A PART OF'/
     +       '   THE COOLING FLOW PASSAGE.  NO QUESTIONS, JUST NEEDED'/
     +       '   TO KNOW WHERE YOU WANTED THE MODULE.')
      RETURN
      END
```

```
C***********************************************************************C
C      FITTING 28:  WASTE HEAT RECOVERY BOILER                           C
C***********************************************************************C
C      REF. EXTENDED SURFACE HEAT TRANSFER, D.Q. KERNS AND A.D. KRAUSS   C
C      PAGES 582-589                                                     C
C      PRELIMINARY DRAWINGS ON THE RACER SYSTEM                          C
C                                                                        C
C***********************************************************************C
       SUBROUTINE FIT28(SORL,GEOM,WKI,WKR)
       REAL WKR,DV,DE,ST,N,TL,VFACT,TEST,CPRIME,AREA
       INTEGER SORL,GEOM,WKI,ANS,STAG,INLINE,YES NO
       DIMENSION WKI(2),WKR(4)
       DATA STAG/'S'/,INLINE/'I'/,YES/'Y'/,NO/'N'/
 10    WRITE (6,600)
       READ (5,601,END=20,ERR=20) ANS
       IF((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 30
 20       REWIND 5
          WRITE (6,602)
          GO TO 10
 30    CONTINUE
       AREA=68.75
       VFACT=1.35095
       CPRIME=35.02027
       DV=0.03987
       IF(ANS.EQ.YES) GO TO 80
       WRITE (6,603)
       CALL READR (DV,5)
       WRITE (6,604)
       CALL READR (DE,5)
       WRITE (6,605)
       CALL READR (ST,5)
 40    WRITE (6,606)
       READ (5,601,END=50,ERR=50) ANS
       IF((ANS.EQ.STAG).OR.(ANS.EQ.INLINE)) GO TO 60
 50       REWIND 5
          WRITE (6,602)
          GO TO 40
 60    CONTINUE
       WRITE (6,607)
       CALL READR (N,5)
       WRITE (6,608)
       CALL READR (SL,5)
       WRITE (6,609)
       CALL READR (TL,5)
       WRITE (6,610)
       CALL READR (XL,5)
C      FIND HIGHEST VELOCITY OF THE TUBE BANK
       VFACT=ST/(ST-DE)
       IF(ANS.EQ.INLINE) GO TO 70
       TEST=(ST+DE)/2.0
       SD=SQRT(SL**2+(ST/2.0)**2)
       IF(SD.LT.TEST) VFACT=ST/(2.0*(SD-DE))
 70    CONTINUE
       AREA=TL*TX
       CPRIME=((DV/ST)**0.4)*((SL/ST)**0.6)*SL*N/DV
 80    CONTINUE
       WKI(1)=GEOM
       WKI(2)=28
       WKR(1)=AREA
       WKR(2)=VFACT
       WKR(3)=CPRIME
       WKR(4)=DV
 600   FORMAT('   YOU HAVE SELECTED A WASTE HEAT BOILER.  DO YOU WANT TO'/
      +       '   USE THE PROPOSED RACER DESIGN DEVELOPED BY SOLAR '/
      +       '   TURBINES (Y/N)?')
 601   FORMAT(A1)
 602   FORMAT('   YOU MUST USE A LETTER IN THE BRACKETS.')
 603   FORMAT('   A NUMBER OF QUESTIONS ARE REQUIRED ABOUT THE TUBE'/
      +       '   BUNDLE GEOMETRY TO OBTAIN LOSS COEFFICIENTS.'/
```

AD-A148 708 AN ANALYTIC MODEL OF GAS TURBINE ENGINE INSTALLATIONS 2/3
(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA S M EZZELL
SEP 84

UNCLASSIFIED F/G 21/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
     +          '  USE CONSISTENT UNITS (FEET).'/
     +          '  **FIRST QUESTION, WHAT IS THE VOLUMETRIC HYDRAULIC '/
     +          '  DIAMETER?  IF YOU DO NOT KNOW 0.040 FEET IS A GOOD'/
     +          '  GUESS FOR THIS APPLICATION.')
604   FORMAT('  WHAT IS THE DIAMETER OR EQUIVALENT DIAMETER OF A '/
     +          '  FINNED TUBE IN THE BUNDLE (FEET)?  IF YOU DO NOT'/
     +          '  KNOW, 1.4 TIMES THE BARE TUBE DIAMETER IS A GOOD'/
     +          '  GUESS.')
605   FORMAT('  WHAT IS THE TUBE SPACING IN A BANK OF TUBES (FEET)?'/
     +          '  TUBE CENTERLINE TO TUBE CENTERLINE.')
606   FORMAT('  ARE THE TUBE BANKS STAGGERED OR INLINE (S/I) ?')
607   FORMAT('  HOW MANY TUBE BANKS ARE THERE ?')
608   FORMAT('  WHAT IS THE DISTANCE BETWEEN THE TUBE BANKS ?'/
     +          '  FROM THE PLANE OF A TUBE CENTERLINE TO TUBE CENTERLINE'/
     +          '  PLANE OF THE NEXT BANK.')
609   FORMAT('  WHAT IS THE DUCT DIMENSION PARALLEL TO THE TUBES ?')
610   FORMAT('  WHAT IS THE DUCT DIMENSION ACROSS THE TUBES ?')
      RETURN
      END
```

```
C**************************************************************C
C       FITTING 29:  ABRUPT EXIT                                C
C**************************************************************C
C       REF. ASHRAE HANDBOOK, PAGE 33.29, TABLE B-2, FITTING 2-1 C
C       THIS SHOULD ALWAYS BE USED FOR THE LAST FITTING OF THE ENGINE C
C       EXHAUST BRANCH, NODE SIX.  IT MAY BE REQUIRED FOR THE COOLING C
C       FLOW IF IT GOES DIRECTLY TO THE ATMOSPHERE (CLASS 1&2).  C
C**************************************************************C
        SUBROUTINE FIT29(SORL,GEOM,WKI,WKR)
        REAL WKR,AREA
        INTEGER SORL,GEOM,WKI
        DIMENSION WKI(2),WKR(4)
        WRITE(6,600)
        CALL READR(AREA,5)
        WKI(1)=GEOM
        WKI(2)=29
        WKR(1)=AREA
        WKR(2)=0.0
        WKR(2)=0.0
        WKR(3)=1.0
        WKR(4)=AREA
  600   FORMAT('   YOU HAVE SELECTED AN ABRUPT EXIT TO THE ATMOSPHERE.'/
     +        '   **JUST ONE QUESTION, WHAT IS THE AREA OF THE EXIT PLANE?
     +')
        RETURN
        END
C**************************************************************C
C       FITTING 30:  FITTING OF YOUR CHOICE, NOT ON MENU        C
C**************************************************************C
C       NO REFERENCE.  THIS IS INTENDED TO BE A CATCH ALL FITTING FOR   C
C       THOSE FITTINGS NOT LISTED ON THE MENU.  IT INPUTS A CONSTANT    C
C       COEFFICIENT FOR MULTIPLICATION TO THE PRESSURE VELOCITY.  THE   C
C       VELOCITY IS COMPUTED THROUGH THE AREA INPUT REQUESTED.          C
C**************************************************************C
        SUBROUTINE FIT30(SORL,GEOM,WKI,WKR)
        REAL WKR,AI,C,AO
        INTEGER SORL,GEOM,WKI
        DIMENSION WKI(2),WKR(3)
        WRITE(6,600)
        CALL READR(AI,5)
        WRITE(6,601)
        CALL READR(C,5)
        WRITE(6,602)
        CALL READR(AO,5)
        WKI(1)=GEOM
        WKI(2)=30
        WKR(1)=AI
        WKR(2)=0.0
        WKR(3)=C
        WKR(4)=AO
  600   FORMAT('   SINCE THE PROGRAM IS LIMITED IN THE NUMBER OF FITTINGS'/
     +        '   FOR WHICH IT CAN PRODUCE PERFORMANCE CHARACTERISTICS,'/
     +        '   THIS OPTION ALLOWS THE USER TO INPUT CHARACTERISTICS'/
     +        '   OF A FITTING NOT LISTED.'/
     +        '   **FIRST QUESTION, WHAT IS THE CHARACTERISTIC AREA OF'/
     +        '   THE FITTING?  THROUGH THIS AREA THE FLOW PRODUCES'/
     +        '   A VELOCITY USED TO CALCULATE THE VELOCITY PRESSURE.')
  601   FORMAT('   WHAT IS THE MULTIPIER, CO, USED IN THE'/
     +        '   VELOCITY PRESSURE EXPRESSION:'//
     +        '      P=CO*RHO*(VELOCITY**2)/(2.0*GC) ? ')
  602   FORMAT('   LAST QUESTION, WHAT IS THE OUTLET AREA?')
        RETURN
        END
```

```
C***********************************************************************C
C       TABLE INTERPOLATION SUBROUTINE:  PRODUCES VALUE FROM 2-D TABLE  C
C                                                                       C
C       INPUT A ONE DIMENSIONAL ARRAY "T", CONTAINING THE FOLLOWING     C
C       INFORMATION: NUMBER OF X'S, NUMBER OF Y'S, THE X'S, THE Y'S, THE C
C       TABLE STARTING WITH THE SMALLEST X-Y VALUE INPUT BY ROW         C
C       INCREASING X VALUES WITH ROWS INPUT WITH INCREASING Y VALUES.   C
C***********************************************************************C
        SUBROUTINE TABLE(T,X,XOUT,FF)
C       INPUT: T,X,      OUTPUT:XOUT,FF
        DIMENSION T(200),X(2),NN(2),XOUT(2),F(100)
        REAL NEV
        INTEGER V(2),XINIT(2),YINC(2)
        NXI=1
        NN(1)=3
        NN(2)=3
        IQ=3
        NXI=3
        M=1
C       LOOP DETERMINES STARTING POINTS IN T ARRAY FOR INTERPOLATION
        DO 20 I=1,2
        K=NXI+T(I)-1
        IF(X(I).GE.T(NXI).AND.X(I).LE.T(K)) GO TO 32
C       IF X OUT OF RANGE, INFORM USER THAT TABLE INTERPOLATION IS NOT
C           POSSIBLE.
        XOUT(I)=0
        GO TO 999
   32   XOUT(I)=1
        J=NXI
   21   L=(J+K)/2
        IF((X(I)-T(J))*(X(I)-T(L)).GT.0.) GO TO 23
        K=L
        GO TO 24
   23   J=L
   24   IF((K-J).GT.1) GO TO 21
        L=K-NN(I)/2
        IF(L.LE.NXI) GO TO 25
        K=NXI+T(I)-NN(I)
        IF(L.GT.K) L=K
        GO TO 26
   25   L=NXI
   26   IQ=IQ+T(I)+(L-NXI)*M
        IA=0
        IF(I.NE.1) IA=NN(I)
        YINC(I)=M*(T(I)-IA)
        XINIT(I)=L
        NXI=NXI+T(I)
        M=M*T(I)
   20   CONTINUE
        V(2)=L
        L=NN(1)
        NXX=NN(1)
C       INTERPOLATE IN FIRST DIMENSION
        V(1)=NXX
        DO 11 J=1,NXX
        F(J)=NEV(X(1),T,XINIT(1),T,IQ,L)
C       INTERPOLATE IN SECOND DIMENSION
   11   IQ=IQ+YINC(1)
        M=NN(1)
        F(M+V(2))=NEV(X(2),T,XINIT(2),F,1,M)
        FF=F(M+V(2))
        RETURN
  999   FF=1000.0
        RETURN
        END
C       FUNCTION TO RETURN INTERPOLATED VALUE FROM TABLE
        FUNCTION NEV(X,AX,NX,AY,NY,N)
C       FUNCTION NEV PERFORMS AN "N" POINT INTERPOLATION FOR X
C       STARTING AT ABSCISSA ARRAY AX(NX) AND ORDINATE ARRAY
```

```
C       AY(NY) WITH THE INTERPOLATED VALUE RETURNED IN NEV
        DIMENSION AX(1),AY(1),F(100)
        REAL NEV
        DO 10 J=1,N
 10     F(J)=AY(NY+J-1)
        N1=N-1
        DO 20 J=1,N1
        NJ=N-J
        DO 20 I=1,NJ
        KI=NX+I-1
        F(I)=(F(I+1)-F(I))*(X-AX(KI))/(AX(KI+J)-AX(KI))+F(I)
 20     CONTINUE
        NEV=F(1)
        RETURN
        END
```

```
C***********************************************************************C
C     LOAD SUBROUTINE:  PLACES FITTING INFORMATION IN A STORAGE ARRAY   C
C                                                                       C
C     SUBROUTINE ALSO CHECKS FOR AREA CONTINUITY IN A BRANCH.  IF THE   C
C     THE PRESENT FITTING AND THE LAST FITTING DO NOT MATCH A WARNING   C
C     IS GIVEN TO THE USER.  AN OPPORTUNITY TO NOT LOAD THE FITTING     C
C     IS PROVIDED AND THE USER IS RETURNED TO THE MENU.                 C
C***********************************************************************C
      SUBROUTINE LOAD(M,GEOM,WKI,WKR,WORKI,WORKR)
      REAL WKR,WORKR,TESTR,LASTA,THISA
      INTEGER M,WKI,WORKI,ANS,YES,NO,GEOM,TESTI,TYPE,LASTYP
      DIMENSION WKI(2),WKR(3),WORKI(200,2),WORKR(200,4)
      DATA YES,NO/'Y','N'/
      IF(M.EQ.1) GO TO 10
      TYPE=WORKI(M,2)
      LASTYP=WORKI(M-1,2)
C     SOME FITTINGS MAY NOT EXHIBIT AREA CONTINUITY
      IF(TYPE.EQ.13) GO TO 10
      IF(TYPE.EQ.15) GO TO 10
      IF(LASTYP.EQ.23) GO TO 10
      IF(TYPE.EQ.23) GO TO 10
      IF(LASTYP.EQ.25) GO TO 10
      IF(TYPE.EQ.25) GO TO 10
      IF(LASTYP.EQ.27) GO TO 10
      IF(TYPE.EQ.27) GO TO 10
      IF(LASTYP.EQ.28) GO TO 10
      IF(TYPE.EQ.28) GO TO 10
C     TEST THE INTERVAL BETWEEN FITTING ID NUMBERS
      TESTI=WKI(2)-WORKI(M-1,1)
C     CHECK TO SEE IF FITTING IS THE START OF A BRANCH
      IF(TESTI.GT.1) GO TO 10
C     LAST AREA, EXIT FROM FITTING
      LASTA=WORKR(M-1,4)
      IF(LASTYP.EQ.7) LASTA=WORKR(M-1,1)
C     THIS AREA, ENTRY TO FITTING
      THISA=WKR(1)
      TESTR=ABS(THISA-LASTA)/THISA
      IF(TESTR.LT.0.05) GO TO 10
        WRITE(6,600)
 10   WRITE (6,601)
      READ (5,602,END=12,ERR=12) ANS
      IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 20
 12     REWIND 5
        WRITE (6,603)
        GO TO 10
 20   CONTINUE
      IF(ANS.EQ.YES) GO TO 30
        GEOM=GEOM-1
        M=M-1
        GO TO 40
 30   WORKI(M,1)=WKI(1)
      WORKI(M,2)=WKI(2)
      WORKR(M,1)=WKR(1)
      WORKR(M,2)=WKR(2)
      WORKR(M,3)=WKR(3)
      WORKR(M,4)=WKR(4)
 40   CONTINUE
      CALL FRTCMS('CLRSCRN ')
 600  FORMAT(//' *** WARNING, AREA CONTINUITY BETWEEN THIS FITTING AND'/
     +'              LAST FITTING IS OFF BY AT LEAST FIVE PERCENT.'//)
 601  FORMAT('  DO YOU WANT TO ENTER THIS FITTING (Y/N) ?')
 602  FORMAT(A1)
 603  FORMAT('  YOU MUST ENTER A LETTER INDICATED IN THE BRACKETS.')
      RETURN
      END
```

```
C*********************************************************************C
C       DUCT DATA FILE OUTPUT SUBROUTINE                              C
C                                                                     C
C       WRITES THE SYSTEM ARRAYS WORKI AND WORKR TO THE DUCT DATA FILE. C
C       ALLOWS THE USER TO SERIALIZE EACH FILE CREATED.               C
C       *WARNING* WRITES OVER OLD FILES, SAVE THEM UNDER A DIFERENT NAME.C
C*********************************************************************C
        SUBROUTINE SUBOUT(WORKI,WORKR,M)
        REAL WORKR
        INTEGER WORKI,M,SERIAL
        DIMENSION WORKI(200,2),WORKR(200,4)
        WRITE (6,600)
        CALL READI(SERIAL,5)
        WRITE (8,601) SERIAL
        WRITE (8,602) M
        DO 10 I=1,M
           WRITE (8,603) I,WORKI(I,1),WORKI(I,2),WORKR(I,1),WORKR(I,2),
     +                   WORKR(I,3),WORKR(I,4)
 10     CONTINUE
        REWIND 8
 600    FORMAT('  WHAT SERIAL NUMBER WOULD YOU LIKE TO GIVE THIS DUCT DATA
     + FILE?'/'  YOU MAY USE UP TO A SIX DIGIT INTEGER NUMBER.')
 601    FORMAT(I6)
 602    FORMAT(I3)
 603    FORMAT(I3,3X,I6,3X,I2,3X,F10.4,3X,F10.4,3X,F10.4,3X,F10.4)
        RETURN
        END
C*********************************************************************C
C       REAL NUMBER READ SUBROUTINE: FREE FORMAT                      C
C       PREVENTS THE INADVERTENT ENTRY OF NULL DATA (HITTING THE RETURN C
C       KEY WITH NO ENTRY) AND INCORRECT DATA, THIS ROUTINE IS USED.  C
C       IT ALLOWS FREE FORMAT INPUT.  TWO NULLS KILLS THE PROGRAM.    C
C*********************************************************************C
        SUBROUTINE READR (ANSR,FD)
        REAL ANSR
        INTEGER COUNT,FD
        COUNT=0
 10     CONTINUE
        COUNT=COUNT+1
        IF (COUNT.LT.3) GO TO 20
        CALL FRTCMS ('CLRSCRN ')
        WRITE(6,600)
        GO TO 40
 20     CONTINUE
        READ (FD,*,END=30,ERR=30) ANSR
        RETURN
 30     REWIND FD
        WRITE(6,601)
        GO TO 10
 40     CONTINUE
        STOP
 600    FORMAT (////'  PROGRAM KILLED - TWO NULL STRINGS ENTERED!'/)
 601    FORMAT ('  WARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUMERIC
     +AL VALUE.')
        END
```

```
C*********************************************************************C
C     INTEGER READ SUBROUTINE: FREE FORMAT                            C
C     PREVENTS THE INADVERTENT ENTRY OF NULL DATA (HITTING THE RETURN C
C     KEY WITH NO ENTRY) AND INCORRECT DATA, THIS ROUTINE IS USED.    C
C     IT ALLOWS FREE FORMAT INPUT.  TWO NULLS KILLS THE PROGRAM.      C
C*********************************************************************C
      SUBROUTINE READI (ANSI,FD)
      INTEGER COUNT, ANSI,FD
      COUNT=0
10    CONTINUE
      COUNT=COUNT+1
      IF (COUNT.LT.3) GO TO 20
      CALL FRTCMS ('CLRSCRN ')
      WRITE(6,600)
      GO TO 40
20    CONTINUE
      READ (FD,*,END=30,ERR=30) ANSI
      RETURN
30    REWIND FD
      WRITE(6,601)
      GO TO 10
40    CONTINUE
      STOP
600   FORMAT (////'  PROGRAM KILLED - TWO NULL STRINGS ENTERED!'/)
601   FORMAT ('  WARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUMERIC
     +AL VALUE.')
      END
C*********************************************************************C
C     OPERATING CONDITIONS INPUT SUBROUTINE:  TEMP, PRESS, HUMIDITY   C
C     SUBROUTINE TO INPUT THE FOLLOWING PARAMETERS:                   C
C        AMBIENT TEMPERATURE (DEGREES F)                              C
C        AMBIENT PRESSURE (PSIA)                                      C
C        RELATIVE HUMIDITY (GRAINS PER POUND MASS DRY AIR)            C
C                                                                     C
C   THE PROGRAM COULD BE MODIFIED TO ACCEPT RELATIVE HUMIDITY (%) AND C
C   CONVERT IT TO GRAINS REQUIRED FOR USE LATER IN THE PROGRAM.  THAT C
C   MODIFICATION SHOULD BE ACCOMPLISHED HERE.                         C
C*********************************************************************C
      SUBROUTINE OPCOND(TO,PO,HUMID)
      REAL TO,PO,HUMID
      WRITE(6,600)
      CALL READR(TO,5)
      WRITE(6,601)
      CALL READR(PO,5)
      WRITE(6,602)
      CALL READR(HUMID,5)
      CALL FRTCMS ('CLRSCRN ')
 600  FORMAT('  THIS PORTION OF THE PROGRAM INPUTS THE ENVIRONMENTAL COND
     +ITIONS.'/'  WHAT IS THE AMBIENT TEMPERATURE (DEGREES F)?')
 601  FORMAT('  WHAT IS THE AMBIENT PRESSURE (PSIA)?')
 602  FORMAT('  WHAT IS THE RELATIVE HUMIDITY (GRAINS PER POUND AIR)?')
      RETURN
      END
```

```
C*****************************************************************************C
C       POWER POINT INPUT SUBROUTINE(HORSEPOWER, POWER TURBINE SPEED)         C
C       DOES A PRELIMINARY TEST TO INSURE TORQUE LIMITS ARE NOT EXCEEDED      C
C       FOR THE OPERATING POINT REQUESTED.  USER IS REQUESTED TO SELECT       C
C       A DIFFERENT OPERATING POINT IF THAT IS THE CASE.                      C
C*****************************************************************************C
        SUBROUTINE PWRPT(HP,NPT,T0,P0)
        REAL HP,NPT,P0,T0,T2C,P2C,DELTA,THETA,HPTP
 10     WRITE (6,600)
        CALL READR(HP,5)
 20     WRITE (6,601)
        CALL READR(NPT,5)
        IF((NPT.GE.1200.0).AND.(NPT.LE.3600.0)) GO TO 30
           WRITE (6,603)
           GO TO 20
 30     CONTINUE
        HPTP=(5177.5-7.0527*T0)+(8.3275-0.0012*T0)*NPT
        IF(HP.LT.HPTP) GO TO 40
        WRITE(6,602)
        GO TO 10
 40     CONTINUE
        CALL FRICMS('CLRSCRN ')
 600    FORMAT('    INPUT THE POWER SETTING YOU DESIRE.'/
       +'       **WHAT IS THE HORSEPOWER?')
 601    FORMAT('    **WHAT IS THE POWER TURBINE SPEED (RPM)?')
 602    FORMAT('    HORSEPOWER IS NOT ON THE PERFORMANCE MAP, PICK A LOWER H
       +ORSEPOWER.')
 603    FORMAT('    POWER TURBINE RPM IS NOT REASONABLE.  IT SHOULD BE'/
       +'       1200 TO 3600 RPM.  RE-ENTER.')
        RETURN
        END
```

```
C**********************************************************************C
C     ENGINE SUBROUTINE: COMPUTES OPERATING POINT FOR GIVEN CONDITIONS C
C                                                                      C
C     REF. 7LM2500 MARINE GAS TURBINE PERFORMANCE DATA, PREPARED BY    C
C     GENERAL ELECTRIC COMPANY MARINE AND INDUSTRIAL PRODUCTS          C
C     DEPARTMENT, NUMBER MID-TD-2500-8, REVISED NOVEMBER 1978.         C
C     ENGINE PERFORMANCE IS REPRODUCED BY STORING A STANDARD CONDITION C
C     OPERATING MAP AND APPLYING CORRECTIONS FOR OFF-STANDARD          C
C     OPERATING CONDITIONS.  MAIN INTEREST IS TO OBTAIN W2,W8, AND T8. C
C     SFC,T54,AND NG ARE ALSO PROVIDED.                                C
C**********************************************************************C
      SUBROUTINE ENGINE(INLOSS,EXLOSS,T0,P0,HUMID,BHP,NPT,W2C,W8C,
     +                  P8C,T8C,SFC,T54C,NGC,OFF)
      REAL T0,P0,HUMID,INLOSS,EXLOSS,BHP,NPT,T2C,P2C,DELTA,THETA,BHPTE,
     +     BHPE,NPTE,W2S,W8S,T8S,P8S,SFCS,T54S,NGS,NGC,W2C,W8C,T8C,P8C,
     +     SFC,T54C
      INTEGER OFF
      T2C=T0+459.67
      P2C=P0
C     DELTA IS THE PRESSURE CORECTION, THETA THE TEMPERATURE CORRECTION
C     INLET AND EXHAUST LOSSES ARE A SEPARATE CORRECTION
      DELTA=P2C/14.696
      THETA=T2C/518.67
C
C     CORRECT DESIRED BHP,NPT TO STANDARD CONDITIONS, INPUT TO ENGINE.
C
      BHPE=BHP/(DELTA*SQRT(THETA))
      NPTE=NPT/SQRT(THETA)
      CALL LM2500(BHPE,NPTE,W2S,W8S,T8S,P8S,SFCS,T54S,NGS,OFF)
      IF(OFF.GT.0) GO TO 20
C
C     CORRECT STANDARD ENGINE PARAMETERS TO OPERATING CONDITIONS.
C
      NGC=CFNG(NGS,THETA,INLOSS,EXLOSS,HUMID)
      W2C=CFW(W2S,THETA,DELTA,INLOSS,EXLOSS,HUMID,NGC)
      W8C=CFW(W8S,THETA,DELTA,INLOSS,EXLOSS,HUMID,NGC)
      T8C=CFT8(T8S,THETA,INLOSS,EXLOSS,HUMID,NGC)
      P8C=CFP8(P8S,DELTA,EXLOSS)
      SFC=SFCS
      T54C=CFT54(T54S,THETA,INLOSS,EXLOSS,HUMID,NGC)
 20   CONTINUE
      RETURN
      END
C     FUNCTION TO CORRECT GAS GENERATOR SPEED
      FUNCTION CFNG(NG,THETA,INLOSS,EXLOSS,HUMID)
      REAL THETA,INLOSS,EXLOSS,HUMID,NG,ADELPI,ADELPE,ADELH,
     +     CF,CFNG
      IF(NGC.LE.9100.0) GO TO 10
      IF(NGC.GE.9200.0) GO TO 20
      ADELPI=0.000733+(NGC-9100.0)*0.000567/100.0
      GO TO 30
 10   ADELPI=0.000733
      GO TO 30
 20   ADELPI=-0.0013
 30   CONTINUE
      ADELPE=0.00035
      ADELH=-0.002200/100.0
      CF=(1.0+ADELPI*INLOSS)*(1.0+ADELPE*EXLOSS)*(1.0+ADELH*HUMID)*
     +   SQRT(THETA)
      CFNG=NG*CF
      RETURN
      END
C     FUNCTION TO CORRECT MASS FLOW RATE
      FUNCTION CFW (W,THETA,DELTA,INLOSS,EXLOSS,HUMID,NGC)
      REAL W,THETA,DELTA,INLOSS,EXLOSS,HUMID,NGC,ADELPI,ADELPE,ADELH,
     +     CF,CFW
      IF(NGC.LE.9100.0) GO TO 10
      IF(NGC.GE.9200.0) GO TO 20
      ADELPI=-0.00075-(NGC-9100.0)*0.000917/100.0
```

```
      GO TO 30
10    ADELPI=-0.00075
      GO TO 30
20    ADELPI=-0.001667
30    CONTINUE
      ADELPE=0.000475
      ADELH=-0.005423/100.0
      CF=(1.0+ADELPI*INLOSS)*(1.0+ADELPE*EXLOSS)*(1.0+ADELH*HUMID)*
     +    DELTA/SQRT(THETA)
      CFW=W*CF
      RETURN
      END
C     FUNCTION TO CORRECT T8
      FUNCTION CFT8(T8,THETA,INLOSS,EXLOSS,HUMID,NGC)
      REAL T8,THETA,INLOSS,EXLOSS,HUMID,NGC,ADELPI,ADELPE,ADELH,
     +    CF,CFT8
      IF(NGC.LE.9100.0) GO TO 10
      IF(NGC.GE.9200.0) GO TO 20
      ADELPI=0.00105+(NGC-9100.0)*0.001242/100.0
      GO TO 30
10    ADELPI=0.00105
      GO TO 30
20    ADELPI=0.002292
30    CONTINUE
      ADELPE=0.00095
      ADELH=-0.000643/100.0
      CF=(1.0+ADELPI*INLOSS)*(1.0+ADELPE*EXLOSS)*(1.0+ADELH*HUMID)*
     +    THETA
      CFT8=T8*CF
      RETURN
      END
C     FUNCTION TO CORRECT P8
      FUNCTION CFP8(P8,DELTA,EXLOSS)
      REAL P8,DELTA,EXLOSS,CF,CFP8
      CF=(1.0+0.00241*EXLOSS)*DELTA
      CFP8=P8*CF
      RETURN
      END
C     FUNCTION TO CORRECT T54
      FUNCTION CFT54(T54,THETA,INLOSS,EXLOSS,HUMID,NGC)
      REAL T54,THETA,INLOSS,EXLOSS,HUMID,NGC,ADELPI,ADELPE,ADELH,
     +    CF,CFT54
      IF(NGC.LE.9100.0) GO TO 10
      IF(NGC.GE.9200.0) GO TO 20
      ADELPI=0.000958+(NGC-9100.0)*0.001/100.0
      GO TO 30
10    ADELPI=0.000958
      GO TO 30
20    ADELPI=0.001958
30    CONTINUE
      ADELPE=0.00056
      ADELH=-0.002057/100.0
      CF=(1.0+ADELPI*INLOSS)*(1.0+ADELPE*EXLOSS)*(1.0+ADELH*HUMID)*
     +    THETA
      CFT54=CF*T54
      RETURN
      END
```

```
C*********************************************************************C
C     LM2500 ENGINE TABULATION OF PERFORMANCE DATA FOR STD. CONDITIONS C
C                                                                      C
C     THIS DATA IS TAKEN FROM CASE NUMBERS 536 TO 607 PAGES 171-185    C
C     OF THE GE MANUAL.  EXTRAPOLATED VALUES PROVIDED BY THE AUTHOR    C
C     USING GRAPHICAL TECHNIQUES.                                      C
C*********************************************************************C
      SUBROUTINE LM2500(BHP,NPT,W2,W8,T8,P8,SFC,T54,NG,OFF)
      REAL BHP,NPT,W2,W8,T8,P8,SFC,T54,NG,X,
     +     W2T,W8T,T8T,P8T,SFCT,T54T,NGT
      INTEGER OFF,XOUT
      DIMENSION X(2),XOUT(2),W2T(64),W8T(64),T8T(64),P8T(64),SFCT(64),
     +          T54T(64),NGT(64)
      DATA W2T/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   41.3,67.6,87.0,121.2,148.0,158.0,169.0,175.0,
     +   40.2,61.6,77.2,105.6,127.5,137.6,146.4,156.0,
     +   43.3,61.2,74.0,99.7,117.5,125.7,133.6,141.9,
     +   48.4,62.7,73.8,96.4,113.3,120.9,127.8,134.3,
     +   51.7,64.5,75.1,96.4,112.4,119.7,126.4,132.9,
     +   54.7,66.4,76.6,96.7,112.2,119.2,125.5,131.6/
      DATA W8T/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   41.3,67.7,87.2,122.0,149.8,160.0,172.5,181.0,
     +   40.2,61.8,77.4,106.1,128.5,138.9,148.0,158.0,
     +   43.4,61.3,74.2,99.1,118.3,126.7,134.6,143.3,
     +   48.5,62.9,74.1,96.9,114.1,121.8,128.9,135.6,
     +   51.3,64.3,75.4,96.9,113.2,120.6,127.5,134.1,
     +   54.3,66.6,77.0,97.3,113.1,120.2,126.6,132.9/
      DATA T8T/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   1144.,1153.,1196.,1395.,1632.,1755.,1877.,2000.,
     +   1185.,1153.,1161.,1253.,1374.,1431.,1499.,1560.,
     +   1234.,1196.,1191.,1214.,1233.,1324.,1364.,1399.,
     +   1281.,1253.,1242.,1243.,1280.,1303.,1329.,1352.,
     +   1306.,1287.,1272.,1263.,1296.,1312.,1335.,1358.,
     +   1334.,1321.,1304.,1298.,1320.,1332.,1347.,1366./
      DATA P8T/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   14.70,14.72,14.73,14.78,14.85,14.89,14.94,15.01,
     +   14.70,14.71,14.73,14.75,14.79,14.81,14.83,14.85,
     +   14.71,14.71,14.72,14.74,14.77,14.78,14.80,14.81,
     +   14.71,14.72,14.72,14.74,14.76,14.77,14.79,14.80,
     +   14.71,14.72,14.73,14.75,14.76,14.77,14.78,14.80,
     +   14.71,14.72,14.73,14.75,14.76,14.77,14.78,14.79/
      DATA SFCT/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   1.4967,0.8632,0.7360,0.6802,0.7135,0.7400,0.7740,0.8180,
     +   1.5251,0.7993,0.6416,0.5303,0.5108,0.5031,0.5105,0.5210,
     +   1.7235,0.8384,0.6420,0.4852,0.4433,0.4343,0.4287,0.4245,
     +   2.0262,0.9162,0.6784,0.4916,0.4313,0.4151,0.4038,0.3947,
     +   2.2151,0.9759,0.7106,0.5043,0.4352,0.4159,0.4031,0.3938,
     +   2.4083,1.0374,0.7476,0.5210,0.4445,0.4222,0.4056,0.3940/
      DATA T54T/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   1214.,1278.,1356.,1615.,1891.,2030.,2170.,2310.,
     +   1258.,1290.,1342.,1509.,1684.,1762.,1850.,1940.,
     +   1303.,1334.,1378.,1489.,1623.,1691.,1755.,1808.,
     +   1343.,1387.,1428.,1524.,1633.,1685.,1739.,1788.,
     +   1364.,1417.,1455.,1548.,1650.,1697.,1749.,1795.,
     +   1389.,1447.,1483.,1575.,1673.,1718.,1764.,1810./
      DATA NGT/ 8.0,6.0,
     +   1000.0,3000.0,5000.0,10000.0,15000.0,17500.0,20000.0,22500.0,
```

```
     +   1200.0,1800.0,2400.0,3000.0,3300.0,3600.0,
     +   6980.6,7623.1,7941.3,8548.3,9505.9,10160.0,10980.0,11700.0,
     +   6908.2,7529.7,7779.3,8250.7,8699.8,8904.3,9337.3,9880.0,
     +   7041.5,7523.2,7723.4,8135.3,8473.2,8600.6,8860.0,9033.0,
     +   7223.3,7547.9,7726.5,8099.2,8381.5,8546.9,8711.0,8880.6,
     +   7334.0,7576.0,7746.7,8098.3,8306.4,8517.8,8676.6,8844.2,
     +   7415.0,7604.3,7772.3,8105.0,8304.4,8508.0,8660.0,8812.7/
      X(1)=SHP
      X(2)=NPT
      CALL TABLE(W2T,X,XOUT,W2)
      CALL TABLE(W8T,X,XOUT,W8)
      CALL TABLE(T8T,X,XOUT,T8)
      CALL TABLE(P8T,X,XOUT,P8)
      CALL TABLE(SFCT,X,XOUT,SFC)
      CALL TABLE(T54T,X,XOUT,T54)
      CALL TABLE(NGT,X,XOUT,NG)
      IF((XOUT(1).GT.0).OR.(XOUT(2).GT.0)) GO TO 10
      OFF=1
      GO TO 20
10    OFF=0
20    CONTINUE
      RETURN
      END
```

```
C**********************************************************************C
C       FAN CHARACTERISTICS INPUT SUBROUTINE                           C
C                                                                      C
C       THE DEFAULT FAN CHARACTERISTIC WAS PROVIDED BY JOY MANUFACTURING C
C       COMPANY AND IS FOR THE FAN INSTALLED ON THE SPRUANCE CLASS     C
C       DESTROYER.  OTHER FANS ARE MODELED AS A QUADRATIC EQUATION     C
C       WITH A MAXIMUM AT MAXIMUM FAN PRESSURE AND DISCHARGE           C
C       AND ANOTHER POINT AT MAXIMUM DISCHARGE AND ZERO FAN PRESSURE.  C
C                                                                      C
C**********************************************************************C
        SUBROUTINE FAN(RHOSTD,CFM0,CFMMAX,DPMAX,K)
        REAL RHOSTD,CFM0,CFMMAX,DPMAX,K
        INTEGER YES,ANS,NO
        DATA YES/'Y'/, NO/'N'/
C       DO YOU WANT THE DEFAULT FAN, THE DD 963 CLASS DESTROYER FAN ???
 2      WRITE(6,600)
        READ(5,601,END=4,ERR=4) ANS
        IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 8
 4         REWIND 5
           WRITE (6,602)
           GO TO 2
 8      CONTINUE
        IF(ANS.EQ.YES) GO TO 10
C       A DIFFERENT FAN HAS BEEN SELECTED, INPUT REQUIRED PARAMETERS
        WRITE(6,602)
        CALL READR(RHOSTD,5)
        WRITE(6,603)
        CALL READR(CFM0,5)
        WRITE(6,604)
        CALL READR(CFMMAX,5)
        WRITE(6,605)
        CALL READR(DPMAX,5)
        K=-1.0*DPMAX/(CFM0-CFMMAX)**2
        GO TO 20
C       FOLLOWING ARE VALUES FOR THE DEFAULT FAN
 10     RHOSTD=0.071
        CFM0=24000.0
        CFMMAX=11000.0
        DPMAX=27.7
        K=-1.0*DPMAX/(CFM0-CFMMAX)**2
 20     CONTINUE
 600    FORMAT('    YOU HAVE SELECTED A SYSTEM WITH A COOLING FAN.  THE'/
     +         '    DEFAULT SPECFICATIONS ARE FOR THE FAN INSTALLED ON'/
     +         '    THE DD963 CLASS SHIP.'//
     +         '    DO YOU WANT TO USE THE DEFAULT SPECFICATIONS (Y/N)?')
 601    FORMAT(A1)
 602    FORMAT('    THE PROGRAM WILL APPROXIMATE YOUR FAN WITH A QUADRATIC'/
     +   '    EQUATION.  TWO POINTS ARE REQUIRED FROM THE FAN PERFORMANCE'/
     +   '     CURVES AND THE REFERENCE AIR DENSITY OF THE CURVES.  WHAT'/
     +   '     IS THE REFERENCE AIR DENSITY (LBM/FT3)?')
 603    FORMAT('    WHAT IS THE FLOW AT ZERO GAGE PRESSURE (CFM)?')
 604    FORMAT('    WHAT IS THE FLOW AT MAXIMUM GAGE PRESSURE (CFM)?'/
     +         '    D(CFM)/DP=0.')
 605    FORMAT('    WHAT IS THE MAXIMUM FAN DISCHARGE GAGE PRESSURE (INCHES
     +W.G.)?'/'    D(CFM)/DP=0.')
        RETURN
        END
```

```
C*********************************************************************C
C      FITTING PRESSURE LOSS CALCULATION SUBROUTINE                    C
C                                                                      C
C      FOR THE 30 FITTINGS AVAILABLE IN THE MENU THERE ARE 13 DIFFERENT C
C      WAYS TO COMPUTE THE LOSS FOR THE FITTING.  THIS SUBROUTINE MUST C
C      BE ABLE TO RECOGNIZE THE FITTING TYPE AND BRANCH TO THE CORRECT C
C      COMPUTATION AREA OF THE SUBROUTINE.  FOR EXAMPLE FILTER DP IS   C
C      A FUNCTION OF FACE VELOCITY, STRAIGHT DUCTING IS F*L/D TIME THE C
C      THE PRESSURE VELOCITY.  WHERE A COEFFICIENT IS DEPENDENT OF THE C
C      REYNOLDS NUMBER, THE COEFFICIENT IS COMPUTED HERE WITH THE INPUT C
C      DATA.  ADDING ANOTHER FITTING WOULD REQUIRE MODIFICATION OF THIS C
C      SUBROUTINE.                                                     C
C*********************************************************************C
       SUBROUTINE FITDP(W,dP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +          DATA4,TYPE,DS,ALFAC,ALFAD,ACWB,ACWM,ACWC,ADWB,ADWM,ADWC,
     +          VCWB,VCWM,VCWC,VDWB,VDWM,VDWC,RHOCC,TO)
       REAL W,dP,ALFAC,ALFAD,ACWB,ACWM,ACWC,PTIN,TIN,PV,TO,CFR,LAMDA,RW,
     +          PTOUT,TOUT,RHO,R,MU,RN,V,DATA1,DATA2,DATA3,E,F,KFE,L,PS,RHOT,
     +          C,X,T,VCWB,VCWM,VCWC,VDWB,VDWM,VDWC,TEST,K2,AR,DATA4,DP,K1
       INTEGER TYPE
       DIMENSION X(2),T(45)
C      GAS CONSTANT AND ROUGHNESS
       DATA R/53.3424/,E/0.00015/,
C      A REYNOLD NUMBER CORRECTION FOR SMOOTH RADIUS RECT ELBOWS
     +      T/10.0,3.0,
     +          1.0,2.0,3.0,4.0,6.0,8.0,10.0,14.0,20.0,100.0,
     +          0.5,0.75,4.5,
     +          1.40,1.26,1.19,1.14,1.09,1.06,1.04,1.00,1.00,1.00,
     +          2.00,1.77,1.64,1.56,1.46,1.38,1.30,1.15,1.00,1.00,
     +          2.00,1.77,1.64,1.56,1.46,1.38,1.30,1.15,1.00,1.00/
C      COMPUTE VISCOSITY OF AIR BASED ON TEMPERATURE OF AIR
       MU=(29.35+0.189304*TIN-2.67587E-5*TIN**2)*1E-7
C      ASSUME A VALUE FOR RHO
       RHO=PTIN/(R*TIN)
C      VELOCITY IS THE MASS FLOW RATE DIVIDED BY DENSITY AND THE FLOW
C      AREA:  V=Q/A  ===> Q=MASS FLOW RATE/RHO
  5    V=W/(RHO*DATA1)
C      PRESSURE VELOCITY (PSF)
       PV=RHO*V**2/(2.0*32.174)
C      COMPUTE THE STATIC PRESS:  EQUALS TOTAL PRESS - VELOCITY PRESS
       PS=PTIN-PV
C      COMPUTE DENSITY OF GAS ENTERING FITTING USING PERFECT GAS LAW
       RHOT=PS/(R*TIN)
C      COMPARE ASSUMED RHO AND COMPUTED RHO
       TEST=ABS(RHOT-RHO)
C      ASSIGN NEW VALUE FOR RHO
       RHO=RHOT
C      IF ASSUMED RHO NOT EQUAL TO COMPUTED RHO RESUME INTERATION
       IF(TEST.GT.0.001) GO TO 5
C      REYNOLDS NUMBER
       RN=RHO*DATA2*V/MU
C      BRANCH FITTING TO CORRECT DP COMPUTATION CODE
       GO TO (10,20,10,10,30,30,40,10,10,30,30,30,50,60,70,80,90,
     +         90,90,90,100,100,10,10,110,10,120,130,10,10),TYPE
C
C      SIMPLE FITTING, COEFFICIENT TIMES VELOCITY PRESSURE
C      FITTINGS:  1,3,4,8,9,22,24,28,29
 10    DP=DATA3*PV
       PTOUT=PTIN-DP
       TOUT=TIN
       GO TO 140
C
C      STRAIGHT DUCT, FRICTION FACTOR IS COMPUTED BY CORRELATION IN
C      SHAMES, MECHANICS OF FLUIDS, PAGE 280, CORRELATION OF SWAMEE AND
C      JAIN.
C      FITTING:  2
 20    F=0.25/(ALOG10(E/(3.7*DATA2))+5.74/RN**0.9)**2
C      LOSS=(F*L/D)*VELOCITY PRESSURE
       DP=F*DATA3/DATA2*PV
```

```
      TOUT=TIN
      PTOUT=PTIN-DP
      GO TO 140
C
C     ELBOW WITH REYNOLDS NUMBER CORRECTION FACTOR
C     FITTINGS: 5,6,10,11,12
   30 KRE=1.3701-0.1485*ALOG(RN*1E-4)
      DP=DATA3*KRE*PV
      TOUT=TIN
      PTOUT=PTIN-DP
      GO TO 140
C
C     SMOOTH RADIUS RECTANGULAR ELBOW WITHOUT VANES, REYNOLDS NUMBER
C     CORRECTION FROM TABLE LISTED IN DATA THIS SUBROUTINE.
C     FITTING: 7
   40 RW=DATA4
      C=DATA3
      IF(RN.GT.10000.0) GO TO 41
      KRE=1.7
      GO TO 42
   41 X(1)=RN
      X(2)=RW
      CALL TABLE(T,X,XOUT,KRE)
   42 DP=C*KRE*PV
      TOUT=TIN
      PTOUT=PTIN-DP
      GO TO 140
C
C     BRANCH SECTION OF A DIVERGING WYE.  LOSS IS DEPENDENT ON
C     VELOCITIES IN MAIN SECTION (VDWM), COMBINED SECTION (VDWC)
C     BRANCH SECTION (VDWB) AND DIVERGENCE ANGLE OF FITTING.
C     VELOCITIES COMPUTED IN THE SYSTEM SUBROUTINE, PASSED TO FITDP AS
C     INPUT DATA.
C     FITTING: 13
   50 TEST=(ADWM-ADWC)/ADWC
      IF(TEST.LT.0.05) GO TO 51
      K2=(((-3.59147E-8*ALFAD+3.8309E-6)*ALFAD+0.0000574)*
     +  ALFAD+0.0010399)*ALFAD+0.000017
      C=1.0+(VDWB/VDWC)**2-2.0*(VDWB/VDWC)*COS(ALFAD/57.3)-K2*(VDWB/
     +  VDWC)**2
      GO TO 52
   51 K1=1.0
      RR=VDWB/VDWM
      IF(RR.GT.0.8) K1=0.9
      C=K1*(1.0+(VDWB/VDWC)**2-2.0*(VDWB/VDWC)*COS(ALFAD/57.3))
   52 PV=RHO*VDWC**2/(2.0*32.174)
      DP=C*PV
      PV=RHO*VDWB**2/(2.0*32.174)
      PTOUT =PTIN-DP
      TOUT=TIN
      GO TO 140
C
C     MAIN SECTION OF A DIVERGING WYE
C     FITTING: 14
C     COEFFICIENT BASED ON THE RATIO OF VELOCITIES VDWM AND VDWC
C     COMPUTED IN THE SYSTEM PART OF THE PROGRAM
   60 C=0.4*(1.0-VDWM/VDWC)**2
      PV=RHO*VDWM**2/(2.0*32.174)
      DP=C*PV
      PV=RHO*VDWM**2/(2.0*32.174)
      PTOUT=PTIN-DP
      TOUT=TIN
      GO TO 140
C
C     BRANCH SECTION OF A CONVERGING WYE, THE JUNCTION OF MODULE
C     COOLING AIR (BRANCH) WITH THE ENGINE EXHAUST (MAIN), NODE 5
C     FITTING: 15
C     ALL INPUT COMPUTED IN THE SYSTEM SUBROUTINE PASSED TO FITDP
   70 C=1.0+(VCWB/VCWC)**2-2.0*ACWM/ACWC*(VCWM/VCWC)**2-2.0*ACWB/ACWC*
```

```
     +    (VCWB/VCWC)**2*COS(ALFAC/57.3)
      PV=RHCCC*VCWC**2/(2.0*32.174)
      DP=C*PV
      PTOUT=PTIN-DP
      TOUT=PTOUT/(R*RHCCC)
      GO TO 140
C
C     MAIN SECTION OF A CONVERGING WYE, THE PATH FOR ENGINE EXHAUST
C     NODE 5, FITTING: 16
C     ALL VELOCITIES COMPUTED IN SYSTEM PART OF PROGRAM AND
C     PASSED TO FITDP
 80   K1=1.15*(ACWB/ACWC)**2.21+(1-ALFAC/60)*(ACWB/ACWC)*0.4
      TEST=ABS((ACWM-ACWC)/ACWC)
      IF(TEST.LT.0.05) K1=0.0
      C=1.0+(VCWM/VCWC)**2-2.0*ACWM/ACWC*(VCWM/VCWC)**2-2.0*
     +    (ACWB/ACWC)*(VCWB/VCWC)**2*COS(ALFAC/57.3)+K1
      PV=RHCCC*VCWC**2/(2.0*32.174)
      DP=C*PV
      PTOUT=PTIN-DP
      TOUT=PTOUT/(R*RHOCC)
      GO TO 140
C
C     DIFFUSERS
C     FITTINGS: 17,18,19,20
C     FRICTION INCLUDED IN THIS FITTING
 90   L=SQRT(4.0*DATA1/3.1416)
      RN=RHC*L*V/MU
      LAMDA=0.3164/RN**0.25
      CFR=DATA2*LAMDA
      C=CFR+DATA3
      DP=C*PV
      PTOUT=PTIN-DP
      TOUT=TIN
      GO TO 140
C
C     CONTRACTIONS
C     FITTINGS: 21,22
 100  V=W/(RHO*DATA4)
      PV=RHC*V**2/(2.0*32.174)
      DP=DATA3*PV
      PTOUT=PTIN-DP
      TOUT=TIN
      GO TO 140
C
C     INLET FILTER
C     FITTING: 24
C     PRESSURE LOSS BASED ON FACE VELOCITY
C     5.19696 IS A CONVERSION FACTOR TO CONVERT INCH HG TO PSF
 110  DP=(DATA2*V**DATA3)*5.19696
      PTOUT=PTIN-DP
      TOUT=TIN
      GO TO 140
C
C     GAS TURBINE MODULE, THIS IS NOT THE ENGINE, BUT THE PATH FOR
C     COOLING AIR AROUND THE ENGINE
C     FITTING: 26
C     LOSS BASED OF THE MASS FLOW OF COOLING AIR THROUGH THE MODULE
 120  DP=(1.61E-3*W**2.15)*5.19696
      PV=0.0
      PTOUT=PTIN-DP
C     THE FOLLOWING MODEL FOR MODULE TEMP OUT SHOULD BE REFINED
C     IT IS JUST A BEST "GUESS-TIMATE".
      TOUT=TIN+25.0/W*(HP/20000.0*100.0)
      GO TO 140
C
C     WASTE HEAT BOILER, GAS SIDE PRESSURE LOSS
C     FITTING: 27
C     BASED ON TUBE BUNDLE GEOMETRY, VELOCITY IN THE NARROW PASSAGE OF
C     OF THE TUBE BUNDLE, FRICTION FACTOR, F, A FUNCTION OF REYNOLDS
```

```
C       NUMBER
  130   V=V*DATA2
        PV=RHO*V**2/(2.0*32.174)
        RN=RHO*V*DATA4/MU
        F=1.334*RN**(-0.1453)
        DP=F*DATA3*PV
        PTOUT=PTIN-DP
        TOUT=0.00185*HP+247.0+TO
        RHO=(PS-DP)/(R*TOUT)
        V=W/(RHO*DATA1)
        PV=RHO*V**2/(2.0*32.174)
        GO TO 140
C
C       NO MORE FITTINGS, IF YOU ADD A DIFFERENT TYPE OF FITTING
C       REQUIRING A DIFFERENT METHOD OF COMPUTATION, THE METHOD
C       SHOULD GO HERE.
  140   CONTINUE
        RETURN
        END
```

```
C*********************************************************************C
C      SYSTEM ONE MATCHING SUBROUTINE                                 C
C                                                                     C
C      IN THIS SYSTEM THE COOLING AIR AND ENGINE COMBUSTION DO NOT    C
C      MIX.  THE LOSSES ARE COMPUTED INDEPENDENTLY.  A FAN IS REQUIRED C
C      FOR THE COOLING SYSTEM TO OPERATE.  SYSTEM MATCHING INVOLVES TWO C
C      PROCESSES, FIRST MAKE THE ENGINE LOSSES AGREE WITH THE COMPUTED C
C      DUCT LOSSES, SECOND MAKE THE FAN PERFORMANCE MATCH THE COOLING C
C      DUCT LOSSES.  NO JUNCTIONS ARE PRESENT.                        C
C                                                                     C
C*********************************************************************C
      SUBROUTINE SYS1(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,T0,P0,HUMID,
     +                RHOSTD,CFM0,CFMMAX,DPMAX,K)
      REAL WORKR,HP,NPT,T0,P0,HUMID,CFMMAX,CFM0,DPMAX,K,W2,W8,P8,T8,
     +     INLOSS,EXLOSS,FANDP,DP13,DP24,DP36,DP45,PV,PTIN,PTOUT,DATA1,
     +     DATA2,DATA3,TEST,DP,FITPV,WC,RHOSTD,TEST1,TEST2,WCN,TSOD,
     +     T54,SFC,NG,DATA4,T4,DELP
      INTEGER WORKI,FIT1ST,OFF,N,P,Q,R,A,B,C,SERIAL,TYPE
      DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(4),DP(200),FITPV(200)
C     THE FOLLOWING ARE THE STARTING AND STOPPING POINTS FOR THE
C     BRANCHES.  START AND STOP BY THE SEQUENTIAL INDEX NUMBER IN DUCT
C     DATA FILE
      P=FIT1ST(2)-1
      Q=FIT1ST(3)-1
      R=FIT1ST(4)-1
      A=FIT1ST(2)
      B=FIT1ST(3)
      C=FIT1ST(4)
C     INITIALIZE INLET AND EXHAUST DUCT LOSSES (INCH WG)
      INLOSS=4.0
      EXLOSS=8.0
C     INITIALIZE COOLING FLOW
      WC=20.0
C     INITIALIZE LOSS IN BRANCH 4-5 (PSF)
      DP45=100.0
C     WITH ASSUMED LOSSES GET THE ENGINE PERFORMANCE
 5    CALL ENGINE(INLOSS,EXLOSS,T0,P0,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
     +            T54,NG,OFF)
      IF(OFF.EQ.0) GO TO 6
         WRITE(6,600)
         GO TO 500
 6    CONTINUE
C     INITIALIZE CONDITIONS FOR START OF BRANCH 1-3, ENGINE INLET FLOW
      DP13=0.0
C     INLET PRESSURE IS AMBIENT (PSF)
      PTIN=P0*144.0
C     INLET TEMPERATURE IS AMBIENT (DEG R)
      TIN=T0+459.7
      DO 10 I=1,P
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +   DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +        0.,0.,IO)
         DP(I)=DELP
         DP13=DP13+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
 10   CONTINUE
C     INITIALIZE INLET CONDITIONS FOR BRANCH 3-6
      PTIN=P8*144.0
 20   TIN=T8
      DP36=0.0
      DO 30 I=B,R
         TYPE=WORKI(I,2)
```

```
          DATA1=WORKR (I,1)
          DATA2=WORKR (I,2)
          DATA3=WORKR (I,3)
          DATA4=WORKR (I,4)
          CALL FITDP(W8,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +      DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +           0.,0.,10)
          DP(I)=DELP
          DP36=DP36+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
   30  CONTINUE
C      IF THE EXIT PRESSURE IS NOT AMBIENT, REPEAT UNTIL IT IS
       TEST=ABS(PTOUT-P0*144.0)
       IF(TEST.LT.1.0) GO TO 40
          PTIN=P0*144.0+DP36
          GO TO 20
   40  CONTINUE
C      COMPARE ASSUMED INLET AND EXHAUST LOSS WITH THE COMPUTED LOSSES
C      IF THEY DO NOT AGREE REPEAT
       INLOSS=INLOSS*5.19696
       EXLOSS=EXLOSS*5.19696
       TEST1=ABS(DP13-INLOSS)
       TEST2=ABS(DP36-EXLOSS)
       INLOSS=DP13/(144.0*0.03609)
       EXLOSS=DP36/(144.0*0.03609)
       IF((TEST1.GT.1.0).OR.(TEST2.GT.1.0)) GO TO 5
C      INITIALIZE INLET CONDITIONS FOR BRANCH 2-4
   45  PTIN=P0*144.0
       DP24=0.0
       TIN=T0+459.7
       DO 50 I=A,B
          TYPE=WORKI(I,2)
          DATA1=WORKR (I,1)
          DATA2=WORKR (I,2)
          DATA3=WORKR (I,3)
          DATA4=WORKR (I,4)
          CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +      DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +           0.,0.,20)
          DP(I)=DELP
          DP24=DP24+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
          IF(TYPE.EQ.26) TMOD=TOUT
   50  CONTINUE
C      INITIALIZE CONDITIONS FOR BRANCH 4-5
       T4=TOUT
   55  PTIN=P0*144.0+DP45
       TIN=T4
       DP45=0.0
       DO 60 I=C,N
          TYPE=WORKI(I,2)
          DATA1=WORKR (I,1)
          DATA2=WORKR (I,2)
          DATA3=WORKR (I,3)
          DATA4=WORKR (I,4)
          CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +        DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +           0.,0.,20)
          DP(I)=DELP
          DP45=DP45+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
          IF(TYPE.EQ.26) TMOD=TOUT
   60  CONTINUE
```

```
C      IF EXIT CONDITION CONDITION IS NOT AMBIENT PRESSURE REPEAT
       TEST=ABS(PTOUT-P0*144.0)
       IF(TEST.LT.1.0) GO TO 70
          GO TO 55
C      FAN PRESSURE RISE
 70    FANDP=(DP24+DP45)/(144.0*0.03609)
C      MATCH FLOW TO SYSTEM FOR NEXT ITERATION WITH WCN
       CALL FANMAT(WC,T0,P0,FANDP,RHOSTD,CFM0,CFMMAX,DPMAX,K,WCN)
C      IF ASSUMED FLOW MATCHES MATCHED FLOW YOU ARE FINISHED
       TEST=ABS(WCN-WC)
       WC=WCN
       IF(TEST.GT.0.1) GO TO 45
C      WRITE THE INFORMATION TO AN OUTPUT FILE
       CALL OUTPUT(T0,P0,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
     +    W2,W9,P8,T8,SFC,T54,NG,SERIAL,IMOD)
       DP13=DP13/5.19696
       DP36=DP36/5.19696
       DP24=DP24/5.19696
       DP45=DP45/5.19696
C      WRITE SUMMARY OF BRANCH LOSSES
       WRITE (4,601) DP13,DP36,DP24,DP45
 500   CONTINUE
 600   FORMAT('  POWER POINT IS NOT ON THE PERFORMANCE MAP.')
 601   FORMAT(/5X,'LOSS BRANCH 1-3:',F12.3,/5X,'LOSS BRANCH 3-6:',F12.3,
     +        /5X,'LOSS BRANCH 2-4:',F12.3,/5X,'LOSS BRANCH 4-5:',F12.3)
       RETURN
       END
```

```
C**********************************************************************C
C        SYSTEM TWO MATCHING SUBROUTINE                                C
C                                                                      C
C        THIS SYSTEM HAS A COMBINED INLET.  ENGINE AIR AND COOLING AIR C
C        ENTER THROUGH THE SAME ENTRY.  THE COOLING AIR SEPERATES IN THE C
C        MAIN INLET DUCT, BRANCHING OFF TO THE COOLING FAN AND THEN TO C
C        THE MODULE.  THE COOLING AIR DOES NOT JOIN THE EXHAUST FLOW.  C
C        IT IS DUCTED SEPARATELY TO THE ATMOSPHERE.                    C
C                                                                      C
C**********************************************************************C
      SUBROUTINE SYS2(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +                ALFAD,ADWB,ADWC,ADWM,
     +                RHOSTD,CFM0,CFMMAX,DPMAX,K)
      REAL WORKR,HP,NPT,TO,PO,HUMID,CFMMAX,CFM0,DPMAX,K,W2,W8,P8,T8,
     +     INLOSS,EXLOSS,FANDP,DP12,DP24,DP36,DP45,PV,PTIN,PTOUT,DATA1,
     +     DATA2,DATA3,TEST,DP,FITPV,WC,RHOSTD,TEST1,TEST2,WCN,TMOD,
     +     T54,SFC,NG,ALFAD,ADWB,ADWC,ADWM,DP23,PT2,RHO2,VDWB,VDWC,VDWM,
     +     DATA4,R,W
      INTEGER WORKI,FIT1ST,OFF,N,PP,QQ,RR,SS,A,B,C,D,SERIAL,TYPE
      DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(5),DP(200),FITPV(200)
C     GAS CONSTANT
      DATA R/53.3424/
C     THE STARTING AND STOPPING POINTS FOR BRANCH COMPUTATION LOOPS
      PP=FIT1ST(2)-1
      QQ=FIT1ST(3)-1
      RR=FIT1ST(4)-1
      SS=FIT1ST(5)-1
      A=FIT1ST(2)
      B=FIT1ST(3)
      C=FIT1ST(4)
      D=FIT1ST(5)
C     INITIALIZE INLET AND EXHAUST LOSSES (INCH WG)
      INLOSS=4.0
      EXLOSS=8.0
C     INITIALIZE COOLING FLOW
      WC=20.0
      DP45=100.0
C     GET THE ENGINE PERFORMANCE WITH THE ASSUMED LOSSES
    5 CALL ENGINE(INLOSS,EXLOSS,TO,PO,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
     +            T54,NG,OFF)
      IF(OFF.EQ.0) GO TO 6
         WRITE(6,600)
         GO TO 500
    6 CONTINUE
C     INITIALIZE THE INLET CONDITIONS FOR BRANCH 1-2
      DP12=0.0
      PTIN=P0*144.0
      TIN=T0+459.7
C     COMPUTE FITTING LOSSES
      DO 10 I=1,PP
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +   DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +           40)
         DP(I)=DELP
         DP12=DP12+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
   10 CONTINUE
C     COMPUTE VELOCITIES IN THE DIVERGING WYE SECTION
      PT2=P0*144.0-DP12
      RHO2=(PT2-PV)/((T0+459.7)*R)
      VDWB=WC/(RHO2*ADWB)
      VDWC=(WC+W2)/(RHO2*ADWC)
```

```
      VDWM=W2/(RHO2*ADWM)
C     INITIALIZE INLET CONDITIONS FOR BRANCH 2-3
      PTIN=PT2
      TIN=T0+459.7
      W=W2+WC
      DP23=0.0
C     COMPUTE LOSSES FOR FITTINGS
      DO 20 I=A,AA
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(W,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
     +           VDWB,VDWM,VDWC,0.,T0)
         DP(I)=DELP
         DP23=DP23+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
   20 CONTINUE
C     INITIALIZE CONDITIONS FOR BRANCH 3-6
      PTIN=P8*144.0
   30 TIN=T8
      DP36=0.0
C     COMPUTE FITTING LOSSES
      DO 35 I=C,SS
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(WB,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,0.,ALFAB,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
     +           VDWB,VDWM,VDWC,0.,T0)
         DP(I)=DELP
         DP36=DP36+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
   35 CONTINUE
C     IF THE EXIT PRESSURE IS NOT AMBIENT REPEAT
      TEST=ABS(PTOUT-P0*144.0)
      IF (TEST.LT.1.0) GO TO 40
         PTIN=P0*144.0+DP36
         GO TO 30
   40 CONTINUE
C     TEST THE ASSUMED LOSSES AGAINST THE COMPUTED LOSSES
      INLOSS=INLOSS*5.19696
      EXLOSS=EXLOSS*5.19696
      TEST1=ABS(DP12+DP23-INLOSS)
      TEST2=ABS(DP36-EXLOSS)
      INLOSS=(DP12+DP23)/5.19696
      EXLOSS=DP36/5.19696
C     REPEAT ITERATION IF ASSUMED LOSSES DO NOT MATCH THE COMPUTED LOSS
      IF((TEST1.GT.1.0).OR.(TEST2.GT.1.0)) GO TO 5
C     INITIALIZE THE  INLET CONDITIONS FOR BRANCH 2-4
   45 PTIN=PT2
      DP24=0.0
      TIN=T0+459.7
C     COMPUTE FITTING LOSSES
      DO 50 I=B,BB
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
```

```
     +     DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
     +          VDWB,VDWM,VDWC,0.,T0)
          DP(I)=DELP
          DP24=DP24+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
          IF(TYPE.EQ.26) TMOD=TOUT
  50   CONTINUE
C      INITIALIZE THE INLET CONDITIONS FOR BRANCH 4-5
       T4=TOUT
  55   PTIN=P0*144.0+DP45
       TIN=T4
       DP45=0.0
C      COMPUTE LOSSES FOR FITTINGS
       DO 60 I=D,N
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +          0.,0.,T0)
          DP(I)=DELP
          DP45=DP45+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
          IF(TYPE.EQ.26) TMOD=TOUT
  60   CONTINUE
C      IF EXIT PRESSURE NOT AMBIENT REPEAT
       TEST=ABS(PTOUT-P0*144.0)
       IF(TEST.LT.1.0) GO TO 70
          GO TO 55
C      COMPUTE FAN PRESSURE AND MATCH FAN PERFORMANCE TO SYSTEM
  70   FANDP=(DP24+DP45+DP12)/5.19696
       CALL FANMAT(WC,T0,P0,FANDP,RHOSTD,CFM0,CFMMAX,DPMAX,K,WCN)
C      IF COOLING FLOW MATCHES YOU ARE FINISHED
       TEST=ABS(WCN-WC)
       WC=WCN
       IF(TEST.GT.0.1) GO TO 5
C      WRITE PERFORMANCE INFORMATION TO THE OUTPUT FILE
       CALL OUTPUT(T0,P0,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
     +    W2,W8,P8,T8,SFC,I54,NG,SERIAL,TMOD)
       DP12=DP12/5.19696
       DP23=DP23/5.19696
       DP36=DP36/5.19696
       DP24=DP24/5.19696
       DP45=DP45/5.19696
C      WRITE THE BRANCH LOSS SUMMARY
       WRITE (4,601) DP12,DP23,DP36,DP24,DP45
 500   CONTINUE
 600   FORMAT('  POWER POINT IS NOT ON THE PERFORMANCE MAP.')
 601   FORMAT(/5X,'LOSS BRANCH 1-2:',F12.2,/5X,'LOSS BRANCH 2-3:',F12.2,
     +         /5X,'LOSS BRANCH 3-6:',F12.2,/5X,'LOSS BRANCH 2-4:',F12.2,
     +         /5X,'LOSS BRANCH 4-5:',F12.2)
       RETURN
       END
```

```
C*****************************************************************C
C     SYSTEM THREE MATCHING SUBROUTINE                            C
C                                                                 C
C     THIS SYSTEM UTILIZES A COMBINED INLET AND EXAUST DUCT FOR BOTH  C
C     ENGINE AIR AND COOLING AIR.  NODE 2 IS A DIVERGING WYE.  NODE 5  C
C     IS THE JUNCTION OF MODULE AIR AND ENGINE EXHAUST.  THE SCHEME IS C
C     TO FIX THE PRESSURES AT NODES 2&5 AND WORK THE PARALLEL BRANCHES C
C     SO THAT THEY HAVE THE SAME INLET AND OUTLET PRESSURE, P2 AND P5. C
C     CHECK ASSUMED LOSSES AGAINST COMPUTED LOSSES REPEAT IS NECESSARY.C
C                                                                 C
C*****************************************************************C
      SUBROUTINE SYS3(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,T0,P0,HUMID,
     +                ALFAD,ADWB,ADWC,ADWM,ALFAC,ACWB,ACWC,ACWM,
     +                RHOSTD,CFM0,CFMMAX,DPMAX,K)
      REAL WORKR,HP,NPT,T0,P0,HUMID,CFMMAX,CFM0,DPMAX,K,W2,W8,P8,T8,
     +     INLOSS,EXLOSS,FANDP,DP12,DP24,DP36,DP45,PV,PTIN,PTOUT,DATA1,
     +     DATA2,DATA3,TEST,DP,FITPV,WC,RHOSTD,TEST1,TEST2,WCN,TMOD,
     +     T54,SFC,NG,ALFAD,ADWB,ADWC,ADWM,DP23,PT2,RHO2,VDWB,VDWC,VDWM,
     +     DATA4,R,ALFAC,ACWB,ACWC,ACWM,VCWB,VCWC,VCWM,TMAIN,TMOD,HSEC,
     +     HMAIN,HSTACK,T4,T5,W,GAIN,LOSS,PSEC,PMAIN,PT4,PT5,TEST3,
     +     PVB,PVC,PVM,PSB,PSC,PSM,RHOCBT,RHOCCT,RHOCMT,TEST1,TEST2
      INTEGER WORKI,FIT1ST,OFF,N,PP,QQ,RR,SS,TT,A,B,C,D,E,SERIAL,TYPE,
     +        IND
      DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(6),DP(200),FITPV(200)
C     GAS CONSTANT
      DATA R/53.3424/
C     SET UP STARTING AND STOPPING POINTS FOR BRANCHES
      PP=FIT1ST(2)-1
      QQ=FIT1ST(3)-1
      RR=FIT1ST(4)-1
      SS=FIT1ST(5)-1
      TT=FIT1ST(6)-1
      A=FIT1ST(2)
      B=FIT1ST(3)
      C=FIT1ST(4)
      D=FIT1ST(5)
      E=FIT1ST(6)
C     INITIALIZE LOSSES (INCH WG)
      INLOSS=4.0
      EXLOSS=8.0
C     INITIALIZE GAIN IN THE MODULE EXHAUST EDUCTOR (PSF)
      GAIN=-30.0
C     INITIALIZE DUCT LOSS IN THE COOLING FLOW PASSAGE (PSF)
      LOSS=30.0
C     INITIALIZE THE COOLING FLOW
      WC=CFMMAX*RHOSTD/60.0
C     INITIALIZE THE BRANCH LOSSES REQUIRE TO START THE PROGRAM
      DP45=100.0
      DP56=100.0
      TMOD=710.0
      PT5=P0*144.0+DP56
C     CHECK TO SEE IF THERE IS A WASTE HEAT BOILER INSTALLED
C     IN BRANCH 3-5.  IT DOES NOT MAKE SENSE TO PUT IT ANYWHERE ELSE.
      IND=0
      DO 4 I=C,SS
         TYPE=WORKI(I,2)
         IF(TYPE.EQ.27) IND=1
    4 CONTINUE
C     GET ENGINE PERFORMANCE BASED ON ASSUMED CONDITIONS
    5 CALL ENGINE(INLOSS,EXLOSS,T0,P0,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
     +            T54,NG,OFF)
      IF(OFF.EQ.0) GO TO 6
         WRITE(6,600)
         GO TO 500
    6 CONTINUE
C     INITIALIZE THE INLET CONDITIONS FOR BRANCH 1-2
      DP12=0.0
      PMAIN=PT5+LOSS
      PSEC=PT5+GAIN
```

```
      PTIN=P0*144.0
      TIN=T0+459.7
C     COMBINED MASS FLOW WC+W2
      W=WC+W2
C     FIND FITTING LOSSES
      DO 8 I=1,PP
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(W,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +   DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +         0.,0.,0.,T0)
         DP(I)=DELP
         DP12=DP12+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
 8    CONTINUE
C     THE JUNCTION PARAMETERS AT NODE 2 AND 5 ARE COMPUTED HERE
C     BASED ON THE CURRENT ASSUMPTIONS.  THE PARALLEL BRANCHES MUST
C     MEET THE VALUES AT THE NODES 2 AND 5.  THE PARAMETERS ARE AS
C     NOTED IN THE COMMENTS
C     TOTAL PRESSURE AT NODE 2
      PT2=P0*144.0-DP12
C     DENSITY AT NODE 2
      RHO2=(PT2-PV)/((T0+459.7)*R)
C     VELOCITY IN THE COOLING BRANCH
      VDWB=WC/(RHO2*ADWB)
C     VELOCITY IN THE COMBINED INLET SECTION ABOVE NODE 2
      VDWC=(WC+W2)/(RHO2*ADWC)
C     VELOCITY OF THE AIR FLOWING TO THE ENGINE FROM NODE 2
      VDWM=W2/(RHO2*ADWM)
C     TEMPERATURE OF THE AIR IN THE PRIMARY FLOW OF THE JUNCTION AT
C     NODE 5, ENGINE EXHAUST TEMPERATURE
      TMAIN=T8
C     IF A BOILER IS IN BRANCH 3-5 THE TEMP IS THE TEMP OUT OF THE
C     BOILER
      IF(IND.EQ.1) TMAIN=770.0+3.70E-3*HP
C     COMPUTATION TO FIND THE TEMPERATURE OF THE COMBINED FLOW
C     BASED OF THE ENTHALOPY OF THE TWO MIXING FLOWS
      HSEC=(1.421385E-5*TMOD+.221091)*TMOD+5.6373
      HMAIN=(1.56051E-5*TMAIN+.22388)*TMAIN+4.75396
      HSTACK=(W8/(W8+WC))*HMAIN+(WC/(W8+WC))*HSEC
      T5=(-0.0008417*HSTACK+4.33577)*HSTACK-9.5778
C     ASSUME THE DENSITIES AT NODE 5 ,COMBINED, MAIN, AND BRANCH
      RHOCC=PT5/(R*T5)
      RHOCB=PSEC/(R*TMOD)
      RHOCM=PMAIN/(R*TMAIN)
C     COMPUTE THE VELOCITIES AT NODE 5, BRANCH, COMBINED, AND MAIN
 10   VCWB=WC/(RHOCB*ACWB)
      VCWC=(WC+W8)/(RHOCC*ACWC)
      VCWM=W8/(RHOCM*ACWM)
C     COMPUTE THE VELOCITY PRESSURES AROUND NODE 5
      PVB=RHOCB*VCWB**2/(2.0*32.174)
      PVC=RHOCC*VCWC**2/(2.0*32.174)
      PVM=RHOCM*VCWM**2/(2.0*32.174)
C     COMPUTE STATIC PRESSURES AROUND NODE 5
      PSB=PSEC-PVB
      PSC=PT5-PVC
      PSM=PMAIN-PVM
C     COMPUTE DENSITIES AROUND NODE 5
      RHOCBT=PSB/(R*TMOD)
      RHOCCT=PSC/(R*T5)
      RHOCMT=PSM/(R*TMAIN)
C     TEST ASSUMED DENSITIES AND COMPUTED DENSITIES
      TEST1=ABS(RHOCBT-RHOCB)
      TEST2=ABS(RHOCCT-RHOCC)
```

```
      TEST3=ABS(RHOCMT-RHOCM)
      RHOCB=RHOCBT
      RHOCC=RHOCCT
      RHOCM=RHOCMT
      IF(TEST1.GT.0.001) GO TO 10
      IF(TEST2.GT.0.001) GO TO 10
      IF(TEST3.GT.0.001) GO TO 10
C     INITIALIZE THE INLET CONDITIONS FOR BRANCH 5-6
 11   TIN=T5
      W=WC+W8
      PTIN=P0*144.0+DP56
      DP56=0.0
C     COMPUTE FITTING LOSSES
      DO 12 I=E,N
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(W,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +    DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +          0.,0.,0.,T0)
          DP(I)=DELP
          DP56=DP56+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
 12   CONTINUE
C     EXIT PRESSURE MUST BE ATMOSPHERIC
      TEST=ABS(PTOUT-P0*144.0)
      IF(TEST.LT.1.0) GO TO 14
          GO TO 11
 14   CONTINUE
C     NOW THE TOTAL PRESSURE AT NODE 5 IS KNOWN FOR THE ASSUMED FLOW
      PT5=P0*144.0+DP56
C     INITIALIZE INLET CONDITIONS FOR BRANCH 2-3
      PTIN=PT2
      TIN=TC+459.7
      DP23=0.0
C     COMPUTE FITTING LOSSES
      DO 20 I=A,DD
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +      DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
     +          VDWB,VDWM,VDWC,0.,T0)
          DP(I)=DELP
          DP23=DP23+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
 20   CONTINUE
C     INITIALIZE INLET CONDITIONS FOR BRANCH 3-5
      PTIN=P8*144.0
 30   TIN=T8
      DP35=0.0
C     COMPUTE FITTING LOSSES
      DO 35 I=C,SS
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(W8,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +     VCWC,0.,0.,0.,RHOCC,T0)
```

```
            DP(I)=DELP
            DP35=DP35+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
C           LOSS IN THE MAIN ENGINE EXHAUST FLOW FOR NODE 5, ENERGY IS
C           TRANSFERED TO THE MODULE COOLING FLOW AS A PRESSURE GAIN.
            IF(TYPE.EQ.16) LOSS=DELP
 35     CONTINUE
C       COMPARE EXIT PRESSURE TO PT5, REVISE INLET CONDITION TO BRANCH
C       3-5 AND REPEAT IF NECESSARY
        TEST=ABS(PTOUT-PT5)
        IF(TEST.LT.1.0) GO TO 40
            PTIN=P0*144.0+DP35+DP56
            GO TO 30
 40     CONTINUE
C       COMPARE ASSUMED LOSSES TO COMPUTED LOSSES REPEAT ITERATION
C       IF REQUIRED
        INLOSS=INLOSS*5.19696
        EXLOSS=EXLOSS*5.19696
        TEST1=ABS(DP12+DP23-INLOSS)
        TEST2=ABS(DP35+DP56-EXLOSS)
        INLOSS=(DP12+DP23)/5.19696
        EXLOSS=(DP35+DP56)/5.19696
        IF((TEST1.GT.1.0).OR.(TEST2.GT.1.0)) GO TO 5
C       INITIALIZE LOSSES FOR BRANCH 2-4
 45     PTIN=PT2
        DP24=0.0
        TIN=T0+459.7
C       COMPUTE FITTING LOSSES
        DO 50 I=B,RR
            TYPE=WORKI(I,2)
            DATA1=WORKR(I,1)
            DATA2=WORKR(I,2)
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +        DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
     +             VDWB,VDWM,VDWC,0.,T0)
            DP(I)=DELP
            DP24=DP24+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
            IF(TYPE.EQ.26) TMOD=TOUT
 50     CONTINUE
C       INITIALIZE INLET CONDITIONS FOR BRANCH 4-5
        T4=TOUT
        PTIN=PTOUT+(K*((WC/RHOSTD*60.0)-CFMMAX)**2+DPMAX)*5.19696
        TIN=T4
        DP45=0.0
C       COMPUTE FITTING LOSSES
        DO 60 I=D,TT
            TYPE=WORKI(I,2)
            DATA1=WORKR(I,1)
            DATA2=WORKR(I,2)
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +        DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +        VCWC,0.,0.,0.,RHOCC,T0)
            DP(I)=DELP
            DP45=DP45+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
C           THE MODULE FLOW GET A BOOST IN PRESSURE BY A TRANSFER
C           OF MOMENTUM FROM THE HIGHER VELOCITY MAIN EXHAUST FLOW
            IF(TYPE.EQ.15) GAIN=DELP
```

```
         IF(TYPE.EQ.26) TMOD=TOUT
 60   CONTINUE
C     TEST THAT EXIT PRESSURE IS PT5, IF NOT REPEAT
      TEST=ABS(PTOUT-PT5)
      IF(TEST.LT.1.0) GO TO 70
C        COOLING FLOW IN INCREASED BY SMALL STEPS UNTIL SYSTEM IS
C        MATCHED
         WC=WC+0.1
         GO TO 5
C     SYSTEM IS MATCEED PRINT RESULTS
 70   CALL OUTPUT(TO,PO,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
     +   W2,W8,P8,T8,SFC,I54,NG,SERIAL,TMOD)
      DP12=DP12/5.19696
      DP23=DP23/5.19696
      DP35=DP35/5.19696
      DP56=DP56/5.19696
      DP24=DP24/5.19696
      DP45=DP45/5.19696
C     PRINT BRANCH LOSS SUMMARY
      WRITE (4,601) DP12,DP23,DP35,DP56,DP24,DP45
 500  CONTINUE
 600  FORMAT('  POWER POINT IS NOT ON THE PERFORMANCE MAP.')
 601  FORMAT(/5X,'LOSS BRANCH 1-2:',F12.2,/5X,'LOSS BRANCH 2-3:',F12.2,
     +         /5X,'LOSS BRANCH 3-5:',F12.2,/5X,'LOSS BRANCH 5-6:',F12.2,
     +         /5X,'LOSS BRANCH 2-4:',F12.2,/5X,'LOSS BRANCH 4-5:',F12.2)
      RETURN
      END
```

```
C***********************************************************************C
C       SYSTEM FOUR MATCHING SUBROUTINE                                 C
C                                                                       C
C       THIS SYSTEM HAS SEPARATE INLETS FOR THE ENGINE AIR FLOW AND     C
C       MODULE COOLING.  NODE 5 IS THE JUNCTION OF MODULE AIR AND       C
C       ENGINE EXHAUST.  FOR THE ASSUMED FLOW THE PRESSURE AT NODE      C
C       5 IS COMPUTED DOWN THE COMBINED EXHAUST.  THEN THE EXIT         C
C       PRESSURE FROM BRANCHES 3-5 AND 4-5 SHOULD MATCH PT5.  IF NOT    C
C       THE ITERATION PROCESS CONTINUES.                                C
C                                                                       C
C***********************************************************************C
        SUBROUTINE SYS4(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
     +                  ALFAC,ACWB,ACWC,ACWM,
     +                  RHOSTD,CFM0,CFMMAX,DPMAX,K)
        REAL WORKR,HP,NPT,TO,PO,HUMID,CFMMAX,CFM0,DPMAX,K,W2,W8,P8,T8,
     +       INLOSS,EXLOSS,FANDP,DP13,DP24,DP35,DP45,PV,PTIN,PTOUT,DATA1,
     +       DATA2,DATA3,TEST,DP,FITPV,WC,RHOSTD,TEST1,TEST2,WCN,TMOD,
     +       T54,SFC,NG,DP56,
     +       DATA4,R,ALFAC,ACWB,ACWC,ACWM,VCWB,VCWC,VCWM,TMAIN,TMOD,HSEC,
     +       HMAIN,HSTACK,T4,T5,W,GAIN,LOSS,PSEC,PMAIN,PT4,PT5,TEST3,
     +       PVB,PVC,PVM,PSB,PSC,PSM,RHOCBT,RHOCCT,RHOCMT,TEST1,TEST2
        INTEGER WORKI,FIT1ST,OFF,N,PP,QQ,RR,SS,TT,A,B,C,D,E,SERIAL,TYPE,
     +          IND
        DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(6),DP(200),FITPV(200)
C       GAS CONSTANT
        DATA R/53.3424/
C       THE STARTING AND STOPPING INDEX FOR A BRANCH IS COMPUTED
        PP=FIT1ST(2)-1
        QQ=FIT1ST(3)-1
        RR=FIT1ST(4)-1
        SS=FIT1ST(5)-1
        A=FIT1ST(2)
        B=FIT1ST(3)
        C=FIT1ST(4)
        D=FIT1ST(5)
C       INITIALIZE THE INLET AND EXHAUST LOSSES
        INLOSS=4.0
        EXLOSS=8.0
C       INITIALIZE THE GAIN AND LOSS AT NODE 5
        GAIN=-30.0
        LOSS=30.0
C       INITIALIZETHE COOLING FLOW
        WC=CFMAMX*RHOSTD/60.0
C       INTIALIZE THE BRANCH LOSSES
        DP45=100.0
        DP56=100.0
C       INITIALIZE THE MODULE TEMPERATURE
        TMOD=710.0
C       INITIALIZE THE PRESSURES AT NODE 5
        PT5=PO*144.0+DP56
        PMAIN=PT5+LOSS
        PSEC=PT5+GAIN
C       SEARCH FOR A WASTE HEAT BOILER IN BRANCH 3-5
        IND=0
        DO 4 I=C,SS
           TYPE=WORKI(I,2)
           IF(TYPE.EQ.27) IND=1
 4      CONTINUE
C       GET INITIAL PERFORMANCE OF ENGINE WITH ASSUMED CONDITIONS
 5      CALL ENGINE(INLOSS,EXLOSS,TO,PO,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
     +              T54,NG,OFF)
        IF(OFF.EQ.0) GO TO 6
           WRITE(6,600)
           GO TO 500
 6      CONTINUE
C       INITIALIZE INLET CONDITIONS FOR BRANCH 1-3
        DP13=0.0
        PTIN=PO*144.0
        TIN=TO+459.7
```

```
C       COMPUTE FITTING LOSSES
        DO 8 I=1,BP
           TYPE=WORKI(I,2)
           DATA1=WORKR(I,1)
           DATA2=WORKR(I,2)
           DATA3=WORKR(I,3)
           DATA4=WORKR(I,4)
           CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +         0.,T0)
           DP(I)=DELP
           DP13=DP13+DELP
           FITPV(I)=PV
           PTIN=PTOUT
           TIN=TOUT
  8     CONTINUE
C       COMPUTE NODE 5 PARAMETERS
C       TEMPERATURE OF MAIN JET, ENGINE EXHAUST
        TMAIN=T8
C       IF A BOILER IS INSTALLED THE TEMPERATURE IS THE BOILER EXIT TEMP
        IF(IND.EQ.1) TMAIN=770.0+3.70E-3*HP
C       COMPUTE THE COMBINED FLOW TEMPERATURE BY MIXING ENTHALOPIES
        HSEC=(1.421385E-5*TMOD+.221091)*TMOD+5.6373
        HMAIN=(1.56051E-5*TMAIN+.22388)*TMAIN+4.75396
        HSTACK=(W8/(W8+WC))*HMAIN+(WC/(W8+WC))*HSEC
        T5=(-0.0008417*HSTACK+4.33577)*HSTACK-9.5778
C       ASSUME DENSITIES AT NODE 5, COMBINED, BRANCH, MAIN
        RHOCC=PT5/(R*T5)
        RHOCB=PSEC/(R*TMOD)
        RHOCM=PMAIN/(R*TMAIN)
C       COMPUTE VELOCITIES AT NODE 5, BRANCH, COMBINED, MAIN
 10     VCWB=WC/(RHOCB*ACWB)
        VCWC=(WC+W8)/(RHOCC*ACWC)
        VCWM=W8/(RHOCM*ACWM)
C       COMPUTE THE VELOCITY PRESSURES AROUND NODE 5
        PVB=RHOCB*VCWB**2/(2.0*32.174)
        PVC=RHOCC*VCWC**2/(2.0*32.174)
        PVM=RHOCM*VCWM**2/(2.0*32.174)
C       COMPUTE STATIC PRESSURES AROUND NODE 5
        PSB=PSEC-PVB
        PSC=PT5-PVC
        PSM=PMAIN-PVM
C       COMPUTE DENSITIES AROUND NODE 5
        RHOCBT=PSB/(R*TMOD)
        RHOCCT=PSC/(R*T5)
        RHOCMT=PSM/(R*TMAIN)
C       TEST ASSUMED DENSITIES AND COMPUTED DENSITIES
        TEST1=ABS(RHOCBT-RHOCB)
        TEST2=ABS(RHOCCT-RHOCC)
        TEST3=ABS(RHOCMT-RHOCM)
        RHOCB=RHOCBT
        RHOCC=RHOCCT
        RHOCM=RHOCMT
        IF(TEST1.GT.0.001) GO TO 10
        IF(TEST2.GT.0.001) GO TO 10
        IF(TEST3.GT.0.001) GO TO 10
C       INITIALIZE INLET CONDITIONS FOR BRANCH 5-6
 11     TIN=T5
        PTIN=P0*144.0+DP56
        W=WC+W8
        DP56=0.0
C       COMPUTE FITTING LOSSES
        DO 12 I=D,N
           TYPE=WORKI(I,2)
           DATA1=WORKR(I,1)
           DATA2=WORKR(I,2)
           DATA3=WORKR(I,3)
           DATA4=WORKR(I,4)
           CALL FITDP(W,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
```

```
     +    DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +         0.,T0)
          DP(I)=DELP
          DP56=DP56+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
 12   CONTINUE
C     EXIT PRESSURE MUST BE ATMOSPHERIC
      TEST=ABS(PTOUT-P0*144.0)
      IF(TEST.LT.1.0) GO TO 14
          GO TO 11
 14   CONTINUE
C     TOTAL PRESSURE AT NODE FIVE BASED ON FLOW IN BRANCH 5-6
      PT5=P0*144.0+DP56
C     INITIALIZE INLET CONCITIONS FOR BRANCH 3-5
      PTIN=P8*144.0
 30   TIN=T8
      DP35=0.0
C     COMPUTE FITTING LOSSES
      DO 35 I=C,SS
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(W8,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +     VCWC,0.,0.,0.,RHOCC,T0)
          DP(I)=DELP
          DP35=DP35+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
C         LOSS OF PRESSURE DUE TO MOMENTUM EXCHANGE WITH SLOWER JET,
C         THE MODULE COOLING FLOW
          IF(TYPE.EQ.16) LOSS=DELP
 35   CONTINUE
C     BRANCH EXIT PRESSURE MUST BE PT5 OR REPEAT
      TEST=ABS(PTOUT-PT5)
      IF(TEST.LT.1.0) GO TO 40
          PTIN=P0*144.0+DP35+DP56
          GO TO 30
 40   CONTINUE
C     COMPARE ASSUMED LOSSES TO COMPUTED LOSSES, REPEAT ITERATION IF
C     REQUIRED
      INLOSS=INLOSS*5.19696
      EXLOSS=EXLOSS*5.19696
      TEST1=ABS(DP13-INLOSS)
      TEST2=ABS(DP35+DP56-EXLOSS)
      INLOSS=DP13/5.19696
      EXLOSS=(DP35+DP56)/5.19696
      IF((TEST1.GT.1.0).OR.(TEST2.GT.1.0)) GO TO 5
C     INITIALIZE INLET CONDITIONS FOR BRANCH 2-4
      PTIN=P0*144.0
      TIN=T0+459.7
      DP24=0.0
C     COMPUTE FITTING LOSSES
      DO 20 I=B,30
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,
     +         VDWB,VDWM,VDWC,0.,0.,T0)
          DP(I)=DELP
          DP24=DP24+DELP
```

```
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
          IF(TYPE.EQ.26) TMOD=TOUT
 20    CONTINUE
       PT4=PTOUT
       T4=TOUT
C      INITIALIZE INLET CONDITIONS FOR BRANCH 4-5
       PTIN=PT4+(K*((WC/RHOSTD*60.0)-CFMMAX)**2+DPMAX)*5.19696
       TIN=T4
       DP45=0.0
C      COMPUTE FITTING LOSSES
       DO 60 I=B,BB
          TYPE=WORKI(I,2)
          DATA1=WORKR(I,1)
          DATA2=WORKR(I,2)
          DATA3=WORKR(I,3)
          DATA4=WORKR(I,4)
          CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +     VCWC,0.,0.,0.,RHOCC,IO)
          DP(I)=DELP
          DP45=DP45+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
C         GAIN IS RESULT OF MOMENTUM TRANSFER FROM EXHAUST FLOW
          IF(TYPE.EQ.15) GAIN=DELP
          IF(TYPE.EQ.26) TMOD=TOUT
 60    CONTINUE
C      EXIT PRESSURE SHOULD BE PT5 OR REPEAT ITERATION
       TEST=ABS(PTOUT-PT5)
       IF(TEST.LT.1.0) GO TO 70
C         ADD A SMALL INCREMENT TO THE COOLING FLOW AND REPEAT ITERATION
          WC=WC+0.1
          GO TO 5
C      SYSTEM IS MATCHED, OUTPUT RESULTS
 70    CALL OUTPUT(T0,P0,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
     +     W2,W8,P8,T8,SFC,I54,NG,SERIAL,TMOD)
       DP13=DP13/5.19696
       DP24=DP24/5.19696
       DP35=DP35/5.19696
       DP45=DP45/5.19696
       DP56=DP56/5.19696
C      OUTPUT BRANCH LOSS SUMMARY
       WRITE (4,601) DP13,DP24,DP35,DP45,DP56
 500   CONTINUE
 600   FORMAT('  POWER POINT IS NOT ON THE PERFORMANCE MAP.')
 601   FORMAT(/5X,'LOSS BRANCH 1-3:',F12.2,/5X,'LOSS BRANCH 2-4:',F12.2,
     +        /5X,'LOSS BRANCH 3-5:',F12.2,/5X,'LOSS BRANCH 4-5:',F12.2,
     +        /5X,'LOSS BRANCH 5-6:',F12.2)
       RETURN
       END
```

```
C*********************************************************************C
C       SYSTEM FIVE MATCHING SUBROUTINE                               C
C                                                                     C
C       THIS SYSTEM HAS COMBINED INLETS AND EXHAUST FLOWS FOR THE ENGINE C
C       AND THE MODULE COOLING.  THERE IS NO COOLING FAN.  THE MOVEMENT C
C       OF COOLING AIR IS ACCOMPLISHED BY AN EDUCTOR ARRANGEMENT AT THE C
C       ENGINE EXHAUST PLANE.  THERE IS A TRANSFEROF MOMENTUM FROM A  C
C       HIGH SPEED JET (ENGINE EXHAUST THROUGH A NOZZLE) TO A LOW S   C
C       JET (MODULE COOLING FLOW).  THE SCHEME IS TO START WITH A SMALL C
C       COOLING FLOW AND SEE IF THERE IS ENOUGH GAIN AVAILABLE FROM THE C
C       EDUCTOR ARRANGEMENT TO MOVE THE AIR.  A PROPERLY DESIGNED SYSTEM C
C       WILL HAVE EXCESS GAIN AT THIS LOW FLOW AND THE ITERATION PROCESS C
C       CAN CONTINUE, INCREASING THE COOLING FLOW UNTIL THE SYSTEM IS  C
C       MATCHED.                                                      C
C                                                                     C
C*********************************************************************C
        SUBROUTINE SYS5(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,T0,P0,HUMID,
     +                  ALFAD,ADWB,ADWC,ADWM,ALFAC,ACWB,ACWC,ACWM)
        REAL WORKR,HP,NPT,T0,P0,HUMID,CFMMAX,CFM0,DPMAX,K,W2,W8,P8,T9,
     +       INLOSS,EXLOSS,FANDP,DP13,DP24,DP35,DP45,PV,PTIN,PTOUT,DATA1,
     +       DATA2,DATA3,TEST,DP,FITPV,WC,RHOSTD,TEST1,TEST2,WCN,TMOD,
     +       T54,SFC,NG,DP56,
     +       DATA4,R,ALFAC,ACWB,ACWC,ACWM,VCWB,VCWC,VCWM,TMAIN,TMOD,HSEC,
     +       HMAIN,HSTACK,T4,T5,W,GAIN,LOSS,PSEC,PMAIN,PT4,PT5,TEST3,
     +       PVB,PVC,PVM,PSB,PSC,PSM,RHOCBT,RHOCCT,RHOCMT,TEST1,TEST2
        INTEGER WORKI,FIT1ST,OFF,N,PP,QQ,RR,SS,A,B,C,D,SERIAL,TYPE,
     +          IND
        DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(6),DP(200),FITPV(200)
C       GAS CONSTANT
        DATA R/53.3424/
C       COMPUTE THE STARTING AND STOPPING POINTS FOR THE BRANCH FITTINGS.
        PP=FIT1ST(2)-1
        QQ=FIT1ST(3)-1
        RR=FIT1ST(4)-1
        SS=FIT1ST(5)-1
        A=FIT1ST(2)
        B=FIT1ST(3)
        C=FIT1ST(4)
        D=FIT1ST(5)
C       INITIALIZE THE INLET AND EXHAUST LOSSES (INCH WG)
        INLOSS=4.0
        EXLOSS=8.0
C       INITIALIZE THE GAIN OR PRESSURE RISE TO MODULE AIR FLOW IN THE
C       EDUCTOR
        GAIN=-30.0
        LOSS=30.0
C       INITIALIZE THE COOLING FLOW TO THE MINIMUM REQUIRED FOR THE ENGINE
        WC=7.5
C       INITIALIZE PARAMETERS TO START ITERATION
        DP56=100.0
        TMOD=710.0
        PT5=P0*144.0+DP56
        PMAIN=PT5+LOSS
        PSEC=PT5+GAIN
C       SEARCH FOR A WASTE HEAT BOILER, THERE PROBABLY IS NOT A BOILER
C       INSTALLED IN THIS SYSTEM.
        IND=0
        DO 4 I=C,SS
           TYPE=WORKI(I,2)
           IF(TYPE.EQ.27) IND=1
    4   CONTINUE
C       GET ENGINE PERFORMANCE BASED ON ASSUMED CONDITIONS
    5   CALL ENGINE(INLOSS,EXLOSS,T0,P0,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
     +              T54,NG,OFF)
        IF(OFF.EQ.0) GO TO 6
           WRITE(6,600)
           GO TO 500
    6   CONTINUE
C       INITIALIZE INLET CONDITIONS FOR BRANCH 1-2
```

```
      DP12=0.0
      PTIN=P0*144.0
      TIN=T0+459.7
      W=WC+W2
C     COMPUTE FITTING LOSSES
      DO 8 I=1,PP
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(W,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +   DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +   0.,T0)
         DP(I)=DELP
         DP12=DP12+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
 8    CONTINUE
C     COMPUTE PARAMETERS AT NODES 2 & 5
C     TOTAL PRESSURE AT NODE 2 (PSF)
      PT2=P0*144.0-DP12
C     DENSITY AT NODE 2
      RHO2=(PT2-PV)/((T0+459.7)*R)
C     VELOCITIES AT NODE 2, BRANCH, COMBINED, MAIN
      VDWB=WC/(RHO2*ADWB)
      VDWC=(WC+W2)/(RHO2*ADWC)
      VDWM=W2/(RHO2*ADWM)
C     TEMPERATURE IN MAIN JET (ENGINE EXHAUST) AT NODE 5
      TMAIN=T8
C     IF A BOILER IS INSTALLED TMAIN IS BOILER EXIT TEMP
      IF(IND.EQ.1) TMAIN=770.0+3.70E-3*HP
C     COMPUTE COMBINED FLOW TEMPERATURE BASE ON ENTHALOPIES
      HSEC=(1.421385E-5*TMOD+.221091)*TMOD+5.6373
      HMAIN=(1.56051E-5*TMAIN+.22388)*TMAIN+4.75396
      HSTACK=(W8/(W8+WC))*HMAIN+(WC/(W8+WC))*HSEC
      T5=(-0.0008417*HSTACK+4.33577)*HSTACK-9.5778
C     ASSUME DENSITIES AT NODE 5, COMBINED, BRANCH, MAIN
      RHOCC=PT5/(R*T5)
      RHOCB=PSEC/(R*TMOD)
      RHOCM=PMAIN/(R*TMAIN)
C     COMPUTE VELOCITIES AT NODE 5, BRANCH, COMBINED, MAIN
 10   VCWB=WC/(RHOCB*ACWB)
      VCWC=(WC+W8)/(RHOCC*ACWC)
      VCWM=W8/(RHOCM*ACWM)
C     COMPUTE THE VELOCITY PRESSURES AROUND NODE 5
      PVB=RHOCB*VCWB**2/(2.0*32.174)
      PVC=RHOCC*VCWC**2/(2.0*32.174)
      PVM=RHOCM*VCWM**2/(2.0*32.174)
C     COMPUTE STATIC PRESSURES AROUND NODE 5
      PSB=PSEC-PVB
      PSC=PT5-PVC
      PSM=PMAIN-PVM
C     COMPUTE DENSITIES AROUND NODE 5
      RHOCBT=PSB/(R*TMOD)
      RHOCCT=PSC/(R*T5)
      RHOCMT=PSM/(R*TMAIN)
C     TEST ASSUMED DENSITIES AND COMPUTED DENSITIES
      TEST1=ABS(RHOCBT-RHOCB)
      TEST2=ABS(RHOCCT-RHOCC)
      TEST3=ABS(RHOCMT-RHOCM)
      RHOCB=RHOCBT
      RHOCC=RHOCCT
      RHOCM=RHOCMT
      IF(TEST1.GT.0.001) GO TO 10
      IF(TEST2.GT.0.001) GO TO 10
      IF(TEST3.GT.0.001) GO TO 10
C     INITIALIZE INLET CONDITIONS FOR BRANCH 5-6
```

```
 11      TIN=T5
         PTIN=P0*144.0+DP56
         DP56=0.0
         W=WC+W8
C        COMPUTE FITTING LOSSES
         DO 12 I=D,N
            TYPE=WORKI(I,2)
            DATA1=WORKR(I,1)
            DATA2=WORKR(I,2)
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(W,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +      DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +           0.,T0)
            DP(I)=DELP
            DP56=DP56+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
 12      CONTINUE
C        EXIT PRESSURE SHOULD BE ATMOSPHERIC, IF NOT REPEAT
         TEST=ABS(PTOUT-P0*144.0)
         IF(TEST.LT.1.0) GO TO 14
            GO TO 11
 14      CONTINUE
         PT5=P0*144.0+DP56
C        INITIALIZE INLET CONDITIONS FOR BRANCH 2-3
         PTIN=PT2
         TIN=T0+459.7
         DP23=0.0
C        COMPUTE FITTING LOSSES
         DO 20 I=A,QQ
            TYPE=WORKI(I,2)
            DATA1=WORKR(I,1)
            DATA2=WORKR(I,2)
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +        DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,
     +            VDWB,VDWM,VDWC,0.,0.,T0)
            DP(I)=DELP
            DP23=DP23+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
 20      CONTINUE
C        INITIALIZE INLET CONDITIONS FOR BRANCH 3-5
         PTIN=P8*144.0
 30      TIN=T9
         DP35=0.0
C        COMPUTE FITTING LOSSES
         DO 35 I=C,SS
            TYPE=WORKI(I,2)
            DATA1=WORKR(I,1)
            DATA2=WORKR(I,2)
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(W3,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +        DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +        VCWC,0.,0.,0.,RHOCC,T0)
            DP(I)=DELP
            DP35=DP35+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
C           LOSS IS FROM MOMENTUM TRANSFER TO COOLING FLOW
            IF(TYPE.EQ.16) LOSS=DELP
 35      CONTINUE
C        EXIT PRESSURE SHOULD BE PT5, IF NOT REPEAT
```

```
      TEST=ABS(PTOUT-PT5)
      IF(TEST.LT.1.0) GO TO 40
         PTIN=P0*144.0+DP35+DP56
         GO TO 30
 40   CONTINUE
C     COMPARE ASSUMED LOSSES WITH COMPUTED LOSSES
      INLOSS=INLOSS*5.19696
      EXLOSS=EXLOSS*5.19696
      TEST1=ABS(DP12+DP23-INLOSS)
      TEST2=ABS(DP35+DP56-EXLOSS)
      INLOSS=(DP12+DP23)/5.19696
      EXLOSS=(DP35+DP56)/5.19696
      IF((TEST1.GT.1.0).OR.(TEST2.GT.1.0)) GO TO 5
C     INITIALIZE INLET CONDITIONS FOR BRANCH 2-5, NO FAN (NODE 4)
      PTIN=PT2
      TIN=T0+459.7
      DP25=0.0
      DO 60 I=3,RR
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +     VCWC,0.,0.,0.,RHOCC,T0)
         DP(I)=DELP
         DP25=DP25+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
C        GAIN IS FROM MOMENTUM TRANSFER FROM ENGINE EXHAUST
         IF(TYPE.EQ.15) GAIN=DELP
         IF(TYPE.EQ.26) TMOD=TOUT
 60   CONTINUE
C     EXIT PRESSURE SHOULD BE PT5, IF NOT REPEAT ITERATION
      TEST=ABS(PTOUT-PT5)
      IF(TEST.LT.1.0) GO TO 70
C        INCREASE COOLING FLOF UNTIL SYSTEM IS MATCHED
         WC=WC+0.1
         GO TO 5
C     SYSTEM IS MATCHED, OUTPUT RESUSTS
 70   CALL OUTPUT(T0,P0,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
     +     W2,W8,P8,T9,SFC,T54,NG,SERIAL,TMOD)
      DP12=DP12/5.19696
      DP23=DP23/5.19696
      DP35=DP35/5.19696
      DP56=DP56/5.19696
      DP25=DP25/5.19696
C     OUTPUT BRANCH LOSS SUMMARY
      WRITE (4,601) DP12,DP23,DP35,DP56,DP25
 500  CONTINUE
 600  FORMAT('   POWER POINT IS NOT ON THE PERFORMANCE MAP.')
 601  FORMAT(/5X,'LOSS BRANCH 1-2:',F12.2,/5X,'LOSS BRANCH 2-3:',F12.2,
     +        /5X,'LOSS BRANCH 3-5:',F12.2,/5X,'LOSS BRANCH 5-6:',F12.2,
     +        /5X,'LOSS BRANCH 2-5:',F12.2)
      RETURN
      END
```

```
C*****************************************************************C
C      SYSTEM SIX MATCHING SUBROUTINE                              C
C                                                                  C
C      THIS SYSTEM HAS SEPARATE INLETS FOR COOLING FLOW AND ENGINE AIR.
C      THE TWO FLOW JOIN AT AN EDUCTOR ARANGEMENT AT THE ENGINE EXHAUST
C      PLANE.  THERE IS NO COOLING FAN INSTALLED.  THE EDUCTOR PROVIDES
C      ALL THE PUMPING ACTION BY MOMENTUM TRANSFER FROM A HIGH VELOCITY
C      JET (ENGINE EXHAUST THROUGH A NOZZLE) TO A LOW VELOCITY JET C
C      (MODULE COOLING FLOW).                                      C
C                                                                  C
C*****************************************************************C
      SUBROUTINE SYS6(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,T0,P0,HUMID,
     +                ALFAC,ACWB,ACWC,ACWM)
      REAL WORKR,HP,NPT,T0,P0,HUMID,CFMMAX,CFM0,DPMAX,K,W2,W8,P8,T8,
     +     INLOSS,EXLOSS,DP13,DP25,DP35,DP56,PV,PTIN,PTOUT,DATA1,
     +     DATA2,DATA3,TEST,DP,FITPV,WC,RHOSTD,TEST1,TEST2,WCN,TMOD,
     +     T54,SFC,NG,
     +     DATA4,R,ALFAC,ACWB,ACWC,ACWM,VCWB,VCWC,VCWM,TMAIN,TMOD,HSEC,
     +     HMAIN,HSTACK,T5,W,GAIN,LOSS,PSEC,PMAIN,PT5,TEST3,
     +     PVB,PVC,PVM,PSB,PSC,PSM,RHOCBT,RHOCCT,RHOCMT,TEST1,TEST2
      INTEGER WORKI,FIT1ST,OFF,N,PP,QQ,RR,A,B,C,SERIAL,TYPE,
     +     IND
      DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(6),DP(200),FITPV(200)
C     GAS CONSTANT
      DATA R/53.3424/
C     STARTING AND STOPPING POINTS FOR THE BRANCH FITTING INDEX
      PP=FIT1ST(2)-1
      QQ=FIT1ST(3)-1
      RR=FIT1ST(4)-1
      A=FIT1ST(2)
      B=FIT1ST(3)
      C=FIT1ST(4)
C     INITIALIZE THE INLET AND EXHAUST DUCT LOSSES (INCH WG)
      INLOSS=4.0
      EXLOSS=8.0
C     INITIALIZE THE GAIN AND LOSS IN THE EDUCTOR (PSF)
      GAIN=-30.0
      LOSS=30.0
C     INITIALIZE TEH COOLING FLOW TO THE MI   MUM REQUIRED
      WC=7.5
C     INITIALIZE OTHER VALUES
      DP56=100.0
      TMOD=710.0
      PT5=P0*144.0+DP56
      PMAIN=PT5+LOSS
      PSEC=PT5+GAIN
C     SEARCH FOR A BOILER, THERE PROBABLY IS NOT ONE INSTALLED FOR THIS
C     SYSTEM
      IND=0
      DO 4 I=C,RR
         TYPE=WORKI(I,2)
         IF(TYPE.EQ.27) IND=1
    4 CONTINUE
C     GET ENGINE PERFORMANCE FOR THE ASSUMED CONDITIONS
    5 CALL ENGINE(INLOSS,EXLOSS,T0,P0,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
     +            T54,NG,OFF)
      IF(OFF.EQ.0) GO TO 6
         WRITE(6,600)
         GO TO 500
    6 CONTINUE
C     INITIALIZE THE INLET CONDITIONS FOR BRANCH 1-3
      DP13=0.0
      PTIN=P0*144.0
      TIN=T0+459.7
C     COMPUTE FITTING LOSSES
      DO 8 I=1,PP
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
```

```
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +      DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +      0.,T0)
            DP(I)=DELP
            DP13=DP13+DELP
            FITPV(I)=PV
            PTIN=PTOUT
            TIN=TOUT
    3     CONTINUE
C         COMPUTE PARAMETERS FOR NODE 5
C         MAIN JET TEMPERATURE (ENGINE EXHAUST)
          TMAIN=T8
C         IF A BOILER IS INSTALLED, TMAIN IS BOILER EXIT TEMPERATURE
          IF(IND.EQ.1) TMAIN=770.0+3.70E-3*HP
C         COMPUTE COMBINED FLOW TEMPERATURE FOR NODE 5, USING ENTHALOPIES
          HSEC=(1.421385E-5*TMOD+.221091)*TMOD+5.6373
          HMAIN=(1.56051E-5*TMAIN+.22388)*TMAIN+4.75396
          HSTACK=(W8/(W8+WC))*HMAIN+(WC/(W8+WC))*HSEC
          T5=(-0.0008417*HSTACK+4.33577)*HSTACK-9.5778
C         ASSUME NODE 5 DENSITIES, COMBINED, BRANCH, AND MAIN
          RHOCC=PT5/(R*T5)
          RHOCB=PSEC/(R*TMOD)
          RHOCM=PMAIN/(R*TMAIN)
C         COMPUTE NODE 5 VELOCITIES BRANCH, COMBINED AND MAIN
   10     VCWB=WC/(RHOCB*ACWB)
          VCWC=(WC+W8)/(RHOCC*ACWC)
          VCWM=W8/(RHOCM*ACWM)
C         COMPUTE THE VELOCITY PRESSURES AROUND NODE 5
          PVB=RHOCB*VCWB**2/(2.0*32.174)
          PVC=RHOCC*VCWC**2/(2.0*32.174)
          PVM=RHOCM*VCWM**2/(2.0*32.174)
C         COMPUTE STATIC PRESSURES AROUND NODE 5
          PSB=PSEC-PVB
          PSC=PT5-PVC
          PSM=PMAIN-PVM
C         COMPUTE DENSITIES AROUND NODE 5
          RHOCBT=PSB/(R*TMOD)
          RHOCCT=PSC/(R*T5)
          RHOCMT=PSM/(R*TMAIN)
C         TEST ASSUMED DENSITIES AND COMPUTED DENSITIES
          TEST1=ABS(RHOCBT-RHOCB)
          TEST2=ABS(RHOCCT-RHOCC)
          TEST3=ABS(RHOCMT-RHOCM)
          RHOCB=RHOCBT
          RHOCC=RHOCCT
          RHOCM=RHOCMT
          IF(TEST1.GT.0.001) GO TO 10
          IF(TEST2.GT.0.001) GO TO 10
          IF(TEST3.GT.0.001) GO TO 10
C         INITIALIZE INLET CONDITIONS FOR BRANCH 1-2
   11     TIN=T5
          PTIN=P0*144.0+DP56
          DP56=0.0
C         COMPUTE FITTING LOSSES
          DO 12 I=C,N
            TYPE=WORKI(I,2)
            DATA1=WORKR(I,1)
            DATA2=WORKR(I,2)
            DATA3=WORKR(I,3)
            DATA4=WORKR(I,4)
            CALL FITDP(W2,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +      DATA4,TYPE,DELP,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     +      0.,T0)
            DP(I)=DELP
            DP56=DP56+DELP
            FITPV(I)=PV
            PTIN=PTOUT
```

```
         TIN=TOUT
 12   CONTINUE
C     EXIT TEMPERATURE SHOULD BE ATMOSPHERIC IF NOT REPEAT ITERATION
      TEST=ABS(PTOUT-P0*144.0)
      IF(TEST.LT.1.0) GO TO 14
         GO TO 11
 14   CONTINUE
      PT5=P0*144.0+DP56
C     INITIALIZE INLET CONDITIONS FOR BRANCH 3-5
      PTIN=P8*144.0
      TIN=T8
      DP35=0.0
C     COMPUTE FITTING LOSSES
      DO 20 I=B,RR
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(W8,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,
     +          VDWB,VDWM,VDWC,0.,0.,T0)
         DP(I)=DELP
         DP35=DP35+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
         IF(TYPE.EQ.16) LOSS=DELP
 20   CONTINUE
C     COMPARE ASSUMED LOSSES AND COMPUTED LOSSES, IF NOT THE SAME REPEAT
      INLOSS=INLOSS*5.19696
      EXLOSS=EXLOSS*5.19696
      TEST1=ABS(DP12+DP23-INLOSS)
      TEST2=ABS(DP35+DP56-EXLOSS)
      INLOSS=(DP12+DP23)/5.19696
      EXLOSS=(DP35+DP56)/5.19696
      IF((TEST1.GT.1.0).OR.(TEST2.GT.1.0)) GO TO 5
C     INITIALIZE INLET CONDITIONS FOR BRANCH 2-5
      PTIN=P0*144.0
 30   TIN=T0+459.7
      DP25=0.0
C     COMPUTE FITTING LOSSES
      DO 35 I=A,QQ
         TYPE=WORKI(I,2)
         DATA1=WORKR(I,1)
         DATA2=WORKR(I,2)
         DATA3=WORKR(I,3)
         DATA4=WORKR(I,4)
         CALL FITDP(WC,HP,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
     +     DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
     +     VCWC,0.,0.,0.,RHOCC,T0)
         DP(I)=DELP
         DP25=DP25+DELP
         FITPV(I)=PV
         PTIN=PTOUT
         TIN=TOUT
C        GAIN IS RESULT OF MOMENTUM TRANSFER FROM EXHAUST TO COOLING
C        FLOW
         IF(TYPE.EQ.15) GAIN=DELP
         IF(TYPE.EQ.26) TMOD=TOUT
 35   CONTINUE
C     EXIT PRESSURE SHOULD BE PT5, IF NOT REPEAT ITERATION
      TEST=ABS(PTOUT-PT5)
      IF(TEST.LT.1.0) GO TO 40
C        NEXT ITERATION IS DONE WITH INCREASED COOLING FLOW, INCREASE
C        UNTIL SYSTEM IS MATCHED
         WC=WC+0.1
         GO TO 5
 40   CONTINUE
```

```
C     SYSTEM IS MATCHED, OUTPUT RESULTS
 70   CALL OUTPUT(T0,P0,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
     +   W2,W8,P8,T8,SFC,TS4,NG,SERIAL,IMOD)
      DP13=DP13/5.19696
      DP25=DP25/5.19696
      DP35=DP35/5.19696
      DP56=DP56/5.19696
C     OUTPUT BRANCH LOSS SUMMARY
      WRITE (4,601) DP13,DP25,DP35,DP56,DP25
 500  CONTINUE
 600  FORMAT('   POWER POINT IS NOT ON THE PERFORMANCE MAP.')
 601  FORMAT(/5X,'LOSS BRANCH 1-3:',F12.2,/5X,'LOSS BRANCH 2-5:',F12.2,
     +          /5X,'LOSS BRANCH 3-5:',F12.2,/5X,'LOSS BRANCH 5-6:',F12.2)
      RETURN
      END
```

```
C*********************************************************************C
C      FAN MATCHING SUBROUTINE                                        C
C                                                                     C
C      THIS SUBROUTINE PRODUCES THE NEXT GUESS AT COOLING FLOW BY     C
C      LOCATING THE INTERSECTION OF THE SYSTEM MODEL CURVE AND THE    C
C      FAN CHARACTERISTIC CURVE.                                      C
C                                                                     C
C*********************************************************************C
      SUBROUTINE FANMAT(WC,TO,PO,FANDP,RHOSTD,CFM0,CFMMAX,DPMAX,K,WCN)
      REAL CFMSTD,DPSTD,WC,RHOSTD,FANDP,PO,TO,C,CFM,WCN,CFM0,CFMMAX,
     +     DPMAX,K,R
C     GAS CONSTANT
      DATA R/53.3424/
C     CONVERT MAS FLOW TO STANDARD VOLUME FLOW (CFM)
      CFMSTD=WC/RHOSTD*60.0
C     CONVERT FAN DELTA PRESSURE TO STANDARD CONDITONS FOR THE FAN
      DPSTD=FANDP*(RHOSTD*R*(T0+459.7)/(PO*144.0))**2
C     C IS THE PROPORTIONALITY CONSTANT FOR THE QUADRATIC MODEL ASSUMED
C     TO REPRESENT THE SYSTEM
      C=DPSTD/CFMSTD**2
C     CFM IS THE INTERSECTION OF THE FAN CHARACTERISTIC AND SYSTEM
C     MODEL
      CFM=(2.0*K*CFMMAX-SQRT((2.0*K*CFMMAX)**2-4.0*(K-C)*(K*CFMMAX**2
     +     +DPMAX)))/(2.0*(K-C))
C     CONVERT CFM TO MASS FLOW
      WCN=RHOSTD*CFM/60.0
      RETURN
      END
```

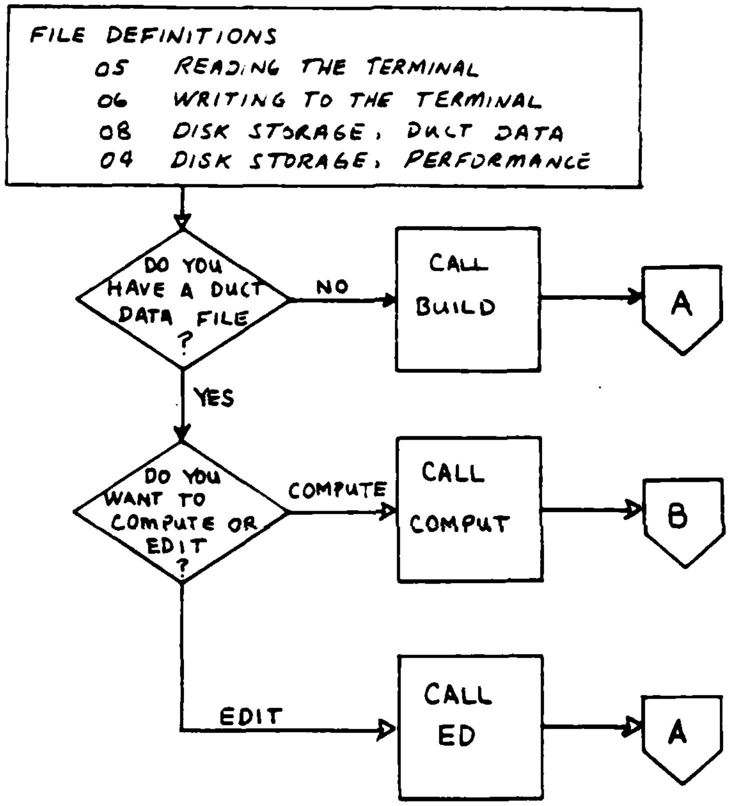
```
C*****************************************************************C
C      COMPUTE OUTPUT SUBROUTINE: PRINTS SYSTEM DATA              C
C                                                                 C
C      THIS SUBROUTINE WRITES TO THE OUTPUT FILE.  IF YOU HAVE AN OUTPUTC
C      FILE ALREADY IT WILL BE WRITTEN OVER BY THIS PROGRAM.  IF YOU C
C      WANT TO SAME THE PREVIOUS RESULTS, RENAME THE FILE.  IF YOU ADD C
C      OR CHANGE FITTINGS YOU MUST MAKE SOME CHANGES HERE.         C
C*****************************************************************C
       SUBROUTINE OUTPUT(TO,PO,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,
     +               EXLOSS,WC,W2,W8,P8,T8,SFC,T54,NG,SERIAL,TMOD)
       REAL TO,PO,HUMID,HP,NPT,DP,FITPV,INLOSS,EXLOSS,WC,W2,TMOD,
     +           W8,P8,T8,SFC,T54,NG
       INTEGER N,WORKI,SERIAL,TYPE
       DIMENSION DP(200),FITPV(200),WORKI(200,2)
       WRITE (4,600) SERIAL,TO,PO,HUMID,HP,NPT
       WRITE (4,601) INLOSS,EXLOSS
       TMOD=TMOD-459.7
       WRITE (4,602) WC,W2,W8,P8,T8,SFC,T54,NG,TMOD
       DO 100 I=1,N
          DP(I)=DP(I)/5.19696
          TYPE=WORKI(I,2)
          FITPV(I)=FITPV(I)/5.19696
          GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
     +          21,22,23,24,25,26,27,28,29,30),TYPE
1         WRITE (4,603) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
2         WRITE (4,604) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
3         WRITE (4,605) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
4         WRITE (4,606) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
5         WRITE (4,607) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
6         WRITE (4,608) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
7         WRITE (4,609) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
8         WRITE (4,610) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
9         WRITE (4,611) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
10        WRITE (4,612) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
11        WRITE (4,613) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
12        WRITE (4,614) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
13        WRITE (4,615) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
14        WRITE (4,616) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
15        WRITE (4,617) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
16        WRITE (4,618) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
17        WRITE (4,619) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
18        WRITE (4,620) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
19        WRITE (4,621) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
20        WRITE (4,622) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
21        WRITE (4,623) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
22        WRITE (4,624) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO 100
23        WRITE (4,625) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
```

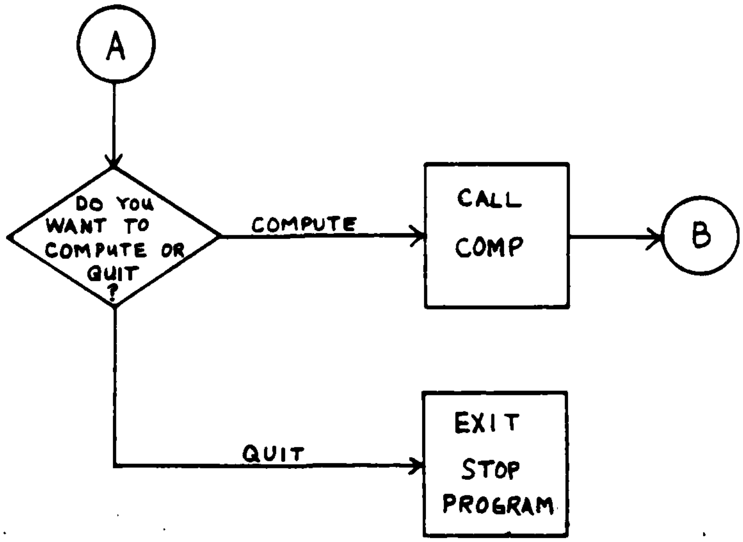
```
          GO TO  100
24        WRITE  (4,626) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO  100
25        WRITE  (4,627) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO  100
26        WRITE  (4,628) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO  100
27        WRITE  (4,629) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO  100
28        WRITE  (4,630) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO  100
29        WRITE  (4,631) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
          GO TO  100
30        WRITE  (4,631) WORKI(I,1),WORKI(I,2),DP(I),FITPV(I)
100   CONTINUE
      WRITE (6,633)
600   FORMAT(//,'   THIS PERFORMANCE RUN WAS DEVELOPED FROM DUCT DATA FIL
     +E, ',I6,//'   INLET CONDITIONS:  AMBIENT TEMP (DEG F)',F10.2,/
     +          '                      AMBIENT PRESS (PSIA)',F10.2,/
     +          '                      HUMIDITY (GRAINS)   ',F10.2,/
     +          '   HORSEPOWER: ',F12.1,/
     +          '   NET (RPM)  : ',F12.1/)
601   FORMAT('  ENGINE DUCT LOSSES (IN.W.G.): INLET',F8.2,3X,'EXHAUST',
     +        F8.2/)
602   FORMAT('  ENGINE PERFORMANCE PARAMETERS:'/
     +       '      WC=',F10.2,'  LBM/SEC'/,
     +       '      W2=',F10.2,'  LBM/SEC'/,
     +       '      W8=',F10.2,'  LBM/SEC'/,
     +       '      P8=',F10.2,'  PSIA'/,
     +       '      T8=',F10.2,'  DEG R'/,
     +       '      SFC=',F9.3,'  LBM(FUEL)/HP*HR'/,
     +       '      T54=',F10.1,'  DEG R'/,
     +       '      NG=',F10.1,'  RPM'/,
     +       '      MODULE COOLING TEMP OUT=',F10.1,'  DEG F'///
     +' FITTING      FITTING     PRESSURE LOSS   VELOCITY PRESSURE'/
     +'   ID          TYPE           INCH W.G.        INCH W.G.'/)
603   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'INTAKE SHAFT INLET')
604   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'STRAIGHT DUCT')
605   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,RND,SMOOTH RAD')
606   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,RND,SEGMT,90 DEG')
607   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,MITERED,ROUND')
608   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,MITERED,RECT')
609   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,RECT,SMOOTH RAD')
610   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,RECT,SMOOTH RAD,W/SPLT')
611   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,RECT,MITERED,W/VANES')
612   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOW,RECT,CONV/DIV FLOW')
613   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOWS,Z-SHAPED')
614   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'ELBOWS,IN DIFF PLANES')
615   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'BRANCH,DIV WYE')
616   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'MAIN SECT,DIV WYE')
617   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'BRANCH,CONV WYE')
618   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'MAIN SECT,CONV WYE')
619   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'DIFF,CONICAL')
620   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'DIFF,PLANE IN LINE')
621   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'DIFF,PYRAMIDAL')
622   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'DIFF,TRANSITIONAL')
623   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'CONTRACTION,ROUND')
624   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'CONTRACTION,RECT')
625   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'SCREEN IN DUCT')
626   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'LOUVER ENTRANCE')
627   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'FILTER')
628   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'SILENCER SECTION')
629   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'GAS TURBINE MODULE')
630   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'WASTE HEAT BOILER')
631   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'EXIT,ABRUPT')
632   FORMAT(I6,7X,I2,9X,F8.2,9X,F8.2,3X,'YOUR CHOICE')
633   FORMAT('  SEE OUTPUT DATA FILE ON YOUR DISK FOR RESULTS')
      RETURN
      END
```

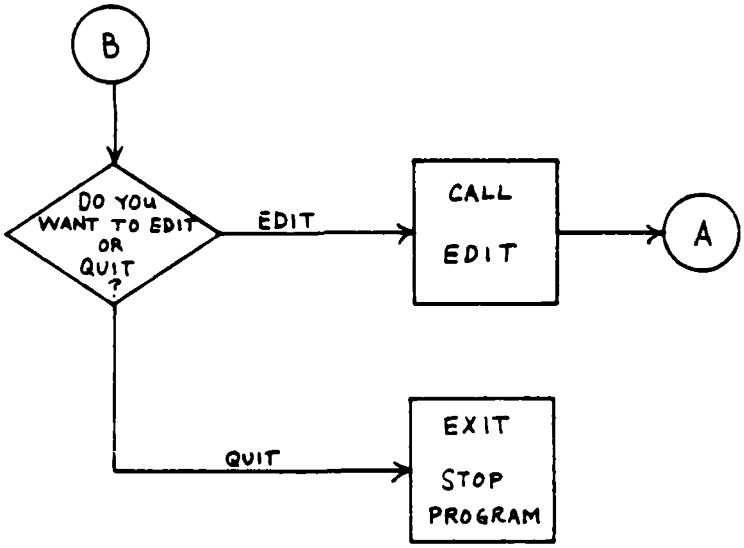
APPENDIX B

FLOW CHARTS

I. <u>MAIN PROGRAM</u> NO INPUT OR OUTPUT VARIABLES

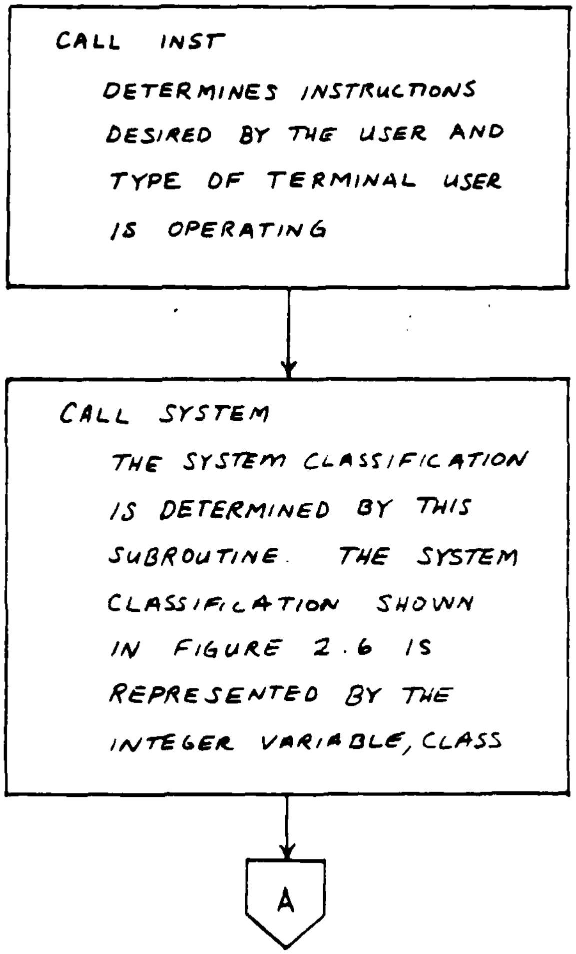


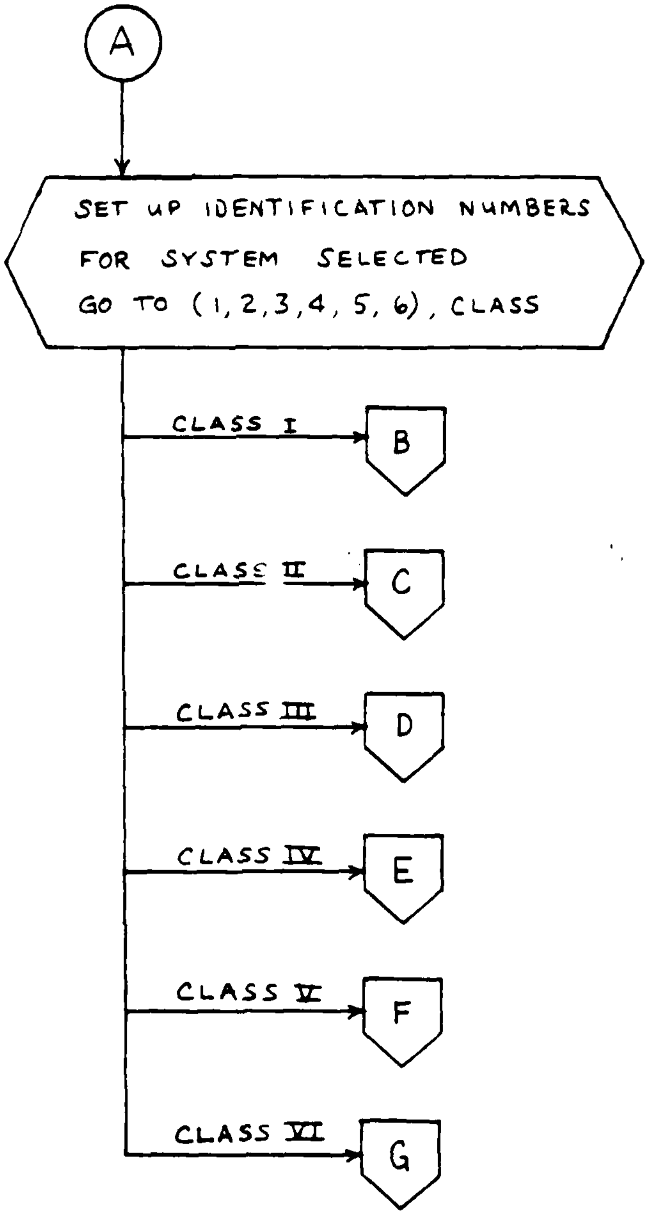

A
DO YOU WANT TO COMPUTE OR QUIT ?
COMPUTE
CALL COMP
B
QUIT
EXIT STOP PROGRAM


B
DO YOU WANT TO EDIT OR QUIT ?
EDIT
CALL EDIT
A
QUIT
EXIT STOP PROGRAM

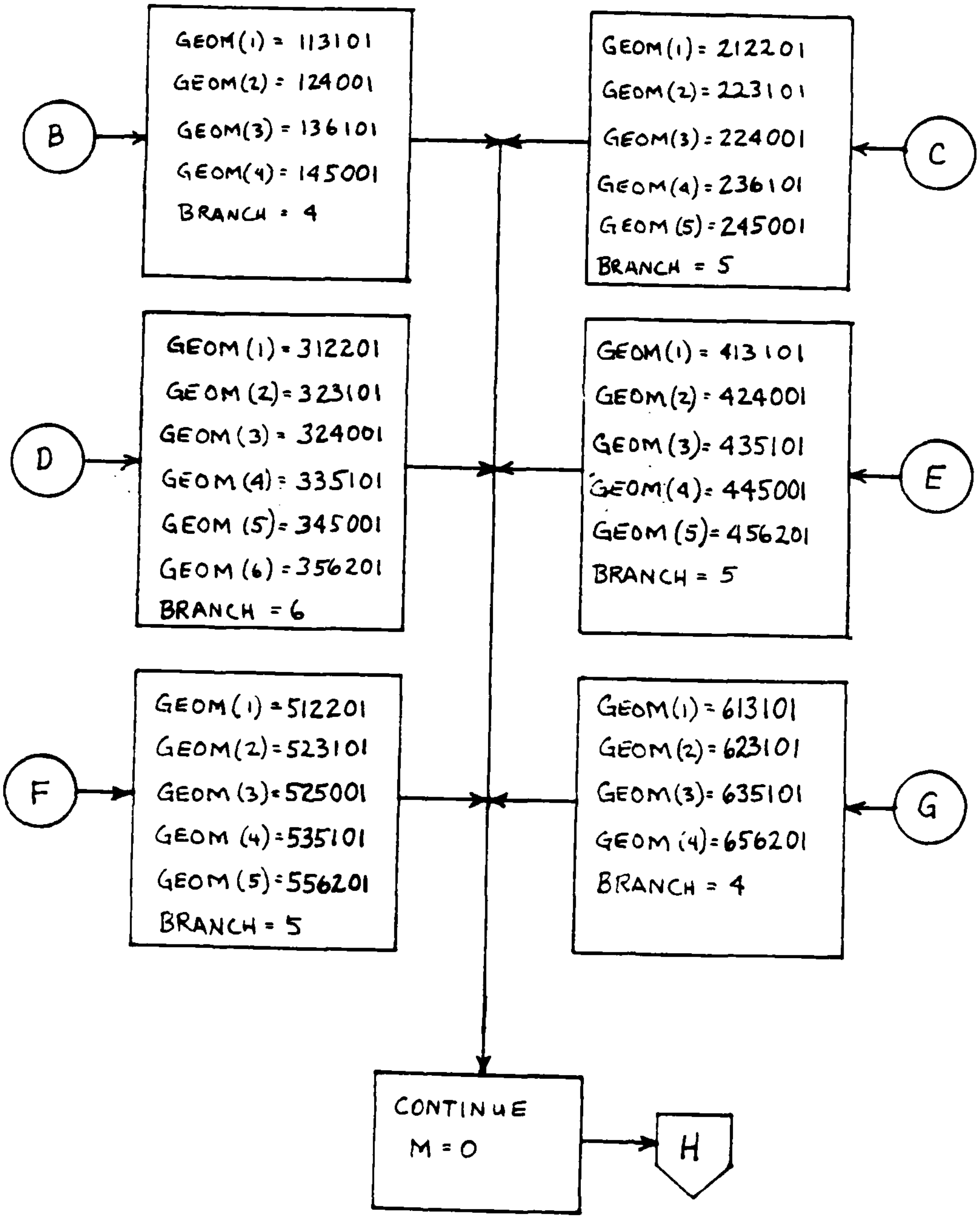
II. BUILD SUBROUTINE

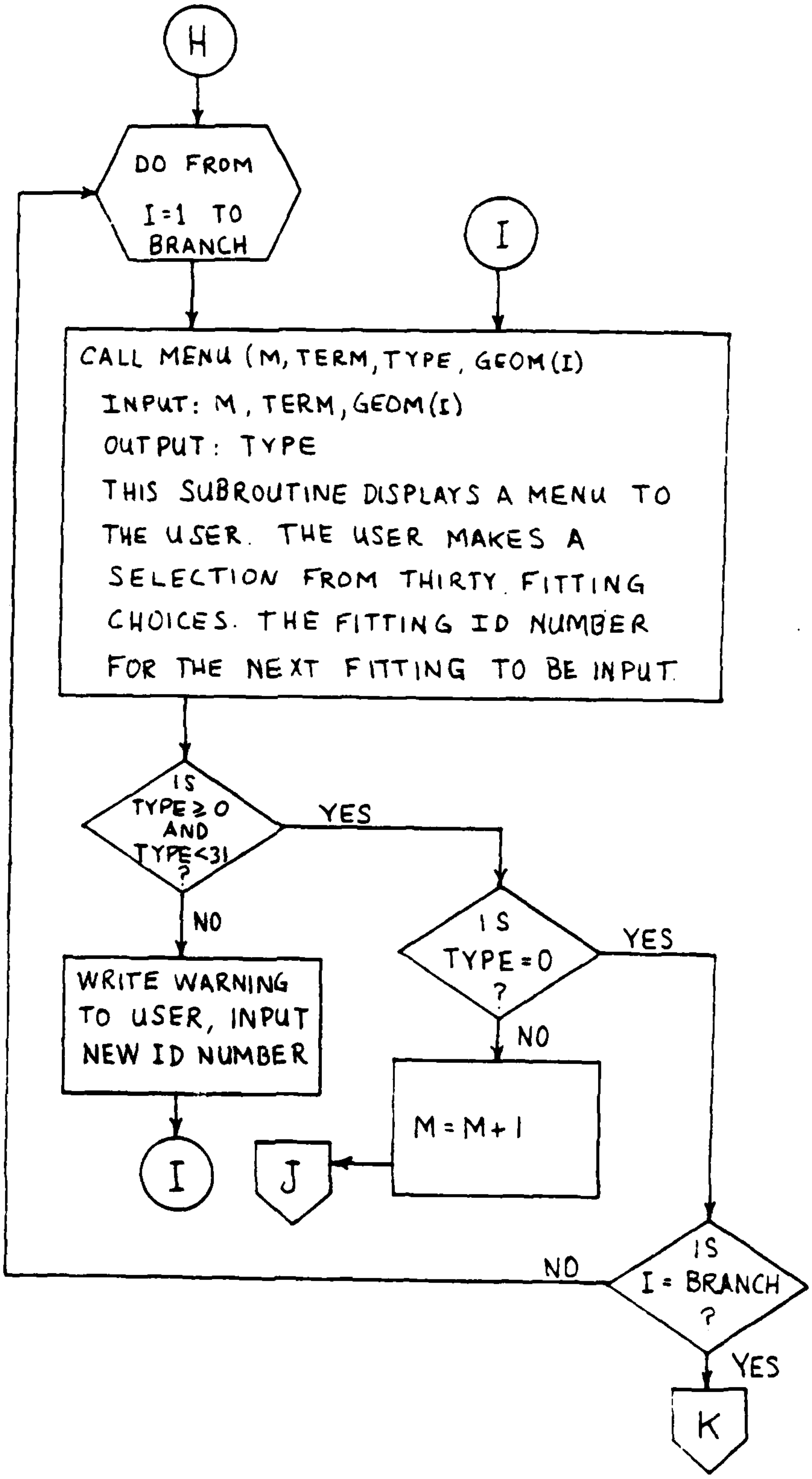
THERE ARE NO INPUT OR OUTPUT VARIABLES FOR THIS SUBROUTINE, HOWEVER SUBROUTINES CALLED BY THE BUILD SUBROUTINE DO HANDLE INPUT AND OUTPUT DATA.



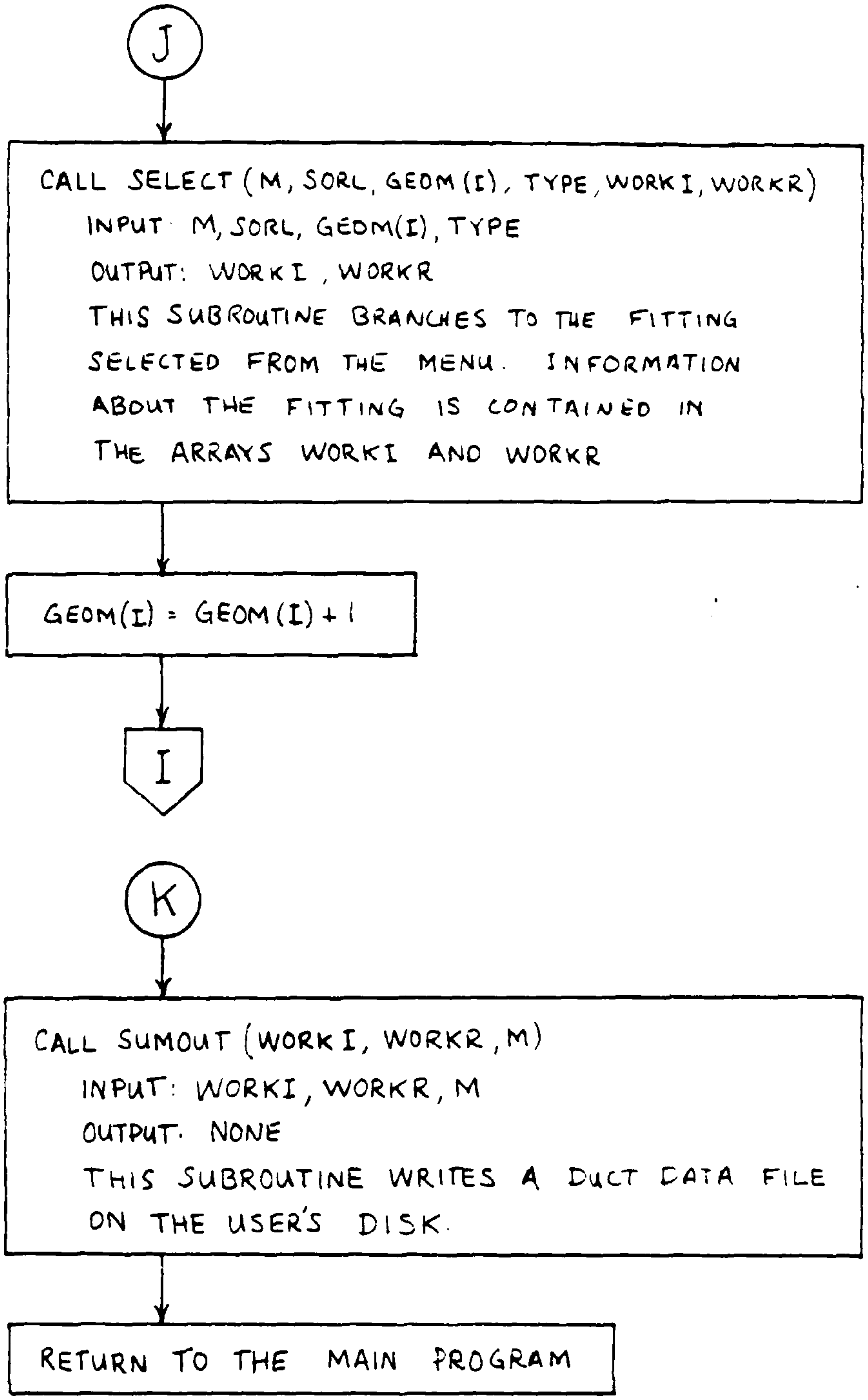


SEE THE PRELIMINARY SECTION OF THE USERS MANUAL FOR EXPLINATION OF IDENTIFICATION NUMBERS.


B
GEOM(1) = 113101
GEOM(2) = 124001
GEOM(3) = 136101
GEOM(4) = 145001
BRANCH = 4
GEOM(1) = 212201
GEOM(2) = 223101
GEOM(3) = 224001
GEOM(4) = 236101
GEOM(5) = 245001
BRANCH = 5
C
D
GEOM(1) = 312201
GEOM(2) = 323101
GEOM(3) = 324001
GEOM(4) = 335101
GEOM(5) = 345001
GEOM(6) = 356201
BRANCH = 6
GEOM(1) = 413101
GEOM(2) = 424001
GEOM(3) = 435101
GEOM(4) = 445001
GEOM(5) = 456201
BRANCH = 5
E
F
GEOM(1) = 512201
GEOM(2) = 523101
GEOM(3) = 525001
GEOM(4) = 535101
GEOM(5) = 556201
BRANCH = 5
GEOM(1) = 613101
GEOM(2) = 623101
GEOM(3) = 635101
GEOM(4) = 656201
BRANCH = 4
G
CONTINUE
M = 0
H



H
DO FROM
I=1 TO
BRANCH
I
CALL MENU (M, TERM, TYPE, GEOM(I)
INPUT: M, TERM, GEOM(I)
OUTPUT: TYPE
THIS SUBROUTINE DISPLAYS A MENU TO
THE USER. THE USER MAKES A
SELECTION FROM THIRTY FITTING
CHOICES. THE FITTING ID NUMBER
FOR THE NEXT FITTING TO BE INPUT
IS
TYPE ≥ 0
AND
TYPE<31
?
YES
NO
WRITE WARNING
TO USER, INPUT
NEW ID NUMBER
I
IS
TYPE = 0
?
YES
NO
M = M + 1
J
IS
I = BRANCH
?
NO
YES
K



CALL SELECT (M, SORL, GEOM(I), TYPE, WORKI, WORKR)

INPUT M, SORL, GEOM(I), TYPE

OUTPUT: WORKI, WORKR

THIS SUBROUTINE BRANCHES TO THE FITTING SELECTED FROM THE MENU. INFORMATION ABOUT THE FITTING IS CONTAINED IN THE ARRAYS WORKI AND WORKR

GEOM(I) = GEOM(I) + 1

CALL SUMOUT (WORKI, WORKR, M)

INPUT: WORKI, WORKR, M

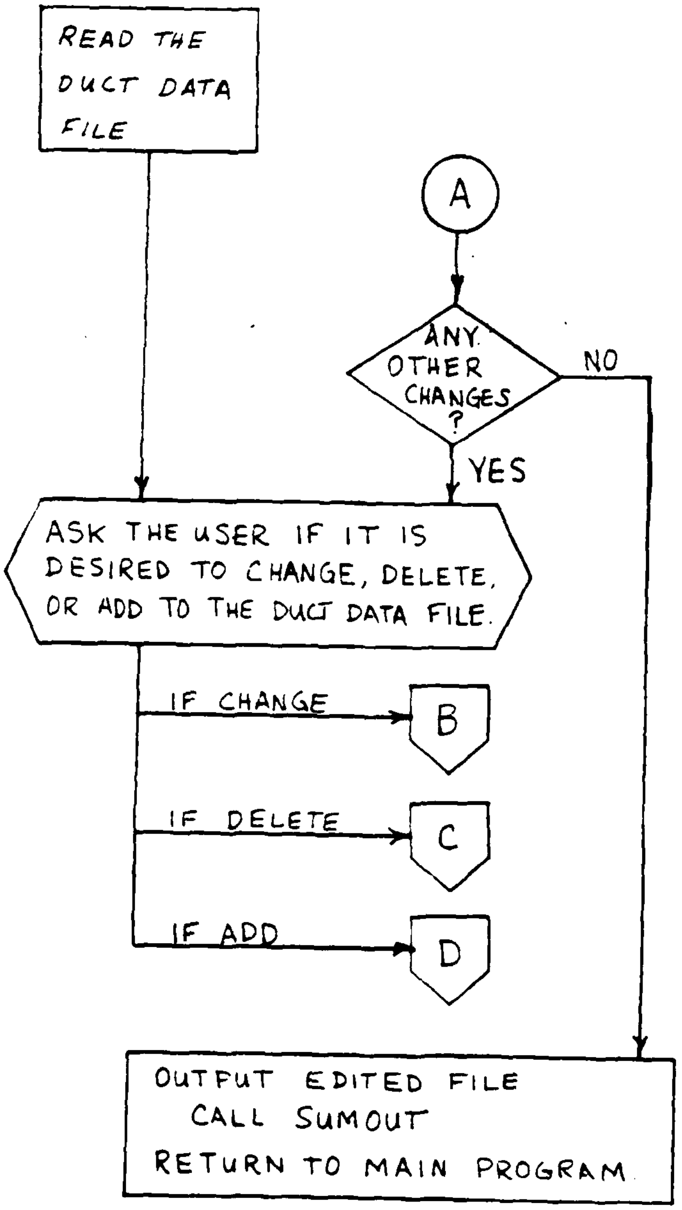
OUTPUT: NONE

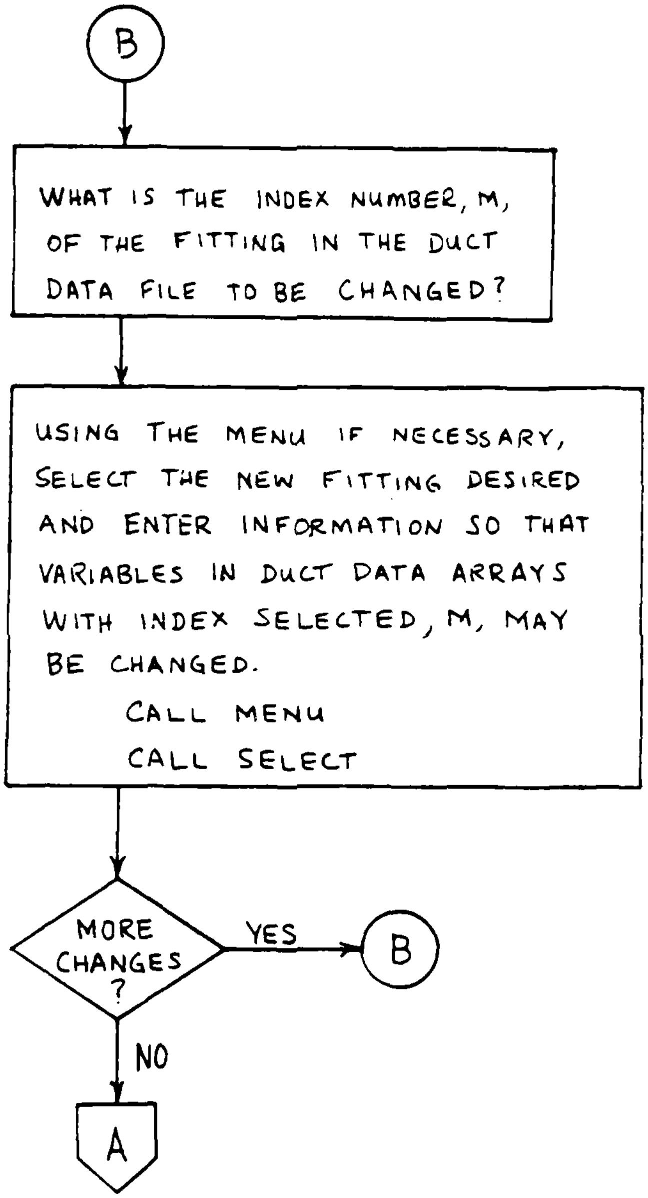
THIS SUBROUTINE WRITES A DUCT DATA FILE ON THE USER'S DISK.

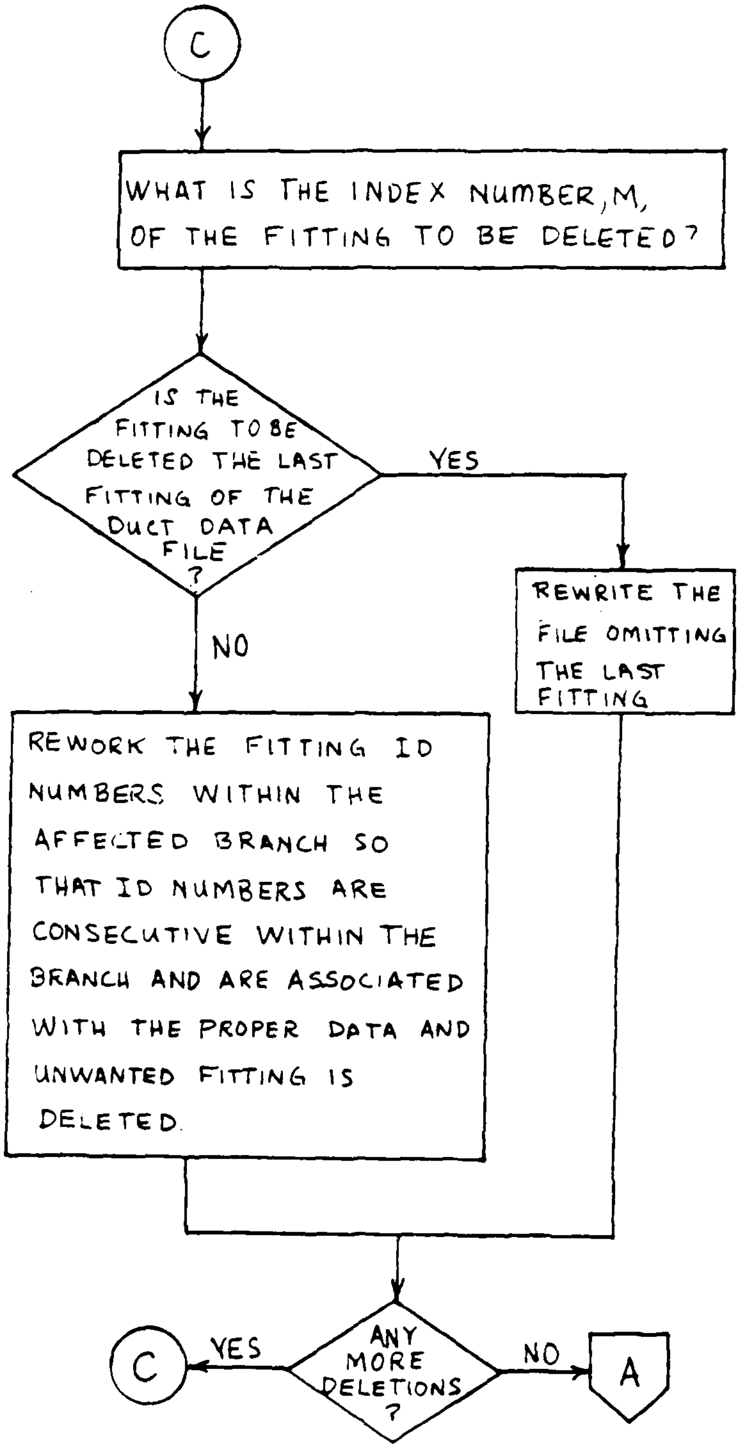
RETURN TO THE MAIN PROGRAM

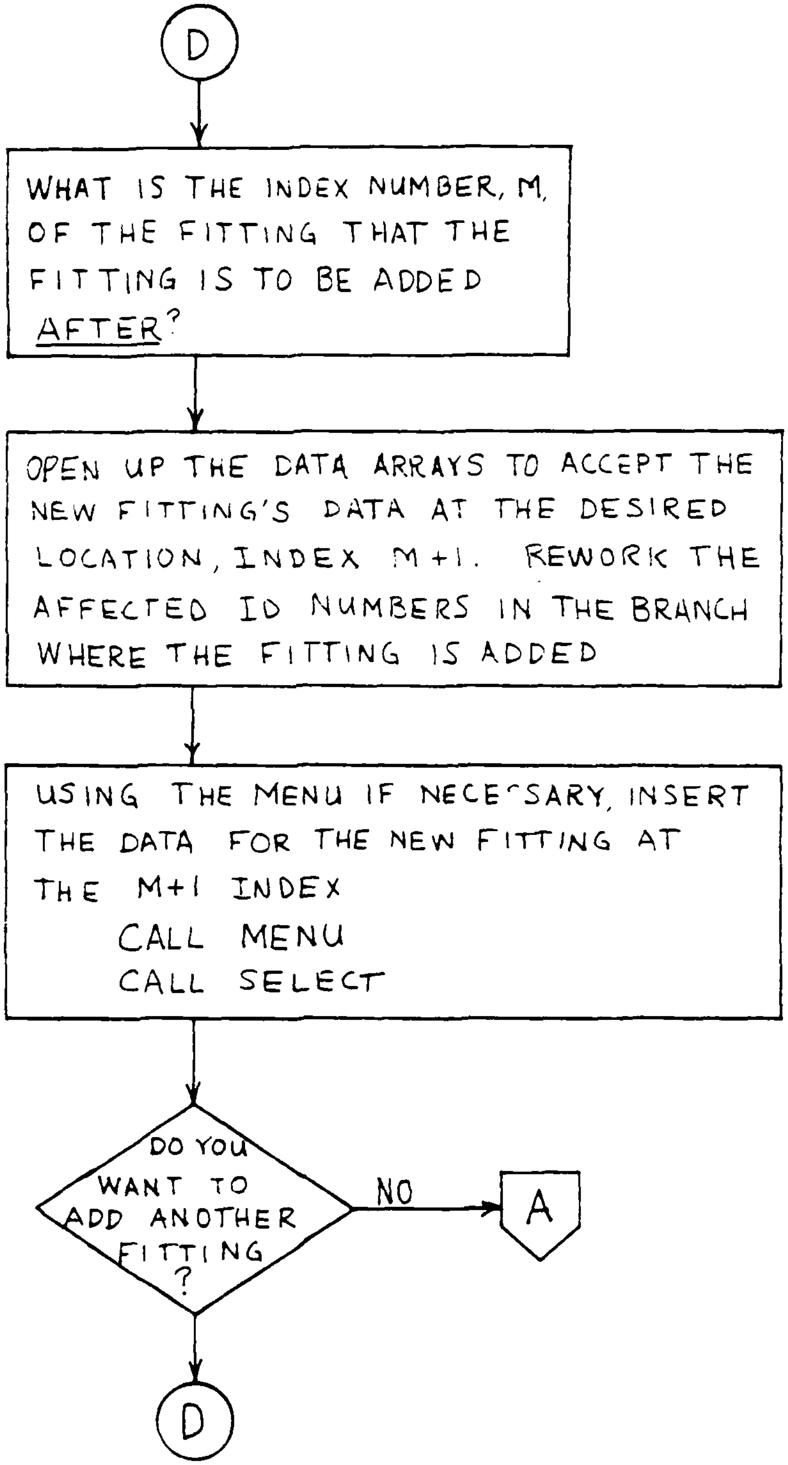
III. EDITING SUBROUTINE (ED)

THERE ARE NO INPUT OR OUTPUT VARIABLES FOR THIS SUBROUTINE, HOWEVER SUBROUTINES CALLED BY THE ED SUBROUTINE DO HANDLE INPUT AND OUTPUT DATA.

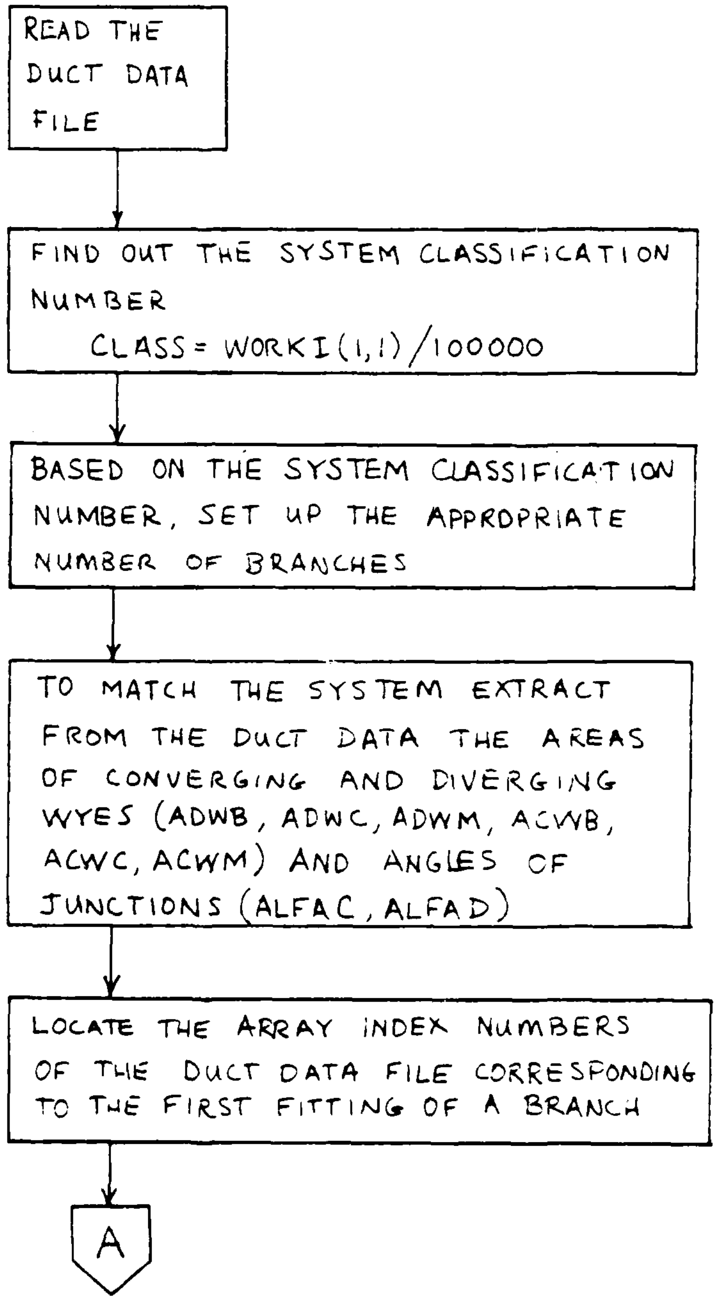


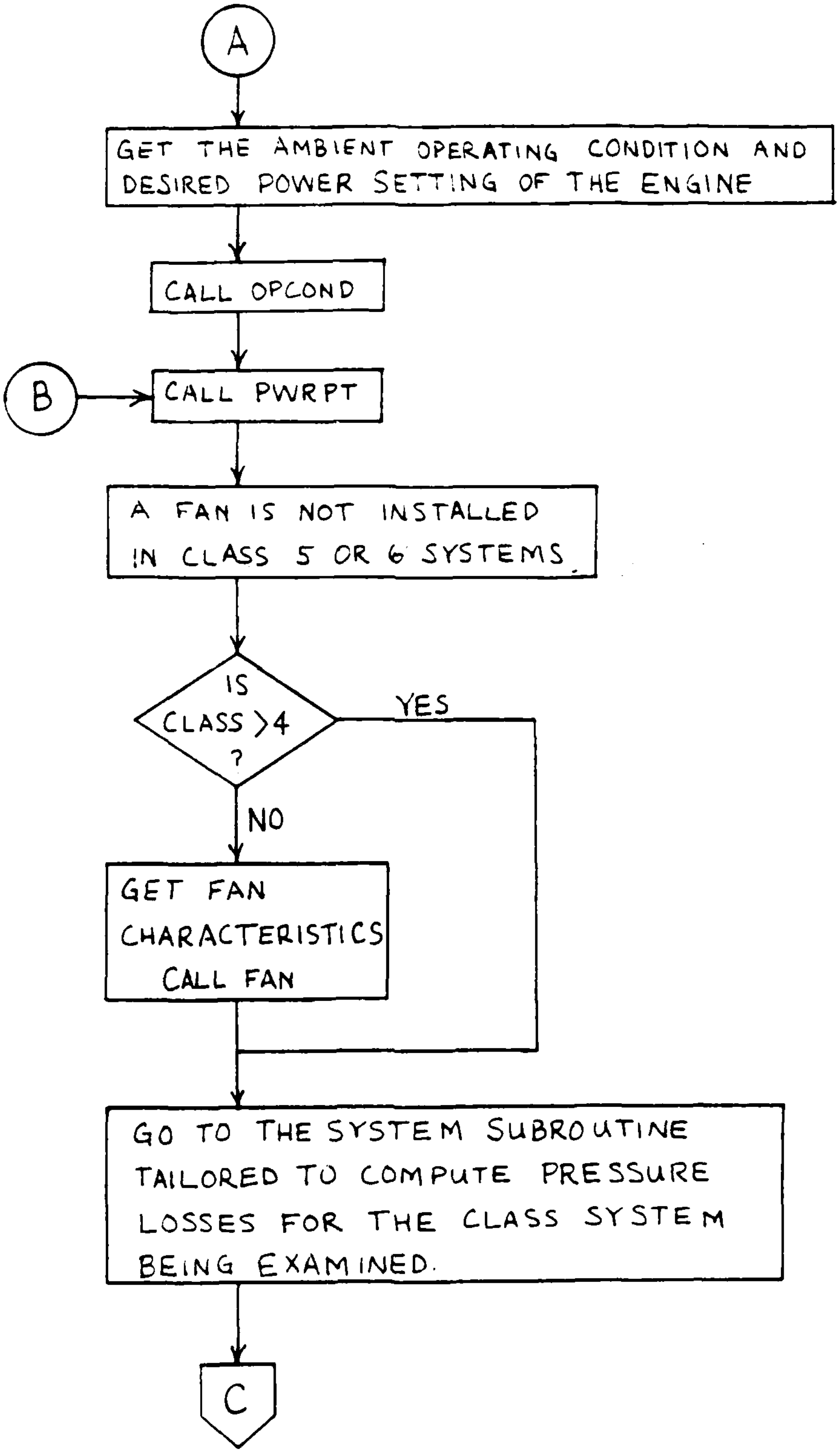

B
WHAT IS THE INDEX NUMBER, M, OF THE FITTING IN THE DUCT DATA FILE TO BE CHANGED?
USING THE MENU IF NECESSARY, SELECT THE NEW FITTING DESIRED AND ENTER INFORMATION SO THAT VARIABLES IN DUCT DATA ARRAYS WITH INDEX SELECTED, M, MAY BE CHANGED.
CALL MENU
CALL SELECT
MORE CHANGES ?
YES
B
NO
A

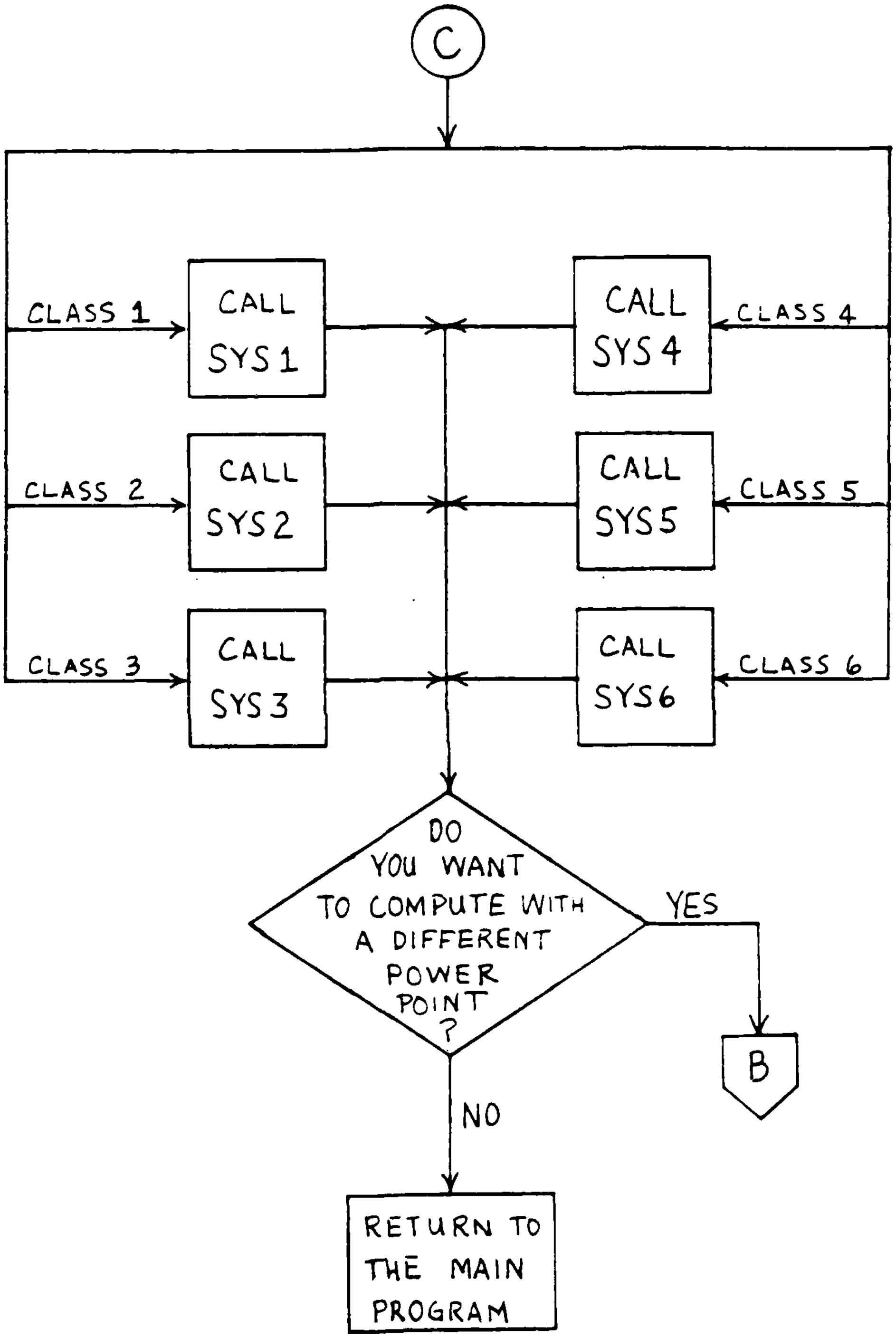

C
WHAT IS THE INDEX NUMBER, M, OF THE FITTING TO BE DELETED?
IS THE FITTING TO BE DELETED THE LAST FITTING OF THE DUCT DATA FILE ?
YES
REWRITE THE FILE OMITTING THE LAST FITTING
NO
REWORK THE FITTING ID NUMBERS WITHIN THE AFFECTED BRANCH SO THAT ID NUMBERS ARE CONSECUTIVE WITHIN THE BRANCH AND ARE ASSOCIATED WITH THE PROPER DATA AND UNWANTED FITTING IS DELETED.
C
YES
ANY MORE DELETIONS ?
NO
A


D
WHAT IS THE INDEX NUMBER, M, OF THE FITTING THAT THE FITTING IS TO BE ADDED AFTER?
OPEN UP THE DATA ARRAYS TO ACCEPT THE NEW FITTING'S DATA AT THE DESIRED LOCATION, INDEX M+1. REWORK THE AFFECTED ID NUMBERS IN THE BRANCH WHERE THE FITTING IS ADDED
USING THE MENU IF NECESSARY, INSERT THE DATA FOR THE NEW FITTING AT THE M+1 INDEX
CALL MENU
CALL SELECT
DO YOU WANT TO ADD ANOTHER FITTING?
NO
A
D

IV. COMPUTE SUBROUTINE

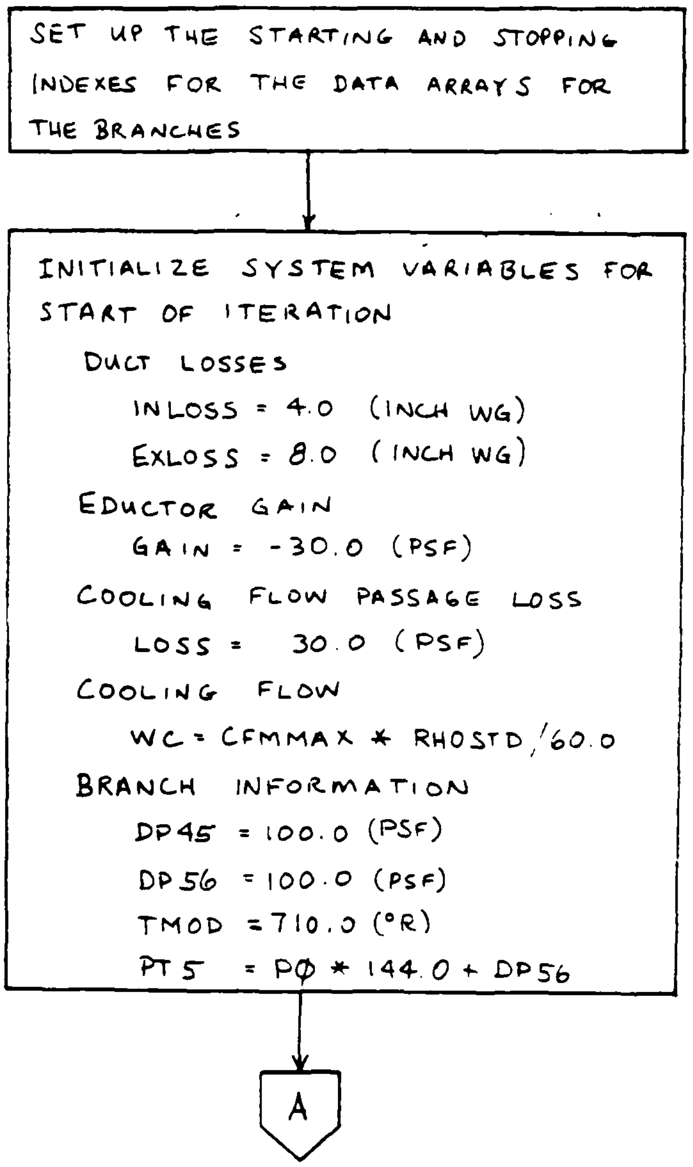


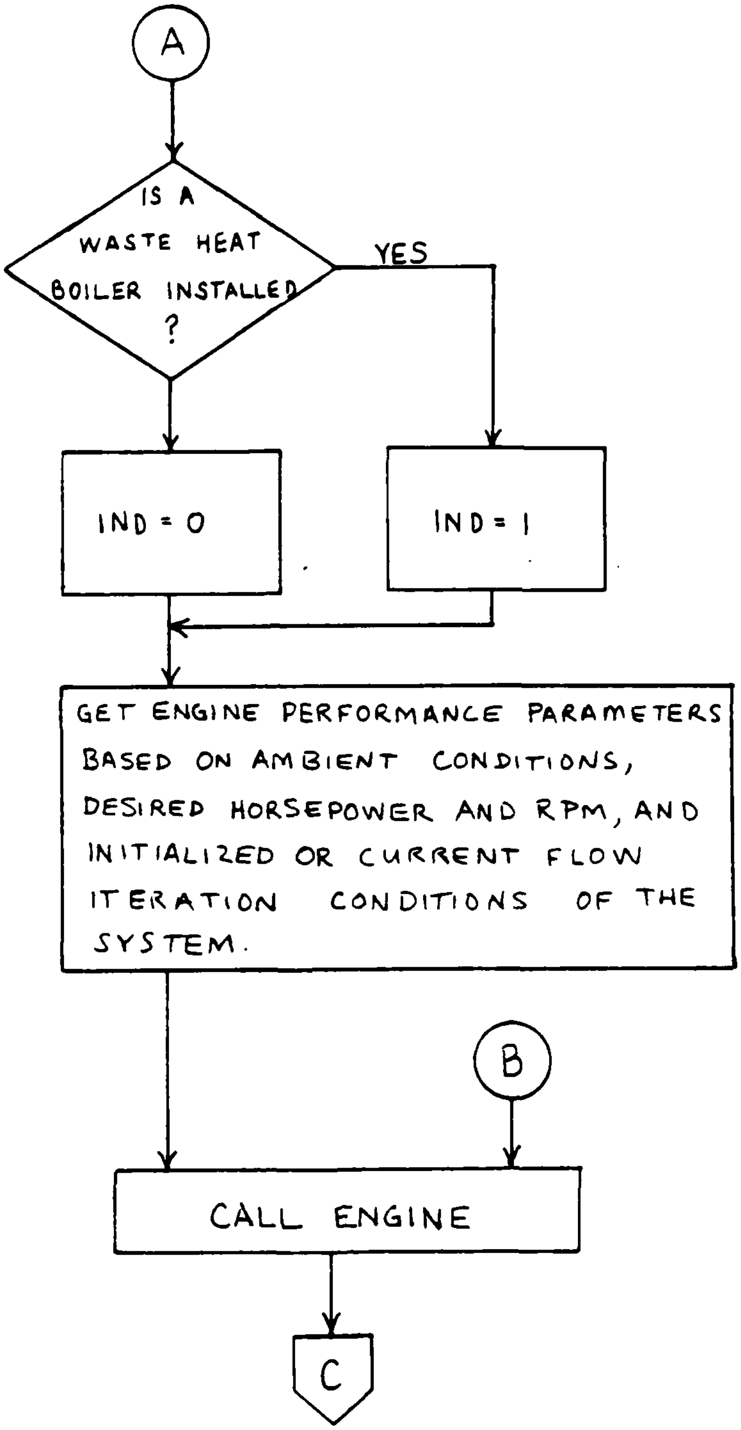

A
GET THE AMBIENT OPERATING CONDITION AND DESIRED POWER SETTING OF THE ENGINE
CALL OPCOND
B
CALL PWRPT
A FAN IS NOT INSTALLED IN CLASS 5 OR 6 SYSTEMS
IS CLASS >4 ?
YES
NO
GET FAN CHARACTERISTICS CALL FAN
GO TO THE SYSTEM SUBROUTINE TAILORED TO COMPUTE PRESSURE LOSSES FOR THE CLASS SYSTEM BEING EXAMINED.
C

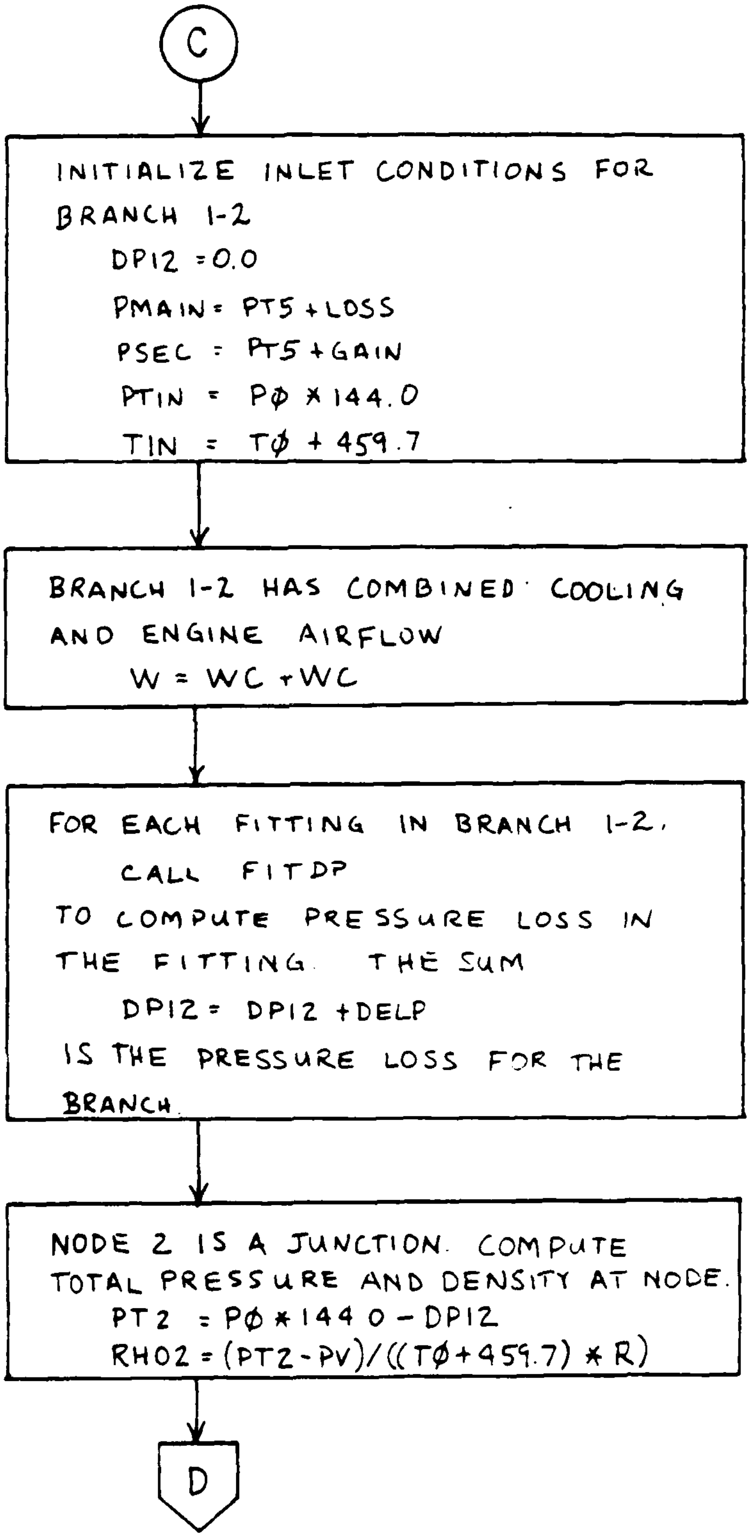

C
CLASS 1
CALL SYS 1
CLASS 2
CALL SYS 2
CLASS 3
CALL SYS 3
CALL SYS 4
CLASS 4
CALL SYS 5
CLASS 5
CALL SYS6
CLASS 6
DO YOU WANT TO COMPUTE WITH A DIFFERENT POWER POINT ?
YES
B
NO
RETURN TO THE MAIN PROGRAM

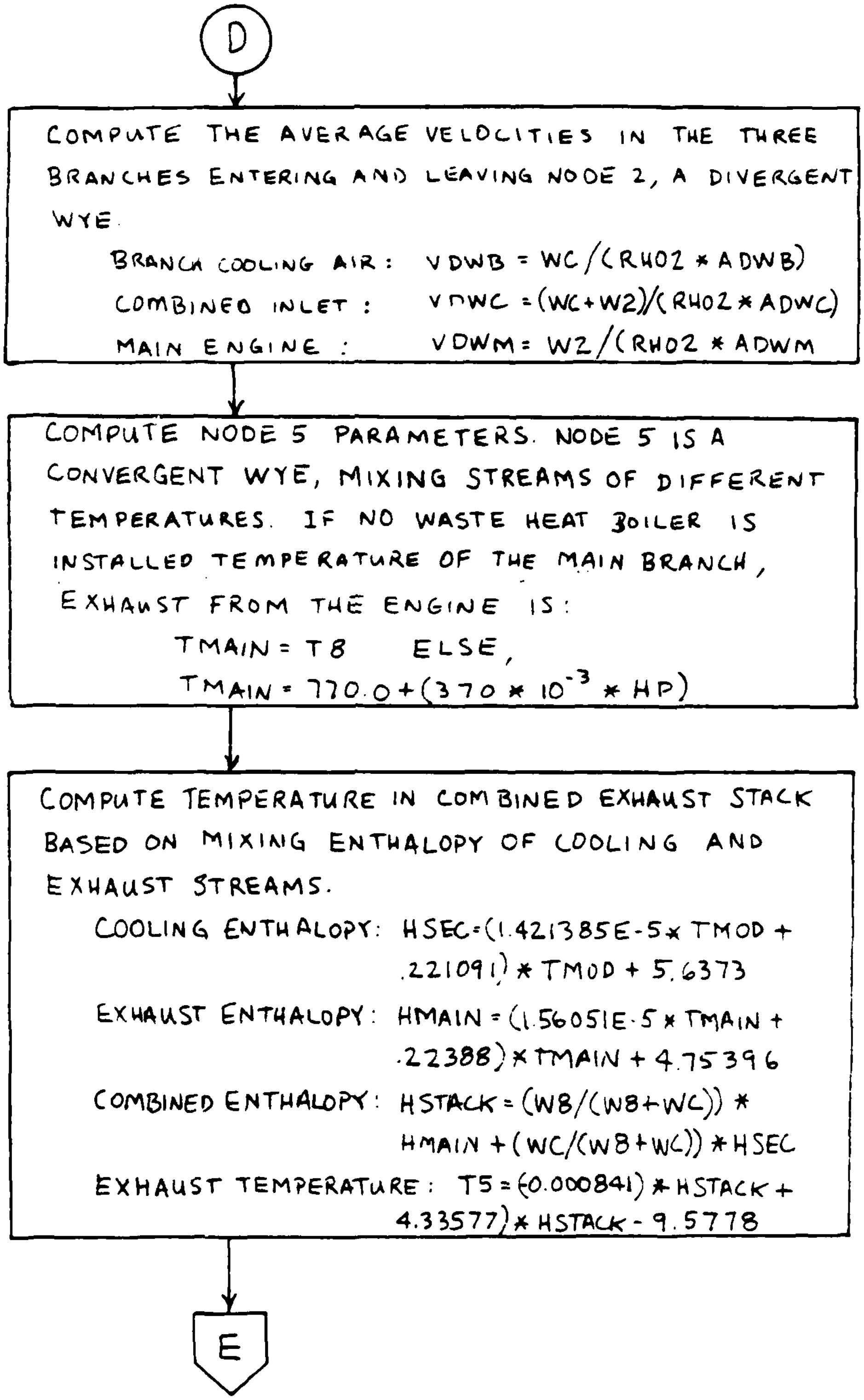
V. SYSTEM THREE MATCHING SUBROUTINE (SYS3)

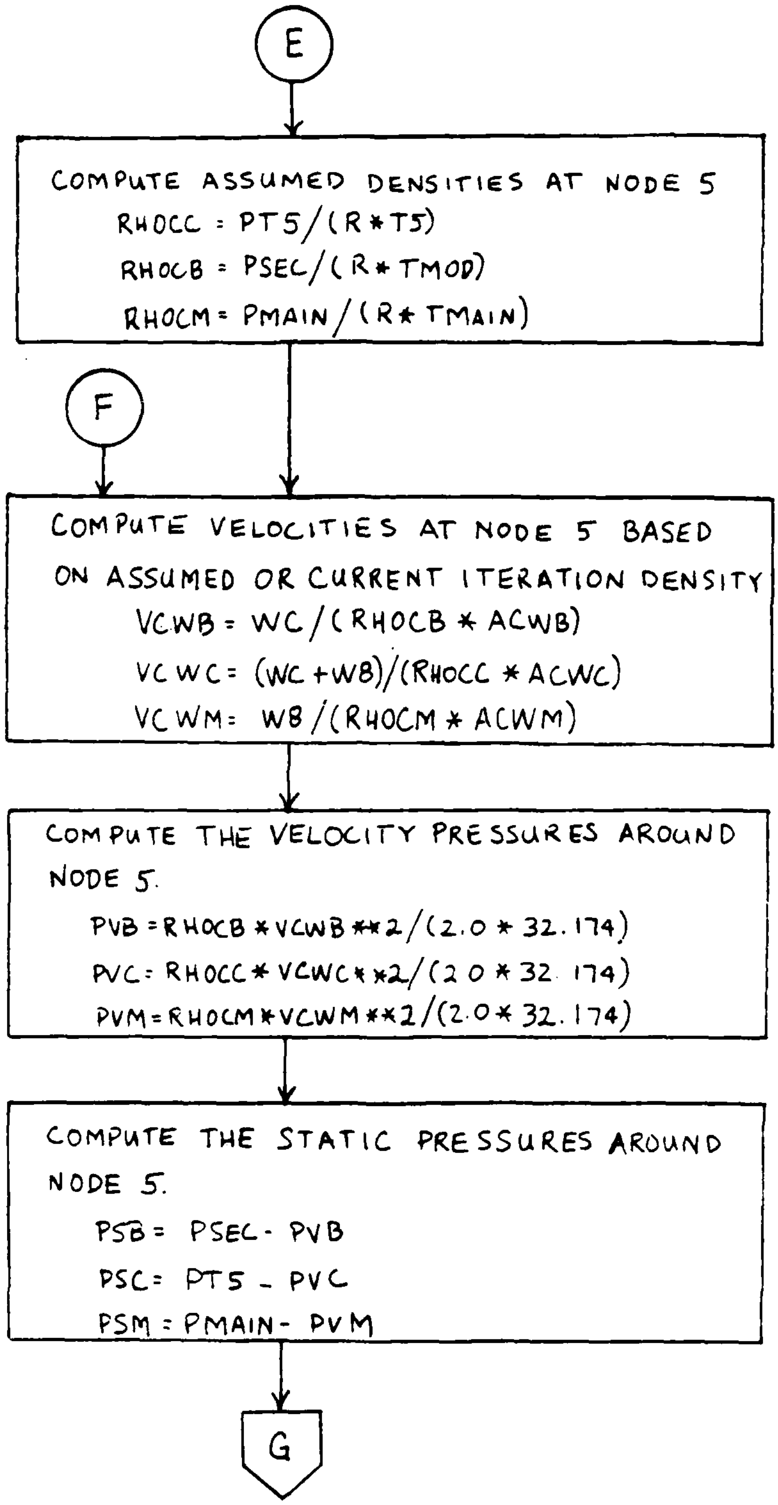
THIS SUBROUTINE IS CALLED BY THE COMPUTE SECTION OF THE PROGRAM. ALL VARIABLES ARE INPUT FROM COMP SUBROUTINE. THERE ARE NO OUTPUT VARIABLES RETURNED TO COMP, ALL OUTPUT IS WRITTEN TO THE PERFORMANCE FILE.

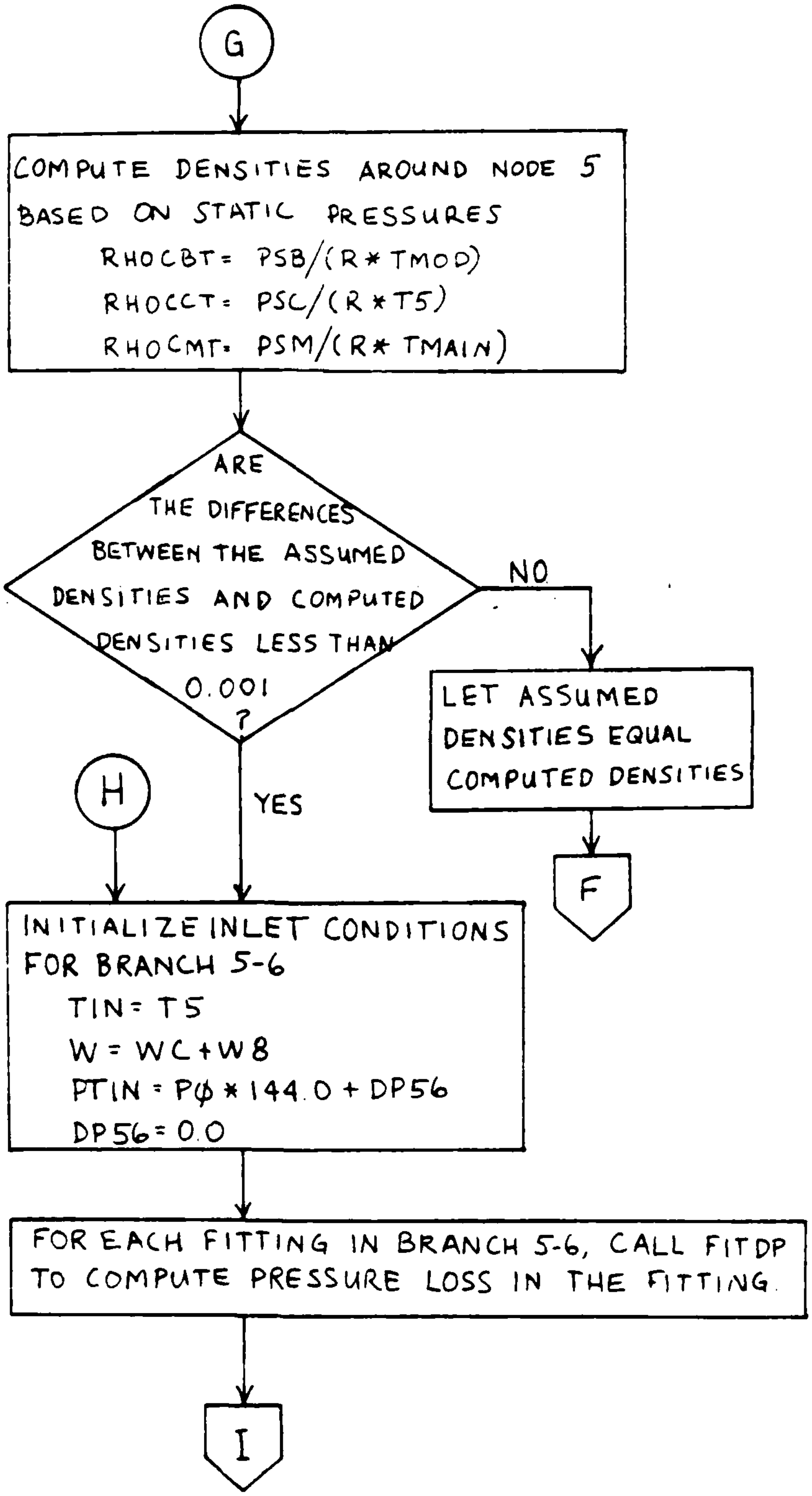


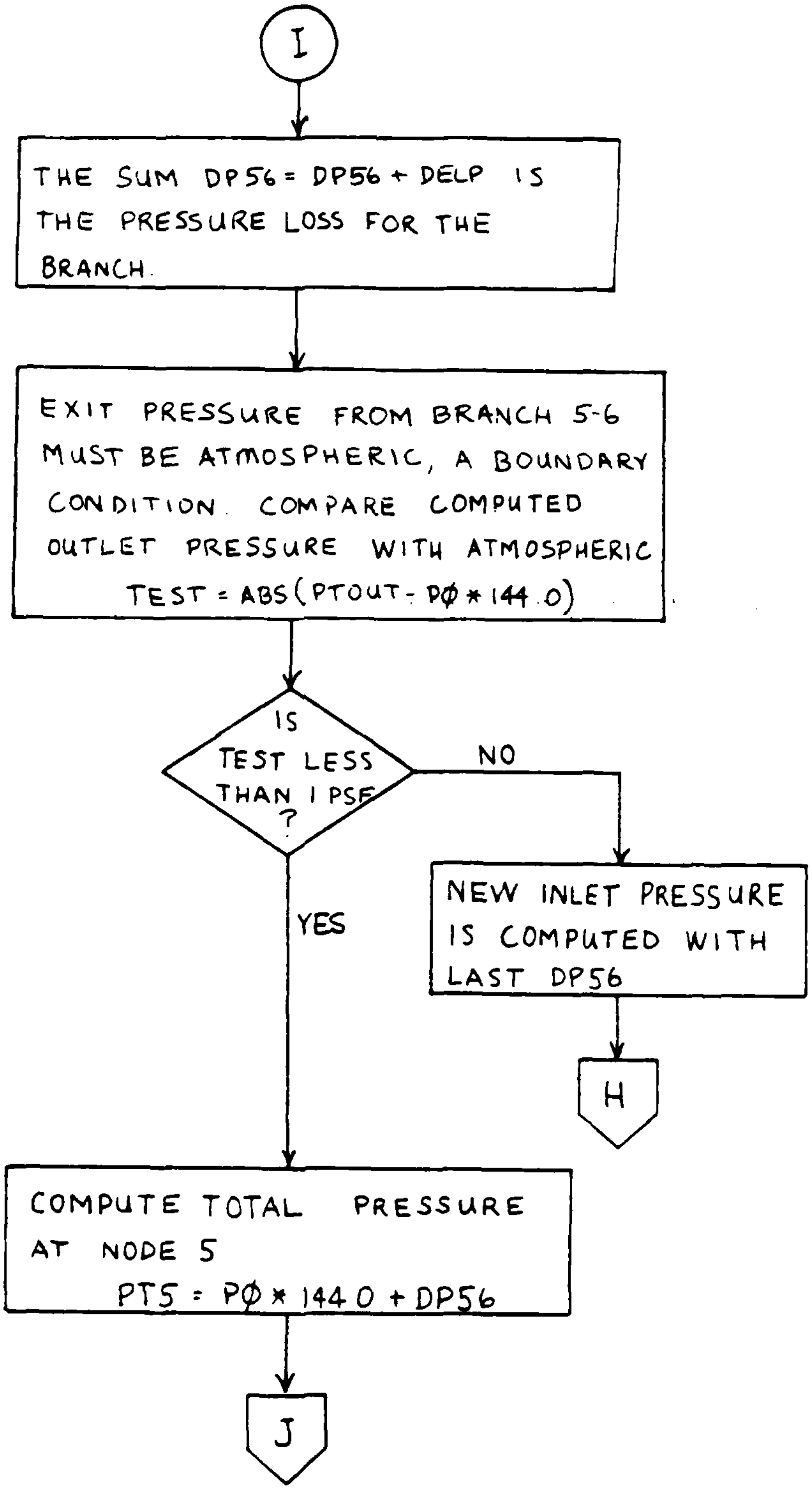

A
IS A WASTE HEAT BOILER INSTALLED ?
YES
IND = 0
IND = 1
GET ENGINE PERFORMANCE PARAMETERS BASED ON AMBIENT CONDITIONS, DESIRED HORSEPOWER AND RPM, AND INITIALIZED OR CURRENT FLOW ITERATION CONDITIONS OF THE SYSTEM.
B
CALL ENGINE
C


C
INITIALIZE INLET CONDITIONS FOR BRANCH 1-2
DP12 = 0.0
PMAIN = PT5 + LOSS
PSEC = PT5 + GAIN
PTIN = P0 * 144.0
TIN = T0 + 459.7
BRANCH 1-2 HAS COMBINED COOLING AND ENGINE AIRFLOW
W = WC + WC
FOR EACH FITTING IN BRANCH 1-2, CALL FITDP TO COMPUTE PRESSURE LOSS IN THE FITTING. THE SUM
DP12 = DP12 + DELP
IS THE PRESSURE LOSS FOR THE BRANCH.
NODE 2 IS A JUNCTION. COMPUTE TOTAL PRESSURE AND DENSITY AT NODE.
PT2 = P0 * 144.0 - DP12
RHO2 = (PT2 - PV)/((T0 + 459.7) * R)
D


D
COMPUTE THE AVERAGE VELOCITIES IN THE THREE BRANCHES ENTERING AND LEAVING NODE 2, A DIVERGENT WYE.
BRANCH COOLING AIR: VDWB = WC/(RHO2 * ADWB)
COMBINED INLET: VDWC = (WC+W2)/(RHO2 * ADWC)
MAIN ENGINE: VDWM = W2/(RHO2 * ADWM
COMPUTE NODE 5 PARAMETERS. NODE 5 IS A CONVERGENT WYE, MIXING STREAMS OF DIFFERENT TEMPERATURES. IF NO WASTE HEAT BOILER IS INSTALLED TEMPERATURE OF THE MAIN BRANCH, EXHAUST FROM THE ENGINE IS:
TMAIN = T8 ELSE,
TMAIN = 770.0+(370 * 10^{-3} * HP)
COMPUTE TEMPERATURE IN COMBINED EXHAUST STACK BASED ON MIXING ENTHALOPY OF COOLING AND EXHAUST STREAMS.
COOLING ENTHALOPY: HSEC=(1.421385E-5 * TMOD + .221091) * TMOD + 5.6373
EXHAUST ENTHALOPY: HMAIN = (1.56051E-5 * TMAIN + .22388) * TMAIN + 4.75396
COMBINED ENTHALOPY: HSTACK = (W8/(W8+WC)) * HMAIN + (WC/(W8+WC)) * HSEC
EXHAUST TEMPERATURE: T5 = (-0.000841) * HSTACK + 4.33577) * HSTACK - 9.5778
E


E
COMPUTE ASSUMED DENSITIES AT NODE 5
RHOCC = PT5/(R*T5)
RHOCB = PSEC/(R*TMOD)
RHOCM = PMAIN/(R*TMAIN)
F
COMPUTE VELOCITIES AT NODE 5 BASED ON ASSUMED OR CURRENT ITERATION DENSITY
VCWB = WC/(RHOCB * ACWB)
VCWC = (WC+WB)/(RHOCC * ACWC)
VCWM = WB/(RHOCM * ACWM)
COMPUTE THE VELOCITY PRESSURES AROUND NODE 5.
PVB = RHOCB*VCWB**2/(2.0*32.174)
PVC = RHOCC*VCWC**2/(2.0*32.174)
PVM = RHOCM*VCWM**2/(2.0*32.174)
COMPUTE THE STATIC PRESSURES AROUND NODE 5.
PSB = PSEC - PVB
PSC = PT5 - PVC
PSM = PMAIN - PVM
G


G
COMPUTE DENSITIES AROUND NODE 5 BASED ON STATIC PRESSURES
RHOCBT= PSB/(R*TMOD)
RHOCCT= PSC/(R*T5)
RHOCMT= PSM/(R*TMAIN)
ARE THE DIFFERENCES BETWEEN THE ASSUMED DENSITIES AND COMPUTED DENSITIES LESS THAN 0.001 ?
NO
LET ASSUMED DENSITIES EQUAL COMPUTED DENSITIES
F
H
YES
INITIALIZE INLET CONDITIONS FOR BRANCH 5-6
TIN= T5
W = WC+W8
PTIN = P0*144.0+DP56
DP56= 0.0
FOR EACH FITTING IN BRANCH 5-6, CALL FITDP TO COMPUTE PRESSURE LOSS IN THE FITTING.
I



THE SUM DP56 = DP56 + DELP IS THE PRESSURE LOSS FOR THE BRANCH.

EXIT PRESSURE FROM BRANCH 5-6 MUST BE ATMOSPHERIC, A BOUNDARY CONDITION. COMPARE COMPUTED OUTLET PRESSURE WITH ATMOSPHERIC

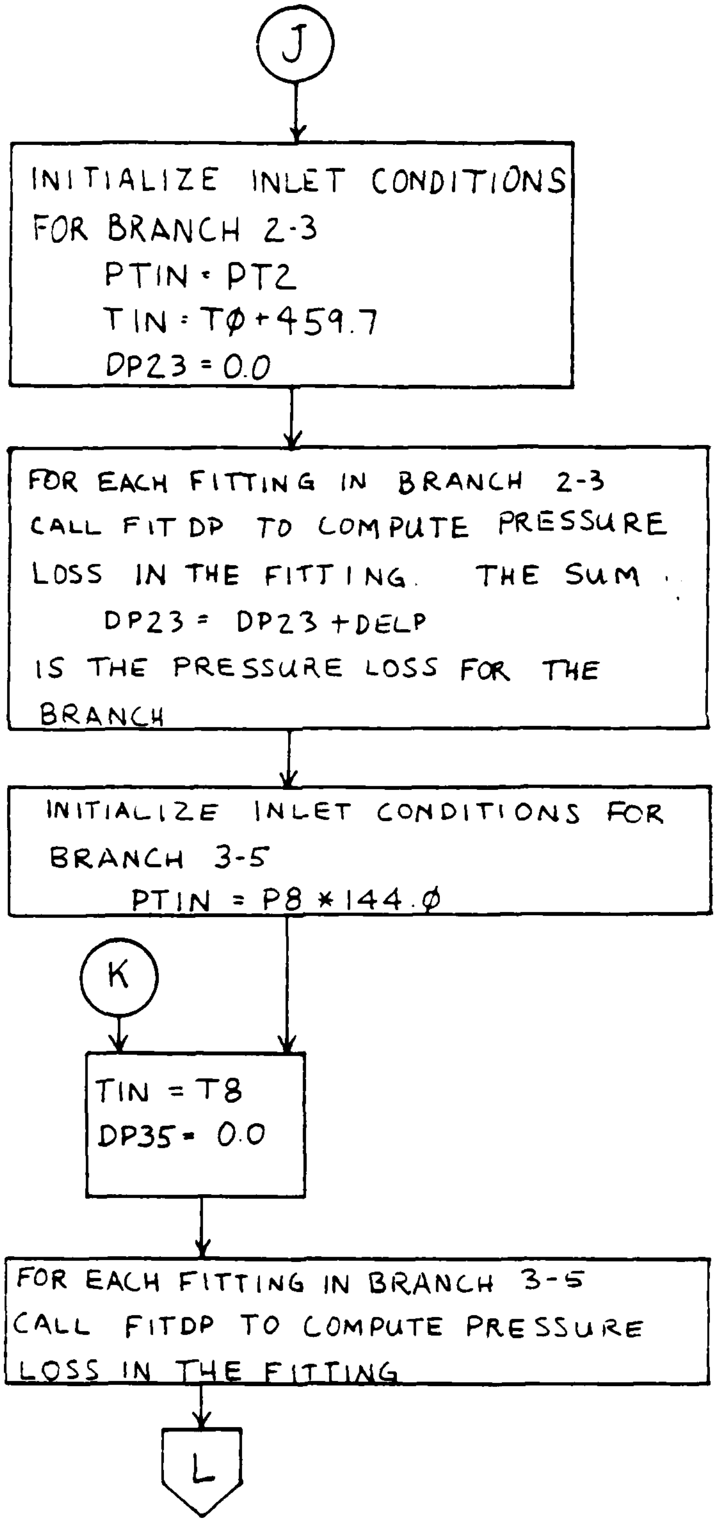
TEST = ABS(PTOUT - P0 * 144.0)

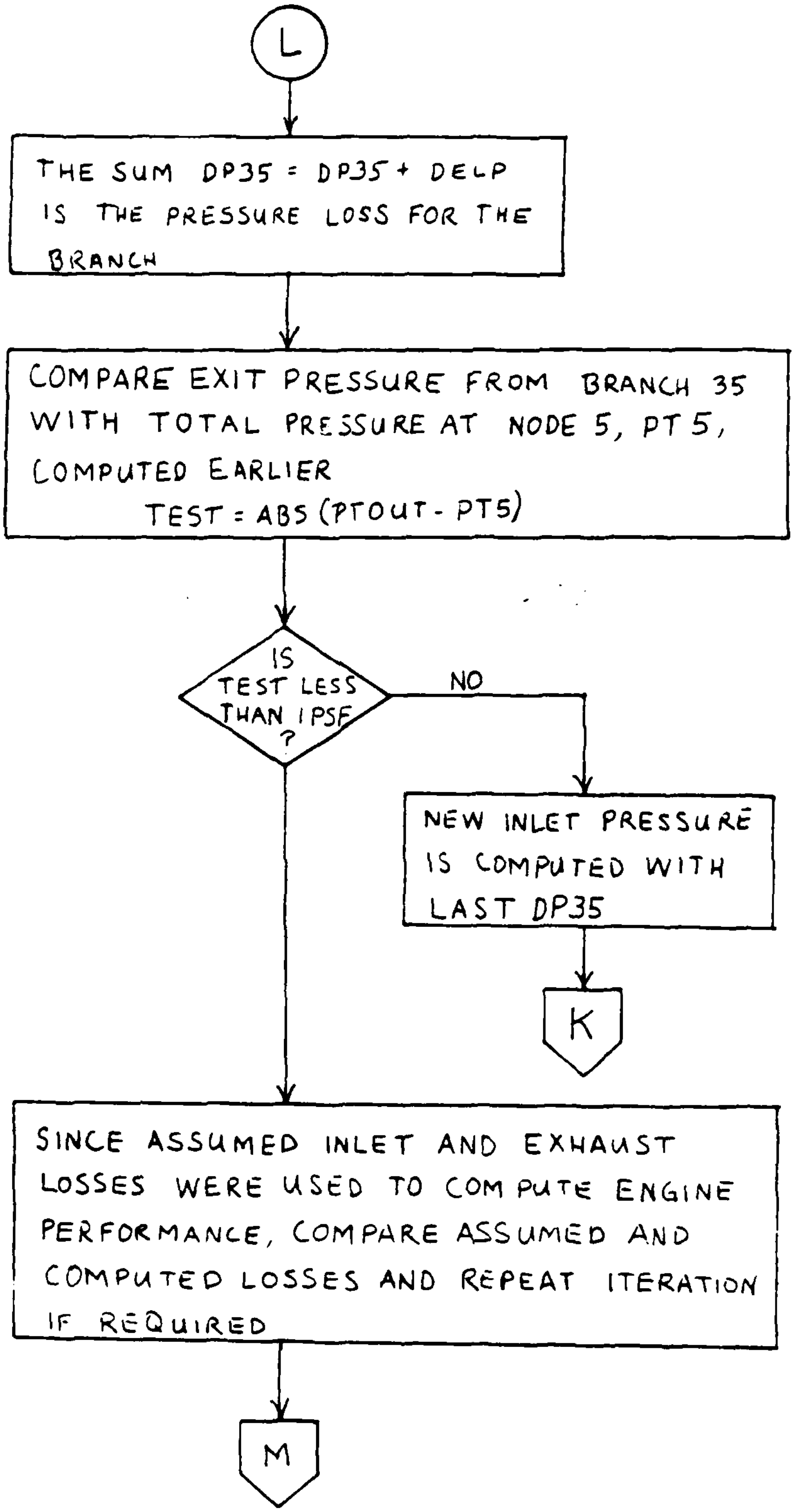
IS TEST LESS THAN 1 PSF ?

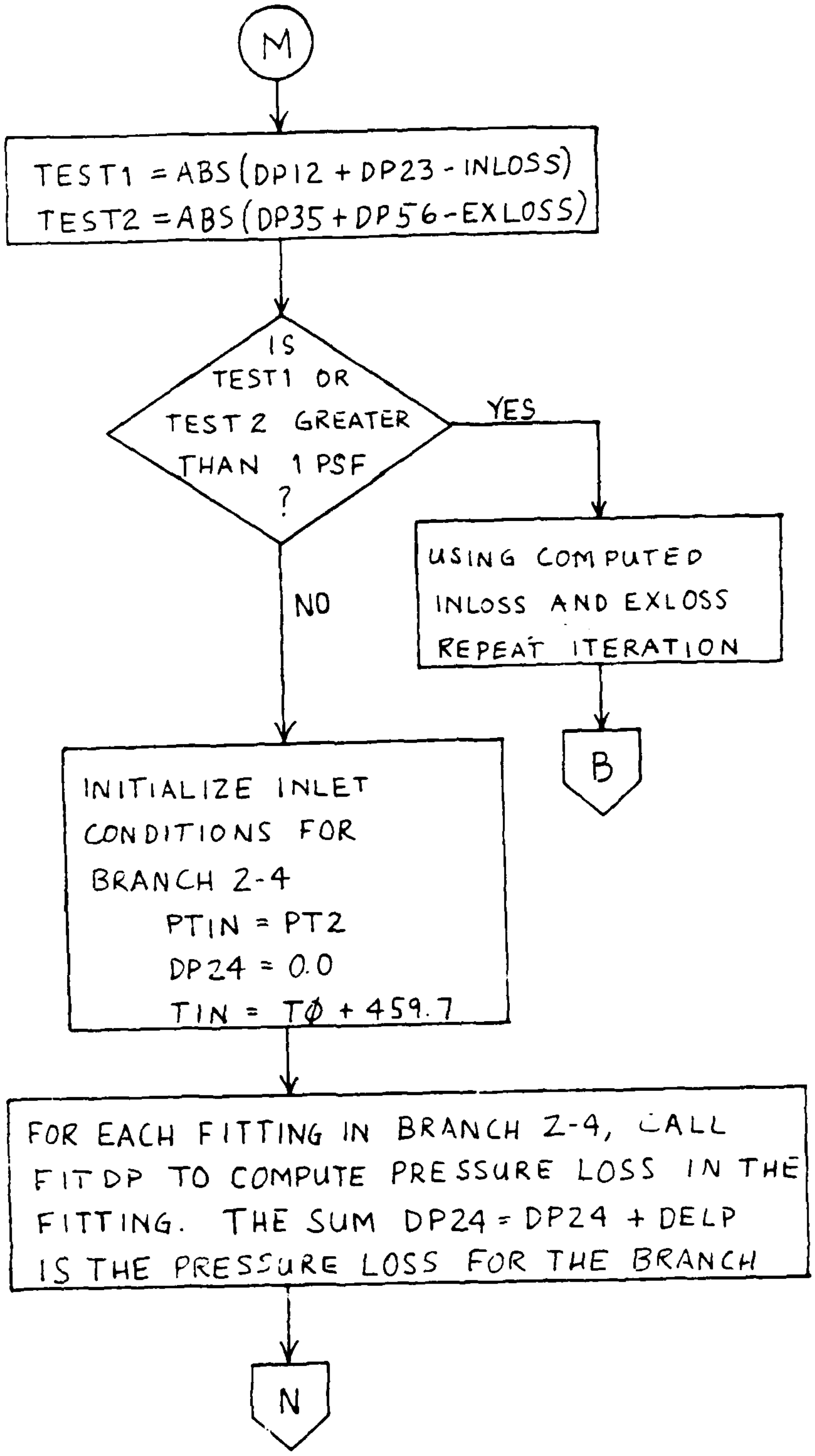
NEW INLET PRESSURE IS COMPUTED WITH LAST DP56

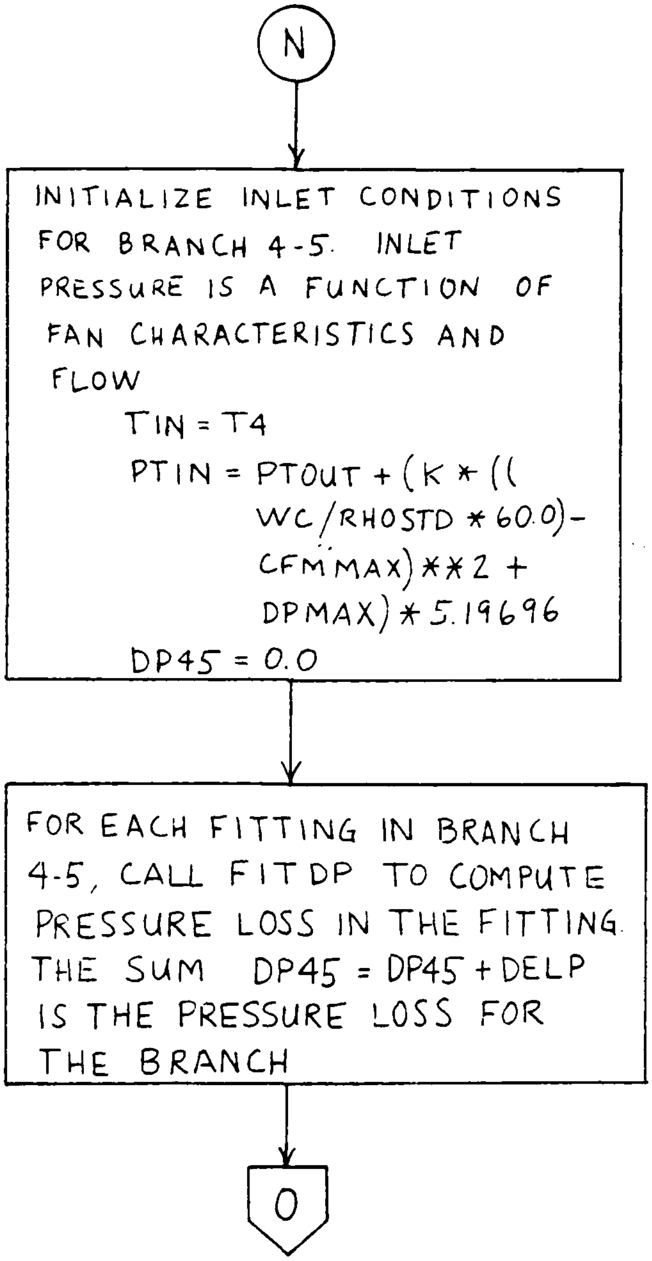
COMPUTE TOTAL PRESSURE AT NODE 5

PT5 = P0 * 144.0 + DP56


J
INITIALIZE INLET CONDITIONS FOR BRANCH 2-3
PTIN = PT2
TIN = T0 + 459.7
DP23 = 0.0
FOR EACH FITTING IN BRANCH 2-3 CALL FIT DP TO COMPUTE PRESSURE LOSS IN THE FITTING. THE SUM
DP23 = DP23 + DELP
IS THE PRESSURE LOSS FOR THE BRANCH
INITIALIZE INLET CONDITIONS FOR BRANCH 3-5
PTIN = P8 * 144.0
K
TIN = T8
DP35 = 0.0
FOR EACH FITTING IN BRANCH 3-5 CALL FITDP TO COMPUTE PRESSURE LOSS IN THE FITTING
L


L
THE SUM DP35 = DP35 + DELP IS THE PRESSURE LOSS FOR THE BRANCH
COMPARE EXIT PRESSURE FROM BRANCH 35 WITH TOTAL PRESSURE AT NODE 5, PT5, COMPUTED EARLIER
TEST = ABS (PTOUT - PT5)
IS TEST LESS THAN 1 PSF ?
NO
NEW INLET PRESSURE IS COMPUTED WITH LAST DP35
K
SINCE ASSUMED INLET AND EXHAUST LOSSES WERE USED TO COMPUTE ENGINE PERFORMANCE, COMPARE ASSUMED AND COMPUTED LOSSES AND REPEAT ITERATION IF REQUIRED
M

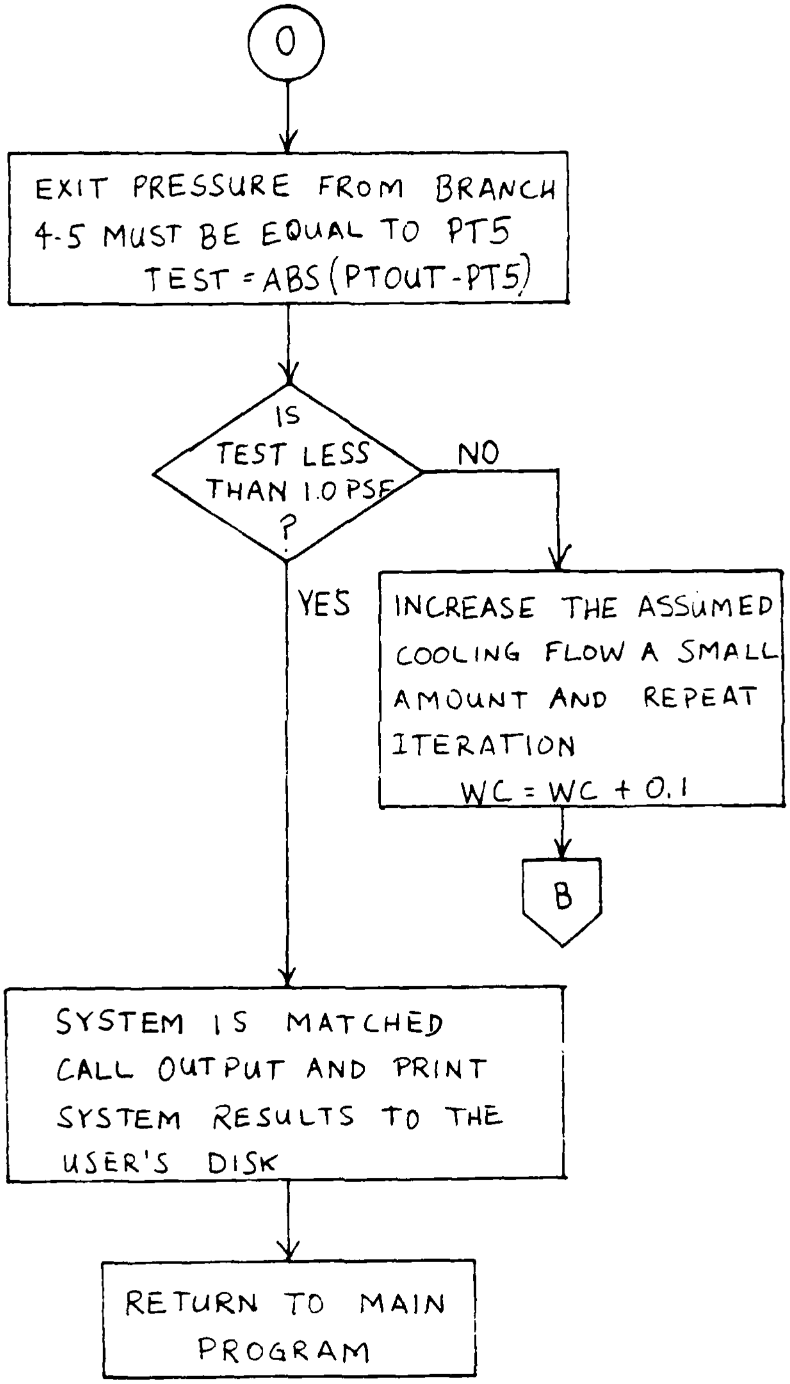

M
TEST1 = ABS(DP12 + DP23 - INLOSS)
TEST2 = ABS(DP35 + DP56 - EXLOSS)
IS TEST1 OR TEST2 GREATER THAN 1 PSF ?
YES
USING COMPUTED INLOSS AND EXLOSS REPEAT ITERATION
B
NO
INITIALIZE INLET CONDITIONS FOR BRANCH 2-4
PTIN = PT2
DP24 = 0.0
TIN = T0 + 459.7
FOR EACH FITTING IN BRANCH 2-4, CALL FITDP TO COMPUTE PRESSURE LOSS IN THE FITTING. THE SUM DP24 = DP24 + DELP IS THE PRESSURE LOSS FOR THE BRANCH
N



INITIALIZE INLET CONDITIONS FOR BRANCH 4-5. INLET PRESSURE IS A FUNCTION OF FAN CHARACTERISTICS AND FLOW

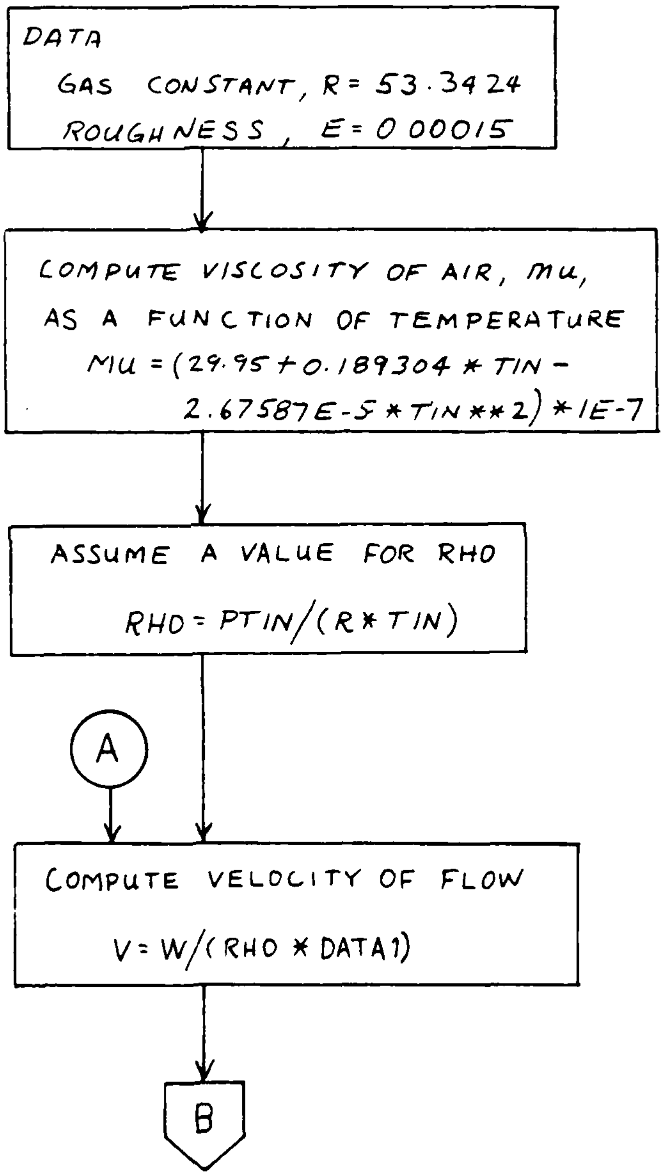
```
    TIN = T4
    PTIN = PTOUT + (K * ((
            WC/RHOSTD * 60.0)-
            CFMMAX)**2 +
            DPMAX) * 5.19696
    DP45 = 0.0
```

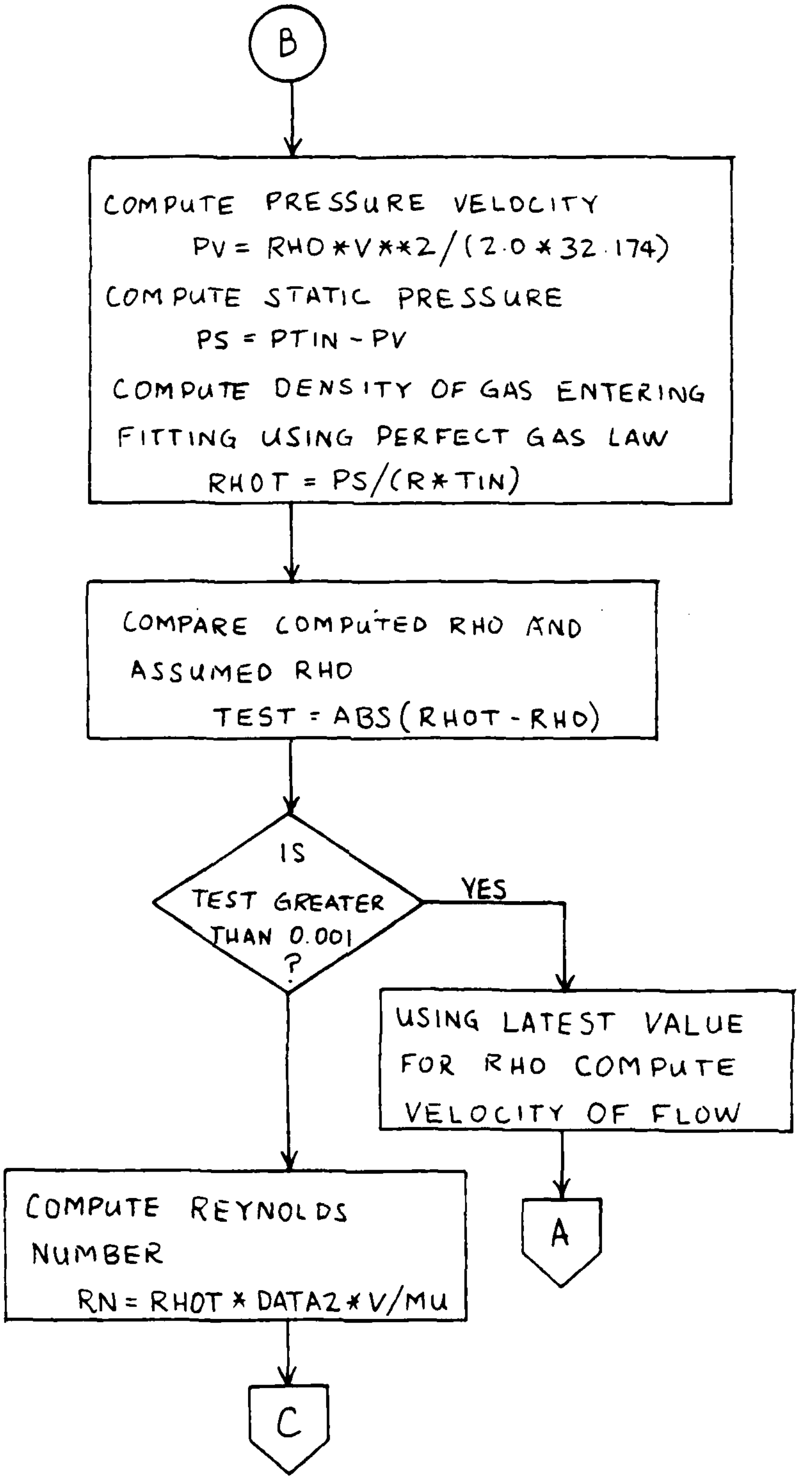
FOR EACH FITTING IN BRANCH 4-5, CALL FITDP TO COMPUTE PRESSURE LOSS IN THE FITTING. THE SUM DP45 = DP45 + DELP IS THE PRESSURE LOSS FOR THE BRANCH

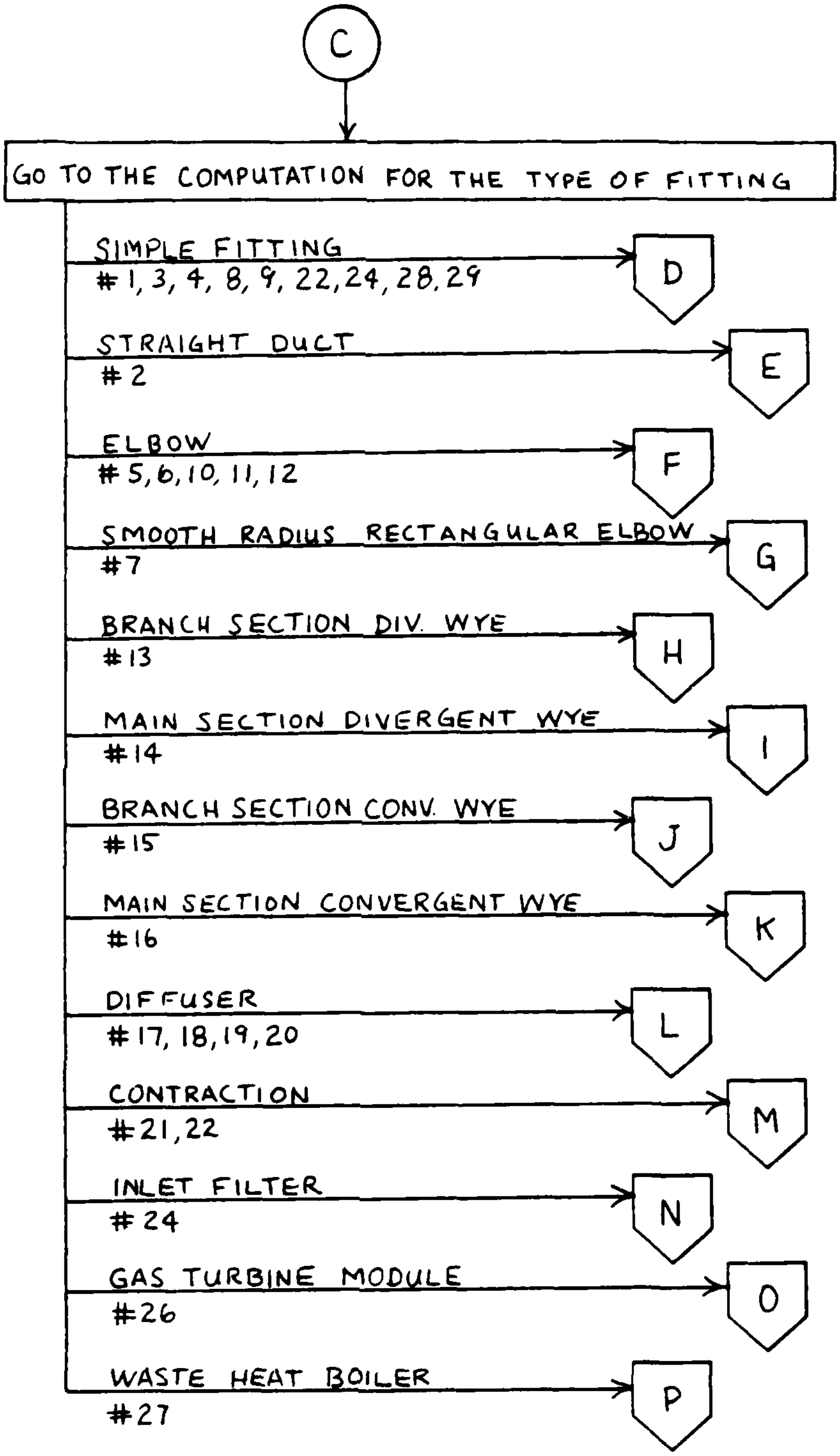

O
EXIT PRESSURE FROM BRANCH 4-5 MUST BE EQUAL TO PT5
TEST = ABS (PTOUT - PT5)
IS TEST LESS THAN 1.0 PSF ?
NO
YES
INCREASE THE ASSUMED COOLING FLOW A SMALL AMOUNT AND REPEAT ITERATION
WC = WC + 0.1
B
SYSTEM IS MATCHED CALL OUTPUT AND PRINT SYSTEM RESULTS TO THE USER'S DISK
RETURN TO MAIN PROGRAM

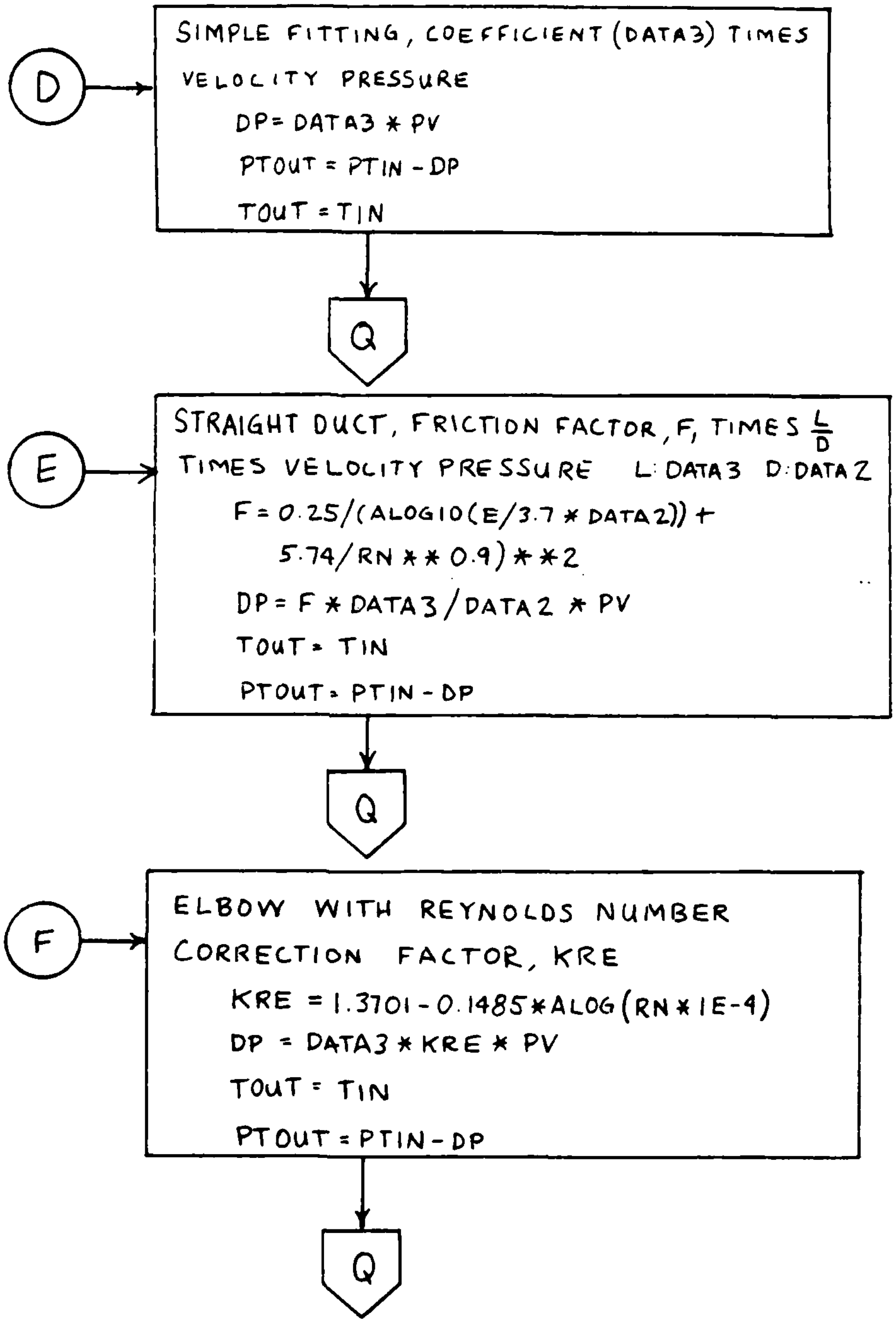
VI. FITTING PRESSURE LOSS CALCULATION SUBROUTINE.

SET UP TO COMPUTE PRESSURE LOSS AND VELOCITY DATA FOR 30 FITTINGS LISTED IN THE MENU




B
COMPUTE PRESSURE VELOCITY
PV = RHO*V**2/(2.0*32.174)
COMPUTE STATIC PRESSURE
PS = PTIN - PV
COMPUTE DENSITY OF GAS ENTERING FITTING USING PERFECT GAS LAW
RHOT = PS/(R*TIN)
COMPARE COMPUTED RHO AND ASSUMED RHO
TEST = ABS(RHOT - RHO)
IS TEST GREATER THAN 0.001 ?
YES
USING LATEST VALUE FOR RHO COMPUTE VELOCITY OF FLOW
A
COMPUTE REYNOLDS NUMBER
RN = RHOT * DATA2 * V/MU
C


C
GO TO THE COMPUTATION FOR THE TYPE OF FITTING
SIMPLE FITTING
#1, 3, 4, 8, 9, 22, 24, 28, 29
D
STRAIGHT DUCT
#2
E
ELBOW
#5, 6, 10, 11, 12
F
SMOOTH RADIUS RECTANGULAR ELBOW
#7
G
BRANCH SECTION DIV. WYE
#13
H
MAIN SECTION DIVERGENT WYE
#14
I
BRANCH SECTION CONV. WYE
#15
J
MAIN SECTION CONVERGENT WYE
#16
K
DIFFUSER
#17, 18, 19, 20
L
CONTRACTION
#21, 22
M
INLET FILTER
#24
N
GAS TURBINE MODULE
#26
O
WASTE HEAT BOILER
#27
P



SIMPLE FITTING, COEFFICIENT (DATA3) TIMES VELOCITY PRESSURE

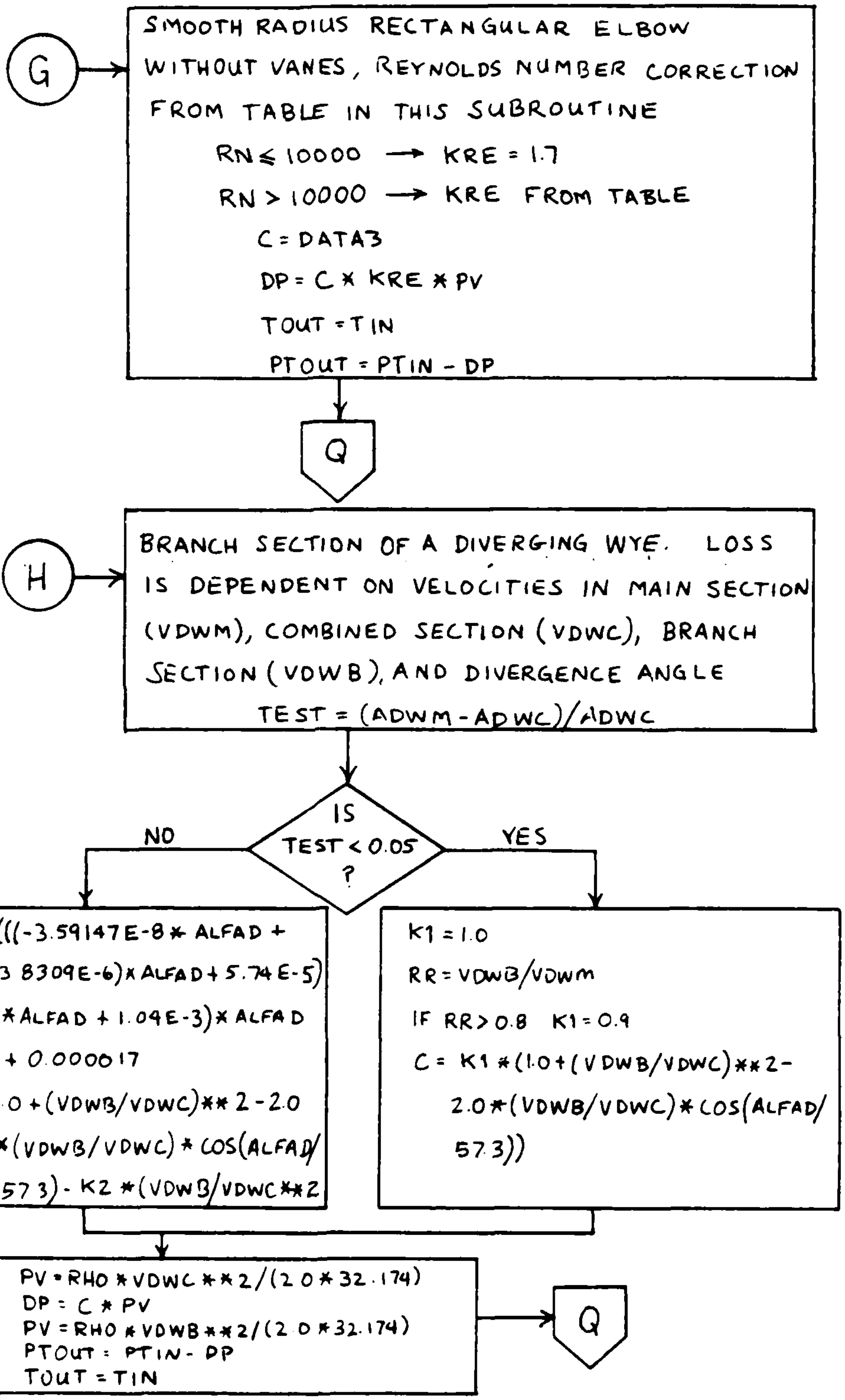
```
    DP= DATA3 * PV
    PTOUT = PTIN - DP
    TOUT = TIN
```

STRAIGHT DUCT, FRICTION FACTOR, F, TIMES $\frac{L}{D}$ TIMES VELOCITY PRESSURE   L: DATA3   D: DATA 2

```
    F = 0.25/(ALOG10(E/3.7 * DATA2)) +
       5.74/RN ** 0.9) ** 2
    DP = F * DATA3 / DATA 2 * PV
    TOUT = TIN
    PTOUT = PTIN - DP
```

ELBOW WITH REYNOLDS NUMBER CORRECTION FACTOR, KRE

```
    KRE = 1.3701 - 0.1485*ALOG(RN*1E-4)
    DP = DATA3 * KRE * PV
    TOUT = TIN
    PTOUT = PTIN - DP
```



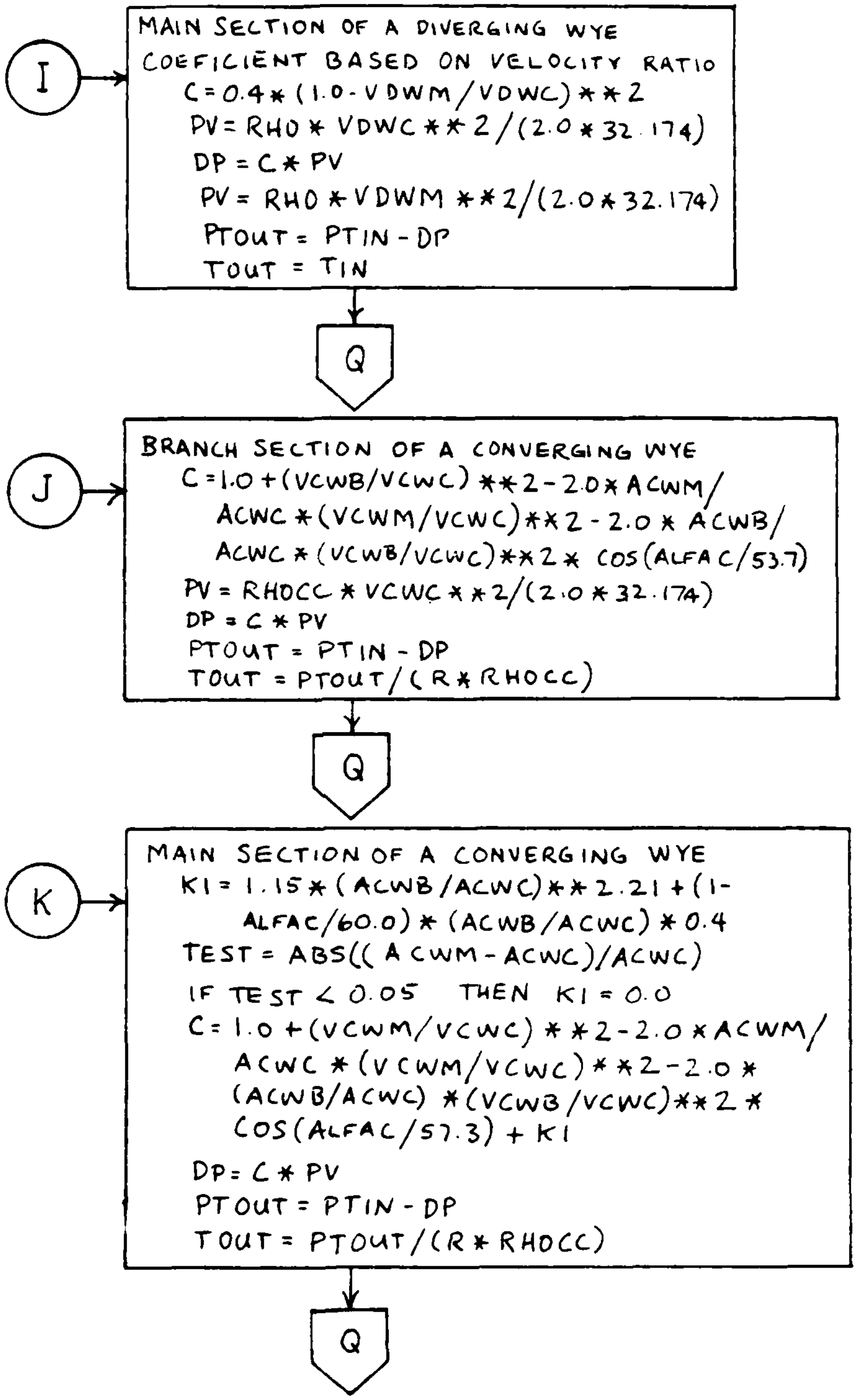
```
SMOOTH RADIUS RECTANGULAR ELBOW
WITHOUT VANES, REYNOLDS NUMBER CORRECTION
FROM TABLE IN THIS SUBROUTINE
     RN ≤ 10000 → KRE = 1.7
     RN > 10000 → KRE FROM TABLE
        C = DATA3
        DP = C * KRE * PV
        TOUT = TIN
        PTOUT = PTIN - DP
```

```
BRANCH SECTION OF A DIVERGING WYE. LOSS
IS DEPENDENT ON VELOCITIES IN MAIN SECTION
(VDWM), COMBINED SECTION (VDWC), BRANCH
SECTION (VDWB), AND DIVERGENCE ANGLE
        TEST = (ADWM-ADWC)/ADWC
```

```
K2=(((-3.59147E-8* ALFAD +
      3.8309E-6)*ALFAD+5.74E-5)
      *ALFAD + 1.04E-3)*ALFAD
      + 0.000017
C = 1.0+(VDWB/VDWC)**2-2.0
      *(VDWB/VDWC)*COS(ALFAD/
      57.3)-K2*(VDWB/VDWC**2
```

```
K1 = 1.0
RR = VDWB/VDWM
IF RR>0.8  K1=0.9
C= K1*(1.0+(VDWB/VDWC)**2-
     2.0*(VDWB/VDWC)*COS(ALFAD/
     57.3))
```

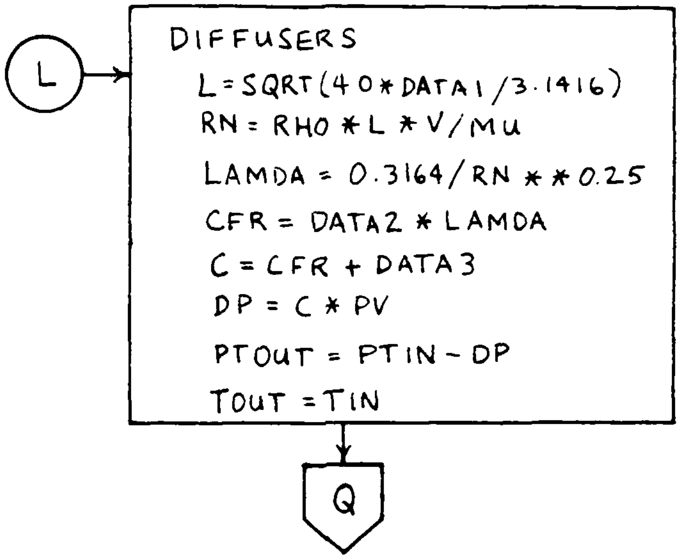
```
PV = RHO*VDWC**2/(2.0*32.174)
DP = C*PV
PV = RHO*VDWB**2/(2.0*32.174)
PTOUT = PTIN - DP
TOUT = TIN
```



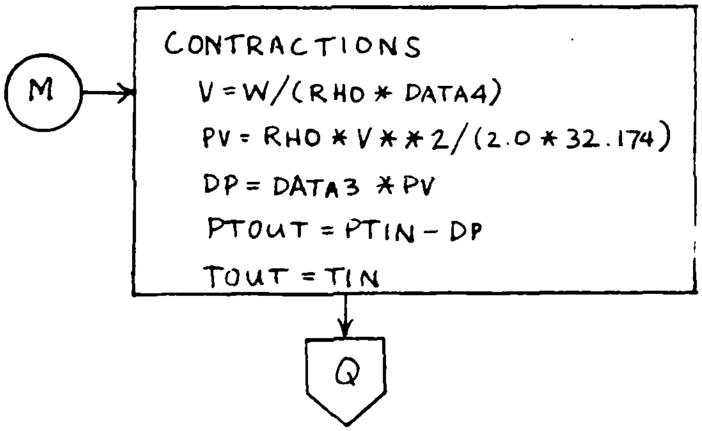
```
MAIN SECTION OF A DIVERGING WYE
COEFICIENT BASED ON VELOCITY RATIO
   C=0.4*(1.0-VDWM/VDWC)**2
   PV=RHO*VDWC**2/(2.0*32.174)
   DP=C*PV
   PV=RHO*VDWM**2/(2.0*32.174)
   PTOUT=PTIN-DP
   TOUT=TIN
```

```
BRANCH SECTION OF A CONVERGING WYE
   C=1.0+(VCWB/VCWC)**2-2.0*ACWM/
      ACWC*(VCWM/VCWC)**2-2.0*ACWB/
      ACWC*(VCWB/VCWC)**2*COS(ALFAC/53.7)
   PV=RHOCC*VCWC**2/(2.0*32.174)
   DP=C*PV
   PTOUT=PTIN-DP
   TOUT=PTOUT/(R*RHOCC)
```

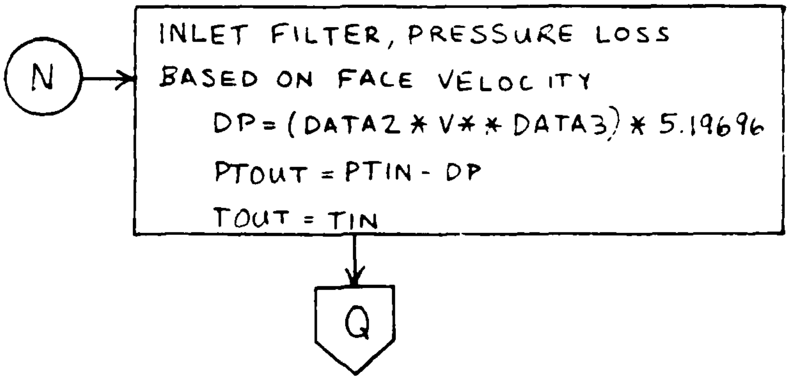
```
MAIN SECTION OF A CONVERGING WYE
   K1=1.15*(ACWB/ACWC)**2.21+(1-
      ALFAC/60.0)*(ACWB/ACWC)*0.4
   TEST=ABS((ACWM-ACWC)/ACWC)
   IF TEST < 0.05   THEN K1=0.0
   C=1.0+(VCWM/VCWC)**2-2.0*ACWM/
      ACWC*(VCWM/VCWC)**2-2.0*
      (ACWB/ACWC)*(VCWB/VCWC)**2*
      COS(ALFAC/57.3)+K1
   DP=C*PV
   PTOUT=PTIN-DP
   TOUT=PTOUT/(R*RHOCC)
```



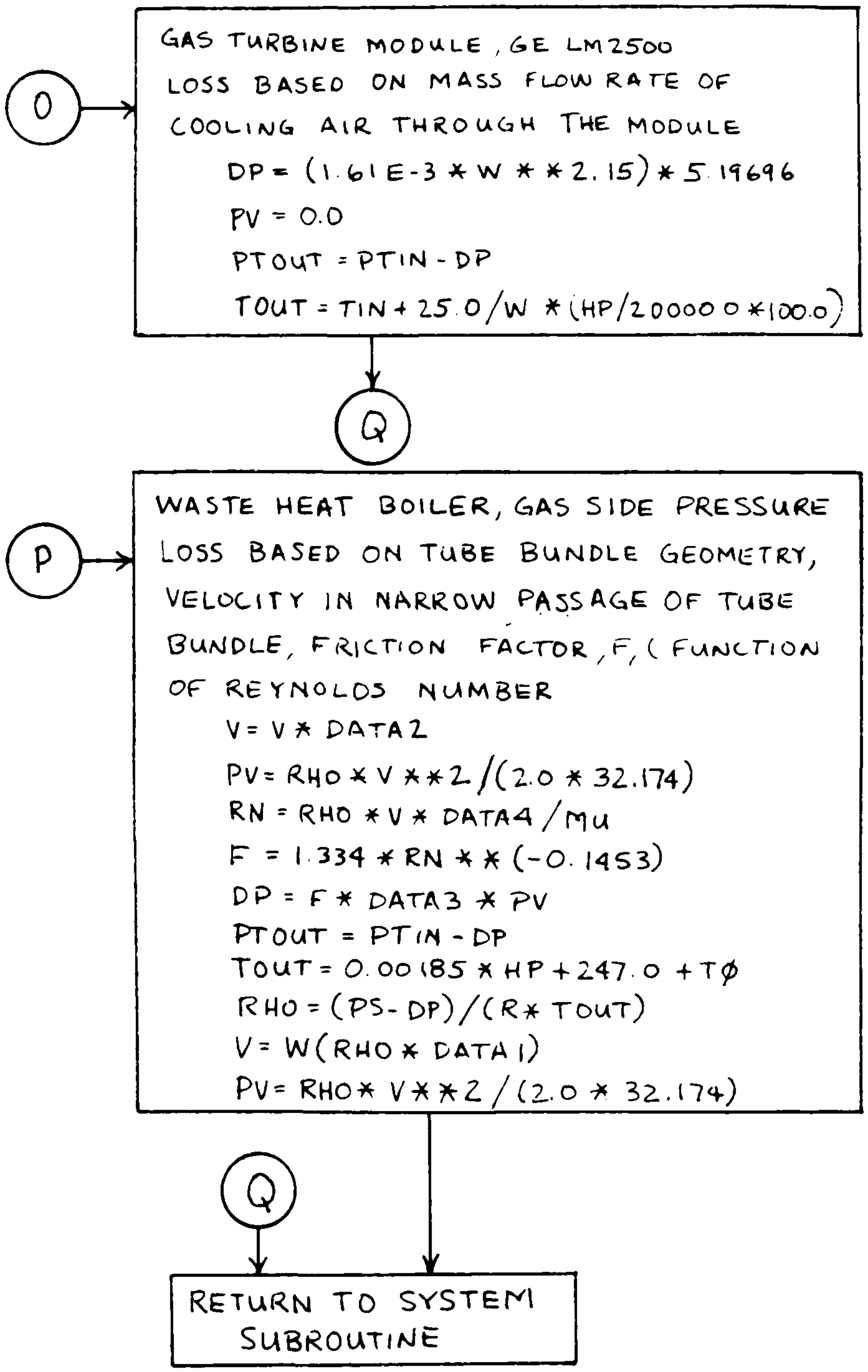
```
DIFFUSERS
  L=SQRT(40*DATA1/3.1416)
  RN = RHO*L*V/MU
  LAMDA = 0.3164/RN**0.25
  CFR = DATA2*LAMDA
  C = CFR + DATA3
  DP = C*PV
  PTOUT = PTIN-DP
  TOUT =TIN
```



```
CONTRACTIONS
  V=W/(RHO*DATA4)
  PV = RHO*V**2/(2.0*32.174)
  DP = DATA3 *PV
  PTOUT = PTIN-DP
  TOUT = TIN
```



```
INLET FILTER, PRESSURE LOSS
BASED ON FACE VELOCITY
  DP=(DATA2*V**DATA3)*5.19696
  PTOUT = PTIN - DP
  TOUT = TIN
```



GAS TURBINE MODULE, GE LM2500 LOSS BASED ON MASS FLOW RATE OF COOLING AIR THROUGH THE MODULE

```
    DP = (1.61E-3 * W ** 2.15) * 5.19696
    PV = 0.0
    PTOUT = PTIN - DP
    TOUT = TIN + 25.0/W * (HP/20000.0*100.0)
```

WASTE HEAT BOILER, GAS SIDE PRESSURE LOSS BASED ON TUBE BUNDLE GEOMETRY, VELOCITY IN NARROW PASSAGE OF TUBE BUNDLE, FRICTION FACTOR, F, (FUNCTION OF REYNOLDS NUMBER

```
    V = V * DATA2
    PV = RHO * V ** 2/(2.0 * 32.174)
    RN = RHO * V * DATA4 /MU
    F = 1.334 * RN ** (-0.1453)
    DP = F * DATA3 * PV
    PTOUT = PTIN - DP
    TOUT = 0.00185 * HP + 247.0 + T0
    RHO = (PS - DP)/(R * TOUT)
    V = W(RHO * DATA1)
    PV = RHO * V ** 2 /(2.0 * 32.174)
```

RETURN TO SYSTEM SUBROUTINE

APPENDIX C
USER'S MANUAL

A. GENERAL

The purpose of this program is to analyze a marine gas turbine installation on board a ship complete with inlet, exhaust, and cooling ductwork. The duct geometry must be input to the program to accomplish this. The program makes a file called "duct data" which contains resistance information on each fitting entered. This file may be edited with the built in editor or if the user is satisfied with the current design the file is read by the program and used in the COMPUTE section of the program. COMPUTE uses the duct data file and inputs dealing with the operating point of the engine to produce the performance parameters of the system. Performance includes both engine parameters and duct losses. All procedures in the program are accomplished using an interactive terminal session.

There are two versions of the program discussed in this user's manual. Version 1.0 is implemented on the NPS IBM 3033 computer. Version 1.1 is implemented on the NPS VAX-11 computer.

This user's manual will discuss the questions posed by the program. Familiarity with the program sections and the questions asked in each section will facilitate program execution and help produce reasonable results. The most critical area for familiarity is in the BUILD and EDIT sections of the program. It is not so critical in the COMPUTE section of the program because only two questions are asked for each operating point run after the ambient conditions are input.

B. PRELIMINARY

The program does not design ducts or read mechanical drawings. The user plays a vital role by interpreting the system for the program. Some fittings are easy to recognize such as elbows, straight duct, transistions, diffusers and contractions. Some are harder to understand, like diverging and converging wyes. Each fitting listed in the menu is sketched for the user. The sketches show a typical view but remember that the dimensions shown on the drawings are variable inputs so the configuration can change drastically by looking at a fitting over the range of variable dimensions.

Before running the program the user should become familiar with the fitting sketches. Comparing the sketch to the fitting to be modeled will assist the user in preparing a list of fittings for the system. The user should note the dimensions and be prepared to input them to the program.

The program looks for fittings in a definite sequence. Branches are groups of fittings or sections of the ductwork. Branches run from node to node. A node is an entry, exit, junction, fan, or engine. Refer to figure 2.6 for the various system configurations. Nodes are indicated in this figure by the numbered black dots. Nodes have numbers from one to six. The branches get their number designation from the end point nodes. The user should become familiar with the system schematics then it will be easy to understand the order that the program will be asking for fittings. Branches are entered in a sequence from the lowest number node to the next lowest number node until all fittings are entered. For example, a class three system enters branches in the following order; 1-2, 2-3, 2-4, 3-5, 4-5, 5-6. To assist the user when entering fittings the program displays the current fitting identification number on the screen with the menu. The ID number is a six digit number where the first digit is the system class, the next two digits are the branch number and the last two numbers are the sequence number of the fitting in the branch. A terminal session has been recorded and the printout annotated to show this number.

It would be helpful to pencil in the node numbers in the system drawings. The following table may help.

TABLE II

Node Designations

1	Main air inlet (engine only or combined)
2	Cooling air inlet or divergent wye off main inlet
3	The engine
4	A fan
5	Cooling air exit or convergent wye with main exhaust
6	Main exhaust (engine only or combined)

The user should prepare a list of fittings organized by branches and continuous with regard to the sequence of fittings. It's the old "toe bone connected to the foot bone" idea. As an example, the following list may help.

- node 1
    - vert intake, 3 orifices, with louvers
    - straight duct
    - rectangular contraction
    - smooth radius rect elbow
- node 3
    - etc.

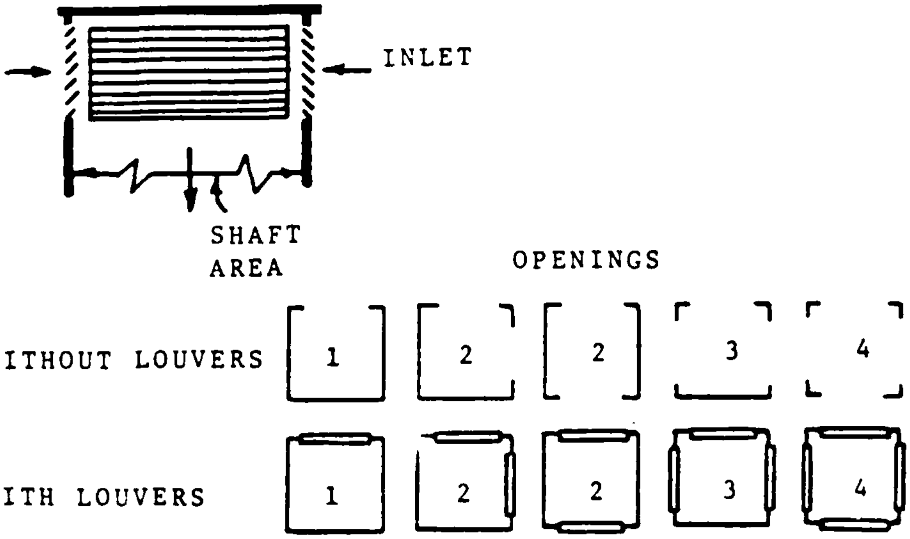
Do not forget to include abrupt exits where they appear. Sometimes it is easy to overlook an obvious fitting such as the engine module as part of the cooling air ductwork.

Only the class one system does not have either a divergent wye or a convergent wye. Class three and five have both. The divergent wye is fairly straight forward. The user only needs to enter the areas indicated in the sketch and the angle of divergence (0-90). The branch section of the divergent wye is the first fitting in branch 2-4 (2-5 if no fan) and the main section (combustion air) is the first fitting in branch 2-3. The combined area and the divergence angle are data entered when entering the branch of the diverging wye. The convergent wye is a more complex. It is located at node five. The branch of a convergent wye should be the last fitting of branch 4-5 (2-5 if no fan). It will usually be the fitting after the module. The main section (engine exhaust) of the convergent wye is the last fitting of branch 3-5. Usually there are just two fittings in branch 3-5. The first is the nozzle or extension bolted to the exhaust plane flange of the engine, and the last is the main section of the convergent wye. The combined area and convergence angle are data entered with the branch section. The convergence angle is usually zero and the combined area is about equal to the sum of the main and branch areas.

FITTING NAME:
Vertical intake shaft with side orifices, with or without louvers

NUMBER:
01

SKETCH:



INPUT REQUIREMENTS:

1. The number of orifices (1,2,3,or 4)
2. The cross section area of the verticalshaft
3. With two orifices, whether they are adjacent or opposite
4. If there are louvers installed

DUCT DATA FILE ENTRIES:

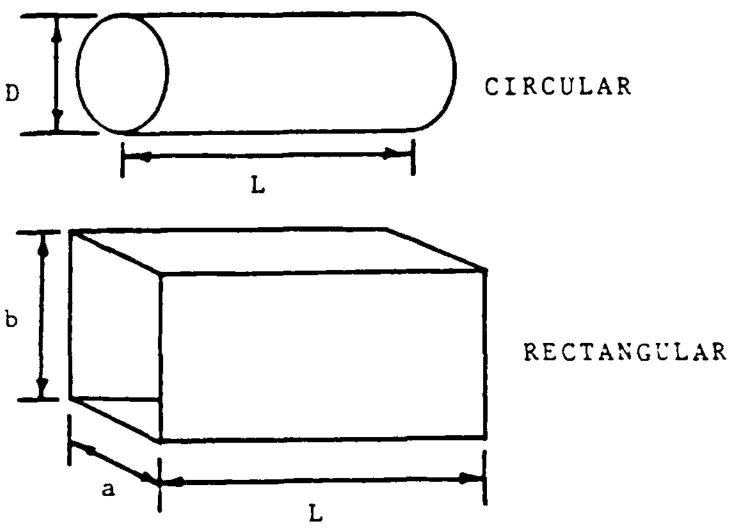
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
shaft area	0.0	resistance coefficient	shaft area

REMARKS:
The louvers are flat plates of standard configuration. The opening areas are not required but should be approximately proportional to those shown in the sketch.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME: Straight duct, round or rectangular	NUMBER: 02

SKETCH:



INPUT REQUIREMENTS:

1. Round: diameter and length
2. rectangular: cross section dimensions (a, b) length

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	diameter or equivalent	length	section area

REMARKS:

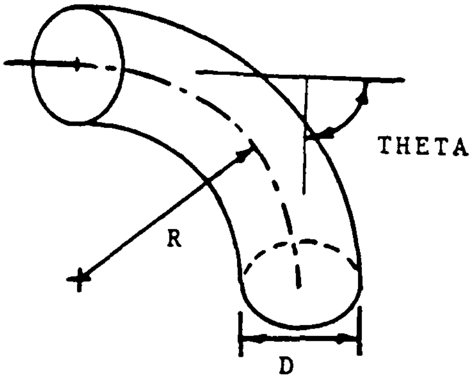
Darcy-Wiesbach Equation used for resistance. Friction factor by correlation by Swamee & Jain. Equivalent circular diameter computed for rectangular sections. Length should be measured to the center of short fittings and to the start or end of a long fitting.

REFERENCE:

Mechanics of Fluids, Shames

FITTING NAME: Smooth radius round cross section elbow	NUMBER: 03

SKETCH:



INPUT REQUIREMENTS:
1. Cross section diameter
2. Radius of the turn measured to the centerline of the section
3. The turn angle

DUCT DATA FILE ENTRIES:

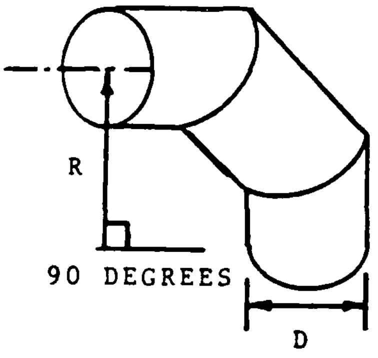
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	0.0	resistance coeficient	section area

REMARKS:
Turn angle should be from 0 to 90 degrees.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME: Segmented round cross section elbow 3, 4, or 5 segments, 90 degree turn	NUMBER: 04

SKETCH:



THREE SEGMENTS SHOWN
(THERE MAY ALSO BE
FOUR OR FIVE SEGMENTS)

INPUT REQUIREMENTS:

1. Number of segments
2. Cross section diameter
3. Radius of the turn measured to the centerline of the turn

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	0.0	resistance coefficient	section area

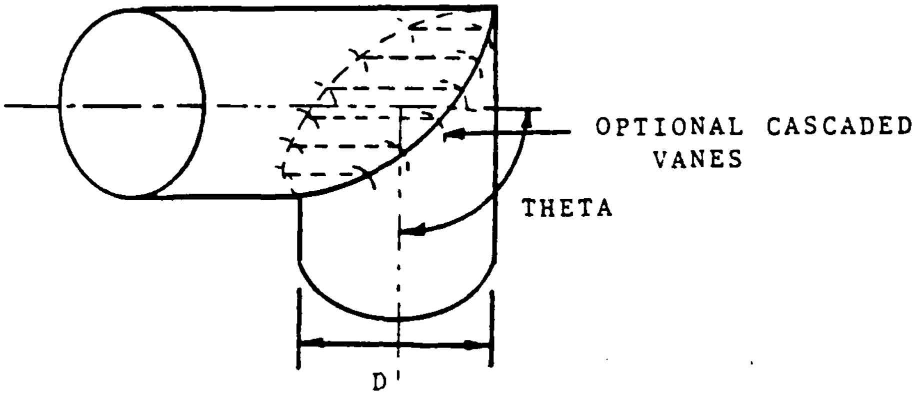
REMARKS:
Note that the number of segments includes the entry and exit segments.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Mitered round cross section elbow

NUMBER:
05

SKETCH:



INPUT REQUIREMENTS:

1. Cross section diameter
2. Turn angle
3. Whether or not concentric guide vanes are installed

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	diameter	resistance coefficient	section area

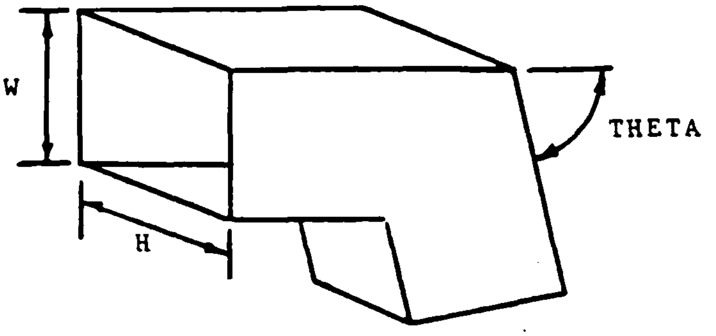
REMARKS:
A Reynolds number correction is applied to this fitting.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Mitered rectangular cross section elbow without turning vanes

NUMBER:
06

SKETCH:



INPUT REQUIREMENTS:

1. Height of the elbow, dimension parallel to turn axis
2. Width of the elbow, dimension in the turn plane
3. Turn angle

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	hydraulic diameter	resistance coefficient	section area

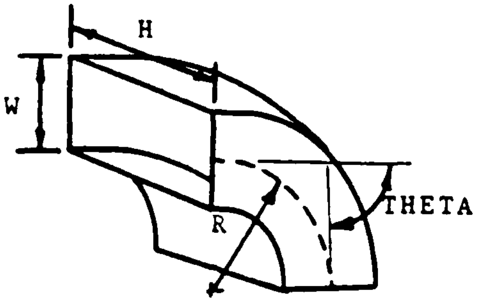
REMARKS:
This fitting has a Reynolds number correction applied to the resistance coefficient.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Smooth radius rectangular elbow without guide vanes

NUMBER:
07

SKETCH:



INPUT REQUIREMENTS:
1. Height of the elbow, the dimension parallel to the turn axis
2. Width of the elbow, the dimension in the turn plane.
3. Radius of the elbow measured to the centerline of the elbow.
4. Turn angle

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	hydraulic diameter	resistance coefficient	radius/ width

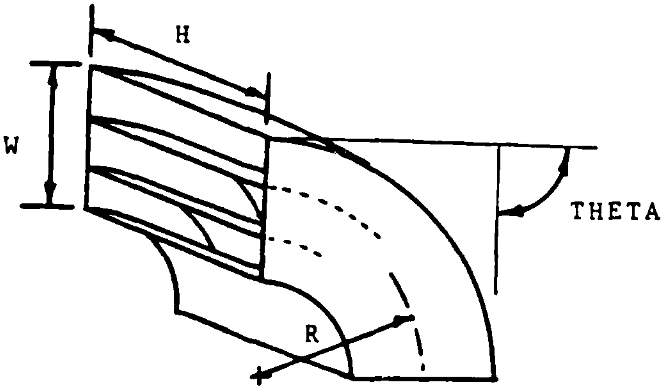
REMARKS:
This fitting has a Reynolds number correction. The correction also varies with the R/W ratio.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Smooth radius rectangular elbow with splitters

NUMBER:
08

SKETCH:



TWO SPLITTERS SHOWN
(THERE MAY ALSO BE
ONE OR THREE)

INPUT REQUIREMENTS:
1. Number of splitters, 1,2, or 3
2. Height, distance parallel to turn axis
3. Width, distance in turn plane
4. Radius of elbow to section centerline
5. Turn angle

DUCT DATA FILE ENTRIES:

WORKKR(I,1)	WORKKR(I,2)	WORKKR(I,3)	WORKKR(I,4)
section area	0.0	resistance coefficient	section area

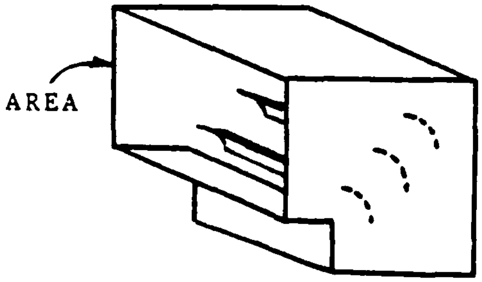
REMARKS:
None

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Mitered rectangular elbow with vanes

NUMBER:
09

SKETCH:



THREE VANES SHOWN

(THERE MAY ALSO BE ONE OR TWO)

INPUT REQUIREMENTS:
1. Number of vanes (1, 2, or 3)
2. Cross section area

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	0.0	resistance coefficient	section area

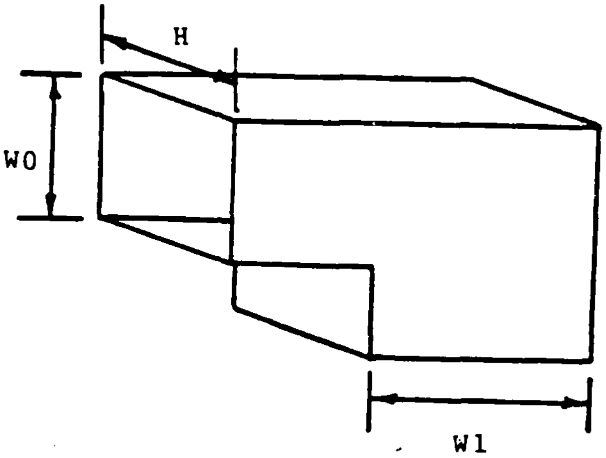
REMARKS:
Flat plate turning vanes are used.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Rectangular elbow with converging or diverging flow

NUMBER:
10

SKETCH:



INPUT REQUIREMENTS:

1. Inlet height, dimension parallel to turn axis
2. Exit height, dimension parallel to turn axis
3. Constant width, dimension in turn plane

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
inlet area	inlet hyd. diameter	resistance coefficient	outlet area

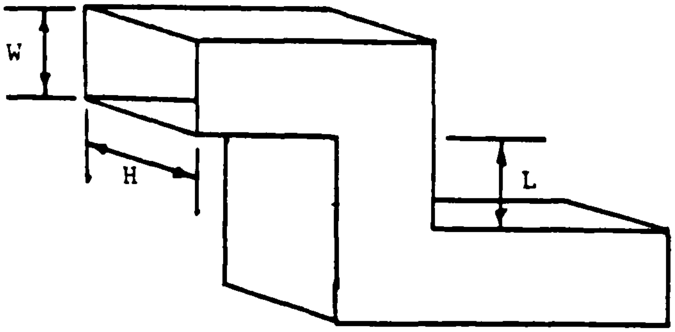
REMARKS:
Elbow should have a 90 deg turn.
The width should remain constant in the elbow.

REFERENCE:
ASRHAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Two 90 degree rectangular elbows in a Z-shaped configuration

NUMBER:
11

SKETCH:



INPUT REQUIREMENTS:

1. Height of elbows, dimension parallel to turn ax
2. Width of elbows, dimension in turn axis
3. The distance between the centerlines of the offset duct

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	hydraulic diameter	resistance coefficient	section area

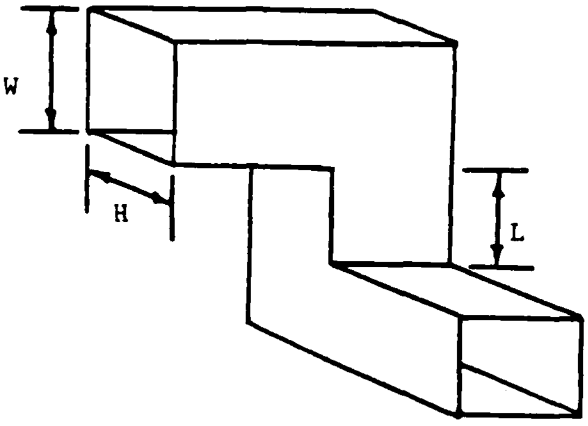
REMARKS:
None.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Two 90 degree elbows in different planes

NUMBER:
12

SKETCH:



INPUT REQUIREMENTS:

1. Height of elbow, dimension parallel to turn axis
2. Width of elbow, dimension in the plane of the turn
3. Distance between the centerlines of the duct connected to this arrangement

DUCT DATA FILE ENTRIES:

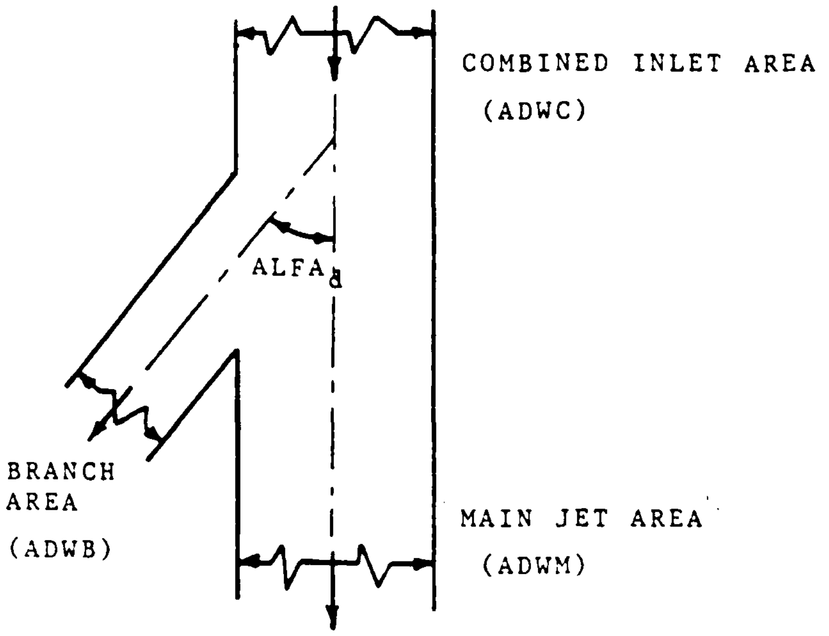
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
section area	Hydraulic Diameter	resistance coefficient	section area

REMARKS:
Resistance coefficient is a curve fit to the tabulated data.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME: Diverging wye, branch and main sections	NUMBER: 13 & 14

SKETCH:



INPUT REQUIREMENTS:

A. Branch section
  1. combined area
  2. branch area
  3. divergence angle

B. Main section
  1. main area

DUCT DATA FILE ENTRIES: (fitting 13)

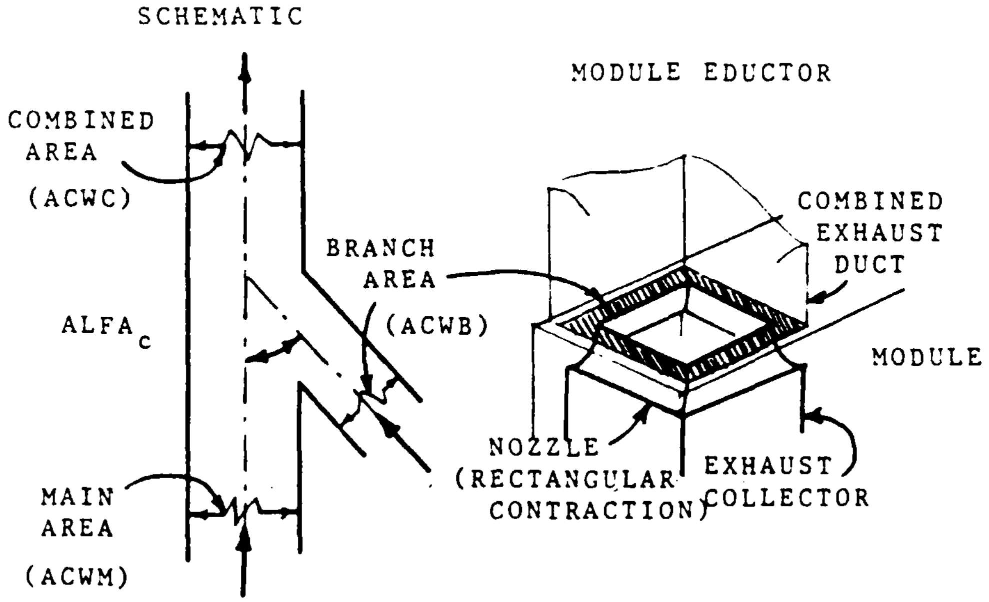
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
combined area	branch area	divergence angle	branch area

REMARKS:
The divergence angle should follow some centerline streamline. The areas are cross section areas perpendicular to the streamline in the sections away from the dividing location. Cooling air flows through the branch section. Main inlet air to the engine flows through the main section. Both flow through the combined section.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME: Convergent wye, branch and main sections	NUMBER: 15 & 16

SKETCH:



INPUT REQUIREMENTS:

A. Branch section
  1. branch area
  2. combined area
  3. convergence angle

B. Main section
  1. main area

DUCT DATA FILE ENTRIES: (fitting 15)

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
combined area	branch area	convergence angle	branch area

REMARKS:

The branch area has module cooling air flowing through it. The main area has engine exhaust flowing through it. The combined area has both. The angle should be measured to representative streamlines at the plane where the two flows meet.

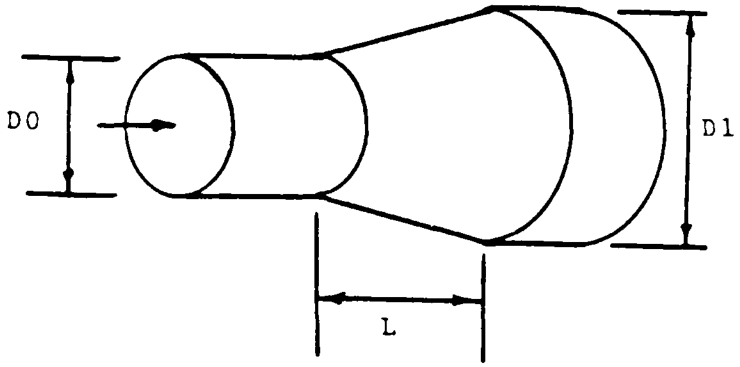
REFERENCE:

Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME:
Conical diffuser

NUMBER:
17

SKETCH:



INPUT REQUIREMENTS:
1. Length of the diffuser
2. Inlet diameter
3. Outlet diameter
4. Is there distorted flow at the inlet
5. Are there dividing wall or baffles installed to reduce resistance

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
inlet area	friction coefficient	flow coefficient	outlet area

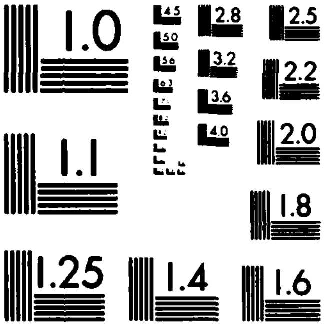
REMARKS:
The program recognizes a wide diverging angle and warns the user. Resistance in this case may be reduced by 35 % with installation of baffles.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'chik

AD-A148 708 AN ANALYTIC MODEL OF GAS TURBINE ENGINE INSTALLATIONS 3/3
(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA S M EZZELL
SEP 84

UNCLASSIFIED F/G 21/5 NL

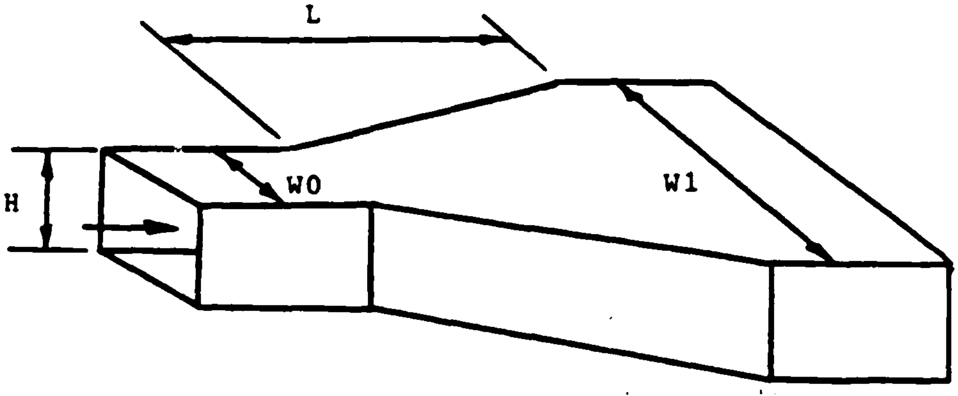
END
FILMED
DTIC


1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

FITTING NAME:
Plane in-line diffuser

NUMBER:
18

SKETCH:



INPUT REQUIREMENTS:

1. Length of the diffuser
2. The constant heigth of the diffuser
3. The inlet width
4. The outlet width
5. Distorted flow
6. Installation of baffles

DUCT DATA FILE ENTRIES:

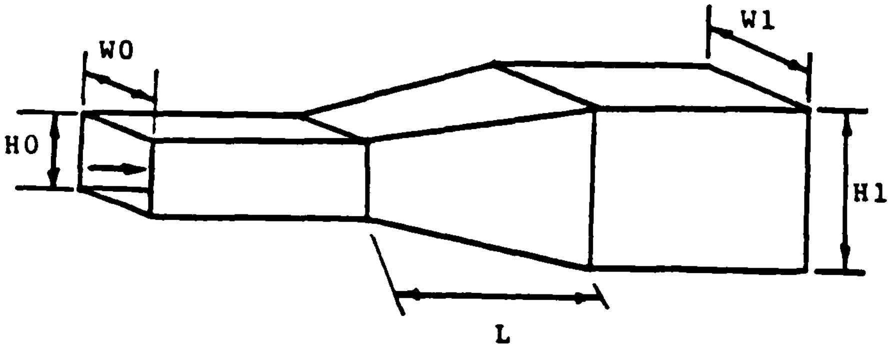
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
inlet area	friction coefficient	flow coefficient	outlet area

REMARKS:
The divergence is assumed to be uniform with respect to the main centerline. A wide divergence angle is recognized and the user is asked if dividing walls or baffles are installed to reduce resistance.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME: Pyramidal in-line diffuser	NUMBER: 19

SKETCH:



INPUT REQUIREMENTS:
1. Length of the diffuser
2. Smaller inlet dimension, larger inlet dimension
3. Dimensions parallel to inlet dimensions
4. Non-uniform velocity profile
5. Are baffles installed

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
inlet area	friction coefficient	flow coefficient	outlet area

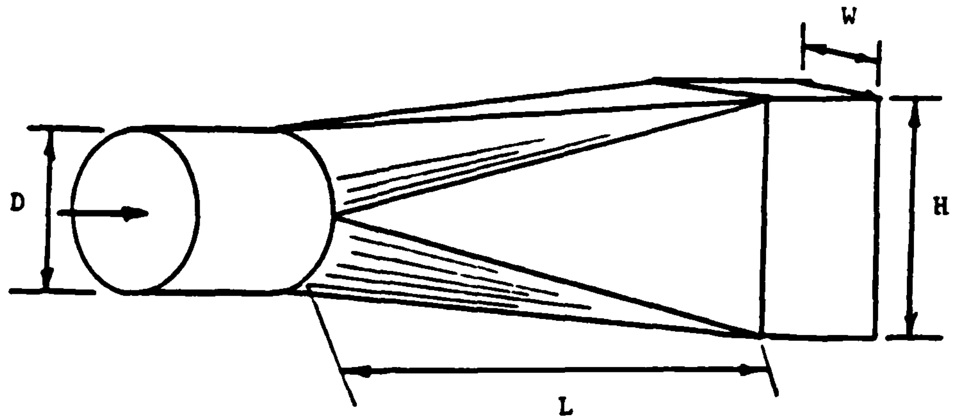
REMARKS:
A uniform divergence with respect to the centerline is assumed. Wide divergence angle is recognized by the program. With a wide angle the flow resistance can be reduced by 35% with baffles or dividing walls.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'cnik

FITTING NAME:
Transition diffuser, round to rectangular or rectangular to round

NUMBER:
20

SKETCH:



INPUT REQUIREMENTS:
1. Manner of transistion
2. Diameter
3. rectangular dimensions
4. Length of the diffuser
5. Non-uniform velocity distribution
6. Installation of baffles or dividing walls

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
inlet area	friction coefficient	flow coefficient	outlet area

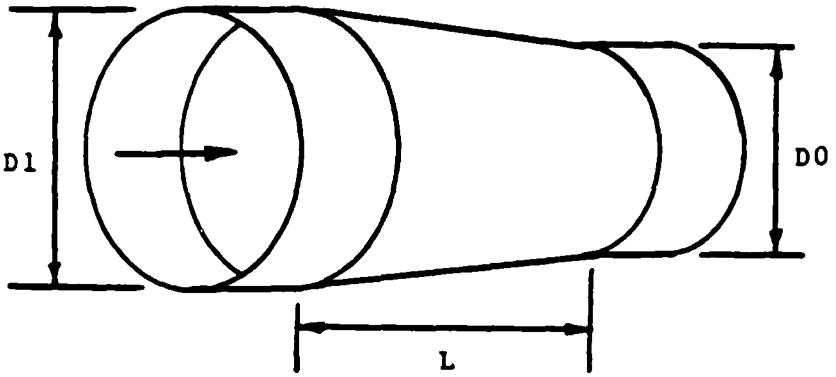
REMARKS:
Uniform divergence with respect to the centerline is assumed. Wide divergence angle is recognized and if baffles or dividing walls are installed the resistance is reduced by 35%.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME:
Circular contraction

NUMBER:
21

SKETCH:



INPUT REQUIREMENTS:

1. Length of the contraction
2. Upstream diameter
3. Downstream diameter

DUCT DATA FILE ENTRIES:

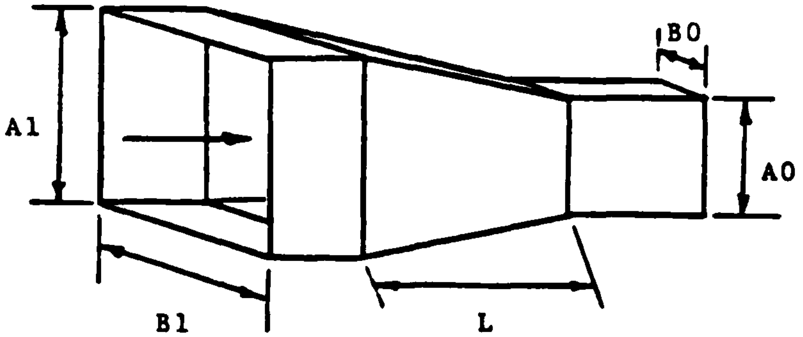
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
outlet area	0.0	resistance coefficient	inlet area

REMARKS:
If you need a transitional contraction you could use this fitting or fitting 22. The area of the inlet or outlet would have to be converted to a circle or rectangle as required by the geometry for input to the program.

REFERENCE:
ASHRAE FUNDMENTALS 1981, chapter 33

FITTING NAME: Rectangular contraction	NUMBER: 22

SKETCH:



INPUT REQUIREMENTS:
1. Length of the contraction
2. Upstream dimensions
3. Downstream dimensions

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
outlet area	0.0	resistance coefficient	inlet area

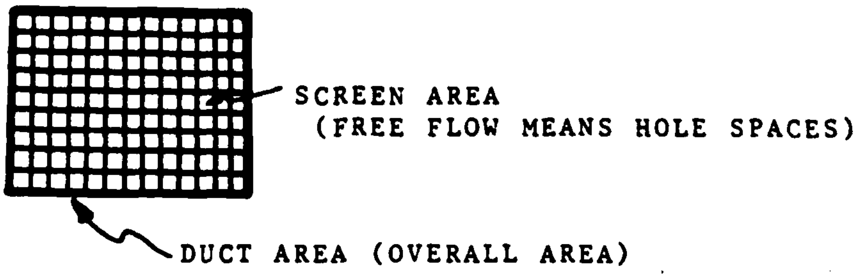
REMARKS:
This fitting can be substituted for a transitional contraction. The inlet or outlet area should remain the same and the area for transition converted as required.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Screen

NUMBER:
23

SKETCH:



INPUT REQUIREMENTS:
1. Overall duct cross section area
2. Screen free flow area

DUCT DATA FILE ENTRIES:

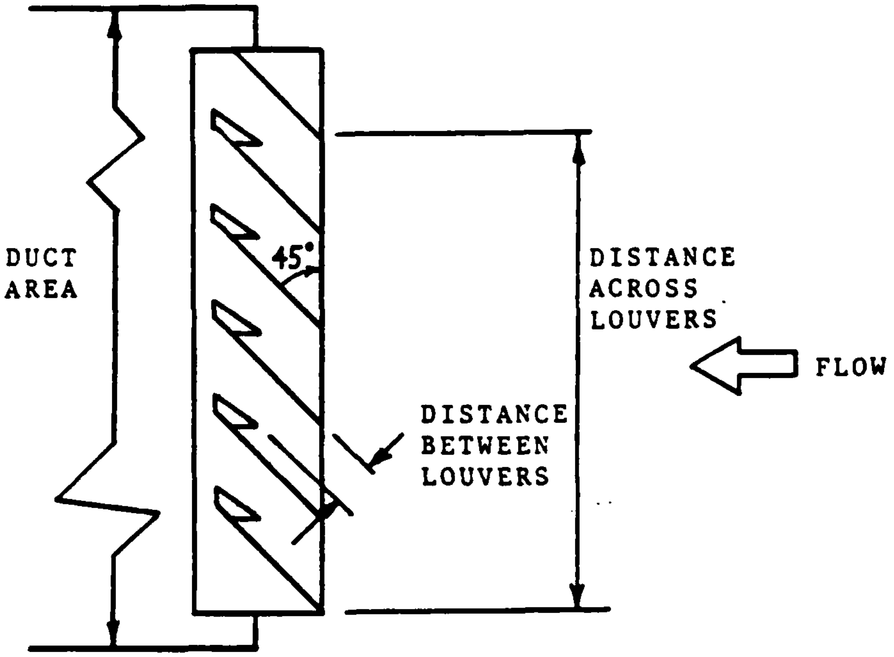
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
duct area	0.0	resistance coefficient	duct area

REMARKS:
This fitting is useful for the screen in front of the engine inlet. The free flow area is the sum of all the holes in the screen.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME: Louver inlet	NUMBER: 24

SKETCH:



INPUT REQUIREMENTS:

1. Distance across the louver openings
2. Distance between the louvers
3. The number of openings between the louvers
4. Duct area just inside the louvers

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
duct area	0.0	resistance coefficient	duct area

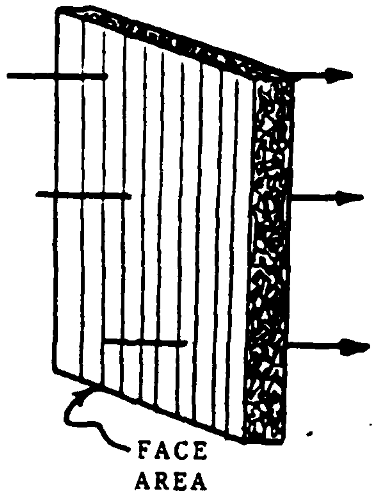
REMARKS:
The correlation is for flat louvers with the front edges flat with the face of the louvers. No friction is included in this correlation. Better models need to be developed for louvers with moisture separator edges. The louver angle is 45 degrees to the face.

REFERENCE:
Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME:
Filter

NUMBER:
25

SKETCH:



INPUT REQUIREMENTS:
None if the default value is used.
If another filter type is to be used then the user should provide pressure loss data as a function of face velocity. Only a few points are required for the power curve fit to work. The number of points is an input (two min.)

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
filter face area	multiplier (A)	exponent (B)	filter face area

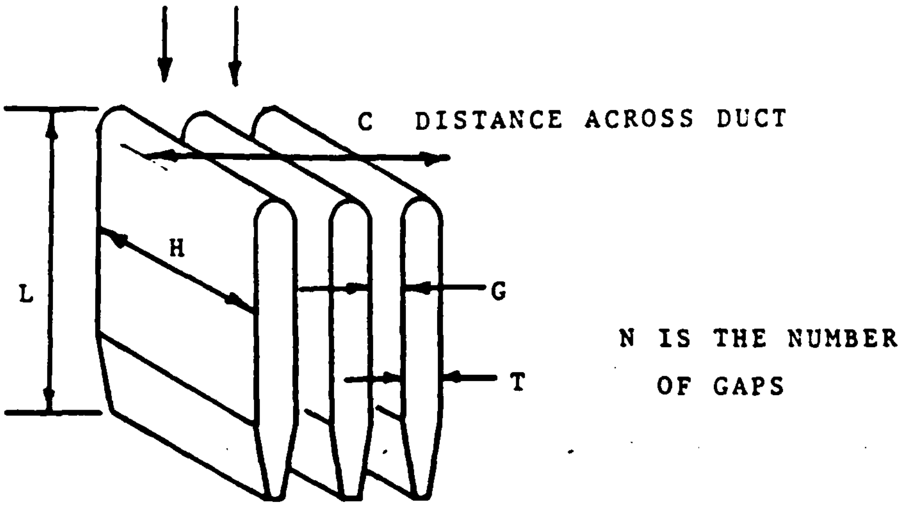
REMARKS:
The power curve fit is of the form:

delta pressure (in WG)= A*(velocity)**B

REFERENCE:
Filter manufacturer's data

FITTING NAME:	NUMBER:
Multi-baffle type silencer	26

SKETCH:



INPUT REQUIREMENTS:
1. Gap between baffles
2. Baffle thickness
3. Baffle length (with flow)
4. Duct dimension parallel to gap
5. Duct dimension across gaps
6. The number of gaps

DUCT DATA FILE ENTRIES:

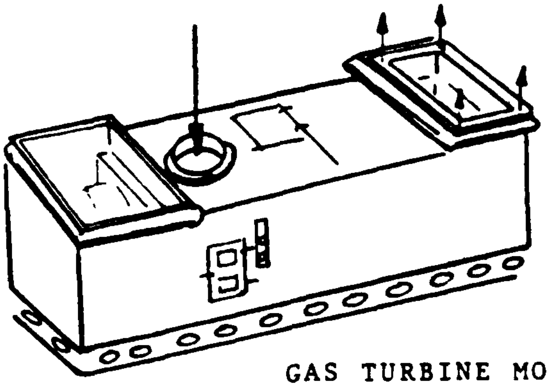
WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
duct area	0.0	resistance coefficient	duct area

REMARKS:
This is a composit model. The resistance coefficient is modeled as a sudden contraction, friction along the length of the baffle, and a sudden expansion. It is not a very good model and a model based on experimental data would be better.

REFERENCE:
NAVSEA Inlet Design Handbook for Marine Gas turbines

FITTING NAME:	NUMBER:
Gas turbine module	27

SKETCH:



GAS TURBINE MODULE

** COOLING AIR PASSAGES ONLY **

INPUT REQUIREMENTS:
None

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
1.0	1.0	1.0	1.0

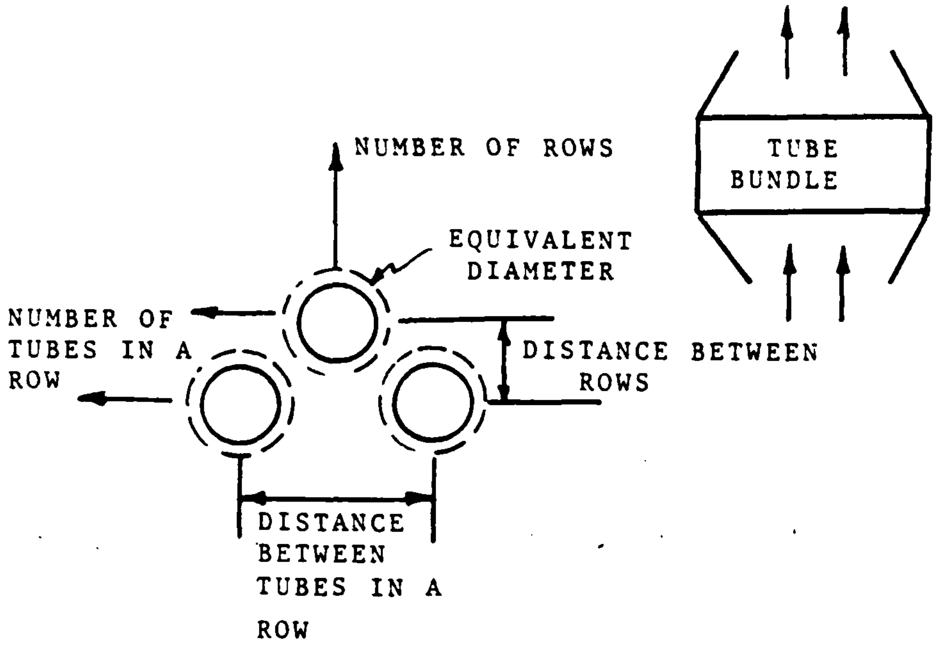
REMARKS:
This model is based on the mass flow rate of cooling air through the module. It is a power fit to data from General Electric Co. It should be good as long as entry and exit areas remain about the same. The 1.0's in the duct data file are there to prevent division by zero in the program and are not actually used.

REFERENCE:
Manufacturer's data

FITTING NAME:
Waste heat recovery boiler

NUMBER:
28

SKETCH:



INPUT REQUIREMENTS:
A default is available. It is based on current design considerations in the racer program. Should you choose not to use it several inputs are required. Read the reference and be prepared to enter the values shown on the sketch and a few you will have to compute yourself (i.e. tube equiv. dia. and hydraulic dia.).

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
duct area	0.0	resistance coefficient	duct area

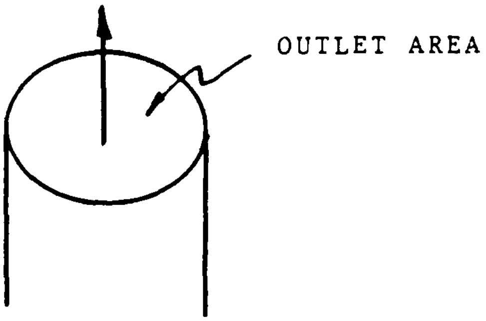
REMARKS:
If the manufacturer will provide the data, write your own model, but this should be close for preliminary studies.

REFERENCE:
Extended Surface Heat Transfer, Kerns and Krauss pages 582-589

FITTING NAME:
Abrupt Exit

NUMBER:
29

SKETCH:



INPUT REQUIREMENTS:
1. The exit area

DUCT DATA FILE ENTRIES:

WORKR(I,1)	WORKR(I,2)	WORKR(I,3)	WORKR(I,4)
exit area	0.0	1.0	exit area

REMARKS:
All velocity energy is assumed lost after exiting the duct, hence a coefficient of 1.0.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

C. EXECUTING THE PROGRAM

1. IBM 3033 at NPS

Issue the following commands to compile and execute the program.

```
FORTHX filename
GLOBAL TXTLIB FORTMOD2 MOD2EEH NONIMSL
LOAD filename (START
```

"filename" is the name of the program in the user's files. NONIMSL is required because the program calls the NONIMSL library with FRTCMS when defining files and clearing the CRT screen. If the file has been compiled on the user's disk the lengthy compiling may be omitted and issue just the last two lines.

2. VAX-11 at NPS

The program version to be used is 1.1. This version is a modified version of the program listed in Appendix A. The modifications include elimination of all calls to FRTCMS. FRTCMS is used for two purposes in version 1.0. First to set up file definitions and second to clear the screen at appropriate times to prevent the format of the display from being chopped up. The file definitions in version 1.1 are set up using the standard OPEN statement of FORTRAN 77 used on the VAX-11/780 at NPS. All calls to FRTCMS to clear the screen were deleted and are not needed on the VAX because it scrolls the display from the bottom and does not cut off any continuous screen displays. One other change was made in the file definition area, all writes to the terminal where made to unit 5 and all reads from the terminal were made from unit 6. This agrees with the convention of FORTRAN 77 as implemented on the VAX. The program runs like any other program on the VAX, first the program must be compiled using the fortran compiler, then linked and run. The program is still interactive on the VAX and about the only word of caution required is to remember to use CAPS ON or upper case input for logical replies. Using lower case leaves the user in a loop where the program keeps asking for for a correct reply. The duct geometry file information is on a file called duct.dat and the performance information is on a file called output.dat.

D. BUILDING A DUCT DATA FILE

The following pages are a recorded session at the terminal where the author entered a system in to the program. The system modeled is made up from drawings for the proposed Arleigh Burke class guided missile destroyer. The session has been annotated to point out features of the program.

```
GLOBAL TXTLIB CMSLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL
LOAD THESIS ( START
EXECUTION BEGINS...
 A ONE-DIMENSIONAL MODEL FOR THE SYSTEM PERFORMANCE
       OF A MARINE GAS TURBINE INSTALLATION

            BY LCDR. STEPHEN M. EZZELL

            VERSION 1.0   MARCH 30, 1984
  OPTIONS:  BUILD A DATA FILE REPRESENTING THE DUCT SYSTEM
            EDIT OR CHANGE THE DUCT DATA FILE
            COMPUTE SYSTEM PERFORMANCE
  METHOD:   INTERACTIVE INPUT OF DATA, BRANCHING TO DESIRED
            OPTION BY ANSWERING QUESTIONS

 *** WARNING, TWO NULL ENTRIES ON NUMERICAL INPUT WILL ***
                 *** KILL THE PROGRAM. ***


 FIRST QUESTION:
 DO YOU HAVE A DATA FILE OF DUCT FITTINGS (Y/N)?
n
 DO YOU WANT LONG OR SHORT INSTRUCTIONS (L/S)?
l
 YOU HAVE SELECTED THE LONG INSTRUCTIONS.
 ARE YOU WORKING ON A CRT OR TYPEWRITER TERMINAL (C/T)?
c
 YOU ARE WORKING ON A CRT TERMINAL.
 DOES THE MODULE COOLING AIR BRANCH OFF THE MAIN INLET?
 (Y,N)
y
 DOES THE MODULE COOLING AIR JOIN THE MAIN ENGINE EXHAUST?
 (Y,N)
y
 IS THERE A COOLING FAN INSTALLED?
t
 YOU MUST ENTER A LETTER IN THE BRACKETS.
 IS THERE A COOLING FAN INSTALLED?
y
SYSTEM IS CLASS THREE, COMBINED INLETS AND EXHAUST
FLOWS FOR THE ENGINE AND MODULE COOLING.  A COOLING FAN IS
INSTALLED.  YOU WILL BE ENTERING FITTINGS FOR SIX BRANCHES.
 1.   COMBINED INLET TO THE COMBINED SECTION
      OF A DIVERGENT WYE.
 2.   MAIN SECTION OF THE DIVERGENT WYE TO THE ENGINE.
 3.   BRANCH SECTION OF THE DIVERGENT WYE TO THE COOLING FAN.
 4.   ENGINE EXHAUST TO MAIN SECTION OF A CONVERGENT WYE.
      AN EDUCTOR INSTALLED AT THE EXHAUST PLANE OF THE ENGINE
      IS CONSIDERED TO BE A CONTRACTION FOLLOWED BY THE MAIN
      SECTION OF A CONVERGING WYE FOR THE PURPOSES OF THIS
      PROGRAM.
 5.   COOLING FAN EXHAUST TO THE BRANCH SECTION
      OF A CONVERGENT WYE.
 6.   COMBINED SECTION OF A CONVERGENT WYE TO THE ATMOSPHERE.


 ENTER ZERO TO CONTINUE
?
0
```

NOTE INCORRECT RESPONSE,
ANSWER SHOULD HAVE BEEN
Y OR N

MENU LOOKS LIKE THIS
IT APPEARS WITH EACH FITTING
BUT IS OMITTED IN THIS LISTING TO
CONSERVE SPACE

```
00 NO MORE FITTINGS THIS BRANCH          * 14 DIVERGING WYE, MAIN SECTION
01 INTAKE SHAFT, RECT SECTION, SIDE      * 15 CONVERGENT WYE, BRANCH SECTION
     ORIFACES, WITH(OUT) LOUVERS         * 16 CONVERGENT WYE, MAIN SECTION
02 STRAIGHT DUCT                         * 17 DIFFUSER, CONICAL
                                                ROUND SECTION
03 ELBOW, SMOOTH RADIUS ROUND            * 18 DIFFUSER, PLANE, IN-LINE
04 ELBOW; 90 DEG; 3,4,5 PCS; ROUND       * 19 DIFFUSER PYRAMIDAL, IN-LINE
05 ELBOW, MITERED, ROUND, W&W/O VANES    * 20 DIFFUSER, TRANSITIONAL (ROUND
06 ELBOW, MITERED, RECTANGULAR           *    TO RECT OR RECT TO ROUND)
07 ELBOW, SMOOTH RADIUS, RECTANGULAR     * 21 CONTRACTION ROUND
08 ELBOW, SMOOTH RADIUS, WITH            * 22 CONTRACTION RECTANGULAR
     SPLITTERS, RECTANGULAR              * 23 OBSTRUCTION,SCREEN IN DUCT
09 ELBOW, MITERED WITH VANES, RECT       * 24 LOUVER ENTRANCE
10 ELBOW, CONVERGING OR DIVERGING        * 25 FILTER
      FLOW, RECTANGULAR                  * 26 MULTI-BAFFLE SILENCER
11 ELBOWS, 90 DEG, Z-SHAPED, RECT        * 27 GT MODULE
12 ELBOWS, 90 DEG, IN DIFFERENT          * 28 WASTE HEAT BOILER
      PLANES, RECTANGULAR                * 29 EXIT ABRUPT
13 DIVERGING WYE, BRANCH SECTION         * 30 FITTING NOT LISTED
  ************USE TWO DIGIT NUMBER, PRESS ENTER***********
>> YOU ARE WORKING ON FITTING NUMBER >> 312201
?
25
YOU HAVE SELECTED THE INLET FILTER .
**FIRST QUESTION, WHAT IS THE TOTAL FACE AREA OF THE FILTER?
?
3
DO YOU WANT TO USE THE DD963 TYPE FILTER
IN THE DRY CONDITION (Y/N) ?
Y
NO MORE QUESTIONS.
DO YOU WANT TO ENTER THIS FITTING (Y/N)?
n
```

MENU OMITTED

```
>> YOU ARE WORKING ON FITTING NUMBER >> 312201
?
24
```

FITTING SELECTED

```
YOU HAVE SELECTED A LOUVERED ENTRANCE.
**FIRST QUESTION, WHAT IS THE DISTANCE ACROSS THE
LOUVER OPENINGS?
?
25.5
WHAT IS THE DISTANCE BETWEEN THE LOUVERS, USE THE
CLOSEST DISTANCE.
?
0.4021
HOW MANY OPENINGS ARE THERE BETWEEN THE LOUVERS?
?
17
LAST QUESTION, WHAT IS THE AREA OF THE DUCT
JUST INSIDE THE LOUVER ENTRANCE?
?
197.75
DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
>> YOU ARE WORKING ON FITTING NUMBER >> 312202
?
25
YOU HAVE SELECTED THE INLET FILTER .
**FIRST QUESTION, WHAT IS THE TOTAL FACE AREA OF THE FILTER?
?
197.75
DO YOU WANT TO USE THE DD963 TYPE FILTER IN
THE DRY CONDITION (Y/N)?
Y
NO MORE QUESTIONS.
DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
>> YOU ARE WORKING ON FITTING NUMBER >> 312203
```

```
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND
 OR RECTANGULAR.

***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR
 (C/R) ?
r
 THE DUCT IS RECTANGULAR, ENTER FIRST CROSS-SECTIONAL
 DIMENSICN.  (FEET)
?
18.83
 SECOND DIMENSION (FEET)
?
10.5
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
17.75
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YCU ARE WORKING CN FITTING NUMBER >> 312204
?

00
 >> YOU ARE WORKING CN FITTING NUMBER >> 323101
?
14
 YOU HAVE SELECTED THE MAIN SECTION OF A DIVERGING WYE.
 THE AIR TO THE ENGINE SHOULD BE FLOWING THROUGH THIS SECTION.
 JUST ONE QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE
 MAIN SECTION?  THIS SHOULD BE THE AREA JUST DOWNSTREAM OF THE
 JUNCTICN AND DIRECTS FLOW TO THE ENGINE.  IT ALSO SHOULD BE
 THE FIRST FITTING OF THE BRANCH.
?
81.375
 >> YCU ARE WORKING CN FITTING NUMBER >> 323102
?
26
 YOU HAVE SELECTED A MULTI-BAFFLE TYPE SILENCER.
 EACH BAFFLE HAS A STREAMLINED SHAPE.  IT IS THE TYPE
 USED IN THE INLETS OF THE DD963.
 **FIRST QUESTION, WHAT IS THE GAP BETWEEN THE BAFFLES?
?
0.333
 WHAT IS THE THICKNESS OF THE BAFFLES?
?
0.666
 WHAT IS THE LENGTH CF THE BAFFLES?
?
9.33
 WHAT IS THE DIMENSICN OF THE BAFFLES PARALLEL TO THE GAP?
?
7.75
 WHAT IS THE DIMENSION OF THE MAIN DUCT ACROSS THE GAPS?
?
10.5
 LAST QUESTION, HOW MANY GAPS ARE THERE?
?
11
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YCU ARE WORKING CN FITTING NUMBER >> 323103
?
22
 YOU HAVE SELECTED A RECTANGULAR CONTRACTION.
 **FIRST QUESTION, WHAT IS THE LENGTH OF THE CONTRACTION?
?
8.5
 WHAT IS THE LEAST UPSTREAM CROSS-SECTION DIMENSION?
```

```
?
7.75
 WHAT IS THE GREATER UPSTREAM CROSS-SECTION DIMENSION?
?
10.5
 WHAT IS THE LEAST DOWNSTREAM CROSS-SECTION DIMENSION?
?
6.667
 LAST QUESTION, WHAT IS THE GREATER DOWNSTREAM
 CROSS-SECTION DIMENSION?
?
7.75

 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 323104
?
06
 YOU HAVE SELECTED A MITERED, RECTANGULAR CROSS-SECTION, ELBOW.
 **FIRST QUESTION, WHAT IS THE HEIGHT OF THE ELBOW?
      (THE DIMENSION PARALLEL TO THE TURN AXIS)
?
6.67
 WHAT IS THE WIDTH OF THE ELBOW CROSS-SECTION?
    (THE DIMENSION IN THE PLANE OF THE TURN)
?
7.75
 LAST QUESTION, WHAT IS THE ANGLE OF THE ELBOW TURN
 (0 - 90 DEGREES)?
?
90
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 323105
?
23
 YOU HAVE SELECTED A SCREEN OBSTRUCTION IN THE DUCT.
 **FIRST QUESTION, WHAT IS THE DUCT CROSS-SECTIONAL AREA?
?
50
 LAST QUESTION, WHAT IS THE FREE FLOW AREA OF THE SCREEN?
?
27.15
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 323106
?
00
 >> YOU ARE WORKING ON FITTING NUMBER >> 324001
?
13
 YOU HAVE SELECTED THE BRANCH SECTION OF A DIVERGENT WYE.
 THE MODULE COOLING AIR SHOULD BE BRANCHING OFF THE MAIN
 INLET AND FLOWING THROUGH THIS SECTION.  THIS SHOULD BE THE
 FIRST FITTING OF THIS BRANCH.
 **FIRST QUESTION, WHAT IS THE ANGLE BETWEEN THE MAIN FLOW
 AXIS AND THE BRANCH FLOW AXIS (DEGREES) ?
?
90
 WHAT IS THE CROSS-SECTIONAL AREA OF THE COMBINED FLOW
 SECTION?  THIS IS WHERE BOTH ENGINE AIR AND COOLING AIR FLOW
 JUST UPSTREAM OF THE BRANCH.
?
197.75
 LAST QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE BRANCH?
?
5.761
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
```

```
 >> YOU ARE WORKING ON FITTING NUMBER >> 324002
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND
 OR RECTANGULAR.
***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR  (C/R) ?
c
 THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)
?
2.708
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
7.5
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 324003
?
00
 >> YOU ARE WORKING ON FITTING NUMBER >> 335101
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND OR RECTANGULAR.

***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR  (C/R) ?
r
 THE DUCT IS RECTANGULAR, ENTER FIRST CROSS-SECTIONAL DIMENSION.  (FEET)
?
6.64
 SECOND DIMENSION (FEET)
?
4.58
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
1
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 335102
?
16
 YOU HAVE SELECTED THE MAIN SECTION OF A CONVERGING
 WYE.  THE ENGINE EXHAUST ALONE SHOULD BE FLOWING THROUGH
 THIS SECTION.  IT SHOULD BE THE LAST FITTING OF THE BRANCH.
 **JUST ONE QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE
   MAIN BRANCH?
?
20.19
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 335103
?
00
 >> YOU ARE WORKING ON FITTING NUMBER >> 345001
?
27
 YOU HAVE SELECTED THE GAS TURBINE MODULE AS A PART OF
 THE COOLING FLOW PASSAGE.  NO QUESTIONS, JUST NEEDED
 TO KNOW WHERE YOU WANTED THE MODULE.
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 345002
?
15
 YOU HAVE SELECTED THE BRANCH SECTION OF A CONVERGENT
 WYE.  THE HOT MODULE COOLING AIR SHOULD BE JOINING THE MAIN
 ENGINE EXHAUST IN THIS WYE.  THIS FITTING SHOULD BE THE LAST
 FITTING IN THE BRANCH.
 **FIRST QUESTION, WHAT IS THE ANGLE BETWEEN THE MAIN FLOW
   AXIS AND THE BRANCH AXIS (DEGREES)?
?
```

```
0
 WHAT IS THE CROSS-SECTIONAL AREA OF THE COMBINED FLOW
 SECTION?  THIS IS WHERE ENGINE EXHAUST AND MODULE COOLING AIR
 FLOW JUST DOWNSTREAM OF THEBRANCH.
?
30.46
 LAST QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE
 BRANCH?
?
10.27
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 345003
?
00
 >> YOU ARE WORKING ON FITTING NUMBER >> 356201
?
21
 YOU HAVE SELECTED A CIRCULAR CONTRACTION.
 **FIRST QUESTION, WHAT IS THE LENGTH OF THE CONTRACTION?
?
9
 WHAT IS THE UPSTREAM DIAMETER?
?
6.2374
 WHAT IS THE DOWNSTREAM DIAMETER?
?
5.4667
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356202
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND OR RECTANGULAR.
***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR  (C/R) ?
C
 THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)
?
5.4667
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
7.11
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356203
?
05
 YOU HAVE SELECTED A MITERED ROUND ELBOW.
 **FIRST QUESTION, WHAT IS THE CROSS-SECTIONAL DIAMETER?
?
5.4667
 WHAT IS THE ANGLE OF THE ELBOW TURN?
?
90
 LAST QUESTION, ARE OPTIMUM NUMBER OF CONCENTRIC VANES
 INSTALLED TO REDUCE RESISTANCE AND TURBULANCE (Y/N)?
Y
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356204
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND OR RECTANGULAR.
***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR  (C/R) ?
C
 THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)
?
```

```
5.5667
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
6.23
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356205
?
05
 YOU HAVE SELECTED A MITERED ROUND ELBOW.
 **FIRST QUESTION, WHAT IS THE CROSS-SECTIONAL DIAMETER?
?
5.4667
 WHAT IS THE ANGLE OF THE ELBOW TURN?
?
90
 LAST QUESTION, ARE OPTIMUM NUMBER OF CONCENTRIC VANES
 INSTALLED TO REDUCE RESISTANCE AND TURBULANCE (Y/N)?
y
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356206
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND OR RECTANGULAR.
***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR  (C/R) ?
c
 THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)
?
5.4667
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
3.033
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356207
?
17
 YOU HAVE SELECTED A CONICAL DIFFUSER WITH CIRCULAR
 INLET AND OUTLET SECTIONS.
 **FIRST QUESTION, WHAT IS THE LENGTH OF THE DIFUSER?
?
2.967
 WHAT IS THE INLET DIAMETER?
?
5.4667
 WHAT IS THE OUTLET DIAMETER?
?
7.1667
 IS THERE A NON-UNIFORM VELOCITY DISTRIBUTION AT THE INLET (Y/N)?
n
 SINCE THERE IS A WIDE DIVERGING ANGLE, THE PROPER
 INSTALLATION OF DIVIDING WALLS OR BAFFLES CAN REDUCE
 THE RESISTANCE OF THIS FITTING.  DO YOU WANT TO INSTALL
 DIVIDING WALLS OR BAFFLES  (Y/N)?
n
 NO MORE QUESTIONS THIS FITTING.
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356208
?
02
 YOU HAVE SELECTED STRAIGHT DUCT.  IT MAY BE ROUND OR RECTANGULAR.
***FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULAR  (C/R) ?
c
 THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)
?
```

```
7.1667
 ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)
?
1.7
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356209
?
21
 YOU HAVE SELECTED A CIRCULAR CONTRACTION.
 **FIRST QUESTION, WHAT IS THE LENGTH OF THE CONTRACTION?
?
0.1
 WHAT IS THE UPSTREAM DIAMETER?
?
7.1667
 WHAT IS THE DOWNSTREAM DIAMETER?
?
4.533
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356210
?
29
 YOU HAVE SELECTED AN ABRUPT EXIT TO THE ATMOSPHERE.
 **JUST ONE QUESTION, WHAT IS THE AREA OF THE EXIT PLANE?
?
16.1384
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
Y
 >> YOU ARE WORKING ON FITTING NUMBER >> 356211
?
00
 WHAT SERIAL NUMBER WOULD YOU LIKE TO GIVE THIS DUCT DATA FILE?
 YOU MAY USE UP TO A SIX DIGIT INTEGER NUMBER.
?
510001
 DO YOU WANT TO COMPUTE WITH THE FILE OR QUIT (C/Q)?
q
```

E. EDITING THE DUCT DATA FILE

This section demonstrates the editing capability of the program. The editor will be demonstrated by changing a fitting. The fitting chosen is an elbow in the exhaust duct. It has cascaded turning vanes installed. By using the editor the turning vanes will be removed and an ordinary mitered round elbow will be substituted. Any fitting that also serves the purpose could be substituted as well.

The program can also add or delete a fitting. It is somewhat limited in the addition ability. The program can not add a fitting to the first of a branch in one step. To add a fitting to the duct data file select the index of the fitting in the file that the fitting is to be placed <u>after</u>. The program will ask what fitting is to be added and then the user can enter the fitting directly or from the menu. To add a fitting at the first of a branch, first add the same first fitting presently in the branch after itself, then change the same index fitting as the first step to the desired new first fitting.

It should be emphasized that the editor does not change a system class. If the user wants a different duct arrangement a new file will have to be entered.

```
GLOBAL TXTLIB CMSLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL
LOAD THESIS ( START
EXECUTION BEGINS...
 A ONE-DIMENSIONAL MODEL FOR THE SYSTEM PERFORMANCE
       OF A MARINE GAS TURBINE INSTALLATION

            BY LCDR. STEPHEN M. EZZELL

           VERSION 1.0   MARCH 30, 1984
  OPTIONS: BUILD A DATA FILE REPRESENTING THE DUCT SYSTEM
           EDIT OR CHANGE THE DUCT DATA FILE
           COMPUTE SYSTEM PERFORMANCE
  METHOD:  INTERACTIVE INPUT OF DATA, BRANCHING TO DESIRED
           OPTION BY ANSWERING QUESTIONS

 *** WARNING, TWO NULL ENTRIES ON NUMERICAL INPUT WILL ***
              *** KILL THE PROGRAM. ***


 FIRST QUESTION:
 DO YOU HAVE A DATA FILE OF DUCT FITTINGS (Y/N)?
y
 DO YOU WANT TO EDIT THE FILE OR USE IT FOR COMPUTATION(E/C)?
e
 DO YOU WANT TO CHANGE, DELETE, OR ADD (C/D/A)?
 YOUR OLD FILE WILL BE PERMANENTLY CHANGED, DID YOU
 COPY THE OLD FILE UNDER A NEW NAME IF YOU WANTED TO
 SAVE IT?  IF NOT, ENTER TWO NULL STRINGS TO KILL THE
 PROGRAM.
c
 WHAT LINE DO YOU WANT TO EDIT?
?
19
 DO YOU NEED A MENU (Y/N)?
y
 00 NO MORE FITTINGS THIS BRANCH        * 14 DIVERGING WYE, MAIN SECTION
 01 INTAKE SHAFT, RECT SECTION, SIDE    * 15 CONVERGENT WYE, BRANCH SECTION
      ORIFACES, WITH(OUT) LOUVERS       * 16 CONVERGENT WYE, MAIN SECTION
 02 STRAIGHT DUCT                       * 17 DIFFUSER, CONICAL ROUND SECTION
 03 ELBOW, SMOOTH RADIUS ROUND          * 18 DIFFUSER, PLANE, IN-LINE
 04 ELBOW: 90 DEG; 3,4,5 PCS; ROUND     * 19 DIFFUSER PYRAMIDAL, IN-LINE
 05 ELBOW, MITERED, ROUND, W&W/O VANES* 20 DIFFUSER, TRANSITIONAL (ROUND TO
 06 ELBOW, MITERED, RECTANGULAR         *        RECT OR RECT TO ROUND)
 07 ELBOW, SMOOTH RADIUS, RECTANGULAR * 21 CONTRACTION ROUND
 08 ELBOW, SMOOTH RADIUS, WITH          * 22 CONTRACTION RECTANGULAR
      SPLITTERS, RECTANGULAR            * 23 OBSTRUCTION,SCREEN IN DUCT
 09 ELBOW, MITERED WITH VANES, RECT     * 24 LOUVER ENTRANCE
 10 ELBOW, CONVERGING OR DIVERGING      * 25 FILTER
       FLOW, RECTANGULAR                * 26 MULTI-BAFFLE SILENCER
 11 ELBOWS, 90 DEG, Z-SHAPED, RECT      * 27 GT MODULE
 12 ELBOWS, 90 DEG, IN DIFFERENT        * 28 WASTE HEAT BOILER
       PLANES, RECTANGULAR              * 29 EXIT ABRUPT
 13 DIVERGING WYE, BRANCH SECTION       * 30 FITTING NOT LISTED
/    ************USE TWO DIGIT NUMBER, PRESS ENTER***********
>> YOU ARE WORKING ON FITTING NUMBER >> 356205
?
05
 YOU HAVE SELECTED A MITERED ROUND ELBOW.
 **FIRST QUESTION, WHAT IS THE CROSS-SECTIONAL DIAMETER?
?
5.4667
 WHAT IS THE ANGLE OF THE ELBOW TURN?
?
90
 LAST QUESTION, ARE OPTIMUM NUMBER OF CONCENTRIC VANES
 INSTALLED TO REDUCE RESISTANCE AND TURBULANCE (Y/N)?
n
 DO YOU WANT TO ENTER THIS FITTING (Y/N)?
```

```
y
 WANT TO CHANGE ANOTHER FITTING (Y/N)?
n
 WANT TO MAKE ANY OTHER CHANGES (Y/N)?
n
 WHAT SERIAL NUMBER WOULD YOU LIKE TO GIVE THIS DUCT DATA FILE?
 YOU MAY USE UP TO A SIX DIGIT INTEGER NUMBER.
?
510002
 DO YOU WANT TO COMPUTE WITH THE FILE OR QUIT (C/Q)?
q
```

F. COMPUTING SYSTEM PERFORMANCE

This section also contains a recorded terminal session. The computing section of the program was exercised here. The session has been annotated to point out program features.

```
GLOBAL TXTLIB CMSLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL
LOAD THESIS ( START
EXECUTION BEGINS...
 A ONE-DIMENSIONAL MODEL FOR THE SYSTEM PERFORMANCE
        OF A MARINE GAS TURBINE INSTALLATION

              BY LCDR. STEPHEN M. EZZELL

             VERSION 1.0   MARCH 30, 1984
  OPTIONS:   BUILD A DATA FILE REPRESENTING THE DUCT SYSTEM
             EDIT OR CHANGE THE DUCT DATA FILE
             COMPUTE SYSTEM PERFORMANCE
  METHOD:    INTERACTIVE INPUT OF DATA, BRANCHING TO DESIRED
             OPTION BY ANSWERING QUESTIONS

 *** WARNING, TWO NULL ENTRIES ON NUMERICAL INPUT WILL ***
                  *** KILL THE PROGRAM. ***


 FIRST QUESTION:
 DO YOU HAVE A DATA FILE OF DUCT FITTINGS (Y/N)?
y

 DO YOU WANT TO EDIT THE FILE OR USE IT FOR COMPUTATION(E/C)?
c
 THIS PORTION OF THE PROGRAM INPUTS THE ENVIROMENTAL CONDITIONS.
 WHAT IS THE AMBIENT TEMPERATURE (DEGREES F)?
?
75
 WHAT IS THE AMBIENT PRESSURE (PSIA)?
?
14.6
 WHAT IS THE RELATIVE HUMIDITY (GRAINS PER POUND AIR)?
?
70
 YOU HAVE SELECTED A SYSTEM WITH A COOLING FAN.  THE
 DEFAULT SPECIFICATIONS ARE FOR THE FAN INSTALLED ON
 THE DD963 CLASS SHIP.

 DO YOU WANT TO USE THE DEFAULT SPECFICATIONS (Y/N)?
y
 INPUT THE POWER SETTING YOU DESIRE.
 **WHAT IS THE HORSEPOWER?
?
20000
 **WHAT IS THE POWER TURBINE SPEED (RPM)?
?
3600
 THE RESULTS OF THIS RUN HAVE BEEN ENTERED
 INTO A FILE CALLED "OUTPUT DATA".
 DO YOU WANT TO COMPUTE WITH DIFFERENT OPERATING CONDITIONS (Y/N)?
y
 INPUT THE POWER SETTING YOU DESIRE.
 **WHAT IS THE HORSEPOWER?
?
10000
 **WHAT IS THE POWER TURBINE SPEED (RPM)?
?
2200
 THE RESULTS OF THIS RUN HAVE BEEN ENTERED
 INTO A FILE CALLED "OUTPUT DATA".
 DO YOU WANT TO COMPUTE WITH DIFFERENT OPERATING CONDITIONS (Y/N)?
n
 DO YOU WANT TO EDIT THE DUCT DATA FILE OR QUIT (E/Q)?
q
```

G. EXAMINING THE OUTPUT

Included in this section are copies of two files. The first is a copy of the file the author built using the Arleigh Burke class example. The other one is a copy of the results from the runs made in the compute section using the sample file at two operating points.

FILE ID NUMBER

NUMBER OF FITTINGS

```
510001
24
  1   312201  24   197.7500      0.0       18.7228    197.7500
  2   312202  25   197.7500      0.0167     1.6287    197.7500
  3   312203   2   197.7150     15.2104    17.7500    197.7150
  4   323101  14    81.3750      0.0        0.0        81.3750
  5   323102  26    81.3750      0.0        0.9499     81.3750
  6   323103  22    81.3750      0.0        0.0325     51.6692
  7   323104   6    51.6925      7.1696     1.2095     51.6925
  8   323105  23    50.0000      0.0        2.1282     50.0000
  9   324001  13   197.7500      5.7610    90.0000      5.7610
 10   324002   2     5.7566      2.7080     7.5000      5.7566
 11   335101   2    30.4112      6.0026     1.0000     30.4112
 12   335102  16    20.1900      0.0        0.0        20.1900
 13   345001  27     1.0000      1.0000     1.0000      1.0000
 14   345002  15    30.4600     10.2700     0.0        10.2700
 15   356201  21    30.5561      0.0        0.0107     23.4715
 16   356202   2    23.4596      5.4667     7.1100     23.4596
 17   356203   5    23.4715      5.4667     0.3111     23.4715
 18   356204   2    24.3257      5.5667     6.2300     24.3257
 19   356205   5    23.4715      5.4667     0.3111     23.4715
 20   356206   2    23.4596      5.4667     3.0330     23.4596
 21   356207  17    23.4715      0.3002     0.1168     40.3394
 22   356208   2    40.3188      7.1667     1.7000     40.3188
 23   356209  21    40.3394      0.0        0.3042     16.1385
 24   356210  29    16.1384      0.0        1.0000     16.1384
```

FITTING TYPE # ; LISTED ON MENU

FITTING ID #

FILE LINE NUMBER, USED IN EDIT

```
THIS PERFORMANCE RUN WAS DEVELOPED FROM DUCT DATA FILE, 510001

INLET CONDITIONS:   AMBIENT TEMP (DEG F)        75.00
                    AMBIENT PRESS (PSIA)        14.60
                    HUMIDITY (GRAINS)           70.00
HORSEPOWER:        20000.0
NPT  (RPM) :        3600.0

ENGINE DUCT LOSSES (IN.W.G.): INLET     1.98    EXHAUST   13.95

ENGINE PERFORMANCE PARAMETERS:
     WC=       24.32    LBM/SEC
     W2=      122.71    LBM/SEC
     W8=      123.78    LBM/SEC
     P8=       15.18    PSIA
     T8=     1405.49    DEG R
     SFC=      0.406    LBM(FUEL)/HP*HR
     T54=     1827.1     DEG R
     NG=      8827.0    RPM
     MODULE COOLING TEMP OUT=       250.3   DEG F


FITTING      FITTING       PRESSURE LOSS   VELOCITY PRESSURE
  ID          TYPE            INCH W.G.       INCH W.G.

312201         24               0.42                0.02    LOUVER ENTRANCE
312202         25               0.72                0.02    FILTER
312203          2               0.00                0.02    STRAIGHT DUCT
323101         14               0.04                0.09    MAIN SECT,DIV WYE
323102         26               0.09                0.09    SILENCER SECTION
323103         22               0.01                0.23    CONTRACTION,RECT
323104          6               0.18                0.23    ELBOW,MITERED,RECT
323105         23               0.52                0.25    SCREEN IN DUCT
324001         13               0.67                0.72    BRANCH,DIV WYE
324002          2               0.02                0.73    STRAIGHT DUCT
335101          2               0.00                1.71    STRAIGHT DUCT
335102         16               1.30                2.24    MAIN SECT,CONV WYE
345001         27               1.54                0.0     GAS TURBINE MODULE
345002         15              -3.24                2.24    BRANCH,CONV WYE
356201         21               0.04                3.81    CONTRACTION,ROUND
356202          2               0.05                3.79    STRAIGHT DUCT
356203          5               0.74                3.79    ELBOW,MITERED,ROUND
356204          2               0.04                3.54    STRAIGHT DUCT
356205          5               0.74                3.80    ELBOW,MITERED,ROUND
356206          2               0.02                3.31    STRAIGHT DUCT
356207         17               0.45                3.30    DIFF,CONICAL
356208          2               0.00                1.29    STRAIGHT DUCT
356209         21               2.46                9.08    CONTRACTION,ROUND
356210         29               8.10                8.10    EXIT,ABRUPT

        LOSS BRANCH 1-2:          1.14
        LOSS BRANCH 2-3:          0.83
        LOSS BRANCH 3-5:          1.31
        LOSS BRANCH 5-6:         12.65
        LOSS BRANCH 2-4:          0.69
        LOSS BRANCH 4-5:         -1.70
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THIS PERFORMANCE RUN WAS DEVELOPED FROM DUCT DATA FILE, 510001

INLET CONDITIONS:  AMBIENT TEMP (DEG F)       75.00
                   AMBIENT PRESS (PSIA)       14.60
                   HUMIDITY (GRAINS)          70.00
HORSEPOWER:       10000.0
NPT (RPM) :        2200.0

ENGINE DUCT LOSSES (IN.W.G.): INLET     1.40    EXHAUST     9.10

ENGINE PERFORMANCE PARAMETERS:
     WC=      25.42   LBM/SEC
     W2=      99.45   LBM/SEC
     W8=      99.88   LBM/SEC
     P8=      14.97   PSIA
     T8=    1281.00   DEG R
     SFC=     0.508   LBM(FUEL)/HP*HR
     T54=    1549.0    DEG R
     NG=     8332.3   RPM
     MODULE COOLING TEMP OUT=     250.3  DEG F


FITTING        FITTING       PRESSURE LOSS   VELOCITY PRESSURE
  ID            TYPE           INCH W.G.         INCH W.G.

312201           24              0.30             0.02     LOUVER ENTRANCE
312202           25              0.55             0.02     FILTER
312203            2              0.30             0.02     STRAIGHT DUCT
323101           14              0.02             0.06     MAIN SECT,DIV WYE
323102           26              0.06             0.06     SILENCER SECTION
323103           22              0.00             0.15     CONTRACTION,RECT
323104            6              0.12             0.15     ELBOW,MITERED,RECT
323105           23              0.34             0.16     SCREEN IN DUCT
324001           13              0.73             0.79     BRANCH,DIV WYE
324002            2              0.02             0.79     STRAIGHT DUCT
335101            2              0.00             1.03     STRAIGHT DUCT
335102           16              0.85             1.46     MAIN SECT,CONV WYE
345001           27              1.69             0.0      GAS TURBINE MODULE
345002           15             -1.84             1.46     BRANCH,CONV WYE
356201           21              0.03             2.48     CONTRACTION,ROUND
356202            2              0.03             2.47     STRAIGHT DUCT
356203            5              0.49             2.47     ELBOW,MITERED,ROUND
356204            2              0.02             2.30     STRAIGHT DUCT
356205            5              0.49             2.48     ELBOW,MITERED,ROUND
356206            2              0.01             2.48     STRAIGHT DUCT
356207           17              0.30             2.48     DIFF,CONICAL
356208            2              0.00             0.84     STRAIGHT DUCT
356209           21              1.60             5.26     CONTRACTION,ROUND
356210           29              5.27             5.27     EXIT,ABRUPT
        LOSS BRANCH 1-2:          0.86
        LOSS BRANCH 2-3:          0.55
        LOSS BRANCH 3-5:          0.85
        LOSS BRANCH 5-6:          8.25
        LOSS BRANCH 2-4:          0.75
        LOSS BRANCH 4-5:         -0.15
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