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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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T217400

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Analytic Model of Gas Turbine Engine Installations		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1984
7. AUTHOR(s) Stephen M. Ezzell		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE September 1984
		13. NUMBER OF PAGES 224
		15. SECURITY CLASS. (of this report) Unclassified
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Gas turbine, ducting		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) 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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An Analytic Model
of
Gas Turbine Engine Installations

by

Stephen M. Ezzell
Lieutenant Commander, United States Navy
E.S., North Carolina State University, 1971

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 1984

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E 992
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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
e	Absolute roughness factor, ft
f	Friction factor, dimensionless
g	Acceleration due to gravity, ft/sec ²
g _c	Gravitational constant, 32.174 ft-lbm/lbf-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
P _S	Static pressure, lbf/ft ²
P _T	Total pressure, lbf/ft ²
P _V	Velocity pressure, lbf/ft ²
P ₀	Ambient pressure, lbf/ft ² or PSIA
P _B	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
W ₈	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

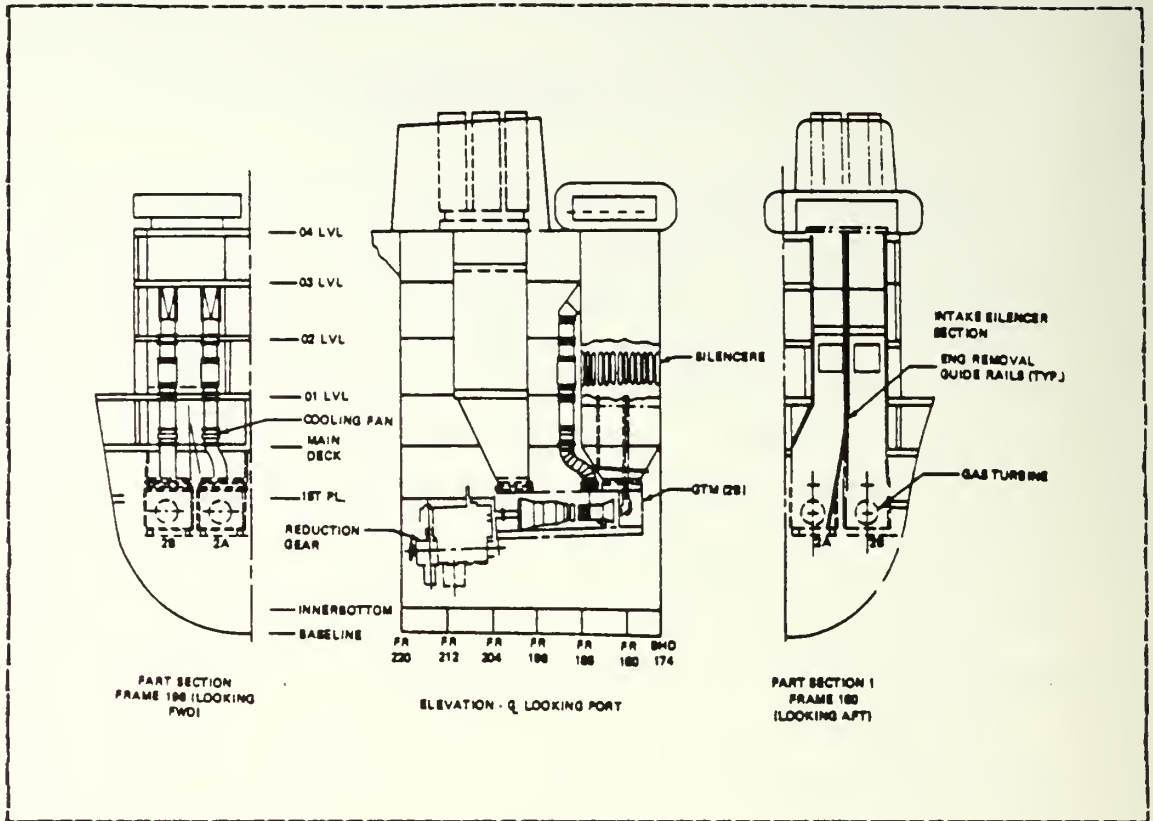


Figure 1.1 Typical Shipboard Inlet and Exhaust Ducting.

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 infrared 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 habitability. 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 creates 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:

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

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/feet³ and expresses the energy per unit volume flow rate. It reduces to pound force/feet² or pressure. Each term in the expression is given a name. The velocity term is the velocity pressure, 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 .

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

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.

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

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

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.

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

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].

$$f = \frac{0.25}{\left[\log \left(\frac{e}{3.7D} + \frac{5.74}{Re^{0.9}} \right) \right]^2} \quad 5000 \leq Re \leq 10^8 \quad (\text{eqn 2.7})$$

$10^{-6} \leq \frac{e}{D} \leq 10^{-2}$

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.

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

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.

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

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

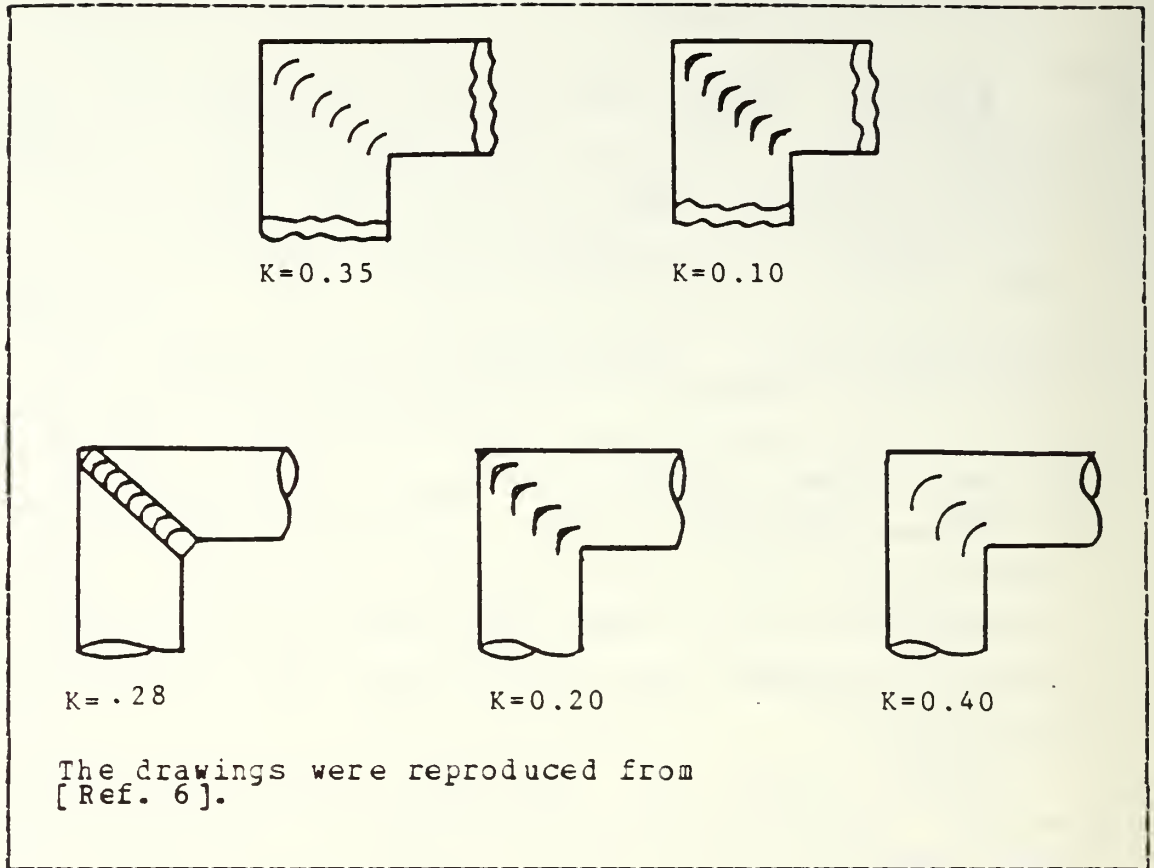


Figure 2.1 Typical K Values for Fittings.

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 inputting 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 summarizes 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

<u>Fitting Number</u>	<u>Description</u>
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	Pyramidal 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. Similarly 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

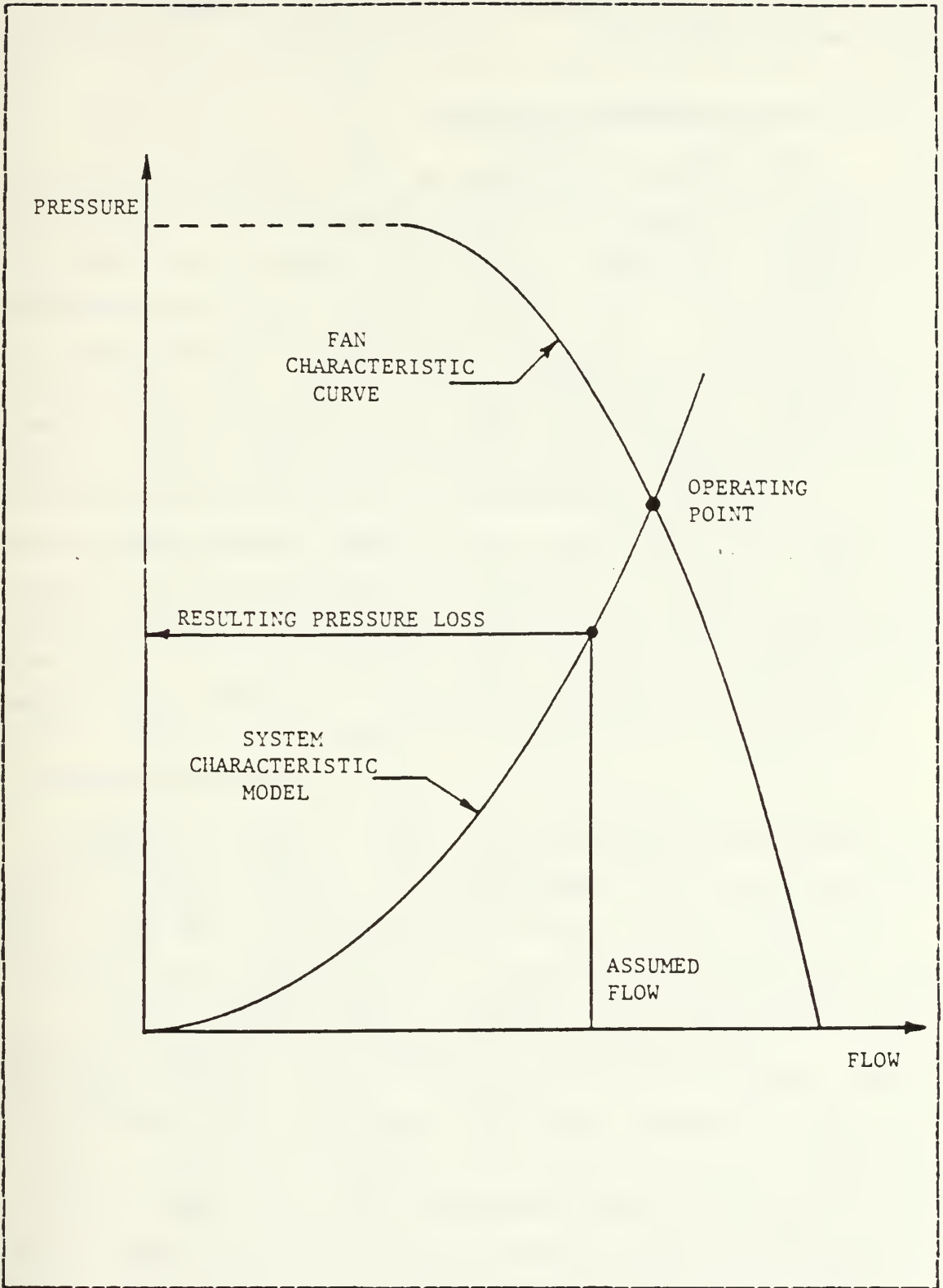


Figure 2.2 Fan/System Interface.

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

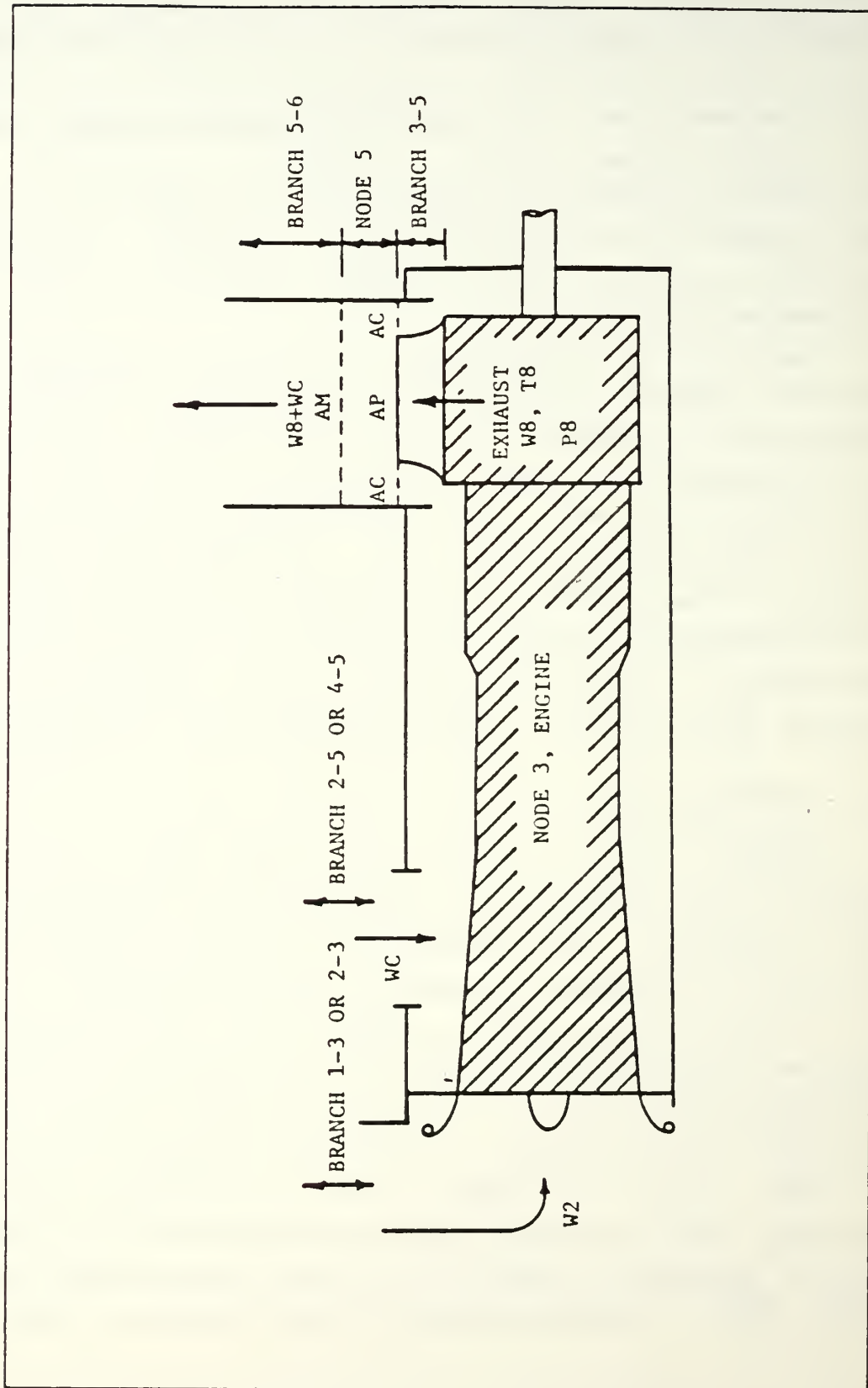


Figure 2.3 Module Cooling Eductor Schematic.

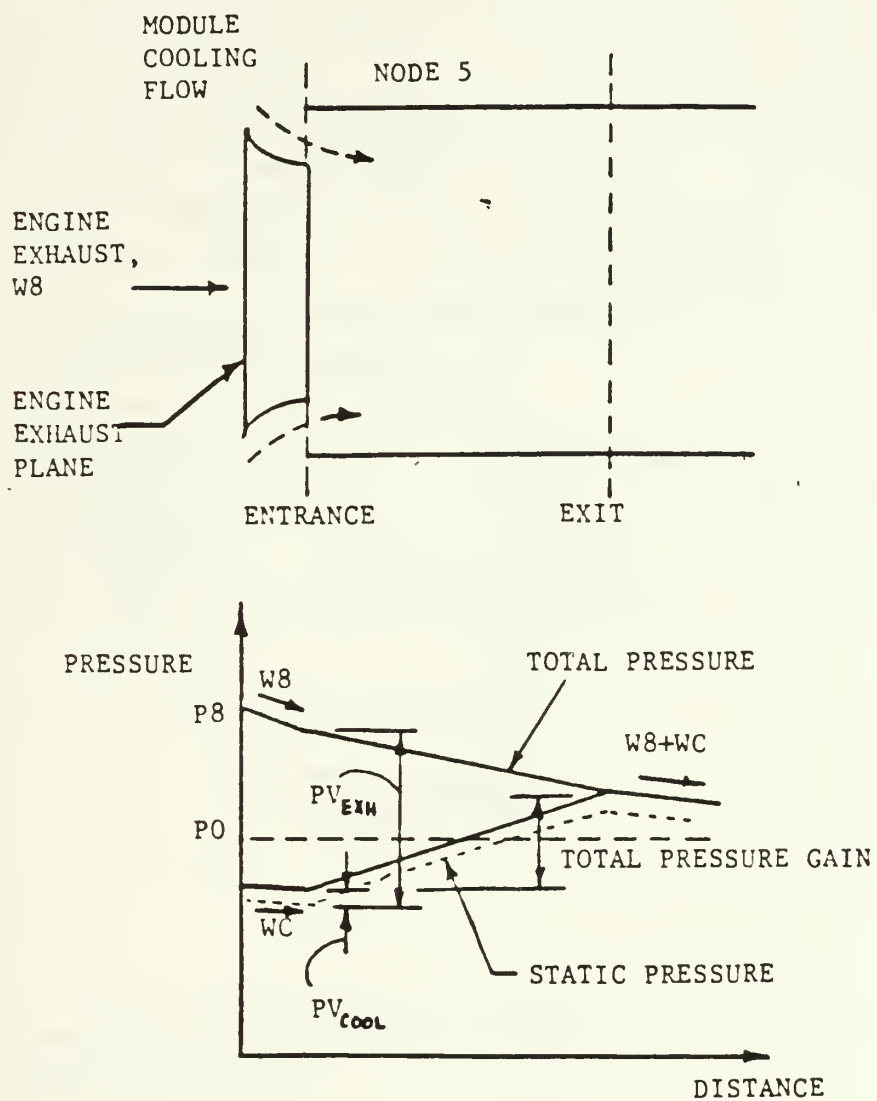


Figure 2.4 Module Eductor Performance.

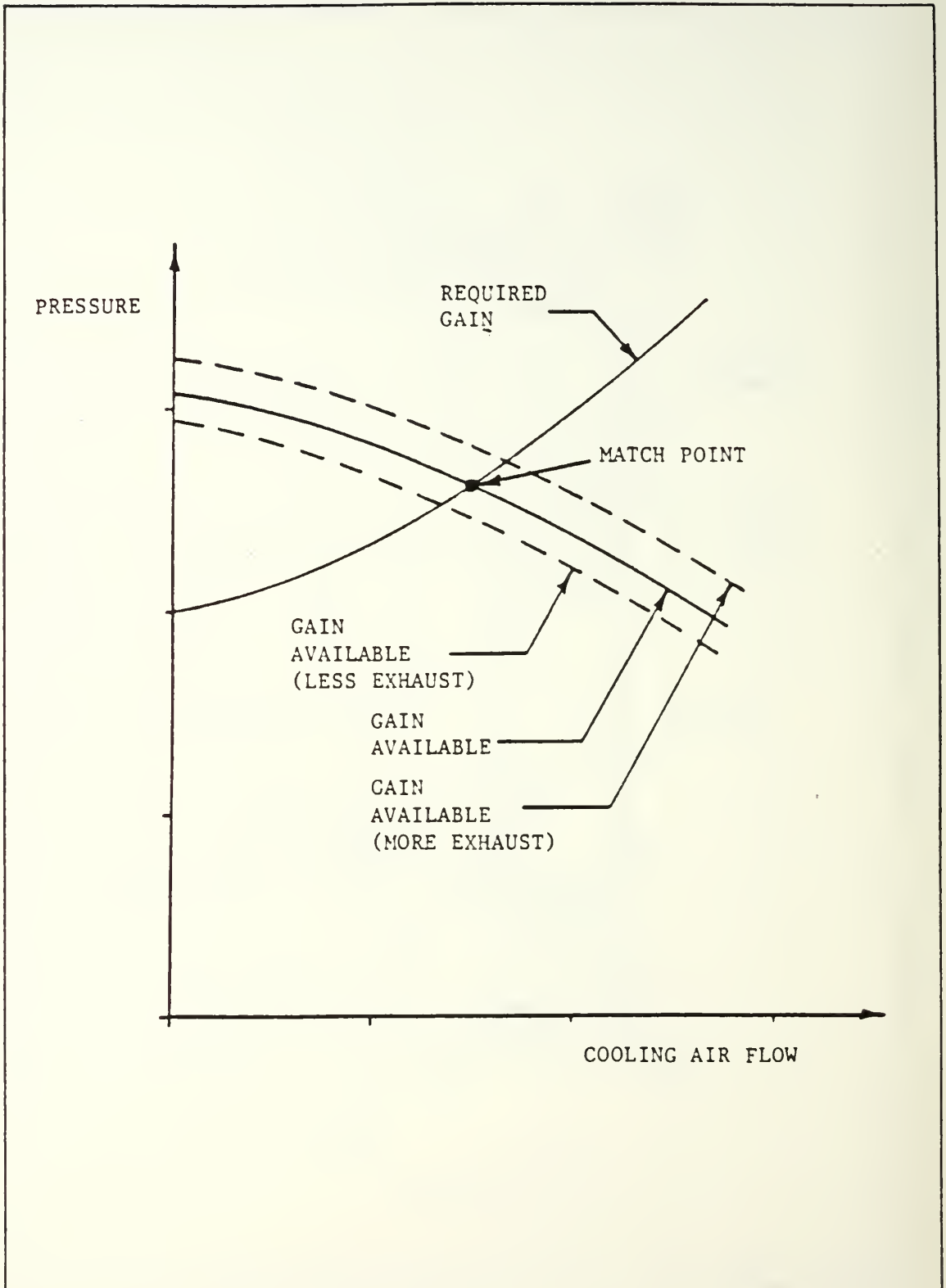


Figure 2.5 Eductor/System Interface.

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 beginning 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.

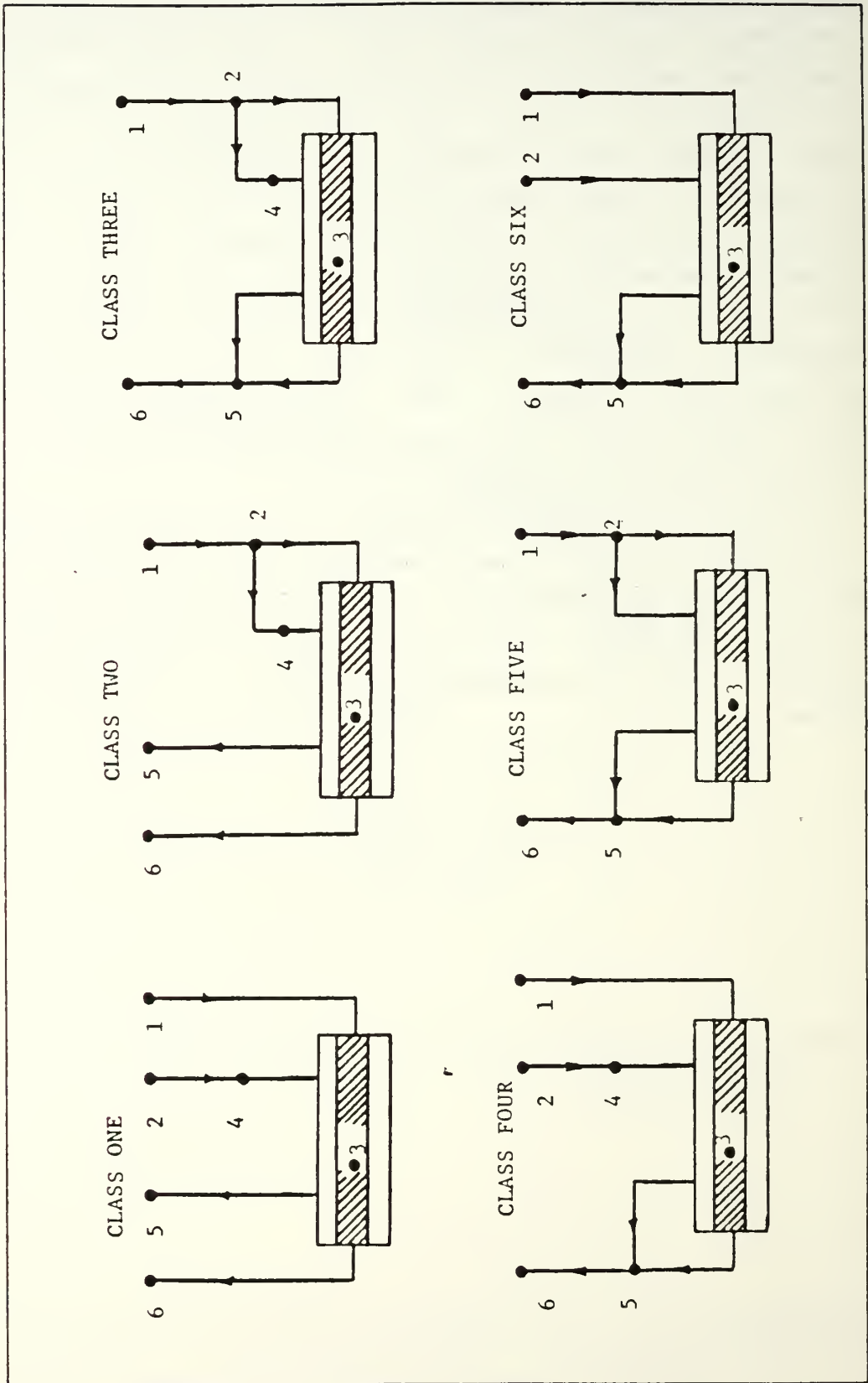


Figure 2.6 System Arrangements and Their Classification.

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.

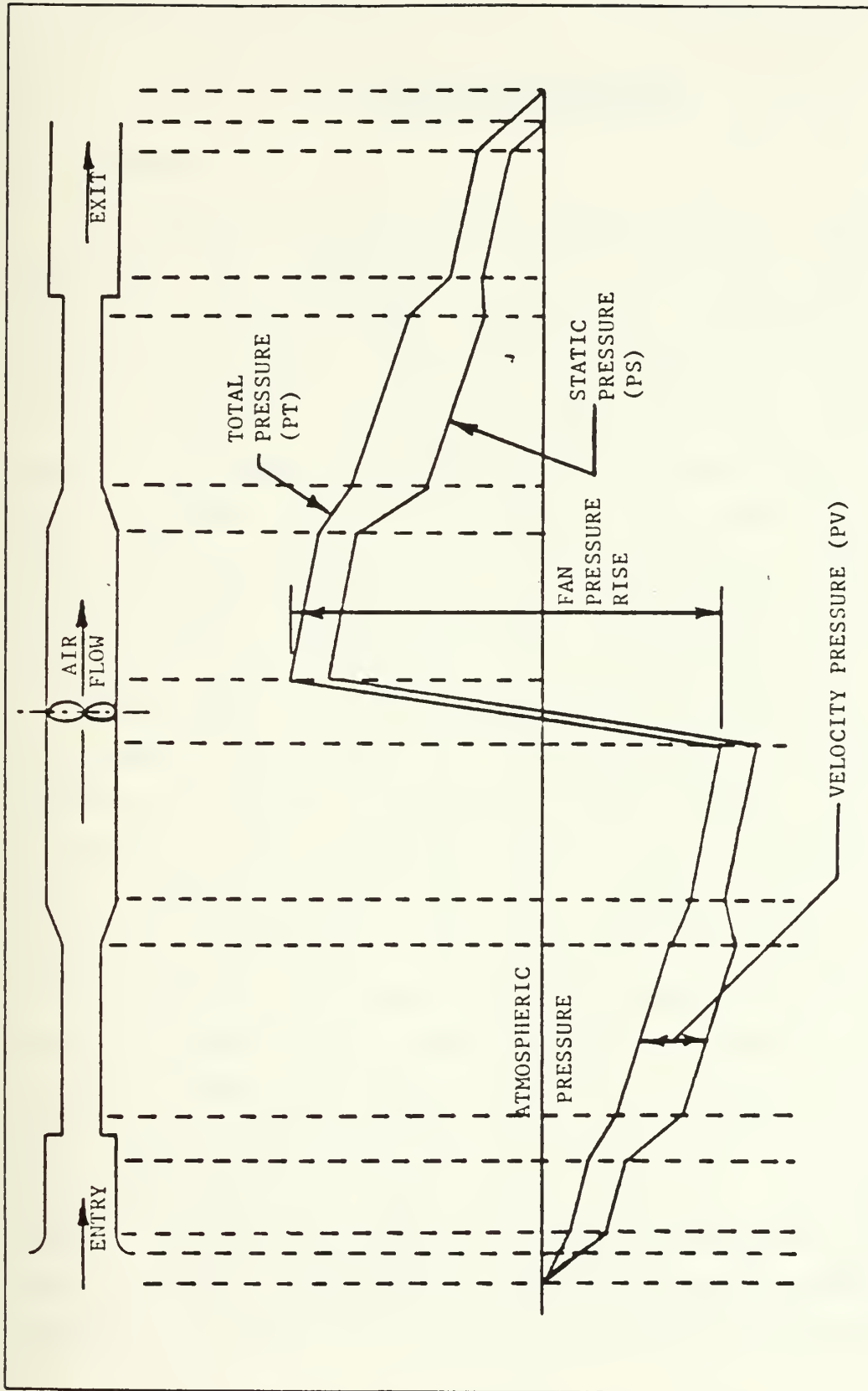


Figure 2.7 Typical Duct Pressure Changes.

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 particularly 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 it 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. In 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 further 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 similar 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 official. 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

```

*****
ANALYTIC MODEL OF A GAS TURBINE INSTALLATION ON BOARD A SHIP
PROGRAM WRITTEN BY STEPHEN M. EZZELL, LCDR, USN
VERSION 1.0 DATE MARCH 30, 1984
PURPOSE: TO ANALYZE THE DUCTING AND GAS TURBINE INSTALLATION
AS MIGHT BE INSTALLED ON A SHIP. INPUT DUCT GEOMETRY,
AMBIENT CONDITIONS, AND POWER SETTING TO GET PERFORMANCE
PARAMETERS.
*****
THIS IS THE MAIN CONTROL PROGRAM. ITS SOLE PURPOSE IS TO BRANCH
TO THE AREA OF THE PROGRAM YOU NEED. IF YOU ARE ANALYZING A NEW
SYSTEM YOU WILL NEED TO BUILD A DATA FILE FOR THE SYSTEM. YOU
WILL BE DIRECTED TO THE BUILD SUBROUTINE. IF YOU WANT TO MAKE
SOME CHANGES TO A SYSTEM YOU WILL GO TO THE EDIT SUBROUTINE.
WHEN YOU HAVE A DATA FILE YOU LIKE YOU WILL NEED TO GO TO
THE COMPUTE SUBROUTINE. IN THE COMPUTE SUBROUTINE YOUR DATA FILE
WILL BE READ AND THEN YOU WILL BE ASKED QUESTIONS TO ESTABLISH
THE OPERATING POINT. THEN THE PROGRAM WILL COMPUTE THE OPERATING
PARAMETERS YOU NEED AND OUTPUT THEM TO THE OUTPUT FILE.

NO COMPUTATIONS ARE DONE IN THE MAIN CONTROL PROGRAM.

SUBROUTINES CALLED: BUILD, EDIT, COMPUT, AND FRTCMS

A NOTE ABOUT FRTCMS, YOU WILL NOT FIND IT IN THE LISTING. IT IS
LIBRARY SUBROUTINE AVAILABLE AT NPS AND IS USED TO CALL THE
OPERATING SYSTEM FROM WITHIN THE FORTRAN PROGRAM. I USE IT FOR
TWO PURPOSES. FIRST TO DEFINE MY FILES. SECOND TO CLEAR THE
SCREEN AT YOUR TERMINAL SO THE WRITE FORMATS DON'T GET CHOPPED
UP. IF YOUR SYSTEM DOES NOT HAVE THIS CAPABILITY YOU WILL HAVE
TO SUBSTITUTE AN APPROPRIATE CODE TO ACCOMPLISH THE SAME THINGS.
THIS NOTE APPLIES TO THE IBM 3033 COMPUTER.
*****
INTEGER ANS, YES, NO, COMPUT, EDIT, QUIT
DATA YES/'Y'//, NO/'N'//, COMPUT/'C'//, EDIT/'E'//, QUIT/'Q'//

NPS IBM 3033 MAIN FRAME COMPUTER PROGRAM REQUIREMENTS

HERE IS WHERE I SET UP THE FILE DEFINITIONS USING THE LIBRARY
SUBROUTINE "FRTCMS". THERE ARE NO OTHER FILEDEF'S REQUIRED.

READING TERMINAL INPUT
CALL FRTCMS ('FILEDEF', '05', 'TERMINAL')
WRITING TO THE TERMINAL
CALL FRTCMS ('FILEDEF', '06', 'TERMINAL')
STORAGE FILE FOR THE DUCT GEOMETRY DEPENDENT VARIABLES
CALL FRTCMS ('FILEDEF', '08', 'DISK', 'DUCT',
+ 'DATA')
* STORAGE FILE FOR THE PERFORMANCE DATA OUTPUT
CALL FRTCMS ('FILEDEF', '04', 'DISK', 'OUTPUT',
+ 'DATA')

CALL FRTCMS ('CIRSCRN',
INTRODUCTION. IS THERE A DUCT DATA FILE ???
WRITE (6,600)

EVERY READ IS PROTECTED AGAINST A NULL ENTRY AND AN ERROR IN
INPUT. THIS IS ACCOMPLISHED WITH "END=XX,ERR=XX". YOUR SYSTEM
MAY NOT HAVE THIS CAPABILITY, IN WHICH CASE DELETE IT OR
SUBSTITUTE AND EQUIVALENT CODE.

READ (5,601,END=12,ERR=12) ANS
CALL FRTCMS ('CLRSCRN')

```

```

C
C
C
C
C
12  EVERY QUESTION REPLY IS CHECKED TO MAKE SURE ONE OF THE ALLOWED
    RESPONSES WAS USED, IF NOT THE USER IS WARNED AND ASKED TO
    ANSWER WITH ONE OF THE CORRECT RESPONSES.
C
C
12  IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 20
    REWIND 3
    WRITE (6,602)
    GO TO 10
C
18  CONTINUE
    IF (ANS.EQ.YES) GO TO 30
    IF (ANS.EQ.NO) GO TO 50
C
C
C
20  DO YOU WANT TO COMPUTE OR EDIT THE DATA FILE ?????
C
C
30  WRITE (6,603)
    READ (5,601,END=32,ERR=32) ANS
    IF ((ANS.EQ.COMPUT).OR.(ANS.EQ.EDIT)) GO TO 40
    REWIND 3
    WRITE (6,602)
    GO TO 10
C
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 PRICMS ('CIRSCRN ')
    IF ((ANS.EQ.COMPUT).OR.(ANS.EQ.QUIT)) GO TO 70
    REWIND 3
    WRITE (6,602)
    GO TO 60
C
70  CONTINUE
    IF (ANS.EQ.COMPUT) GO TO 30
    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
    REWIND 3
    WRITE (6,602)
    GO TO 60
C
100 CONTINUE
    IF (ANS.EQ.EDIT) GO TO 110
    IF (ANS.EQ.QUIT) GO TO 999
C
110 CALL ED
C
999 GO TO 60
600 CCNTINUE
    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'//

```

```
603 +   FORMAT (' FOR A PROPER ANSWER !!!!!!!')
      +   (E/C)?') (/ ' DO YOU WANT TO EDIT THE FILE OR USE IT FOR COMPUTATION
604 +   FORMAT (' DO YCU WANT TO CCMPUTE WITH THE FILE OR QUIT (C/Q)?')
605 +   FORMAT (' DO YCU 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 THIS 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  VARIABLES:  WKI AND WKR ARE TRANSPORT ARRAYS USED TO FILL THE
C              SYSTEM ARRAYS WORKI AND WORKR. WORKI(NNN,1) IS THE
C              ID NUMBER, AND WORKI(NNN,2) IS THE FITTING TYPE.
C              WORKR STORES FITTING DATA SUCH AS LENGTHS, AREAS, AND
C              RATIOS.
C*****C
C  SUBROUTINE BUILD
C  REAL WKR,WORKR
C  INTEGER SORL,WKI,WORKI,TERM,TYPE,BRANCH,FITID,GEOM,DUMMY,M,CLASS
C  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)
C  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
C 1
C  GEOM(1)=113101
C  GEOM(2)=124001
C  GEOM(3)=136101
C  GEOM(4)=145001
C  BRANCH=4
C  CALL FRTCMS ('CIRSCRN ')
C  WRITE(6,00)
C  GO TO 10
C
C 2
C  GEOM(1)=212201
C  GEOM(2)=223101
C  GEOM(3)=224001
C  GEOM(4)=236101
C  GEOM(5)=245001
C  BRANCH=5
C  CALL FRTCMS ('CIRSCRN ')
C  WRITE(6,001)
C  GO TO 10
C
C 3
C  GEOM(1)=312201
C  GEOM(2)=323101
C  GEOM(3)=324001
C  GEOM(4)=335101
C  GEOM(5)=345001
C  GEOM(6)=356201
C  BRANCH=6
C  CALL FRTCMS ('CIRSCRN ')
C  WRITE(6,002)
C  GO TO 10

```

```

4  GEOM(1) = 4 13101
   GEOM(2) = 4 24001
   GEOM(3) = 4 35101
   GEOM(4) = 4 45001
   GEOM(5) = 4 56201
   BRANCH=5
   CALL FRTCMS ('CLRSCRN ')
   WRITE (6, 603)
   GO TO 10
5  GEOM(1) = 5 12201
   GEOM(2) = 5 23101
   GEOM(3) = 5 35001
   GEOM(4) = 5 35101
   GEOM(5) = 5 56201
   BRANCH=5
   CALL FRTCMS ('CLRSCRN ')
   WRITE (6, 604)
   GO TO 10
6  GEOM(1) = 6 13101
   GEOM(2) = 6 25001
   GEOM(3) = 6 35101
   GEOM(4) = 6 56201
   BRANCH=4
   CALL FRTCMS ('CLRSCRN ')
   WRITE (6, 605)
10 CONTINUE
   M=0
   WRITE (6, 606)

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)
C CALL FRTCMS('CLRSCRN ')

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
C   CALL MENU (I, 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
C   IF ((TYPE.EQ.0).AND.(TYPE.LT.31)) GO TO 30
C     CALL FRTCMS('CLRSCRN ')
C     WRITE(6, 607)
C     GO TO 20
C   ZERO MEANS NO MORE FITTINGS THIS BRANCH
C   IF (TYPE.EQ.0) GO TO 40
C   M=M+1

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)
C   CALL FRTCMS ('CLRSCRN ')
C   GEOM(I) = GEOM(I) + 1
C   GO TO 20
40 CONTINUE

C ALL THE FITTINGS HAVE BEEN ENTERED AND THE DATA FILE IS ABOUT
C TO BE WRITTEN.
C 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 PAN. ' //
        ' 4. ENGINE EXHAUST TO THE 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 PAN. ' //
        ' 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. ' //
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. ' //
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 RECOMMENDED. ' //
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 ATMOSPHERE ' //
        ' E. ' //
606  FORMAT('///' ENTER ZERO TO CONTINUE.')
607  FORMAT(' YOU DID NOT ENTER A CORRECT FITTING ID NUMBER. ')
      RETURN
      END

```

```

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

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68 IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 70
    REWIND 5
    WRITE (6,604)
    GO TO 66
70 CCNTINUE
    IF (ANS.EQ.YES) GO TO 40
    GO TO 250
C
C A FITTING IS TO BE DELETED
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)
    WOPKR(I,1)=WCRKR(I+1,1)
    WORKR(I,2)=WORKR(I+1,2)
    WORKR(I,3)=WCRKR(I+1,3)
    WORKR(I,4)=WORKR(I+1,4)
110 CCNTINUE
120 CONTINUE
C WRITE (6,609)
    ANY MORE DELETICNS ???
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
150 WRITE (6,611)
    CALL READI(M,5)
    FITID=WORKI(M,1)+1
    S=N-M
    M=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 ???

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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 CCNTINUE
    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 CCNTINUE
    IF (ANS.EQ.YES) GO TO 20
    CALL SUMOUT (WORKI,WORKR,N)
    REWIND 8
600 FORMAT (16,/,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

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C*****
C COMPUTE SUBROUTINE: PRODUCES PERFORMANCE DATA OF SYSTEM
C*****
C THE DUCT DATA FILE IS READ AND THEN THE USER MUST INPUT THE
C DESIRED OPERATING POINT. INPUT THE AMBIENT TEMPERATURE
C (DEGREES F), THE AMBIENT PRESSURE (PSIA), AND HUMIDITY (GRAINS),
C HORSEPOWER AND POWER TURBINE SPEED. OUTPUT IS THE ENGINE
C PERFORMANCE AND DUCT RESISTANCES. THE OUTPUT GOES TO YOUR DISK
C UNDER FILE OUTPUT DATA.
C*****
C SUBROUTINE COME
C REAL WORKR, TO, PO, HUMID, HP, NPT, ACWB, ACWM, ACWC, ADWB, ADWC,
C + ADMX, ALFAL, ALFAC, RHOSTD, CMFJ, CMMAK, DOPMAX, K
C INTEGER N, INDEX, WORKI, CLASS, BRANCH, FIT1ST, I, TEST, NBR, OFF, SERIAL,
C + ANS, YES, NC
C DIMENSION INDEX(200), WORKI(200,2), WORKR(200,4), FIT1ST(7), NBR(6)
C DATA YES, 'Y', NC, 'N'
C CALL FRTCMS ('CIRSCRN ')
C READ FILE SERIAL NUMBER AND HOW MANY FITTINGS ARE IN THE FILE
C READ (8,600) SERIAL, N
C READ INDEX, ID NUMBER, FITTING TYPE, AND FOUR ELEMENTS OF DATA
C FOR EACH FITTING
C DO 10 I=1, N
C   READ (8,601) INDEX(I), WORKI(I,1), WORKI(I,2), WORKR(I,1),
C   + WORKR(I,2), WORKR(I,3), WORKR(I,4)
C 10 CONTINUE
C REWIND 8
C FIND OUT WHAT CLASS SYSTEM IS IN THE DUCT DATA FILE
C CLASS=WORKI(1,1)/100000
C SET UP FOR THE CORRECT NUMBER OF BRANCHES FOR THE SYSTEM
C IF (CLASS.EQ.1) BRANCH=4
C IF (CLASS.EQ.2) BRANCH=5
C IF (CLASS.EQ.3) BRANCH=6
C IF (CLASS.EQ.4) BRANCH=3
C IF (CLASS.EQ.5) BRANCH=5
C IF (CLASS.EQ.6) BRANCH=4
C 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.
C 20 DO 70 I=1, N
C   IF (WORKI(I,2).EQ.13) GO TO 30
C   IF (WORKI(I,2).EQ.14) GO TO 40
C   IF (WORKI(I,2).EQ.15) GO TO 30
C   IF (WORKI(I,2).EQ.16) GO TO 60
C   GO TO 70
C 30 ADWC=WORKR(I,1)
C   ADWB=WORKR(I,2)
C   ALFAC=WORKR(I,3)
C   GO TO 70
C 40 ADWM=WORKR(I,1)
C   GO TO 70
C 50 ACWC=WORKR(I,1)
C   ACWB=WORKR(I,2)
C   ALFAC=WORKR(I,3)
C   GO TO 70
C 60 ACWM=WORKR(I,1)
C 70 CONTINUE
C 80 CONTINUE
C 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.
C FIT1ST(1)=1
C DO 90 I=1, N
C   TEST=WORKI(I+1,1)-WORKI(I,1)
C   IF (TEST.EQ.1) GO TO 90
C   FIT1ST(I)=INDEX(I+1)
C   M=M+1
C 90

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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 (RHOSID,CFM0,CFMMAX,DPMAX,K)
95 CALL FWRPT (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,
+ RHOSID,CFM0,CFMMAX,DPMAX,K)
GO TO 400
150 CALL SYS2(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
+ ALFAC,ACWB,ADWC,ADWM,
+ RHOSID,CFM0,CFMMAX,DPMAX,K)
GO TO 400
200 CALL SYS3(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
+ ALFAC,ACWB,ACWC,ACWM,
+ RHOSID,CFM0,CFMMAX,DPMAX,K)
GO TO 400
250 CALL SYS4(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
+ ALFAC,ACWB,ACWC,ACWM,
+ RHOSID,CFM0,CFMMAX,DPMAX,K)
GO TO 400
300 CALL SYS5(SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
+ ALFAC,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.')
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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 CHECK 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,LCNG,SHORT,CRT,TYPE
DATA LONG,SHORT,CRT,TYPE/'L','S','C','T'/'
5 WRITE(6,600)
READ(S,601,END=7,ERR=7) ANS
7 IF((ANS.EQ.LONG).OR.(ANS.EQ.SHORT)) GO TO 10
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(S,601,END=42,ERR=42) ANS
42 IF((ANS.EQ.CRT).OR.(ANS.EQ.TYPE)) GO TO 50
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

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C*****SYSTEM SUBROUTINE: DETERMINES WHICH SYSTEM, 1,2,3,4,5,OR 6*****C
C*****CALLED BY THE BUILD SUBROUTINE. USED TO SET UP THE PROGRAM FOR*****C
C*****THE VARIATIONS IN DUCT SYSTEMS AVAILABLE. THE EDITING SUBROUTINE*****C
C*****CAN NOT CHANGE THE SYSTEM TYPE. ONCE SET JP HERE ANOTHER RUN OF*****C
C*****THE BUILD SUBROUTINE IS REQUIRED TO GET A DIFFERENT SYSTEM.*****C
C*****SUBROUTINE SYSTEM(SORL,CLASS)*****C
C*****INTEGER,SORL,CLASS,ANS1,ANS2,ANS3,YES,NO,SHORT*****C
C*****DATA YES/'Y',NO/'N',SHORT/0/*****C
C*****IF(SORL.EQ.SHORT)GO TO 30*****C
C*****DOES THE COOLING AIR BRANCH OFF THE MAIN INLET ???*****C
5 WRITE(6,600)
  READ(5,601,END=7,ERR=7)ANS1
  IF((ANS1.EQ.YES).OR.(ANS1.EQ.NO))GO TO 10
  REWIND 5
  WRITE(6,602)
  GO TO 5
C*****DOES THE COOLING AIR JOIN THE MAIN EXHAUST ???*****C
10 WRITE(6,603)
  READ(5,601,END=12,ERR=12)ANS2
  IF((ANS2.EQ.YES).OR.(ANS2.EQ.NO))GO TO 15
  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 ???*****C
20 WRITE(6,604)
  READ(5,601,END=22,ERR=22)ANS3
  IF((ANS3.EQ.YES).OR.(ANS3.EQ.NO))GO TO 25
  REWIND 5
  WRITE(6,602)
  GO TO 20
C*****SYSTEM CLASSIFICATION DEPENDS ON THE CONFIGURATION OF THE SYSTEM*****C
C*****AND IF A COOLING FAN IS INSTALLED. CONFIGURATION MEANS HOW THE*****C
C*****DUCT ARE JOINED TOGETHER IN THE SYSTEM.*****C
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*****C
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 CCNTINUE
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

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

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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)
CHANGING THE NUMBER OF FITTINGS REQUIRES A CHANGE TO THE FOLLOWING
GO TO STATEMENT AND THE ADDITION OF A CALL TO THE SUBROUTINE
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,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
20 CALL FIT20 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
21 CALL FIT21 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
22 CALL FIT22 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
23 CALL FIT23 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
24 CALL FIT24 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
25 CALL FIT25 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
26 CALL FIT26 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
27 CALL FIT27 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
28 CALL FIT28 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
29 CALL FIT29 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
GO TO 40
30 CALL FIT30 (SORI,GEOM,WKI,WKR)
CALL LOAD (M,GECM,WKI,WKR,WORKI,WORKR)
C A NEW FITTING WOULD REQUIRE ANOTHER CALL STATEMENT HERE
40 CONTINUE
RETURN
END

```



```
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 COEFFICIENT 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
C SUBROUTINE FIT02 (SORL,GEOM,WKI,WKR)
C REAL A,B,L,D,WKR
C INTEGER SORL,GEOM,WKI,ANS1,CIR,REC,SHORT
C DIMENSION WKI(2),WKR(4)
C DATA CIR/'C'/REC/'R'/SHORT/0/
C IS DUCT CIRCULAR OR RECTANGULAR ???
C 5 WRITE(6,600)
C READ(5,601,END=6,ERR=6) ANS1
C 6 IF((ANS1.EQ.CIR).OR.(ANS1.EQ.REC)) GO TO 7
C WRITE(6,608)
C GO TO 9
C 7 IF (ANS1.EQ.CIR) GO TO 30
C IF (SORL.EQ.SHORT) GO TO 10
C WRITE(6,602)
C CALL READR(A,5)
C WRITE(6,603)
C CALL READR(B,5)
C WRITE(6,604)
C CALL READR(L,5)
C GO TO 20
C 10 WRITE(6,605)
C CALL READR(A,5)
C CALL READR(B,5)
C CALL READR(L,5)
C 20 CONTINUE
C 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
C  $D = 1.3 * ((A * B) ** 0.625) / (A + B) ** 0.25$ 
C R=L/D
C GO TO 100
C 30 IF (SORL.EQ.0) GO TO 40
C WRITE(6,606)
C CALL READR(D,5)
C WRITE(6,604)
C CALL READR(L,5)
C GO TO 50
C 40 WRITE(6,607)
C CALL READR(D,5)
C CALL READR(L,5)
C 50 AREA=3.14*(D**2/4.0)
C 100 WKI(1)=GEOM
C WKI(2)=2
C WKR(1)=AREA
C WKR(2)=D
C WKR(3)=L
C WKR(4)=AREA
C 600 FORMAT(' YOU HAVE SELECTED STRAIGHT DUCT. IT MAY BE ROUND OR REC
C *TANGULAR. '/'*****FIRST QUESTION, IS THE DUCT CIRCULAR OR RECTANGULA
C *R (C/R) ?')
C 601 FORMAT(A1)
C 602 FORMAT(' THE DUCT IS RECTANGULAR, ENTER FIRST CROSS-SECTIONAL DIM
C *ENSION. (FEET)')
C 603 FORMAT(' SECOND DIMENSION (FEET)')
C 604 FORMAT(' ENTER THE LENGTH OF THIS DUCT SECTION. (FEET)')
C 605 FORMAT(' ENTER THE RECTANGULAR DUCT DIMENSIONS. (FEET)')
C *' FORMAT: FIRST DIMENSION SAMPLE: 10
C *' SECOND DIMENSION 8.35
C *' LENGTH 18.5
C 606 FORMAT(' THE DUCT IS CIRCULAR, ENTER THE DIAMETER (FEET)')

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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-3, 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(SOCL,GEOM,WKI,WKR)
REAL R,D,THETA,KTHETA,C,AREA,CPRIME,WKR
INTEGER GEOM,SOCL,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***** FITTING 04: ELBOW, SEGMENTED ROUND CROSS-SECTION, 90 DEGREE *****C
C*****
C***** REF. ASHRAE HANDBOOK, PAGE 33.33, TABLE B-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*****
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 READER(N,5)
IF((N.LT.3).OR.(N.GT.5)) GO TO 5
WRITE(6,601)
CALL READER(D,5)
WRITE(6,602)
CALL READER(R,5)
AREA=0.7854*D**2
M=N-2
10 GO TO (10,20,30),M
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
+RE 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

```

```

*****
FITTING 05:  ELECW MITERED CIRCULAR CROSS-SECTION
*****
REF.  ASHRAE HANDBOOK, PAGE 33.33, TABLE E-3, FITTING 3-3
CURVE FIT TO DATA.
THIS IS A SHORT FITTING.  CONNECTING DUCTS SHOULD BE MEASURED
TO THE CENTER OF THIS FITTING.
*****
SUPEROUTLINE 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'/,NC/'N'/
WRITE (6,600)
CALL HEADR (D,5)
WRITE (6,601)
CALL HEADR (THETA,5)
K=1.0
10  WRITE (6,602)
    READ (5,603,END=12,ERR=12) ANS
    IF ((ANS.EQ.YES).OR.(ANS.EQ.NC)) GO TO 20
    REWIND 3
    WRITE (6,604)
    GO TO 10
20  CONTINUE
    IF (ANS.EQ.YES) K=0.27
    CPRIME=(3.74E-4)*(THEIA**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.')
```

```

C*****
C***** FITTING J6: ELBOW MITERED RECTANGULAR CROSS-SECTION *****C
C*****
C***** REF. ASHRAE HANDBOOK, PAGE 33.33, TABLE B-3, FITTING 3-6 AND *****C
C***** THE HANDBOOK OF HYDRAULIC RESISTANCE, IEDL'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, CP, PRIME, 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)+2.35*((SIN (RAD/2.0))**4.0)
CP=PRIME=C1*A*PHI
WKI (1)=GEOM
WKI (2)=6
WKR (1)=AREA
WKR (2)=DH
WKR (3)=CP*PRIME
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 B-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
C SUBROUTINE FIT07 (SORL,GEOM,WKI,WKR)
C REAL WKR,H,W,R,THETA,T,X,KTHETA,C,CPRIME,DH,AREA
C INTEGER WKI,SORL,GEOM,XOUT
C 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
C 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
C + 0.50,0.75,1.00,1.50,2.00,
C THE TABLE INCREASING X TO THE RIGHT, INCREASING Y DOWN
C + 1.30,1.30,1.20,1.20,1.10,1.10,0.98,0.92,0.89,
C + 0.57,0.52,0.48,0.44,0.40,0.39,0.39,0.40,0.42,
C + 0.27,0.25,0.23,0.21,0.19,0.18,0.18,0.19,0.20,
C + 0.22,0.20,0.19,0.17,0.15,0.14,0.14,0.15,0.16,
C + 0.20,0.18,0.16,0.15,0.14,0.13,0.13,0.14,0.14/
C WRITE (6,600)
C 10 WRITE (6,601)
C CALL READR(H,5)
C WRITE (6,602)
C CALL READR(W,5)
C WRITE (6,603)
C CALL READR(R,5)
C WRITE (6,604)
C CALL READR(THETA,5)
C X(1)=H/W
C X(2)=R/W
C CALL TABLE (T,X,XOUT,C)
C IF (XOUT.GT.0) GO TO 20
C WRITE (6,605)
C GO TO 10
C 20 KTHETA=0.0306*THETA**0.7825
C DH=2.0*(H*W)/(H+W)
C CPRIME=C*KTHETA
C AREA=H*W
C WKI(1)=GEOM
C WKI(2)=7
C WKR(1)=AREA
C WKR(2)=DH
C WKR(3)=CPRIME
C WKR(4)=R/W
C 600 FORMAT(' YOU HAVE SELECTED A SMOOTH RADIUS RECTANGULAR ELBOW WITH
C OUT VANES. ')
C 601 FORMAT(' **FIRST QUESTION, WHAT IS THE HEIGHT OF THE ELBOW?'/
C '(THE CROSS-SECTIONAL DIMENSION PARALLEL TO THE TURN AXIS)')
C 602 FORMAT(' WHAT IS THE WIDTH OF THE ELBOW (THE CROSS-SECTIONAL
C DIMENSION IN THE PLANE OF THE TURN)?')
C 603 FORMAT(' WHAT IS THE RADIUS OF THE ELBOW, MEASURED TO THE CENTER'
C OF THE ELBOW CROSS-SECTION?')
C 604 FORMAT(' LAST QUESTION, WHAT IS THE ANGLE OF THE TURN (0-90 DEGR
C EES)?')
C 605 FORMAT(' CROSS-SECTION EXTREMELY NARROW, RE-ENTER BETTER DATA. ')
C RETURN
C END

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```

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

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```

C SUBROUTINE FIT08 (SORL, GEOM, WKI, WKR) C
C REAL WKR, H, W, R, THETA, KTHETA, AREA, X, C, CP, T1, T2, T3 C
C INTEGER WKI, W, XOUT, SORL, GEOM C
C DIMENSION WKI (2), WKR (4), X (2), T1 (100), T2 (100), T3 (100), XOUT (2) C
C ONE SPLITTER C

```

```

C DATA T1/8.00, 10.00, 0.25, 0.50, 1.00, 1.50, 2.00, 3.00, 4.00, 5.00, 1.00,
+ 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, 0.60, 0.75, 0.84,
+ 0.36, 0.27, 0.25, 0.23, 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, 0.06,
+ 0.10, 0.07, 0.06, 0.05, 0.05, 0.05, 0.05, 0.05,
+ 0.09, 0.06, 0.05, 0.05, 0.05, 0.04, 0.04, 0.05/

```

```

C TWO SPLITTERS C
C DATA T2/8.00, 10.00, 0.25, 0.50, 1.00, 1.50, 2.00, 3.00, 4.00, 5.00, 1.00,
+ 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, 0.15, 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, 0.06, 0.06, 0.06, 0.06, 0.06,
+ 0.09, 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,
+ 0.09, 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 C
C DATA T3/8.00, 10.00, 0.25, 0.50, 1.00, 1.50, 2.00, 3.00, 4.00, 5.00, 1.00,
+ 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/

```

```

C 10 WRITE (6, 600) C
C HOW MANY SPLITTERS ??? C
C WRITE (6, 601) C
C CALL READR (N, 5) C
C IF ((N.LT.1).OR.(N.GT.3)) GO TO 10 C
C WRITE (6, 602) C
C CALL READR (H, 5) C
C WRITE (6, 603) C
C CALL READR (W, 5) C
C WRITE (6, 604) C
C CALL READR (R, 5) C
C WRITE (6, 605) C
C CALL READR (THETA, 5) C
C KTHETA=0.0306*THETA**0.7825 C
C X(1)=H/W C
C X(2)=H/R C
C AREA=H*W C
C GO TO (20, 30, 40), N C

```

```

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 IN 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 B-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 (SOR,L,GEOM,WKI,WKR)
REAL WKR,C,AREA
INTEGER SOR,L,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
+' LBC#?')
RETURN
END

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C*****
C FITTING 10: ELBOW RECTANGULAR WITH CONVERGING OR DIVERGING FLOW 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 FITT10 (SORL,GEOM,WKI,WKR)
C REAL WKR,C,AREA,DH,X,CPRIME,W0,W1,H0
C INTEGER WK1,SORL,GEOM,N
C DIMENSION WKI(2),WKR(4),T(36),X(2),XOUT(2)
C DATA 1/6.00,4.00,0.60,0.80,1.20,1.40,1.60,2.00,
+ 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/
C WRITE(6,600)
C WRITE(6,601)
C CALL HEADR(H0,5)
C WRITE(6,602)
C CALL HEADR(W0,5)
C WRITE(6,603)
C CALL HEADR(W1,5)
C X(1)=W1/W0
C X(2)=H0/W0
C CALL TABLE(T,X,XOUT,CPRIME)
C IF((XOUT(1).GT.0).OR.(XOUT(2).GT.0)) GO TO 20
C WRITE(6,604)
C GO TO 10
20 DH=2.0*(H0*W0)/(H0+W0)
C AREA=H0*W0
C WKI(1)=GEOM
C WKI(2)=10
C WKR(1)=AREA
C WKR(2)=DH
C WKR(3)=CPRIME
C 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.')
C RETURN
C END

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C*****
C FITTING 11: ELBOWS 90 DEGREE RECTANGULAR IN Z-SHAPED CONFIG. C
C*****
C REF. ASHRAE HANDBOOK, PAGE 33.32, TABLE B-3, FITTING 3-11 C
C CURVE FIT TO TEE TABLE DATA C
C*****
SUBROUTINE FIT11 (SORL,GEOM,WKI,WKR)
REAL WKR,C,AREA,DH,L,W,H,CPRIME,X,Y,K
INTEGER SORL,SECM,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

```

```

*****
FITTING 12: ELBOWS 90 DEGREE IN DIFFERENT PLANES
*****
REF. ASHRAE HANDBOOK, PAGE 33,33, TABLE B-3, FITTING 3-12
CURVE FIT TO THE TABULATED DATA
*****
SUBROUTINE FIT12 (SORL,GEOM,WKI,WKR)
REAL WKR,C,AREA,DH,L,W,H,CPRIME,X,Y,K
INTEGER SORL,SECM,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=1.4-0.10*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 "2" ENTRANCE AND "2" EXIT?')
RETURN
END

```

```

C*****FITTING 13: BRANCH SECTION DIVERGING WYE*****C
C*****REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN*****C
C*****PAGES 247-253*****C
C*****
SUBROUTINE FIT13(SORL,GEOM,*KXI,*KX)
REAL *KX,ALFAD,AC,AB
INTEGER SORL,SECM,*KXI
DIMENSION *KXI(2),*KX(4)
WRITE(6,600)
CALL READR(ALFAD,5)
WRITE(6,601)
CALL READR(AC,5)
WRITE(6,602)
CALL READR(AB,5)
*KXI(1)=GEOM
*KXI(2)=13
*KX(1)=AC
*KX(2)=AB
*KX(3)=ALFAD
*KX(4)=AB
600 *CALL 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 FITTING 14: MAIN SECTION DIVERGING WYE
C*****
C REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN
C PAGES 247-253
C*****
C
C SUBROUTINE FIT14(SORL,GEOM,WKI,WKR)
C REAL WKR,AM
C INTEGER SORL,GEOM,WKI
C DIMENSION WKI(2),WKR(4)
C WRITE(6,600)
C CALL READR(AM,5)
C WKI(1)=GEOM
C WKI(2)=14
C WKR(1)=AM
C WKR(2)=0.0
C WKR(3)=0.0
C 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.')
C RETURN
C END

```

```

C***** FITTING 15: BRANCH SECTION CONVERGING WYE *****C
C***** REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN *****C
C***** PAGES 247-253 *****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
WKR(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 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) ?')
601 FORMAT(' WHAT IS THE CROSS-SECTIONAL AREA OF THE COMBINED FLOW ' /
+' SECTION? THIS IS WHERE ENGINE EXHAUST AND MODULE COOLING AIR ' /
+' FLOW JUST JOINS STREAM OF THE BRANCH. ')
602 FORMAT(' LAST QUESTION, WHAT IS THE CROSS-SECTIONAL AREA OF THE ' /
+' BRANCH? ')
RETURN
END

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```

C*****C
C FITTING 16: MAIN SECTION CONVERGING WYE C
C*****C
C REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION SEVEN C
C*****C
C PAGES 247-253 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'//
+' YES. 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

```



```

*****
FITTING 17: CONICAL DIFFUSER
*****
REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE,
PAGE 167
*****
SUBROUTINE FIT17(SORL,GEOM,WKI,WKR)
REAL WKR,L,DO,D1,K1,K2,AO,A1,THETA,CEXP,CFRPRI
INTEGER GEOM,SCR1,WKI,ANS,YES,NO
DIMENSION WKI(2),WKR(4)
DATA YES/'Y'/,NO/'N'/
WRITE(6,600)
10  CALL I3E HEADR(L,5)
    CALL I3E HEADR(DO,5)
    CALL I3E HEADR(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=0.8
    AO=0.7854*DO**2
    A1=0.7854*D1**2
    IF(A1.GT.AO) GO TO 20
    WRITE(6,605)
    GO TO 20
20  THETA=2.0*ATAN((D1-DO)/(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
    IF(THETA.GT.0.7) GO TO 40
    CEXP=1.3454*(THETA**1.2)*(1.0-AO/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-AO/A1)**2
50  CEXP=((-0.0061*THETA)-0.0139)*THETA-0.09293)*THETA+1.2623)*
    * (1.0-AO/A1)**2
60  CONTINUE
    WRITE(6,607)
    CFRPRI=(1.0-(AO/A1)**2)/(8.0*SIN(THETA/2.0))
    WKI(1)=GEOM
    WKI(2)=17
    WKR(1)=AO
    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 DIFFUSER?')
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)?')

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604 FORMAT(A1)
605 FORMAT(' DOWNSTREAM AREA IS NOT GREATER THAN UPSTREAM AREA. '/
+ FITTING IS A NECESSARY CONDITION FOR THE FLOW TO BE STABLE. '/
606 + FORMAT(' INSTALLATION IS A NECESSARY CONDITION FOR THE FLOW TO BE STABLE. '/
+ ' THE RESULT OF THIS FITTING. DO YOU WANT TO REDUCE? '/
+ ' 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

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```

*****
***** FITTING 18: PLANE IN-LINE DIFFUSER *****
***** REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE, *****
***** PAGE 171 *****
*****
SUBROUTINE FIT18(SCRL,GEOM,WKI,WKP)
REAL WKR,L,H,W0,A1,K1,K2,A0,A1,THETA,CEXP,CFRPRI
INTEGER GEOM,SCAL,K1,ANS,YES,NO
DIMENSION N(2),NKR(4)
DATA N/1,2/,NKR/4/
WRITE(6,600)
CALL HEADR(L,5)
WRITE(6,601)
CALL HEADR(H,5)
10 WRITE(6,602)
CALL HEADR(W0,5)
WRITE(6,603)
CALL HEADR(W1,5)
12 READ(6,604)
IF((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 16
14 READ(6,605)
WRITE(6,609)
GO TO 12
16 CONTINUE
K1=1.0
IF(ANS.EQ.YES) K1=6.3
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 READ(6,607)
IF((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 26
24 READ(6,608)
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)-0.3715)*THETA+3.0218)*THETA-0.6410)*
+ (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
CFRPRI=((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)=CFRPRI*K2
WKR(3)=CEXP*K1*K2
WKE(4)=A1
600 FORMAT(' YOU HAVE SELECTED A PLANE INLINE DIFFUSER WITH ONE'//
+ ' DIMENSION CONSTANT THROUGHOUT AND RECTANGULAR INLET'//
+ ' AND CUTLET.'//
+ '**FIRST QUESTION, WHAT IS THE LENGHE OF THE DIFFUZER?')

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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 NON-UNIFORM VELOCITY DISTRIBUTION AT THE INLE
+      ' (Y/N)?')
605  FORMAT('a')
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

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C*****FITTING 19: PYRAMIDAL DIFFUSER, IN LINE*****C
C*****REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE,*****C
C*****PAGE 169*****C
C*****
SUBROUTINE FIT19(SORL,SECM,WKI,WKR)
REAL WKR,L,H0,W1,H1,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 FEADR(L,5)
10 WRITE(6,6001)
CALL FEADR(H0,5)
WRITE(6,6002)
CALL FEADR(W0,5)
WRITE(6,6003)
CALL FEADR(H1,5)
WRITE(6,6004)
12 CALL FEADR(W1,5)
WRITE(6,6005)
IF(ANS.EQ.YES).OR.(ANS.EQ.NO) GO TO 16
14 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))
IF(THETA=MAX1(ALFA,BETA)) GO TO 30
22 WRITE(6,6008)
IF(ANS.EQ.YES).OR.(ANS.EQ.NO) GO TO 26
24 WRITE(6,610)
GO TO 22
26 CONTINUE
K2=1.0
IF(ANS.EQ.YES) K2=0.65
30 THETA=0.491 GO TO 40
X=1.0818*(THETA**1.2)*(1.0-A0/A1)**2
GO TO 60
40 THETA=0.60
CEXP=((3.3593*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
H=(1.0-(A0/A1)**2)/(8.0*SIN(THETA/2.0))
WRITE(6,6009)
WKI(1)=GEOM
WKI(2)=19
WKI(3)=A0
WKI(4)=CFRPRI*K2
WKI(4)=CEXP*K1*K2
WKI(4)=A1
600 *(' YOU HAVE SELECTED A PYRAMIDAL INLINE RECTANGULAR DIFFUSE
R.'/'**FIRST QUESTION, WHAT IS THE LENGTH OF THE DIFFUSER/')

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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('A')
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

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*****
FITTING 20: TRANSITIONAL DIFFUSER
*****
REF. IDEL'CHIK, HANDBOOK OF HYDRAULIC RESISTANCE, SECTION FIVE,
PAGE 174
*****

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SUBROUTINE FIT20(SORL, GEOM, WKI, WKR)
DIMENSION L(5), H(5), THETA, AO, A1, K1, K2, CEXP, CFRPRI
DIMENSION SCAL, GEOM, WKI, ANS, YES, NO
DIMENSION WKI(2), WKR(4)
DATA YES/'Y'/, NO/'N'/
WRITE(6,600)
10 READ(5,601)
READ(5,602,END=14,ERR=14) ANS
IF((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 16
14 WRITE(6,611)
GO TO 10
16 CONTINUE
WRITE(6,603)
CALL HEADR(L,5)
WRITE(6,604)
CALL HEADB(H,5)
WRITE(6,605)
CALL HEADR(W,5)
WRITE(6,606)
CALL HEADR(D,5)
IF(ANS.EQ.YES) GO TO 30
AO=H**2
A1=0.7854*D**2
IF(A1.GT.AO) 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
AO=0.7854*D**2
IF(A1.GT.AO) 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
IF(THETA.GT.0.44) GO TO 70
CEXP=1.6618*(THETA**1.2)*(1.0-AO/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-AO/A1)**2
GO TO 90
80 CEXP=1.1*(1.0-AO/A1)**2
90 CONTINUE
WRITE(6,610)
CFRPRI=(1.0-(AO/A1)**2)/(8.0*SIN(THETA/2.0))
WKI(1)=GEOM

```

```

      NKKRR1(2)=20
      NKKRR1(1)=AO
      NKKRR1(2)=CE
      NKKRR1(3)=EX
      NKKRR1(4)=A1
      PR1*K2
      EX?K1*K2
600  FORLA(1) 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('A')
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 23: SCREEN C
C REF. ASHRAE HANDBOOK, PAGE 33.42, TABLE B-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
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 FITTING 24: LOUVER ENTRANCE
C*****
C REF. HANDBOOK OF HYDRAULIC RESISTANCE, IDEL'CHIK
C CURVE FIT TO DYNAMIC LOSS INFORMATION, NO FRICTION INCLUDED
C*****
C SUBROUTINE FIT24(SORL,GEOM,WKI,WKR)
  REAL DX,DB,N,DUCTA,P,C
  INTEGER WKI,SORI,GEOM
  DIMENSION WKI(2),WKR(4)
  WRITE (6,600)
  CALL READER(DX,5)
  WRITE (6,601)
  CALL READER(DB,5)
  WRITE (6,602)
  CALL READER(N,5)
  WRITE (6,603)
  CALL READER(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

```



```

+ ' ** HOW MANY DATA POINTS DO YOU HAVE (1 TO 9)? ' /
+ ' DO NOT PUT IN THE POINT (0.0,0.0) ' )
604 FORMAT (' FACIE 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. ')
END
RETURN

```

```

C*****C
C FITTING 26: SILENCER MULTI-BAFFLE TYPE C
C*****C
C REM. NAVSEA INLET DESIGN HANDBOOK C
C COMPOSITE LOSS COEFFICIENT BASED ON A SUDDEN CONTRACTION, C
C FRICTION AND A SUDDEN EXPANSION C
C*****C
C SUBROUTINE FIT26(SORL, GEOM, WKI, WKR) C
C REAL WKR(5), G, T, L, H, CX, A0, A1, DH, R, C1, C2, C3, C, N C
C INTEGER SORL, GEOM, WKI C
C DIMENSION WKI(2), WKR(4) C
C A0=0.0 C
C CALL READR(G, 5) C
C WRITE(6, 6001) C
C CALL READR(T, 5) C
C WRITE(6, 6002) C
C CALL READR(L, 5) C
C WRITE(6, 6003) C
C CALL READR(H, 5) C
C WRITE(6, 6004) C
C CALL READR(CX, 5) C
C WRITE(6, 6005) C
C CALL READR(N, 5) C
C A0=CX*H C
C A1=N*G*H C
C DH=2.0*G*H/(G+H) C
C P=(CX-N*G)/(2.0*N) C
C SUDDEN CONTRACTION C
C C1=0.1141*((R/DH+0.1)**14.4405)*(1.0-A1/A0) C
C FRICTION C
C C2=0.05*L/DH C
C SUDDEN EXPANSION C
C C3=0.47*(1.0-N*G/CX)**2+0.02 C
C COMPOSITE COEFFICIENT C
C C=C1+C2+C3 C
C WKI(1)=GEOM C
C WKI(2)=26 C
C WKR(1)=A0 C
C WKR(2)=0.0 C
C WKR(3)=C C
C WKR(4)=A0 C
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.'/
601 FORMAT(' **FIRST QUESTION, WHAT IS THE GAP BETWEEN THE BAFFLES?')
602 FORMAT(' WHAT IS THE THICKNESS OF THE BAFFLES?')
603 FORMAT(' WHAT IS THE LENGTH OF THE BAFFLES?')
+ ' 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?')
C RETURN C
C END C

```

```

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*****C
SUBROUTINE FIT27(SORL,GEOM,WKI,WKR)
REAL WKR, AO
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

```



```

*****
FITTING 28: WASTE HEAT RECOVERY BOILER
*****
REF. EXTENDED SURFACE HEAT TRANSFER, D.Q. KERNS AND A.D. KRAUSS
PRACTICE 382-589
PRELIMINARY DRAWINGS ON THE RACER SYSTEM
*****
SUBROUTINE FIT28(SORL,GEOM,WKI,WKR)
REAL WKR,DV,DE,ST,N,TL,VFACT,TEST,CPRIME,AREA
DIMENSION SORL,GEOM,WKI,ANS,STAG,INLINE,YES NO
DIMENSION WKI(2),WKI(4)
DATA STAG,'S',/ ,INLINE,'I',/ ,YES,'Y',/ ,NO,'N' /
10 READ(6,600)
   IF ((ANS.EQ.YES).OR.(ANS.EQ.NO)) GO TO 30
20 REWIND 5
   WRITE(6,602)
   GO TO 40
30 CONTINUE
   AREA=08.75
   VFACT=1.35095
   CPRIME=35.02027
   DV=0.03387
   IF (ANS.EQ.YES) GO TO 80
   WRITE(6,603)
   CALL READER(DV,5)
   WRITE(6,604)
   CALL READER(DE,5)
   WRITE(6,605)
   CALL READER(ST,5)
40 READ(6,606)
   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 READER(N,5)
   WRITE(6,608)
   CALL READER(SL,5)
   WRITE(6,609)
   CALL READER(TL,5)
   WRITE(6,610)
   CALL READER(XL,5)
   FIND HIGHEST VELOCITY OF THE TUBE BANK
   VFACT=ST/(ST-DE)
   IF ((ANS.EQ.INLINE).OR.(ANS.EQ.STAG)) GO TO 70
   VFACT=(ST**2+(SL**2+(TL**2+(XL**2)/2.0)**2)**2)**2
70 IF (TEST) VFACT=ST/(2.0*(SD-DE))
   COMMON TURBINE
   AREA=TX
   CPRIME=((DV/ST)**0.4)*((SL/ST)**0.6)*SL*N/DV
80 CONTINUE
   WKI(1)=GEOM
   WKI(2)=28
   WKI(3)=AREA
   WKI(4)=VFACT
   WKRR(1)=CPRIME
   WKRR(2)=VFACT
   WKRR(3)=CPRIME
   WKRR(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.' /

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+      ' USE CONSISTENT UNITS (FEET).'/
+      ' **FIRST QUESTION, WHAT IS THE VOLUMETRIC HYDRAULIC'/
+      ' DIAMETER? IF YOU DO NOT KNOW 0.040 FEET IS A GOOD.'/
604  ' GUESSES FOR THIS APPLICATION.'//
+      ' 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.'/
+      ' GUESSES.'//
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 JUCT. 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 THIS ASHRAE HANDBOOK, PAGE 33.29, TABLE B-2, FITTING 2-1 C
C THIS SHOULD ALWAYS BE USED FOR THE SELECTION 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 182). C
C*****C
SUBROUTINE FIT29(SORL,GEOM,*KI,*KR)
REAL *KR, AREA
INTEGER SCRL,GEOM,*KI
DIMENSION *KI(2),*KR(4)
WRITE(6,600)
CALL HEADR(AREA,5)
*KR(1)=GEOM
*KR(2)=29
*KR(3)=AREA
*KR(4)=J.O
*KR(5)=0.0
*KR(6)=1.0
*KR(7)=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 THE USER'S CHOICE. THIS IS LISTED ON THE MENU. THE INPUTS A CONSTANT C
C VELOCITY IS COMPUTED THROUGH THE AREA INPUT REQUESTED. C
C*****C
SUBROUTINE FIT30(SORL,GEOM,*KI,*KR)
REAL *KR, AI,C,AO
INTEGER SORL,GEOM,*KI
DIMENSION *KI(2),*KR(3)
WRITE(6,600)
CALL HEADR(AI,5)
*KR(1)=GEOM
*KR(2)=30
*KR(3)=AI
*KR(4)=0.0
*KR(5)=C
*KR(6)=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.//
+ ' WHAT IS THE MULTIPLIER CO, USED IN//
+ ' VELOCITY PRESSURE EQUATION: //
+ ' CO=RHO*(VELOCITY**2)/(2.0*GC) ? ')
601 FORMAT(' LAST QUESTION, WHAT IS THE OUTLET AREA?')
602 FORMAT('
RETURN
END

```

```

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

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```

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

```

```

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

```

C*****C
C      DUCT DATA FILE OUTPUT SUBROUTINE
C*****C
C      WRITES THE SYSTEM ARRAYS WORKI AND WORKR TO THE DUCT DATA FILE.
C      ALLOWS THE USER TO SERIALIZE EACH FILE CREATED.
C      *WARNING* WRITES OVER OLD FILES, SAVE THEM UNDER A DIFFERENT NAME.
C*****C
C      SUBROUTINE SOUTOUT(WORKI,WORKR,M)
      REAL WORKR
      INTEGER WORKI, 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)
      END
C*****C
C      REAL NUMBER REAL SUBROUTINE: FREE FORMAT
C      PREVENTS THE INADVERTENT ENTRY OF NULL DATA (HITTING THE RETURN
C      KEY WITH NO ENTRY) AND INCORRECT DATA, THIS ROUTINE IS USED.
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 ERICMS ('CLRSCRN ')
      WRITE (6,600)
      GO TO 10
      20 CONTINUE
      READ (FD,*,END=30,ERR=30) ANSR
      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
      + VALUE.')
```

```

      END
C*****C

```

```

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
C*****C
10  CCOUNT=0
    CCOUNT=COUNT+1
    IF (COUNT.LT.3) GO TO 20
    CALL FRTCMS ('CLRSCRN ')
    WRITE (6,600)
    GO TO 40
20  CCOUNTINUE
    READ (FD,*,END=30,ERR=30) ANSI
    RETURN
30  REWIND FD
    WRITE (6,601)
    GO TO 10
40  CCOUNTINUE
    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      THE PROGRAM COULD BE MODIFIED TO ACCEPT RELATIVE HUMIDITY (%) AND C
C      CONVERT IT TO GRAINS PER POUND REQUIRED FOR USE LATER IN THE PROGRAM. THAT C
C      MODIFICATION SHOULD BE ACCOMPLISHED HERE.                    C
C*****C
SUBROUTINE OPCND(T0,P0,HUMID)
REAL T0,P0,HUMID
WRITE (6,600)
CALL READR(T0,5)
WRITE (6,601)
CALL READR(P0,5)
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

```



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C*****ENGINE SUBROUTINE: COMPUTES OPERATING POINT FOR GIVEN CONDITIONS*****C
C
C REF. 7LM2500 MARINE GAS TURBINE PERFORMANCE DATA, PREPARED BY
C GENERAL ELECTRIC COMPANY MARINE AND INDUSTRIAL DEPARTMENTS
C DEPARTMENT NUMBER MD-1-2500-3, REVISED NOVEMBER 1973.
C ENGINE PERFORMANCE CURVES PRODUCED BY STORING A STANDARD CONDITION
C OPERATING MAP AND APPLYING CORRECTIONS FOR OFF-STANDARD
C OPERATING CONDITIONS. MAIN INTEREST IS TO OBTAIN W2, W8, AND T8.
C SFC, T54, AND NG ARE ALSO PROVIDED.
C*****
C SUBROUTINE ENGINE(INLOSS, EXLOSS, T0, P0, HUMID, BHP, NPT, W2C, W8C,
+ REAL T0, P0, HUMID, INLOSS, EXLOSS, T54C, NGC, OFF)
+ BHP, NPT, W2S, W8S, T8S, P8S, SFC, T54S, NGS, NGC, W2C, W8C, T8C, P8C,
+ SFC, T54C
C INTEG SER OFF
W2C=0+459.67
W8C=0
C DELTA IS THE PRESSURE CORRECTION, THETA THE TEMPERATURE CORRECTION
C INLET AND EXHAUST LOSSES ARE A SEPARATE CORRECTION
C DELTA=P2C/14.696
C THETA=T2C/518.67
C
C CORRECT DESIRED BHP, NPT TO STANDARD CONDITIONS, INPUT TO ENGINE.
C
C BHP2=BHP/(DELTA*SQRT(THETA))
C NPT2=NPT/SQRT(THETA)
C CALL LM2500(BHP2, NPT2, W2S, W8S, T8S, P8S, SFC, T54S, NGS, OFF)
C IF(OFF.GT.0) GC TO 20
C
C CORRECT STANDARD ENGINE PARAMETERS TO OPERATING CONDITIONS.
C
C NGC=CFNG(NGS, THETA, INLOSS, EXLOSS, HUMID)
C W2C=CFW2(W2S, THETA, DELTA, INLOSS, EXLOSS, HUMID, NGC)
C W8C=CFW8(W8S, THETA, DELTA, INLOSS, EXLOSS, HUMID, NGC)
C T8C=CFW8(T8S, THETA, INLOSS, EXLOSS, HUMID, NGC)
C P8C=CFW8(P8S, DELTA, EXLOSS)
C SFC=CFW8(SFC, THETA, INLOSS, EXLOSS, HUMID, NGC)
20 CONTINUE
RETURN
END
C
C FUNCTION TO CORRECT GAS GENERATOR SPEED
C FUNCTION CFNG(NG, THETA, INLOSS, EXLOSS, HUMID)
C REAL THETA, INLOSS, EXLOSS, HUMID, NG, ADELPI, ADELPE, ADELH,
+ CF, CFNG
C IF(NG.LE.9100.0) GO TO 10
C IF(NG.LE.9200.0) GO TO 20
C ADELPI=0.000733+(NG-9100.0)*0.000567/100.0
10 ADELPI=0.000733
GO TO 30
20 ADELPI=-0.0013
CONTINUE
C ADELPE=0.00035
C ADELH=-0.002200/100.0
C CF=(1.0+ADELPI*INLOSS)*(1.0+ADELPE*EXLOSS)*(1.0+ADELH*HUMID)*
+ SQRT(THETA)
C CFNG=NG*CF
RETURN
END
C
C FUNCTION TO CORRECT MASS FLOW RATE
C FUNCTION CFW(W, THETA, DELTA, INLOSS, EXLOSS, HUMID, NGC)
C REAL W, THETA, DELTA, INLOSS, EXLOSS, HUMID, NGC, ADELPI, ADELPE, ADELH,
+ CF, CFW
C IF(NGC.LE.9100.0) GO TO 10
C IF(NGC.LE.9200.0) GO TO 20
C ADELPI=-0.00075-(NGC-9100.0)*0.000917/100.0

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```

10 GO TO 30
   ADELPI=0.00075
20 GO TO 30
   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)*
   *CF/SQRT(THETA)
   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.EQ.9100.0) GO TO 10
   IF (NGC.EQ.9200.0) GO TO 20
   ADELPI=0.00105+(NGC-9100.0)*0.001242/100.0
10 GO TO 30
   ADELPI=0.00105
20 GO TO 30
   ADELPI=0.002292
30 CONTINUE
   ADELPE=0.00095
   ADELH=-0.00643/100.0
   CF=(1.0+ADELPI*INLOSS)*(1.0+ADELPE*EXLOSS)*(1.0+ADELH*HUMID)*
   *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=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.EQ.9100.0) GO TO 10
   IF (NGC.EQ.9200.0) GO TO 20
   ADELPI=0.000958+(NGC-9100.0)*0.001/100.0
10 GO TO 30
   ADELPI=0.000958
20 GO TO 30
   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)*
   *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.EQ.9100.0) GO TO 10
   IF (NGC.EQ.9200.0) GO TO 20
   ADELPI=0.000958+(NGC-9100.0)*0.001/100.0
10 GO TO 30
   ADELPI=0.000958
20 GO TO 30
   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)*
   *CF
   RETURN
END
C

```

 LM2500 ENGINE TABULATION OF PERFORMANCE DATA FOR STD. CONDITIONS *****

THIS DATA IS TAKEN FROM CASE NUMBERS 536 TO 607 PAGES 171-185
 OF THE ENGINE MANUAL. EXTRAPOLATED VALUES PROVIDED BY THE AUTHOR
 USING GRAPHICAL TECHNIQUES.

 SUBROUTINE LM2500 (BHP, NPT, W2, W8, T3, P8, SFC, T54, NG, CFF)
 REAL BHP, NPT, W2, W8, T3, P8, SFC, T54, NG, X,
 W2T, W8T, T3T, P8T, SFC, T54T, NGT

 INTEGER OFFT, KOFT
 DIMENSION X(2), KOFT(2), W2T(64), W8T(64), T3T(64), P8T(64), SFC(64),
 T54T(64), NGT(64)

DATA W2T / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 175.0, 175.0,
 + 41.1, 36.7, 32.3, 27.9, 23.5, 19.1, 14.7, 10.3, 158.0, 169.0, 175.0,
 + 40.2, 35.8, 31.4, 27.0, 22.6, 18.2, 13.8, 9.4, 127.5, 133.7, 146.4, 156.0,
 + 43.1, 38.7, 34.3, 29.9, 25.5, 21.1, 16.7, 12.3, 117.5, 125.7, 133.6, 141.3,
 + 48.9, 44.5, 40.1, 35.7, 31.3, 26.9, 22.5, 18.1, 113.3, 120.9, 127.8, 134.3,
 + 51.1, 46.7, 42.3, 37.9, 33.5, 29.1, 24.7, 20.3, 112.4, 119.9, 126.4, 132.9,
 + 54.4, 49.0, 44.6, 40.2, 35.8, 31.4, 27.0, 22.6, 112.2, 119.2, 125.5, 131.8

DATA W8T / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 175.0, 175.0,
 + 1200.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 172.5, 181.0,
 + 41.1, 36.7, 32.3, 27.9, 23.5, 19.1, 128.5, 138.3, 148.0, 158.0,
 + 40.2, 35.8, 31.4, 27.0, 22.6, 18.2, 118.3, 126.7, 134.8, 143.8,
 + 43.1, 38.7, 34.3, 29.9, 25.5, 21.1, 114.1, 121.8, 128.5, 135.6,
 + 48.9, 44.5, 40.1, 35.7, 31.3, 26.9, 113.2, 120.8, 127.5, 134.1,
 + 51.1, 46.7, 42.3, 37.9, 33.5, 29.1, 113.1, 120.8, 126.6, 132.9

DATA T3T / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 175.0, 175.0,
 + 114.4, 115.3, 119.2, 123.1, 127.0, 130.9, 134.8, 138.7, 175.5, 187.7, 200.0,
 + 118.5, 119.6, 124.4, 129.2, 134.0, 138.8, 143.6, 148.4, 149.9, 156.0,
 + 123.4, 124.5, 129.3, 134.1, 138.9, 143.7, 148.5, 153.3, 153.3,
 + 128.1, 129.2, 134.0, 138.8, 143.6, 148.4, 153.2, 158.0, 158.0,
 + 130.0, 131.1, 135.9, 140.7, 145.5, 150.3, 155.1, 160.0, 160.0,
 + 133.4, 134.5, 139.3, 144.1, 148.9, 153.7, 158.5, 163.4, 163.4

DATA P8T / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 175.0, 175.0,
 + 14.70, 14.72, 14.74, 14.76, 14.78, 14.80, 14.82, 14.84, 14.85, 14.86, 15.01,
 + 14.70, 14.71, 14.73, 14.75, 14.77, 14.79, 14.81, 14.83, 14.84, 14.85, 14.95,
 + 14.71, 14.72, 14.74, 14.76, 14.78, 14.80, 14.82, 14.84, 14.85, 14.86, 14.96,
 + 14.71, 14.72, 14.74, 14.76, 14.78, 14.80, 14.82, 14.84, 14.85, 14.86, 14.97,
 + 14.71, 14.72, 14.74, 14.76, 14.78, 14.80, 14.82, 14.84, 14.85, 14.86, 14.99

DATA SFC / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 0.7740, 0.8180,
 + 1.4996, 1.3632, 1.2268, 1.0904, 0.9540, 0.8176, 0.6812, 0.5448, 0.5105, 0.5210,
 + 1.5235, 1.3871, 1.2507, 1.1143, 0.9779, 0.8415, 0.7051, 0.5687, 0.5031, 0.4245,
 + 1.7333, 1.5969, 1.4605, 1.3241, 1.1877, 1.0513, 0.9149, 0.7785, 0.7031, 0.4947,
 + 2.0222, 1.8858, 1.7494, 1.6130, 1.4766, 1.3402, 1.2038, 1.0674, 0.9420, 0.3939,
 + 2.2111, 2.0747, 1.9383, 1.8019, 1.6655, 1.5291, 1.3927, 1.2563, 1.1309, 0.3939,
 + 2.4000, 2.2636, 2.1272, 1.9908, 1.8544, 1.7180, 1.5816, 1.4452, 1.3188, 0.3940

DATA T54T / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 23.10,
 + 1214.78, 1356.00, 1615.33, 1891.1, 2030.0, 2170.0,
 + 1258.8, 1290.0, 1342.0, 1509.9, 1684.4, 1762.0, 1850.0, 1940.0,
 + 1303.3, 1334.5, 1386.7, 1488.5, 1623.3, 1691.0, 1755.0, 1808.0,
 + 1343.3, 1387.0, 1429.9, 1524.4, 1633.3, 1688.0, 1739.0, 1788.0,
 + 1366.4, 1417.0, 1459.9, 1524.4, 1600.0, 1650.0, 1749.0, 1799.0,
 + 1389.0, 1447.0, 1489.9, 1524.4, 1575.0, 1673.0, 1748.0, 1810.0

DATA NGT / 8.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0, 10000.0, 15000.0, 17500.0, 20000.0, 22500.0,
 + 1000.0, 1800.0, 2400.0, 3000.0, 3300.0, 3600.0, 175.0, 175.0, 175.0, 175.0, 175.0, 175.0

```

+ 12000.0, 18000.0, 24000.0, 30000.0, 36000.0, 42000.0, 48000.0, 54000.0, 60000.0, 66000.0, 72000.0, 78000.0, 84000.0, 90000.0, 96000.0, 102000.0, 108000.0, 114000.0, 120000.0,
+ 69980.0, 76960.0, 83940.0, 90920.0, 97900.0, 104880.0, 111860.0, 118840.0, 125820.0, 132800.0, 139780.0, 146760.0, 153740.0, 160720.0, 167700.0, 174680.0, 181660.0, 188640.0, 195620.0, 202600.0,
+ 70411.0, 77391.0, 84371.0, 91351.0, 98331.0, 105311.0, 112291.0, 119271.0, 126251.0, 133231.0, 140211.0, 147191.0, 154171.0, 161151.0, 168131.0, 175111.0, 182091.0, 189071.0, 196051.0, 203031.0, 210011.0,
+ 72233.0, 79213.0, 86193.0, 93173.0, 100153.0, 107133.0, 114113.0, 121093.0, 128073.0, 135053.0, 142033.0, 149013.0, 155993.0, 162973.0, 169953.0, 176933.0, 183913.0, 190893.0, 197873.0, 204853.0, 211833.0, 218813.0,
+ 73334.0, 80314.0, 87294.0, 94274.0, 101254.0, 108234.0, 115214.0, 122194.0, 129174.0, 136154.0, 143134.0, 150114.0, 157094.0, 164074.0, 171054.0, 178034.0, 185014.0, 191994.0, 198974.0, 205954.0, 212934.0, 219914.0, 226894.0,
+ 74150.0, 81130.0, 88110.0, 95090.0, 102070.0, 109050.0, 116030.0, 123010.0, 130000.0, 136980.0, 143960.0, 150940.0, 157920.0, 164900.0, 171880.0, 178860.0, 185840.0, 192820.0, 199800.0, 206780.0, 213760.0, 220740.0, 227720.0, 234700.0,

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X(1) = BHP
X(2) = NPT
CALL TAB (1, X, XOUT (1), XOUT (2))
CALL TAB (2, X, XOUT (1), XOUT (2))
CALL TAB (3, X, XOUT (1), XOUT (2))
CALL TAB (4, X, XOUT (1), XOUT (2))
CALL TAB (5, X, XOUT (1), XOUT (2))
CALL TAB (6, X, XOUT (1), XOUT (2))
CALL TAB (7, X, XOUT (1), XOUT (2))
CALL TAB (8, X, XOUT (1), XOUT (2))
CALL TAB (9, X, XOUT (1), XOUT (2))
CALL TAB (10, X, XOUT (1), XOUT (2))
CALL TAB (11, X, XOUT (1), XOUT (2))
CALL TAB (12, X, XOUT (1), XOUT (2))
CALL TAB (13, X, XOUT (1), XOUT (2))
CALL TAB (14, X, XOUT (1), XOUT (2))
CALL TAB (15, X, XOUT (1), XOUT (2))
CALL TAB (16, X, XOUT (1), XOUT (2))
CALL TAB (17, X, XOUT (1), XOUT (2))
CALL TAB (18, X, XOUT (1), XOUT (2))
CALL TAB (19, X, XOUT (1), XOUT (2))
CALL TAB (20, X, XOUT (1), XOUT (2))
CALL TAB (21, X, XOUT (1), XOUT (2))
CALL TAB (22, X, XOUT (1), XOUT (2))
CALL TAB (23, X, XOUT (1), XOUT (2))
CALL TAB (24, X, XOUT (1), XOUT (2))
CALL TAB (25, X, XOUT (1), XOUT (2))
CALL TAB (26, X, XOUT (1), XOUT (2))
CALL TAB (27, X, XOUT (1), XOUT (2))
CALL TAB (28, X, XOUT (1), XOUT (2))
CALL TAB (29, X, XOUT (1), XOUT (2))
CALL TAB (30, X, XOUT (1), XOUT (2))
CALL TAB (31, X, XOUT (1), XOUT (2))
CALL TAB (32, X, XOUT (1), XOUT (2))
CALL TAB (33, X, XOUT (1), XOUT (2))
CALL TAB (34, X, XOUT (1), XOUT (2))
CALL TAB (35, X, XOUT (1), XOUT (2))
CALL TAB (36, X, XOUT (1), XOUT (2))
CALL TAB (37, X, XOUT (1), XOUT (2))
CALL TAB (38, X, XOUT (1), XOUT (2))
CALL TAB (39, X, XOUT (1), XOUT (2))
CALL TAB (40, X, XOUT (1), XOUT (2))
CALL TAB (41, X, XOUT (1), XOUT (2))
CALL TAB (42, X, XOUT (1), XOUT (2))
CALL TAB (43, X, XOUT (1), XOUT (2))
CALL TAB (44, X, XOUT (1), XOUT (2))
CALL TAB (45, X, XOUT (1), XOUT (2))
CALL TAB (46, X, XOUT (1), XOUT (2))
CALL TAB (47, X, XOUT (1), XOUT (2))
CALL TAB (48, X, XOUT (1), XOUT (2))
CALL TAB (49, X, XOUT (1), XOUT (2))
CALL TAB (50, X, XOUT (1), XOUT (2))
CALL TAB (51, X, XOUT (1), XOUT (2))
CALL TAB (52, X, XOUT (1), XOUT (2))
CALL TAB (53, X, XOUT (1), XOUT (2))
CALL TAB (54, X, XOUT (1), XOUT (2))
CALL TAB (55, X, XOUT (1), XOUT (2))
CALL TAB (56, X, XOUT (1), XOUT (2))
CALL TAB (57, X, XOUT (1), XOUT (2))
CALL TAB (58, X, XOUT (1), XOUT (2))
CALL TAB (59, X, XOUT (1), XOUT (2))
CALL TAB (60, X, XOUT (1), XOUT (2))
CALL TAB (61, X, XOUT (1), XOUT (2))
CALL TAB (62, X, XOUT (1), XOUT (2))
CALL TAB (63, X, XOUT (1), XOUT (2))
CALL TAB (64, X, XOUT (1), XOUT (2))
CALL TAB (65, X, XOUT (1), XOUT (2))
CALL TAB (66, X, XOUT (1), XOUT (2))
CALL TAB (67, X, XOUT (1), XOUT (2))
CALL TAB (68, X, XOUT (1), XOUT (2))
CALL TAB (69, X, XOUT (1), XOUT (2))
CALL TAB (70, X, XOUT (1), XOUT (2))
CALL TAB (71, X, XOUT (1), XOUT (2))
CALL TAB (72, X, XOUT (1), XOUT (2))
CALL TAB (73, X, XOUT (1), XOUT (2))
CALL TAB (74, X, XOUT (1), XOUT (2))
CALL TAB (75, X, XOUT (1), XOUT (2))
CALL TAB (76, X, XOUT (1), XOUT (2))
CALL TAB (77, X, XOUT (1), XOUT (2))
CALL TAB (78, X, XOUT (1), XOUT (2))
CALL TAB (79, X, XOUT (1), XOUT (2))
CALL TAB (80, X, XOUT (1), XOUT (2))
CALL TAB (81, X, XOUT (1), XOUT (2))
CALL TAB (82, X, XOUT (1), XOUT (2))
CALL TAB (83, X, XOUT (1), XOUT (2))
CALL TAB (84, X, XOUT (1), XOUT (2))
CALL TAB (85, X, XOUT (1), XOUT (2))
CALL TAB (86, X, XOUT (1), XOUT (2))
CALL TAB (87, X, XOUT (1), XOUT (2))
CALL TAB (88, X, XOUT (1), XOUT (2))
CALL TAB (89, X, XOUT (1), XOUT (2))
CALL TAB (90, X, XOUT (1), XOUT (2))
CALL TAB (91, X, XOUT (1), XOUT (2))
CALL TAB (92, X, XOUT (1), XOUT (2))
CALL TAB (93, X, XOUT (1), XOUT (2))
CALL TAB (94, X, XOUT (1), XOUT (2))
CALL TAB (95, X, XOUT (1), XOUT (2))
CALL TAB (96, X, XOUT (1), XOUT (2))
CALL TAB (97, X, XOUT (1), XOUT (2))
CALL TAB (98, X, XOUT (1), XOUT (2))
CALL TAB (99, X, XOUT (1), XOUT (2))
CALL TAB (100, X, XOUT (1), XOUT (2))

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

```



```

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
        ZTCUT=PTIN-DP
        TOUT=0.30185*HP+247.0+TO
        RHO=(PS-DP)/(R*TOUT)
        V=W/(RHO*DATA1)
        PV=RHO*V**2/(2.0*32.174)
        GO TC 140

```

```

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    CCNTINUE
        RETURN
        END

```



```

+ DATA4,TYPE,DELP,0.,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
+ VDNB,VDWM,VDWC,0.,TO)
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+DF45
TIN=T4
DP45=0.0
C COMPUTE LOSSES FOR FITTINGS
DO 60 I=1,N
TYPE=WORKI(I,2)
DATA1=WORKR(I,1)
DATA2=WORKR(I,2)
DATA3=WORKR(I,3)
DATA4=WORKR(I,4)
CALL FITDP(C,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.,10)
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 FANF=(DP24+DP45+DP12)/5.19696
CALL FANMAT(WC,TO,PO,FANF,RHOSTD,CFM0,CFMMAX,DPMAX,K,WCN)
C IF COILING FLOW MATCHES YOU ARE FINISHED
TEST=ABS(WCN-WC)
WC=WCN
C IF (TEST.GT.0.1) GO TO 5
WRITE PERFORMANCE INFORMATION TO THE OUTPUT FILE
+ CALL OUTPUT(70,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
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 CCNTINUE
600 FORMAT(' POWER POINT IS NOT ON THE PERFORMANCE MAP.')
601 + /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

```



```

DP(I)=DEL P
DP35=DP35+DEL P
FITPV(I)=PV
PTIN=PTOUT
TIN=TOUT
C      LOSS IN THE MAIN ENGINE EXHAUST FLOW FOR NOLE 5, ENERGY IS
C      TRANSFERED TO THE MODULE COOLING FLOW AS A PRESSURE GAIN.
35     IF (TYPE.EQ.16) LOSS=DEL P
C     CONTINUE
C     CCMPARE 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=PO*144.0+DP35+DP56
GO TO 30
40     CCNTINUE
C     COMPARE ASSUMED LOSSES TO COMPUTED LOSSES REPEAT ITERATION
IF REQUIRED
INLOSS=INLOSS*5.19696
EXLOSS=EXLOSS*5.19696
TEST1=ABS(DP12+DP23-INLOSS)
TEST2=ABS(DP35+DP56-EXLOSS)
INLOSS=(DP12+DE23)/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=BR
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,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,0.,
+     VDWB,VDWM,VDWC,0.,T0)
DP(I)=DEL P
DP24=DP24+DEL P
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=DR
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)=DEL P
DP45=DP45+DEL P
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=DEL P

```

```

        IF (TYPE.EQ.26) TMOD=TCUT
60  C  CCN=TIME
      C  TEST=1 THAT EXIT PRESSURE IS PT5, IF NOT REPEAT
      C  TEST=ABS(PTOUT-PT5)
      C  IF (TEST.LT.1.0) GO TO 70
      C  COOLING FLOW IN INCREASED BY SMALL STEPS UNTIL SYSTEM IS
      C  MATCHED
      C  WC=WC+0.1
      C  GO TO 5
70  C  SYSTEM IS MATCHED PRINT RESULTS
      C  CALL OUTPUT(TO,PO,HUMID,HP,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,PC,
      C  *  X2,X3,P8,P3,SPC,I54,NG,SERIAL,TMOD)
      C  DP12=DP12/5.196996
      C  DP23=DP23/5.196996
      C  DP35=DP35/5.196996
      C  DP56=DP56/5.196996
      C  DP24=DP24/5.196996
      C  DP45=DP45/5.196996
      C  PRINT BRANCH LOSS SUMMARY
      C  *WRITE (4,601) DP12,DP23,DP35,DP56,DP24,DP45
500  C  CONTINUE
600  C  FORMAT(' POWER POINT IS NOT ON THE PERFORMANCE MAP.')
601  C  FORMAT(/5X,'LOSS BRANCH 1-2:',F12.2,/5X,'LOSS BRANCH 2-3:',F12.2,
      C  * /5X,'LOSS BRANCH 3-5:',F12.2,/5X,'LOSS BRANCH 5-6:',F12.2,
      C  * /5X,'LOSS BRANCH 2-4:',F12.2,/5X,'LOSS BRANCH 4-5:',F12.2)
      C  RETURN
      C  END

```

```

C*****
C      SYSTEM FOUR MATCHING SUBROUTINE
C
C      THIS SYSTEM HAS SEPARATE INLETS FOR THE ENGINE AIR FLOW AND
C      MODULE COOLING.  NODE 5 IS THE JUNCTION OF MODULE AIR AND
C      ENGINE EXHAUST.  FOR THE ASSUMED FLOW THE PRESSURE AT NODE
C      5 IS COMPUTED DOWN THE COMBINED EXHAUST.  THEN THE EXIT
C      PRESSURE FROM BRANCHES 3-5 AND 4-5 SHOULD MATCH P15.  IF NOT
C      THE ITERATION PROCESS CONTINUES.
C*****
C      SUBROUTINE SYS4 (SERIAL, N, WORKI, WORKR, HP, NPT, FIT1ST, T0, P0, HUMID,
C      + ALFAC, ACWB, ACWC, ACWM,
C      + RHOSTD, CFM0, CFMAX, DPMAX, K)
C      REAL WORKR, HP, NPT, T0, P0, HUMID, CFMAX, CFM0, DPMAX, K, W2, W8, P8, T8,
C      + INLOSS, EXLOSS, P15, P14, DP13, DP2, DP35, DP45, PV, PTIN, PTOU, DATA1,
C      + DATA2, DATA3, TEST, DP, FITPV, WC, RHOSTD, TEST1, TEST2, WCN, TMOD,
C      + T54, SFC, NG, DP56
C      DATA 4, R, ALFAC, ACWB, ACWC, ACWM, VCWB, VCWC, VCWM, TMAIN, TMOD, HSEC,
C      + HMAIN, RHSTACK, I4, T5, W, GAIN, LOSS, PSEC, PMAIN, P14, P15, TEST1, TEST2,
C      + PVB, PVC, PVM, PSB, PSC, PSM, RHOCBT, RHOCCT, RHOCMT, TEST1, TEST2
C      INTEGER WORKI, FIT1ST, OFF, N, PP, QQ, RR, SS, TT, A, B, C, D, E, SERIAL, TYPE,
C      + IND
C      DIMENSION WORKI(200, 2), WORKR(200, 4), FIT1ST(6), DP(200), FITPV(200)
C      GAS CONSTANT
C      DATA R/53.3424/
C      THE STARTING AND STOPPING INDEX FOR A BRANCH IS COMPUTED
C      PP=FIT1ST(2) - 1
C      QQ=FIT1ST(3) - 1
C      RR=FIT1ST(4) - 1
C      SS=FIT1ST(5) - 1
C      TT=FIT1ST(6) - 1
C      U=FIT1ST(7)
C      V=FIT1ST(8)
C      W=FIT1ST(9)
C      INITIALIZE THE INLET AND EXHAUST LOSSES
C      INLOSS=4.0
C      EXLOSS=9.0
C      INITIALIZE THE GAIN AND LOSS AT NODE 5
C      GAIN=-30.0
C      LOSS=30.0
C      INITIALIZE THE COOLING FLOW
C      WC=CFMAX*RHOSTD/60.0
C      INITIALIZE THE BRANCH LOSSES
C      DP45=100.0
C      DP56=100.0
C      INITIALIZE THE MODULE TEMPERATURE
C      TMOD=710.0
C      INITIALIZE THE PRESSURES AT NODE 5
C      P15=P0*144.0+DP56
C      PMAIN=P15+LOSS
C      PSEC=P15+GAIN
C      SEARCH FOR A WASTE HEAT BOILER IN BRANCH 3-5
C      IND=0
C      DO 4 I=C, SS
C      TYPE=WORKI(I, 2)
C      IF (TYPE.EQ.27) IND=1
C      CONTINUE
C      GET INITIAL PERFORMANCE OF ENGINE WITH ASSUMED CONDITIONS
C      CALL ENGINE (INLOSS, EXLOSS, T0, P0, HUMID, HP, NPT, W2, W8, P8, T8, SFC,
C      + T54, NG, OFF)
C      IF (OFF.EQ.0) GO TO 6
C      WRITE(6, 600)
C      GO TO 500
C      CONTINUE
C      INITIALIZE INLET CONDITIONS FOR BRANCH 1-3
C      DP13=0.0
C      PTIN=P0*144.0
C      TIN=T0+459.7

```



```

FITPV(I)=PV
PTIN=PTOUT
TIN=TOUT
IF (TYPE.EQ.26) TMOD=TOUT
20 CCN=1
FI4=PTOUT
T4=TOUT
C INITIALIZE INLET CONDITIONS FOR BRANCH 4-5
PTIN=PT4+(K*((WC/RHOSD*60.0)-CFMMAX)**2+DPMAX)*5.19696
TIN=FI4
DP45=0.0
C COMPUTE FITTING LOSSES
DO 60 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,HD,PTIN,TIN,PTOUT,TOUT,PV,DATA1,DATA2,DATA3,
+ DATA4,TYPE,DELTA,ALFAC,ALFACB,ALFACM,ALFAC,0.,0.,0.,VCFB,VCFM,
+ VCF,0.,0.,0.,RHOC,10)
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(TO,PO,HUMID,HE,NPT,N,WORKI,DP,FITPV,INLOSS,EXLOSS,WC,
+ DP13,DP24,DP35,DP45,DP56,SFC,T54,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 CCN=1
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 SYSTEM FIVE MATCHING SUBROUTINE
C
C THIS SYSTEM HAS COMBINED INLETS AND EXHAUST FLOWS FOR THE ENGINE
C AND THE MODULE COOLING. THERE IS NO COOLING FAN. THE MOVEMENT
C OF COOLING AIR IS ACCOMPLISHED BY AN EDUCTOR ARRANGEMENT AT THE
C ENGINE EXHAUST PLANE. THERE IS A TRANSFER OF MOMENTUM FROM A
C HIGH SPEED JET (ENGINE EXHAUST THROUGH A NOZZLE) TO A LOW SPEED
C JET (MODULE COOLING FLOW). THE SCHEME IS TO START WITH A SMALL
C COOLING FLOW AND SEE IF THERE IS ENOUGH GAIN AVAILABLE FROM THE
C EDUCTOR ARRANGEMENT TO MOVE THE AIR. A PROPERLY DESIGNED SYSTEM
C WILL HAVE EXCESS GAIN AT THIS LOW FLOW AND THE ITERATION PROCESS
C CAN CONTINUE, INCREASING THE COOLING FLOW UNTIL THE SYSTEM IS
C MATCHED.
C*****
C SUBROUTINE SYS5 (SERIAL, N, WORKI, WORKR, HP, NPT, FIT1ST, TO, PO, HUMID,
C + ALFAD, ADWB, ADWC, ADWM, ALFAC, ACWB, ACWC, ACWM)
C REAL WORKE, HP, NPT, TO, PO, HUMID, CFMAX, CFMO, DPMAX, K, W2, W8, P8, T8
C + EXLOSS, FANDB, DP13, DP24, DP35, DP45, PV, PTIN, PTOUT, DATA1,
C + DATA2, DATA3, TEST, DP, FITPV, WC, RHOSID, TEST1, TEST2, GCN, TMOD,
C + T54, SFC, NG, DP56
C + DATA4, R, ALFAC, ACWB, ACWC, ACWD, VCWB, VCWC, VCWM, TMAIN, TMOD, HSEC,
C + HMAIN, HSTACK, T4, T5, W, GAIN, LOSS, PSEC, PMAIN, PT4, PT5, TEST3,
C + FVB, PVC, PVM, PSB, PSC, PSM, RHOCBT, RHOCCT, RHOCMT, TEST1, TEST2
C + INTEGER WORKI, FIT1ST, OFF, N, PP, QQ, RR, SS, A, B, C, D, SERIAL, TYPE,
C + IND
C DIMENSION WORKI(200,2), WORKR(200,4), FIT1ST(6), DP(200), FITPV(200)
C GAS CONSTANT
C DATA R/53.3424/
C COMPUTE THE STARTING AND STOPPING POINTS FOR THE BRANCH FITTINGS.
C PP=FIT1ST(2) -1
C CC=FIT1ST(3) -1
C RE=FIT1ST(4) -1
C SS=FIT1ST(5) -1
C A=FIT1ST(2)
C B=FIT1ST(3)
C C=FIT1ST(4)
C D=FIT1ST(5)
C INITIALIZE THE INLET AND EXHAUST LOSSES (INCH WG)
C INLOSS=4.0
C EXLOSS=8.0
C INITIALIZE THE GAIN OR PRESSURE RISE TO MODULE AIR FLOW IN THE
C EDUCTOR
C GAIN=-30.0
C LOSS=30.0
C INITIALIZE THE COOLING FLOW TO THE MINIMUM REQUIRED FOR THE ENGINE
C WC=7.5
C INITIALIZE PARAMETERS TO START ITERATION
C DP56=100.0
C TMOD=710.0
C FTS=PO*144.0+DP56
C PGAIN=PT5+LOSS
C PSEC=PT5+GAIN
C SEARCH FOR A WASTE HEAT BOILER, THERE PROBABLY IS NOT A BOILER
C INSTALLED IN THIS SYSTEM.
C IND=0
C DO 4 I=C,SS
C TYPE=WORKI(I,2)
C IF (TYPE.EQ.27) IND=1
C CONTINUE
C GET ENGINE PERFORMANCE BASED ON ASSUMED CONDITIONS
C CALL ENGINE(INLOSS, EXLOSS, TO, PO, HUMID, HP, NPT, W2, W8, P8, T8, SFC,
C + T54, NG, OFF)
C IF (OFF.EQ.0) GC TO 6
C WRITE(6,600)
C GO TO 500
C CONTINUE
C INITIALIZE INLET CONDITIONS FOR BRANCH 1-2

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```

TEST=ABS (PTOUT-PT5)
IF (TEST.LT.1.0) GO TO 40
PTIN=PO*144.0+DP35+DP56
GO TO 30
40 C 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
C 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=TO+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,TCOUT,PV,DATA1,DATA2,DATA3,
+ DATA4,TYPE,DELP,ALFAC,0.,ACWB,ACWM,ACWC,0.,0.,0.,VCWB,VCWM,
+ VCWC,0.,J,0.,RHOCC,TO)
DE (I)=DELP
DP25=DP25+DELP
FITPV (I)=PV
PTIN=PTCUT
TIN=TCOUT
C GAIN IS FROM MOMENTUM TRANSFER FROM ENGINE EXHAUST
IF (TYPE.EQ.15) GAIN=DELP
IF (TYPE.EQ.26) TMOD=TCOUT
60 C 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 FLOW UNTIL SYSTEM IS MATCHED
WC=WC+0.1
GO TO 5
70 C SYSTEM IS MATCHED, OUTPUT RESULTS
CALL OUTPUT (TO,PO,HUMID,HP,WPT,N,WORKI,IP,FITPV,INLOSS,EXLOSS,WC,
+ DP12,DP23,DP35,DP56,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 C 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 SYSTEM SIX MATCHING SUBROUTINE
C*****
C THIS SYSTEM HAS SEPARATE INLETS FOR COOLING FLOW AND ENGINE AIR.
C THE TWO FLCW JCIN AT AN EDUCTOR ARRANGEMENT 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 (MODULE COOLING FLOW) .
C*****
C SUBROUTINE SYS6 (SERIAL,N,WORKI,WORKR,HP,NPT,FIT1ST,TO,PO,HUMID,
+ ALFAC,ACWB,ACWC,ACWM)
C REAL WORKR,HP,NPT,TO,PO,HUMID,CFMAX,CFMO,DPMAX,K,W2,W8,P8,T8,
+ INLOSS,EXLOSS,DP13,DP25,DP35,DP56,PV,PTIN,PTOUT,DATA1,
+ DATA2,DATA3,TSST,DP,FITPV,WC,RHOSID,TEST1,TEST2,WCN,TMOD,
+ T54,SFC,NG
+ DATA4,R,ALFAC,ACWB,ACWC,ACWM,VCWB,VCWC,VCWM,PMAIN,TMOD,HSEC,
+ HMAIN,HSTACK,IS,W,GAIN,LOSS,PSEC,PMAIN,PTS,TEST3
+ PVB,PVC,PVH,PSB,PSC,PSI,RHOCBT,RHOCCT,RHCCMT,TEST1,TEST2
+ INTEGER WORKI,FIT1ST,OFF,N,PP,QQ,RR,A,B,C,SERIAL,TYPE,
+ IND
C DIMENSION WORKI(200,2),WORKR(200,4),FIT1ST(6),DP(200),FITPV(200)
C GAS CONSTANT
C DATA R/53.3424/
C STARTING AND STOPPING POINTS FOR THE BRANCH FITTING INDEX
C PP=FIT1ST(2)-1
C QQ=FIT1ST(3)-1
C RR=FIT1ST(4)-1
C A=FIT1ST(2)
C B=FIT1ST(3)
C C=FIT1ST(4)
C INITIALIZE THE INLET AND EXHAUST DUCT LOSSES (INCH WG)
C INLOSS=4.0
C EXLOSS=8.0
C INITIALIZE THE GAIN AND LOSS IN THE EDUCTOR (PSF)
C GAIN=30.0
C LOSS=30.0
C INITIALIZE THE COOLING FLOW TO THE MINIMUM REQUIRED
C WC=7.5
C INITIALIZE OTHER VALUES
C DP56=100.0
C TMOD=710.0
C PT5=PO*144.0+DP56
C PMAIN=PT5+LOSS
C PSEC=PT5+GAIN
C SEARCH FOR A BOILER, THERE PROBABLY IS NOT ONE INSTALLED FOR THIS
C SYSTEM
C IND=0
C DO 4 I=C,RR
+ TYPE=WORKI(I,2)
+ IF (TYPE.EQ.27) IND=1
C CONTINUE
C GET ENGINE PERFORMANCE FOR THE ASSUMED CONDITIONS
C CALL ENGINE(INLOSS,EXLOSS,TO,PO,HUMID,HP,NPT,W2,W8,P8,T8,SFC,
+ T54,NG,OFF)
C IF (OFF.EQ.0) GO TO 6
C WRITE(6,600)
C GO TO 500
C CONTINUE
C INITIALIZE THE INLET CONDITIONS FOR BRANCH 1-3
C DP13=0.0
C PTIN=PO*144.0
C TIN=TO+459.7
C COMPUTE FITTING LOSSES
C DO 8 I=1,PP
+ TYPE=WORKI(I,2)
+ DATA1=WORKR(I,1)
+ DATA2=WORKR(I,2)

```



```

12      TIN=TOUT
      CCNTINUE
      EXIT TEMPERATURE SHOULD BE AT ATMOSPHERIC IF NOT REPEAT ITERATION
      TEST=ABS(PTOUT-PT0*144.0)
      IF (TEST.LT.1.0) GO TO 14
      GO TO 11
14      CONTINUE
      PT5=PT0*144.0+DP56
      INITIALIZE INLET CONDITIONS FOR BRANCH 3-5
      PTIN=PT8*144.0
      TIN=T8
      DP35=0.0
      CCMPUTE FITTING LOSSES
      DO 20 I=B,RR
          TYPE=WORKR(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,ALFAD,0.,0.,0.,ADWB,ADWM,ADWC,0.,0.,
+             VDWB,VDWM,VDWC,0.,0.,TO)
          DP(I)=DELP
          DP35=DP35+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
          IF (TYPE.EQ.16) LOSS=DELP
20      CCNTINUE
      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
      INITIALIZE INLET CONDITIONS FOR BRANCH 2-5
30      PTIN=PT0*144.0
      TIN=T0+459.7
      DP25=0.0
      CCMPUTE FITTING LOSSES
      DO 35 I=A,QQ
          TYPE=WORKR(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,TO)
          DE(I)=DELP
          DP25=DP25+DELP
          FITPV(I)=PV
          PTIN=PTOUT
          TIN=TOUT
      GAIN IS RESULT OF MOMENTUM TRANSFER FROM EXHAUST TO COOLING
      FLCH
      IF (TYPE.EQ.15) GAIN=DELP
      IF (TYPE.EQ.26) TMOD=TOUT
35      CONTINUE
      EXIT PRESSURE SHOULD BE PT5, IF NOT REPEAT ITERATION
      TEST=ABS(PTOUT-PT5)
      IF (TEST.LT.1.0) GO TO 40
      NEXT ITERATION IS DONE WITH INCREASED COOLING FLOW, INCREASE
      UNTIL SYSTEM IS MATCHED
      WC=WC+0.1
      GC TO 5
40      CONTINUE

```



```

C      SYSTEM IS MATCHED, OUTPUT RESULTS
70    CALL OUTPUT(TO,FO,HUMID,HE,NPT,H,WORNI,DP,FITPV,INLCSS,EXLOSS,WC,
      * W2,W3,P3,T3,SFC,T54,IG,SERIAL,IMOD)
      DP13=DP13/S.196696
      DP25=DP25/S.196696
      DP35=DP35/S.196696
      DP56=DP56/S.196696
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      FAN MATCHING SUBROUTINE
C
C      THIS SUBROUTINE PRODUCES THE NEXT GUESS AT COOLING FLOW BY
C      LOCATING THE INTERSECTION OF THE SYSTEM MODEL CURVE AND THE
C      FAN CHARACTERISTIC CURVE.
C*****
C      SUBROUTINE FANMAT(WC, TO, PO, FANDP, RHOSTD, CFM0, CFMMAX, DPMAX, K, WCN)
C      REAL CFMSTD, DPSTD, WC, RHOSTD, FANDP, PO, TO, C, CFM, WCN, CFM0, CFMMAX,
C      + DPMAX, K, R
C      GAS CONSTANT
C      DATA R/53.3424/
C      CONVERT MASS FLOW TO STANDARD VOLUME FLOW (CFM)
C      CFMSTD=WC/RHOSTD*60.0
C      CONVERT FAN DELTA PRESSURE TO STANDARD CONDITIONS FOR THE FAN
C      DPSTD=FANDP*(RHOSTD*R*(TO+459.7)/(PO*144.0))**2
C      C IS THE PROPORTIONALITY CONSTANT FOR THE QUADRATIC MODEL ASSUMED
C      TO REPRESENT THE SYSTEM
C      C=DPSTD/CFMSTD**2
C      CFM IS THE INTERSECTION OF THE FAN CHARACTERISTIC AND SYSTEM
C      MODEL
C      CFM=(2.0*K*CFMMAX-SQRT((2.0*K*CFMMAX)**2-4.0*(K-C)*(K*CFMMAX**2
C      +DPMAX)))/(2.0*(K-C))
C      CONVERT CFM TO MASS FLOW
C      WCN=RHOSTD*CFM/60.0
C      RETURN
C      END

```

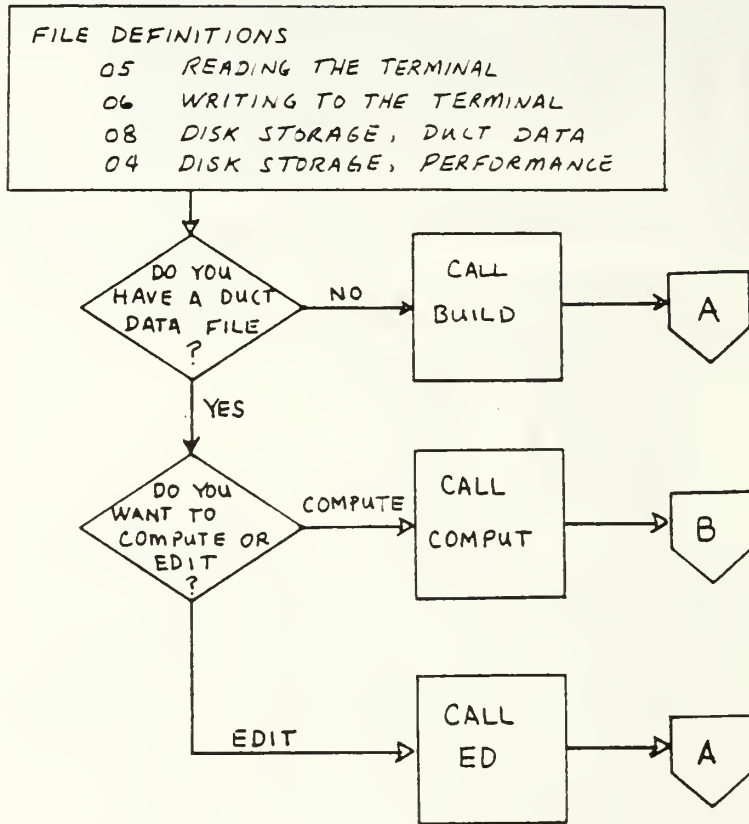
```

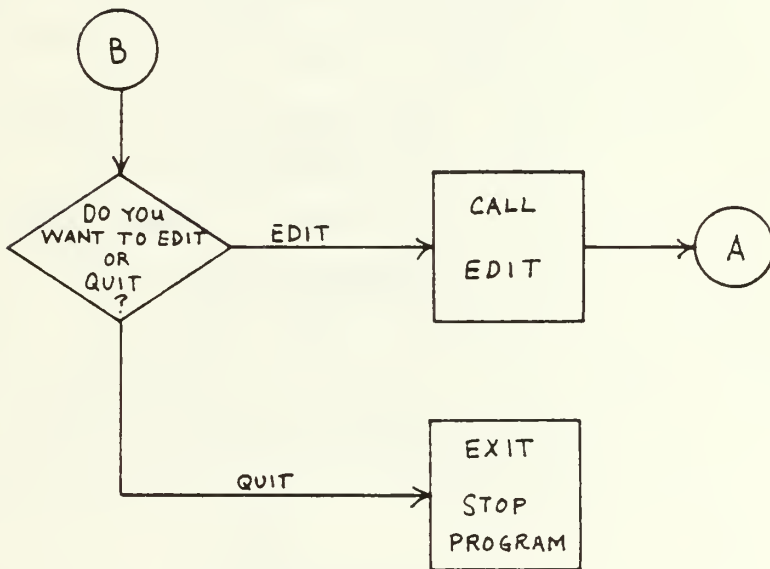
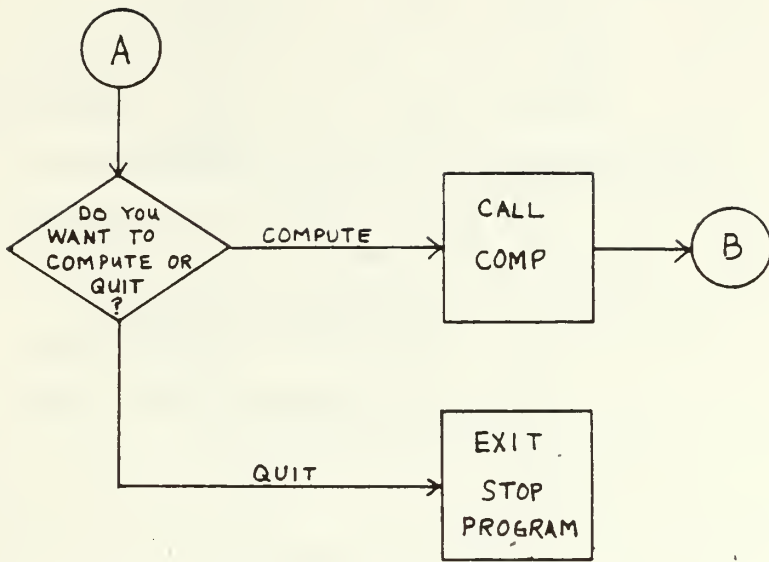
C*****
C      COMPUTE OUTPUT SUBROUTINE: PRINTS SYSTEM DATA
C*****
C      THIS SUBROUTINE WRITES TO THE OUTPUT FILE.  IF YOU HAVE AN OUTPUT
C      FILE ALREADY IT WILL BE WRITTEN OVER BY THIS PROGRAM.  IF YOU
C      WANT TO SAME THE PREVIOUS RESULTS, RENAME THE FILE.  IF YOU ADD
C      OF CHANGES FITTINGS YOU MUST MAKE SOME CHANGES HERE.
C*****
C      SUBROUTINE JUTPUT(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,
+      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
DC 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)

```


APPENDIX B
FLOW CHARTS

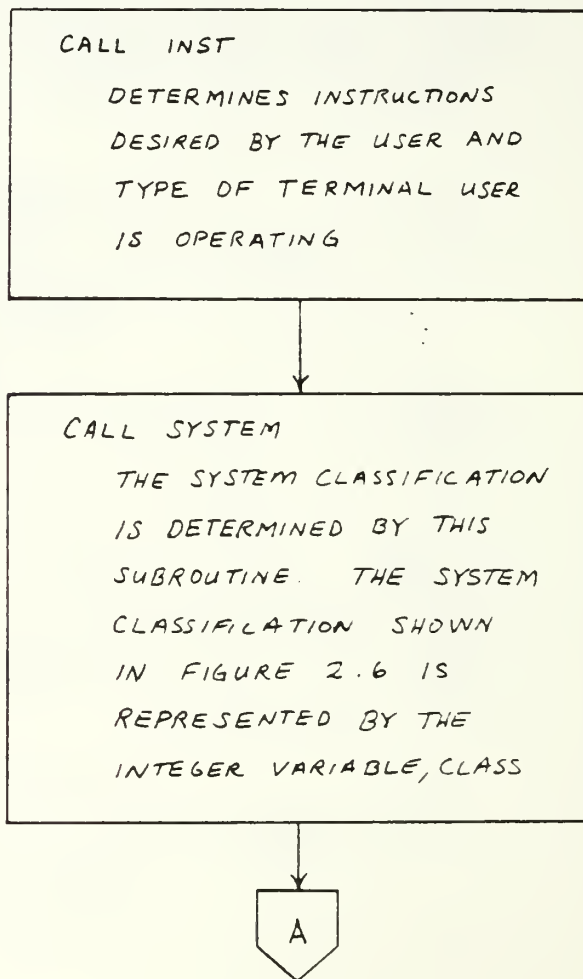
I. MAIN PROGRAM NO INPUT OR OUTPUT VARIABLES

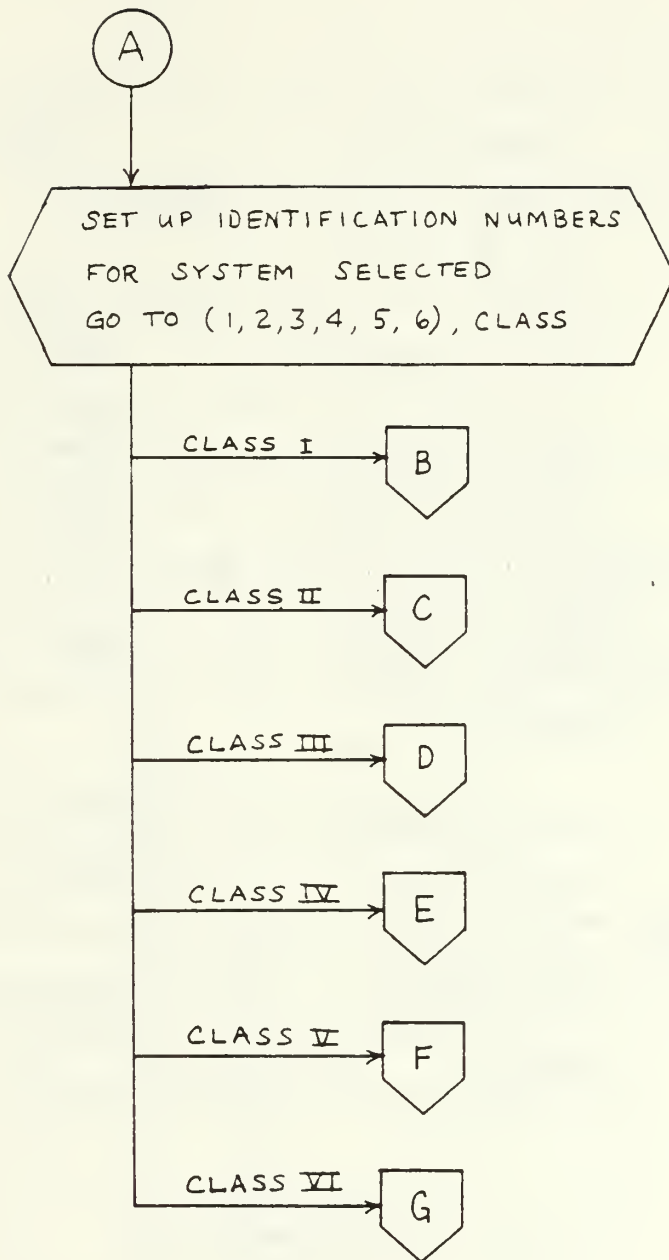




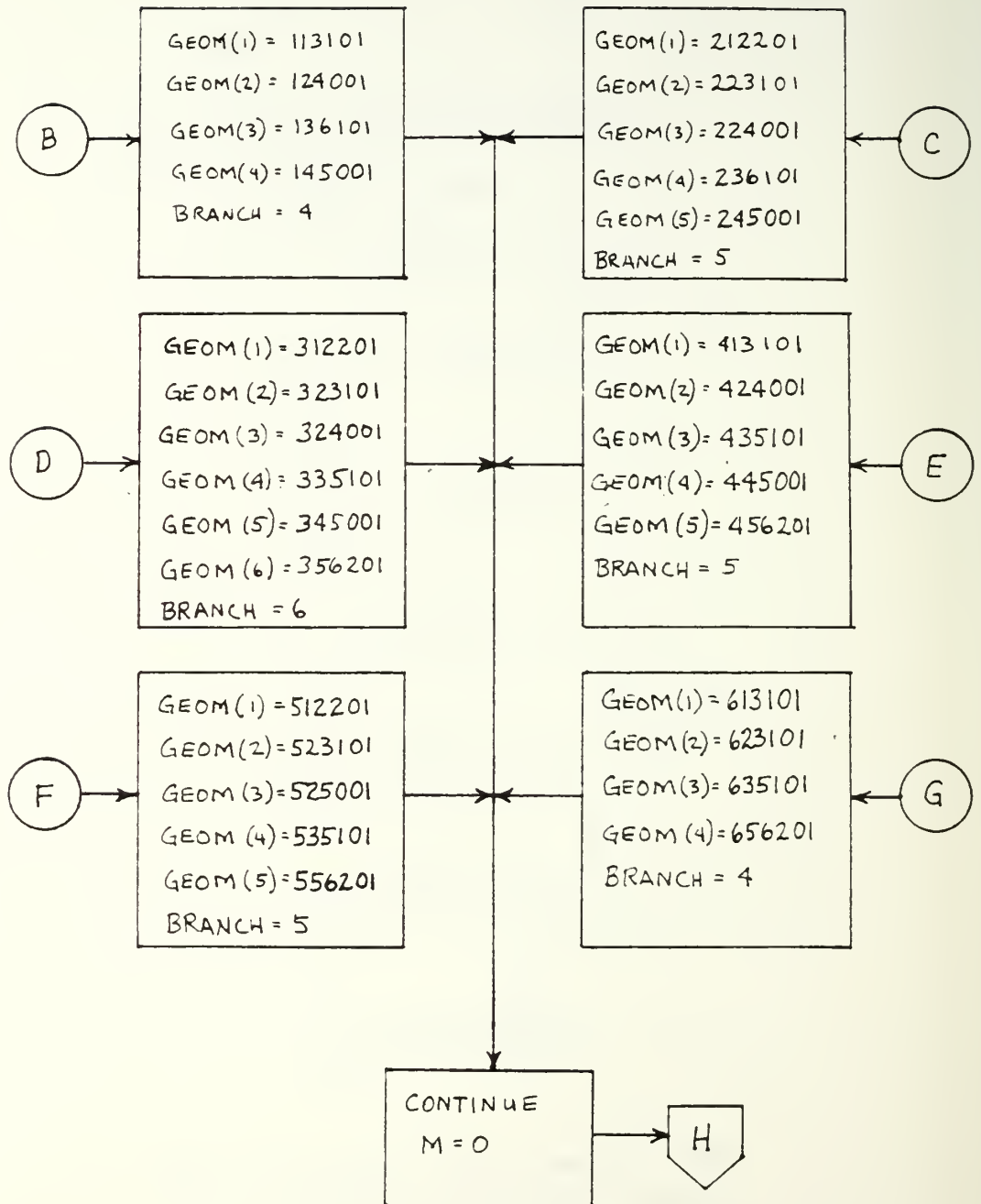
II. BUILD SUBROUTINE

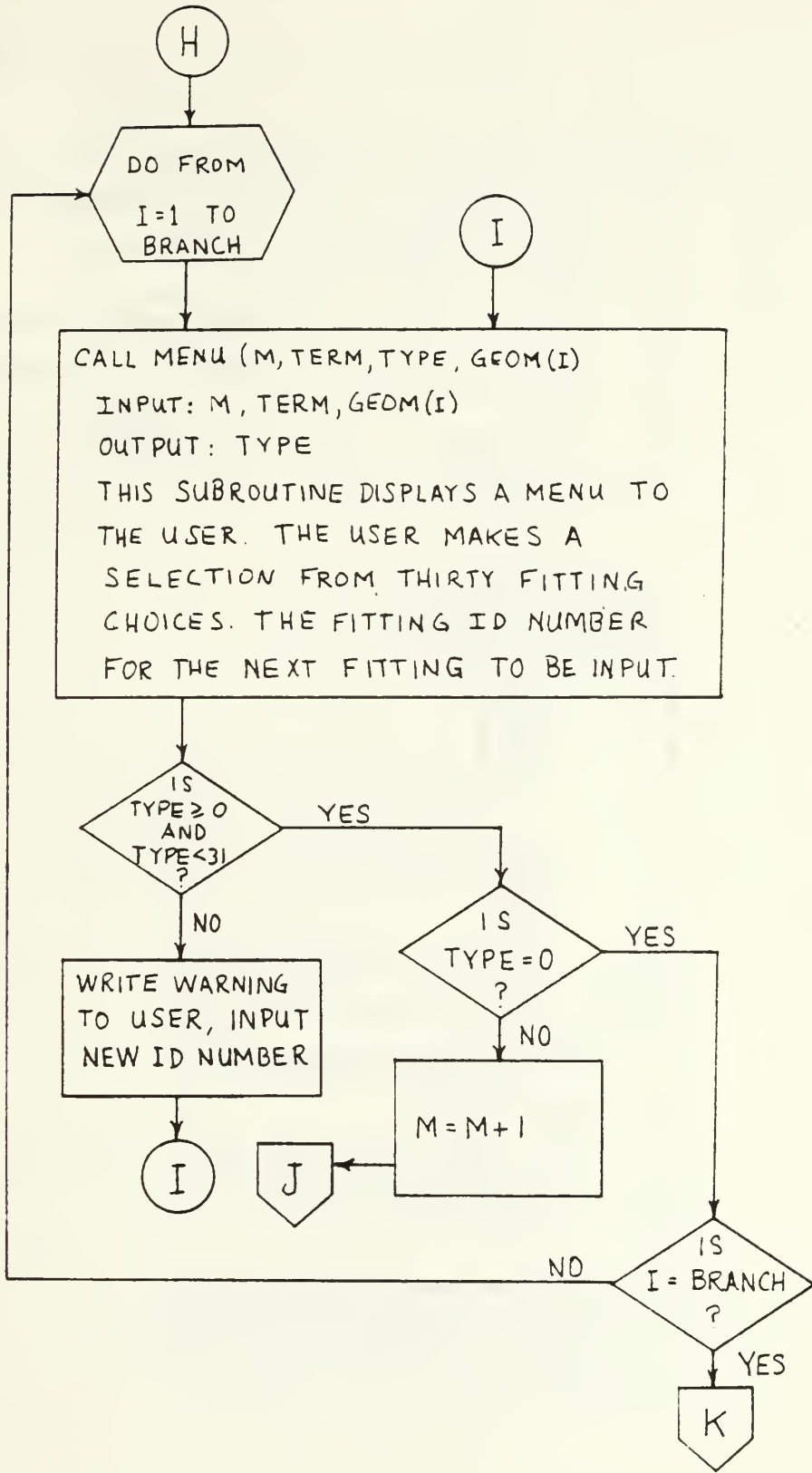
THERE ARE NO INPUT OR OUTPUT VARIABLES FOR THIS SUBROUTINE, HOWEVER SUBROUTINES CALLED BY THE BUILD SUBROUTINE DO HANDLE INPUT AND OUTPUT DATA.

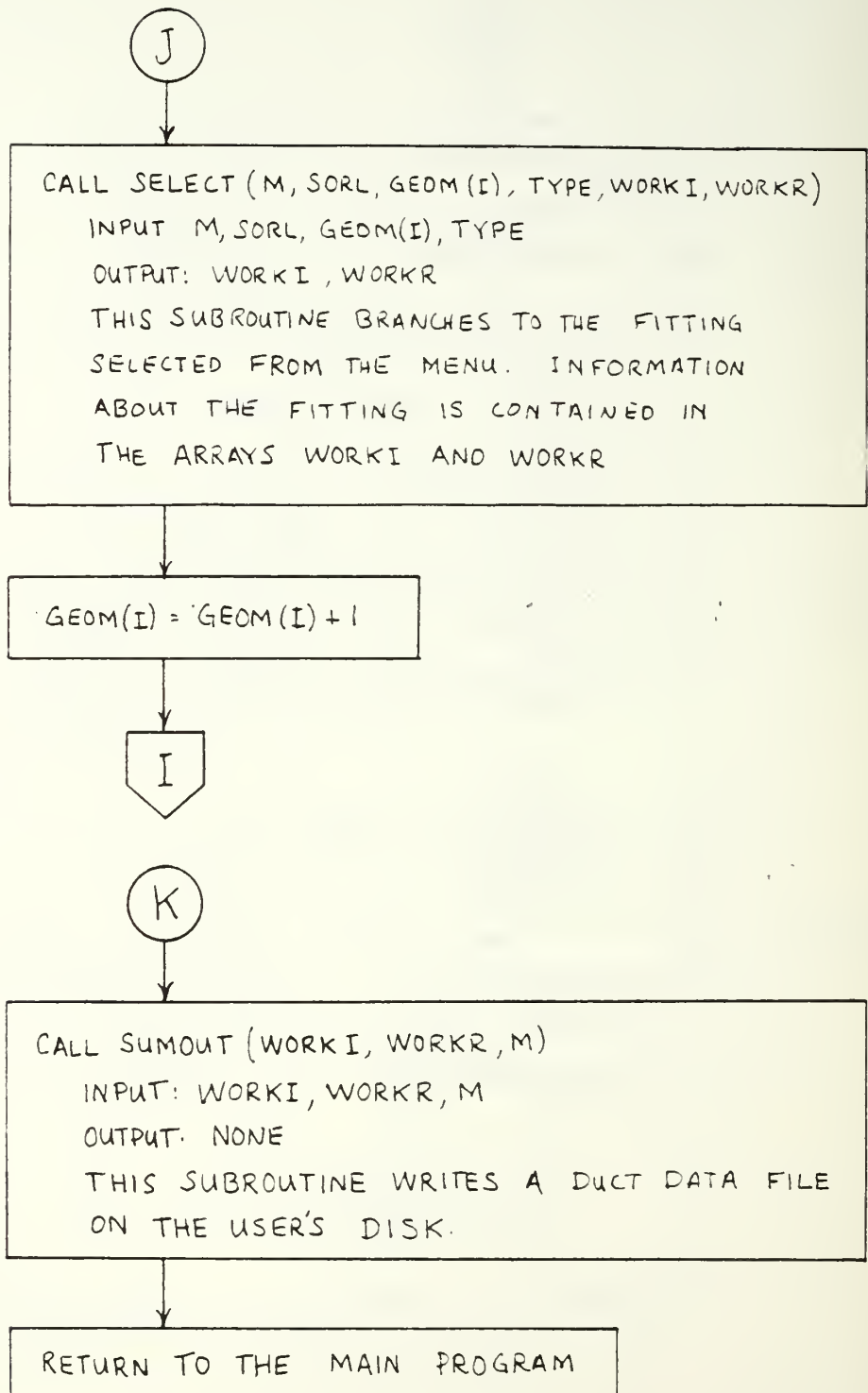




SEE THE PRELIMINARY SECTION OF THE
USERS MANUAL FOR EXPLANATION OF
IDENTIFICATION NUMBERS.

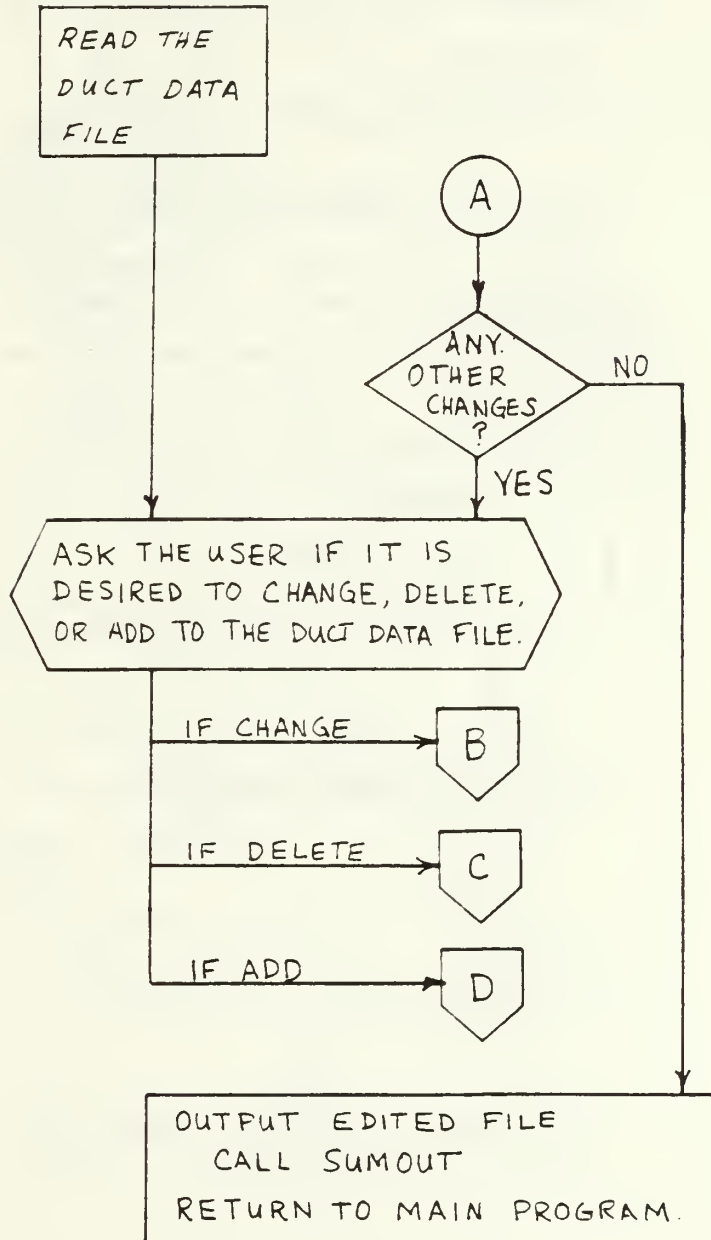


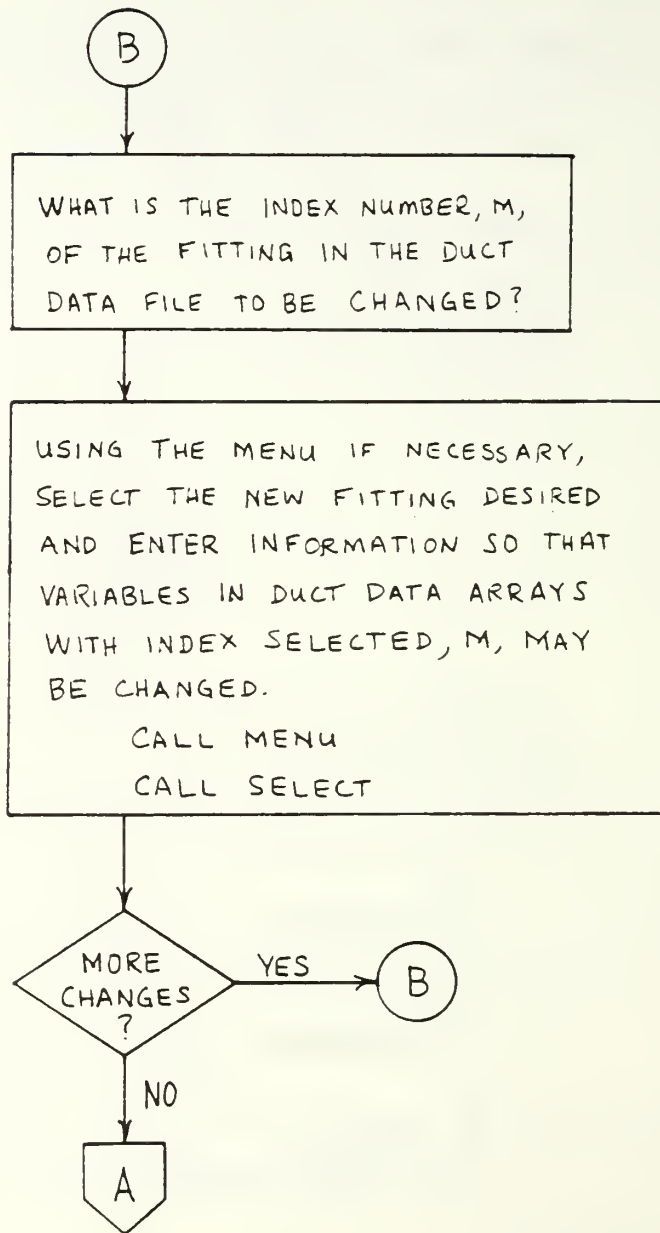


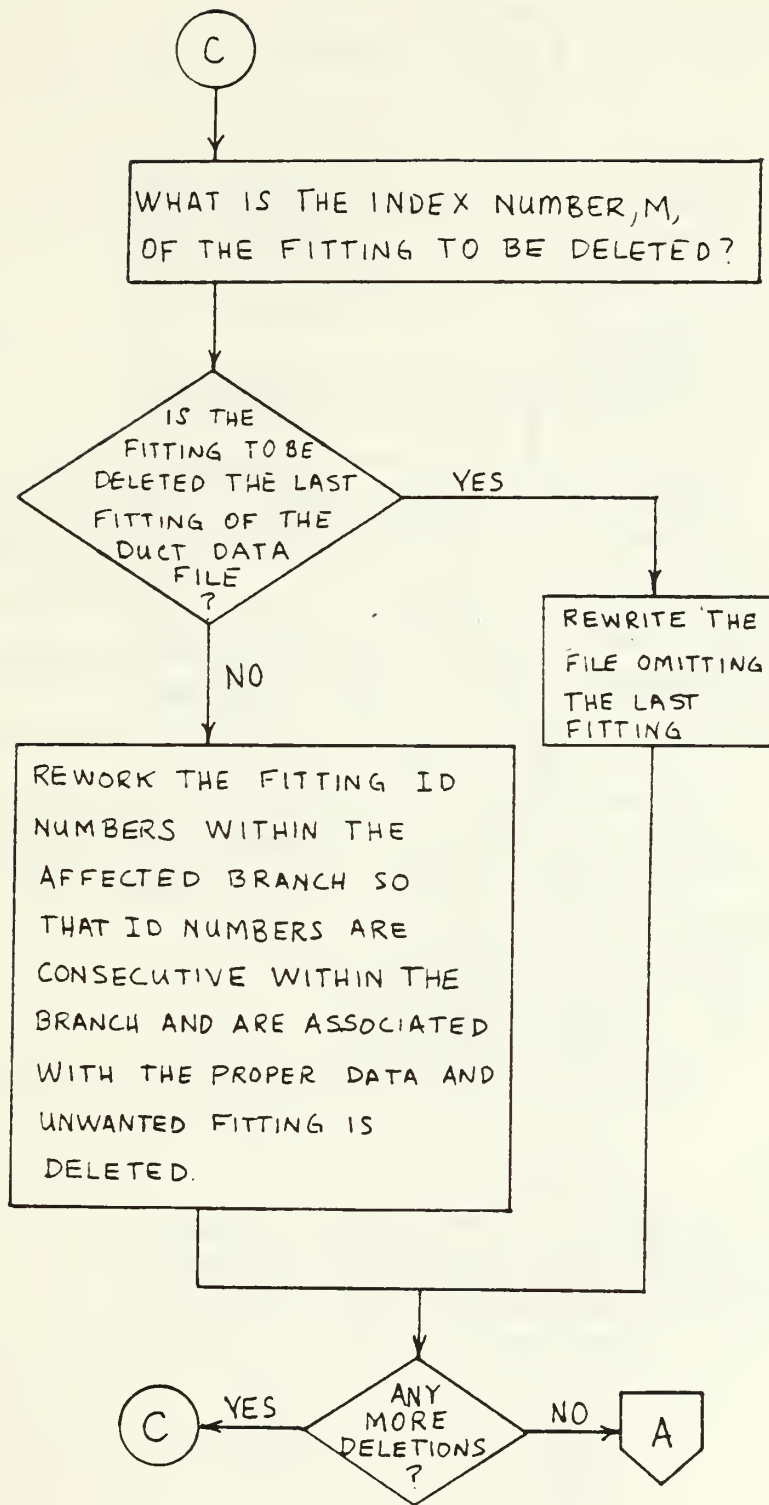


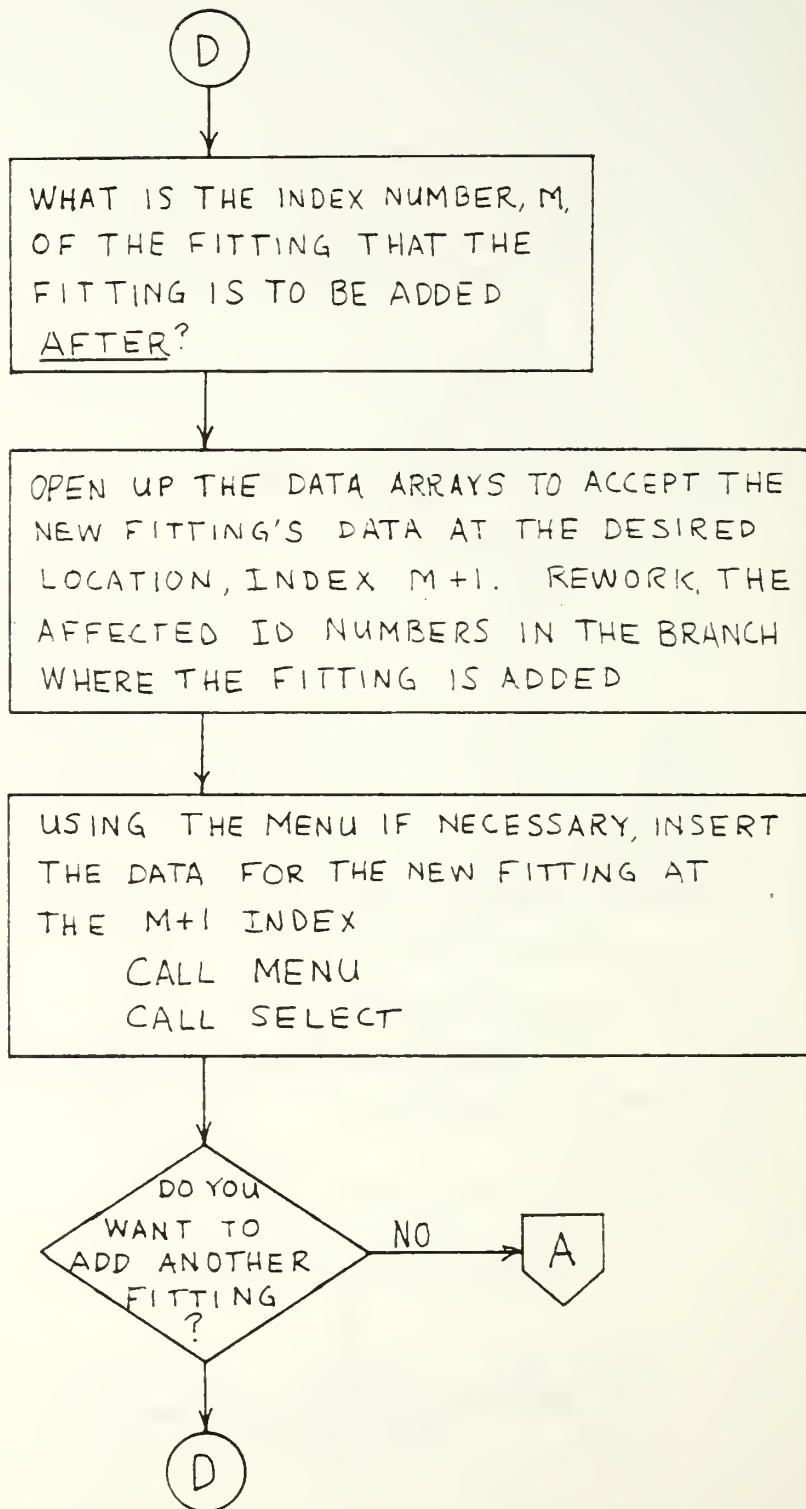
III. EDITING SUBROUTINE (ED)

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

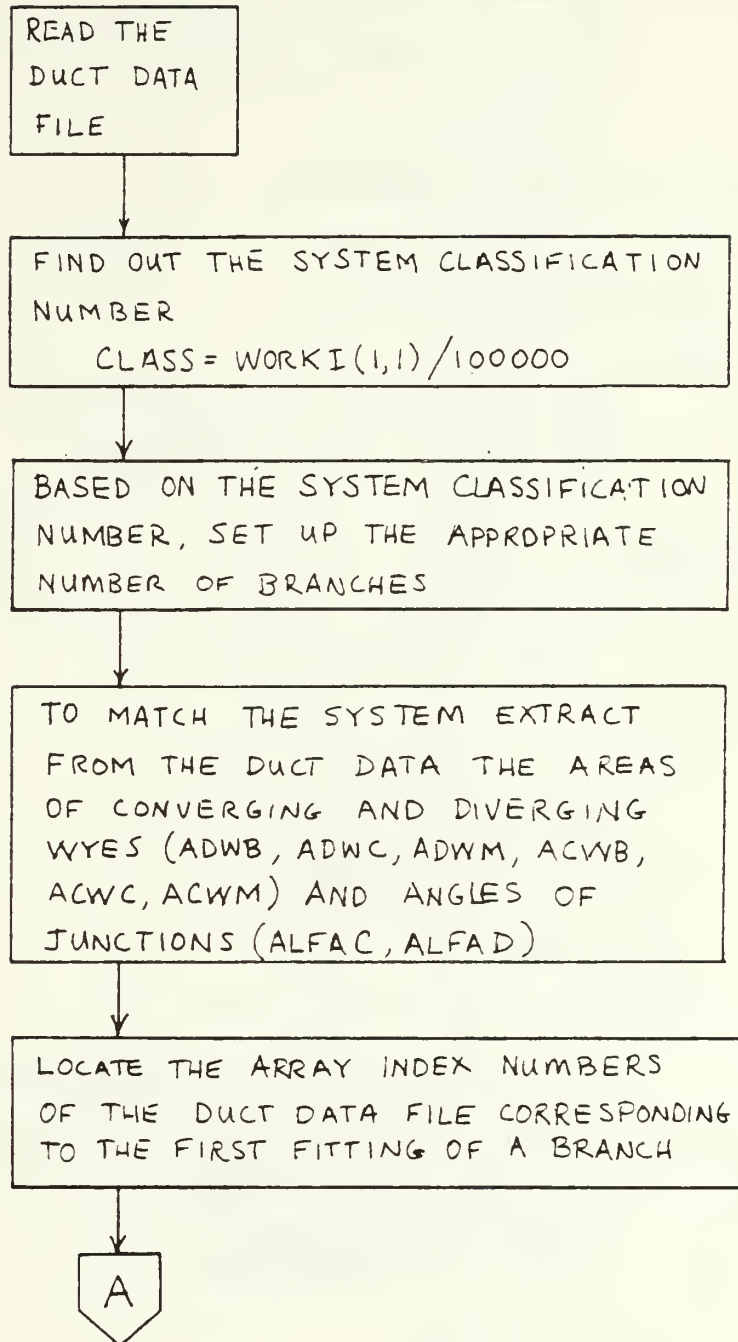


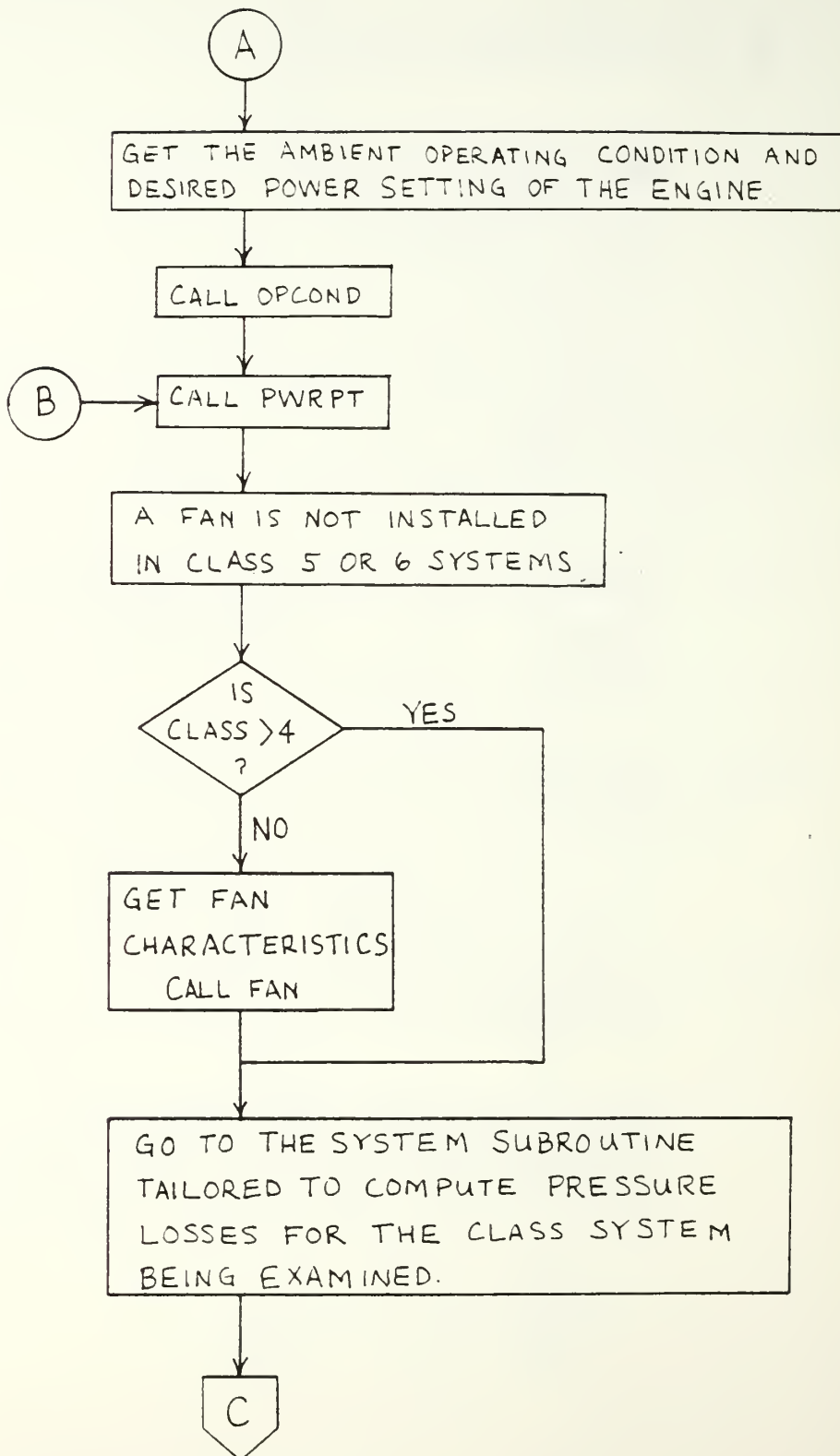


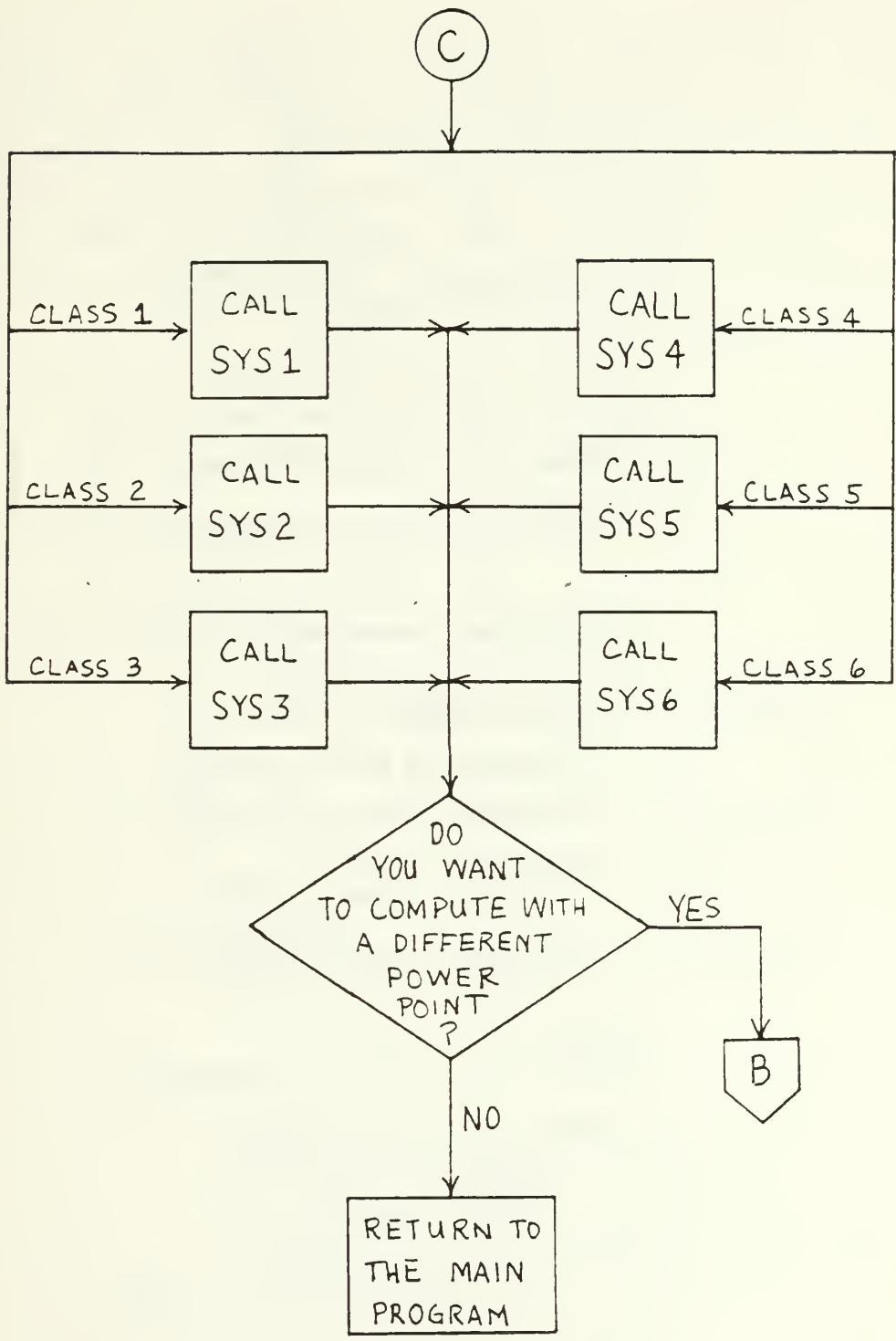




IV. COMPUTE SUBROUTINE

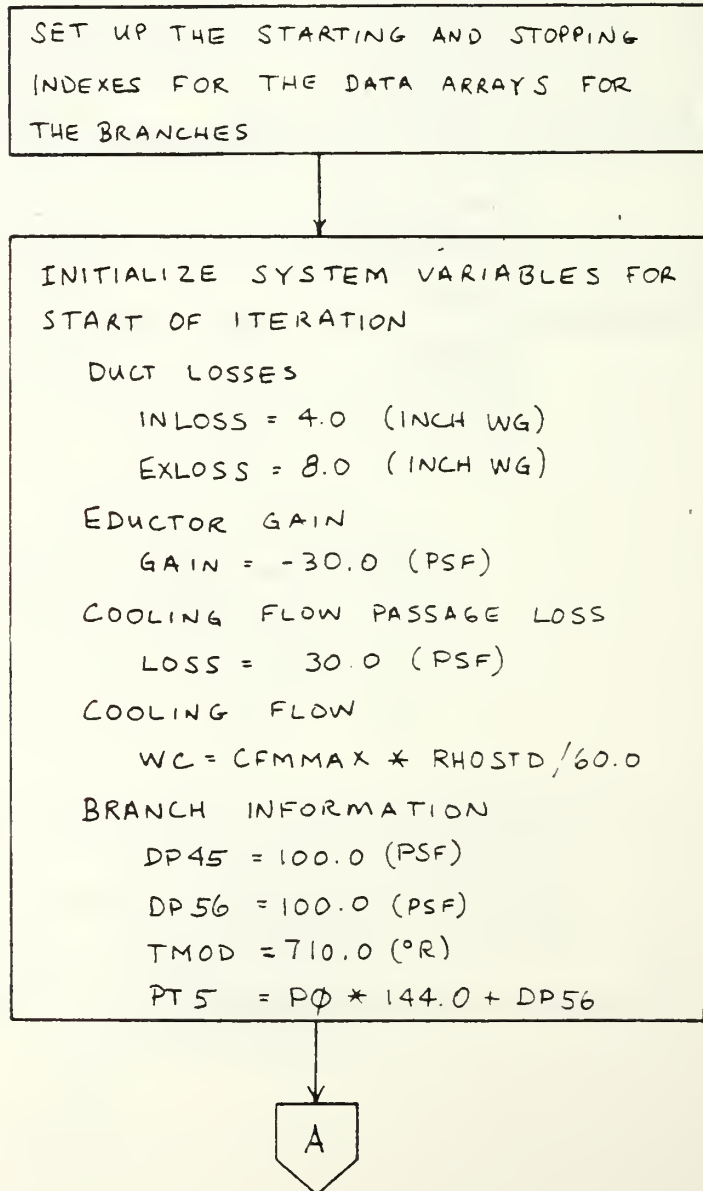


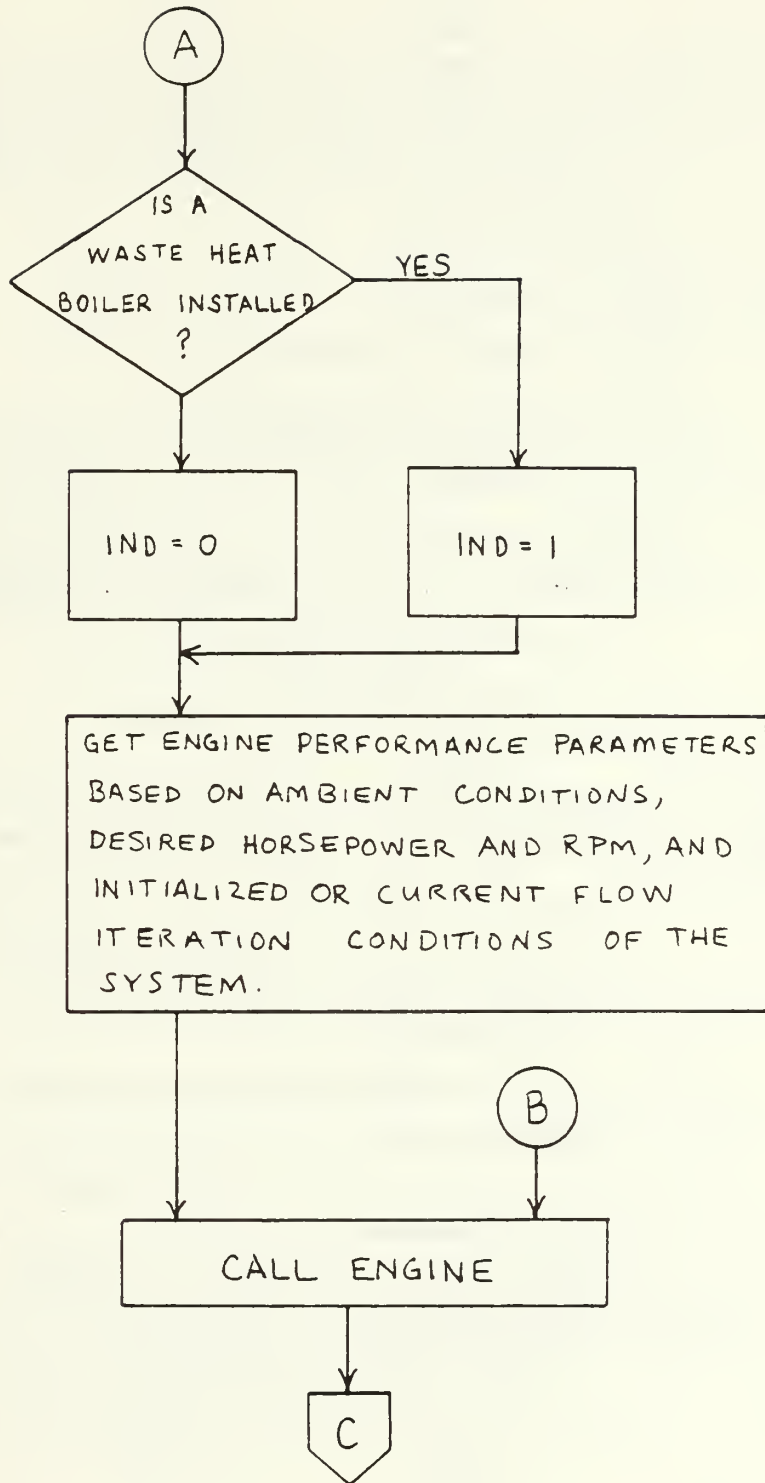




II SYSTEM THREE MATCHING SUBROUTINE (SYS3)

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.





C

INITIALIZE INLET CONDITIONS FOR
BRANCH 1-2

$$DP_{12} = 0.0$$

$$P_{MAIN} = P_{T5} + LOSS$$

$$P_{SEC} = P_{T5} + GAIN$$

$$P_{TIN} = P_{\phi} \times 144.0$$

$$T_{IN} = T_{\phi} + 459.7$$

BRANCH 1-2 HAS COMBINED COOLING
AND ENGINE AIRFLOW

$$W = W_C + W_E$$

FOR EACH FITTING IN BRANCH 1-2,

CALL FITDP

TO COMPUTE PRESSURE LOSS IN
THE FITTING. THE SUM

$$DP_{12} = DP_{12} + \Delta P$$

IS THE PRESSURE LOSS FOR THE
BRANCH

NODE 2 IS A JUNCTION. COMPUTE
TOTAL PRESSURE AND DENSITY AT NODE.

$$P_{T2} = P_{\phi} \times 144.0 - DP_{12}$$

$$RH_{O2} = (P_{T2} - P_V) / ((T_{\phi} + 459.7) \times R)$$

D

D

COMPUTE THE AVERAGE VELOCITIES IN THE THREE BRANCHES ENTERING AND LEAVING NODE 2, A DIVERGENT WYE.

$$\text{BRANCH COOLING AIR: } VDWB = WC / (RHO2 * ADWB)$$

$$\text{COMBINED INLET: } VDWC = (WC + W2) / (RHO2 * ADWC)$$

$$\text{MAIN ENGINE: } VDWM = W2 / (RHO2 * ADWM)$$

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:

$$T_{MAIN} = T_8 \quad \text{ELSE,}$$

$$T_{MAIN} = 770.0 + (370 * 10^{-3} * HP)$$

COMPUTE TEMPERATURE IN COMBINED EXHAUST STACK BASED ON MIXING ENTHALPY OF COOLING AND EXHAUST STREAMS.

$$\text{COOLING ENTHALPY: } H_{SEC} = (1.421385E-5 * T_{MOD} + .221091) * T_{MOD} + 5.6373$$

$$\text{EXHAUST ENTHALPY: } H_{MAIN} = (1.56051E-5 * T_{MAIN} + .22388) * T_{MAIN} + 4.75396$$

$$\text{COMBINED ENTHALPY: } H_{STACK} = (W_8 / (W_8 + W_C)) * H_{MAIN} + (W_C / (W_8 + W_C)) * H_{SEC}$$

$$\text{EXHAUST TEMPERATURE: } T_5 = (0.000841) * H_{STACK} + 4.33577 * H_{STACK} - 9.5778$$

E

E

COMPUTE ASSUMED DENSITIES AT NODE 5
 $\rho_{OCC} = P_{T5} / (R * T_5)$
 $\rho_{OCB} = P_{SEC} / (R * T_{MOD})$
 $\rho_{OCM} = P_{MAIN} / (R * T_{MAIN})$

F

COMPUTE VELOCITIES AT NODE 5 BASED
ON ASSUMED OR CURRENT ITERATION DENSITY
 $V_{CWB} = W_C / (\rho_{OCB} * A_{CWB})$
 $V_{CWC} = (W_C + W_B) / (\rho_{OCC} * A_{CWC})$
 $V_{CWM} = W_B / (\rho_{OCM} * A_{CWM})$

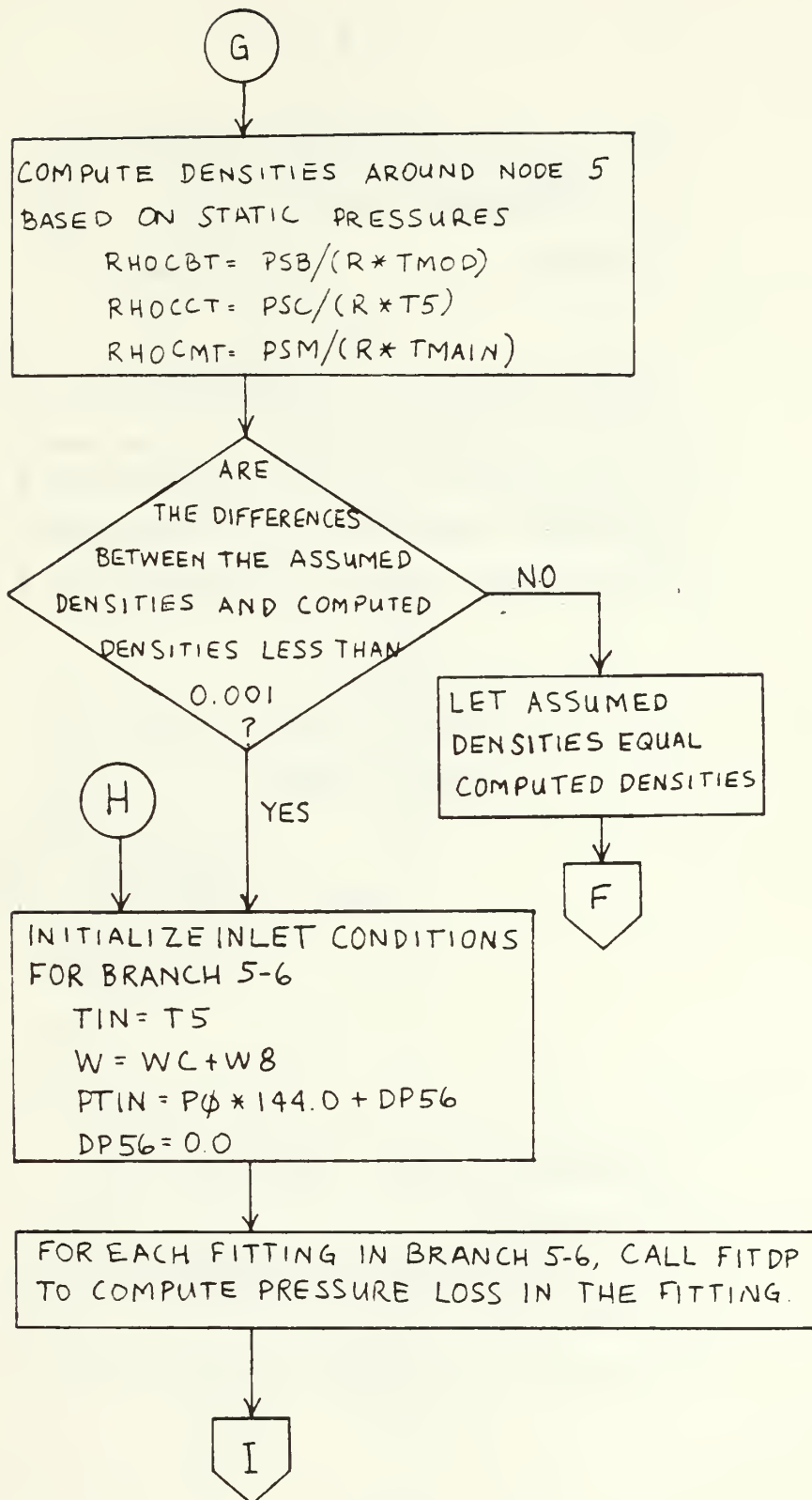
COMPUTE THE VELOCITY PRESSURES AROUND
NODE 5.

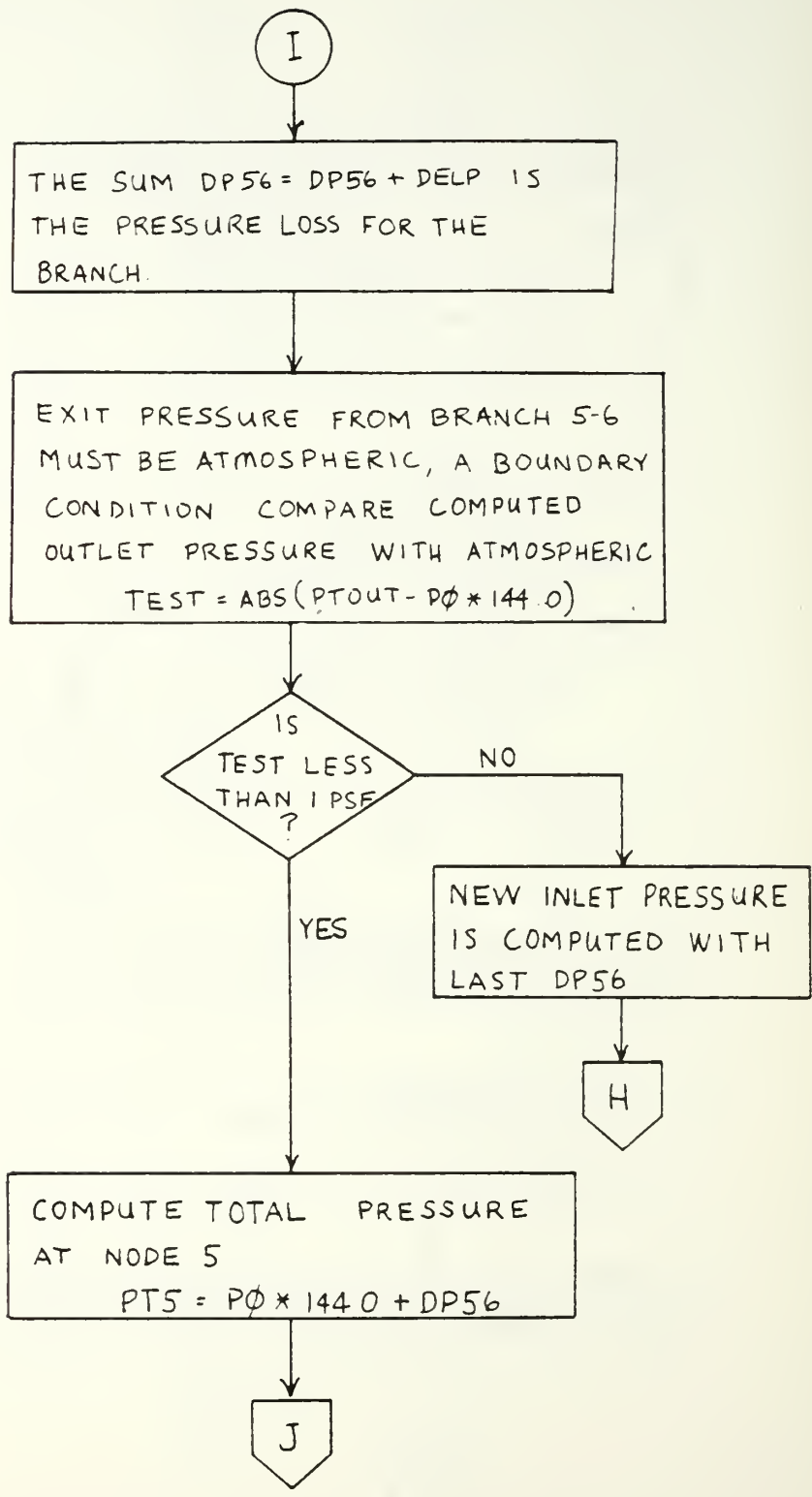
$$P_{VB} = \rho_{OCB} * V_{CWB}^2 / (2.0 * 32.174)$$
$$P_{VC} = \rho_{OCC} * V_{CWC}^2 / (2.0 * 32.174)$$
$$P_{VM} = \rho_{OCM} * V_{CWM}^2 / (2.0 * 32.174)$$

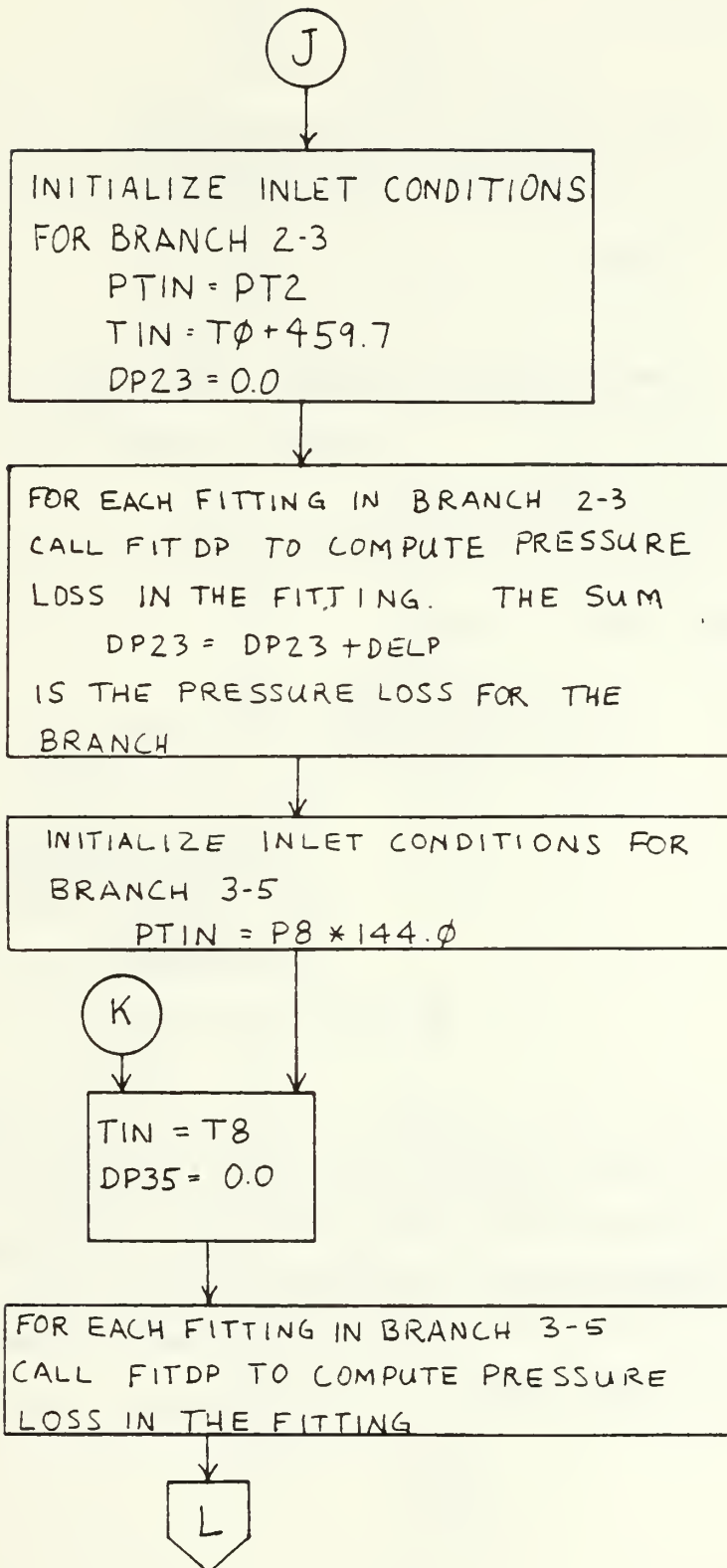
COMPUTE THE STATIC PRESSURES AROUND
NODE 5.

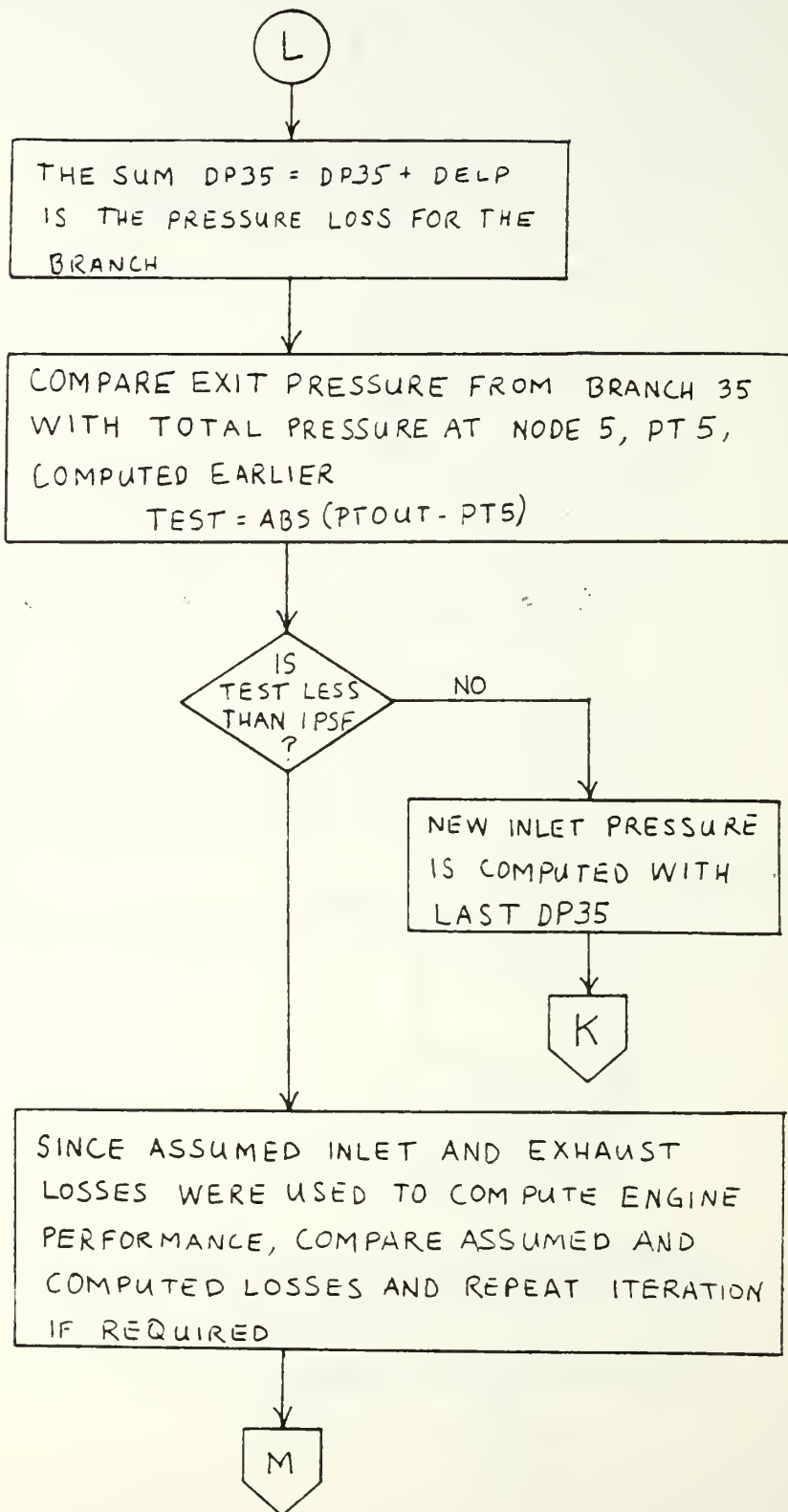
$$P_{SB} = P_{SEC} - P_{VB}$$
$$P_{SC} = P_{T5} - P_{VC}$$
$$P_{SM} = P_{MAIN} - P_{VM}$$

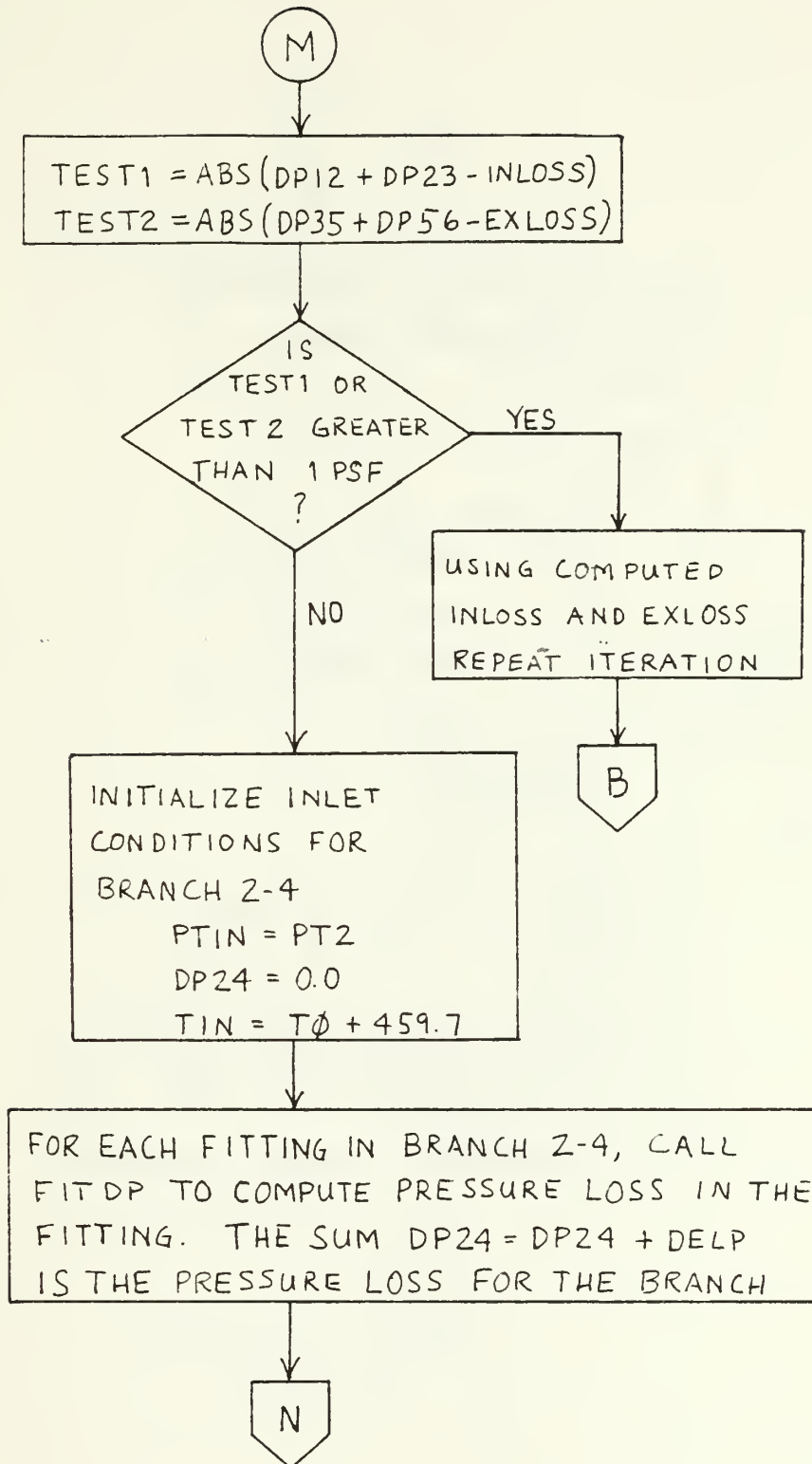
G











N

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

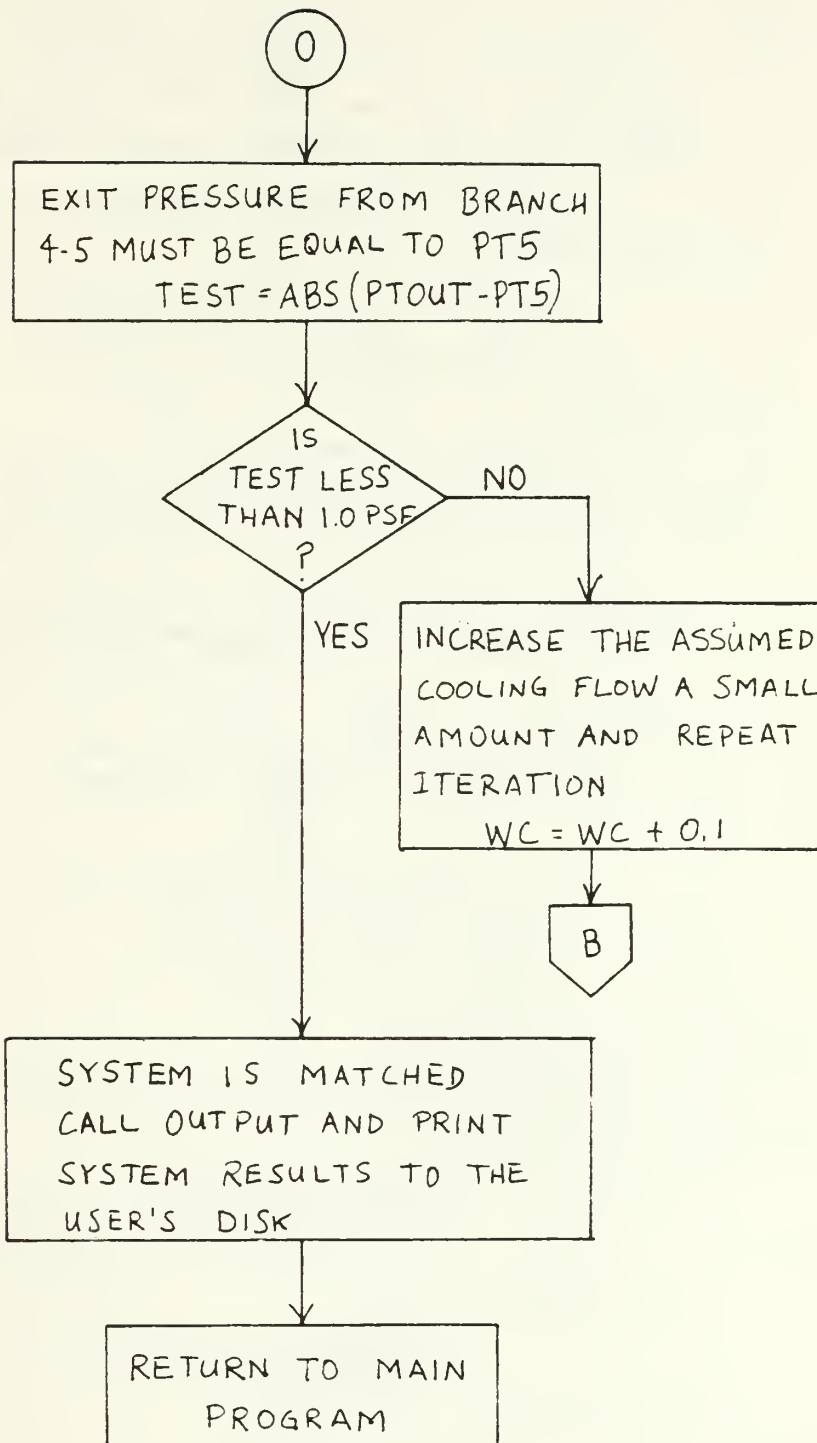
$$T_{IN} = T_4$$

$$P_{TIN} = P_{TOUT} + (K * ((WC / RHO_{STD} * 60.0) - CFM_{MAX})^2 + DP_{MAX}) * 5.19696$$

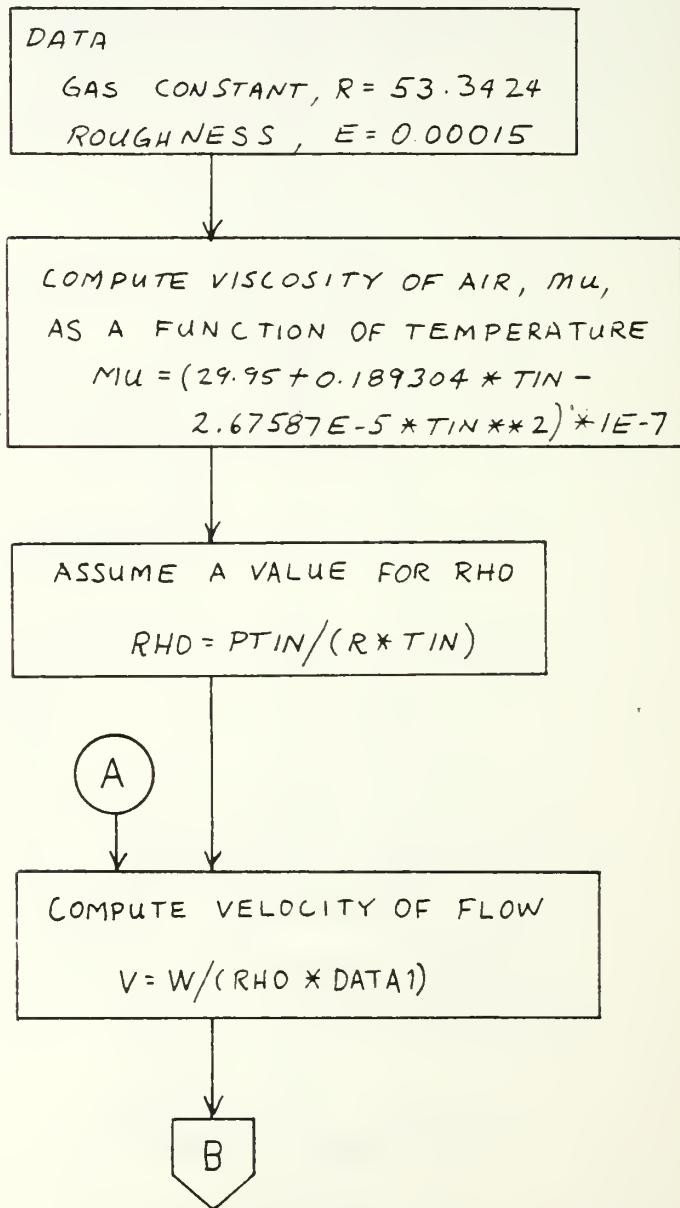
$$DP_{45} = 0.0$$

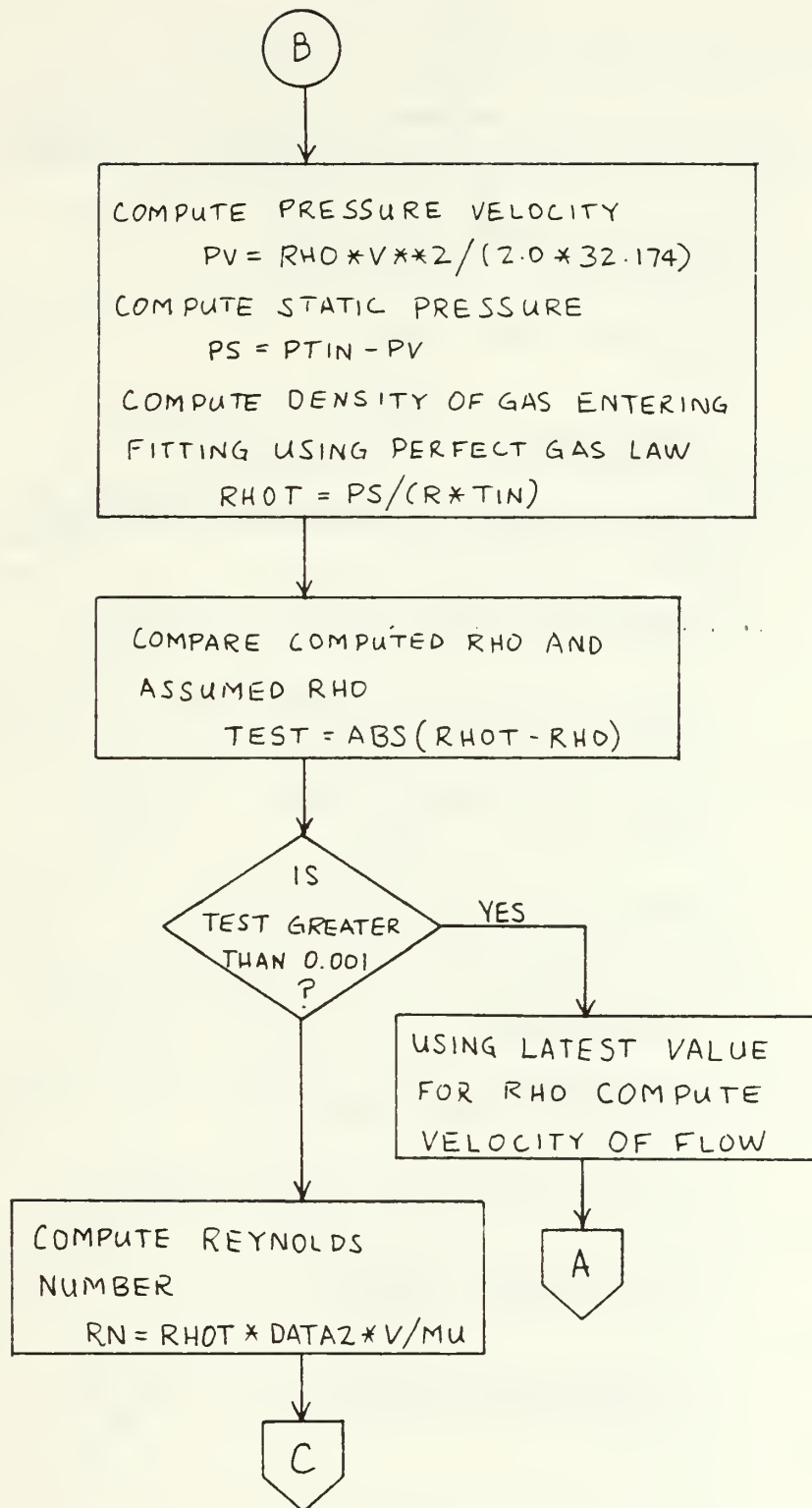
FOR EACH FITTING IN BRANCH
4-5, CALL FIT DP TO COMPUTE
PRESSURE LOSS IN THE FITTING.
THE SUM $DP_{45} = DP_{45} + DELP$
IS THE PRESSURE LOSS FOR
THE BRANCH

O



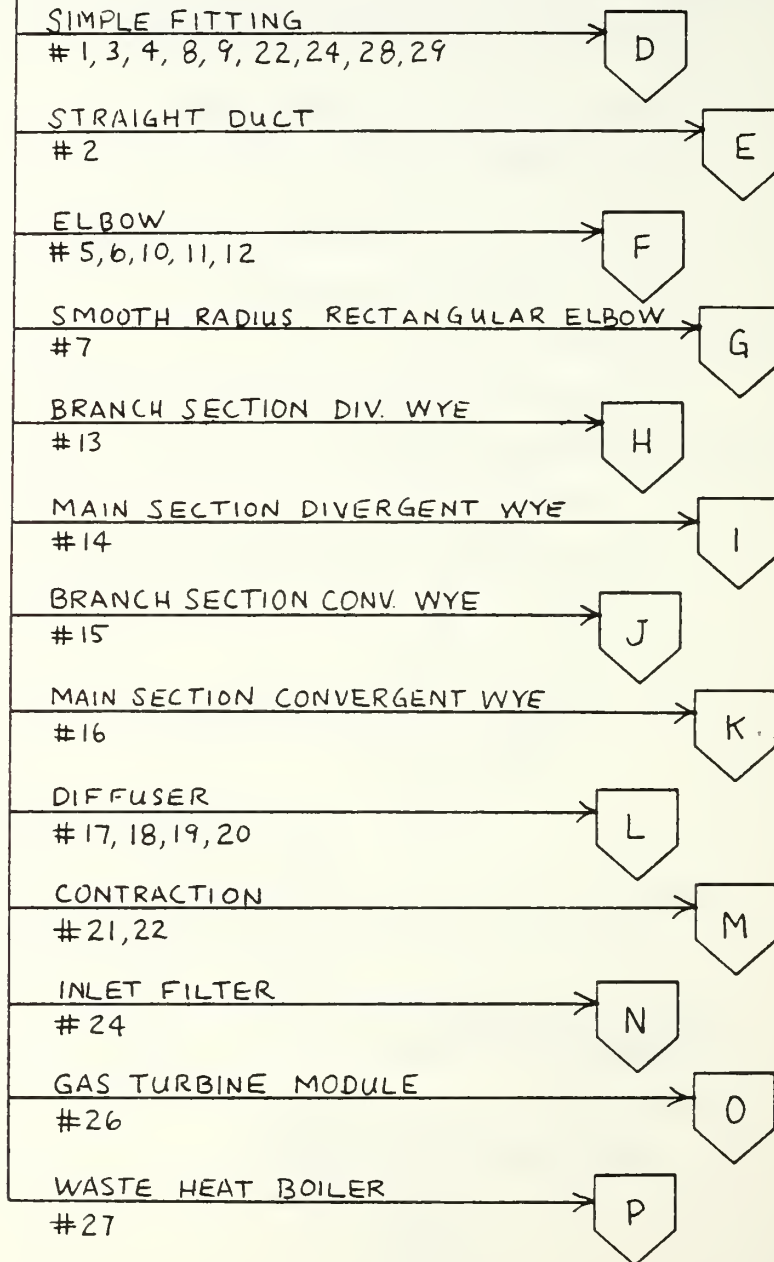
VI. FITTING PRESSURE LOSS CALCULATION
SUBROUTINE. SET UP TO COMPUTE
PRESSURE LOSS AND VELOCITY DATA FOR
30 FITTINGS LISTED IN THE MENU

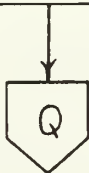
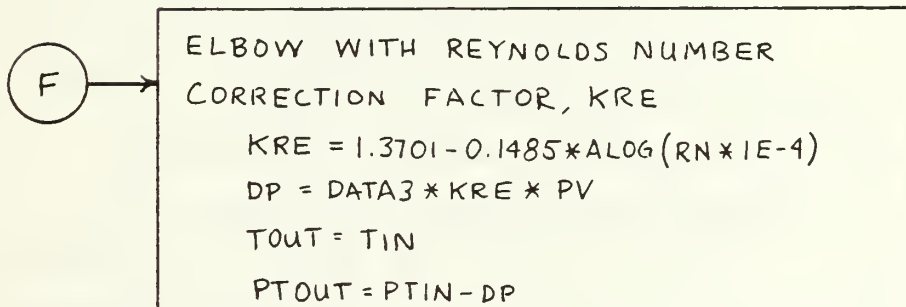
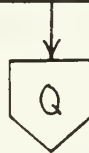
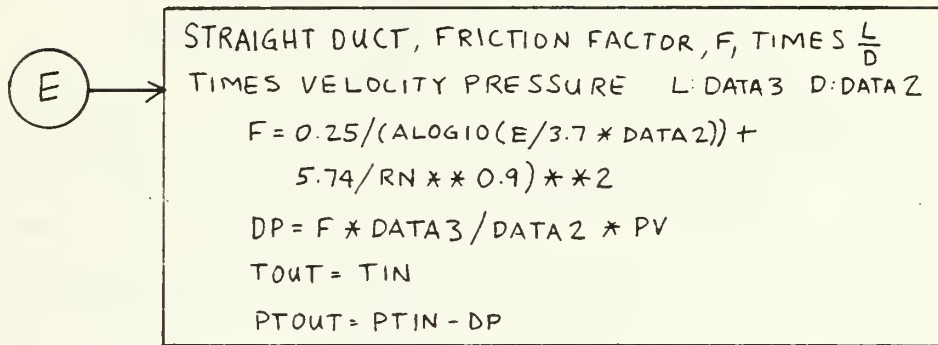
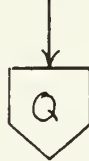
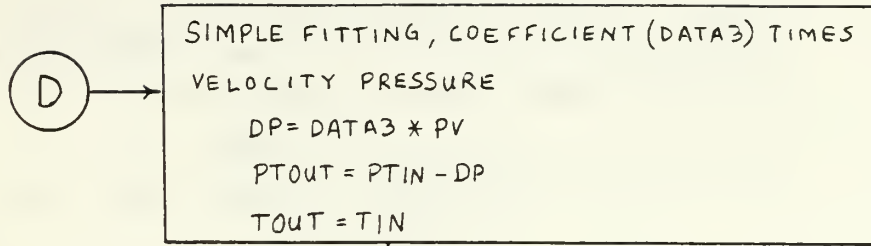


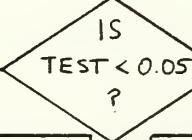
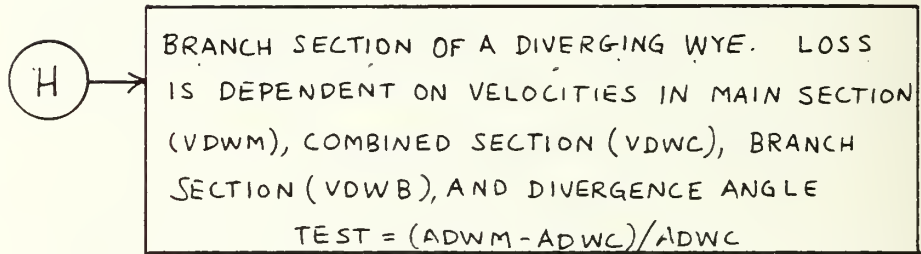
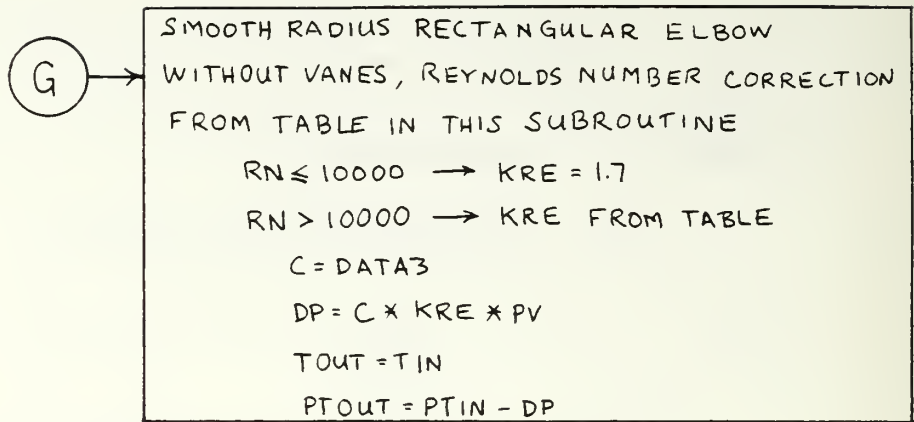


C

GO TO THE COMPUTATION FOR THE TYPE OF FITTING







NO

YES

```

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))

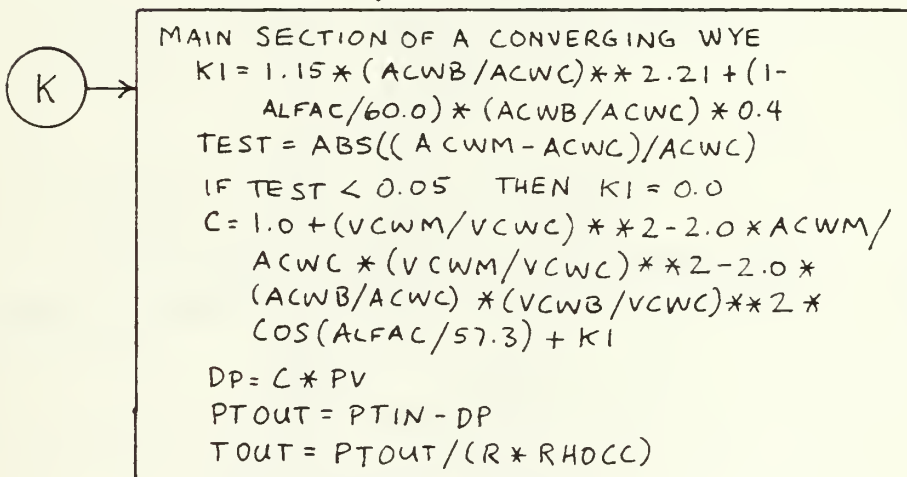
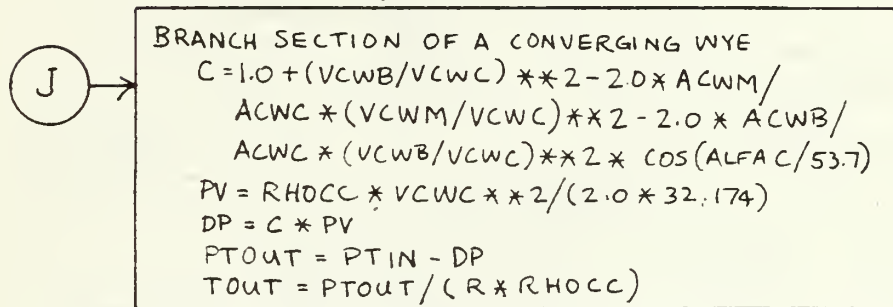
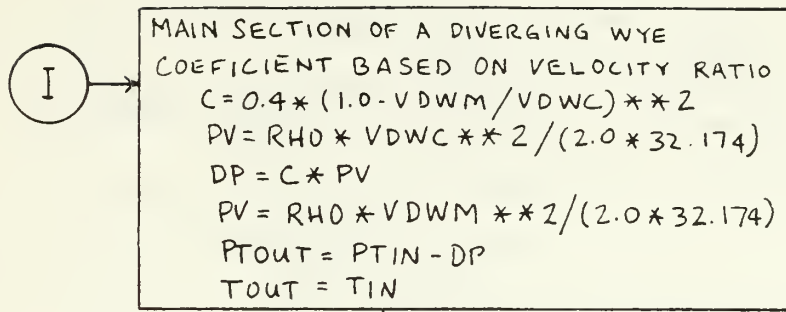
```

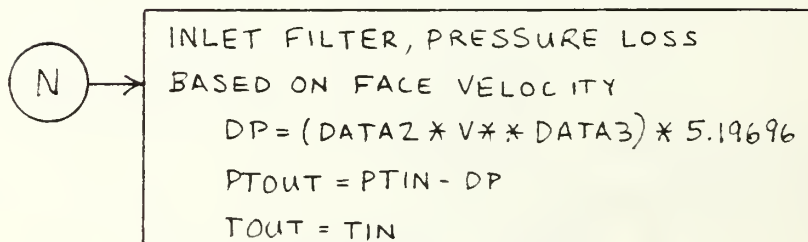
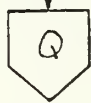
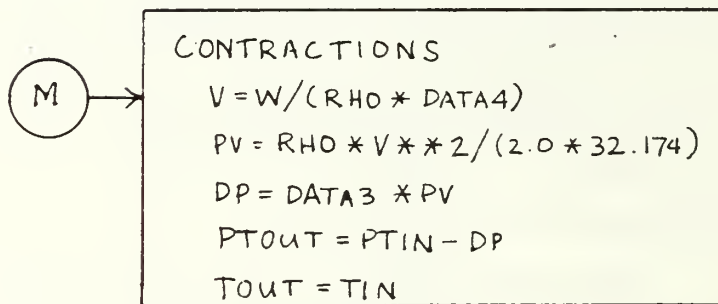
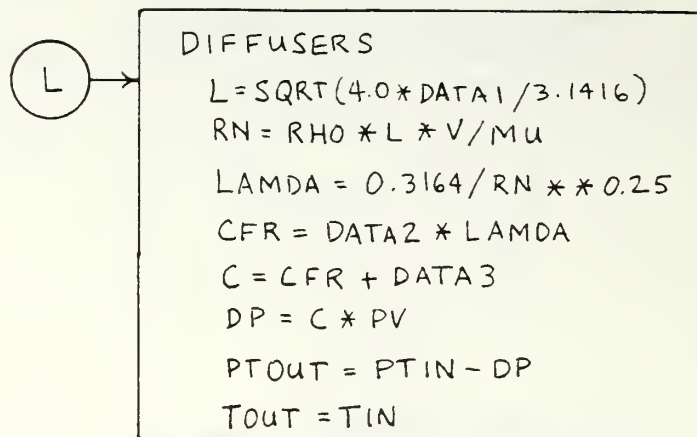
```

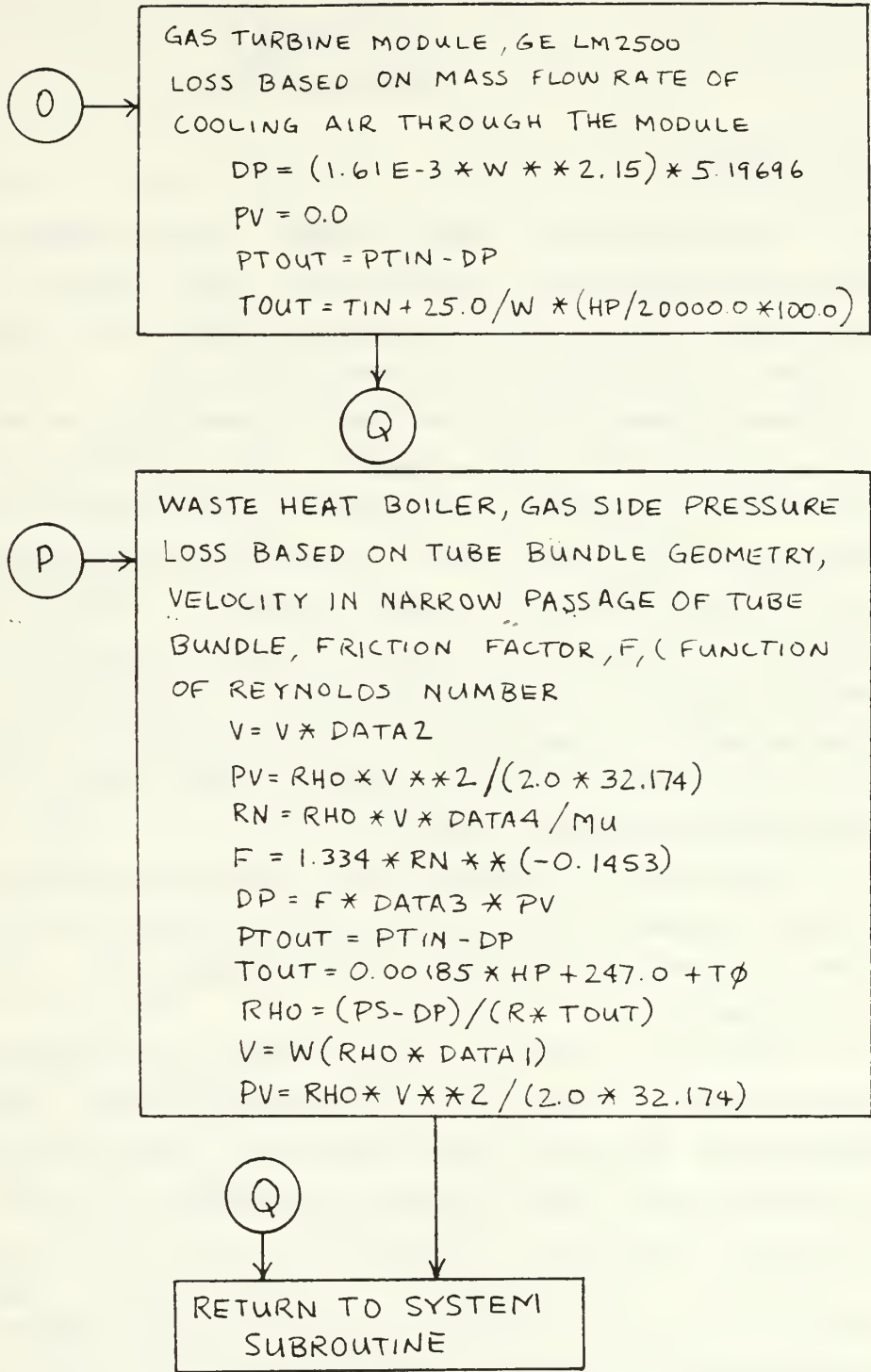
PV = RHO * VDWC ** 2 / (2.0 * 32.174)
DP = C * PV
PV = RHO * VDWB ** 2 / (2.0 * 32.174)
PTOUT = PTIN - DP
TOUT = TIN

```









GAS TURBINE MODULE, GE LM2500
LOSS BASED ON MASS FLOW RATE OF
COOLING AIR THROUGH THE MODULE
 $DP = (1.61E-3 * W * * 2.15) * 5.19696$
 $PV = 0.0$
 $PTOUT = PTIN - DP$
 $TOUT = TIN + 25.0 / W * (HP / 20000.0 * 100.0)$

Q

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

Q

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, transitions, 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.

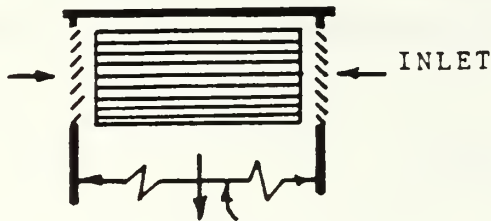
Do not forget to include abrupt exits where they appear. Sometimes it is easy to overlook an obvious fitting such as the engine module as part of the cooling air ductwork.

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

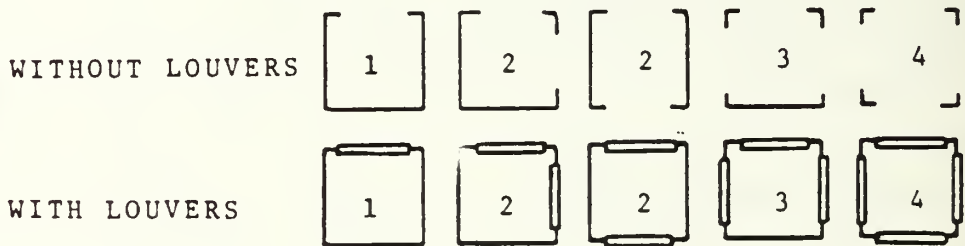
NUMBER:
 01

SKETCH:



SHAFT
 AREA

OPENINGS



INPUT REQUIREMENTS:

1. The number of orifices (1,2,3,or 4)
2. The cross section area of the vertical shaft
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.

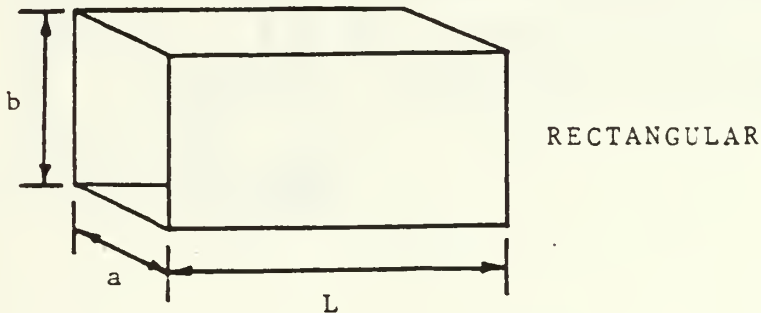
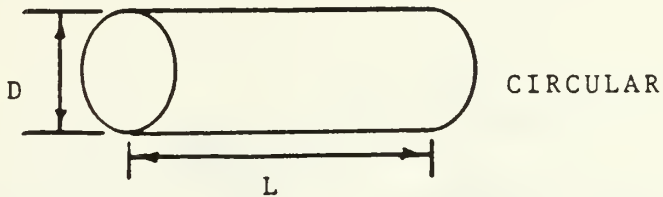
REFERENCE:

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.

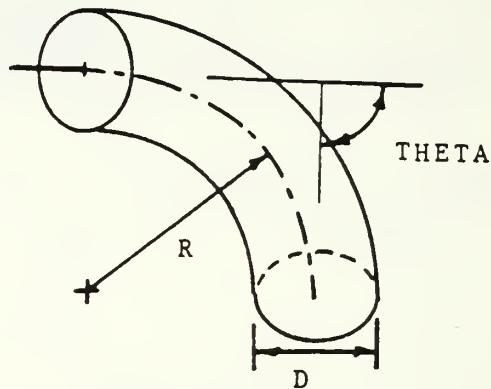
REFERENCE:

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 coefficient	section area

REMARKS:

Turn angle should be from 0 to 90 degrees.

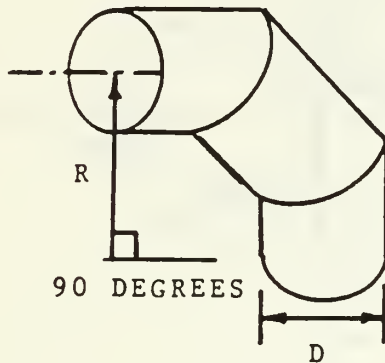
REFERENCE:

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.

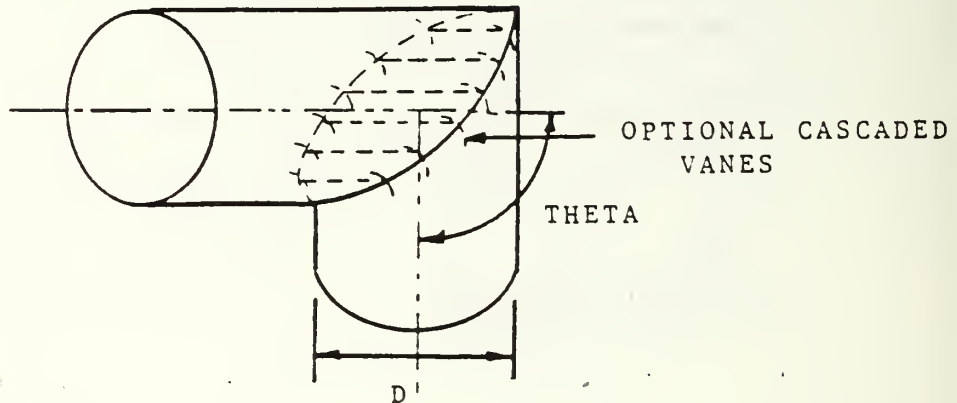
REFERENCE:

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.

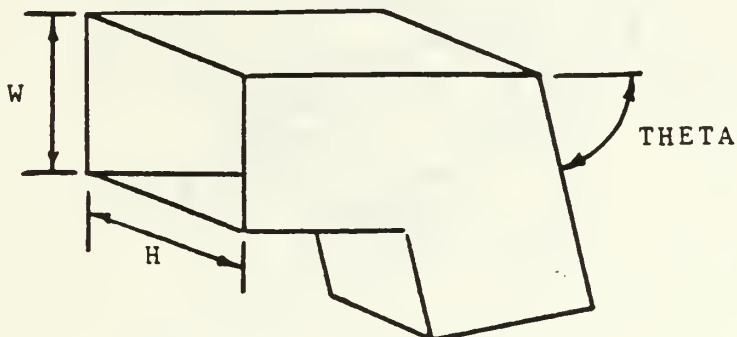
REFERENCE:

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:

WCRKR(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.

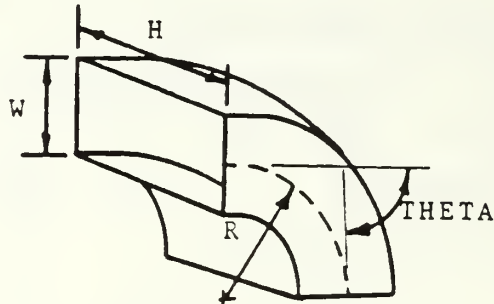
REFERENCE:

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.

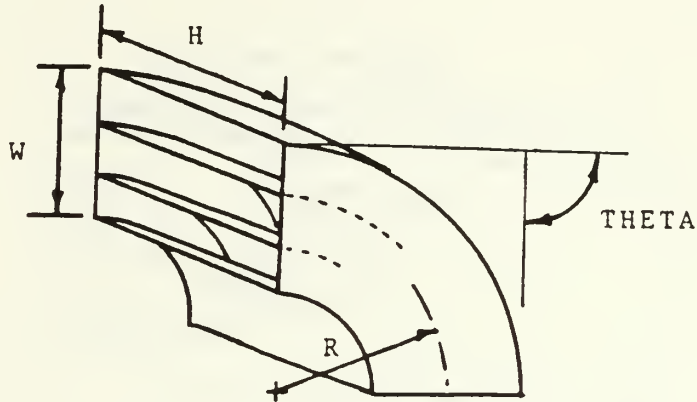
REFERENCE:

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:

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

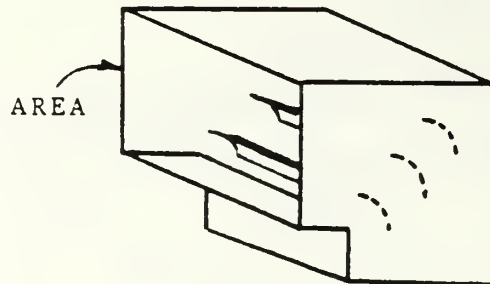
REMARKS:
None

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	0.0	resistance	section
area		coefficient	area

REMARKS:

Flat plate turning vanes are used.

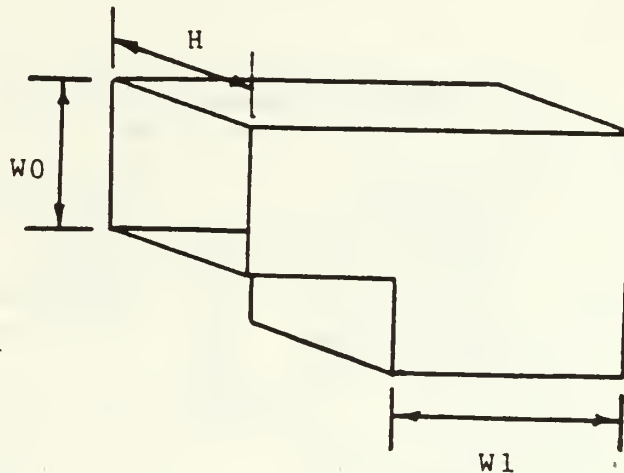
REFERENCE:

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.

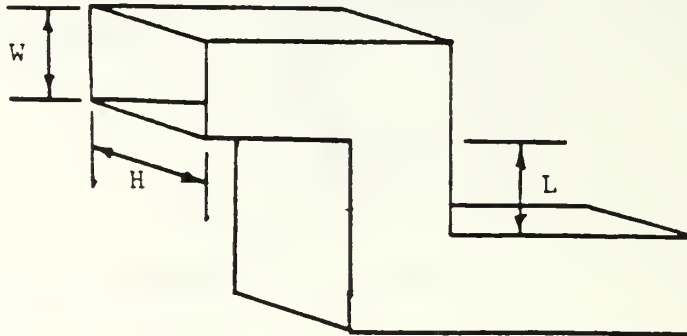
REFERENCE:

ASHRAE 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 axis
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	hydraulic	resistance	section
area	diameter	coefficient	area

REMARKS:

None.

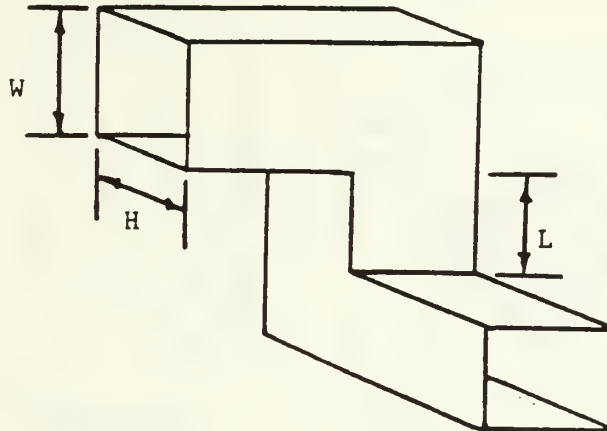
REFERENCE:

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	Hydraulic	resistance	section
area	Diameter	coefficient	area

REMARKS:

Resistance coefficient is a curve fit to the tabulated data.

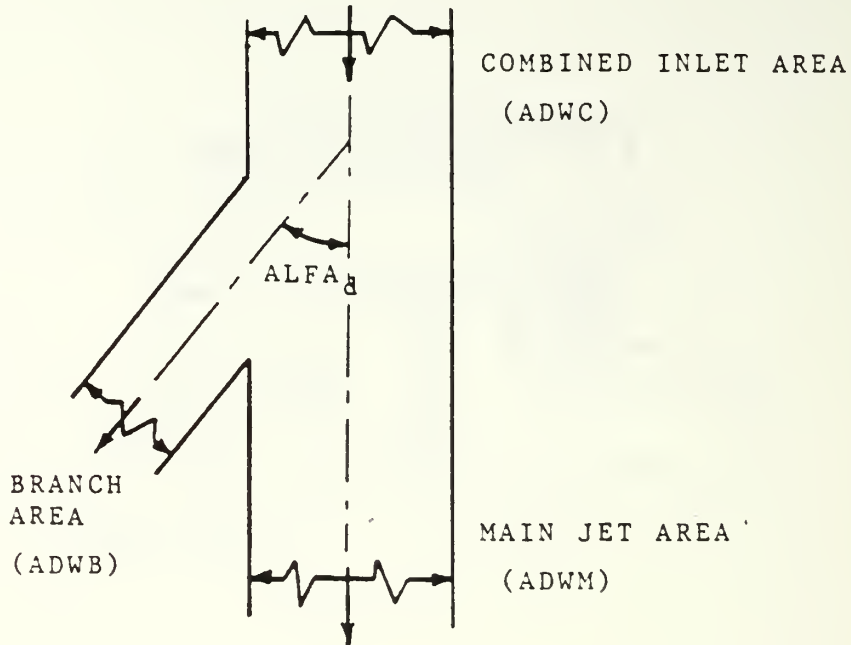
REFERENCE:

ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Diverging wye, branch and main sections

NUMBER:
13 8 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.

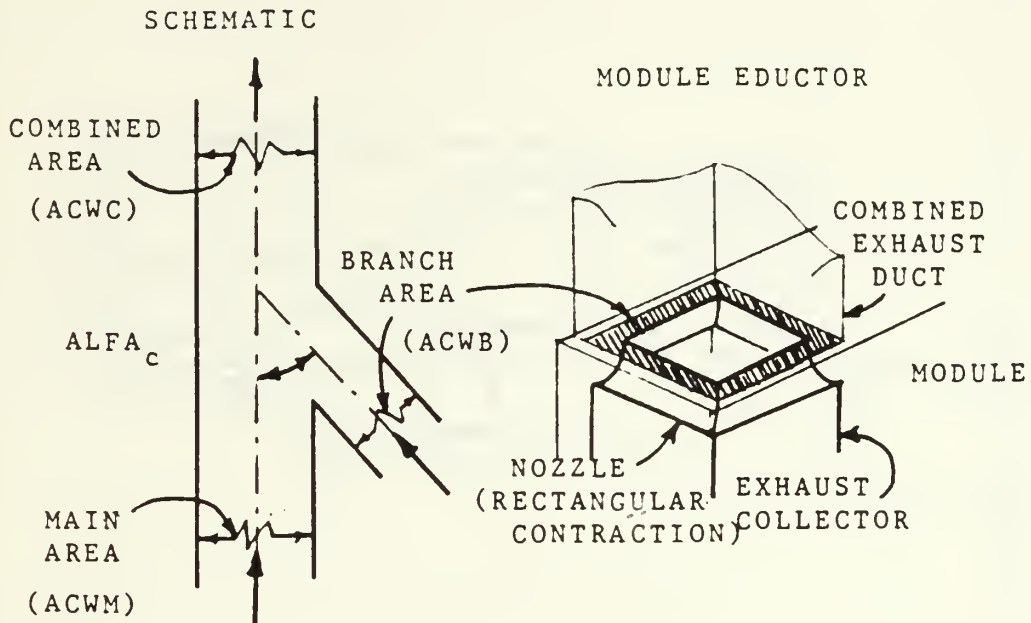
REFERENCE:

Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME:
Convergent wye, branch and main sections

NUMBER:
15 8 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.

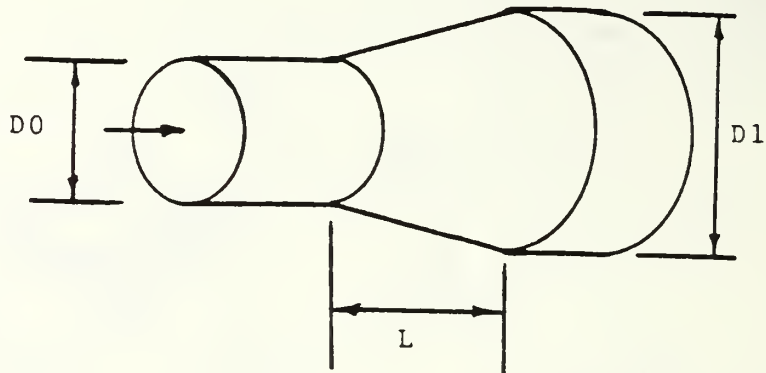
REFERENCE:

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	friction	flow	outlet
area	coefficient	coefficient	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.

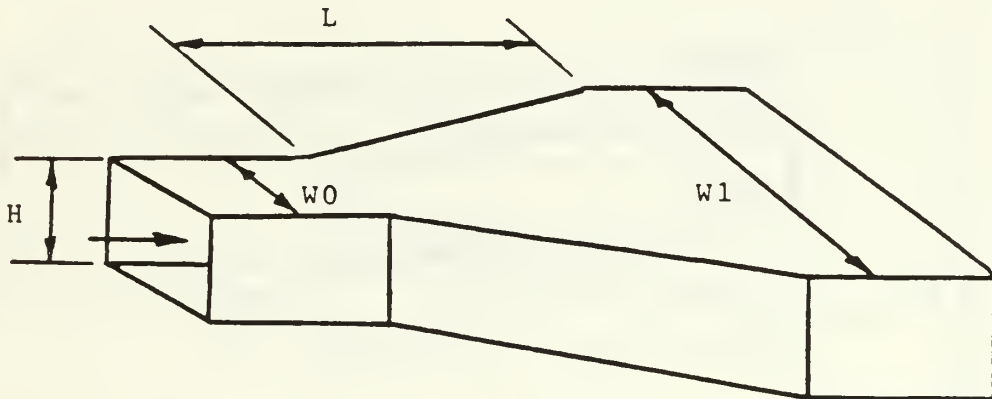
REFERENCE:

Handbook of Hydraulic Resistance, Idel'chik

FITTING NAME:
Plane in-line diffuser

NUMBER:
18

SKETCH:



INPUT REQUIREMENTS:

1. Length of the diffuser
2. The constant height 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	friction	flow	outlet
area	coefficient	coefficient	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.

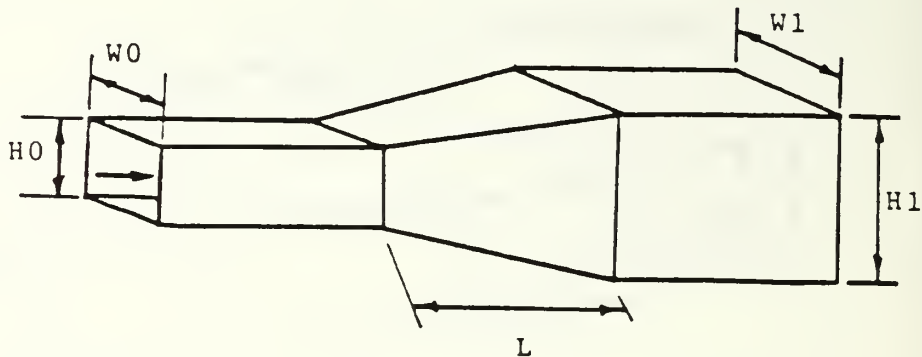
REFERENCE:

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 outlet 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	friction	flow	outlet
area	coefficient	coefficient	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.

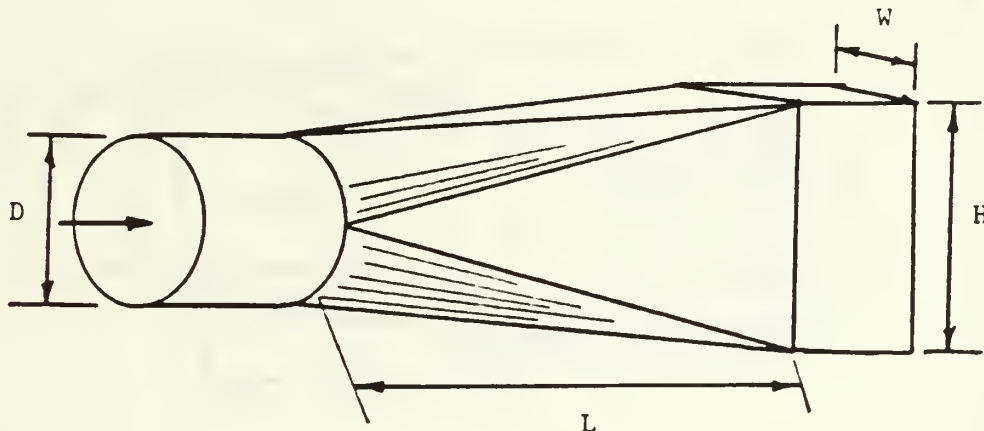
REFERENCE:

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 transition
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	friction	flow	outlet
area	coefficient	coefficient	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%.

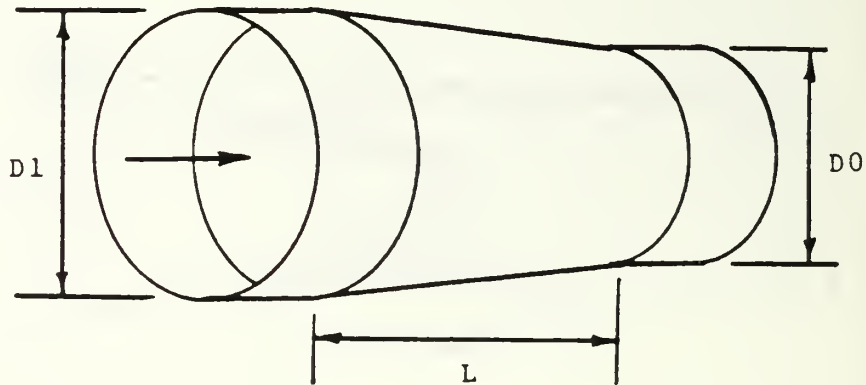
REFERENCE:

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	0.0	resistance	inlet
area		coefficient	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.

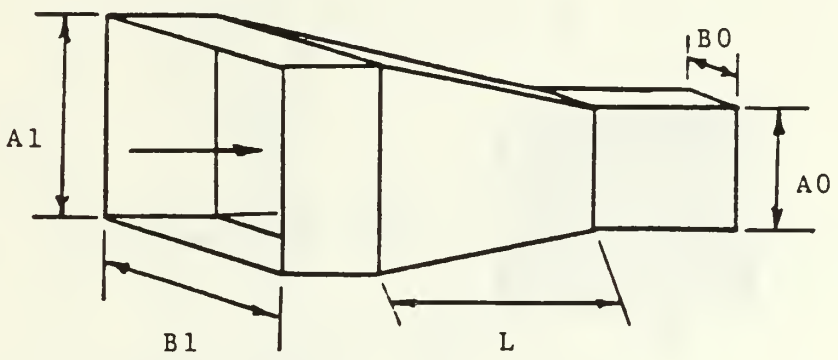
REFERENCE:

ASHRAE FUNDAMENTALS 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:

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

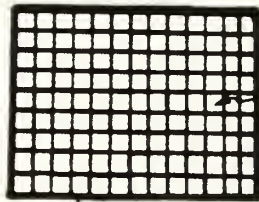
REMARKS:
This fitting can be substituted for a transitional contraction. The inlet or outlet area should remain the same and the area for transition converted as required.

REFERENCE:
ASHRAE FUNDAMENTALS 1981, chapter 33

FITTING NAME:
Screen

NUMBER:
23

SKETCH:



SCREEN AREA
(FREE FLOW MEANS HOLE SPACES)

DUCT AREA (OVERALL AREA)

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.

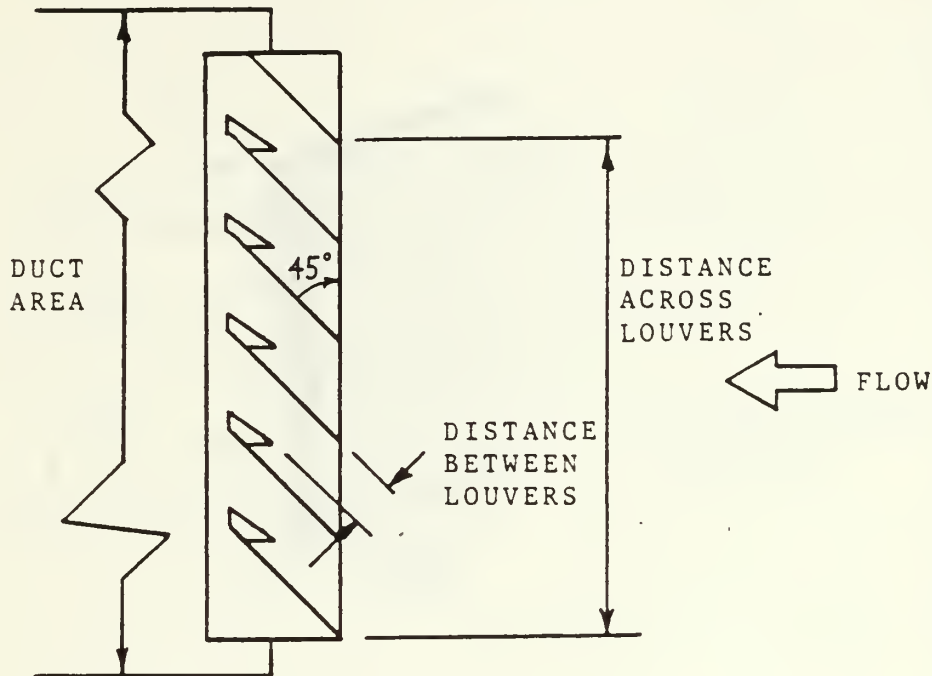
REFERENCE:

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	0.0	resistance	duct
area		coefficient	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.

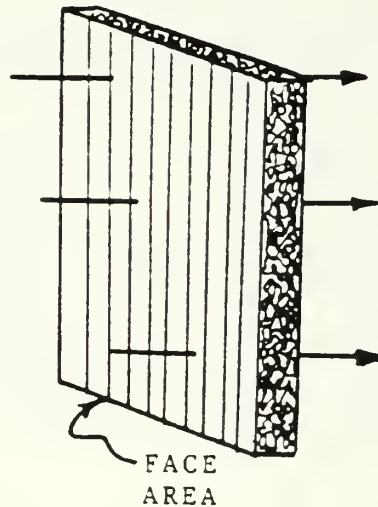
REFERENCE:

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.)

DJCI 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:

$$\text{delta pressure (in WG)} = A * (\text{velocity}) ** B$$

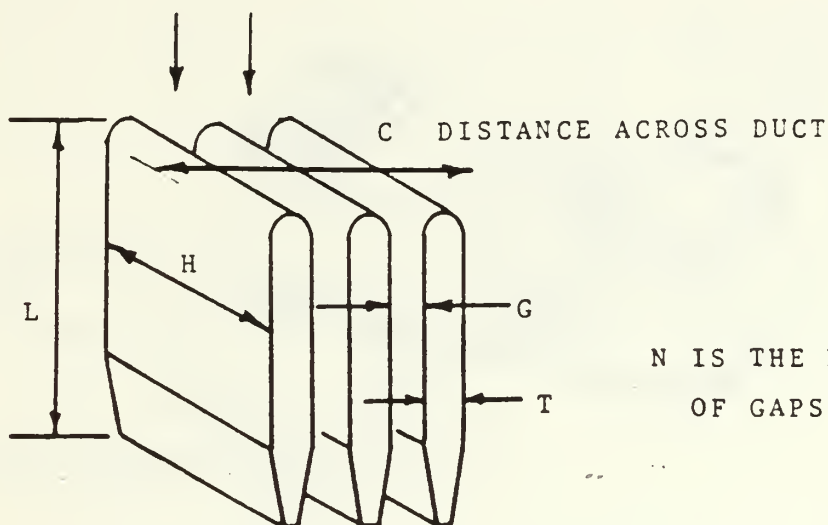
REFERENCE:

Filter manufacturer's data

FITTING NAME:
Multi-baffle type silencer

NUMBER:
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	0.0	resistance	duct
area		coefficient	area

REMARKS:

This is a composite 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.

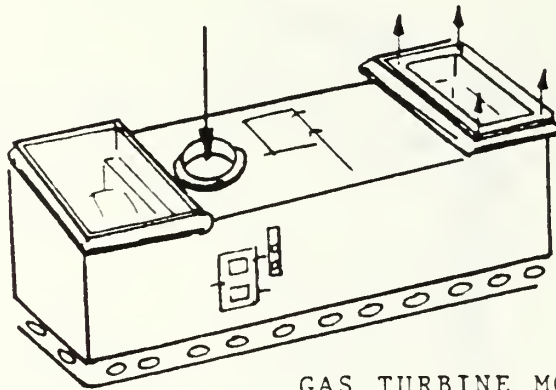
REFERENCE:

NAVSEA Inlet Design Handbook for Marine Gas turbines

FITTING NAME:
Gas turbine module

NUMBER:
27

SKEETCH:



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

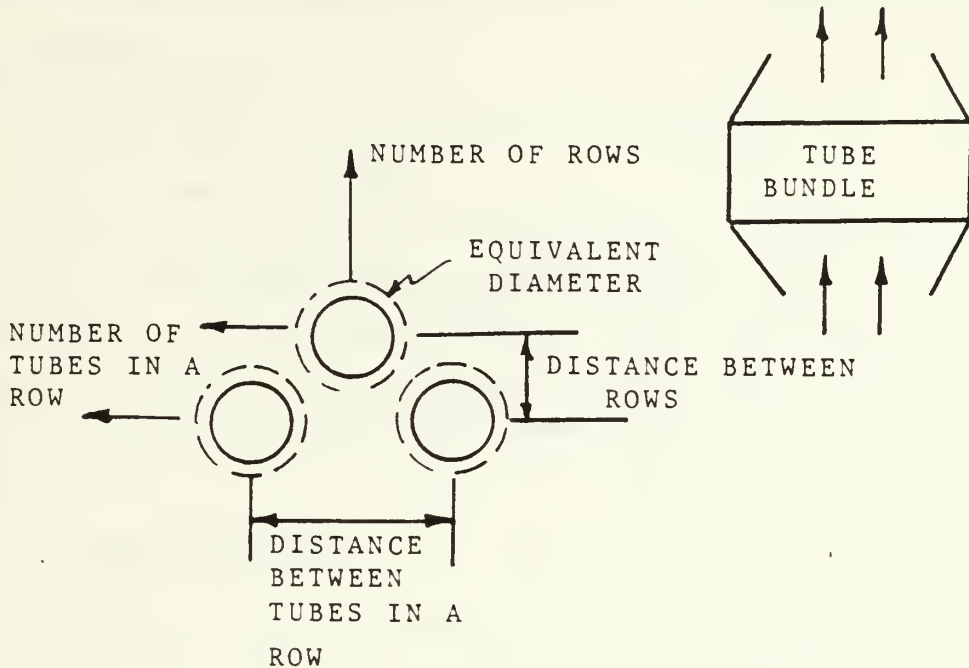
REMARKS:
This model is based on the mass flow rate of cooling air through the module. It is a power fit to data from General Electric Co. It should be good as long as entry and exit areas remain about the same. The 1.0's in the duct data file are there to prevent division by zero in the program and are 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	0.0	resistance	duct
area		coefficient	area

REMARKS:

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

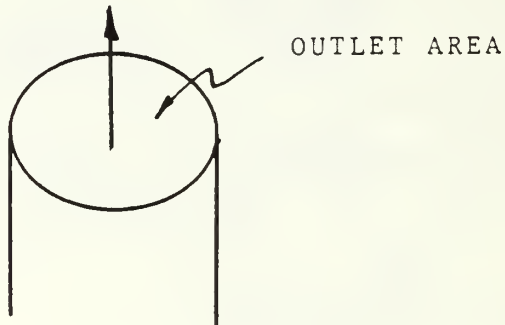
REFERENCE:

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.

```
FCRTHX filename
```

```
GLOBAL TXTLIB FORTMOD2 MOD2EEH NONIMSL
```

```
LCAD 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 were 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 TXLIB 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

OPTIONS: VERSION 1.0 MARCH 30, 1984
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)

^v IS THERE A COOLING FAN INSTALLED?

NOTE INLDRRECT RESPONSE,
ANSWER SHOULD HAVE BEEN
Y OR N

^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

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 + 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, 30 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
  
```

? YOU HAVE SELECTED THE INLET FILTER.
 ? **FIRST QUESTION, WHAT IS THE TOTAL FACE AREA OF THE FILTER?

? 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)?

MENU OMITTED

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

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

? 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/F) ?

F
THE DUCT IS RECTANGULAR, ENTER FIRST CROSS-SECTIONAL
DIMENSION. (FEET)

?
18.33
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
>> YOU 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
JUNCTION AND DIRECTS FLOW TO THE ENGINE. IT ALSO SHOULD BE
THE FIRST FITTING OF THE BRANCH.

?
81.375
>> YOU 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 OF THE BAFFLES?

?
9.33
WHAT IS THE DIMENSION 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
>> YOU 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 CN FITTING NUMBER >> 324002
 ?
 02 YOU HAVE SELECTED STRAIGHT DUCT. IT MAY BE ROUND
 OF 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 CN FITTING NUMBER >> 324003
 ?
 00 >> YOU ARE WORKING CN 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
 SECCND 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 CN FITTING NUMBER >> 335102
 ?
 16 YOU HAVE SELECTED THE MAIN SECTION OF A CONVERGING
 WYE. THE ENGINE EXHAUST ALONE SHOULD BE FLOWING THROUGH
 THIS SECTICN. IT SHCULD 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 CN FITTING NUMBER >> 335103
 ?
 00 >> YOU ARE WORKING CN FITTING NUMBER >> 345001
 ?
 27 YOU HAVE SELECTED TEE 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 CN 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 THE BRANCH.
?
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 CN 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 CN 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 CN 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 after. 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 INT113 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&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
w
n
n
?
510002
g

WANT TO CHANGE ANOTHER FITTING (Y/N)?
WANT TO MAKE ANY OTHER CHANGES (Y/N)?
WHAT SERIAL NUMBER WOULD YOU LIKE TO GIVE THIS DUCT DATA FILE?
YOU MAY USE UP TO A SIX DIGIT INTEGER NUMBER.
DO YOU WANT TO COMPUTE WITH THE FILE OR QUIT (C/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 TYTLIB CMSLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL
LOAD THESIS (START
EXECUTION BEGINS...
A ONE-DIMENSIONAL MCDL FOR THE SYSTEM PERFORMANCE
OF A MARINE GAS TURBINE INSTALLATION

BY LCDR. STEPHEN M. EZZELL

VERSION 1.C MARCH 30, 1984
OPTICNS: 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 DEPAULI SPECIFICATIONS (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	11201	24	197.7500	0.0	18.7228
2	11122	25	197.7500	0.0167	1.6287
3	11103	2	197.7150	15.2104	17.7500
4	11101	14	81.3750	0.0	0.0
5	11102	26	81.3750	0.0	0.9499
6	11103	22	81.3750	0.0	0.0325
7	11104	6	51.6925	7.1696	1.2095
8	11105	23	50.0000	0.0	2.1282
9	11101	13	197.7500	5.7610	90.0000
10	11102	2	5.7566	2.7080	7.5000
11	11101	2	30.4112	6.0026	1.0000
12	11102	16	20.1900	0.0	0.0
13	11101	27	1.0000	1.0000	1.0000
14	11102	15	30.4600	10.2700	0.0
15	11101	21	30.5561	0.0	0.0107
16	11102	2	23.4596	5.4667	7.1100
17	11103	2	23.4715	5.4667	0.3111
18	11104	5	24.3257	5.5667	6.2300
19	11105	5	23.4715	5.4667	0.3111
20	11106	2	23.4596	5.4667	3.0330
21	11107	17	23.4715	0.3002	0.1168
22	11108	2	40.3188	7.1667	1.7000
23	11109	21	40.3394	0.0	0.3042
24	11110	29	16.1384	0.0	1.0000
					197.7500
					197.7500
					197.7150
					81.3750
					81.3750
					51.6925
					51.6925
					50.0000
					5.7610
					5.7566
					30.4112
					20.1900
					1.0000
					10.2700
					23.4715
					23.4596
					23.4715
					24.3257
					23.4715
					23.4596
					40.3394
					40.3188
					16.1385
					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 LEM/SEC
 W2= 122.71 LEM/SEC
 W8= 123.78 LEM/SEC
 P8= 15.18 PSIA
 T8= 1405.49 DEG R
 SEC= 0.406 LB1(FUEL)/HP*HR
 T54= 1327.1 DEG R
 NG= 8827.0 RPM
 MCDULE COOLING TEMP OUT= 250.3 DEG F

FITTING ID	FITTING TYPE	PRESSURE LOSS INCH W.G.	VELOCITY PRESSURE INCH W.G.	
312201	24	0.42	0.02	LOUVER ENTRANCE
122202	25	0.72	0.02	FITTING
122203	25	0.00	0.02	STRAIGHT DUCT
223101	14	0.04	0.09	MAIN SECT, DIV WYE
223102	26	0.09	0.09	SILENCE SECTION
223103	22	0.01	0.23	CONTRACT, RECT
223104	28	0.18	0.23	ELBOW, MITERED, RECT
223105	23	0.52	0.25	SCREEN IN DUCT
240001	13	0.67	0.72	BRANCH, DIV WYE
240002	25	0.02	0.73	STRAIGHT DUCT
330001	25	0.00	1.71	STRAIGHT DUCT
330002	16	1.30	2.24	MAIN SECT, CONV WYE
430001	27	1.54	2.04	GAS IN SECT, MODULE
450002	15	-3.24	2.24	BRANCH, CONV WYE
550201	21	0.04	3.81	CONTRACT, ROUND
550202	22	0.05	3.79	STRAIGHT DUCT
550203	5	0.74	3.79	ELBOW, MITERED, ROUND
550204	5	0.04	3.54	STRAIGHT DUCT
550205	5	0.74	3.80	ELBOW, MITERED, ROUND
550206	2	0.02	3.91	STRAIGHT DUCT
550207	17	0.45	3.90	JIFFY, CONICAL
550208	22	0.00	1.29	STRAIGHT DUCT
560209	21	2.48	3.89	CONTRACT, ROUND
560210	29	8.10	8.10	EXIT, ABRUPT
LOSS	ANCH	1-2:	1.14	
LOSS	ANCH	2-3:	0.83	
LOSS	ANCH	3-5:	1.31	
LOSS	ANCH	5-6:	12.65	
LOSS	ANCH	2-4:	0.69	
LOSS	ANCH	4-5:	-1.70	

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 (REM) : 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
 F8= 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 ID	FITTING TYPE	PRESSURE LOSS INCH W.G.	VELOCITY INCH W.G.	PRESSURE	
312201	24	0.30	0.32		LOUVER ENTRANCE
122202	25	0.55	0.32		FILTER
122203	22	0.00	0.32		STRAIGHT DUCT
223101	14	0.02	0.06		MAIN SECT DIV WYE
223102	26	0.06	0.06		SILENCER SECTION
223103	22	0.00	0.15		CONTRACTION, RECT
223104	6	0.12	0.15		ELBOW, MITERED, RECT
223105	23	0.34	0.16		SCREEN, IN DUCT
240001	13	0.73	0.79		BRANCH, DIV WYE
240002	22	0.02	0.79		STRAIGHT DUCT
35101	22	0.00	1.03		STRAIGHT DUCT
35102	16	0.85	1.46		MAIN SECT CONV WYE
450001	27	-1.69	0.3		GAS DIRECT, MODULE
450002	15	-1.84	1.46		BRANCH, CONV WYE
556201	21	-0.03	2.48		CONTRACTION, ROUND
556202	22	0.03	2.47		STRAIGHT DUCT
556203	5	0.49	2.47		ELBOW, MITERED, ROUND
556204	5	0.02	2.30		STRAIGHT DUCT
556205	5	0.49	2.48		ELBOW, MITERED, ROUND
556206	5	0.01	2.48		STRAIGHT DUCT
556207	17	0.30	2.48		DIFF, CONICAL
556208	21	0.00	0.00		STRAIGHT DUCT
556209	21	1.60	5.26		CONTRACTION, ROUND
556210	29	5.27	5.27		EXIT, ABRUPT
LOSS BRANCH 1-2		0.86			
LOSS BRANCH 2-3		0.55			
LOSS BRANCH 3-5		0.65			
LOSS BRANCH 5-6		8.25			
LOSS BRANCH 2-4		0.75			
LOSS BRANCH 4-5		-0.15			

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