COMPUTER PROGRAM FOR THE DESIGN AND COST ESTIMATION OF HAZARDOUS WASTE INCINERATION FACILITIES

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Bachelor of Science

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Stillwater, Oklahoma

1986

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1986

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Thesis Approved:

Thesis Adviser

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PREFACE

The purpose of this study was to construct a computer program to design and cost estimate a hazardous waste incineration facility. This program also provides a method to economically analyze each facility. The combustors available for the design include; rotary kiln, fluidized bed, and liquid injection. Other process units were available to provide pollution control and other important facility requirements. These units include; afterburners, heat recovery boilers, quench chambers, venturi scrubbers, packed bed absorbers, and exhaust stacks. This program allows for a design up to a 10,000 lb/hr waste feed rate.

I am especially grateful to my thesis adviser, Dr. Robert A. Wills, for his valuable and friendly guidance, patience, and cooperation during this study. I am thankful to Dr. Billy L. Crynes and Dr. Robert L. Robinson for their cooperation as committee members. I am in appreciation of Hasan Qabazard and Carlos Ruiz for their professional and personnal assistance in completing this project. A special note of thanks is due all the office secretaries.

Financial support from the School of Chemical Engineering is greatly appreciated.

Finally, I wish to dedicate this achievement to my wife Marianne, and my parents Dean and Ebba who understood, inspired, and supported my work.

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LIST OF VARIABLES

a - Constant for packed bed absorption process.

b - Constant for packed bed absorption process.

c - Constant for packed bed absorption process.

d - Heat capacity constant(See equation 42).

e - Heat capacity constant(See equation 42).

f - Heat capacity constant(See equation 42).

g - Constant for packed bed absorption process.

g1 - Constant for materials of construction for heat recovery boiler.

g2 - Constant for materials of construction for heat recovery boiler.

m - Slope of the vapor-liquid equilibrium curve(See figure 23).

n - Constant for packed bed absorption process.

t - Time(seconds).

ug - Gas viscosity(cps).

ul - Liquid viscosity(cps).

z - Constant for packed bed absorption process.

A - Area(square feet).

Ac - Constant for Venturi scrubber removal efficiency.

Bc - Constant for Venturi scrubber removal efficiency.

C - Cost of heat recovery boiler(U.S. Dollars).

Cb - Base cost for the Storage tank and heat recovery boiler(U.S. Dollars).

CC - Incineration facility capital cost(U.S. Dollars).

Ci - Inlet concentration(lb / cubic feet).

Co - Outlet concentration(lb/cubic feet).

Cst - Constant for calculation of induction fan horsepower.

Cp - Heat capacity(Btu/lb Fahrenheit).

D - Diameter of ductwork(inches).

Deg - Density of gas phase(lb/cubic feet).

Del - Density of liquid phase(lb/cubic feet).

Dg - Diffusivity of caustic in the gas phase(square feet/second).

Dl - Diffusivity of caustic in the liquid phase(square feet/second).

Dp - Diameter of particle(microns).

DTm - Log mean temperature difference(Fahrenheit).

EA - Excess air(Percent).

F - Packing factor.

FV - Future cost(U.S. Dollars).

Fd - Exchanger type cost factor.

Fm - Materials of construction cost factor for storage tanks and heat recovery boiler.

Fp - Design pressure cost facotr for the heat recovery boiler.

Gm - Mass velocity of the gas phase(lb/hour cubic feet).

H - Height of exhaust stack(feet).

Hg - Height of has transfer unit(Feet).

Hl - Height of liquid mass transfer unit(Feet).

Hog - Total height of one mass transfer unit(Feet).

HP - Power(Horsepower).

HR - Heat release rate(millions of Btu /hour).

Kp - Reaction equilibrium constant.

L - Length(feet).

Lm - Mass velocity of liquid phase(lb/hour square feet).

Nog - Number of mass transfer units required in the absorption process.

Pd - Penentration fraction of gas entrained particulates through the venturi scrubber.

PD - Pressure drop(inches H2O).

PV - Present value cost(U.S. Dollars).

Pg - Gas density(lb/cubic feet).

Pl - Liquid density(lb/cubic feet).

Q - Heat transfer rate(Btu/hour).

Qf - Liquid flooding rate(cubic feet/minute square foot area).

Qr - Heat release rate(Btu/hour cubic feet).

T - Temperature(Fahrenheit).

RT - Rate of interest.

TCP - Theoretical combustion products rate(scf/Btu).

Te - Exit temperature from incinerator(Fahrenheit).

Tf - Temperature in incinerator(Fahrenheit).

U - Heat transfer coefficient(Btu/hour/ft°2/Fahrenheit).

V - Volume(Gallons).

Vf - Gas flooding rate(cubic feet/minute square feet).

Vm - Volume rate(cubic feet/minute).

YR - Number of years that money is borrowed.

Y1 - Inlet gas mole fraction.

Y2 - Outlet gas mole fraction.

CHAPTER I

INTRODUCTION

One of the most important areas of the treatment of hazardous wastes is the ultimate disposal method. Land and ship based facilities are both technically feasible and economically viable at high feed rates. This program provides the process designer with a quick way to compare different incineration systems with the same waste feed rate.

The specific objectives of this project are:

1) Allow design and cost estimation for the available combustion systems.
2) Print a breakdown of the equipment, indirect, and operating expenses.
3) Provide a method to economically evaluate the facilities that have been designed and cost estimated.
4) Construct the computer program in a modular format to allow for additional incineration and pollution control process unit options.

The problem was solved by integrating information obtained from literature and visits to operating hazardous waste incineration facilities.

This report will outline a computer program for the design and cost estimation of hazardous waste incineration facilities. Design parameters and cost data obtained for this program are from literature or from visitation to operating incineration facilties. The accuracy of this program is compared with capital and operating costs published for specific facilities.

CHAPTER II

LITERATURE REVIEW

Incineration Design and Operation Literature

There is much literature pertaining to the design and operation of non-hazardous waste incineration facilities. Unfortunately, there is little technical data for hazardous waste incineration facilities. This is due to the proprietary nature of the industry and the relative recentness of the technology. Much of the information that applies to hazardous waste incineration processes is obtained from incineration of sludges and solid wastes.

This literature review will cover the following topics. First, literature pertaining to general information on the incineration of hazardous wastes is presented. Second, literature on the design and operation of combustors and pollution equipment is discussed. Finally, literature pertaining to other components of the capital cost not covered above is presented.

Incineration of Non-Hazardous wastes

Many aspects of non-hazardous waste incineration practices are discussed by Brunner (1). He lays the groundwork for the design and operation for the incineration of sewage sludges. This discussion includes the disposal alternatives, design parameters, operations, legislation, and capital costs of incineration facilities. This information is discussed more thoroughly in each section of this thesis.

A review of the state of art of incineration practices for the destruction of sewage sludges is presented by Balakrishnan et. al. (2). Balakrishnan discusses pretreatment options and operational characteristics of sewage sludge incineration systems. While pretreatment of hazardous wastes is limited, some of the discussed methods are applicable.

A more detailed evaluation of the sewage sludge incineration applied to fluidized bed and multiple hearth furnaces is presented by the Environmental Protection Agency (3). This publication discusses the incinerator and scrubbing performances of the units. Much of the data presented details the emission concentration of several pollutants.

Incineration of toxic wastes and other disposal methods is discussed in a publication by Powers (4). Powers book covers a much broader range of disposal methods. Applications and limitations of certain incineration processes are the major topics.

Incineration of Hazardous Wastes

Many sources for the design and operation of non-hazardous incinerators are available for more specific applications unimportant to hazardous waste incineration.

Application of incineration to hazardous waste was published by Bonner (5). He discusses many aspects of hazardous waste incineration design and operation. The book discusses many of the same subjects covered by Brunner on non-hazardous incineration. Important subjects covered are waste incineration practices, waste characterization, incineration and air pollution control design, and overall operation and monitoring of hazardous waste incineration processes.

A more complete discussion of the subject of hazardous waste incineration facilities is presented by The Electric Power Research Institute (EPRI). This publication provides an analysis of an incineration design parameters (for the rotary kiln, fluidized bed, and liquid injection incinerators) and cost analysis of PCB preprocessing, and permitting procedures. This is one of the few sources that discusses incineration technology applied to PCB combustion.

Combustor Design and Operation Literature

Survey of Industry

Frankel et. al. published data from a survey of the waste incineration industry (6). This data is based on information acquired from 119 different vendors of commercially available incineration systems. The purpose of this article was to determine the type of units in operation, their operating capacities, and the types of wastes incinerated. Incineration methods included are fluidized bed, multiple hearth, rotary kiln, liquid injection, and others. He presents data on the number of units in service, unit capacities, type of wastes incinerated, and design and operation conditions for the combustor.

Combustors

Fluidized Bed Combustors. Very little technical data is available on the design and cost estimation of fluidized bed incinerators. Fortunately, design parameters for fluidized beds can be calculated from data published in literature on operating facilities. Sizing characteristics and technical data for the bed diameter is presented by Brunner (1). Sewage sludge data is based on a water-based feed waste.

Huang discusses the operating characteristics of fluidized bed incinerators (7). In this, he covers the temperature distribution, residence time, height, operating conditions and fluidizing characteristics. Diameter of a fluidized bed (based on heat release rate) and sizing procedures are presented in an article published by Sneyd (8). This information generally overlays data from the sources discussed above.

Literature available on procedures for the cost estimation of fluidized beds is unavailable. Fortunately, there has been cost data for specific operating facilities published in literature. One source of this cost data is by Brunner (1). This work includes the installed cost of fluidized bed incinerators with air preheaters.

A second source of cost data for a fluidized bed incinerator is published by Balakrishanan et. al. (2). This information was made available by Dorr-Oliver Incorporated; a well known consulting firm for the design of fluidized bed incinerators. Their costs include the installed incinerator not just the cost of the equipment.

A cost estimation method which can be applied to fluidized bed incinerators is presented by Vogel and Martin (9). While this method is specifically for rotary kiln and liquid injection units, it can also be applied to fluidized beds.

The design of a particular fluidized bed unit is discussed in a publication by Gottko (10), whereby technical information on dimensions, materials of construction, and steam generation is presented. Operating parameters such as bed and flyash removal are also discussed.

Rotary Kiln and Liquid Injection Combustors. Information on the design and cost estimation of rotary kiln and liquid injection are available in literature. No doubt because these technologies have been used for years. Bonner describes the rotary kiln and liquid injection sub-systems along with incinerator applications (5).

A more complete discussion of the design and operation parameters of the rotary kiln and liquid injection incinerators is presented by Powers (4). Here, he presents data to calculate the dimensions of each incinerator type and the important factors that affect incineration operation. Powers also presents some approximations for the cost estimation of uninstalled commercially available incineration facilities. This cost data is based on the feed rate of the waste.

A more accurate method for the cost estimation of rotary kiln and liquid injection incinerators is presented by Vogel and Martin (9). This method estimates the cost of incinerator sub-systems including:

1) Waste feed system
2) Refractory
3) Shell
4) Ash removal

Cost factors are included for the assembly and installation of the incineration system. According to Vogel and Martin, this cost estimation method is accurate to $\pm$20 percent.

Pollution Control

Information concerning the design and cost estimation of pollution control systems is well documented in the literature. This is due to the wide range of application of pollution control units and the importance of proper operation. Because of this, only publications pertaining to the incineration technology will be discussed. Presentation of the literature obtained will occur under each units topic. First, literature published dealing with emission legislation and emission standards will be discussed.

Pollution Control Regulations

A summary of important federal regulations that apply to generation storage, and disposal of hazardous waste is presented by Kahane et. al. (11). Kahane indicates that the important bodies of regulations are; the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response and Liability Act, the Clean Water Act, Clean Air Act, and The Toxic Substances Control Act (TOSCA).

The actual regulations for processing hazardous wastes and the emissions standards for facilities is listed under Title 40 of the Federal Register (12). These regulations present base values for emission standards, destruction conditions, storage and operation procedures.

For incineration facilities, pollution control units selected are; afterburners, heat recovery boilers, quench chambers, venturi and packed bed scrubbers, induction fans and exhaust stacks. The literature on ductwork is also discussed under this section.

Afterburners

The design of afterburners is similar to that of liquid injection units. Therefore, literature on liquid injection units apply to afterburner units. Vogel and Martin have recommended some sizing parameters to design liquid injection incinerators (9). They also presented a cost estimation method.

Heat Recovery Boilers

Literature available on heat recovery units is limited to general design parameters and cost estimation. Specification of heat recovery systems based on feed rate is presented by Lepeau (13). Lepeau limited the specification of heat recovery units to a payback period of 6 years. This was determined by an economic optimization for the specification of heat recovery from incineration. Literature on design parameters and cost estimation is presented by Vatavuk and Neveril(48). The design is limited to the calculation of heat transfer area. The dimensions of the heat recovery boilers are not determined. Fortunately, these dimensions are not important to estimate the cost of the unit.

A second method to estimate the cost of heat recovery systems for the incineration industry is presented by Vogel and Martin (14). This cost estimation method is highly restricted. A more accurate cost estimation procedure is presented by Corripio et. al. (15). Vogel's method, which is curve-fit from data obtained in industry, estimates the cost of these units to ± 20 percent.

A publication by Santoleri discusses the design parameters and operational considerations for heat recovery for the incineration of chlorinated hydrocarbons (16). Specifically, Santoreli recommends corrosion resistant materials, amount of heat to recover, and problems that may arise during operation. Information is available on estimation of the overall heat transfer coefficient for combustion gases(36).

An alternative heat recovery system, discussed by Sneyd (8), preheats air with the waste heat before incineration. Sneyd studied the effect of preheating air for fluidized bed combustors.

Quench Chamber

Quench chambers are implemented in many different industries. Therefore, there is much data available on this process. The literature available discusses the design parameters, operating requirements and problems common to quench chambers.

Vatavuk and Neveril present design and cost estimates for quench chambers (17). This method applies specifically to the incineration industry.

Particulate and Caustic Scrubbing

Scrubbers are pollution control systems important to many industries. Therefore, there is a large body of information in the literature covering the many aspects of scrubber design, operation and cost estimation. Only information important for this work will be discussed (caustic and particulates removal). Two kinds of scrubbers are normally specified for removal of particulates and caustics. These are the venturi and packed bed scrubber.

Selection of scrubbers for particulate control is discussed by Seymor (18). Seymor describes the different types of scrubbers and test performance procedures. Equations to curve-fit particulate removal efficiency are available from this source.

Venturi Scrubbers. Design of venturi scrubbers is presented by Hesketh and Mohan (30). This method uses experimental data generated by the Environmental Protection Agency. Some important design parameters are also estimated. Cheremisoff also presents data for venturi scrubber designs. This is based on experimental cut-diameter data for venturi scrubbers. Recommended operating conditions are presented.

The cost of venturi scrubbers is also available in literature. Two design procedures for venturi scrubbers, that apply to incineration are discussed below.

The equipment and operating cost for a venturi scrubbers is estimated by Vogel and Neveril (14,19). Unfortunately, the design parameters are not adjustable. Cost is based on volume flowrate.

Estimation of the cost of a venturi scrubber is presented by Vatavuk (20). Material of construction, pressure drop, and gas volumetric flow rate are accounted for by Vatavuk. Also included is the cost estimation and dimensions of the vapor liquid separator after the venturi scrubber. Recommended range of operating parameters is also presented. Accuracy of the cost data is estimated at ± 30 percent. Other procedures for design and cost of venturi scrubbers are available, but these methods are not for incineration operation or are not flexible design methods.

Packed Bed Scrubbers. The design of packed bed scrubbers is well documented in literature. Two design methods are discussed below.

The Air Pollution Control Association has published a method to design (and cost estimate) packed bed or tray bed absorbers (21). Column diameter was obtained using correlated data and the height was estimated by the mass transfer unit (MTU) method.

Another design method for packed bed scrubber is presented by Cheremisinoff (22). The procedure determines the diameter of the column from an empirical equation. Height is calculated by the mass transfer unit method.

A publication by Hanf and MacDonald presents information on scrubber applications and the height of packed bed scrubbers for a given removal efficiency (23). This data applies to highly soluble gases or absorption followed by chemical reaction. Also presented is data on water feed rates for the volume rate of fluegas.

Other sources for designing packed bed absorbers are available, but these are similar versions to the sources described above. Diffusion coefficients for caustics in gas and liquid phase are published by the Air Pollution Control Association (21).

The cost estimation of packed bed absorbers is available from a few sources in literature. The cost methods available are based on the volume rate of gas. Cost data was supplied by Hanf and MacDonald (23), the Air Pollution Control Association (21), and Peters and Timmerhaus (24).

Exhaust Stacks

The design and cost of exhaust stacks is available from many sources. Vatavuk and Neveril provide data to design and cost estimate exhaust stacks (14). Stack design using this method is limited to 200 feet, due to materials limitations, and does not include accessories. Vogel and

Martin also published cost data on exhaust stacks (25). The cost is based on a per foot basis and the accuracy of the method is estimated at ± 30 percent.

Ductwork

The design and cost of ductwork is available. A superior method to design and cost estimate ductwork and accessories is presented by Vatavuk and Neveril (26). Vatavuk provides recommended physical parameters for proper design of ductwork. Cost estimation method includes installation, bends, and materials of construction. Extra costs, such as firebrick for high temperature operation are not included.

Induction Fans

Information for the design of induction fans is provided in many sources in literature. Most design methods are not flexible. An exception to this was presented by Vatavuk and Neveril (27). This method allows specification of the number of fans, the pressure drop, motor rpm's. Fan selection is limited to radial or backward curved fan blades. The cost of induction fans and motors is also provided. This is the sum of the motor, fans, inlet and outlet dampers and extras costs.

Another method for compressor cost estimation is presented by Vogel and Martin (14). The only variable design parameter allowed is the fluegas flowrate. Pressure difference and outlet temperature are specified. Cost factors are available to adjust for different pressure head and temperatures.

Literature on Other Facility Costs

Besides the equipment costs for incinerators, information on facility design are generally unavailable in the literature. Some design parameters and costs not available from the literature were obtained from visitations to incineration facility sites. Some sources from the literature pertaining to the design and cost of miscellaneous facility components are discussed below. Much of this data is from Lepeau (3) and Vogel and Martin (14,28).

Waste Storage

Hazardous waste is typically stored before incineration to insure an adequate feedstock. Vogel and Martin presented data to estimate the cost of storage tanks at 25,000, 10,000, and 5,000 gallons (9). This includes the accessory costs required for the storage of hazardous wastes. Also included is extra equipment that may be required for volatile wastes.

A more flexible method to estimate storage tank costs is presented by Corripio (15). The data presented was curve-fit from industrial costs. Costs include different materials of construction, lining and design pressure.

Sitework

Sitework and foundation costs can be significant due to the special design considerations. Unfortunately, data in the literature is unavailable for hazardous wastes. Lepeau does provide cost data for sitework and foundations (13). The variation in cost of sitework is discussed by Vatavuk and Neveril (29). He estimates, depending on the extent of work, that the costs may vary by up to 200 percent.

CHAPTER III

BACKGROUND

Incineration Facility Design and Cost

This background section is divided into seven parts. These are: incineration facility design practices, design and capital cost of incinerators and pollution control systems, miscellaneous facility components, operating costs, and facility capital costs. Information available was, with a few exceptions, limited to generalized process descriptions. Many important design parameters and cost information are not available. Much information was obtained from on-site visits to operating hazardous waste incineration facilities. This section provides an overview of the information on design of a hazardous waste incineration facility and the alternative data available for the cost estimation of the various process equipment.

Equipment specified for most hazardous incineration facilities are the same, but the actual design of the equipment may be very different. Specifications of the process units are dependent on the waste feed characteristics and the experience of the designer (31). Incineration is ideal for destruction of most chlorinated wastes, reducing the chlorine content in the ash, and reducing the volume of waste that must be landfilled (16).

Waste Incineration Practices

Process Variables

A list of process variables for incineration considered are:

1) Amount of excess air
2) Characteristics of waste
3) Pretreatment of the waste
4) Type of Heating Fuel
5) Conditions for Destruction
6) Pollution Control

Each parameter will be discussed separately.

Excess Air

Literature sources recommend a range of 25 to 100 percent excess air (depending on the type of waste and type of incinerator selected) (1,32). Much data is available on excess air calculations. If waste feed contains significant amounts of nitrogen, incineration should take place under oxygen starved conditions (pyrolysis). Unfortunately, this risks incomplete combustion of the waste. This is recommended by Powers to prevent the formation of nitrous oxides from the nitrogen in the waste (4). Under starved air conditions, the nitrogen in the waste is converted to molecular nitrogen gas (N_2).

Characteristics of Waste

The characteristics of the waste feed is another important design parameter. Wastes vary widely in composition. Some wastes cannot be properly disposed of by incineration; for example wastes contaiminated with heavy metals. A list of waste types, and their proper disposal methods is summarized by Brunner (1). The composition of some common sewage sludges was published by Balakrishnon et. al. (2). The properties of PCB's was published by Sebastian et. al. (33). Many equations are available to predict the heat value of the waste feeds. Two equations which predict the heat value of chlorinated and non-chlorinated hydrocarbon wastes are given below (32). Heat of combustion for waste feed can range from 4000 to 8,000 Btu/lb (2,16). The first equation predicts the lower waste heat value limit and the second equation predicts the upper heat value limit (as defined by Sterns et. al.) (32).

Low Value

$$\text{(Btu/lb)} = 14{,}100*(C) + 45{,}000*(H - O/8) - 760*(Cl) + 4{,}500 \quad (1)$$

High Value

$$\text{(Btu/lb)} = 14{,}100*(C) + 54{,}500*(H - O/8) - 150*(Cl) + 4{,}500 \quad (2)$$

The variables are expressed in weight fractions of each element (between 0 and 1) of the waste feed volatiles components. Other equations, used for different types of wastes are available from many sources (2,4).

Pretreatment

Pretreatment is implemented in most waste incineration processes to improve the combustability of the feed. A comprehensive publication on this subject was published by Balakrishnon el. al. (2). Some common methods of waste pretreatment are degritting, blending, and thickening. Some of these methods are not applicable because nothing may be removed from a hazardous waste before incineration. Since nothing may be removed from a hazardous waste feed before incineration, pretreatment processes are limited. The costs of chemical pretreatment (to stablize the waste) ranges from 15 to 30 U.S. Dollars (1970) per ton of waste according to Balakrishnon (2).

Fuel

Selection of fuel feed and fuel requirements are also discussed by Balakrishnon et. al. (2). Fuel requirements must include the following considerations:

1) Vaporize free water
2) Heat oxidation products to desired temperature.
3) Heat requirements for endothermic reaction of the ash products.
4) Heat losses due to radiation.

Selection of the fuel type depends on the cost and availability of the source. Two commonly available fuel sources for the incineration process are fuel oil #2 and natural gas. Combustion properties for both are listed in Table I (35).

TABLE I

COMPOSITION AND HEATING VALUE OF COMMON INCINERATOR FUELS

Composition (Mole Percent)	Fuel Oil No. 1	Fuel Oil No. 2	Natural Gas
Carbon	86.4	87.3	74.4
Hydrogen	13.6	12.6	25.6
Oxygen	0.01	0.04	0.0
Nitrogen	0.003	0.006	0.0
Sulfur	0.09	0.22	0.0
Ash	<0.01	<0.01	<0.01
Heat of Combustion	137,000 (Btu/lb)	153,000 (Btu/lb)	1,020 (Btu/SCF)

Destruction Conditions

The destruction of these hydrocarbons is recommended to be 99.9999 % (6- nines) (35). The conditions for the destruction of the waste feed are another important design parameter. The temperature of the incineration process depends on the type of waste in question. For some non-hazardous wastes, the combustor temperature is selected to eliminate the odor emissions (40). Chlorinated hydrocarbons begin to decompose at 500^{o} C (54). The primary incinerator is specified to vaporize the waste feed if an afterburner is also specified. Unburned volatiles from the primary incinerator require the addition of afterburners (40). The concentration of contaminants for the destruction of hydrocarbons are listed in Figure 1 (32). Pressure in the incinerator is usually less than atmospheric (except for fluidized bed) (36).

For the combustion of chlorinated hydrocarbons, Santolari el. al. recommends the following design specifications (16). Chlorinated hydrocarbons require high air rates due to the slow combustion rates. Unfortunately, high air rates promote the formation of molecular chlorine. The amount of free chlorine formed at equilibrium is predicted by the equation below (31):

$$K_p = \frac{(HCL)^2 \, (O_2)^{0.5}}{(H_2O) \, (Cl_2)} \qquad (3)$$

Here, the variables represent the relative concentrations of products and reactants. This indicates the effects of chlorine formation on the product gas concentration. Values of Kp are available from data published in the literature (5,32). Reduction of molecular chlorine can be accomplished by increasing the temperature of combustion, adding a light solvent, or injecting additional quantities of water to the

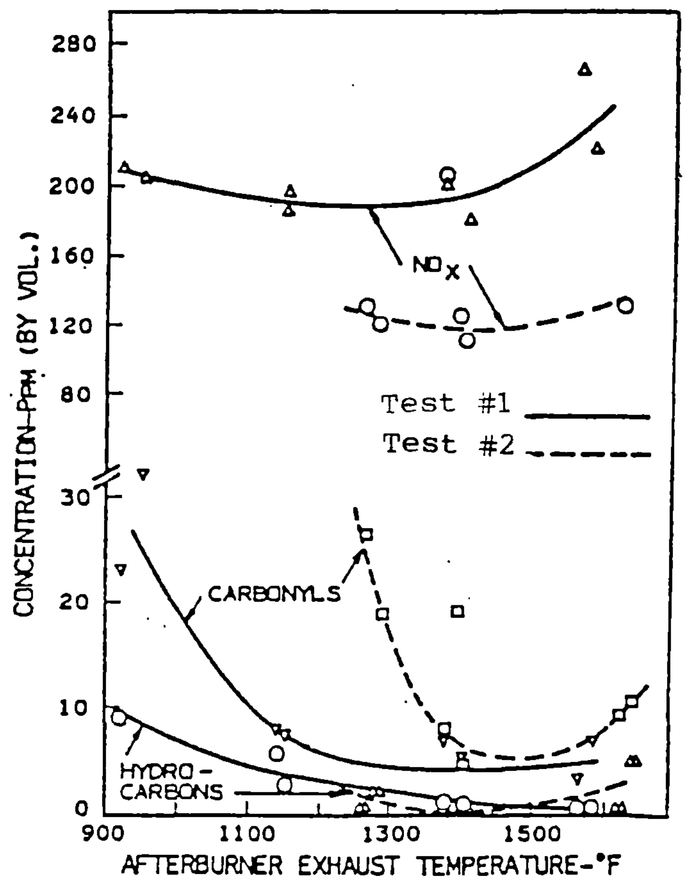

Figure 1. The effluent equilibrium concentration of incinerated hydrocarbons (53).

incinerator. If the waste feed exceeds 54 weight percent chlorine, an additional supply of hydrogen (in the form of a hydrocarbon or water) must be added because there is a lack of hydrogen for hydrogen chloride formation (32).

Selection of the conditions for destruction of the waste must be determined experimentally. Information published in the literature can provide guidelines, but each waste is very different. For the combustion of dioxins, the EPA recommends the following conditions (36):

1) For <u>liquids</u> with dioxin concentrations less than 357 ppm in a waste oil, the destruction efficiency of 99.9999 percent requires a primary temperature of 1,800 ^{o} F and 2,200^{o} F in the afterburner.

2) For <u>solids</u> with dioxin concentrations less than 1.01 ppm in a soil, the destruction efficiency of 99.9999 percent requires a primary incinerator temperature of 1,800^{o} F and 2,200^{o} F in the afterburner.

The retention time and heat release rate was not estimated from the source.

A different source suggested the same conditions for destruction of chlorinated hydrocarbons, but with an incinerator retention time of 2 s (11). For most hazardous waste feeds, 1,830^{o} F is required in the afterburner. For chlorinated hydrocarbons, 2,200^{o} F is recommended in the afterburner (11).

Pollution Control

Disposal of the incinerated refuse and exhaust scrubbing water is an important factor that must be considered in the design. Incinerator ash from hazardous waste may still be dangerous. Tests on ash from PCB wastes have indicated trace amounts of PCB's left in the ash (36).

Venturi quench chamber, and absorber waste waters are usually treated by ponding (37). This leaves a polluted, unuseable area. While this is acceptable for non-hazardous wastes, it is not feasible for hazardous wastes. Particulates may also be separated from the water with a thickener and use of vacuum filtration (or centrifugation) (38). The removed particulates are usually disposed of with the bottom ash from the primary incinerator (37).

The selection and amount of pollution control equipment varies with different locations due to local pollution control regulations. One common requirement is to reduce the exhaust stack opacity to less than 20 % (18). Federal requirements for particulate matter and effluent chemical requirements are covered under Title 40 (12). A list of wastes and their classification is also available under Title 40 (12)

Test methods are available to determine the particulate and chemical emissions from the facility. Particulates emissions exhibit a large variety of particle distribution and chemical composition (37). Equipment used and experimental methods for stack sampling is discussed in an article by Lindsey (37). Particulate control is dependent on venturi scrubber efficiency (37).

Process Design

From the design practices discussed in the previous section and the physical and chemical characteristics of the waste feed, a selection of equipment and design parameters can be made. This section discusses the information available on the incinerator, pollution control equipment (used in incineration technology), other facility capital costs, and the operating requirements.

Primary Combustors Components and Accessories

Many types of incinerators are available. Some incinerator technologies are not feasible for hazardous waste due to temperature limitations. Of the many types of incinerators, the following are accepted as hazardous incineration alternatives:

1) Liquid Injection
2) Multiple Hearth
3) Rotary Kiln
4) Fluidized Bed

These technologies have been proven as accepted methods of hazardous waste destruction (6). A computer program predicting the facility design and cost of a multiple hearth furnace has been published (39). Therefore, this type is not covered in this paper. The basis for the program is different from this author's approach. Design and cost data used were obtained from total costs of hearth facility for different waste feeds. Design and cost of individual units was not conducted. The program is also not very flexible, but does attempt to account (stoichiometrically) for the endothermic reactions associated with the ash products.

Waste Feed System for Combustors. If the waste is pumpable, burners are implemented most often. Special burners are available for the waste feed systems with placement of the burners based on the waste heat content. If the waste feed has a low heat content, burners are placed counter-current to the waste feed. If high, the burners are placed co-current (40). If the waste is not pumpable, an alternate waste feed system, such as screw pump or a container method must be selected.

Fuel Burner System for Combustors. The fuel burner system is another important design parameter for the incinerator. The size of a fuel burner system is based on the number and capacity of the burners required (9). If the heat content of the waste feed is low (less than 4,000 Btu/lb), two of more fuel burners should be implemented.

Firebrick and Shell. Selection of firebrick and shell is based on the incineration product temperature, chemistry, and volume. The temperature of the incinerator specifies the type of heat resistant firebrick used and the required thickness. Two types of refractory are available; castable and firebrick. Castable refractory is plastic and may be formed or sprayed on (9,40). More than one type of refractory may be used to line an incinerator (9). Firebrick lining and insulating firebrick is selected to protect the shell from a corrosive environment and high temperatures. Acid resistant firebrick is permeable to corrosive acids. Here, an insulating liner is required to protect the shell from corrosion. Firebrick linings cannot exceed 800 - 900^{o} F. All firebrick are sensitive to temperature shock (4).

Firebrick refractory, high in aluminum oxide , breaks down with exposure to some salts in the ash (40). Manganese oxide firebrick should be used for refractory with high Sodium content (4). High alumina refractory is seldom used with waste high in alkalies or halides (11,16).

Other Combustor Design Considerations. Generally, incinerator design for hazardous waste incineration facility is as follows:

1) Minimize auxillary fuel requirements.
2) Operate with minimum excess air.
3) Produce minimum free chlorine.
4) High turbulence to provide efficient combustion.
5) Minimize combustion volume.
6) Minimize soot formation.

Soot formation can be reduced by not overloading the incineration system. Highly volatile, hard to burn materials (such as rubber) can overload the system causing incomplete burning (41).

The discussion above included information applicable to all incineration systems. The following section discusses, separately, each option available for the different incinerators.

Combustors

Rotary Kiln Combustor. Rotary kiln incinerators are used mainly to vaporize volatiles in solid wastes (4,40), but the rotary kiln may incinerate liquids or solids. A picture of a rotary kiln is shown in Figure 2 (32). Kiln temperatures are usually based on the heat required to completely vaporize the volatiles within the solids retention time in the incinerator. Destruction of the volatiles takes place primarily in the afterburner (40). Solids retention time is recommended to range from 30 minutes to 1 hour (4). The time is based on the angle of inclination, rotary speed and length. The rotary speed of a rotary kiln is recommended to range from one to five revolutions per minute. For liquid feeds, kiln rotation is not required (4).

Solid waste can be fed by all methods discussed earlier. The feed rate is recommended to be 10 percent of the total volume of incinerator (4,40). If containers are fed, a single unit should not exceed 30 percent of the total volume (42). The volume of a rotary kiln can be sized based on the

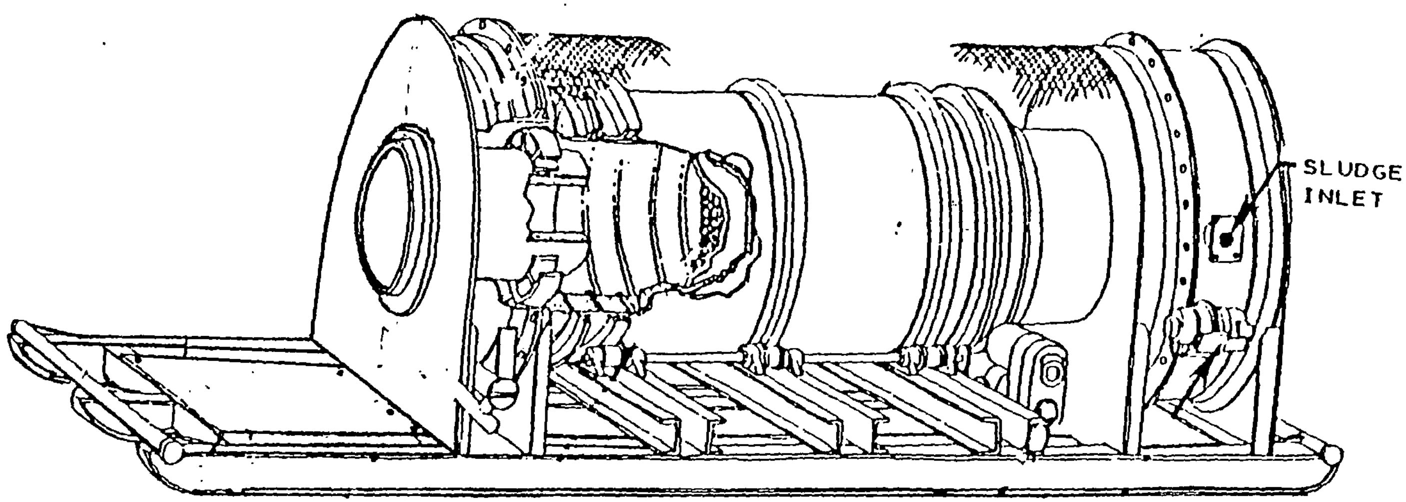

Figure 2. Diagram of an average rotary kiln incinerator for destruction of hazardous wastes (9).

retention time, heat release rate, or container size. If retention time is selected, the dimensions based on the volume rate of the exhaust gas and length to diameter ratio. The heat release rate for a rotary kiln ranges from 25,000 to 40,000 Btu/cubic feet (42). Values of heat release rate as low as 16,000 Btu/cubic feet of combustor volume have been found in literature (42,43). If containers are fed to the rotary kiln, the incinerator volume can be calculated from the relationship in Table II below (42):

TABLE II

CONTAINER SIZE VERSUS CHAMBER SIZE FOR THE ROTARY KILN INCINERATOR

Container Size (gal)	Heat Release (million Btu/hr)
5	5
15	14
30	30
55	55

The volume of the combustion chamber is calculated based on 16,000 Btu/hour/cubic feet of emission gas (42).

As discussed earlier, temperatures in the kiln are dependent on the characteristics of the waste. Therefore, the temperature to volatize each waste should be determined experimentaly in an incinerator (40). Combustion temperature in a kiln can reach 3,000° F (4,11), however the outside shell temperature will usually be around 500° F (4). Heat loss for a rotary kiln is reported to be 5 percent of the total heat released (42). Phillips reported heat losses of about 10 percent for a stainless steel shell (43). Heat loss from the ash is negligible (4). This simplifies the heat balance calculations. The dimension of a rotary kiln, in all cases, is based on the length to diameter ratio. For the rotary kiln, the recommended length to diameter ratio ranges from two to ten (4). Most kilns are designed with a ratio of three (11). The average design capacity for kilns is 1,600 lb/hr (6). The kiln is usually operated under a less than atmospheric pressure to prevent gas leaks (6). Air leaking into the system may cause problems, but efficient air seals will reduce the heat losses (43). Rings with wear pads are used most often. These seals reduce air leaks to 10 percent of the original value (4).

Factors that affect the rotary kiln capacity include (4):

1) Feed rate
2) Temperature
3) Excess air
4) Rotational speed
5) Moisture content
6) Preheat combustion air
7) Heat leaks
8) Instruments to optimize operation

For chlorinated hydrocarbons, materials range from inconel clad stainless steel shell (40) to a carbon steel shell (41).

The major problem with rotary kilns is due to the rotation of the walls. First, brick losses are higher in a kiln than other incineration technologies. Second, mechanical wear from ash may compound the brick loss problem. Third, the sleeve connecting the feed system to the shell may leak significant amounts of air.

Capital costs of rotary kiln incinerators can be estimated by different methods. Most methods available are highly uncertain. Powers estimates the uninstalled cost of rotary kiln to range from 30 to 60 U.S. Dollars (1976) / cubic feet (4). Installed costs are 200 percent of the free on board (fob) costs. Powers also estimates the cost of a municiple incinerator at 10,000 U.S. Dollars (1976) per daily ton of feed. Smaller industrial type kilns cost from 2,500 to 5,000 U.S. Dollars (1976) per daily ton of feed.

A superior method of cost estimation is provided by Vogel et. al. (9). The cost of the system is based on the cost of the incinerator sub-units. The cost of the shell and rotary drive is estimated at 175 U.S. Dollars (1976) per square foot of inside surface area (9). The cost of the drive system alone is based on $ 100 / square foot of inside surface area. The larger cost includes the rotary drive system and carbon steel shell construction.

<u>Fluidized Bed Combustor</u>. Fluidized bed incinerator technology handles the same variety of wastes as the rotary kiln. Figure 3 shows a fluidized bed incinerator (1). The

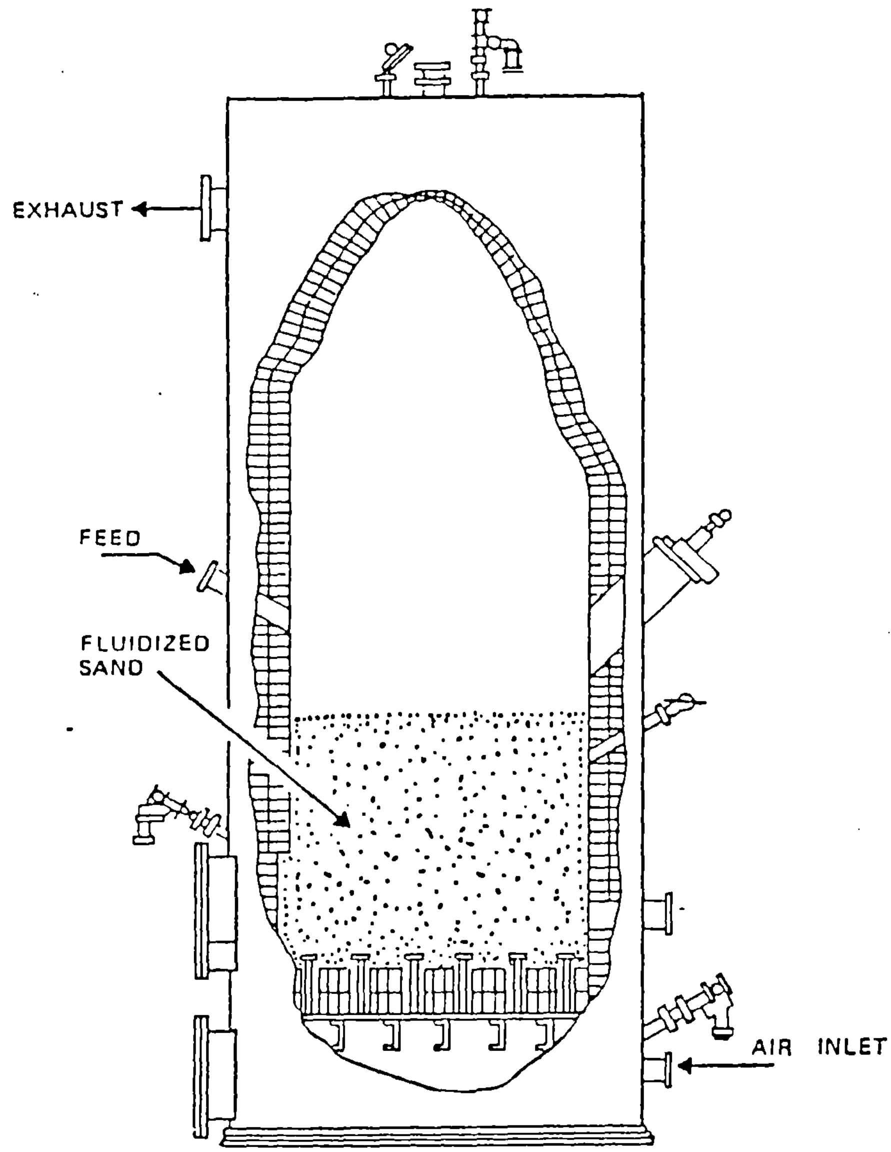

Figure 3. Example of one design of a fluidized bed combustor (6).

factors affecting the combustor performance are listed below (7):

1) Diameter
2) Height
3) Fluidizing air
4) Distribution Characteristics
5) Method of bed feed
6) Location and type of injection mechanism
7) Physical and chemical characteristics of the waste
8) Operating bed height
9) Fluidizing conditions

Factors one to six are fixed parameters that cannot be changed easily. The last four parameters are operating parameters (56). Recommended operating procedures to insure proper incineration are:

1) Uniform temperature distribution
2) Stable bed fluidization
3) Adequate fluidized bed retention time.

The waste is fed from the top into the fluidized bed. The fluidizing media (usually silica sand) is fluidized by an upflow of air supplied from a blower at the bottom (8). The gas/solids mixing in the fluidized bed provides a high degree of turbulence to insure complete volatilization (2). Air is used as the fluidizing gas (8). This type of design allows construction of incinerators with much higher feed rates (designs up to 36,000 lb/hr have been found) (1). This is due to the much smaller length to diameter ratio used as compared to other incineration systems (10). This low ratio reduces the shell and firebrick costs. The length to diameter ratio ranges from one to two, but complete design information is not available (7,10,43). Diameter of the fluidized bed is based on the superfical velocity (7). A correlation for fluidized bed diameter is not available (7,8), but is based on the amount of ash entrained in the emission gases (7). The height of the bed must be determined experimentally. Correlations for calculation of the height of a fluidized bed are not available. This is a design parameter unique to each waste.

Literature available on fluidized bed heights was found by studying specific examples. The height of the bed serves two purposes. First, the height allows the separation of ash entrained in the emission gases. This height is a function of the particle size, air density, and terminal velocity of ash particles (7). Second, the height provides a reasonable retention time for combustion (57). The efficiency of the fluidized bed allows excess air to be reduced to 20 to 25 % (8). The superficial velocity in the disengaging section of the fluidized bed range from 2.13 to 3.00 feet per second (7).

Conditions for destruction of wastes in fluidized beds are available from literature. An example of the destruction of a specific halogenated hydrocarbon was published by the Union Chemical Company (43). The primary incinerator (fluidized bed) temperature was 1,600 F. The afterburner temperature was 2,000 F. The residence time in the fluidized bed was two seconds. The shell and bed were constructed of Hastealloy. Destruction efficiency was 99.9 to 99.9999 percent. Because of the lower temperature requirements, flyash and nitrous oxide formation is significantly reduced (2).

Capital cost data on a fluidized bed is almost non-existant in the literature. Cost data is limited to one incomplete source published by Brunner (1).

Liquid Injection Combustors. Liquid injection incinerators can destroy liquid hazardous wastes, but cannot handle solid wastes. The liquid feed is atomized in special waste burners, and this promotes efficient combustion. A diagram of a liquid injection incinerator is shown in Figure 4 (32). The primary design parameters for the liquid injection incinerator are based on the retention time and high turbulence. The average design capacity for a liquid injection incinerator is 1,600 lb/hr (6). Liquid injection incinerators are the most commonly used incinerators today (6). Operating pressure in the incinerator may be positive or negative (6). The length to diameter ratio of a liquid injection unit can range from two to ten (5). Combustion temperature is dependent upon the waste's characteristics. For some, easy to combust wastes, afterburners may not be required. These units can be placed horizontally or vertically (11). Tests published by Balakrishan et. al. recommend the use of 90 percent alumina firebrick for temperatures between 2,500 to 2,800^{o} F (2).

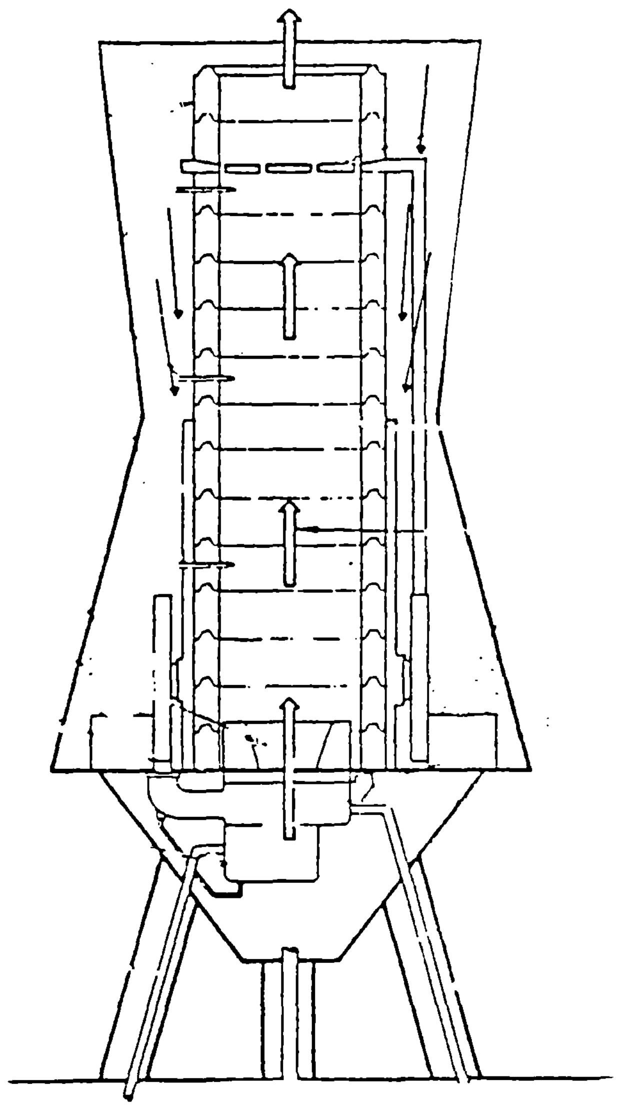

Figure 4. A vertical design of a liquid injection combustor. This type of incinerator may be horizontal or vertical (9).

The capital cost of the liquid injection incinerator is covered in the section on general incinerator design and costs. No ash removal system is required.

Afterburners

Afterburners are implemented after the primary combustor to insure the complete destruction of unburned volatiles released in the primary combustor (4). These units are designed and costed identically to the liquid injection incinerator unit. The pollution control system is specified after the incineration process to remove the chemicals and particulates in the gas stream.

Pollution Control System Design and Cost

This section covers the cost and design data for the pollution control systems. Due to the wide variety of industries requiring pollution control systems, an adequate amount of cost and design data has been published. Selection of the pollution process equipment was based on the equipment commonly used in the incineration industry (40,43). The units considered are:

Heat Recovery unit
Quench chamber
Venturi Scrubber and Separator
Induction Fan
Packed Bed Absorber
Exhaust Stack

Each unit will be discussed separately.

Heat Recovery Unit

Ninety percent of all incinerators are equipped with heat recovery (6). Figure 5 shows a fire-tube boiler for waste heat recovery (21). The design of water-tube or fire-tube boilers is complicated. Therefore, for cost estimation purposes, the design parameters for a heat recovery unit are limited to estimation of heat transfer area. The overall heat transfer coefficient for the boiler can range from two to eight Btu/hr/square foot (36). Implementation of a heat recovery system is limited to a payback period, as mentioned before, of 6.1 years (13). For most wastes, the feed rate must exceed 1,400 lb/hr (13).

Severe corrosion problems arise in the heat recovery boilers due to exposure to acid gases and molecular chlorine (Cl_2) (16). Carbon steel can be used if temperatures in the heat recovery unit are less than 500 ^oF and greater than the dew-point of the vapor (16). Proper operating parameters include (16):

1) Uniform gas temperature entering heat exchanger.
2) A high gas velocity to prevent ash build-up. Recover 70-75 percent of total heat released.
3) A gas temperature leaving the boiler should be between 500 and 700 ^oF.

Implementation of heat recovery units significantly reduces the amount of water required in the quench chamber.

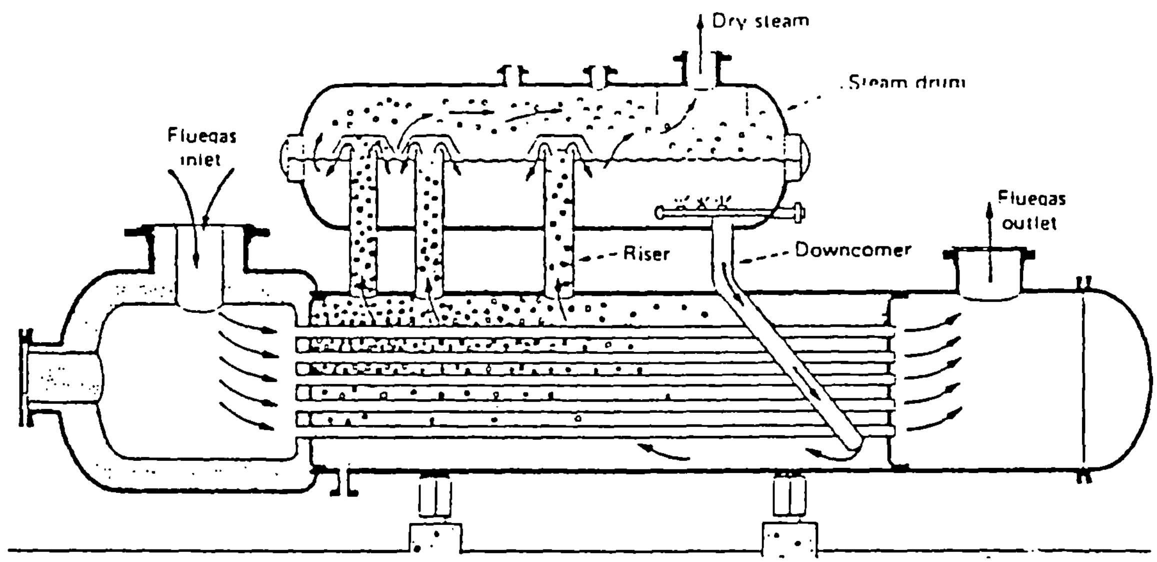

Figure 5. A fire-tube boiler for recovery of waste heat (73).

Quench Chamber

The quench chamber is a pollution control unit which cools the incinerator emissions. This unit is placed after the heat recovery system.

Two types of quench chambers are available depending on the amount of cooling. If the emission gases are cooled to saturation, a quencher should be used. If the outlet temperature is to be controlled, a spray chamber is specified. More controls are required on the spray chamber. The length to diameter ratio and superficial gas velocity and the design parameters affecting the construction of the quench chambers. The length to diameter should be large to promote water gas mixing. The superficial velocity should be low to increase the gas/liquid contacting time.

The materials of construction for a quench chamber are usually of corrosion resistant materials. This is due to the highly corrosive conditions within the quench chamber (17,43). Refractory is installed if temperatures in the chamber exceeds the limits of the shell material (See Table XI). Water requirements for the quench chamber depend on the amount of cooling in the chamber. Quench water requirements can be calculated from an energy balance or estimated by equation 4 below (44):

$$\frac{\text{gallon H2O}}{\text{1000 cubic feet}} = 2.4 * 10^{-3} * T \qquad (4)$$

Here, T is the temperature is ^{o}F.

<u>Venturi Scrubber</u>

Venturi scrubbers are sized to remove particulates from the incinerator gas emission stream. Venturi scrubbers are always accompanied with a gas liquid separator. An example of a venturi scrubber with separator is shown in Figure 6 (4). The parameters that must be identified to design and cost the venturi scrubber/separator system are (18):

Particle size distribution
Particle concentration
Physical properties of particles
Volumetric flow rate

Air pollution control regulations specify the maximum rate of emission, and concentration limit. Scrubbing efficiency is measured by equation 5 below (45):

$$\text{Efficiency (\%)} = \frac{\text{Solids Measured in Effluent}}{\text{Total Solids In}} \tag{5}$$

Parameters that control the collection efficiency in the venturi scrubber are (30):

Gas Velocity
Water Feed Rate
Time Involved in Collection
Pressure Drop

These parameters are directly related to the throat diameter and length (30). Methods are available to optimize the throat length, pressure drop, and particulate removal efficiency (30). The gas phase pressure drop and collection

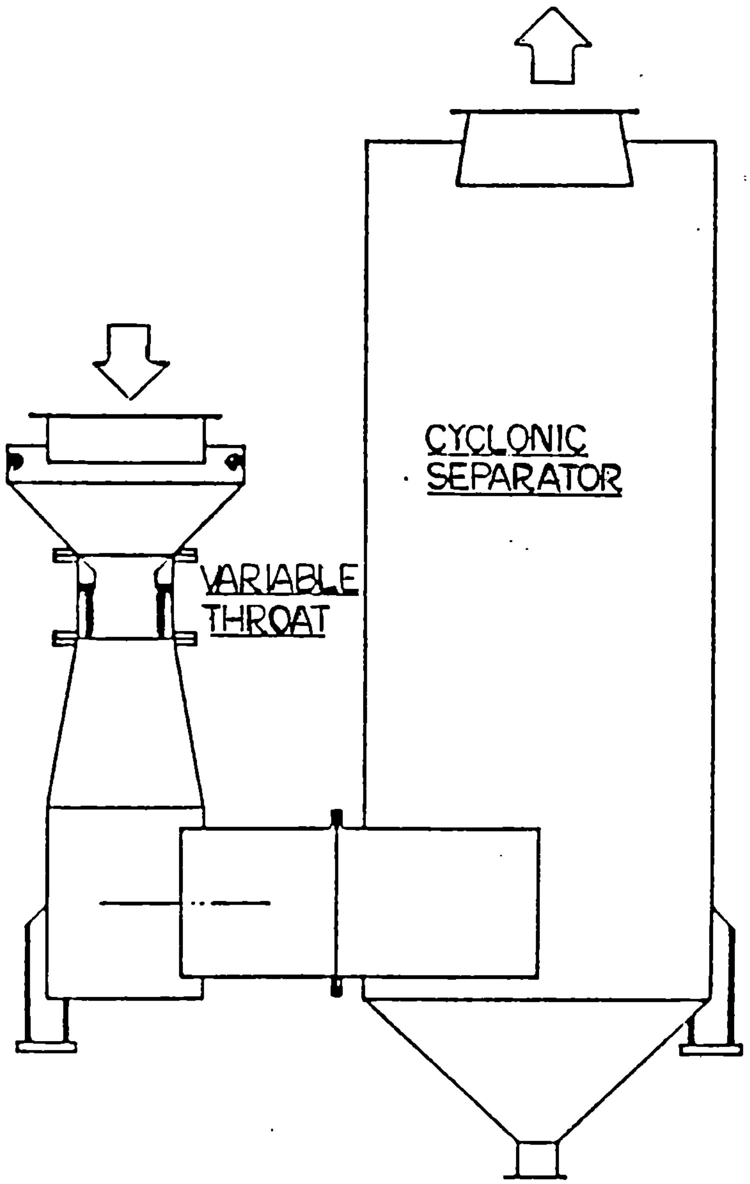

Figure 6. A venturi scrubber and separator for removal of particulates entrained in the gas emissions (52).

efficiency increase with the throat length (30). Generally, the length of the venturi throat should be 3 to 4 times the diameter of the venturi (22,30,46).

Design of a venturi scrubber is dependent on the particulate size distribution, specific gravity of the particulate, and collection curves, as a function of pressure drop. The particulate distribution must be determined experimentally for each waste. Figure 7 represents commonly observed particulate ranges (46).

The collection efficiency can be determined in many methods. The first design method, published by Vatavuk and Neveril, compares the pressure drop to the minimum particle size that is removed 100 percent. This relationship is represented by equation 6 (7,20):

$$Pd = 15.4 * Dp ^{\wedge} -1.39 \qquad (6)$$

The pressure drop is expressed in inches of water and particle diameter is measured in microns. The variable Pd is the smallest particle size that is removed completely. The collection efficiency will vary with throat velocity and scrubber liquid flow rate (7). Accuracy of the Vatavuk's method is unknown.

The second method to estimate collection efficiency was published by Calvert (18). Calvert's method determines the cut diameter for a given venturi pressure drop.

Scrubbing water fed to the venturi is an important design parameter. The higher the water rate, the better the

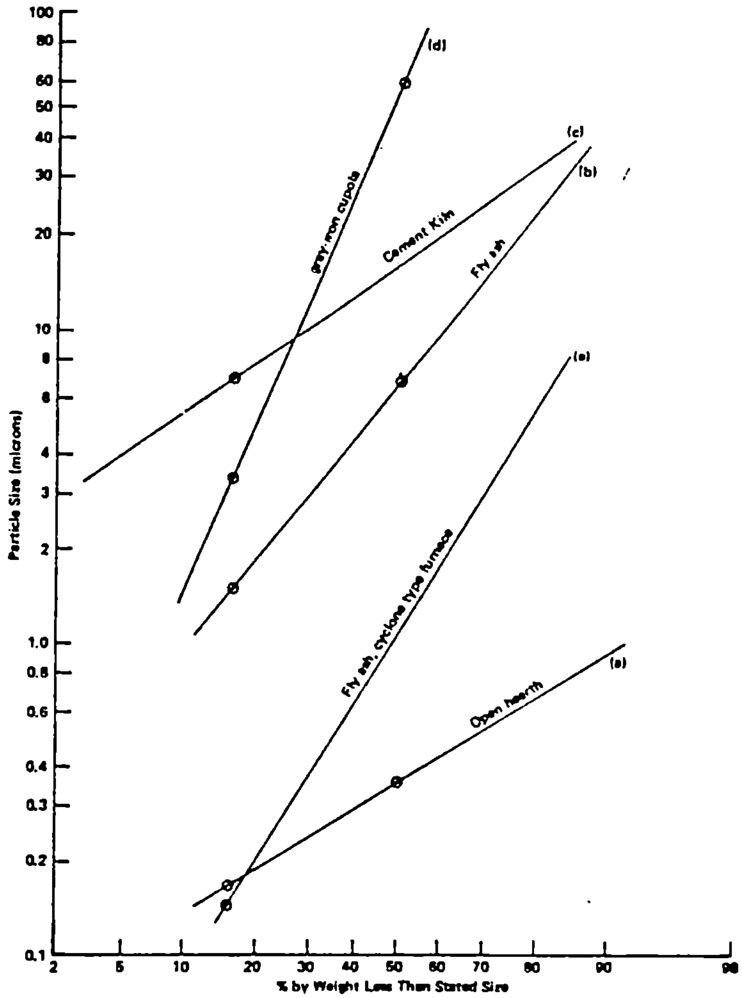

Figure 7. Example of the large range of particulate distributions that may occur from the combustion process (11).

collection efficiency (and greater pressure drop). Liquid rates in the venturi range from 7 to 10 gallons per 1000 cubic feet of gas (46). Liquid rates below 3 gallons per 1000 cubic feet of gas are too low for adequate particulate water contacting. Another source lists a much broader range of 5 to 20 gallons of water per 1000 cubic feet of gas (18). Liquid rates recommended for specific applications range from 8 gallon per 1000 cubic feed (22) to 28 gallon per 10000 cubic feet (30). Sosa et. al. suggest that water rates above 10 gallons per 1000 cubic feet do not improve scrubber performance (18). More information is available in the literature (22). Large liquid to gas ratios reduce the amount of scaling in the venturi scrubber (45).

The throat velocity in the venturi scrubbers is recommended to range from 200 to 400 feet per second (18). Air velocities below 100 feet per second do not produce enough turbulence for efficient particulate removal (22,46).

Venturi scrubbers are also effective in removing acid gases from the gas streams (46).

Water losses depend on the moisture content of the gas entering the scrubber. For high efficiency scrubbing, the gas stream is usually saturated with moisture (4). When humidified, the gas stream becomes corrosive.

Sulfite scaling occurs when the pH of the scrubbing water is not within certain limits. If limestone conditioning is used, the pH should always remain below six. If lime conditioning is used, the pH should remain below nine (45).

Bubbling oxygen in the scrubbing water holding tank can reduce scaling. Addition of magnesium sulfate will depress sulfite saturation levels (45). The scaling control methods discussed above are implemented in the holding tank (40).

The holding tank holds the scrubber water to be recycled. Addition of chemicals can decrease the saturation level of scrubber liquid forming solids (8). The retention time of this tank is five to 15 minutes to reduce saturation (37). To control solids concentration, a supply of seed crystals should be left in the tank. Solids should be no more than five to 15 percent suspended solids (45). Often, the holding tank is located at the bottom of the gas liquid separation chamber (43). Corrosion and scaling can be reduced by spraying the walls of the venturi with water (4).

Packed Bed Scrubber

Packed bed scrubbers are specified to reduce the concentration of caustics in the gas emissions. These units are effective due to the large surface area provided by the packing (21). Like the venturi scrubber, many design methods are available. Important design parameters for packed bed absorbers are (21):

1) Height of Packing
2) Absorption Characteristics of Caustics
3) Inlet/Outlet Caustic Concentration
4) Volumetric Flow Rate

All of the methods discussed below are based on these parameters.

Three types of packed absorbers are used in the pollution control industry. These are counter-current, co-current and cross-current (21). Only vertical counter-current absorbers will be discussed, because they are often selected for pollution control. Design recommendations found in the literature include (21):

1) Bed packing diameter should be no larger than 1/8 of the absorber diameter.
2) Redistributors placed every 10 - 15 feet apart.
3) Design for 40 - 70 percent flooding point.

The height of the packed bed can be determined by several methods.

The first method to be discussed is based on the calculation of a mass transfer unit. The height of one transfer unit depends on (21):

1) Packing Type
2) Relative gas and liquid flow rates
3) Concentration and solubility of contaminants

The total number of transfer units required to remove the contaminants may be determined by three methods.

First, the total number of transfer units may be determined from a solubility equilibrium diagram (See Figure 8). The total number is calculated between the operating and equilibrium curves. The total number of transfer units may also be estimated using equation 7 below (22):

$$Nog = \ln(Y1/Y2) \tag{7}$$

In this equation, Y1 is the inlet gas mole fraction of caustic, and Y2 is the final gas mole fraction of the caustic. Using this equation, Table III can be calculated to determine the number of transfer units versus scrubbing efficiency (22).

TABLE III

SCRUBBING EFFICIENCY VERSUS NUMBER OF MASS TRANSFER UNITS

Nog	Scrubbing Efficiency(%)
0.50	39.0
1.00	63.0
2.00	86.5
3.00	95.0
4.0	98.2
5.0	99.3
6.0	99.75

This method assumes a straight vapor/liquid equilibrium curve (See Figure 8). This is an acceptable assumption for the hydrogen chloride absorption.

The second method to calculate the bed height estimates the number of mass transfer units from practices common in

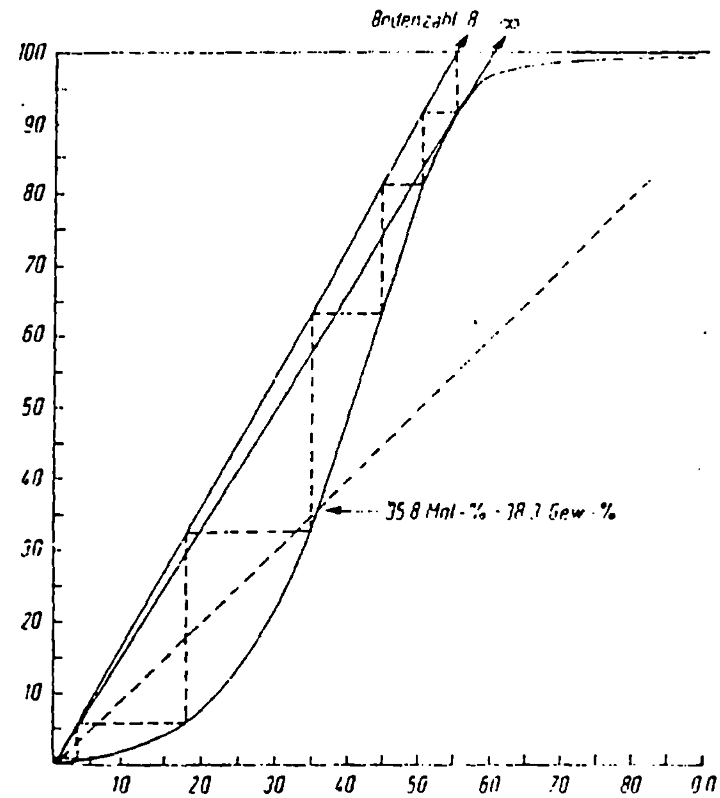

Figure 8. The equilibrium curve for the HCl/water system. The slope of the curve becomes very small as the hydrogen chloride in the liquid approaches zero (84).

the industry (22). For the pollution control industry, data has been published to predict the height of one transfer unit for the vapor/liquid systems with the following characteristics (22):

1) Highly soluble gases
2) Low soluble gases with reaction in liquid the liquid phase.

Data available for a specific scrubbing efficiency are listed in Table IV.

Absorption characteristics depend on the type of acid gas to be absorbed and the type of relative gas/liquid ratios. This method of bed height calculation presents the effect of the particular gas absorbed. The important physical properties are:

1) Viscosity
2) Density
3) Diffusivity

These properties (and their variation with temperature) can be calculated (22,34). The liquid flow rate recommended for packed bed absorbers ranges from 15 gallon per 1,000 cubic feet for water with caustic to 35 gallon per 1,000 cubic feet for water without caustic (22,40). For hydrogen chloride, the absorption process is effective without added caustic. Effective chlorine absorption requires addition of caustic (22). If hydrogen chloride is removed, Sodium Hypochlorite may form causing scaling problems (22). Caustic added to increase removal of the acid gas may be of

TABLE IV

HEIGHTS OF PACKING (FEET) TO OBTAIN LISTED EFFICIENCY[a]

Packing efficiency	Packing size				
	1 in.	1-1/2 in.	2 in.	3 in.	3-1/2 in.
63.2	1	1.25	1.5	2.25	3
77.7	1.5	2	2.25	3.5	4.25
86.5	2	2.5	3	4.5	5.75
90	2.5	3.25	3.75	5.75	7
95	3	3.75	4.5	6.75	8.5
98	4	5	6	9	11.25
99	4.6	5.75	7	10.25	13
99.5	5.25	6.5	8	12	14.75
99.9	7	8.75	10.5	15.75	19.75
99.99	9.25	11.5	14	21	26

[a]Restricted to specific applications on highly soluble gases or absorption followed by chemical reaction.

limestone or hydrated lime. To distribute the scrubbing water, solid cone spray nozzles are most often used (40). Unfortunately, these nozzles are prone to clogging if recycled water is used (15).

The diameter of the packed bed scrubber is usually calculated from experimental data. This is important to prevent flooding in the packed bed based on relative water/gas rates. The Lobo correlation (and many others) are used to estimate the diameter of the packed bed at the flooding point (79). The Lobo correlation can be used for many liquid and gas absorption processes (15). The design height can be determined by including a percent flooding factor. Figure 9 represents the data from the Lobo correlation. Equation 8 below also may be used to estimate the flooding point of the absorption process (22).

$$((28.6*Vf/(DEl/DEg)^{1/2})*(F*ul^{0.2})^{1/3} + (Qf/7.481*(F*ul^{0.2}))^{1/2} = 18.91 \qquad (8)$$

The variables for this equation are described in the list of variables. This equation must be solved by trial and error for the diameter of the bed.

Exhaust Stack

Exhaust stacks are specified to safely release gas emissions to the atmosphere. The design of an exhaust stack is based on the following parameters (26):

1) Wind loading
2) Seismic Zone
3) Soil bearing zone
4) Building code requirements

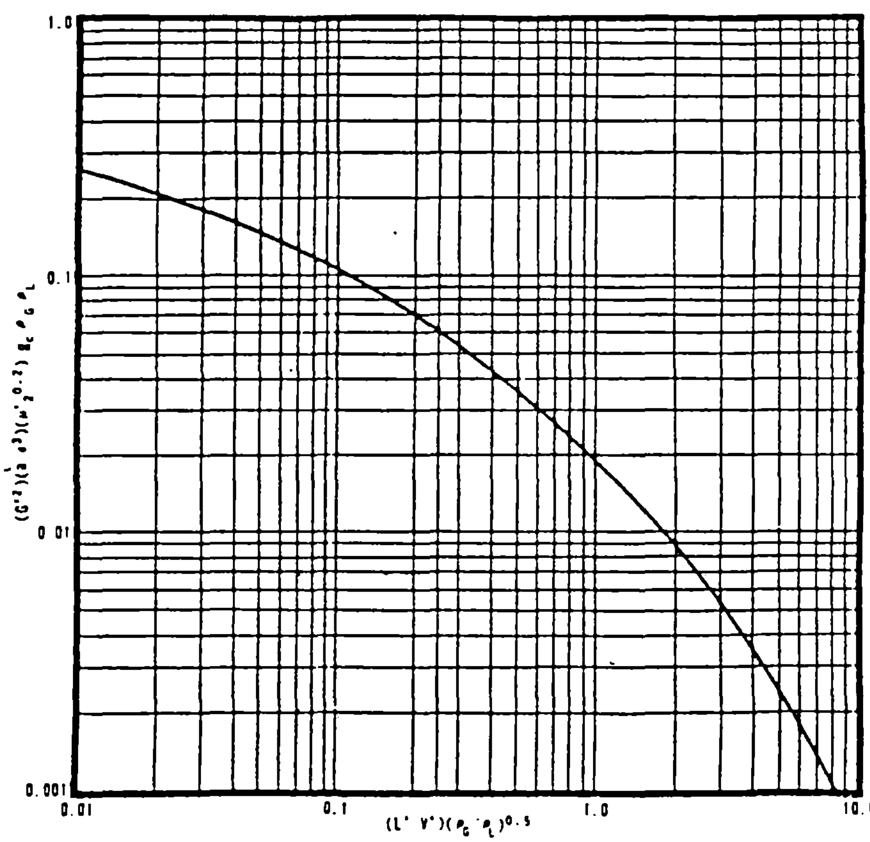

Figure 9. The Lobo correlation for the prediction of packed bed absorber flooding diameter (15).

The height of an exhaust stack is dependent on local regulations where the facility is located (9). The diameter of the stack is based on the expected wind velocity at the site. According to Vatavuk and Neveril, the gas velocity in the exhaust stack should be 1.5 times the expected wind velocity (26). The maximum exit velocity is limited to 9,000 feet per minute (26). Generally, the stack exit velocity should range from 600-3,000 feet per minute (42). The normal dimension of most exhaust stacks range from 15 inches to 9 feet in diameter and from 9 to 200 feet in height (42).

Many cost estimation methods are available in the literature. Major cost effects for the exhaust stacks are:

1) Diameter
2) Height
3) Material of Construction
4) Thickness
5) Lining materials

Materials of construction for the exhaust stack is usually carbon steel or plastic reinforced fiberglass (23,40). The thickness of the stack materials depends on practices common in industry. Lining is selected if emissions in the stack are reactive with the exhaust stack materials of construction.

One method of installed exhaust stack cost estimation is presented by Lepeau (13). Very little is known about the design parameters. The cost is based on the feed rate (of which 14 percent is non-volatile). The cost is for installed stacks. The data from this source is represented in Figure 10 (13).

Miscellaneous Capital Cost Data

Along with the design and cost estimation of incinerators and pollution control systems, there are many other factors that must be included. Additional costs for a hazardous waste incineration facility include:

1) Waste Storage
2) Sitework and Foundations
3) Ductwork
4) Offices
5) Structural Steel
6) Certification
7) Electrical Materials
8) Engineering
9) Instruments and Controls
10) Waste water treatment system

Each of these cost parameters will be discussed separately. Unlike the incinerator and pollution control systems, the costs above can be highly variable depending upon the location of the incineration facility site, placement of facility process equipment, selection of custom equipment and other design options that the designer desires to include.

Waste Storage

Storage facilities are required to accumulate enough waste to provide the incineration facility with a dependable, constant supply of feed. Current regulations

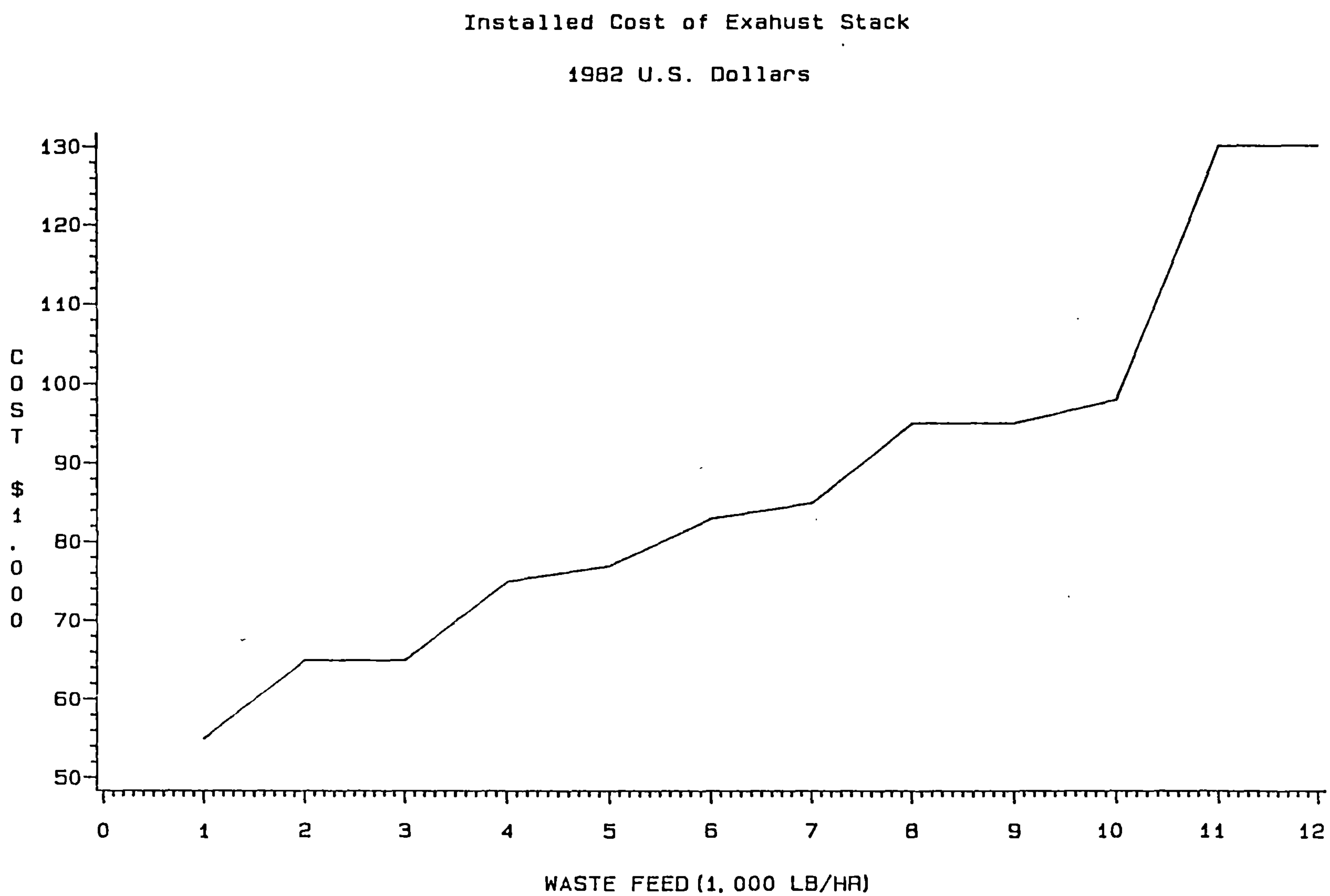

Figure 10. The cost of an installed exhaust stack (18).

limit the on-site storage capacity to a 48 hour supply (12). Of course, off-site storage facilities may also be constructed. Storage for hazardous wastes is generally limited to storage tanks or barrel barns. there are many methods to estimate the cost of storage tanks, but few to calculate the cost of a drum storage site. Each storage facility has special considerations that must be accounted for.

Two pertinent methods of cost estimation were found in literature for storage tanks. The first method was published by Corripio et. al. (15). Using this method, the cost of the tank is estimated in equation 9 (15).

$$Ct = Cb * Fm \qquad (9)$$

Here, the variable Fm is a material of construction cost factor (Table V) and Cb is the base cost of the storage tank, as shown below:

TABLE V

STORAGE TANK MATERIALS OF CONSTRUCTION
COST FACTORS

Materials of Construction	Cost Factor(Fm)
Stainless Steel 316	2.7
Stainless Steel 304	2.4
Nickel	3.5
Inconel	3.8
Brick-and-Rubber-lined Steel	2.75
Brick-and-Rubber-lined Steel	2.75

Rubber lined Steel	1.9
Concrete	0.55

The material is specified by the user. The variable Cb is estimated for shop fabricated tanks from equation 10 and field erected units are estimated by equation 11 below (15):

$$Cb = EXP\ (\ 2.331 + 1.3673*(\ln(V) - 0.06309*(\ln(V))^{2.0}\ ) \quad (10)$$

$$Cb = EXP\ (11.362-0.6104*\ln(V) - 0.04536*\ln(V)^{2.0}\ ) \quad (11)$$

In this equation, the variable V is in gallons and the cost is calculated to January 1979. The error in the cost is estimated at 30 percent. Capacity of fabricated storage tanks range from 1,300 gallons to 21,000 gallons. For the field erected tanks, the volume (V) ranges from 21,000 to 11,000,000 gallons. These costs from equations 10 and 11 also include a 20 percent overcapacity factor (15). This cost does not include other accessories required for hazardous waste storage.

The second method of storage tank cost estimation was published by Vogel and Martin (9). While this method is less flexible (sizes tanks for 5,000, 10,000, and 25,000 gallons only) the estimation method is for storage of hazardous wastes and includes all of the accessories required. Other, special equipment can also be cost estimated from this source.

Sitework and Foundations

Cost estimation of sitework and foundations is highly variable. Costs for sitework may vary by 200 percent depending on the location (13,42). According to Vogel and Martin, the amount of land required is less than 10,000 square feet (without storage facility) (42).

Lepeau published cost data for sitework. This data is presented in Figure 11 (13). The cost is for non-hazardous waste incineration. From information published by Vatavuk and Neveril, Lepeau's values should be doubled for hazardous waste incineration processes (29).

A second method for sitework and foundation costs for hazardous waste incineration facilities was presented by Vogel and Martin (14). From this method, site preparation is estimated at 7 percent of the process equipment costs. Cost to bring utilities to the incineration site and for hook-up is estimated at 10 percent of the total equipment costs. Again, these costs may vary by 200 percent based on facility location (29).

Instruments and Controls

The cost of instruments for hazardous waste incineration facilities is highly variable depending upon many factors. Legal requirements specify what instruments should be used (6). Unfortunately, there is little uniformity in the industry about placement. Most cost estimation methods estimate instruments with cost factors (used with the total equipment cost). Vogel and Martin recommended a cost factor of 20 percent of equipment cost for instruments and controls. This factor is for hazardous waste incineration facilities.

Lepeau published data for instrumentation and controls costs for non-hazardous waste incineration facilities. This cost data is presented in Figure 11 (13). Cost of instruments for hazardous waste incineration is much higher, but the extra equipment can be identified. Instruments and controls required for incineration process are (40,43):

1) Shielded thermocouples
2) Pressure monitoring taps
3) Flame detectors
4) Exhaust stack monitoring system
5) pH monitoring system

Most of the equipment is standard to all incineration facilties. The exhaust monitoring system between hazardous and non-hazardous incineration is the greatest difference.

Hazardous waste incineration facilities require a continuous stack monitoring system. This costs about 15,000 1985 U.S. Dollars (43) per each gas recording. Carbon monoxide and oxygen are generally monitored on a continuous basis. A gas chromatograph may also be selected to determine chemical emissions. These units cost about 64,000 U.S. Dollars (1983) and two units are usually specified (43). This includes equipment cost and installation.

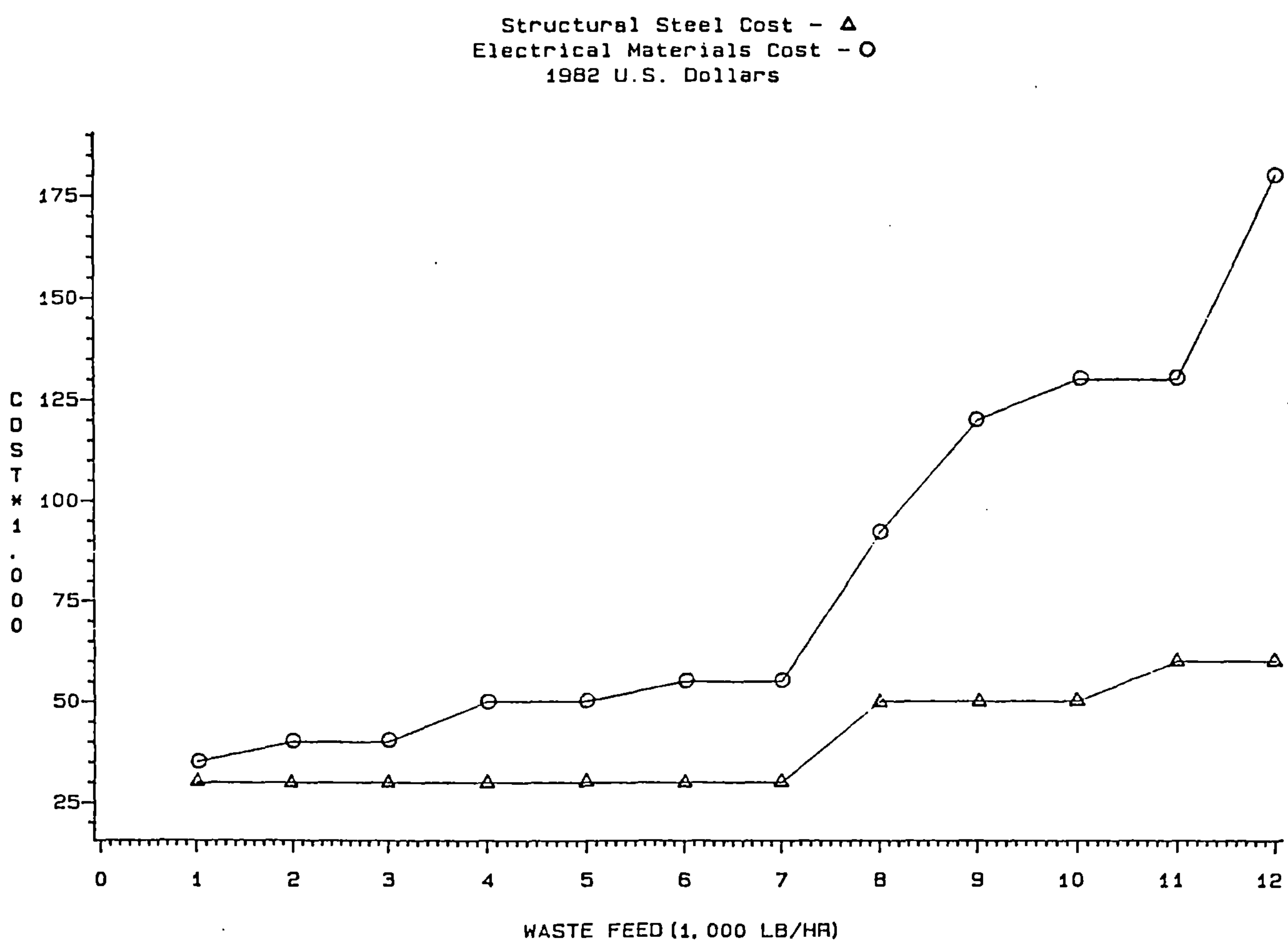

Figure 11. The cost of structural steel and electrical materials for non-hazardous waste incineration facilities (18).

Operations Building and Offices

The cost estimation of offices and operations building is highly variable depending on the designer and location. Building construction can range from simple weather enclosures with utilites, road, and fencing to a complex building with laboratories, heating, sanitation, offices and truck depot (29). Building costs associated with these facilities may vary by 200 percent (29). Lapeau has published cost estimates for a prefabricated steel building. This cost data is presented in Figure 11 (13). Other cost data for building costs is available, but the data was not useable (39).

Ductwork

Ductwork is specified for connecting the incineration and pollution control system process units. Much data is available in literature on this subject (14,24). Vogel and Margin published cost data for installed ductwork. Unfortunately, this cost data is not adequately described to be of any use. Vatavuk and Neveril presented a more detailed method for cost estimation of ductwork. Selection of ductwork is based on the following parameters:

1) Dust loading
2) Gas temperature
3) Corrosive nature of gas emissions
4) Number of bends and joints

The three basic types of ductwork are water-cooled, refractory lined, stainless steel and carbon steel. Carbon steel ductwork (without refractory) is specified for non-corrosive environments and gas temperatures below 1,150^{o} F. With refractory lined carbon steel breeching, the wall temperature is limited to 800^{o} F. Stainless steel ductwork (unlined) is limited to temperatures below 1,500^{o} F. Wall temperature for refractory lined stainless steel ductwork should not exceed 1,200^{o} F. Water-cooled ductwork is generally specified at temperatures above 1,500^{o} F. Selection of water-cooled ductwork is unlikely for hazardous waste facilities due to the high cost. Therefore, this method will not be discussed further.

Calculations of the the diameter of ductwork is based on the dust loading. Gas velocities in ductwork can range from 2,000 feet per minute (for light dust loading) to 9,000 feet per minute (for heavy dust loading) (26).

Specification of the materials of construction for ductwork is also affected by the corrosive nature of the incinerated gas emissions. For destruction of chlorinated hydrocarbons, specification of unlined carbon steel ductwork is not recommended (43). Lined carbon steel ductwork has been shown to withstand chlorinated hydrocarbon incineration products (40). Specification of an inconel-clad-stainless steel is also an effective combination (43). Cost factors for inconel-clad- stainless steel is estimated at 3.3 times the cost of carbon steel ductwork (9).

Certification and Engineering

The cost of certification and engineering is different for each incineration design. Each facility has different problems based on local requirements and other unexpected factors. Certification for incineration of hazardous wastes is estimated at 10 percent of the capital cost by Vogel and Neveril (14). Certification costs were also obtained from Zinc (40). Three tests were usually required for certification. Each certification test costs around 22,000 (U.S. Dollars 1986) and lasts for 24 hours. Additionally, one test lasting 48 to 100 hours is also required and costs about 120,000 U.S. Dollars 1986. This includes all costs required to start-up and operate the incinerator for the required time to insure adequate destruction of a waste (40). The incinerator must be certified for each new waste that is burned(40).

The costs required to engineer an incineration facility is estimated at 4 to 7 percent of the design and an additional 4 to 7 percent for start-up and shakedown (1,14). An equation published by Unterburg et. al. estimates the engineering costs as:

$$\text{Cost} = 0.5 * e^{\wedge}[(CC)^{\wedge}0.846] \qquad (12)$$

The error in the equation is unknown, but it is recommended for capital costs ranging from 10,000 1969 U.S. Dollars to 5 million 1969 U.S. Dollars (1971) (39).

Structural Steel and Electical Materials

Cost data for structural steel and electrical materials for hazardous waste incineration facilities were published by Lepeau (13). This data is for non-hazardous incineration facilities. The cost data from this source is presented in Figure 12 (13). Vogel and Martin presented factors for estimation of electrical materials at 20 percent of the total facility equipment cost (28).

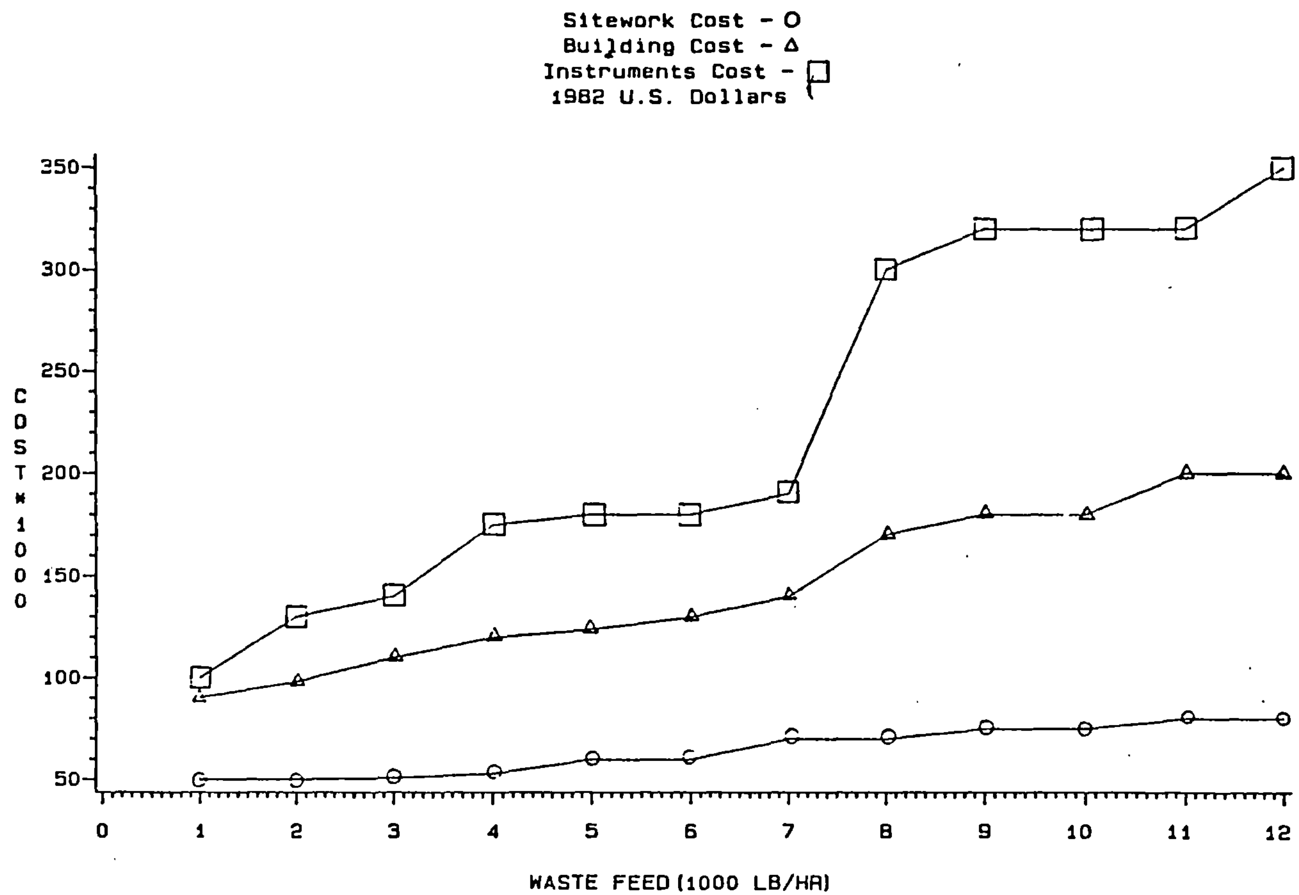

Figure 12. The cost of sitework, buildings, and instrument for non-hazardous waste incineration facilities (18).

CHAPTER IV

COMPUTER PROGRAM DESIGN AND COST ESTIMATION

Though spread widely in the literature, information has been published to adequately design and cost hazardous waste incineration facilities. A computer program is the ideal method in which to design and cost estimate a hazardous waste facility, based on the physical and chemical characteristics of the waste feed, as well as to meet the different standards that each area of the country requires. Any design must allow for a selection of a variety of individual pollution control units.

While the equipment used for incineration and pollution control is the same, the actual shape and cost are different from vendor to vendor. Figure 13 represents an example of a flow diagram for the incineration process. There are some methods to reduce the amount of materials required for the capital costs, but the final facility cost does not change significantly. Below is a description of the work included in the computer program HWSTBRN. The discussion is divided under each different process unit. Operating costs specific to each unit are also presented. Operating costs common to all units (such as maintenance) are discussed separately.

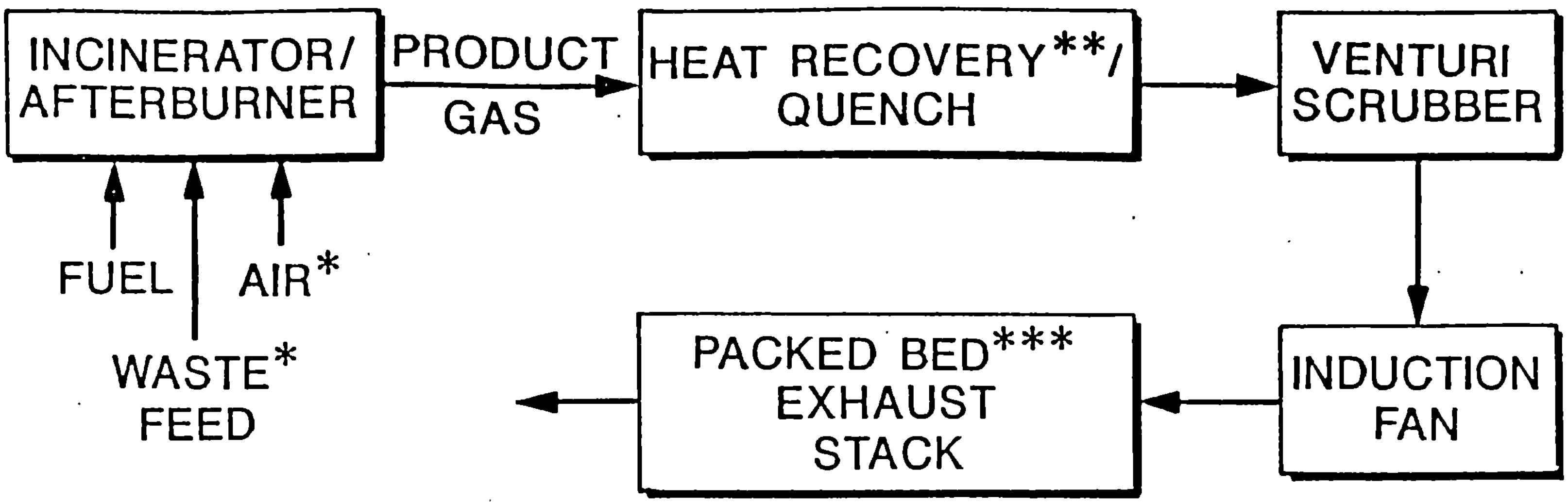

Figure 13. An example of a process flow diagram for a hazardous waste incineration facility.

Incinerators

Primary Combustor

The design and cost estimation of the primary incinerator is based on the heat release rate for solid wastes or retention time for liquid waste. These are both options that are selected by the user. The dimensions of the incinerator depend on the unit selected.

Retention Time. For PCB's, equation 13 can be used to estimate the retention time required to destroy PCBs to 99.9999 percent (6-9's) (32).

$$t= 3600 / (Qr * TCP * (1+EA/100) * (Tf+Te)/1040) \quad (13)$$

Definitions of the variables and their units are included on page viii. The retention time can also be specified by the user.

Fuel and Waste Burner System. To determine the amount of fuel required to reach the destruction temperature, combined mass and energy balances are solved. These balances are solved in a specific order (See page 140). These equations are solved by interval halving method for fuel. The balance of products from reactants is solved directly (for a given amount of fuel) by a simple stoichiometric balance for an ideal (100 %) combustion.

The design and cost of an incinerator is based on the following:

1) Fuel Burner System
2) Waste Feed System
3) Refractory and Shell
4) Ash Removal System
5) Special Equipment

These charactristics are common to all incineration systems. Special costs pertaining to individual types will be discussed under each section.

The cost of a fuel burner system is listed below in Table VI (9):

TABLE VI

COST OF INCINERATOR FUEL BURNER SYSTEM

Burner Heat (Million Btu/hr)	Burner Cost (1981 Dollars)
0.20 - 1.5	1,200 /burner
5.0	5,000 /burner
10.0	8,000 /burner

The equipment for the larger burner systems include:

1) Combustion Air Blower
2) Ductwork
3) Windbox
4) Valve Trains
5) Refractory Tile
6) Combustion Control System,
7) Flame Protection System

The method of waste feed depends on the type of waste and storage method. Three methods are available for waste feeding. This is selected by the user. The cost of a burner system was published by Vogel (9,18). The cost includes:

1) Air blower
2) Ductwork
3) Windbox
4) Valve trains
5) Refractory Tile
6) Combustion Control System
7) Flame Protection Devices

The cost of the waste burner system is represented by equation 14 (9).

$$1981 \text{ Cost} = 2727 * HR + 4545 \tag{14}$$

In this equation, the variable HR is the waste heat release rate in millions of Btu's. The cost of the waste burner system is referenced to January 1981 (9).

Other Waste Feed Systems. The second option for liquid waste feed is by containers. If the container capacity ranges from 5 to 30 gallons, hydraulic rams are usually specified. The cost of the rams (1981) is based on the total heat input (Btu/hr) (9). The cost of a ram system is listed in equation 15 (9).

$$1981 \text{ Cost} = 2727 * HR +4545 \tag{15}$$

In this equation, the variable HR is the waste heat release rate in millions of Btu's. Feed systems for 55 gallon drums require special systems.

For 55 gallon drum feed systems, the cost is listed below in Table VII (9):

TABLE VII

COST OF 55-GALLON DRUM FEED SYSTEM

U.S. Dollars(1981)	Heat Release(Btu/hr)
175,000	60 - 70
300,000	> 90

To incinerate containerized waste, each container should be less than 10 percent of the total incineration volume (40). This system may be loaded manually or used with a cart system (9). A cart loading system includes:

1) 25 carts (2 - 3 cubic yards each)
2) Each cart handles 1,150 lb waste)

The cost of the cart loading system is 26,000 U.S. Dollars (1981) for a process with less than 40 million Btu/hr (9).

Another method to feed waste to an incinerator is a screw feed system. Information on this system is provided by Vogel (9). This cost includes (9):

1) 5 ft of screw conveyor
2) Trough
3) Feed Hopper
4) Drive Motor

Equipment cost is based on the screw length for a specific diameter (38). is listed in equations 16 and 17 (38).

$$(1978\ \text{Cost}) = 632.5 + 66 * L \qquad \text{9 inch screw} \quad (16)$$
$$(1978\ \text{Cost}) = 747.5 + 67.8 * L \qquad \text{12 inch screw} \quad (17)$$

These feed systems are often implemented in a fluidized bed combustor.

Firebrick and Shell. The cost of firebrick is also based on the waste characteristics. Data available are listed in Table XVI. Insulation firebrick is one inch for 2,000 ^{o}F to four inches at 2,500 ^{o}F. Refractory insulation ranges from four inches thick at 2,000 ^{o}F to 12 inches at 2,500 ^{o}F (28). Refractory thickness can also be estimated from thermal conductivity values of the refractories.

Shell cost data applies for a carbon steel shell Materials of construction are the same as the other incinerator types. This cost is estimated at 75 U.S. Dollars (1984)/square foot of surface area of shell (9). Cost factors that adjust the cost for different materials of construction and are listed in Table VIII (26).

TABLE VIII

COST FACTORS FOR SHELL MATERIALS

Stainless Steel (316)	- 2.7
High Nickel Alloy	- 3.5
Monel	- 3.3

These cost factors are applied to the cost of a carbon steel shell. Exact shell cost depends on the dimensions of the incinerator selected. These design parameters are discussed in each section.

Rotary Kiln Combustor. The dimensions of the rotary kiln are based on the retention time and length to diameter ratio. For the rotary kiln, the drive assembly cost is based on $100/ square feet of surface area (9). Installation cost is 200 percent of the equipment cost (9).

Fluidized Bed Combustor. The diameter of the fluidized is based on information on common industry practice (See Table IX) (2).

TABLE IX

DIAMETER OF FLUIDIZED BED INCINERATORS BASED ON THE MOISTURE EVAPORATION RATE

Diameter(Feet)	Hot Air(lb/hour)	Cold Air(lb/hour)
9	2,800	2,240
10	3,470	2,770

11	4,200	3,350
12	4,950	3,940
13	5,800	4,620
14	6,750	5,350
15	7,750	6,150
16	8,760	7,000
17	9,900	7,900
18	11,100	8,700
19	12,350	9,750
20	13,600	10,600
21	15,100	11,900
22	16,550	13,100
23	18,100	14,300
24	19,700	15,500
25	21,400	16,800

This is applicable if the water content of the waste is greater than 70 percent. If the water content is less than 70 percent, the diameter of the fluidized bed is calculated using the data in Table X (8).

TABLE X

DIAMETER OF FLUIDIZED BED INCINERATORS
BASED ON THE HEAT RELEASE RATE

Diameter(Feet)	Hot Air(Btu/hour)
10	9.6 million
14	18.9
18	31.3
22	46.7
25	60.3
28	75.7

The sizing method is selected by the user. The length to diameter ratio of a fluidized bed can range from 1 to 2. This is selected by the user based on ash characteristics (entrainment of particulates with the incinerated emissions). Cost of the shell, firebrick, and waste feed systems are the same as for the rotary kiln and liquid injection. Extra costs include the oversized air compressor and water cooled grid (made of carbon or stainless steel) to support the fluidizing media. Costs are not available for these grids, but can be estimated from valve or sieve trays used with tray absorption towers (47). These cost data are presented in Figure 14 and 15. Cost factors for shell materials are listed in Table VIII. Installation cost of the fluidized bed is estimated at 100 percent of equipment cost.

Liquid Injection Combustor. If the waste feed is pumpable, liquid injection incinerator may be selected. The dimensions of the unit are based on retention time and length to diameter ratio (between 2 and 10). The design and cost method is the same as the rotary kiln.

Afterburners

The design and cost estimation of afterburners is similar to the primary liquid injection incinerator. Length to diameter ratio and the retention time are specified by the user and is high to promote turbulence. The mass and energy

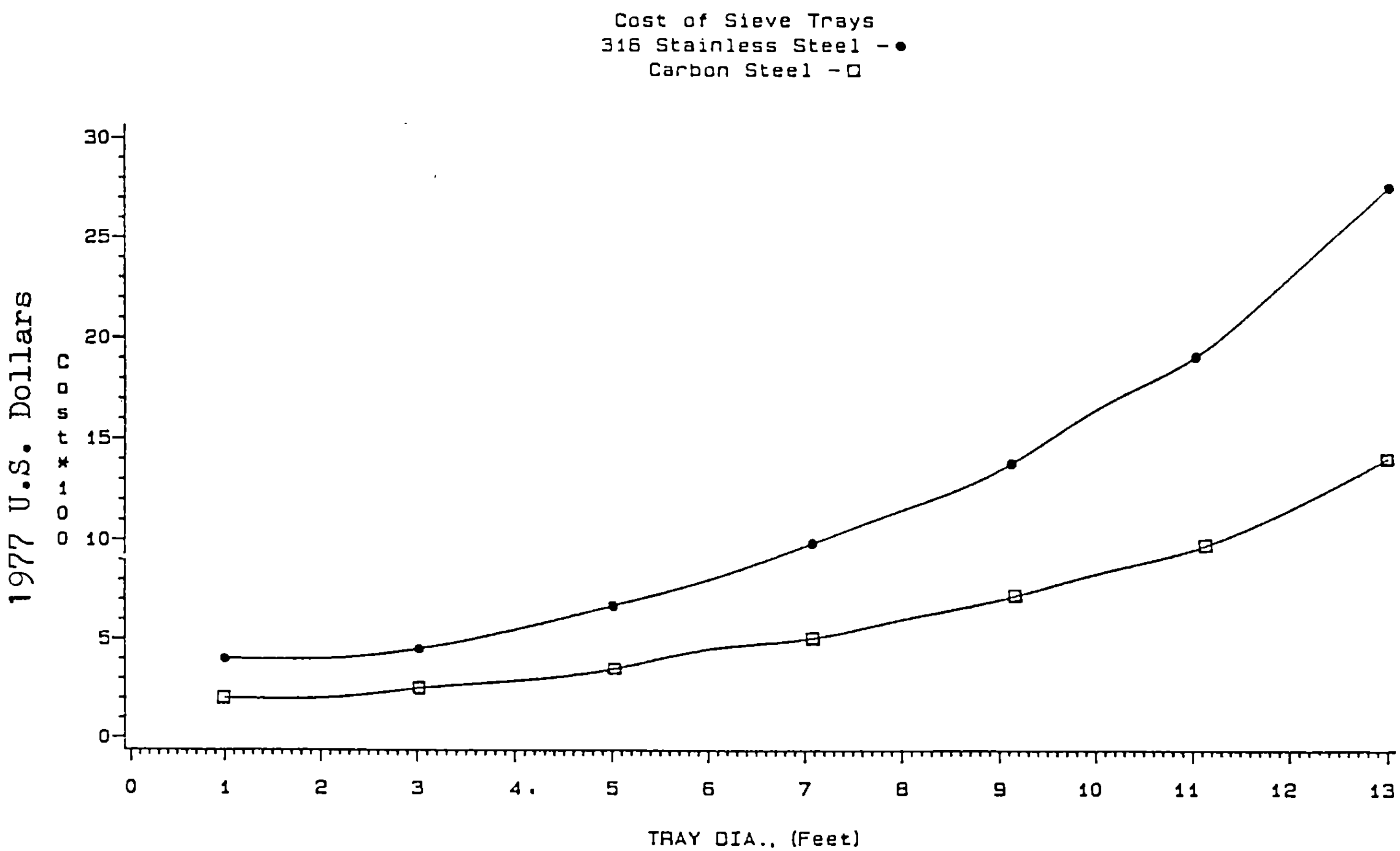

Figure 14. The cost of carbon steel and stainless steel sieve trays (18).

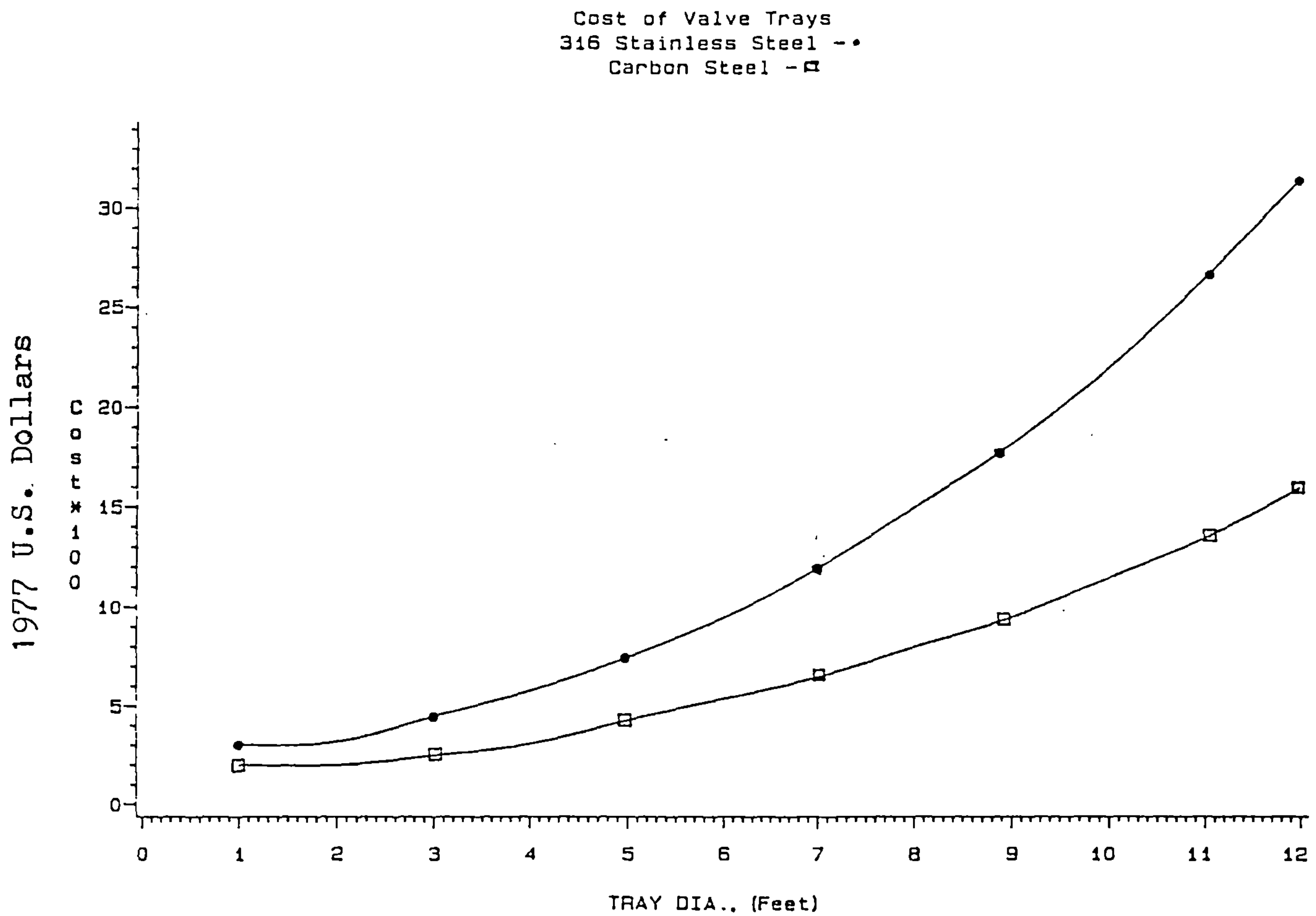

Figure 15. The cost of carbon steel and stainless steel valve trays (18).

balance based on added fuel is solved to determine fuel requirements to reach the afterburner temperature. The cost method for shell, firebrick, burners and intallation is the same for the primary liquid injection incinerator. Materials of construction and installation are also the same as for the primary liquid injection incinerator.

Computer Design and Cost of Pollution Control Systems

Quench Chamber

The quench chamber is designed to cool the gas to provide effective downstream pollution control processes and specify less expensive materials of construction. Two types of quench chambers are available for selection. A quencher is selected to cool the emissions to its saturation temperature. A spray chamber can be selected if a specific outlet temperature is required. The quench chamber is lined with firebrick if the gas temperature is greater than materials (specified by the user) can withstand (See Table VIII).

The length to diameter ratio of the venturi scrubber or spray chamber is set at three. The superficial velocity is the chamber is set at 10 feet per second (17). Cost of the quencher is represented by equation 18 and the cost of the spray chamber is represented by equation 19 below (17):

$$\text{Quencher} \quad - \quad (1977\ \text{Cost}) = 0.22 * Vm + 8{,}000 \qquad (18)$$
$$\text{Spray} \quad - \quad (1977\ \text{Cost}) = 0.235 * Vm + 43{,}000 \qquad (19)$$

Here the variable V is in cubic feet per minute. These costs include the cost of the vessel, support rings, platform ladders, grating, spray system and controls. The cost does not include refractory, piping and installation (17). The costs of these accessories are the same as for the combustors. Materials of construction cost factors are listed in Table VIII. Selection of conditions for firebrick specifications depends on materials of construction listed in Table XI (26).

TABLE XI

MATERIALS OF CONSTRUCTION TEMPERATURE LIMITATIONS OF QUENCH CHAMBERS

Temperature (^{o}F)	Quench Materials
600	Carbon Steel
900	Stainless Steel
1,100	Inconel clad stainless steel

Heat exchangers can be placed before the quench chamber to reduce the water load required. Operating costs are based on pumping costs of water and utilities cost of water. The quench water rate is calculated from a heat balance.

Heat Recovery

Heat recovery units are used on larger projects to produce steam and reduce quench water load. Specific heat recovery equipment is based on the heat recovery rate and the payback period on the equipment. A 6.1 year payback period is considered the maximum (13). Twenty percent of the produced steam is considered lost during production and transportation.

The pressure drop in an incineration heat recovery process is dependent on the amount of heat recovered. The relationship is illustrated below in Table XII (46).

TABLE XII

HEAT RECOVERY VERSUS PRESSURE DROP FOR HEAT RECOVERY BOILERS

Heat Recovery (%)	Pressure Drop (inches of H2O)
0	2.0
3.0	6.0
5.0	8.0
7.0	10.0

Installed cost is approximately the same for both boiler types. One of the two costs method may be selected by the user. The first method found was published by Corripio (15) and uses the cost estimation listed below:

$$C = Cb * Fd * Fp * Fm \qquad (20)$$

C - Exchanger cost (1979)
Cb - Base exchanger cost
Fd - Pressure cost factor
Fp - Exchanger type cost factor
Fm - Materials of construction cost factor

The cost of the heat exchanger is based on the surface area required for heat exchangers. The base cost of the heat recovery boiler is estimated from equation 21.

$$Cb=EXP\ (8.551-0.30863*LN(A)+0.06811*LN(A^{\wedge}2)) \qquad (21)$$

For a kettle reboiler, the exchanger type cost factor are represented by equation 22.

$$Fd = 1.35 \qquad (22)$$

The design pressure cost factor are estimated from equation 23:

$$Fp= 0.7771+0.04981*LN\ (A) \qquad (23)$$

Materials of construction cost adjustment factors is estimated from equation 24.

$$Fm=g1+g2*LN\ (A) \qquad (24)$$

The constants g1 and g2 are listed in Table XIII and are based on the material selected.

TABLE XIII

MATERIALS OF CONSTRUCTION CONSTANTS
FOR HEAR RECOVERY BOILERS

Material	g1	g2
Stainless Steel 316	0.8608	0.23290
Stainless Steel 304	0.8193	0.15984
Stainless Steel 347	0.6116	0.22186
Nickel 200	1.5092	0.60859
Monel 400	1.2989	0.43377
Inconel 600	1.2040	0.50764
Incoloy 825	1.1854	0.49706
Titanium	1.5420	0.42913
Hastalloy	0.1549	1.51774

The variable A in the equations above is in units of square feet of heat exchanger area. The equation used to predict the area of the heat exchanger is:

$$A = Q / U * DTm \qquad (25)$$

The overall heat transfer coefficient for the boiler can range from 2 to 8 Btu/hour/square foot (36). Additional information is available on overall heat transfer coefficients for combustion gases (36).

The second method of heat recovery cost estimation is also included in the computer program (48). The installed cost of heat recovery boilers is estimated according to equation 26 (36):

$$C=(28,800 * A^{-0.440}) * \exp(0.0672 * (\ln A)^{2}) \qquad (26)$$

This equation applies to heat exchange area from 200 to 50,000 square feet. This method assumes:

1) 35% Heat Recovery
2) Residence time 0.5 seconds
3) Cost includes exchangers and accessories

Accuracy of the data is estimated at ±50 percent . Area of heat transfer is calculated from equation 25.

Venturi Scrubber

Venturi scrubbers are specified primarily to remove particulates from a gas stream. The fraction of particles removed in a gas stream is directly related to the pressure drop. Removal efficiency varies depending on the particulate size. Separation chambers are always specified with a venturi scrubber. For this computer program, the pressure drop can either be directly selected, or the pressure drop may be determined based on a particle size distribution selected by the user. Total pressure loss is 15 percent of the total pressure drop (18). If the particle distribution method is specified, removal efficiency is determined from data supplied by Cheremisinoff et. al. (22). The data is represented in Figure 16 for specific pressure drops (18). This data is curve-fit and included in the computer program (see Appendix A). The concentration of particulates emitted must be less than legal requirements. These requirements are already included in the program.

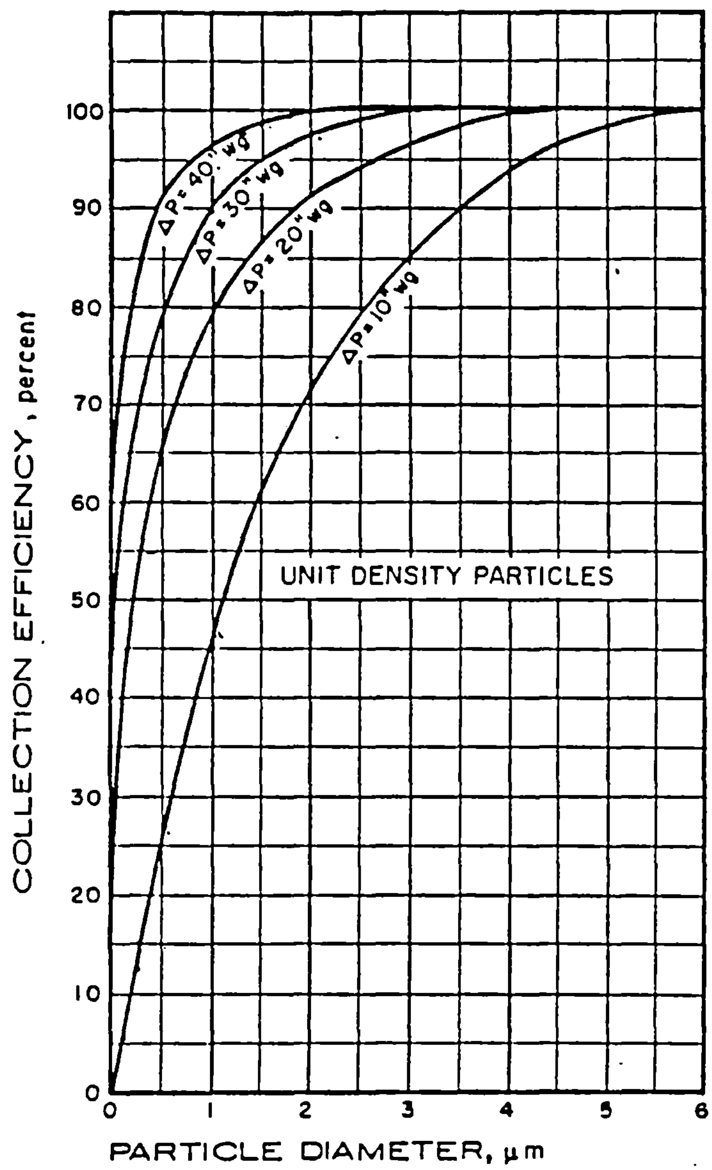

Figure 16. Experimental values for removal efficiency of particles at specific pressure drops (22).

A second method, included in the program, uses experimentally determined particulate collection efficiencies. Data found in literature limits the pressure drop of 10, 20, 40, and 60 inches of water. Given a particle distribution, inlet particulate concentration, and the scrubber pressure drop, the outlet concentration of the particulates is estimated. The fraction collected is the integral of the performance curves and the particle distribution. Stepwise integration is ideal for this method.

An alternative method to calculate the removal efficiency is presented below. The cut diameter for a given particle distribution is the particulate diameter at which the mass fraction removed is 50 percent. Venturi scrubbers collect particles by inertial compaction. This phenomena is described by equation 27 below (18):

$$Pt = \exp(-Ac*Dpa \wedge Bc) = Co/Ci \qquad (27)$$

Here, A and B are empirical constants. For venturi scrubber, the constant Ac is estimated at 2. The mass concentration of particles out is related to the cut diameter according to equation 27. Cut diameter for a pressure drop is given in Figure 17.

These values were experimentally determined. The method of solution is to determine the pressure drop (cut diameter) which reduces the outlet concentration to an acceptable levels.

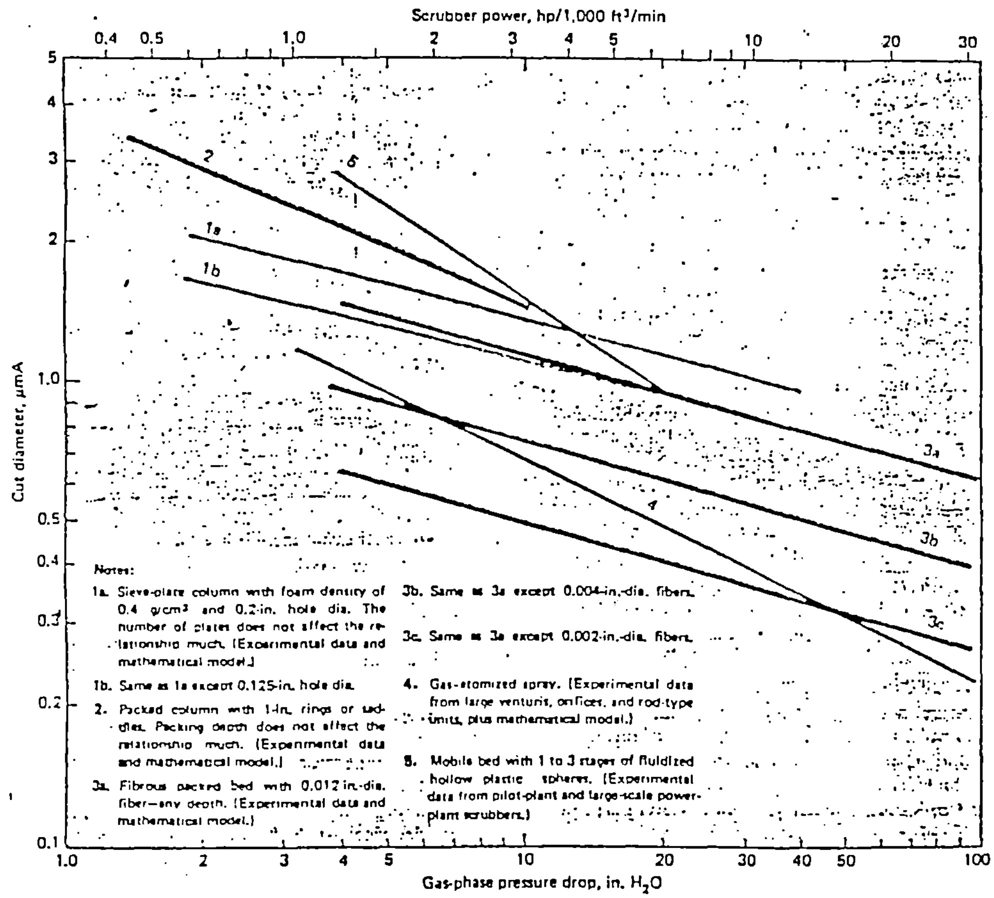

Figure 17. The cut diameter for removal of 50 percent of entrained particulates is plotted against venturi pressure drop (22).

If no particle distribution is provided, a pressure drop must be specified. This method bypasses all particulate removal calculations. The rate of water has a direct effect on particle collection efficiency. Water rates should range between three to ten gallons / million actual cubic feet of emission gas. This value is specified by the user.

Cost data for the venturi scrubber was published by Vatavuk and Neveril (20). The cost is based on the gas volume flow rate and total pressure drop in the venturi. Costs and pressure drop adjustment factors for venturi scrubber and separator are summarized in Figures 18 and 19. This cost data was compiled in 1977. This includes:

Venturi
Elbow
Separator
Pumps
Controls
1/8 inch carbon steel

Cost adjustments are also available for materials of construction. These values are listed in Table XIV (20), and are included in the computer program.

TABLE XIV

MATERIALS OF CONSTUCTION COST FACTORS FOR VENTURI SCRUBBERS

Stainless Steel 304	-	2.3
Stainless Steel 316	-	3.2

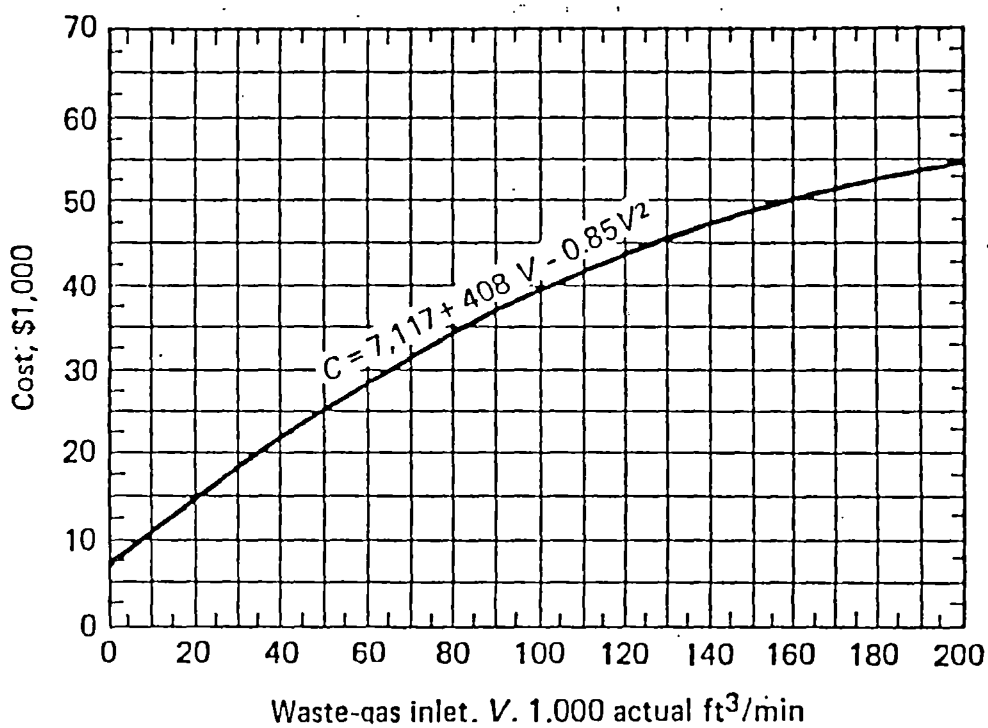

Figure 18. The cost of a venturi scrubber and separator (31).

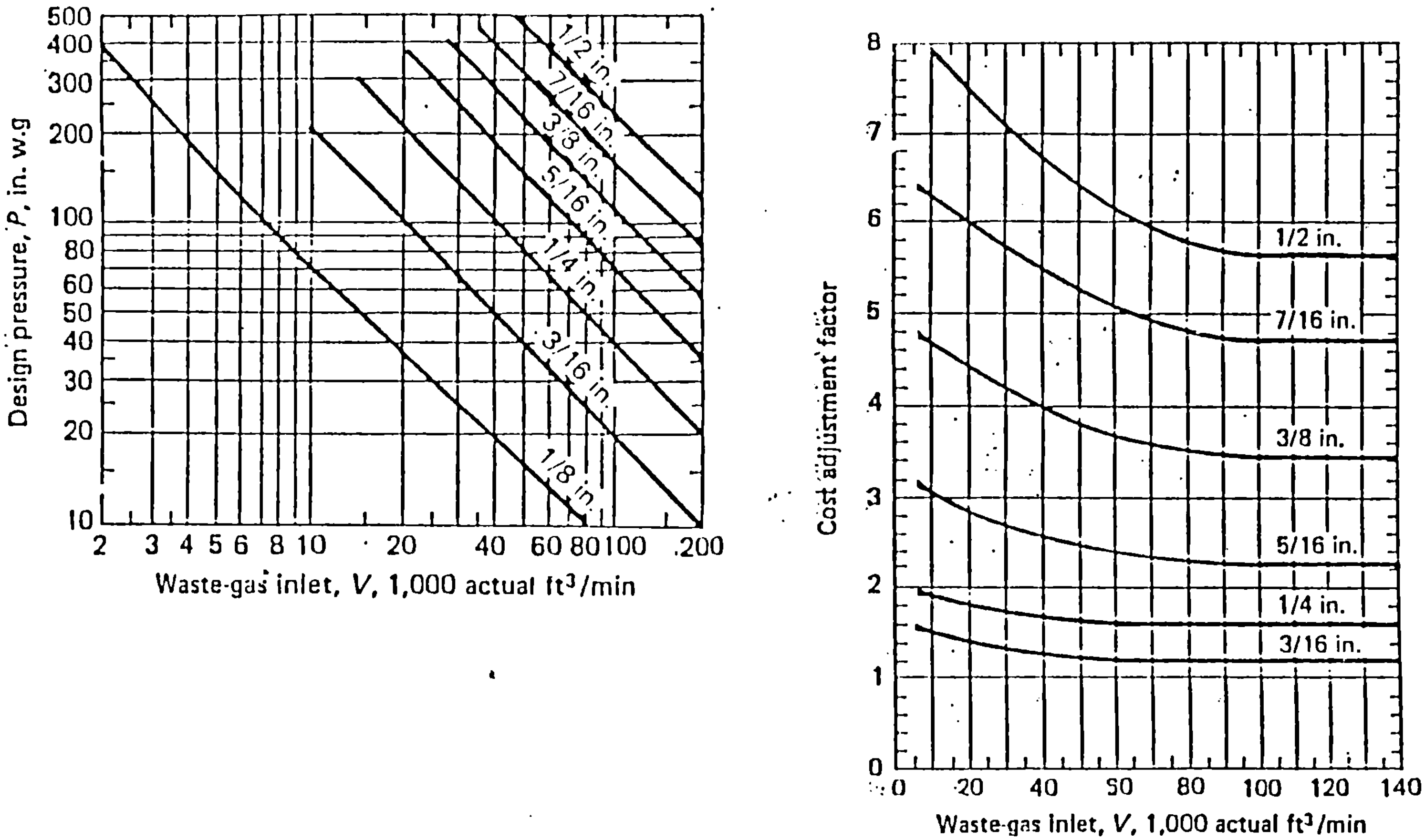

Figure 19. These figures are used together to determine the cost adjustment factor for venturi scrubbers. First, the pressure drop and waste gas feed rate are used to determine the required venturi shell thickness. Second, the cost adjustment factor is determined based on the shell thickness and the waste gas rate. This factor should be multiplied by the cost determined in Figure 17 (31).

If an automatic throat adjustment mechanism is installed, 6,350 (1981) U.S. Dollars is added to the venturi system cost. If a manual throat adjustment mechanism is specified, 3,450 (1981) U.S. Dollars is added to the cost of the system (20).

Separators are specified with the venturi scrubbers to allow vapor and liquid separation after the scrubbing process. Diameter and length of the separator is based on industrial practice and is described by equations 28 and 29.

$$\text{Height} \quad H=8+0.25*Vm-0.00048*Vm^2 \qquad (28)$$
$$\text{Diameter} \quad D=5+0.11*Vm-0.00024*Vm^2 \qquad (29)$$

This cost is included with the veturi scrubber equipment.

Operating costs for the venturi scrubber (and separator) are primarily the utility and pumping cost of water. Since the water is usually recycled after use, only 25 percent of the total water requirements is added. Start-up costs were estimated at 5 percent of equipment cost (29).

Induction Fan

Induction fans are used to transport the emission gases of the incineration process through the pollution control system. The induction fan should be specified after the particulate removal unit to reduce the fan blade wear. The total cost of an induction fan includes the cost of fans, motors, and inlet and outlet dampers. Design and cost method used were published be Vatavuk (27). Cost of the fan is dependent on the air flowrate and fan pressure drop. For pressure discharges greater than 30 in water, multiple fans in series are specified. Fan operation conditions are corrected for temperature and pressure other than 70^{o} F and 14.7 Psia (Figure 20). Fan costs are represented in Table XV, based on the impellor diameter (27).

TABLE XV

FAN COSTS FOR INDUCTION FANS

Diameter of Impellor (Inches)	Cost of Fan (U.S. Dollars 1977)
18	2,200
27	4,000
40	7,000
60	10,500
80	25,000
98	38,000

These costs are for class 4 (high performance) fans. Fan costs are adjusted for materials of construction based on factors listed in Table XVI (27).

TABLE XVI

MATERIALS OF CONSTRUCTION
COST FACTORS FOR FANS

Stainless Steel	-	2.50

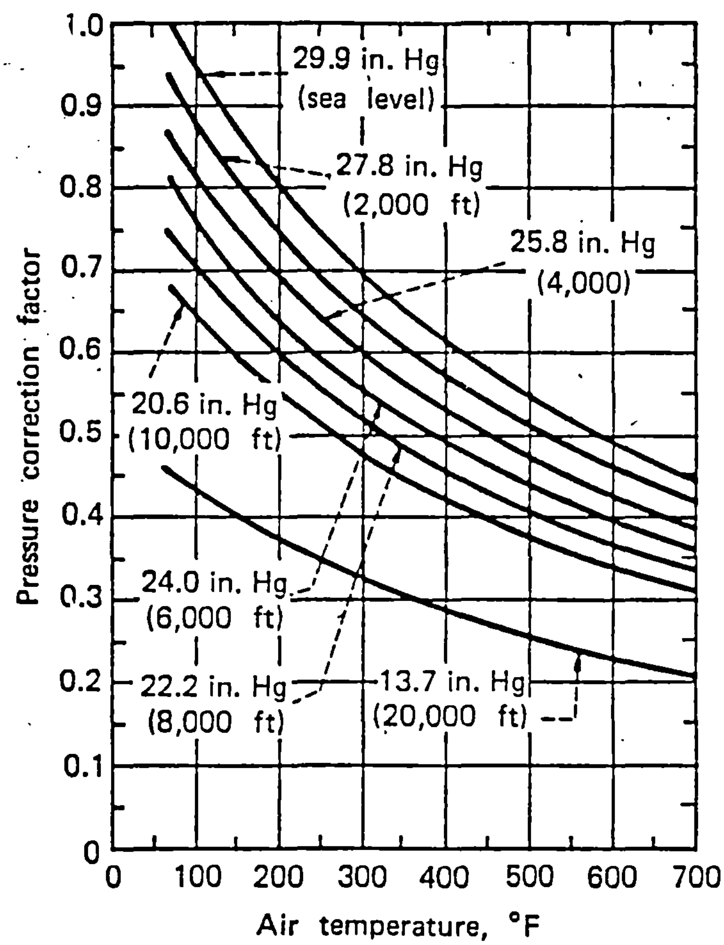

Figure 20. The actual design pressure head required for conditions different than 60 Fahrenheit and 14.696 Psia pressure (31).

Inconel-Clad-Stainless steel	-	3.0

If the fan service temperature is between 250 and 600 ^{o}F, a 3 percent charge is added to the total fan cost (27).

The design and cost of the motor is dependent on the power requirements, the fan's rpm, and the air flow rate. The cost of the electric motor is found by using Figures 20 and 21 (20). The cost is based to 1977. Cost of the inlet and outlet dampers is based on the volume rate of the gas and diameter of the impellor. Figure 22 summarizes this cost data. Cost data was compiled in December 1977 (27).

Operating costs specific to induction fans consist of electricity cost to operate the motor.

Packed Bed

Packed bed absorbers are implemented to reduce the concentration of water soluble caustics (usually HCl, SO_2, and NO_2). The packed bed design and cost method were presented by Cheremisinoff et. al. (22). The diameter of the packed bed is based on the liquid and vapor mass rates. The diameter is determined by two methods. The first method, using the Lobo correlation, can be used to directly solve for the diameter from experimental data. This correlation has been curve-fit for this program. The second method to calculate the diameter of a packed bed absorber

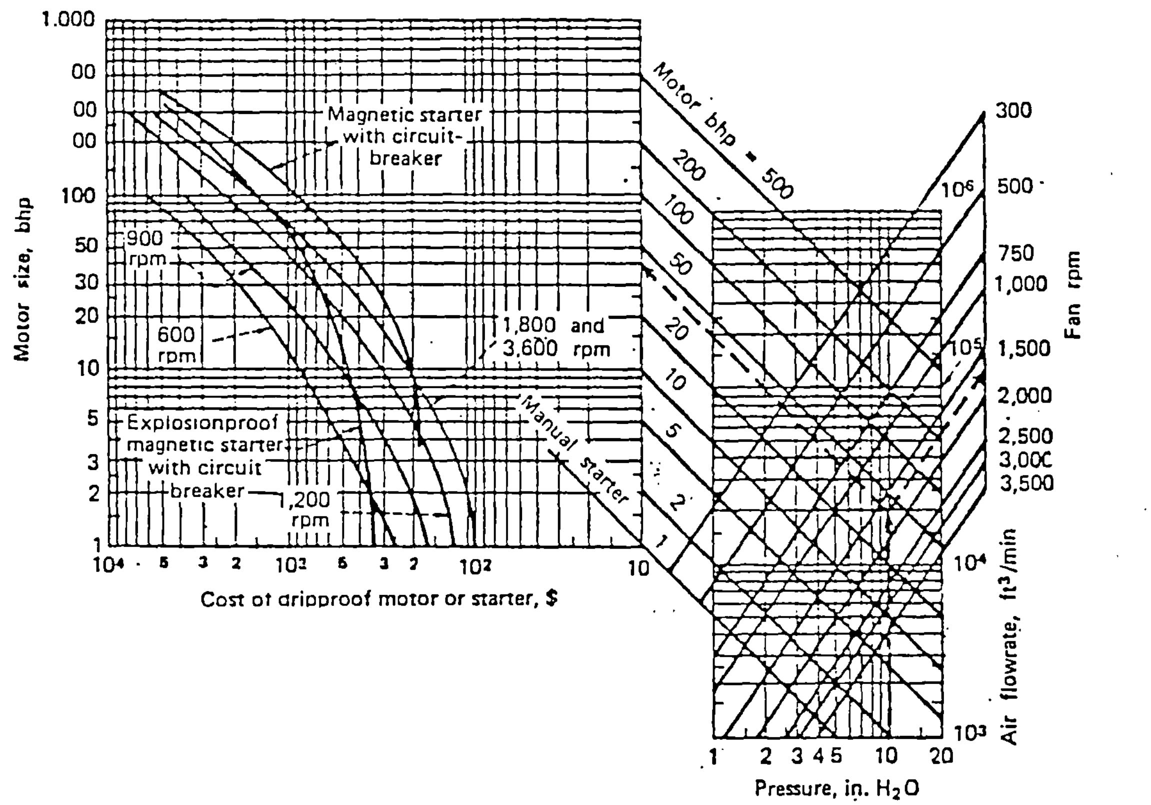

Figure 21. The cost of an electric motor based on the power requirements and motor rpm's (31).

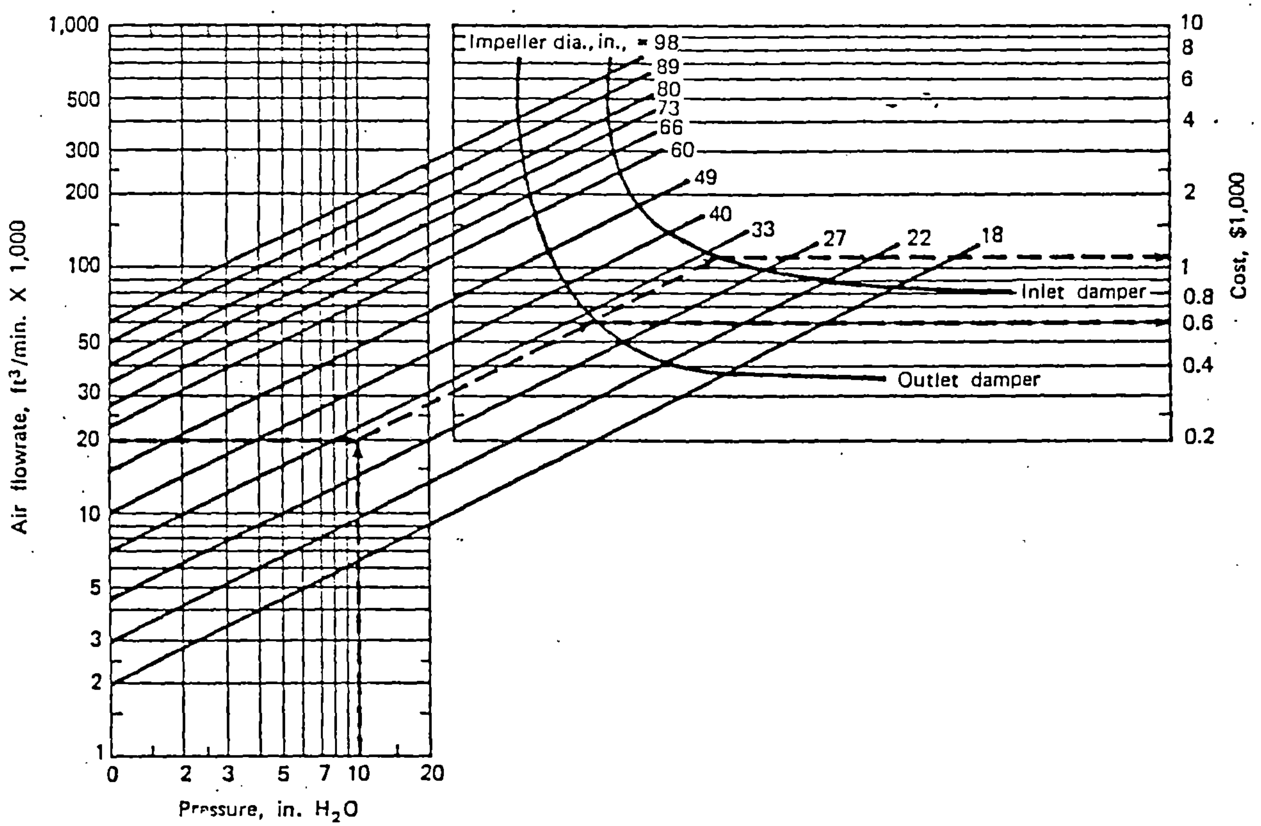

Figure 22. The cost of both the inlet and outlet dampers (81).

requires the solution of an empirical relationship (See equation 8). The diameter is solved by the interval halving method. One of the two methods must be selected by the user for this program.

Both methods require a correction factor dependent on the type of packing used. These factors are shown in Figure 23 (22). The packing factor is dependent on the packing type and size.

The height of the packed bed can be determined in two ways. First the user may directly select the height of the packed bed, eliminating all absorption calculations. Second, the mass transfer method may also be selected to determine the packed bed design height.

Using an alternate method, included in the program, the user must specify the total number of transfer units required to scrub the gas. The height of one transfer unit is based on the diffusion rate of the caustic in the gas and liquid phase. A method to calculate the height of a packed be column was published by The Air Pollution Control Association (21). The height on one transfer unit is calculated from the equations 30 to 32 below (21):

```
Hog = Hg + (m)(Gm/Lm)*Hl                        (30)
      Hg = a*Gm^b/Lm^q * (ug/Pg/Dg)^0.50        (31)
      Hl = z(L/ul)^n * (ul/Pl/Dl)^0.50          (32)
```

Here a,b,q,n,z are constants based on the packing size. These contants are given in Tables XVII and XVIII (21). The variables Dl and Dg are the diffusivity of the caustic in

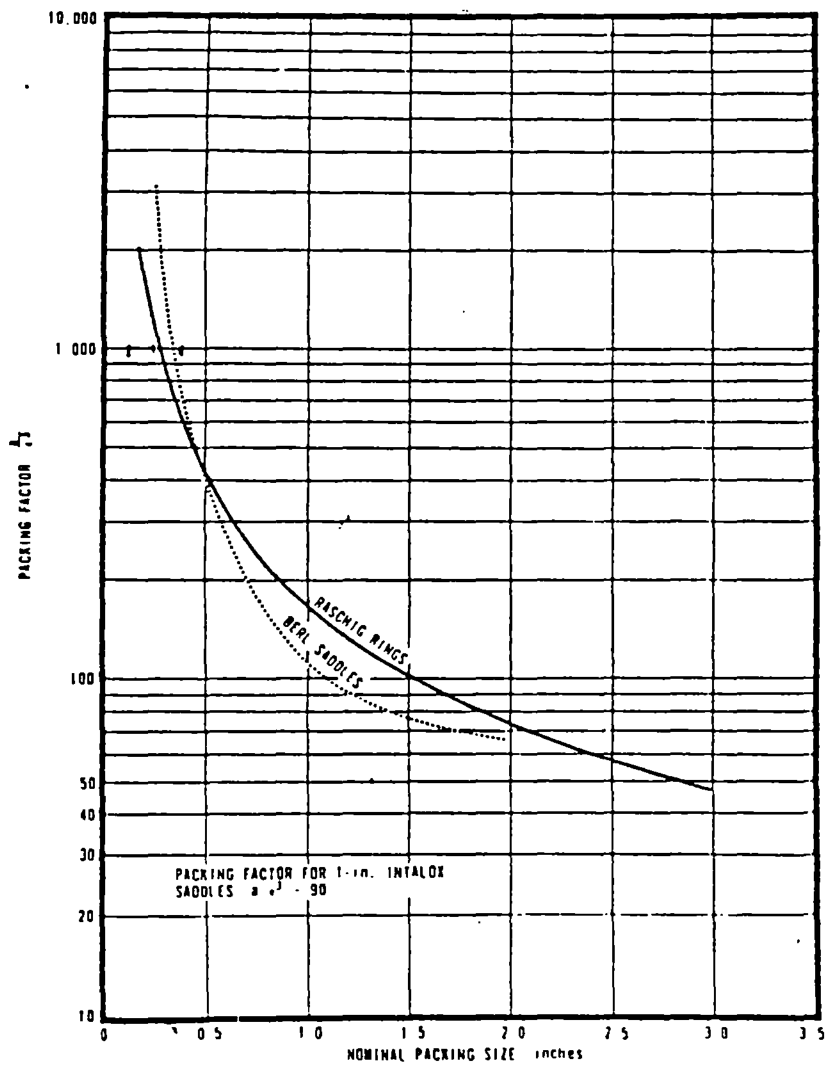

Figure 23. Packing factors for use with the Lobo correlation (73).

TABLE XVII

CONSTANTS FOR GAS MASS TRANSFER UNITS

Packing	a	b	g	Range of Gas (lb/hr/ft°2)	Liquid
Raschig Rings					
3/8 inch	2.32	0.45	0.47	200 - 500	500 - 1,500
1 inch	7.00	0.39	0.58	200 - 800	400 - 500
1 inch	6.41	0.32	0.51	200 - 600	500 - 4,500
1-1/2 inch	17.30	0.38	0.66	200 - 700	500 - 1,500
1-1/2 inch	2.58	0.38	0.40	200 - 700	1,500 - 4,500
2 inch	3.82	0.41	0.45	200 - 800	500 - 4,500
Berl Saddles					
1/2	32.40	0.30	0.74	200 - 700	500 - 1,500
1/2	0.81	0.30	0.24	200 - 700	1,500 - 4,500
1	1.97	0.36	0.40	200 - 800	400 - 4,500
1-1/2 inch	5.05	0.32	0.45	200 -1500	400 - 4,500

TABLE XVIII

CONSTANTS FOR LIQUID MASS TRANSFER UNITS

Packing	Nominal size (inches)	z	n	Range of Liquid (lb/hr/ft°2)
Raschig Rings	1/2	0.0018	0.46	400 -15,000
	3/4	0.0036	0.35	400 -15,000
	1	0.0100	0.22	400 -15,000
	1-1/2	0.0111	0.22	400 -15,000
	2	0.0125	0.22	400 -15,000
Berl Saddles	1/2	0.0067	0.28	400 -15,000
	3/4	0.0058	0.28	400 -15,000
	1	0.0058	0.28	400 -15,000
	1-1/2	0.0062	0.28	400 -15,000

Constants available for packed bed absorber calculation of the liquid mass transfer unit. This data is used with equation 32(22).

the liquid and gas phases respectively. The variable m represents the slope of the equilibrium curve (See Figure 24)(49) The pressure drop in a packed bed absorber is determined, based on the type of packing, from equation 33.

$$DP/Z = m * (10 -8) * (10 (n*Lm/Pg)) * Gm /Pg \quad (33)$$

Data used in this equation are represented in Table XIX (21).

These values must be selected by the user. This allows selection of the caustic to be absorbed. For hydrogen chloride absorption, typical values for diffusion coefficients are listed below.

$$D(liquid)= 2.64*10°-5\ cm°2/sec. \quad (34)$$
$$D(gas)= 0.360*10°-2\ cm°2/sec \quad (35)$$

The effect of temperature has been estimated from correlations published in the literature (34,50).

The cost data for a packed bed absorber, included in the program, was published by the Air Pollution Control Association. This data is represented in Figure 25. The cost of the bed is for a one foot section and includes the cost of accessories.

Exhaust Stack

Exhaust stacks are pollution control used to release gas emissions safely to the atmosphere. The design of exhaust stack is based on the diameter and height. The diameter is

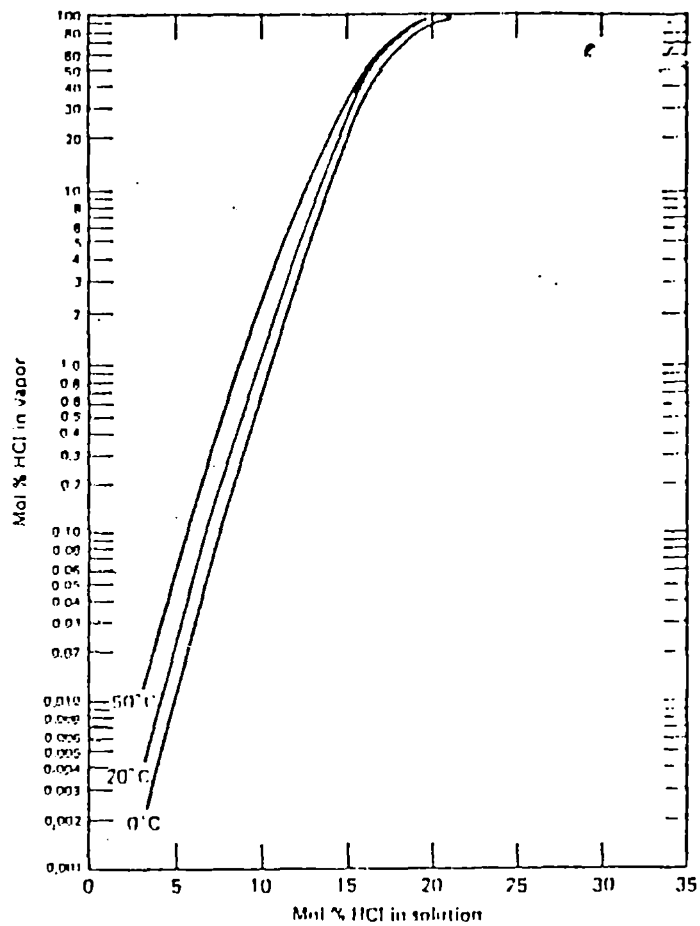

Figure 24. Vapor liquid equilibrium curve used to calculate the slope(m) for absorption calculations(85).

TABLE XIX

CONSTANTS FOR PRESSURE DROP CALCULATION

Packing	Nominal size (inches)	m	n	Range of Liquid (lb/hr/ft°2)
Raschig Rings	1/2	139.00	0.00720	300 - 8,600
	3/4	32.90	0.00450	1800 -10,800
	1	32.10	0.00434	360 -27,000
	1-1/2	12.08	0.00398	720 -18,000
	2	11.13	0.00295	720 -21,000
Berl Saddles	1/2	60.40	0.00340	300 -14,100
	3/4	24.10	0.00295	360 -14,400
	1	16.01	0.00295	720 -78,800
	1-1/2	8.01	0.00225	720 -21,600
Intalox	1	12.44	0.00277	2520 -14,400
Saddles	1-1/2	5.66	0.00225	2520 -14,400

This table represents the constants used to calculate the pressure drop for a packed bed absorber. Constants presented in this table are applied to equation 33(22).

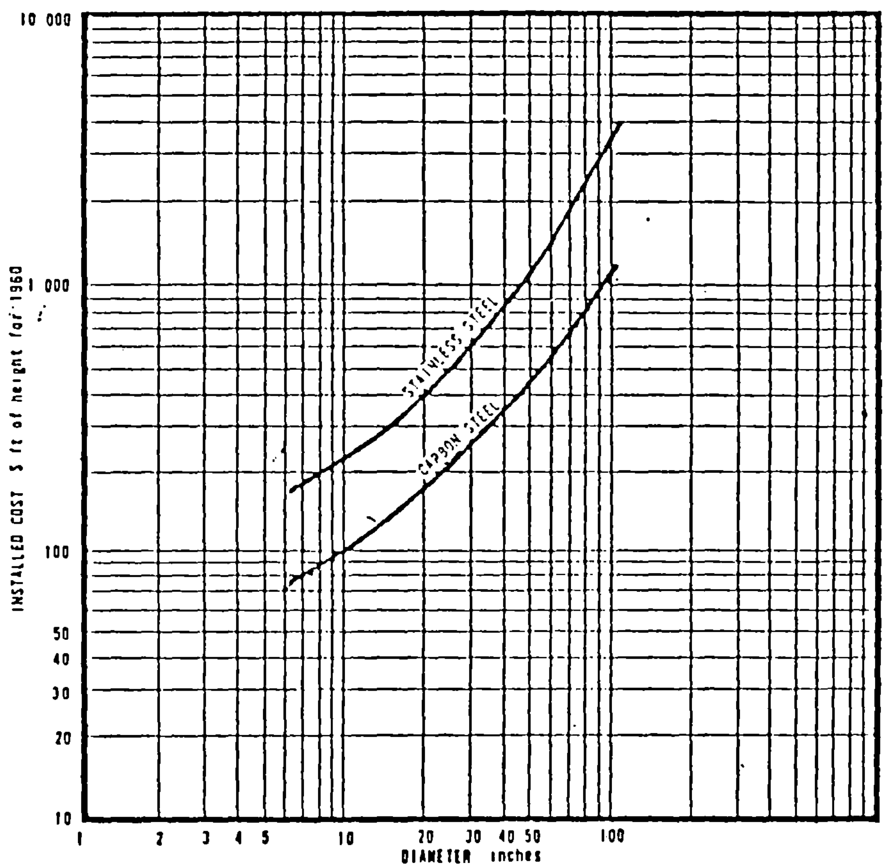

Figure 25. Cost of a packed bed absorber per foot (15).

directly related to the average wind velocity at the facility site. The stack velocity is 1.5 times the expected wind velocity (which is specified by the user). The maximum allowed stack velocity is 9,000 ft/minute (25). The height of the exhaust stack is selected by the user. If the diameter of the stack exceeds 60 inches, stack height must be between 100 and 200 feet.

Cost data to estimate exhaust stacks were obtained from information published by Vatavuk el. al. (25). Using this method, the uninstalled cost of the exhaust is calculated based on the height of the stack at a given diameter. The cost data is divided into many categories based on stack height, thickness, and diameter. The results of the data are presented below in equation form from Table XX (25).

TABLE XX

COST OF EXHAUST STACKS

20-100 feet high stacks

1/4-inch plate

Diameter (inches)	Cost (Dec. 1977)
60	1,265 + 87.4 * H
54	1,150 + 83.9 * H
48	1,035 + 79.3 * H
42	977 + 70.0 * H
36	862 + 65.5 * H
30	862 + 59.8 * H
24	862 + 49.4 * H

3/8-inch plate

Continued

Diameter(inches)	Cost(Dec. 1977)
60	2,070 + 104. * H
54	1,840 + 102. * H

5/16-inch plate

Diameter(inches)	Cost(Dec. 1977)
60	1,667 + 98.0 * H
54	1,495 + 95.0 * H
48	1,380 + 86.0 * H
42	1,092 + 80.0 * H

200-600 foot high stacks

1/4-inch plate

Diameter(feet)	Cost(Dec. 1977)
40	-946 + 9.23 * H
30	-1050 + 8.25 * H
20	-1325 + 8.63 * H

In this table, the variable H represents the stack height. The height of the exhaust stack is in feet. This cost method includes (26):

1) Flanges
2) 4 Cables (Stainless steel)
3) Clamps
4) Surface coating

These costs do not include installation and lining (refractory or plastic). Installation costs range from 30-100 percent of the equipment costs (17,18). The computer program included a cost factor of 50 percent. This factor is low for shop fabricated stacks and high for field erected exhaust stacks (14). This factor is selected by the user.

Ductwork

Ductwork must be specified to connect the incineration and pollution control process units. The design of the ductwork is for a heavy dust loading, or 9,000 feet / minute superficial velocity (26). The type of ductwork (Materials of construction), length, and number of bends must be selected by the user.

The cost of fabricated straight carbon steel ductwork is presented in in Table XXI based on the ductwork wall thickness and diameter (26).

TABLE XXI

COST OF STRAIGHT CARBON STEEL DUCTWORK

Thickness(inches) (inches)	Cost(Dec 1977) (Dec 1977)	Diameter Range (inches) High	Low
1/2	-3.86+3.01*D	85	10
3/8	-2.93+2.38*D	140	15
1/4	-2.05+1.77*D	155	30
3/16	-1.76+1.37*D	190	40
1/8	-1.46+1.09*D	200	50

The diameter of the ductwork (D) is in inches. The cost of duct elbows is shown in Figure 26 (26). The cost of refractory (if required) is listed below in Table XXII (26):

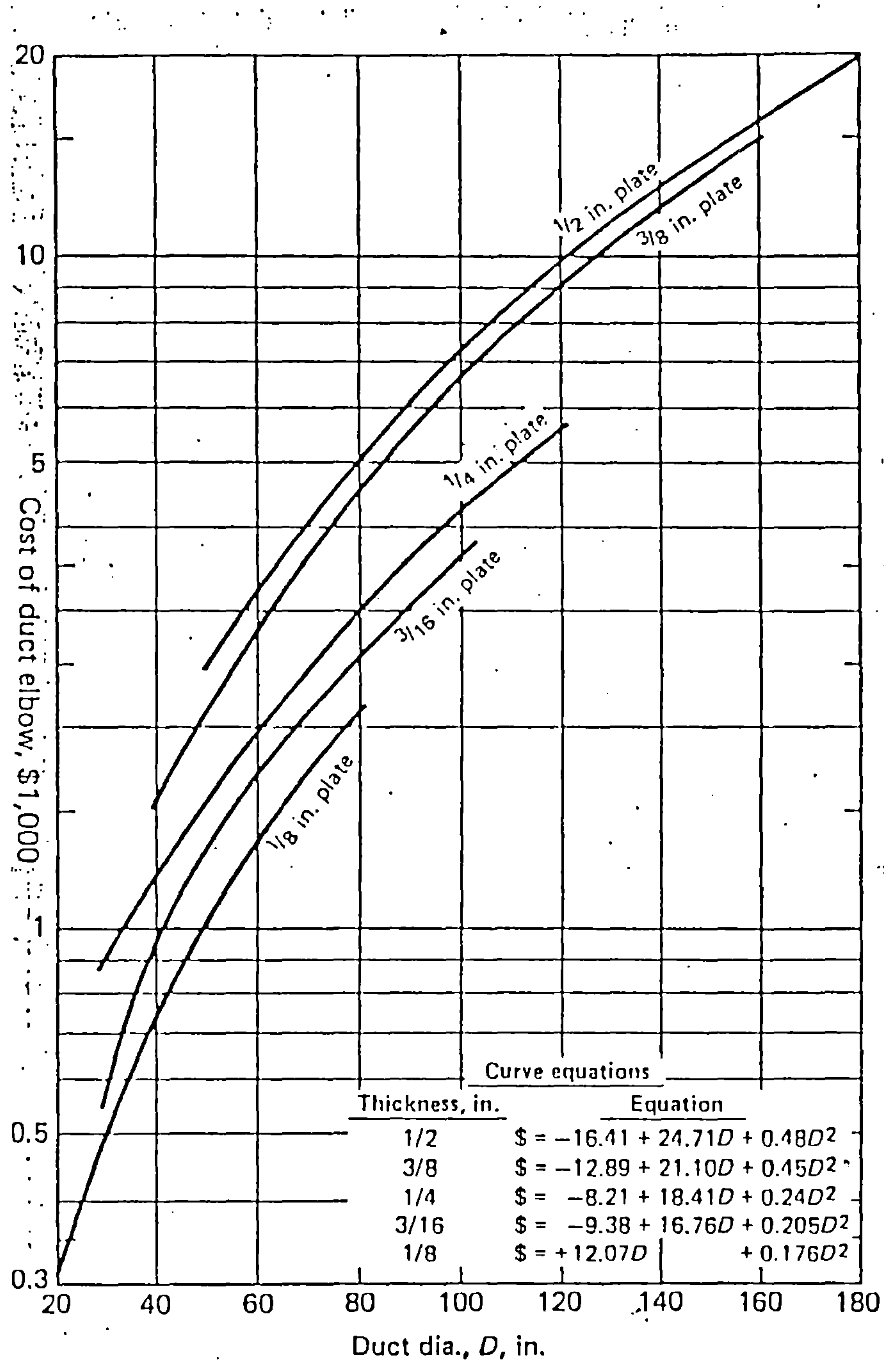

Figure 26. The cost of carbon steel ductwork elbows (29).

TABLE XXII

PROPERTIES AND COST OF FIREBRICK FOR DUCTWORK

TYPE OF REFRACTORY	THERMAL CONDUCTIVITY (Btu/hr/ft°2/F/in)		PURCHASE PRICE	INSTALLED PRICE
	$1000^{o}F$	$2000^{o}F$	($/ft°3)	($/ft°3)
Firebrick	9.3	10.0	7	90
Insulation	1.9	2.1	6	30
Castable	5.1	5.7	25	75
Plastic	N.A.	N.A.	13	N.A.
Ceramic	N.A.	N.A.	N.A.	25

The temperature limitations of the refractory is 3,200 for the firebrick, 2,000 ^{o}F for the insulation, 3,000^{o} F for the castable, 3,000 ^{o}F for the plastic, and 2,300 for the ceramic fibers (36).

Miscellaneous Facility Costs

Waste Storage Facility

Selection of size and number of tanks is left to the designer. The cost of storage tanks using this method includes (9):

1) Vessel (Carbon Steel)
2) Dimple jacketing
3) Agitator
4) Pumps (2 stainless steel)
5) Piping
6) Insulation
7) Grating
8) Diking

The cost of each storage unit is calculated in Table XXIII. Cost factors for the materials of construction apply to the vessel cost only and are (9):

TABLE XXIV

COST FACTORS FOR MATERIALS OF CONSTRUCTION FOR WASTE STORAGE TANKS

2.7	Stainless Steel 316
2.4	Stainless Steel 304
1.7	Rubber lining
5.8	Glass lining

Other special equipment may also be included if required. This includes equipment to control volatiles and combustable wastes.

Equipment to control volatile emissions include nitrogen blanketing, condensors, or disposable carbon absorption filter units.

The cost of nitrogen blanketing is presented as operating expenses by Vogel and Martin (9). The nitrogen storage system is rented at an estimated annual rate of 2,500 U.S. Dollars for small units to 6,000 U.S. Dollars for large multiple tank storage facilities. The annual cost of nitrogen is estimated at 1,000 U.S. Dollars per 25,000 gallons storage tank. These costs are based to June 1981

TABLE XXIII

COST OF WASTE STORAGE FACILITY

Item	Tank Capacity, gallons 5,000	10,000	25,000
Vessel, Carbon Steel*	$8,000	$11,000	$23,000
Dimple Jacketing	3,000	5,000	12,000
Agitator, Stainless Steel	6,000	8,000	9,000
Pumps(2), Stainless Steel	10,000	11,000	24,000
Piping	8,000	10,000	13,000
Insulation	3,000	5,000	13,000
Grating	1,000	2,000	5,000
Diking	5,000	7,000	13,000
Total	$44,000	$59,000	$112,000

(9). If condensors are selected, by the user, the cost of the condensor is estimated at 4,000 U.S. Dollars for copper finned tubes to 10,000 U.S. Dollars for stainless steel tubes (June 1981) (36). These are one time capital costs.

Disposable carbon absorption units can also be selected. The cost for disposable filter systems is an annual operating cost. One filter can last 6 months and each unit costs about 600 U.S. Dollars (June 1981) (36).

An option to waste storage tanks is a barrel barn. Like the storage tank facilities, barrel barns must have special safety precautions to minimize waste leaks. Cost estimation methods for a barrel barn were published by Vogel and Martin (26). On-site storage capacity is limited,as for storage tanks, to a 48 hour supply of waste (12). The cost of a barrel storage facilities (for 55 gallon drums) is estimated at 40 U.S. Dollars (1981) per square foot of surface area. This cost includes fire-prevention and ventilation equipment (9). For the program, the storage requirements for drums are 75 drums per 100 square feet of surface area of warehouse space (26).

Other Facility Costs

Besides the cost of each incineration and pollution control units, there are other capital cost involved. These costs are:

Structural Steel Supports
Instruments and Controls
Electrical Materials
Sitework

Metal Building
Spare Parts

Costs may vary greatly depending upon the location and waste feed characteristics.

Data for structural steel supports, electrical materials, sitework and buildings were obtained from Lepeau (13). For hazardous waste incineration facilities, the cost of controls and instruments is doubled over that of non-hazardous incineration facilities. An additional $150,000 U.S. Dollars (1985) is added for special instruments. Spare parts inventory costs were set at 8 percent of the equipment costs. Figures 11 and 12 represent this data (13).

Indirect Costs

Indirect costs involved in the capital cost of incineration facilities are installation, first-time start-up costs, certification for hazardous waste, and miscellaneous engineering costs. These costs are estimated using cost factors published by Vogel (28). Installation costs include all installation not covered in the specific unit operation routines. Estimation factors are listed in Table XXV (28).

TABLE XXV

MISCELLANEOUS CAPITAL COSTS

1)	Installation	- 50% of equipment cost
2)	Start-up	- 10% of equipment cost
3)	Certification	- 10% of equipment cost + 170,000
4)	Engineering	- 7% of equipment cost
5)	Instrumentation	- 20% of equipment cost + 150,000

The extra certification costs include three short-term test trials and one 48 hours test burn required by the EPA for certification (40). Instrument costs include extra monitoring equipment required for hazardous waste operation.

Operating Costs

The operating costs of the incineration facility is calculated from the labor utilites, start-up , annual maintanance, insurance, and land taxes. The labor costs are calculated from data in the literature for labor requirement for hazardous waste incineration facilities. Labor costs include field labor, lab technicians, operators chief operators, lab supervisor, and payroll expenses. The labor time is calculated from data obtained from literature on common practice. This data is presented in Table XXVI (32).

TABLE XXVI

LABOR COSTS

Position	($/hr) Salary	(hr/day) Operation Time	Percent Required
Lab Technician	7.00	8.0	100
Chief Operator	8.00	24.0	50
Operator	7.00	24.0	100
Yard Workers	7.00	8.0	100
Secretaries	7.00	8.0	50

The number of each position required for the facility depends on the size. An estimation of these requirements is listed in Table XXVII (32).

TABLE XXVII

LABOR REQUIREMENTS

Position	1,000 lb/hr	10,000 lb/hr	> 10,000 lb/hr
Lab Technician	1	1	2
Chief Operator	0	1	1
Operator	1	2	4
Yard Workers	1	2	3
Secretaries	1	1	2

Other charges related to labor are estimated at twenty percent of total labor costs (32).

Other operating costs for the facility include:

1) Utilities Costs
2) Waste treatment and disposal
3) Land taxes
4) Lime caustic
5) Waste Heat Recovery
6) Start-up Costs
7) Maintanence
8) Insurance Costs
9) Revenue Generated

<u>Utilities Costs</u>

Fuel costs are the sum of the fuel requirements for the incinerator and afterburner. Water costs include the sum of quench, venturi scrubber, packed bed, and heat recovery boiler. Electricity costs include pumping requirements (for fuel and water) in the incinerator, afterburner, quench chamber, venturi scruber, and packed bed absorber. Liquid pumping costs are estimated from equation 35 (19):

$$Hp = 0.36 * (\text{gallon/minute}) \tag{36}$$

This equation assumes a 30 psig spray pressure. Power calculations include a 50 percent loss factor. Fan compressor costs from air blowers and induction fans are estimated from equation 36 (41).

$$Hp = PD * Vm / 4{,}464 \tag{37}$$

In this equation, PD is the pressure drop in inches of water and V is the volumetric flowrate of the gas in actual cubic feet per minute.

Waste Treatment

Waste disposal costs are calculated for the amount of ash generated by the incineration facility. Disposal costs range from $40/ton to $400/ton to landfill the ash waste (51).

Capital cost data for a waste water treatment system were not available in the literature. Information published by Vatavuk and Neveril does estimate the total capital cost and operating cost based on the water feed rate. This data is presented in Table XXVIII (44) and is included in the program.

TABLE XXVIII

WASTE WATER TREATMENT OPERATING AND CAPITAL COSTS

Waste Flow Rate (gallon/minute)	Installed Cost ($1,000)	Operate Cost (U.S. $ / Kilogallon)
1190	3,380	2.10
2290	4,450	1.50
5270	5,270	1.26

These costs are based to December 1982. The operating costs include (44):

1) Elecricity
2) Water treatment chemicals
3) Capital Recovery
4) Miscellaneous charges

Labor is not included in these costs.

Land Taxes

Land taxes for the facility are estimated at 2 percent of the capital cost (29).

Lime Caustic

Lime or limestone added in the venturi and packed bed is calculated from the amount of caustic added. Caustic is used to neutralize the acid gases produced by the incineration process, and increase the vapor/liquid absorption properties in the venturi scrubber and packed bed absorber. Absorption reactions in the program include:

$$2HCl + CaO \text{ (lime)} \rightarrow CaCl_2 + H_2O \quad (38)$$
$$SO_2 + CaO \text{ (lime)} + 1/2O_2 \rightarrow CaSO_4 \quad (39)$$

The cost of lime (CaO) is estimated at 40.0 U.S. Dollars (1980) / ton (29).

Steam Cost Recovery

The production of steam in the heat recovery boiler reduces the operation cost. Steam produced is calculated by the sensible heat loss of the incinerator emissions and the latent heat of vaporization of steam at 185 Psia. A 20 percent loss factor is included for heat losses. Steam recovery costs are calculated based on $ 5.04 per 1000 lbs produced (41).

Start-up Costs

Start-up costs for yearly start-up is calculated for incinerator reheat time and start-up cost factors for each facility unit. Costs to reheat incinerator are estimated from Figure 27 (14). The cost to reheat the incinerator is based on the time from cold start and the heat released per cubic foot of volume from the fuel burner. Start-up time must be at least 2 weeks long per year (14). Additional start-up costs are estimated at 1 to 2 percent of the equipment cost (different for each piece of equipment).

Maintenence Costs

The yearly maintenence cost of the facility is estimated at three to six percent of fluidized bed and liquid injection equipment cost. For the rotary kiln, start-up cost is estimated at 8 percent of the brick costs (for replacement). Maintenence labor costs is 100 percent of the maintenance materials costs.

Insurance Costs

Insurance costs are estimated from cost factors discovered in literature (41). Insurance is estimated at 1 percent of the capital cost.

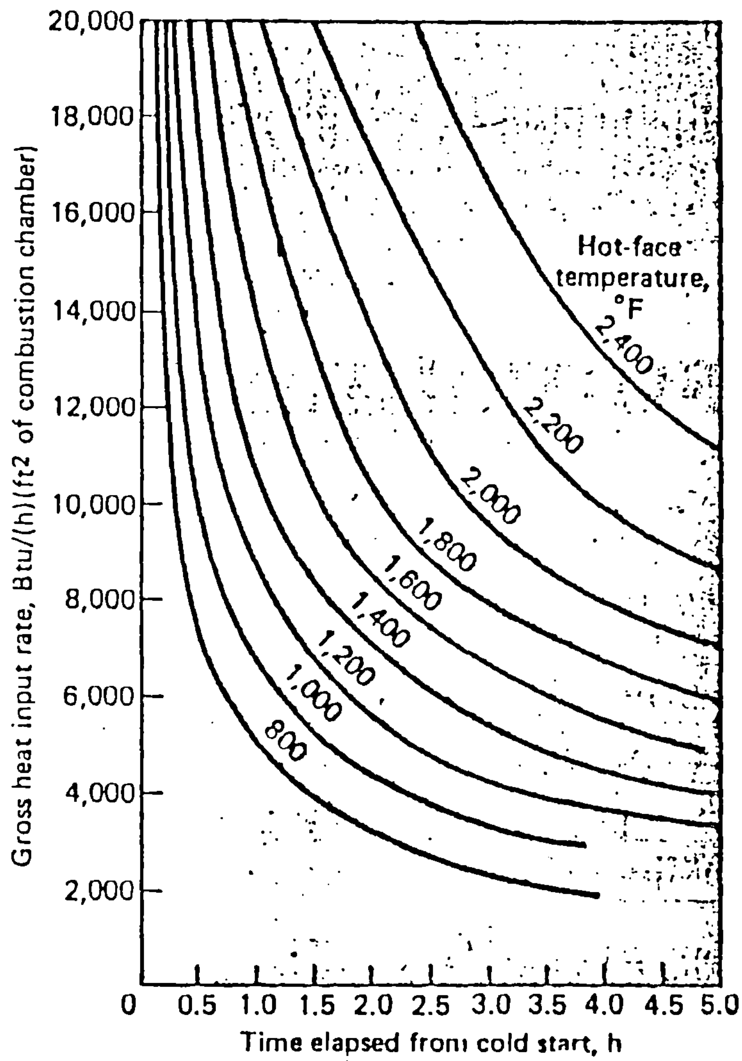

Figure 27. Heat input required to preheat incinerators (except fluidized beds) based on the surface area of the combustor (36).

Operating Revenues

Operating revenues is selected by the user on a dollars per ton basis. For this program, the default value for revenue is 400 U.S. dollars per ton of feed.

Summary of the individual operating costs are summed to estimate the total yearly costs. These costs are used for the economic analysis option.

Economic Analysis

Several methods are available to economically evaluate hazardous waste incineration facilities. The Present Value method and the Discount Cash Flow Rate of Return factor are calculated by this program (52). These methods may be selected or these procedures can be omitted by the user.

The present value adjusts all costs to the present. An example of this present value method is shown in Table XXIX. From this, a discount rate of return factor is calculated. This number represents the greatest interest rate at which money can be borrowed and still break even over the process life of the facility (See Table XXIX). For incineration facilities, the process life is estimated at 10 years. This method is presented by Gerald Smith (52). The costs involved are multiplied by the present value factor calculated from equation 39 (52).

$$PV = FV * EXP (YR * RT) \qquad (40)$$

TABLE XXIX

PRESENT VALUE CALCULATIONS

DISCOUNTED CASH FLOW RATE OF RETURN
ANALYSIS OUTPUT
(MILLIONS OF U. S. DOLLARS)

YEAR	0	1	2	3	4	5	6	7	8	9	10
INCOME	0.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
OPERATE	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
DEPREC.	0.0	0.7	1.3	1.1	0.9	0.9	0.9	0.8	0.8	0.8	0.8
TAXABLES	0.0	7.8	7.2	7.4	7.6	7.6	7.6	7.7	7.7	7.7	7.7
TAXES	0.0	3.9	3.6	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8
NET INC.	*****	3.9	3.6	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8
DEPREC.	0.0	0.7	1.3	1.1	0.9	0.9	0.9	0.8	0.8	0.8	0.8
CAPITAL	-9.2	-	-	-	-	-	-	-	-	-	-
CASH FLW	-9.2	4.6	4.9	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7

THE TOTAL CASH FLOW = 38.00 MILLION DOLLARS
DISCOUNTED CASH FLOW RATE OF RETURN = 30.6%

In this equation, PV is the present value, FV is the equivalent value, YR is the year in question, and RT is the interest rate at which the money is borrowed. The depreciation method selected is the Accelerated Cash Recovery System (ACRS) and was specified according to U.S. tax law (as of September 1986). These values can be easily modified if required. Table XXX represents the depreciation rate for a variety of facility lives (52).

TABLE XXX

ACCELERATED CASH RECOVERY SYSTEM (ACRS) DEPRECIATION METHOD

3 Years	5 Years	10 Years	15 Years
25 %	15 %	8 %	5 %
38	22	14	10
37	21	12	9
-	21	10	8
-	21	10	7
-	-	10	6
-	-	9	6
-	-	9	6
-	-	9	6
-	-	9	6
-	-	-	6
-	-	-	6
-	-	-	6
-	-	-	6
-	-	-	6

The tax rate is specified by the user (usually at 50 percent).

CHAPTER V

DESCRIPTION OF COMPUTER PROGRAM

The computer program HWSTBRN is a modular package containing over 51 routines. The program is written in Fortran 77 and was run on a IBM 3085 computer system. The program was fully conceived by the author. No other packaged routines were incorporated. Design and cost of the incineration facility obtained varied from the open literature to information obtained from research facilities and commercial vendors (Phillips Petroleum and The John Zinc Company).

An important objective in the design of this program was to provide a flexible package in which different process units could be added without difficulty. The package is written in a modular form. Each unit can be specified independently and the the program can be easily altered.

The software package consists of 2 modules. These modules control the input, the design and cost estimation and the output created from the analysis. The input module allows creating new data sets or recalls old data sets. The input module allows inspection of all data, and making any alterations that are required. Physical and certain cost data are also available for inspection and alterations.

This methods prevents the problem of creating data sets manually, reducing the chance of errors.

The main module of the software package, designs and cost estimates the facility based on the design specifications selected in the input module. A subroutine flowchart for the main program is listed in Figure 28. The user is allowed to specify up to nine units in series. The only restriction controlled by the program is the temperature limitation for downstream pollution control equipment. The flexibility provides a large number of alternatives in the design of the hazarous waste incineration facility. Unfortunately, this method allows the specification in any order without regard for proper design consideration.

Design of each unit operation is determined by a controlling subroutine. Each unit available has one such routine. This controlling routine calls other support routines that break the design and cost procedures down into a series of small steps. This method of programming is common with large software packages used today.

Selection of the support routines available is controlled by logical variables which are turned on and off, depending on the physical conditions for each unit or selection by the user. All options available are engaged in the controlling subroutines; except for selection of materials of construction, which is selected in the main routine

The third section of the software package controls the output supplied on the design and cost estimation results.

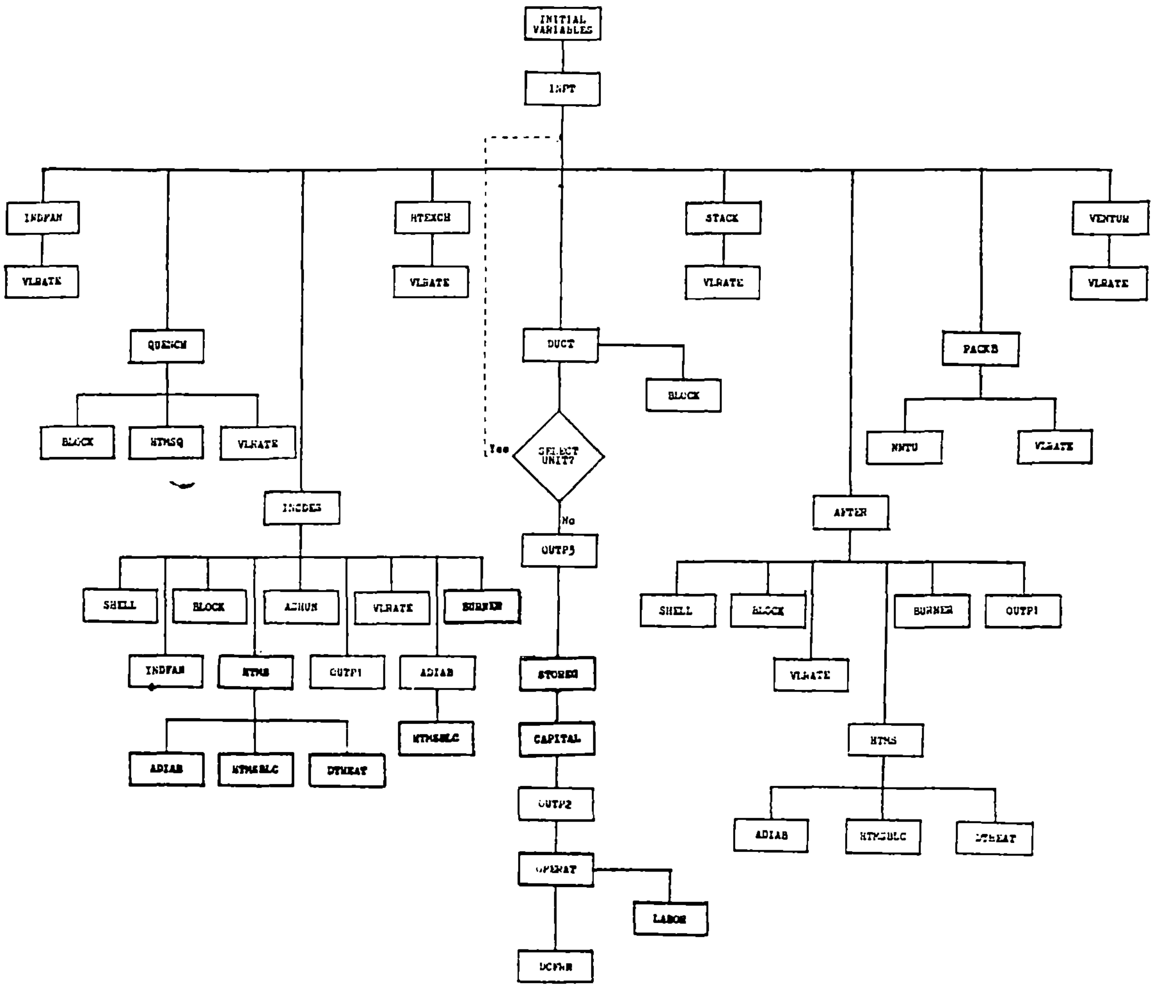

Figure 28. Subroutine flowchart for the main program HWSTBRN.

Many levels of output are available, depending on what the user specifies. The level of output is selected by the user in the input section of the program. See the output section for additional information.

Subroutine Description

Below is a description of each routine provided as an option for program HWSTBRN. The information indicates the type of subroutine, options available, routines that call the subroutine, routines called by the subroutine, and a description of the type of calculations completed. For the program two types of routines are recognized. Controlling subroutines are called to control the design and cost of each unit operation available. Controlling routines are selected by the user. Support routines are called by the controlling routines to perform operations used more than once.

Synopsis of Individual routines

The main program controls selection of the unit operations specified by the user. Design parameters common to each unit (i.e. materials of construction) are specified in the main routine. Each unit is selected in the order specified by the user. Each routine and the unit it represents is listed below.

INCDES	-	Primary Incinerator
AFTER	-	Afterburner
QUENCH	-	Quench Chamber
HTEXCH	-	Heat Recovery System

VENTUR	-	Venturi Scrubber/Separator
INDFAN	-	Induction fan Assembly
PCKBD	-	Packed Bed Absorber
STACK	-	Exhaust Stack
ADIAB	-	Adiabatic combustion

After each controlling routine, ductwork is designed and costed to connect the next unit. The length and number of elbows is selected by the user after each unit. After all the specific units are analyzed, subroutines CAPTAL calculates all miscellaneous capital costs. Operating costs are calculated from subroutine OPER. A series of output routines are then called depending on the requirements of the user.

Subroutine Adiab

The subroutine ADIAB is implemented from the controlling subroutine INCDES if the user specifies adiabatic combustion of the waste feed; or from subroutine HTMS if the total heat released by the waste feed exceeds the combustion temperature specified by the user without the addition of any excess fuel. Subroutine ADIAB calls subroutine HTMSBL and DTHEAT to solve the adiabatic combustion problem. Solution to the adiabatic process is solved by directly determining the mass balance and a trial and error solution of the energy balance to determine the temperature. Interval halving is the method used to determine the exit temperature of the emission gases.

Subroutine After

Subroutine AFTER is a controlling routine implemented to design and cost estimate a liquid injection afterburner. This subroutine is called only by the main program and is one of the unit options that the user can specify.

The design of the afterburner is based on the desired exit temperature, retention time, and length to diameter ratio. Fuel and air added to increase the temperature to the required exit temperature. The amount of fuel (and air) is determined from subroutine HTMS (see subroutines INCDES AND HTMS) from the specified outlet temperature selected by the user. The design volume is determined from the volume rate (calculated in subroutine VLRATE) and the retention time specifed by the user. The diameter and length are calculated from the length to diameter ratio specified by the user.

The capital cost of the afterburner is calculated from its components. The cost of refractory and insulation firebrick is calculated from subroutine BLOCK, the cost of the shell is calculated in subroutine SHELL. Fuel burner costs were calculated from subroutine BURNER. Contengency costs are not included unless specified by the user. Installation cost of the afterburner is 50 percent of equipment costs and is calculated in subroutine CAPTAL. Operating costs are based on the following: Maintenence costs are 9 percent of the equipment costs. Operating costs for the afterburner includes only the cost to pump the fuel into the chamber and cost of the fuel. All other operating costs are negligible.

Options available with the afterburner are the materials of construction. The shell can be constructed of carbon steel, stainless steel, or Inconel-clad-stainless steel. This option is selected by the user.

Subroutine Ashun

The subroutine AHSUN is called by INCDES and is implemented to determine the cost of an ash handling system. The cost of the ash control system is based on the heat release rate of the waste feed. Two types of ash handling systems are available depending on the size of the incinerator. Incinerators with a heat release greater than 15 million Btu/hour require automatic ash control systems.

Subroutine Block

The subroutine BLOCK is called by INCDES, QUENCH, and DUCT. This subroutine determines the thickness and amount of refractory and insulation firebrick for the incinerators, afterburners, quench chambers and ductwork.

The thickness of the refractory is determined by two methods. The first method is used if heat loss through the shell is specified by the user. The thickness is based on the thermal conductivity of the the firebrick. If no heat loss is specified, the thickness is based on data from the literature. The thickness, using this method is based on the hot-face temperature. These values are based on practice common in the industry.

The cost estimation of the refractory and insulation firebrick is listed in Table VIII. The cost is based on the hot-face temperature of the firebrick, the corrosive nature of the emissions, and the thickness of the refractory. If the weight fraction of chlorine is greater than 0.5%, corrosive resistant materials are selected. Selection of firebrick material also sets the cost. Installation of the bricks is 100% of the materials cost. Shipping is estimated at 30% of the brick materials costs. Yearly maintenance, excluding materials, is 15 % of the total materials cost for the rotary kiln, ten percent for fluidized bed, and five percent for the liquid injection incinerator. Costs are updated using the Chemical Engineering Plant cost Index factors for fabricated materials.

<u>Subroutine Burner</u>

Subroutine BURNER is used to determine the number, heat release rate and cost of both the waste feed burners and fuel burners. Subroutine BURNER is called by subroutine INCDES and AFTER.

Waste feed burners are sized and costed based on the heat released rate of the waste feed and the water content. If the heat value of the waste feed is less than 4,000 Btu/lb, or if the water content is greater than twenty percent, at least two fuel burners must be used. Burners of three different sizes are available (see literature review) depending on the heat released by the fuel. If the total heat load requires more than eight fuel burners, a warning message is printed indicating a need to inspect the number of burners selected. Burner costs are calculated anyway.

Waste feed burner systems are based on the total heat released rate from the waste feed. Costs of both burner systems were obtained from data supplied by Vogel (See literature review) (9).

Subroutine Captal

Subroutine CAPTAL is a controlling routine that is called by the main routine. This routine calculates information on miscellaneous parts of the capital cost. This routine determines the cost of a metal building for instruments and operations room, the sitework required to prepare the land for the facility, cost of structural steel used to support the incineration and pollution control units, cost of electrical materials, and other indirect capital costs. Cost data for all but indirect costs are calculated by equations listed by equation 44. Indirect costs include installation costs not included in each specific unit operation, the first-time start-up costs, cost of spare parts inventory, cost of certification and engineering costs to design the facility.

Options available with this routine are selection of start-up and sitework cost factors. These values are specified by the user.

Subroutine Dtheat

Subroutine DTHEAT is called by subroutines HTMS, ADIAB, QUENCH, HTEXCH, and others. This routine determines the amount of heat required for a given temperature difference. The equations used are:

$$Q = Cp\ DT \qquad (41)$$

where

$$Cp = c + fT + eT^2 + dT^3 \qquad (42)$$

The constants c,d,e, and f where obtained for the product gases (See Table XXXI) (54).

Along with the emission gas, the ash products heat requirements and a 10 percent heat loss factor is also included in the heat calculations.

Subroutine Duct

Subroutine DUCT is a support routine called by the main program. This subroutine designs and cost estimates ductwork and breeching connecting the incineration and pollution control units. Depending on the materials of construction, firebrick insulation and refractory may be selected. This material is designed and cost estimated in

TABLE XXXI

HEAT CAPACITY VALUES FOR COMBUSTION PRODUCTS

Compound	a	b*10°2	c*10°5	d*10°9
Water	33.46	0.6880	0.7604	-3.593
Hydrogen Chloride	29.10	-0.1340	0.9710	-4.333
Carbon Dioxide	36.10	4.2330	-2.8870	7.464
Carbon Monoxide	28.90	0.4110	0.3550	-2.220
Nitrogen	29.00	0.2200	0.5720	-2.870
Oxygen	29.00	1.1580	-0.6076	1.311
Nitrous Oxide	29.50	8.1900	-0.2950	3.650
Nitrogen Dioxide	36.10	3.9700	-2.8800	7.780
Chlorine	33.60	1.3700	-1.6100	6.470
Sulfur Dioxide	38.90	3.9000	-3.1000	8.610
Hydrogen Sulfate	139.00	15.6000	-	
Fluorine	29.00	-	-	
Hydrogen Fluoride	72.4	-	-	

subroutine BLOCK. Different materials of construction can be selected for each unit. This allows the use of less expensive materials at low temperatures.

The diameter of the ductwork is based on the velocity of the gas (to prevent particulate settling in the ductwork). Since heavy particulate loading is very probable, a velocity of 9,000 feet per minute is selected. The length and number of elbows depends on the placement of each unit and is specified by the user.

The cost of ductwork is based on the diameter, materials of construction and the number of elbows. The cost (per foot length) of ductwork is listed in in Table XXI based on ductwork wall thickness and diameter. If the diameter of the ductwork exceeds the information on cost, the gas velocity is increased 20 percent, then the design and cost analysis is repeated. If the diameter needs to be increased, the gas velocity is decreased by 20 percent.

Subroutine Eng

Subroutine ENG is a support routine called by many routines. This subroutine converts physical and design data from metric units to english units. The converted units are:

Energy - Btu
Length - Ft
Temperature - F
Mass - pounds(lb)
Pressure - PSIA

Units are converted from the metric units listed in subroutine METRC. This routine is used for the output routines and some design routines.

Subroutine Htexch

Subroutine HTEXCH is a controlling routine implemented to cost estimate the heat recovery unit for pollution control systems. The design of a two phase heat exchanger is complicated and was not conducted.

The cost estimation of the heat recovery unit can be calculated by two methods. The first method requires an estimation of the overall heat transfer coefficient. This value is used to calculate the area of the heat transfer for the steam generation process. The calculated area of heat exchange is used to estimate the cost of the heat recovery boiler. The second cost estimation method is based on the gas flow rate and an exit temperature of 500 ^{o}F. Cost is estimated for installed units.

Material of construction and the cost method are options available to the user. Both of the options are selected by the user. Cost data is updated from Chemical Engineering Plant Cost Index updating cost factors for equipment costs. The operating cost is essentially the steam produced from the boiling process. The amount of steam produced is calculated from the enthalpy change between the inlet and outlet streams and include a 20 percent loss factor.

Subroutine Htms

Subroutine HTMS is called from subroutine INCDES if the outlet temperature of the incineration is specified. The subroutine is designed to solve a simultaineous mass and energy balance. These balances are based on the required exit temperature from the incinerator (selected by the user) and the amount of fuel required to reach this temperature. If, on the first loop of the balance, no fuel is required, the heat released by the waste feed exceeds the amount of heat required to reach the exit temperature. Control is then transferred to subroutine ADIAB. Interval halving is used to converge to the amount of fuel required to reach the desired incineration temperature.

The subroutine HTMSBL is called from the subroutine ADIAB and HTMS. This routine serves two purposes. First, the amount of air required to achieve 100 percent combustion is determined and increased to meet the excess air required by the user. Second, the incineration products are balanced based on the waste feed. The equations are balanced in the following order:

1- All Carbon is converted to Carbon dioxide
2- All sulfur is converted to Sulfur dioxide.
3- All Nitrogen is converted to Nitrogen gas.
4- All chlorine is converted to Hydrogen chloride until all hydrogen is consumed. All remaining chlorine is converted to molecular chlorine (Cl_2).
5- All fluorine is converted to Hydrogen fluoride until all hydrogen consumed. All remaining fluorine converted to molecular fluorine (Fl_2).
6- All remaining hydrogen converted to water.

7- All remaining oxygen converted to molecular oxygen (O_2).

Since the destruction conditions must be set by the user, there is no guarantee that the stack gases will reach 100 % combustion efficiency.

The results of this subroutine are stored in the variable MLPRDT. Additional space has been allotted for production of other product chemicals. This is left to future work. An error message is printed if the error in the mass balance is greater than 1 percent.

Subroutine Htmsq

Subroutine HTMSQ is a support routine called by subroutine QUENCH. This routine calculates the amount of water required to cool the gas stream in the Quench chamber. The amount of heat required is calculated from subroutine DTHEAT. The amount of water required to cool the stream is then determined (using the interval halving method). Antoine's equation is used to determine the maximum amount of water that can be evaporated. Therefore, heat removed by evaporation from water cannot exceed the saturation limit. If further cooling is required, the specific heat of water is used.

No capital costs are considered in this routine, but the operating costs for the water, and the pumping costs are calculated. All water that is not vaporized is removed and recirculated. Water that is vaporized is added to the gas stream.

Subroutine Incdes

The subroutine INCDES is the controlling routine that designs and cost estimates the primary incinerator for the facility. The design procedures (and their routines) are as follows. For an adiabatic combustion (no fuel added), control is moved to subroutine ADIAB. The mass balance is solved directly and the energy balance (routine DTHEAT) is solved by trial and error for the outlet temperature. If the outlet temperature is specified, the mass and energy balance are solved simultaneously (in routine HTMS) for the added fuel and outlet temperature. If no extra fuel is added in routine HTMS, control of the energy balance is moved to subroutine ADIAB for an adiabatic combustion solution to the problem. With either method, control to subroutine INCDES is returned with the waste feed converted to product gas (in subroutine HTMSBL) at the combustion temperature.

The design of the primary incinerator is based on the retention time (liquid injection or rotary kiln), total heat released from the combustion (rotary kiln) or design parameters available in literature (fluidized bed). The length and diameter relationship is determined by the length to diameter ratio supplied by the user (in all cases).

Once the dimensions are calculated, the firebrick insulation and refractory are selected, designed and costed in subroutine BLOCK. The cost of the incinerator shell is calculated in subroutine SHELL and is based on material of construction. If the ash production rate is greater than 1 percent, then an ash bin is costed from subroutine ASHUN.

Subroutine INCDES has available the following options:

1) Incinerator type:
   - fluidized bed
   - Rotary Kiln
   - Liquid Injection
   - Rectangular
2) Waste Feed Mechanism:
   - Waste Burners(liquid waste only)
   - Cart feed system
   - Barrel Loader
   - Rams Loader
3) Ash Removal System
   - Included
   - Excluded
4) Combustion Calculation
   - Specific Exit Temperature
   - Adiabatic Combustion

These options are selected by the user and/or the program based on the conditions of incineration.

Special design considerations are included depending on the type of incinerator selected. For fluidized bed, these characteristics are:

1) Diameter of unit determined from common industry practice Table IX and X.
2) Cost of fluidizing air support trays(2 required) based on sieve or valve tray construction sized from the diameter of the fluidized bed.
3) Installation cost is 100 percent of equipment cost.
4) Maintenence cost is 7 percent of equipment cost.
5) Cost of air blower for fluidizing air to 5 Psig.

Design and cost calculated from subroutine INDFAN.

For the rotary kiln, the special design considerations are:

1) Diameter based on retention time or heat release rate for incinerator volume.
2) Cost of rotary drive unit.
3) Installation cost of 200 percent of equipment cost.
4) Maintanence cost is 20 percent of equipment cost.

For the liquid injection unit, the special cost considerations are:

1) Installation cost based on 50 percent of equipment cost
2) Maintenence cost is 9 percent of equipment cost.

The operation cost (excluding maintenance) includes only the electricity costs to compress the air (for fluidized bed only) and to operate the rotary drive mechanism. All other operating costs are negligible or are approximated in subroutine OPER. Feeds are not included unless specified by the user (as a percentage of the equipment costs).

<u>Subroutine</u> <u>Indfan</u>

Subroutine INDFAN is a controlling routine called in the main program. This routine is a unit operation selected by the user. The routine designs and cost estimates the cost of an induction fan system. The routine implements subroutine VLRATE fo calculate the volume rate of gas. The design of the induction fan system is dependent on the gas rate and the pressure head. The pressure head of the fan is selected by the user. This value is usually equal to the venturi pressure drop.

The cost of the system includes the motor cost, fan cost and inlet and outlet dampers cost. Motor cost is calculated from Equation 49. The fan cost method is discussed in on page 95 and the cost data is listed in Figures 20 and 21.

Options available to the user are the material of construction for the fan and dampers and the total pressure head. Selection of most paramaters is made by the program.

Subroutine Inpt

Subroutine INPT is called by the main program to read data from an external data file. These files can be created manually, or as an interactive input program provided. Physical data and utilities costs are read from routine BLOCK DATA. All design operation parameters and economic input are read from the external file created by the user. If specified by the user, all data read will be printed to insure accuracy of input variables.

Subroutine Labor

Subroutine LABOR is a support routine called by the subroutine OPERAT. This routine is an option selected by the user. The routine calculates the labor costs associated with operating a hazardous waste facility. Personnel accounted for are:

1) Chief Operator
2) Laboratory Supervisor

3) Operators
4) Lab Technicians
5) Secretaries
6) Yard Workers

The number of each, and hours per day worked is summarized in Table XXVI. Payroll supply charges are estimated at 20 percent of Labor costs Plant and laboratories supervisors is estimated at 20 percent of labor costs apiece. Other payroll related expense is estimated at 30 percent of labor costs. A summary of the costs can be printed in a table if specified by the user.

Subroutine Nntu

Subroutine NNTU is a support routine called by subroutine PCKBD. This routine is called as an option (selected by the user) as a method to determine the height of the absorption packing required to remove the desired chemical (21).

The method in this routine is the Mass Transfer Unit method. The height of one transfer unit is solved with equations 30 to 32. Constants used in the equations are dependent of the packing type, size and size as well as the physical characteristics of the caustic being scrubber. The height of one transfer is multiplied by the number of transfer units required (specified by the user). The total height of packing is then returned to subroutine PCKBD.

Subroutine Outp1

Subroutine OUTP1 is a print routine called by the main program. This routine prints out the data pertaining to facility operation. An example of this output is listed in Table XXXII.

Subroutine Outp2

Subroutine OUPT2 is a print routine called by the main program. It is an option selected by the user. This routine prints a table representing the capital cost for the hazardous waste incineration facility. Capital costs are updated to the year specified by the user. An example of this output is listed in Table XXXIII.

Subroutine Outp3

Subroutine OUTP3 is a print routine called by the main program. This routine is an option selected by the user. A table is produced representing the design and cost parameters determined by subroutine DUCT. The routine is called after all ductwork has been determined. An example of this table is listed in Table XXXIV.

Subroutine Outp6

Subroutine OUTP6 is a print routine called by subroutine INCDES. This routine prints the incineration design parameters, the calculated dimension, and the cost

TABLE XXXII

COMPUTER OUTPUT PERTAINING TO INCINERATION FACILITY OPERATIONS PARAMETERS

INCINERATOR DESIGN AND COST FOR
ROTARY KILN

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE	189708.69 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLITILES FEED RATE	9000.00 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	3252.70 LB/HR
AIR FEED RATE (AT 50.00% EXCESS)	177514.50 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	50.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT
INCINERATOR TEMPERATURE	2000.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.
DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	289.00 DAYS/YEAR.
SHUTDOWN LENGTH	76.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	5.00

TABLE XXXIII

COMPUTER OUTPUT PERTAINING TO CAPITAL COST OF THE INCINERATION FACILITY

TOTAL CAPITAL COST	
COMBUSTION CHAMBERS:	1976 $
PRIMARY COMBUSTOR	989407.19
SECONDARY COMBUSTOR	1006837.00
ENERGY ROCOVERY BOILER	149723.69
AIR POLLUTION CONTROL SYSTEM	
QUENCH CHAMBER	45399.73
VENTURI SCRUBBER AND SEPARATOR	91359.50
PACKED BED SCRUBBER	4691.82
INDUCTION FAN	179274.37
EXHAUST STACK(0 FEET HIGH)	0.00
WASTE WATER TREATMENT FACILITY	173989.2
STORAGE TANK FACILITY	608000.00
TOTAL DUCTWORK	113383.56
METAL BUILDING	143025.25
SITEWORK AND FOUNDATIONS	247.82
STUCTURAL STEEL	35935.28
ELECTRICAL MATERIAL	118699.69
INSTRUMENTS AND CONTROLS	113578.75
TOTAL-----	3773546.00
TOTAL INSTALLATION COST	2459029.00
START-UP (10 % OF EQUIPMENT COST)	377354.69
SPARE PARTS (8 % OF EQUIPMENT COST)	301883.56
CERTIFICATION (10 % OF EQUIPMENT COST)	377354.69
ENGINEERING (7 % OF EQUIPMENT COST)	264148.19
INSTRUMENTATION (20 % OF EQUIPMENT COST)	882709.12
CONTENGENCY FEE (20 % OF EQUIPMENT COST)	754709.12
TOTAL INDIRECT COSTS	5417186.00
***** TOTAL CAPITAL COST=	9190732.00

TABLE XXXIV

COMPUTER OUTPUT PERTAINING TO THE DESIGN AND COST OF DUCTWORK

COST OF DUCTWORK

COST	DUCTWORK COST	FIREBRICK COST	DAMPERS COST	TOTAL COST
1 TO 2	11628.8	16310.2	8143.1	36082.0
2 TO 3	21746.4	21935.2	9030.3	52711.8
3 TO 4	1448.8	0.0	4061.2	5509.9
4 TO 5	1152.9	0.0	4080.4	5233.2
5 TO 6	2841.8	0.0	4081.5	6923.3
6 TO 7	2841.9	0.0	4081.5	6923.4
7 TO 8	0.0	0.0	0.0	0.0

DUCTWORK DESIGN OUTPUT

UNITS	OUTER DIAMETER	BRICK DIAMETER	MATERIALS OF CONSTRUCTION	DUCT LENGTH	NUMBER OF ELBOWS
1 TO 2	75.6	0.00	IC	10.00	1.
2 TO 3	81.8	0.00	IC	10.00	2.
3 TO 4	38.8	0.00	IC	10.00	0.
4 TO 5	39.0	0.00	CS	10.00	1.
5 TO 6	39.0	0.00	CS	15.00	3.
6 TO 7	39.0	0.00	CS	15.00	3.
7 TO 8	0.0	0.00	CS	0.00	0.

breakdown. Table XXXV represents an example of this routine. This routine is an option selected by the user.

Subroutine Outp7

Subroutine OUTP7 is a print routine called by the main program. This routine is selected by the user. If called , a table of the mass balance and inlet and outlet conditions is printed. Table XXXVI is an example of the output.

Subroutine Operat

Subroutine OPERAT is a controlling routine called by the main program. The routine is selected by the user. All operation costs involved in operating the hazardous waste facility are summarized in this routine. Costs calculated in this routine are:

1) Utilities
2) Labor
3) Land Taxes
4) Insurance
5) Depreciation
6) Steam Production
7) Start-up Costs

Labor costs are calculated in subroutine LABOR. Utilities are determined by summing the amount used by each unit. Insurance, start-up, and taxes are calculated from the cost factors below:

Taxes	-	2% of Capital Cost
Insurance	-	0.6% of Capital Cost
Start-up	-	10% of Capital Cost

TABLE XXXV

COMPUTER OUTPUT PERTAINING TO INCINERATION DESIGN AND COST BREAKDOWN

```
INCINERATOR DIAMETER (FT)=                        12.8267
INCINERATOR LENGTH (FT)=                          58.4393
MATERIALS OF CONTRUCTION FOR THE INCINERATOR
     REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK              THICKNESS =   1.5 INCHES
     INSULATION SELECTED = INSULATING FIREBRICK               THICKNESS =   5.3 INCHES
INCINERATOR SURFACE AREA (FT**2)               6269.8516
INCINERATOR VOLUME          (FT**3)            6269.8789
INCINERATOR BURNER DATA
     NUMBER OF FUEL BURNERS =   5
     WASTE FEED BURNER HEAT LOAD =  0.810E+08 BTU/HR
OPTIONS IN EFFECT
A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED IN THE HEAT/MASS BALANCE
     WASTE FEED IS A LIQUID.  WASTE BURNERS ARE SELECTED
     INCONEL WAS SELECTED TO CONTRUCT THE SHELL


               INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $             197151.25
TOTAL SHELL COST $             409029.87
COST OF BURNER SYSTEM $         70604.44
COST OF ASH SYSTEM $                0.00
COST OF DRIVE SYSTEM $         165264.56
COST OF SKIRTING $              10000.00
EXTRA COSTS $                  137357.06
----------------------------------------
TOTAL INCINERATOR COST         989407.19
```

TABLE XXXVI

COMPUTER OUTPUT FOR THE MASS BALANCE AND PROCESS CONDITIONS

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 2000.00 FAHRENHEIT
P= 14.68 PSIA

OUTPUT STREAM T= 2200.00 FAHENHEIT
P= 14.64 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	1008.65	0.00
AIR	0.00	0.00
H2O	2331.53	2448.61
HCL	1849.08	1849.08
CO2	34818.07	38462.77
CO	0.00	0.00
N2	136107.81	136107.81
O2	14602.17	11848.75
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

Subroutine Pckbd

Subroutine PCKBD is a controlling routine implemented to design and cost estimate a packed bed absorber. This subroutine is called by the main program and is a unit operation selected by the user.

The subroutine is divided into two main parts, the design and the installed cost. For the design, the user selects the packing type and the size (See Table XVII - XIX). The user has the option of specifying a minimum height to insure adequate scrubbing, or selected as a constant, by-passing the physical absorption calculations altogether. If the user specifies Mass Transfer Method to determine bed height, diffusion coefficients of the caustic in gas and water must be specified. Additional design information such as absorption efficiency, percent flooding and the number of absorption transfer units must be specified by the user. The diameter of the column is calculated in subroutine absorption height is calculated in subroutine NNTU and is based on equations 30 to 32. Constants used in these equations are listed in Table XVII to XVIII.

The cost of an installed packed bed is calculated from data available in literature. Costs were updated by Chemical Engineering Plant Cost Index factor for fabricated equipment.

Several options are available to design the packed bed absorber. These options are listed below:

1) Packing Type:

Raschig Rings
Berl Saddles
4) Packing Sizes
1/2 inch
3/4 inch
1 inch
1.5 inch
2 inch
1) Material of Construction:
Fibergalss Reinforced Plastic
Carbon Steel
Stainless Steel
Inconel Clad Stainless Steel

The cost and physical absorption properties for each packing is different for each packing type and size.

Subroutine Quench

Subroutine QUENCH is a controlling routine implemented to design and cost estimate a quench chamber. This subroutine is called only by the main program and is selected by the user as one of the unit operations.

The dimensions of the quench chamber are based on the volume rate of the emission gases at the average temperature. The velocity of the emission gas is set at 10 ft/s and the length to diameter ratio of three. These parameters are set to fit the cost data (equation 18 and 19) for the carbon steel shell. Two types of quench chambers can be implemented. A quencher is selected if the gas temperature is to be cooled to its saturation temperature. A spray chamber is selected if the outlet stream of the quencher is specified.

Cost of the quench chamber is based on carbon steel construction (38). Depending on the material of construction firebrick may be required to line the quench chamber. The temperature allowed is listed in Table XI. Subroutine BLOCK is called if the temperature exceeds the limitations above. Installation costs for the quench chamber is 67 percent of the equipment costs. Cost update method is based on Chemical Engineering Plant Cost Index factor for fabricated equipment.

Options available with the quench chamber are the materials of construction and type of quench chamber selected. These are both selected by the user.

Subroutine Shell

Subroutine SHELL is a support routine called by subroutines INCDES and AFTER. This routine cost estimates the shell for all incinerators and afterburners, and rotary drive mechanism for the rotary kiln incinerator. Cost of the shell is based on the surface area of the incinerator design which itself is based on the diameter of the incinerator plus the thickness of the refractory and insulating firebrick. Thickness of the metal shell is 2 inches for all designs. The cost updating method is based on the Chemical Engineering Plant Cost Index factors for fabricated equipment.

Options available with shell cost is the materials of construction. Cost factors are available for carbon steel, 316 stainless steel, or Inconel-clad-stainless steel.

Subroutine Stack

Subroutine STACK is a controlling routine that is specified by the user. This routine designs and estimates the cost of exhaust stacks used in the pollution control industry. The dimensions of the exhaust stack used to cost estimate the stack. The height of the exhaust stack is selected by the user. The diameter is based on the expected wind velocity (selected by the user). Due to the limitations in cost data, stacks with a diameter greater than 60 inches in diameter must be between 100 and 200 feet high. Short stacks, between 0 and 100 feet high can be constructed of plastic reinforced fiberglass, carbon steel, or stainless steel. Large stacks are constructed of carbon steel.

Options available for the exhaust stack are limited to the material of construction. This must be selected by the user.

Subroutine Storage

Subroutine Storage is a controlling routine that is selected by the user as a unit operation. This routine designs and cost estimates the waste storage facility for on site storage of liquids (storage tanks) or solids (barrel barn). The size of the storage facility is based on the incinerator feed rate, the number of days of waste to be stored. Design includes a 20 percent overdesign. Tank sizes, and the cost to outfit each tank is listed in Table XXII.

Options available with this routine are:

1) Selection of total storage volume.
2) Materials of contruction
3) Type of storage (barrel or storage tanks)

Additional equipment may be selected by the routine depending on the waste characteristics.

Subroutine Ventur

Subroutine VENTUR is a controlling routine implemented to design and cost estimate a venturi scrubber. This subroutine is called by the main program and is a unit option selected by the user.

The design of the venturi scrubber is based on the pressure drop required to remove particulate matter entrained in the gas stream. The pressure drop calculation are initiated at 20 inches water and increased by 10 in H_20 until the emission limit (input by the user) is met. This method is used because venturi particulate removal efficiency data is only known for specific pressure drops. Data determined from actual use.

The capital cost of venturi scrubber and separators is based on the gas flow rate and pressure drop.

Subroutine Vlrate

Subroutine VLRATE is called by many routines. This routine calculates the total volumetric rate, mass rate, and mole rate. The calculations can be in metric or english units depending on the program requirements.

Function Lists

A number of functions were developed with this routine to represent certain cost and design data.

Function Fanfxn

Function FANFXN is called by subroutine INDFAN to determine the cost of electric motors used to operate the induction fans. The cost of the motor is dependent on the fan rpm's and the total horsepower required to operate the fans at the desired pressure. Appendix A contains the cost data. This data was obtained from a method published by Vatavuk (27).

Function Fx1

Function FX1 is called by subroutine PCKBD and determines the diameter of the packed bed based on the Lobo correlation. The diameter can be determined from data in Figure 9.

Function Fx3

Function FX3 is called by subroutine PCKBD and is used to determine the cost of a packed bed absorber. The cost of the absorber is dependent on the diameter of the bed. This data was published be The Air Pollution Control Association.

Function Fx4

Function FX4 is called by subroutine INDFAN and is used to determine the power requirements of the induction fan system. This data was correlated from information published by Vatavuk (27). See Appendix A for more information.

Function Fxpack

Function FXPACK is called by subroutine PCKBD and determines the packing factor for Beryl saddles and Raschig rings. The value of the packing factor depends on the type of packing selected and the size of the packing. This data was curve-fit from information published by The Air Pollution Control Association. See Appendix A for more information.

Function Loadr

Function LOADR is called to estimate the cost of a containerized or drum fee system. Cost of the system is based on the feed rate of waste. For more information see Appendix A.

Function Pakdia

Function PAKDIA is one method of determining the diameter of a packed bed absorption column (22). The relationship used is listed in equations 16 and 17. The equation is solved by trial and error using the interval halving method for the diameter. Information required for the function is the liquid viscosity, the liquid and gas density, the packing factor, and the mass flow rate of the liquid and the gas.

Function Pressr

Function PRESSR is called by many unit operations and subroutine DUCT. This function estimates the pressure drop of the system using the pressure drop equation listed below (34).

$$DP = -f * Pg * L * VEL\ \ 2 / 2 * Gc * C \qquad (43)$$

In this equation, f is the friction factor (estimated at 0.0045), C is the hydraulic radius, Gc is the gravity constant, and VEL is the gas velocity.

Function Scrfed

Function SCRFED is called to estimate the cost of a screw feed system for the incinerator. The feed should be a solid to specify. The cost of the screw feed system is based on the waste feed rate. Cost data used is listed in equations 16 and 17.

Function Traycs

Function TRAYCS is called to estimate the cost of the support trays used for the fluidized bed incinerator. Either valve of seive trays may be specified. Trays may be constructed of carbon steel or stainless steel. The cost of the trays is based on the diameter. For further information see Appendix A.

Function Wtpprt

Function WTPPRT is the method used to determine the particulate removal efficiency of the venturi scrubber. This function calculates the removal efficiency for a given particle size for a given pressure drop. For more information, see Appendix A.

Input and Output For Program

Design and physical data used to cost and design a hazardous waste incineration is read from external data files by subroutine INPT. An additional interactive program is available to build data files for Program HWSTBRN.

This program allows selection of equipment to completely design and cost estimate a hazardous waste incineration facility,the incineration system only, pollution control subsystems, or single units. The input routine asks for data in the following order.

1) Waste feed rate and characteristics.
2) Ambient facility conditions
3) Selection of Unit and all the design

parameters required for the
particular unit.
4) Operating parameters
5) Economic parameters
6) Output level.

For further information, see Appendix C.

Design of hazardous waste incineration facility requires the coordination of the many options that must be available to the user. The output routine in this program, prints output on several levels, depending on the requirements of the user. The user has the option of selecting the following levels of output:

1) Economic Cost Analysis
2) Capital and operating cost tables
3) Design and cost parameters for each unit.
4) All print statements in program.

Example of print levels 1 to 3 are listed in Appendix E. The input variables are printed to insure accurate data files.

CHAPTER VI

RESULTS OF THE COMPUTER PROGRAM

The results of the output of computer program HWSTBRN are presented below. These results are analyzed in two ways. First, the results of the computer program will be compared with the results of hand calculations using the same design and cost methods. Second, the accuracy of the capital cost method used will be compared with capital cost data provided from sources in the literature and visitation to an operating hazardous waste incineration facility.

Comparison of Program Results With Hand Calculations

Before construction of computer program HTSTBRN, a series of hand calculations were conducted to determine the feasibility of the program and to provide some results to compare program output. The results of these calculations were presented at the American Institute of Chemical Engineers 1986 Spring Convention. These calculations allowed for the economic comparison of different types of hazardous waste incineration facilities (55). These facilities were compared according to the Discounted Cash Flow Rate of Return Method. A description of the facility and the design parameters are presented below.

Waste Feed Characteristics

The land based facilities are compared for two different types of waste sludge with three different waste feed rates. The two sludges are a water based sludge with a low concentration of polychloride biphenyls (PCBs) (waste feed #1) and an oil based waste of essentially pure PCBs (waste feed #2). For the three feeds, each of the systems is designed for a small feed rate, 500 pounds of waste feed per hour, and two large feed rates, 10,000 and 20,000 pounds of waste feed per hour. Characteristics of the waste feed must be known for the proper choice of the incinerator alternatives and for the proper design and selection of materials. The elemental and the overall compositions of the two model waste feeds are given in Table XXXVII. Physical properties of the oil-based waste feed are available from the literature (3,4). Heating value of the waste (5) was predicted by Equation 2.

Product Gas Characteristics

Composition of the product gas must be determined to specify pollution control devices. For all processes, 100 percent combustion was assumed.

Primary and Afterburner Combustors

The conditions for incineration for all systems were chosen to be at a temperature of 1,800 F for two seconds

TABLE XXXVII

CHARACTERISTICS OF WASTE SLUDGES

	COMPOSITION SLUDGE #1 (Weight Percent)	COMPOSITION SLUDGE #2 (Weight Percent)
OVERALL COMPOSITION		
Total Volatiles	60.00	100.00
Free Moisture	20.00	--
Ash	20.00	--
VOLATILES		
C	29.83	57.00
H	3.99	3.00
O	25.69	7.60
S	0.12	--
N	0.37	--
C_1	--	32.40
HEAT OF COMBUSTION (BTU/LB Volatiles)	6000.0	9500.0
VISCOSITY	> 500 SSU	< 500 SSU
ASH COMPOSITION		
SiO_2	30.0	--
Al_2O_3	12.0	--
Fe_2O_3	13.0	--
MgO	2.0	--
CaO	34.0	--
P_2O_5	7.0	--

retention time in the primary incinerator and 2,000° F for two seconds in the afterburner to comply with legal restrictions (7). For the fluidized bed, a pressure of five psig is desired to insure proper fluidization (8). Relative dimensions for each system were obtained from the literature as common practice in industry (9). For the water based feed, the waste is unpumpable, therefore liquid injection combustors were considered unsuitable.

Dimensions of the combustors were based on the retention time and the length to diameter ratio. For the liquid injection primary and afterburner combustors, the length the diameter ratio was set at five. For the fluidized bed combustor, the length to diameter was set at two; and the rotary kiln was set at three. For all combustors, the material of construction was inconel-clad-stainless steel.

Pollution Control

Figure 13 indicates all of the equipment for all facilities used and the placement of each unit. Selection and placement of each process unit was based on practices common in the incineration industry.

Heat Recovery. Heat recovery units were used to cool the gases from 2,000 to 500° F to produce 150 psig steam. Heat recovery was used for all units except waste #1 at low feed rates (10,11). Additional cooling was supplied by a quench chamber to cool the emission gases to 180° F. The shell material chosen for the quench chamber was Inconel-625 (13).

Venturi Scrubber. The venturi was designed to remove particulates in the stack gas to 0.08 grains per actual cubic feet of exhaust gas. Inconel was also selected for the materials of construction. The pressure drop was specified to be 40 inches of water to remove the particulates.

Packed Bed Absorber. Packed bed absorbers are specified to remove the hydrogen chloride produced in the combustion process. The material of construction was specified to be plastic reinforced fiberglass (approximately the same as carbon steel in cost). Packed bed scrubbing was not required for the water based sludge due to the low hydrogen chloride content.

Induction Fan. Induction fans were used to move the emission gases through the pollution control system. Placement of fan varies depending on the combustion system in question. For the rotary kiln and liquid injection system, the fan is located after the venturi. For the fluidized bed combustor, the fan is placed before the combustor to provide the air for the fluidization process. A pressure difference of 40 inches of water was specified as the pressure head for the downstream fans. A pressure head of 5 psig was specified for the fluidized bed fan. Because of the corrosive environment in the downstream fans, they were constructed of Inconel-625 (13). All of other fans were constructed of carbon steel.

Exhaust Stack. Exhaust stacks were selected to be 50 feet tall for the small waste feed and 100 feet tall for the larger systems. Material of construction for all exhaust stacks was carbon steel.

Results of Hand Calculations

From the design parameters specified above, capital cost calculations were carried by hand and computer program to estimate the complete hazardous waste facility. Equipment selected for each system is summarized in Tables XXXVIII and XXXIX. These costs are based to 1985. The facilities were compared, according the DCFRR method and the results are shown is Figures 29 and 30. While these are the results of the hand calculations, the are close to the values of the computer program.

Examination of the results in Figure 29 and 30 suggest the following. First, all systems are economically cost competitive at large waste feed rates. The is due to the fact that the cost of the combustor is not significant compared to the other facility costs. At smaller waste feed rates, the liquid injection combustors are more cost effective than fluidized bed or rotary kiln combustors. Unfortunately, liquid injection combustors are not as

TABLE XXXVIII

HAZARDOUS WASTE INCINERATION PROCESS EQUIPMENT
SLUDGE #1

SYSTEM	LB/HR	HEAT RECOVERY	QUENCH CHAMBER	VENTURI SCRUBBER	INDUCTION FAN	PACKED BED	EXHAUST STACK
Rotary Kiln	500		X	X	X		X
	10,000	X	X	X	X		X
	20,000	X	X	X	X		X
Fluidized Bed	500						
	10,000	X	X	X	X		X
	20,000	X	X	X	X		X
Liquid Injection	500	THIS SYSTEM IS NOT APPROPRIATE FOR AN UNPUMPABLE SLUDGE					
	10,000						
	20,000						
Plasma Arc Pyrolysis	500	THIS SYSTEM IS NOT APPROPRIATE FOR AN UNPUMPABLE SLUDGE					
	10,000						
	20,000						

TABLE XXXIX

HAZARDOUS WASTE INCINERATION PROCESS EQUIPMENT
SLUDGE #2

SYSTEM	LB/HR	HEAT RECOVERY	QUENCH CHAMBER	VENTURI SCRUBBER	INDUCTION FAN	PACKED BED	EXHAUST STACK
Rotary Kiln	500	X	X	X	X	X	X
	10,000	X	X	X	X	X	X
	20,000	X	X	X	X	X	X
Fluidized Bed	500	X	X	X	X	X	X
	10,000	X	X	X	X	X	X
	20,000	X	X	X	X	X	X
Liquid Injection	500	X	X	X	X	X	X
	10,000	X	X	X	X	X	X
	20,000	X	X	X	X	X	X
Plasma Arc Pyrolysis	500	X	X	X	X	X	X
	10,000	X	X	X	X	X	X
	20,000	X	X	X	X	X	X

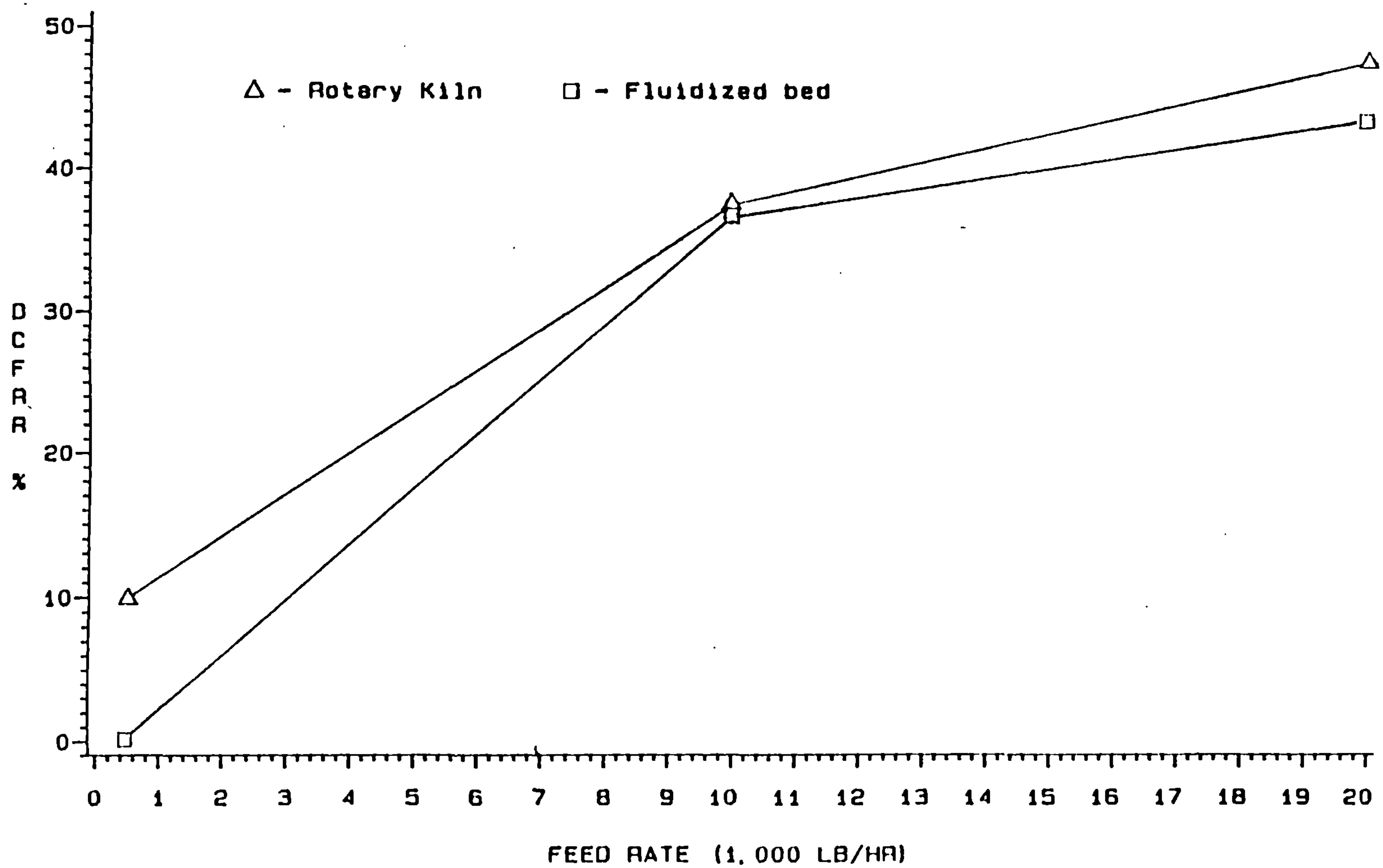

Figure 29. Discounted cash flow rate of return results for the hand design using waste feed #1.

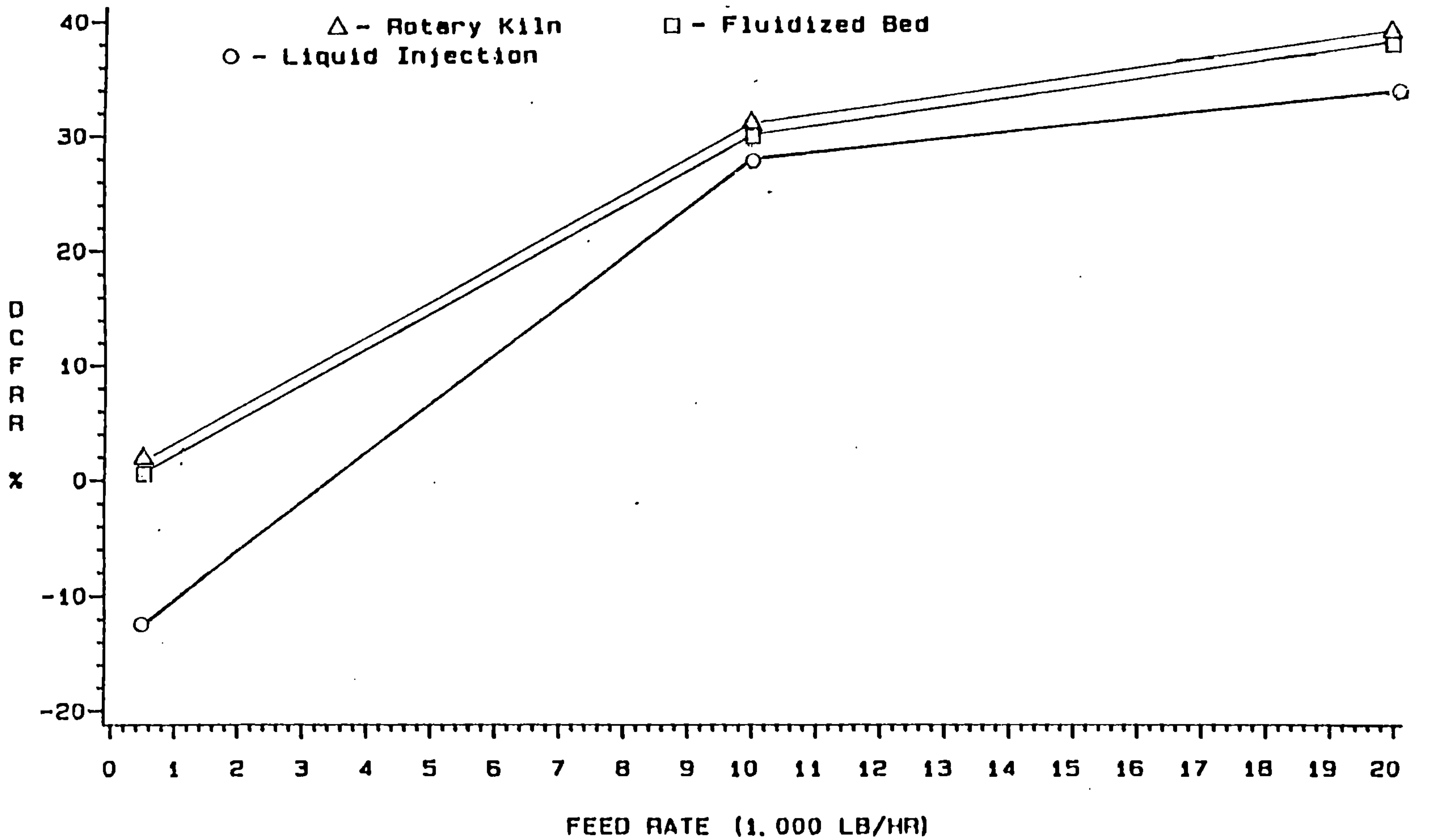

Figure 30. Discounted cash flow rate of return results for the hand design using waste feed #2.

flexible in the types of waste that are combusted. Athough, not shown here, fluidized bed become more cost effective for wastes with high ash content at low feed rates. Third, the results indicate that with a 400 U.S. Dollars per ton charge to incinerate the wastes, at large feed rates, the facilities can be profitable.

Comparison of Hand Calculations and Computer Program Results. Figure 31 shows the comparison of the DCFRR determined by hand calculation and the results determined by the program. Comparison of the fluidized bed and liquid injection combustors yields the same results discussed above for the rotary kiln. The results apply for a rotary kiln combustor with waste #2 as the feed. Both results are approximately the same. The difference in the DCFRR at low feed rates is due to differences in process design and cost estimation proceedures between the hand calculations and the program.

Comparison of Computer Costs With Actual Facility Costs

Very few capital costs were discovered in literature. The examples that were present, are not adequately described for comparison with the computer program. Cost estimates for comparison were also obtained from visitation to operating hazardous waste incineration facilities. The comparison of these results are presented below.

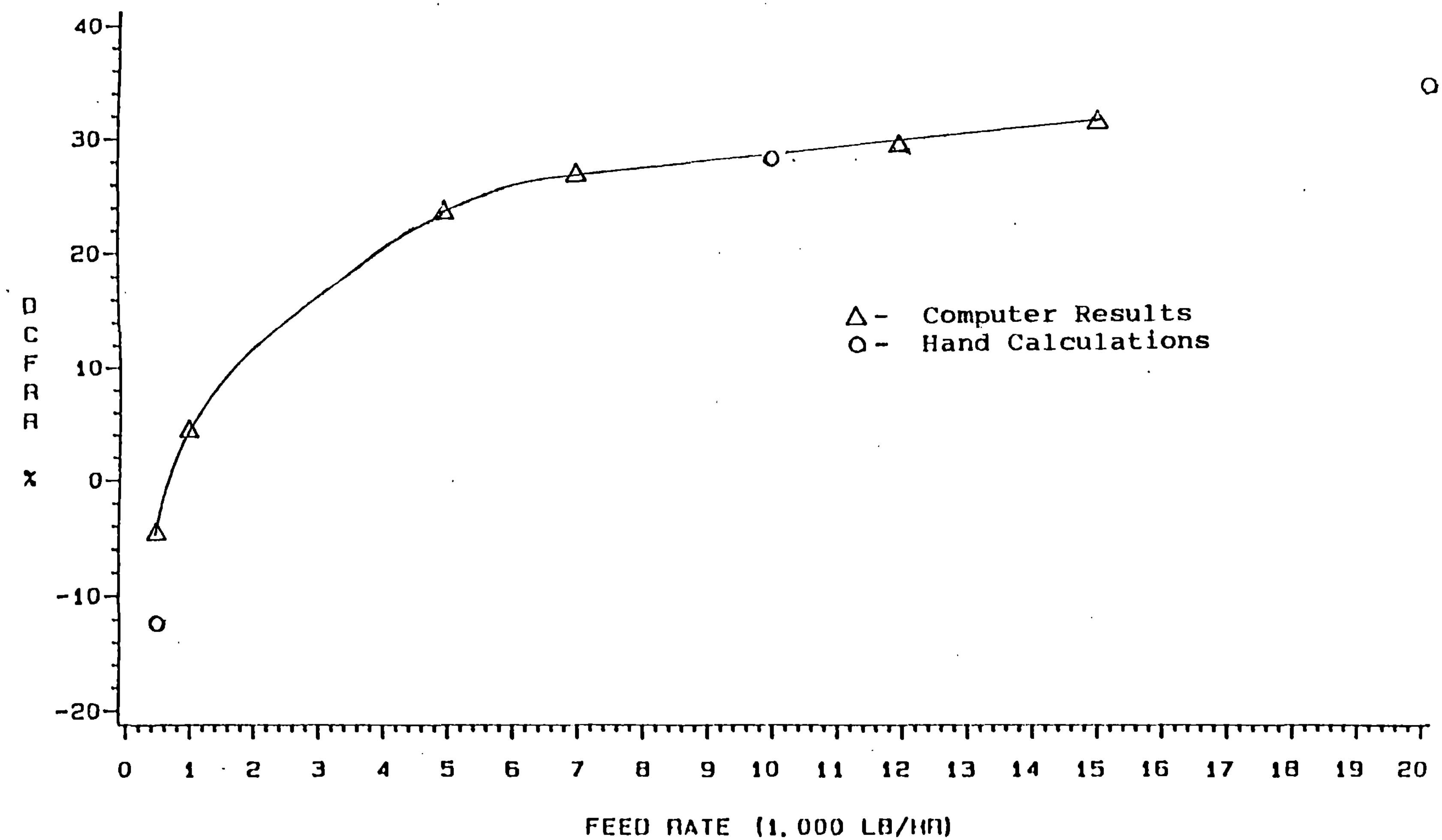

Figure 31. Comparison of the DCFRR values for the hand calculations with that of the computer results.

Capital Costs Obtained From Industry

A rotary kiln incinerator, for the combustion of chlorinated solvents, was constructed by Phillips Petroleum at the Phillips Research Center in Bartlesville Oklahoma. The cost of the facility equipment and installation was estimated at 2.7 to 3.0 million U.S Dollars (1981) (40). The computer program's cost estimation is 2.94 million U.S. Dollars (1981).

Capital Costs Obtained From Literature

A source that estimates the cost of a rotary kiln incinerator was published in literature by the Eastman Kodak Company (53). The capital cost of this facility was estimated at 11.3 million U.S. Dollars (1976). The computer program estimated, for the same facility, a capital cost of 9.20 million U.S. Dollars (1976).

Other sources were available in literature. Unfortunately, these sources did not adequately describe their design parameters and waste feed characteristics.

One source provides cost data for a fluidized bed incinerator and air preheater unit. This data was published by Brunner (1). The cost of these systems and computer program cost estimated is listed in Table XXXX and is based on the waste feed rate.

TABLE XXXX

COMPARISION OF CAPITAL COST ESTIMATED FROM THE COMPUTER PROGRAM WITH DATA PUBLISHED BY BRUNNER

Feed Rate(lb/hour)	Brunner	Program
200	180,000	188,100
400	300,000	318,000
1,000	550,000	865,000
2,000	850,000	1,466,000
2,900	1,150,000	2,500,000

These cost are calculated to 1980 (1). The difference in Brunners costs compared to those generated by the computer are due more to the heat recovery unit and not the cost of a fluidized bed combustor.

Comparison of the capital cost estimated by the computer program with that of the data available from different sources indicate that the program accurately estimates the cost of hazardous waste incineration facilities. In all cases, the greatest error in the cost was over 100 percent (See Table XXXX). The average error for all comparisons is 20 percent. While this indicates a reasonable amount of accuracy, more sources with adequate descriptions of the process conditions and waste characteristics must be found. Since sources in the literature have been exhausted, these costs must come from incineration facilities. Presently, from the capital cost data available, the accuracy of program HWSTBRN is limited to waste feed rates less than 10,000 lb per hour.

CHAPTER VII

FUTURE WORK

Further development is needed on this program. Presently, this program provides adequate combustion and pollution control options to accomplish the required design considerations. Unfortunately, little has been done beyond this. Additional work that is recommended includes; combustion reaction calculations, additional process units, include portable as well as permanent facility sitework costs, increase user friendliness of the program, provide more flexibility in the economic analysis, more accurate cost estimates for some direct and indirect capital costs, and more data is needed to compare actual capital costs with that of the computer program. Improvements in these areas would greatly improve the quality of the program results and improve the user's ability to use the program

Combustion Reaction Calculations

One design method that can be improved is the calculation of the products of the combustion reaction. Presently, a simple stoichiometric balance is applied for a definite number of product gases. More waste feed elements and a larger variety of combustion product gases should be included. There are also other methods available to calculate the product gas composition using advanced mathematical procedures.

Addition of Process Units

There are many combustors and pollution control options that are not available with this program. More hazardous waste combustors should be made available to expand the programs ability to handle special wastes and provide a greater range for economic comparisons. Additional pollution control process units should be included to provide more flexibility in particulate and caustic removal systems and to allow combining two units into one (such as packed bed absorbers and exhaust stacks).

Combustors

Additional destruction units that are recommended include; multiple hearth combustors and pyrolysis units. Multiple hearth should be included because it has proved to be effective in combustion of hazardous wastes with high solids (non-combustibles) content. Cost data is available on these units (See Literature Review section). Pyrolysis systems need to be included because this is an expanding field of hazardous waste destruction. An example of a pyrolysis system that has adequate cost data available is the plasma arc pyrolysis. Unfortunately, inclusion of pyrolysis presents special problems. Foremost of these problems is calculation of the equilibrium destruction concentration. Complex computer programs are available. Unfortunately, the results of these programs (to my knowledge) are less than adequate for design purposes.

I also recommend inclusion of special combustion systems. Many of these systems, such as vertically fired updraft combustors, are variations of basic combustors which include (or do not require) special combustion or downstream process equipment.

Improvements on the capital cost estimation of the fluidized be combustor should also be considered. Presently, this combustor cost estimation is questionable due to the use of bubble-cap trays to substitute for the fluidizing support trays.

Pollution Control

Additional pollution control units that should be included with the program are centered around particulate and caustic gas removal. The process units involved are venturi scrubbers and packed bed absorbers. The physical removal mechanisms (particulate entrainment and caustic gas chemical absorption) are the same in most cases regardless of the type of removal system in question. Therefore, in most cases, addition of these options would only require cost data.

Particulate Scrubbers. Presently, the computer program only allows specification of standard type venturi scrubbers. Other high energy scrubbers are available and used by many incineration facilities. These types should be included to improve the economic comparison aspect of the program with specific incineration facilities.

Besides high energy wet scrubbers, there are methods available to remove particulates from a gas stream without addition of water or large system pressure losses. The most prominent and economical of these is the electrostatic precipitators. These units are often specified. Therefore, design and cost data is probably available in literature.

Caustic Gas Scrubbers. Other pollution control options that should be included in the program are used to control caustic gas emissions. While counter-current vertical absorbers are used most often, plate absorption columns and horizontal co-current and counter-current absorbers may have practical applications. Plate type absorbers can be used if high absorption rates are desired. Horizontal units would have applications on skid-mounted and portable incineration facilities.

Other Capital Cost Improvements

Besides the addition of specific process units, other improvements can be made on the capital costs. Foremost of these is the sitework, direct, and indirect capital costs.

The cost of sitework, as mentioned before is highly variable depending on the type of waste, location of facility, and other sitework specifics. Options, such as portable combustion facilities and ship-based facilities are feasible for inclusion in the program.

Indirect facility capital costs are estimated by cost factors. As the accuracy of the cost estimation package is employed, a more logical approach will be required.

Economic Comparison Improvements

Future work for economic evaluation and comparison of facilities can be improved be several methods. Presently, only one simple method is used. An alternative method would be to calculate the revenue requirements to achieve a specific rate of return based on facility capital cost and process life. This would determine the cost per ton to incinerate a particular waste. Additionally, the time required to build the facility and time value of money should also be provided as an economic alternative.

Program Improvements

The most important area of future work is to improve the user friendliness of the computer package. Included are; change the program for interactive operation, allow design parameter changes without having to recompile the main program, increase amount of output relating to incorrect or unwise design parameters that are specified by the user.

Since the program is operated on a IBM 3085, only part of the computer package is interactive (the part that builds the input data file for the main program). Presently, changing the program is not feasible. But, with a different host computer, this would be a wise change. It would allow implementation of design changes to compare several processes and from warning messages issued by the main program. Once the main program becomes interactive, the other changes discussed above could be implemented.

Once the design and cost of a facility has been determined, the user should be allowed to respecify a single (or multiple) design parameter and recalculate the new cost. This would significantly improve the cost to operate the program and would require the addition of a small amount of computer code.

More improvement is also required on warning messages issued by the program. Presently, only critical design and cost problems cause the printing of a warning message. The additional messages would alert the user if the design or cost data for a individual unit is above or below the recommended range from the data source.

CHAPTER VIII

CONCLUSIONS

From the information presented in the previous chapters, the following conclusions can be drawn. First, there is adequate information available in literature to design and cost estimate hazardous waste incineration facilities. This is based primarily upon information on non-hazardous incineration and pollution control equipment. Second, the information available has been organized into a computer program. This includes allowing the selection of a large variety of combustor and pollution control options. Third, the results of this program are reasonably accurate compared to results available for specific operating facilities. Data available in literature limits the maximum waste feed rate to 10,000 lb/hr. This program should significantly add to information pertaining to the cost and economics of hazardous waste incineration facilities.

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APPENDIXES

APPENDIX A

CURVE FITTING CALCULATIONS

All of the design and cost data for the computer program, was curve-fit using the simplex method(55). Non-linear and linear curve-fit methods are used depending on the form of the data. The simplex method was used to optimize the curve-fit on non-linear equations. A computer program based on this method is listed in Appendix B.

A simple sum of least square method is used to curve-fit linear equations. The computer program to optimize the linear equation is presented in Appendix B. The data and the curve-fit equation are discussed separately under each unit. The maximum fractional error for all the curve-fitting procedures did not exceed 0.10 (10 percent error) and in most cases was less than 0.01 (1 percent).

Waste Feed Burners

The equation for the cost of a waste burner system was curve-fit from data in literature. Equation 44 was used to curve-fit this data.

$$Y = a * X + b \qquad (44)$$

The constants for this data are listed in Table XXXXI.

TABLE XXXXI

CURVE-FIT CONSTANTS FOR WASTE FEED BURNER SYSTEM COSTS

a	b
5.0E-4	26,000

The cost is based on the heat release rate of the waste feed. The equation was curve-fit using the linear curve-fit program in Appendix B.

Incinerator Waste Feed System

The cost of a waste feed system to feed containers(other than 55-gallon barrels) was obtained from literature(9). The data was curve-fit to equation 44. The cost of a ram feed system is based on the waste feed rate(lb/hour). The constants for this curve-fit are listed in Table XXXXII.

TABLE XXXXII

CURVE-FIT CONSTANTS FOR SOLIDS WASTES FEED SYSTEM

a	b
2727	4545.

This equation was fit using the linear curve-fitting program in Appendix B. Appendix B.

Cost of Sieve and Valve Trays Based on Fluidized Bed Diameter

The data used to curve-fit the equation is listed in Figure 11. The general equation used is listed in equation 45.

$$Y = a + b * X + c * X \;\; 2 + d * X \;\; 3 \qquad (45)$$

This equation was curve-fit using a linear curve-fiting program(See Appendix B. The results are represented in Table XXXXIII.

TABLE XXXXIII

CURVE-FIT CONSTANTS TO COST SUPPORT TRAYS FOR THE FLUIDIZED BED COMBUSTOR

Carbon Steel Construction				
Type	a	b	c	d
Sieve Tray	2.00	0.157	0.111	0.00
Valve Tray	2.91	-0.185	0.212	0.00

316 Stainless Steel Construction				
Type	a	b	c	d
Sieve Tray	2.81	-0.462	0.103	0.00
Valve Tray	1.28	-0.589	0.066	0.0075

These equations are applied in Function TRAYCS.

Cost factors, depending on the quantity of trays required, is listed in Table XXXXIV.

TABLE XXXXIV

QUANTITY FACTORS TO DETERMINE COST OF FLUIDIZED BED SUPPORT TRAYS

Quantity	Cost Factors
1	3.00
2	2.80
3	2.65
4	2.50
5	2.30

For the computer program, this value is one. Two trays are required, but they are different sizes.

Fluidized Bed Diameter

A linear equation was used to fit both sets of data to calculate the fluidized bed diameter(See Table IX and X). The data was fit to equation 44. The value of the constants ae listed in Table XXXXV.

TABLE XXXXV

CURVE-FIT CONSTANTS TO CALCULATE FLUIDIZED BED SUPPORT TRAYS

Data	a	b
TABLE IX(Cold Air Feed)	0.001	7.83
TABLE IX (Hot Air Feed)	0.001	7.89
TABLE X(Hot Air Feed)	0.267	8.69

The constants calculated from Table X are based on the evaporation rate of the water in the waste feed. The constants calculated from Table X are based on the heat release rate in the incinerator(millions of Btu/hour). These equations are applied in Subroutine INCDES.

Heat Recovery Boiler Pressure Drop

The pressure drop through the heat recovery boiler is estimated from Table XII. This data was curve-fit to equation 44. The constants for this equation are listed below in Table XXXXVI.

TABLE XXXXVI

CURVE-FIT CONSTANTS TO CALCULATE THE PRESSURE DROP IN A HEAT RECOVERY BOILER

a	b
0.872	-1.920

The independent variable in this equation in the percent of heat recovered. The pressure drop is calculated in inches of water. This equation is used in subroutine HTEXCH.

Particulate Cut Diameter
versus Venturi Scrubber
Pressure Drop

Calculation of particulate removal efficiency using the cut-diameter method was curve-fit using the data in Figure 16. The data was curve fit to equation 47. The constants for this equation are listed in Table XXXXVII.

TABLE XXXVII

CURVE-FIT CONSTANTS TO CALCULATE THE CUT-DIAMETER FOR PARTICULATE REMOVAL IN VENTURI SCRUBBERS

a	b
-0.519	0.856

The independent variable in this equation is the gas phase pressure drop(inches of H2O). The cut diameter is in microns. This equation is used in subroutine VENTUR. bototm

Particulate Removal Efficiency versus the Particle Size for a Specific Pressure Drop

The set of curves represented by Figure 12 are curve fit using the general equation:

$$Y = a \exp(b*x^c)+d \quad (46)$$

The equation was curve-fit using the non-linear curve-fitting program SIMP listed in Appendix B. The constants(a,b,c, and, d) depend on the pressure drop and are represented in Table XXXXVIII.

TABLE XXXXVIII

CURVE-FIT CONSTANTS TO CALCULATE THE CUT DIAMETER FOR PARTICULATE REMOVAL IN VENTURI SCRUBBERS

Pressure Drop (Inches H2O)	a	b	c	d
10	9.437	1.864	0.178	-12.43
20	17.856	1.455	0.126	0.9600
30	48.714	1.324	0.054	-95.25
40	20.473	1.730	0.041	-20.30
60	25.735	1.329	0.029	1.339
80	25.695	1.340	0.018	1.836

These equations are used in Function WTPPRT.

Venturi Scrubber Wall Thickness

The thickness of the venturi scrubber wall was curve-fit from data in Figure 17. This data is fit using equation 47.

$$Y = a * LOG (X) + b \tag{47}$$

A linear curve-fit method was used to determine the constants of equation 43. These constants are represented in Table XXXXIX. The equation are based on the venturi pressure drop for a given wall thickness.

TABLE XXXXIX

CURVE-FIT CONSTANTS TO CALCULATE THE VENTURI SCRUBBER WALL THICKNESS

Wall Thickness(inches)	a	b
1/8	-0.956	9.509
3/16	-0.991	9.294
1/4	-1.00	8.888
5/16	-1.046	8.535
3/8	-1.00	7.601
7/16	-1.00	6.685
1/2	-0.930	9.796

The dependent variable(x-value) is the venturi scrubber pressure drop. The equations are used in Function THICK.

Venturi Scrubber Cost
Adjustment Factor

The cost adjustment factors data for venturi scrubber is represented in Figure 17. This data is curve-fit using equation 47. The linear curve-fit routine was used to fit the data(See Appendix B). The constants are represented in Table L.

TABLE L

CURVE-FIT CONSTANTS TO CALCULATE THE COST ADJUSTMENT FACTOR FOR VENTURI SCRUBBER WALL THICKNESS

Wall Thickness(inches)	a	b
1/8	0.0	1.0
3/16	-7.0E-3	1.57
1/4	-6.25E-3	1.96
5/16	-0.0121	3.22
3/8	-0.0175	4.83
7/16	-0.021	6.46
1/2	-0.003	8.30

These equations are based on the gas volume rate for a given metal th thickness. The dependent variable(x-value) in this equation is the gas volume rate for a given metal wall thickness. These equations are used in subroutine VENTUR.

Pressure Adjustment Factors for Height and Temperature

Factors to correct the pressure head of the induction fans(due to elevation) is represented in Figure 19. The non-linear curve-fitting program(Appendix B) was used to determine the constants in equation 48.

$$Y = a * TAN (X \quad b + c) + d \tag{48}$$

These constants are presented in Table LI depending on the elevation above sea level.

TABLE LI

CURVE-FIT CONSTANTS TO CALCULATE THE PRESSURE ADJUSTMENT FACTOR FOR THE INDUCTION FAN

Height(Feet)	a	b	c	d
0.0	4.883	-1.03	0.258	0.467
2000	1.220	-1.72	0.137	-0.138
4000	1.956	-1.228	0.118	-0.361
8000	1.708	0.101	-2.775	-1.062
20000	2.419	-0.931	0.052	-1.272

The dependent variable (x-value) in these equations are the temperature. The equations are used in subroutine INDFAN.

Induction Fan Horsepower and

RPMs Calculation

The set of curves represented by Figure 20 are curve-fit using the general equation 47. The equation was curve-fit using a linear curve fit program listed in Appendix B. The constants a and b are calculated depending on the horsepower(for the energy calculation). These constants are represented in Table LII.

TABLE LII

CURVE-FIT CONSTANTS TO CALCULATE THE INDUCTION FAN HORSEPOWER

HP	a	b
5.0	-0.999	8.5172
2.0	-1.000	9.2100
5.0	-1.060	10.13
10.0	-1.000	10.82
20.0	-1.000	11.51
50.0	-1.080	12.43
100.0	-1.000	13.12
200.0	-1.000	13.82
500.0	-1.080	14.88

Constants curve-fit for to calculate the rpms is listed below in Table LIII.

TABLE LIII

CURVE-FIT CONSTANTS TO CALCULATE THE INDUCTION FAN HORSEPOWER

RPM	a	b
300	1.416	10.043
500	1.441	8.99
750	1.476	8.01
1000	1.441	7.60
1500	1.731	5.97
2000	1.571	5.84
2500	1.441	5.59
3000	1.244	5.54
3500	1.450	4.899

The power and rpms for the fan system was determined by the following method. First, a pressure head for a single fan is guessed(beginning at 20 inches of H_2O). The pressure is inserted as the independent variable in the equations to determine the volumetric flow rate for a given amount of power(HP). If the calculated volume rate is less than the actual volume rate, the program moves to the next highest horsepower equation(See Table LIV). This procedure is repeated until the calculated volume rate is greater than the actual volume rate. If the program moves through the entire set of equations, the pressure drop is decreased and the procedure is repeated until the problem is solved. The calculation of the rpms is the same as for the horsepower procedure.

Cost of Induction Fan Motor

The relationship between motor rotation and brake horsepower determines the cost of the motor in question. Data curve-fit was obtained from Figure 20. The general equation for this data is listed in equation 49.

$$Y = c + a * X + c * X \quad 2 \tag{49}$$

One equation must be curve-fit for every motor rotation speed. Motor costs were available only for specific rotation speeds. The constants from equation 49 applied to the data in Figure 20 is listed in Table LIV.

TABLE LIV

CURVE-FIT CONSTANTS TO CALCULATE THE COST OF AN INDUCTION FAN MOTOR

RPMs	a	b	c
600	0.088	0.0965	4.337
900	0.185	0.159	5.924
1200	0.225	0.093	4.721
1800 - 3600	0.125	0.103	4.546

These equations are applied in Subroutine INDFAN. Calculation of horse-power and fan rpm's is based on pressure drop per fan versus the air volumetric flowrate

Lobo Correlation for Packed Bed Absorbers

Data used to calculate the diameter of a packed bed absorber are represented in Figure 9. Due to the difficulties, the data was curve fit in three parts. The value of these constants are listed in Table LV.

TABLE LV

CURVE-FIT CONSTANTS FOR THE LOBO CORRELATION TO CALCULATE THE PACKED BED ABSORBER DIAMETER

X-axis Range	a	b	c
0.01 - 0.10	-3.981	22.91	0.2827
0.10 - 1.00	-0.219	0.131	0.112
1.00 - 8.00	-7.4E-3	5.94E-4	0.0236

This data was curve-fit using the linear curve-fit program in Appendix B. Variables for the X and Y axis are listed in Figure 9.

Packing Factor for Packed Bed Absorbers

Packing factors used to calculate the diameter of a packed bed absorber are represented in Figure 22. Two equations were required; one for Berl saddles, and one for

Raschig rings. Data was curve-fit using equation (45). The constants for this data is listed in Table LVI.

TABLE LVI

CURVE-FITCONSTANTS TO DETERMINE THE PACKING FACTOR FOR THE PACKED BED ABSORBER

Packing Type	a	b	c	d
Berl Saddles	9558	-37200	50500	-28383
Raschig Rings	3714	-17151	34400	-34100

Packed Bed Absorber Cost

The cost of a packed bed absorber is represented in Figure 24. Two equations are curve-fit; one for carbon steel materials, and the other for 316 stainless steel materils of construction. These curves are represented by equation 45. The constants for the data (from Figure 24) is represented in Table LVII.

TABLE LVII

CURVE-FIT CONSTANTS TO CALCULATE THE COST OF A PACKED BED ABSORBER

Construction	a	b	c	d
Carbon Steel	24.29	7.71	-4.e-4	3.e-4
Stainless Steel	28.91	22.03	-0.166	0.003

This data is used in Subroutine PCKBD.

Structural Steel, Metal Building,
Instruments and Electrical
Materials Cost

The cost of structural steel, metal building instruments and electrical materials is curve-fit to equation 44. These costs are represented in Figures 11 and 12. The values of the constants from this equation are listed in Table LVIII.

TABLE LVIII

CURVE-FIT CONSTANTS TO CALCULATE THE COST OF STRUCTURAL STEEL, METAL BUILDING, INSTRUMENTS AND ELECTRICAL MATERIALS

	a	b
Structural Steel	3.146	19.54
Metal Building	10.696	73.54
Instruments and Controls	3.211	43.60
Electrical Materials	12.280	1.616

This data is used in Subroutine CAPTAL.

Capital and Operating Costs for a Wastewater Treatment Facility

Calculation of the capital and operating costs for the treatment of waste water effluent is represented in Table XXVI. These costs were curve-fit to equation 44. The constants calculated are represented in Table LIX.

TABLE LIX

CURVE-FIT CONSTANTS TO CALCULATE THE CAPTIAL AND OPERATING COSTS FOR WASTEWATER TREATMENT FACILITIES

	a	b
Capital Cost	1.221	-11.0
Operating Cost	-1.8E-4	2.15

The independent variable for these equations are gallons of waste water per minute. For the capital cost, the cost is in thousands of U.S. Dollars. The operating cost is in U.S. Dollars per thousand gallons of waste water feed. The capital cost equation is used in subroutine CAPTAL, and the operating cost equation is used in subroutine OPER.

APPENDIX B

COMPUTER PROGRAM LISTING FOR THE LINEAR AND NON LINEAR CURVE FITTING PROCEDURE

```
      COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
     1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
      COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
      COMMON/LOGIC/ DONE
       DIMENSION SIMP(20,20),NEXT(20,20)
       LOGICAL DONE
       REAL L,MEAN,MAXERR,NEXT
       IDEBUG=0
       M=3
       NVPP=2
       N=M+1
       NP=200
       ALFA =1.0
       BETA=0.5
       GAMMA=2.0
       LW=5
       PAGE=12
       ROOT2=1.414214
      CALL ENTER(SIMP)
      CALL SOR(SIMP,1)
      DO 39 I=1,M
         P(I)=STEP(I)*(N**0.50+M-1.)/(M*ROOT2)
         Q(I)=STEP(I)*(N**0.50-1.0)/(M*ROOT2)
   39 CONTINUE
      DO 40 I=2,N
         DO 41 J=1,M
            SIMP(I,J)=SIMP(1,J)+Q(J)
   41    CONTINUE
         SIMP(I,I-1) = SIMP(1,I-1) + P(I-1)
         CALL SOR(SIMP,I)
   40 CONTINUE
      DO 42 I=1,N
         L(I)=1
         H(I)=1
   42 CONTINUE
      CALL FIRST(SIMP)
      NITER=0
  100 CONTINUE
      DONE = .TRUE.
      NITER=NITER+1
      DO 43 I=1,N
         CENTER(I)=0.0
   43 CONTINUE
      DO 44 I=1,N
         IF(I.NE.H(N)) THEN
           DO 46 J=1,M
              CENTER(J)=CENTER(J)+SIMP(I,J)
   46      CONTINUE
          ENDIF
   44 CONTINUE
      DO 60 I=1,N
         CENTER(I)=CENTER(I)/M
         NEXT(1,I)=(1.0+ALFA)*CENTER(I)-ALFA*SIMP(H(N),I)
   60 CONTINUE
      CALL SOR(NEXT,1)
      IF(NEXT(1,N).LE.SIMP(L(N),N))THEN
         CALL NV(NEXT,SIMP)
         DO 47 I=1,M
            NEXT(1,I)=GAMMA*SIMP(H(N),I)+(1.0-GAMMA)*CENTER(I)
   47    CONTINUE
         CALL SOR(NEXT,1)
           IF(NEXT(1,N).LE.SIMP(L(N),N)) CALL NV(NEXT,SIMP)
      ELSE
         IF(NEXT(1,N).LE.SIMP(H(N),N) ) THEN
            CALL NV(NEXT,SIMP)
         ELSE
            DO 49 I=1,M
               NEXT(1,I)=BETA*SIMP(H(N),I)+(1.0-BETA)*CENTER(I)
   49       CONTINUE
         CALL SOR(NEXT,1)
         IF(NEXT(1,N).LE.SIMP(H(N),N)) THEN
            CALL NV(NEXT,SIMP)
```

```
         ELSE
            DO 50 I=1,N
               DO 51 J=1,M
                  SIMP(I,J)=(SIMP(I,J)+SIMP(L(N),J))*BETA
   51          CONTINUE
               CALL SOR(SIMP,I)
   50    CONTINUE
         ENDIF
         ENDIF
      ENDIF
      CALL ORDER(SIMP)
      DO 52 J=1,N
         ERROR(J)=ABS((SIMP(H(J),J)-SIMP(L(J),J))/SIMP(H(J),J))
      IF(IDEBUG.EQ.1) WRITE(6,505) ERROR(J),MAXERR(J)
  505 FORMAT(5X,'ERROR CALCULATED= ',E14.4,'MAXERR=',E14.4)
         IF(DONE) THEN
           IF(ERROR(J).GT.MAXERR(J)) THEN
             DONE=.FALSE.
           ENDIF
          ENDIF
   52 CONTINUE
      IF(.NOT.(DONE.OR.NITER.GE.MXITER)) GOTO 100
      DO 53 I=1,N
         MEAN(I)=0.0
         DO 54 J=1,N
            MEAN(I)=MEAN(I)+SIMP(J,I)
   54    CONTINUE
         MEAN(I)=MEAN(I)/N
   53 CONTINUE
      CALL REPORT(SIMP)
      STOP
      END
      SUBROUTINE ENTER(SIMP)
      COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
     1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
      COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
      COMMON/LOGIC/ DONE
       DIMENSION SIMP(20,20),NEXT(20,20)
       LOGICAL DONE
       REAL L,MEAN,MAXERR,NEXT
      WRITE(6,10)
   10 FORMAT(5X,'INPUT DATA')
      READ(4,11) MXITER
   11 FORMAT(1X,I3)
      DO 20,I=1,M
         READ(4,21) SIMP(1,I)
   21 FORMAT(1X,F7.2)
   22 FORMAT(1X,E7.2)
   24 FORMAT(1X,I3)
   23 FORMAT(1X,5(F9.3))
   20 CONTINUE
      DO 30 I=1,M
         READ(4,21) STEP(I)
   30 CONTINUE
      DO 40 I=1,N
         READ(4,22) MAXERR(I)
   40 CONTINUE
      NP=0
      READ(4,24) NP
      DO 31 II=1,NP
      READ(4,23) DATA(II,1),DATA(II,2)
C     DATA(II,1) = LOG(DATA(II,1))
C     DATA(II,2) = LOG(DATA(II,2))
   31 CONTINUE
      WRITE(6,100) MXITER
  100 FORMAT(5X,'MAXIMUM ITERATIONS= ',I5)
      WRITE(6,101) (SIMP(1,I),I=1,M)
  101 FORMAT(5X,'STARTING COEFFICIENTS:',5(E15.5))
      WRITE(6,102) (STEP(I),I=1,M)
  102 FORMAT(5X,'STARTING STEPS:',5(E15.5))
      WRITE(6,103) (MAXERR(I),I=1,N)
  103 FORMAT(5X,'MAXUMUM ERROR:',5(E15.5))
```

```
      WRITE(6,106)
  106 FORMAT(5X,'POINT #        X-VALUE            Y-VALUE')
  104 FORMAT(5X,I3,2E15.5)
      DO 105 I=1,NP
         WRITE(6,104) I,(DATA(I,II),II=1,NVPP)
  105 CONTINUE
      RETURN
      END
      SUBROUTINE SOR(X,II)
      COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
     1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
      COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
      COMMON/LOGIC/ DONE
       DIMENSION X(20,20)
       LOGICAL DONE
       REAL L,MEAN,MAXERR,NEXT
      DO 12 I=1,NP
         XVAR(I)=DATA(I,1)
         IF (IDEBUG.EQ.1) WRITE(6,500) I,XVAR(I)
  500 FORMAT(5X,'#= ',I3,'X-VALUE= ',F9.2)
   12 CONTINUE
      DO 11 I=1,M
         TSIMP(I)=X(II,I)
         IF(IDEBUG.EQ.1) WRITE(6,501) I,TSIMP(I)
  501 FORMAT(5X,'#= ',I3,'COEFF = ',F9.2)
   11 CONTINUE
      X(II,N)=0.0
      DO 10 I=1,NP
         X(II,N) = X(II,N) + (ABS(F(TSIMP,XVAR(I))- DATA(I,2)))**2.0
   10 CONTINUE
      RETURN
      END
      SUBROUTINE FIRST(SIMP)
      COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
     1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
      COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
      COMMON/LOGIC/ DONE
       DIMENSION SIMP(20,20),NEXT(20,20)
       LOGICAL DONE
       REAL L,MEAN,MAXERR,NEXT
      DO 10 J=1,N
         WRITE(6,20) J,(SIMP(J,I),I=1,N)
   20 FORMAT(5X,'SIMP(',I2,')= ',5(E15.5))
   10 CONTINUE
      RETURN
      END
      SUBROUTINE NV(NEXT,SIMP)
      COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
     1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
      COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
      COMMON/LOGIC/ DONE
       DIMENSION SIMP(20,20),NEXT(20,20)
       LOGICAL DONE
       REAL L,MEAN,MAXERR,NEXT
      IF(IDEBUG.EQ.1) WRITE(6,10) NITER
   10 FORMAT(5X,'-----',I4)
      DO 20 I=1,N
         SIMP(H(N),I)=NEXT(1,I)
   20 CONTINUE
       RETURN
       END
        SUBROUTINE ORDER(SIMP)
      COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
     1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
      COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
      COMMON/LOGIC/ DONE
       DIMENSION SIMP(20,20),NEXT(20,20)
       LOGICAL DONE
       REAL L,MEAN,MAXERR,NEXT
       DO 10 J=1,N
          DO 20 I=1,N
             IF(SIMP(I,J).LT.SIMP(L(J),J)) L(J)=I
```

```
         IF(SIMP(I,J).GT.SIMP(H(J),J)) H(J)=I
 20    CONTINUE
 10 CONTINUE
    RETURN
    END
    SUBROUTINE REPORT(SIMP)
    COMMON/FRST/ L(20),H(20),CENTER(20),ERROR(20),TSIMP(20),XVAR(20),
   1 MAXERR(20),MEAN(20),STEP(20),DATA(20,2),P(20),Q(20)
    COMMON/SEC/M,NITER,MXITER,NVPP,N,NP,ALFA,BETA,GAMMA,ROOT2,IDEBUG
    COMMON/LOGIC/ DONE
     DIMENSION SIMP(20,20),NEXT(20,20)
     LOGICAL DONE
     REAL L,MEAN,MAXERR,NEXT
    WRITE(6,10) NITER
 10 FORMAT(5X,'PRIGRAM EXITED AFTER ',I5,' ITERATIONS')
    WRITE(6,11)
 11 FORMAT(5X,'THE FINAL SIMPLEX IS')
    DO 100 J=1,N
       WRITE(6,12) (SIMP(J,I),I=1,N)
 12 FORMAT(2X,(7F9.3))
100 CONTINUE
    WRITE(6,13)
 13 FORMAT(5X,'THE MEAN IS;')
       WRITE(6,14) (MEAN(I),I=1,N)
 14 FORMAT(5X,7(F9.5))
    WRITE(6,110)
110 FORMAT(5X,'THE ESTIMATED FRACTIONAL ERROR IS;')
    WRITE(6,15) (ERROR(I),I=1,N)
 15 FORMAT(2X,(7E12.4))
    WRITE(6,120)
120 FORMAT(5X,'#        X          Y          Y""         DY')
    SIGMA=0.0
    DO 51 I=1,NP
       XVAR(I)= DATA(I,1)
 51 CONTINUE
    DO 50 I=1,NP
        Y=F(MEAN,XVAR(I))
        DY=DATA(I,2)-Y
        SIGMA=SIGMA+(ABS(DY))**2.0
        WRITE(6,130) I,DATA(I,1),DATA(I,2),Y,DY
130 FORMAT(3X,I3,5(E12.5))
 50 CONTINUE
    SIGMA=(SIGMA/NP)**0.50
    WRITE(6,140) SIGMA
140 FORMAT(5X,'THE STANDARD DEVIATION IS=',F15.4)
    SIGMA=SIGMA/(NP-M)**0.50
    WRITE(6,150) SIGMA
150 FORMAT(5X,'THE FRACTIONAL ESTIMATED ERROR OF THE '/5X,
   1 ' IS= ',E15.4)
    STOP
     END
     FUNCTION F(X,D)
     DIMENSION X(20)
     F=X(1) * D + X(2)*D**2. + X(3)
     IF(IDEBUG.EQ.1) WRITE(6,10) F,X(1),X(2),X(3),X(4),D
 10 FORMAT(5X,'FUNCTION = ',E15.5/5X,'A= ',F9.2,'B= ',F9..2/
   1 5X,'X-VALUE= ',F9.2)
     RETURN
     END
```

APPENDIX C

SELECTED LIST OF VARIABLES USED IN PROGRAM HWSTBRN

AFTINC - Total capital cost of afterburner (U.S Dollars).

AREA - Cross sectional area of each process unit(if calculated).

AOP - Input variable. Present value cost adjustment factor.

ASH - Ash flow rate of waste feed(lb/hr). ASH=MASSSL=VOLIT=FREH2O

ASHCST - ATotal cost of ash handling subunit used with incinerators that produce ash(U.S. Dollars).

BAL - Logical variable. Indicates if feed needs to be balanced stoichiometrically.

BARREL - Logical variable. If true, a barrel storage facility is costed.

BCOST - This array contains the cost of insulation and refractory firebrick(U.S. Dollars per square feet per inch).

BNMFR - This array contains the name of the refractory selected for the process unit in question.

BNMIN - This array contains the name of the insulation selected for the process unit in question.

BRIKNM - This array contains the name of all firebrick options available for selection.

BRKTOT - Total cost of firebrick required for the routine acce accessing subroutine BLOCK.

CONST - Constants used for the packed bed absorber design calculations(absorption and pressure loss).

CONTEN - Input variable. Percent contengency fee based on the total capital cost.

CP - Heat capacity of product gas (joules/gmole/Celcius).

CS - Logical variable. If true, carbon steel capital material of constuction is selected.

CSTCNT - Cost of instruments and controls(U.S. Dollars).

CSTCRT - Cost of certification for hazardous waste destruction (U.S. Dollars).

CSTEM - Cost of electrical materials(U.S. Dollars).

CSTELC - Cost of electriciy($/Kilowatt hour).

CSTENG - Engineering costs required to design and construct the incineration facility(U.S/ Dollars).

CSTFAN - Total cost of the induction fan(U.S. Dollars).

CSTFUL - Cost of fuel oil #2($/lb).

CSTHTR - Total cost of the heat recovery boiler(U.S. Dollars).

CSTIIN - Installation cost of all equipment without special installation requirements (10 percent of total capital cost)(U.S. Dollars).

CSTINS - Total capital cost of primary incinerator(U.S. Dollars).

CSTINT - Total capital cost required to install and test all in instruments use to monitor the incineration process(US. Dollars).

CSTMTB - Total cost of metal on-site building(U.S. Dollars).

CSTPAK - Total cost of the packed bed scrubber installed(U.S. D Dollars).

CSTPK - This array contains the packing cost for the packing mate riamaterials options.

CSTQUE - Total cost of the quench chamber(U.S. Dollars).

CSTSIT - Total cost of sitework and preperation(U.S. Dollars).

CSTSPR - Cost of spare parts required for facility(U.S. Dollars).

CSTSTC - Total cost of structural steel required for incineration facility(U.S. Dollars).

CSTSTK - Total cost(including installation) of exhaust stack(U.S. Dollars).

CSTSTR - First time start-up costs. 8 percent of total capital costs(U.S. Dollars).

CSTVEN - Total cost of the venturi scrubber and the liquid/gas separating chamber(U.S. Dollars).

DAY - Number of hours per day in operation(hours).

DCBRIK - Total cost of insulation and/or refractory brick used for the ductwork(U.S. Dollars). This includes instal lation.

DCDIA - Inside diameter of ductwork between each unit(feet).

DCMATL - Material of construction for ductwork between each unit.

DCS - Logical variable. If true, ductwork is constructed of carbon steel.

DCTBCS - Cost of the firebrick used to line the ductwork (U.S. Dollars).

DCTFLG - Logical variable. If true, firebrick design calculations are determined for ductwork.

DCTTST - Total ductwork equipment cost for the incineration system.

DCTCST - Cost of ductwork for each unit required to connect the process units(U.S. Dollars).

DCTLEN - Length of ductwork between each process unit(feet)

DCTVEL - Velocity of gas flowing through the ductwork(feet/minute).

DELTAH - Amount of heat required to heat or cool the product gas from T1 to T2(Joules/hour).

DEPREC - Amount of depreciation for the total hazardous waste facility(U.S. Dollars). Used only for straight line depreciation method.

DESVOL - Volume of process unit if calculated(cubic feet).

DFHCLL - Diffusion coefficient of caustic in liquid ph asphase(square feet per hour).

DFHCLG - Diffusion coefficient of caustic in gas phase(square feet /hour).

DIA - Diameter of process unit if calculated(feet).

DIABRK - Diameter of unit including the thickness of firebricks used(feet).

DIC - Logical variable. If true, material of construction of ductwork in inconel clas stainless steel.

DP - Absolute pressure in each process unit(Psia).

DRVCST - COst of rotary kiln drive unit to rotate the drum(U.S. Do Dollars). Calculated only if rotary kiln is designed.

DSDIA - Ductwork shell thickness(inches).

DSPCST - Cost of dispoal(U.S. Dollars/hour).

DSS - Logical variable. If true, stainless steel material is used for the ductwork.

EFFABS - Effective absorption factor. Range of 0 to 1.0. FOr ideal absorption process value = 1.0.

ELBNUM - Number of elbows between each process unit.

ENGL - Logical variable. If true, the variables are converted to english units of measurements.

EQVCAP - Total equivalent capital cost spread out over the process life of facility(U.S. Dollars).

EQVFIN - Finance charges for borrowing money(U.S. Dollars /year).

EQVOPR - Operating costs for future worth calculations(U.S. Dollars).

EQVPFT - Profit from facility for future worth calculations(U.S. Dollars).

EQVREV - Total revenues generated from receiving waste(U.S. Dollars).

EXCESS - Excess air feed to each process unit(percent).

EXTRA - Extra costs based on the total facility costs(U.S. Dollars). See variable CONTEN.

FACCEB - Input variable. Updating cost factor for building cost and construction.

FACCEE - Input variable. Updating cost factor for machinery and equipment.

FACCEF - Input variable. Updating cost factor for fabricated equipment.

FACCES - Input variable. Updating cost factor for structural steel and supports.

FACMCS - Class of fan being designed(always equal to 4 for high performance fans).

FEED - Mass rate of each product in the gas phase(lb/hour).

FG - Logical variable. If true, fiberglass is used to to line the venturi scrubbers.

FINCRG - Input variable. Insterest ratge for borrowing mon money(percent). Used only for future worth calculations.

FLGPAS - Logical variable. If true, ductwork is designed. IF false, ductwork is not designed.

FLTOT - Total fuel required for the entire facility(lb/hour).

FLUID - Logical variable. IF true, fluidized bed incinerator is designed.

FREH2O - Free water in waste feed. FREH2O=MASSSL*WTPH2O

FUELNM - Names of the options on the type of fuel used to provide extra heat for incinerator to reach the required temperature.

FULC - Fuel cost(U.S. Dollars/million Btu).

HEIGHT - Total height of packed bed absorption column(feet).

HTCNT - Heat of combustion of the fuel feed(Btu/lb).

HTCOMB - Heat of combustion of volatiles(Btu/hour).

HPTOT - Total horse-power required to operate all electric equipment at the facility(horse-power).

HSTVAP - Heat of vaporization of water at 1 atm(Btu/lb).

HTLS - Logical variable. If true, an additional heat loss of 10 percent is added to the heat valance.

IC - Logical variable. If true, inconel-clad stainlesss steel is specified.

IDEBUG - Dubug variable

0 - No debug printouts
5 - Prints final answer for each unit.
25 - Prints important intermediate calculations.
50 - Prints all debug messages.

III - Number of unit presently being analyzed by the program.

INCDIA - Diameter of unit in question(feet).

INCLEN - Length of process unit in question(feet).

IYEAR - Variable indicating date for basis of cost estimation(year).

JPIK - Selection of packing type(and associated constants for the packed bed design subroutine).

LCOST - Logical variable. If true, cost calculations are printed.

LIQI - Logical variable. If true, liquid injection incinerators is designed.

LQD - Logical variable. IF true, the waste feed is a pumpable liquid and waste feed burners are specified).

MASSAR - Input variable. Total mass rate of air feed(lb/hr).

MASSFL - Input variable. Total mass rate of fuel feed(lb/hr).

MASSSL - Input variable. Total mass rate of waste feed(lb/hour).

MATL - Input variable. Type of material selected for each process unit. Options to place in variable are:

CS - Carbon Steel
IC - Inconel-clad stainless steel
CP - Fiberglass reinforced carbon steel

METRIC - Logical variable. If true, the metric system is used for calculations.

MLPRDT - Mole rate of each product gas(lbmole/hour).

MSAIR - Total amount of air added to each process unit(lb/hour).

MSFUEL - Total amount of fuel added to each unit(lb/hour).

MSSLUD - Total mass rate of sludge feed for each element for each unit(lb/hour).

MSTOT - Total amount of vapor for each element for each unit(lb/hour).

MTLDCT - Input variable. Specifies materials of construction for ductwork(See MATL).

MTLBRK - Firebrick material used to line ductwork.

NRES - Input variable. The relative resistance of brick-type against corrosion.

NSET - Data. Indicates the relative corrosion resistance of available materials of construction.

NTU - Input variable. Number of absorption transfer units required in the absorption column.

NUMBRN - Total number of burners in the fuel burner system.

NUNT - Input variable. Number of units for incineration an dpollution control.

PAKH2O - The mass rate of H2O feed to the packed bed absorber(lb/hour).

PCKSIZ - The size of the packing selected for the design of the absorption column(inches).

PINC - System pressure entering the unit in question(Psia).

PRDMW - Data. Molecular weight of each product speci(AMU).

PSIZE - The selection of absorption column packing sizes(inches).

RECT - Logical variable. If true, a rectangular incinerator is designed.

REFINS - Thickness of refractory in the brick calculation subroutines(inches).

RETIM - The retention time allowed for each unit(if specified by the user or calculated by the program)(seconds).

REVLB - Input variable. The profit generated per pound of waste feed(U.S. Dollars/lb waste feed).

RHO - Density of gas(lb/cubic feet).

RHOL - Density of liquid(lb/cubic feet).

RLD - Input variable. The length to diamter ratio of each unit(specified by the user or calculated by the program).

ROTARY - Logical variable. If true, a rotary kiln incinerator is designed.

RTINST - Input variable. Rate of interest to bo rrow money for future worth calculations(percent).

PAKRAG - Data. The range of liquid and vapor mass velocities for constants used to design the packed bed absorber(lb/hour/square feet). See variable CONST.

PAYEXP - Labor related expenses(U.S. Dollars/year).

PCKCHS - Data. The name of the packing selected for the packed bed absorber.

PCKNAM - Data. Name of packing available for the design of the packed bed absorber.

SCRW - Logical variable. If true, the waste is fed to the incinerator with a screw feed sub-unit.

SECC - Total secretaries salary(U.S. Dollars/year).

SEMI - Logical variables. If true, semi-automatic ash removal system is specified.

SHLCST - Cost of incinerator shell(U.S. Dollars).

SLD - Logical variable. If true, the waste feed incinerated is a solid.

SLPABS - Input variable. The slope of the equilibrium curve for the absorption. process.

SS - Logical variable. If true, the material of construction is of stainless steel.

STMCST - Amount of steam recovered in the heat recovery unit(U.S. Dollars).

STMREC - Amount of steam recovered in the heat recovery unit(lb/hour).

SUNIT - Name of unit opitons available.

SUNIT(1) - Incinerator(INC)
SUNIT(2) - Quench Chamber(QUE)
SUNIT(3) - Heat Recovery Boiler(HTE)
SUNIT(4) - Venturi Scrubber(VEN)
SUNIT(5) - Induction Fan(FAN)
SUNIT(6) - Packed Bed Absorber(PCK)
SUNIT(7) - Tray Absorber(TRA)
SUNIT(8) - Afterburner(AFT)
SUNIT(9) - Exhaust Stack(STK)
SUNIT(10)- Adiabatic Temperature(ADB)

SUPC - Supervisors salary($/year).

SUPP - Supervisors total salary($/year).

T1 - Inlet temperature to unit under consideration (degrees fahrenheit).

T2 - Outlet temperature to unit under consideration (degree fahrenheit).

TA - Input variable. Ambient temperature(Fahrenheit).

TBRNTT - Total cost of burner system (fuel and waste feed) (U.S. Dollars).

TEKC - Technicians salary(U.S. Dollars / hour).

THCKIN - Total thickness of the insulation firebrick(inches).

TKOND - Thermal conductivity of firebrick used to line incinerator(Btu/hour/square foot/Fahrenheit/inch).

TLIM - Data. Limiting temperature of use(Fahrenheit)

TOTCAP - Total capital cost of all units and sub-units(U.S. Dollars).

TOTDP - Total pressure drop across the incinerator and pollution control systmeem.

TOTELC - Total amount of electricity cost for the facility(U.S. Dollars/year).

TOTH2O - Total amount of water used by the incineration facility(lb/year).

TOTLAB - Total labor costs for the incineration facility(U.S. Dollars /year).

TOTTOT - Total equipment and indirect capital costs required to build an incineration facility(U.S. Dollars /year).

TTCAUS - Total amount of caustic used in the absorption and the venturi scrubber(lb/hour).

TTL - The mass rate of gas in each unit(lb/hour).

TTMP - Input variable. Stores the temperature in each unit specified by the user(Fahrenheit).

UNIT - Input variable. Name of units being considered. See SUNIT.

VENAUT - Logical variable. If true, automatic venturi throat adjustment is selected. If false, a manuel venturi throat adjustment is selected.

VISCG - Viscosity of gas.

VISCL - Viscosity of liquid(lb/hour/foot).

VOLIT - Volitiles flow rate of waste feed. VOLIT= MASSSL*WTVOL.

VOLTIL - Logical variable. If true, the waste feed is considered to have volatile components.

VOLRAT - Volumetric flow rate of gas in each unit(cubic fee/ hour).

WATRAT - Water rate in the packed bed absorber(lb/hour).

WSTNME - Input variable. Identity name of waste being incinerated.

WTRCST - Cost of water($/lb).

WTRTOT - Total water required for the facility(lb/hour).

XXAIR - Elemental composition of air(weight percent).

XXFUEL - Elemental composition of fuel(weight percent).

XXSLUD - Elemental composition of the waste feed(weight percent).

YEAR - Number of days per year in operation(days).

YRNUM - Estimated facility life(years). Used for economic analysis.

Z - Total height of the packed bed absorption column(feet).

ZFLHT - Input variable. Heat of combustion of sludge feed(lb volatiles/hour).

ZINSUR - The amount of insurance for the waste incineration facility(U.S. Dollars / year).

ZLOSS - Heat loss from incinerator(Btu/hour). Used if logical variable HTLS is true.

ZSLHT - Data. Heat of combustion of fuel(Btu/lb).

ZTOT - Cost of all labor except management(U.S. Dollars / year).

APPENDIX D

LISTING OF THE COMPUTER PROGRAMS INPUT HWSTBRN, THEIR CONTROLLLING PROGRAMS AND DATA SET CP

PROGRAM INCIN

```
00000010SET &DOT = .
00000020ATTRIB ROSE LRECL(80) BLKSIZE(7440) RECFM(F B) DSORG(PS)
00000030START:WRITE IS THIS A NEW PROBLEM (Y OR N) ?
00000040READ &NAME
00000050IF &NAME = Y THEN GOTO NEW
00000060OLD:WRITE ENTER DATASET NAME TO BE RETRIEVED  FROM TAPE:
00000070READ &NAME
00000080ALLOC DS(&NAME) FILE(FT14F001) OLD USING(ROSE) CAT SPACE(100,100) TRACKS
00000100NEW:WRITE ENTER THE NEW DATA SET TO BE CREATED ON TAPE:
00000110READ &NAME
00000120ALLOC DS(&NAME) FILE(FT12F001) NEW USING(ROSE) CAT SPACE(100,100) TRACKS
00000130NNEXT:WRITE ALLOCATE ANOTHER DATASET (Y OR N)    :
00000140READ &NEXT
00000150IF &NEXT = Y THEN GOTO START
00000151ALLOC DS(CP.DATA) FILE(FT04F001) OLD USING(ROSE) CAT SPACE(100,100) TRACKS
00000160CALL INPUT1
00000170FREEALL
```

PROGRAM KILN

```
//U15500AC  JOB (?,XXX-XX-XXXX),'XXX',TIME=(0,10),CLASS=A,              00000100
//   REGION=3000K,MSGCLASS=X,NOTIFY=*,MSGLEVEL=(1,1)                    00000200
/*PASSWORD ?                                                            00000300
/*JOBPARM ROOM=E                                                        00000400
// EXEC FORTVCLG,FVREGN=3000K,GOREGN=3000K,FVLNSPC='3200,(100,20)'      00000500
//FORT.SYSIN DD DSN=U15500D.FACIL.CNTL,DISP=SHR                         00000600
//GO.FT04F001 DD DSN=U15500D.CP.DATA,DISP=SHR                           00000900
//GO.FT15F001 DD DSN=U15500D.KODAK.DATA,DISP=SHR                        00001000
//GO.SYSIN DD *                                                         00001100
//GO.FT10F001 DD UNIT=STORAGE,DISP=(OLD,CATLG),                         00001200
// SPACE=(TRK,(100,25),RLSE),                                           00001300
// DCB=(LRECL=80,BLKSIZE=7440,RECFM=FB),                                00001400
// DSN=U15500D.CCP.DATA                                                 00001500
//                                                                      00001600
```

DATA SET CP

```
PHYSICAL PROPERTIES DATA FOR INCINERATIOR DESIGN

 FIRST DATA SET...
 HEAT CAPACITY DATA WITH UNITS J/GMOLE DEG. CEL.
  FORMAT OF CP=A+BT+CT**2+DT**3
    --A--       --B--       --C--       --D--      -TLOW-      -THIGH-      --MW-
 0.3346E+02 0.6880E-02 0.7604E-05-0.3593E-08 0.0000E+00 0.1500E+04   18.01601
 0.2913E+02-0.1341E-02 0.9715E-05-0.4335E-08 0.0000E+00 0.1200E+04   36.45000
 0.3611E+02 0.4233E-01-0.2887E-04 0.7464E-08 0.0000E+00 0.1500E+04   44.00999
 0.2895E+02 0.4110E-02 0.3548E-05-0.2220E-08 0.0000E+00 0.1500E+04   28.00999
 0.2900E+02 0.2199E-02 0.5723E-05-0.2871E-08 0.0000E+00 0.1500E+04   28.02000
 0.1100E+03 0.0000E+00 0.0000E+00 0.0000E+00 0.2500E+02 0.2500E+02   31.99200
 0.2950E+02 0.8188E-02-0.2950E-05 0.3652E-09 0.0000E+00 0.3500E+04   30.00999
 0.3607E+02 0.3970E-01-0.2880E-04 0.7870E-08 0.0000E+00 0.1200E+04   46.00999
 0.3360E+02 0.1367E-01-0.1607E-04 0.6473E-08 0.0000E+00 0.1200E+04   70.91000
 0.3891E+02 0.3904E-01-0.3104E-04 0.8606E-08 0.0000E+00 0.1500E+04   64.07001
 0.1391E+03 0.1559E+00 0.0000E+00 0.0000E+00 0.1000E+02 0.4500E+02   98.08000
 0.2900E+02 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.3500E+04   36.89000
 0.7240E+02 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.1000E+04   19.00841
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00  100.00000
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00   20.18300
40-50%-ALUMINA FIREBRICK  2000.0000  4.000000  0  001.61000
60-70%-ALUMINA FIREBRICK  2500.0000  3.000000  0  002.41000
90%-ALUMINA FIREBRICK     4000.0000  2.000000  1  010.25000
INSULATING FIREBRICK      2000.0000  2.000000  0  001.25000
INSULATING FIREBRICK      2230.0000  2.000000  0  001.30000
INSULATING FIREBRICK      2600.0000  2.000000  1  001.90000
CASTABLE                  2200.0000  2.000000  0  001.20000
CASTABLE                  2600.0000  2.000000  0  001.70000


  NAME, HEAT DATA AND COST OF FUELS.
  SPECIES          $/GAL    BTU/GAL    $/BTU  BTU/LB
NO. 2 FUEL OIL    1.251370000.00 0.9120E+06 0.1840E+05


  DESIGN AND COST DATA FOR PACKED BED.
         DATA ACQUIRED FROM MODERN POLLUTION CONTROL TECHNOLOGY VOL 1
         STAFF OF RESEARCH AND EDUCATION ASSOCIATION
         628.5 R432M V.1 AT OSU LIBRARY.
RASCHIG RINGS     0.5 11.70  2.32 0.45 0.47 2 5 5 15 0.00182 0.46 139.00 0.00720
RASCHIG RINGS     1.0  6.50  7.00 0.39 0.58 2 8 4  5 0.00357 0.35  32.90 0.0045
RASCHIG RINGS     1.5  5.05 17.30 0.38 0.66 2 7 5 15 0.0111  0.22  12.08 0.00400
RASCHIG RINGS     2.0  4.85  3.82 0.41 0.45 2 8 5 45 0.0125  0.22  11.13 0.00295
BERL SADDLES      0.5 24.80 32.40 0.30 0.74 2 7 5 15 0.00666 0.28  60.40 0.00340
BERL SADDLES      1.0  9.90  1.97 0.36 0.40 2 8 4 45 0.00588 0.28  16.01 0.00295
BERL SADDLES      1.5  7.50  5.05 0.32 0.45 210 4 45 0.00625 0.28   8.01 0.00225
 STM $/LB    WTR $/LB    DISP $/LB    FUEL $/LB    ELC $/KWH   $/TON LIME
0.00504000 0.00025000 0.00500000 0.17600000 0.043200000 33.500000
 40.656000
```

PROGRAM INPUT

```
C$JOB            ,NOLIST
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,PRI,SLD,LQD,PLASMA,BRN,ADIA
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
      LOGICAL INCIP,AFTINC
      LOGICAL FEDPT,QUNCH,HTEIN,VININ,ININ,PCIN,STKIN
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*20
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
      CHARACTER MATLC*2,SCRNME*20,FLNAM*15
      CHARACTER ELEMNT*10
      DIMENSION MATLC(4),ELEMNT(9)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,EXFUEL(9),FEDRG2
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC
     1,AOP,WTPVOL,WTPH2O,WATRAT,NTU,AOQ,CSTSTO,SCHMDT,PRCFLD
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,PREXTI,DPTOT,PREXT,ELEVAT,TOTDP,QSET,QTEMP,HCLRM
     2 ,CSTIIN,CSTSTR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  VENWAT,DIAPT(100),WTPRT(100),FINCRG,REFINS,THCKIN,EQVFIN
       COMMON/UPDATE/ FACSUM,FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1 ,FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NPRTS,NUMBRN
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK,SCRNME(6)
     2,WSTNME(6),BNMFR(6),BNMIN(6),FLNAM
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC
     2,SLD,SCRW,VENAUT,PLASMA,BRN,ADIA,PRI,FG,LQD
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
C
      FEDRG2= 1.142E-5
      MATLC(1)='CS'
      MATLC(2)='SS'
      MATLC(3)='IC'
      QSAT=0.0
      QTEMP=0.0
      SIEVE=.FALSE.
      VALVE=.TRUE.
      DO 123 I=1,9
        EXFUEL(I)=0.0
  123 CONTINUE
      XSUM=0.0
      SUNIT(1)='INC'
      SUNIT(2)='QUE'
      SUNIT(3)='HTE'
      SUNIT(4)='VEN'
      SUNIT(5)='IND'
      SUNIT(6)='PCK'
      SUNIT(7)='TRA'
      SUNIT(8)='AFT'
      SUNIT(9)='STK'
      SUNIT(10)='ADI'
       SUNIT(11)='   '
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      ELEMNT(1)='HYDROGEN'
      ELEMNT(2)='CARBON'
      ELEMNT(3)='OXYGEN'
      ELEMNT(4)='NITROGEN'
      ELEMNT(5)='CHLORINE'
      ELEMNT(6)='SULPHUR'
      ELEMNT(7)='FLUORINE'
      ELEMNT(8)='PHOSPHOR'
      ELEMNT(9)='NEON'
      PLASMA=.FALSE.
      ROTARY=.FALSE.
      FLUID=.FALSE.
      LIQI=.FALSE.
      METRIC=.FALSE.
      ENGL=.FALSE.
      ADIA=.FALSE.
      LCOST=.FALSE.
      BARREL=.FALSE.
      SCRW=.FALSE.
      BRN=.FALSE.
      CALL DEFALT
  665 WRITE(6,664)
  664 FORMAT(10X,'SELECT ONE OF THE FOLLOWING OPTIONS'/
     1 15X,'1 - CREATE A NEW FILE'/
     2 15X,'2 - ALTER AN EXISTING FILE')
      READ*, ITEMP
      IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 665
      IF(ITEMP.EQ.1) GOTO 200
      CALL INPT(NREAC,NPRD)
      GOTO 230
  200 WRITE(6,80)
   80 FORMAT(5X,'SELECT METRIC(ENTER 1) OR ENGLISH(ENTER 2) SYSTEM'/
     1 5X,'OF MEASUREMENTS')
      METRIC=.FALSE.
      ENGL=.FALSE.
      READ*, TEMPER
      IF(TEMPER.EQ.1) METRIC=.TRUE.
      IF(TEMPER.EQ.2) ENGL=.TRUE.
      IF(TEMPER.LT.1.O.OR.TEMPER.GT.2.0) WRITE(6,131)
  131 FORMAT(5X,'***  SELECT THE NUMBER 1 OR 2  ***')
      IF(TEMPER.LT.1.OR.TEMPER.GT.2) GOTO 200
      WRITE(6,90)
      WRITE(6,500)
   90 FORMAT(7X,'WASTE FEED CHARACTERISTICS AND PROPERTIES'///)
  500 FORMAT(5X,'INPUT WASTE FEED IDENTIFICATION NAME')
      READ*, WSTNME(1)
 3033 XSUM=0.0
      WRITE(6,3036)
 3036 FORMAT(10X,'FOR THE WASTE FEED')
      DO 3020 I=1,8
       WRITE(6,3021) ELEMNT(I)
 3021 FORMAT(10X,'INPUT WEIGHT PERCENT OF ',A10,' IN WASTE FEED')
      READ*,  XXSLUD(I)
      XSUM=XSUM+XXSLUD(I)
      IF(XSUM.LE. 1.0 ) GOTO 3020
         WRITE(6,3022)
 3022 FORMAT(10X,'TOTAL WEIGHT FRACTION ABOVE 1.0. '/10X,'REDO FROM',
     1 ' START')
         GOTO 3033
 3020 CONTINUE
      IF(XSUM.GT.0.98) GOTO 7038
         WRITE(6,3037)
 3037 FORMAT(10X,'TOTAL WEIGHT PERCENT OF WASTE FEED IS BELOW 98%'/
     1  10X,'WILL NORMALIZE')
      XXSM=0.0
      DO 7039 L=1,8
         XXSM=XXSM+XXSLUD(L)
 7039 CONTINUE
      DO 7040 L=1,8
         XXSLUD(L)=XXSLUD(L)/XXSM
 7040 CONTINUE
  372 WRITE(6,371)
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  371 FORMAT(10X,'SELECT ONE OF THE FOLLOWING OPTIONS'/
     1 10X,'1 - SPECIFY THE HEATING VALUE OF THE WASTE'/
     2 10X,'2 - CALCULATE THE HEAT VALUE OF A CHLORINATED HYDROCARBON'
     3 ,' (LOW VALUE)'/
     4 10X,'3 - CALCULATE THE HEAT VALUE OF A CHLORINATED HYDROCARBON'
     5 ,' (HIGH VALUE)')
      READ*, ITEMP
      IF(ITEMP.GT.3.OR.ITEMP.LT.1) GOTO 372
      HT1=.FALSE.
      HT2=.FALSE.
      HT3=.FALSE.
      IF(ITEMP.EQ.1) HT1=.TRUE.
      IF(ITEMP.EQ.2) HT2=.TRUE.
      IF(ITEMP.EQ.3) HT3=.TRUE.
      IF(HT1) GOTO 7038
      IF(HT2) ZSLHT=14100* XXSLUD(2)+ 45000*(XXSLUD(3)-XXSLUD(1)/8)
     1 760*XXSLUD(5)+4500
      IF(HT2) ZSLHT=14100* XXSLUD(2)+ 54500*(XXSLUD(3)-XXSLUD(1)/8)
     1 150*XXSLUD(5)+4500
 7038 IF(ENGL)WRITE(6,93)
      IF(METRIC) WRITE(6,94)
   93 FORMAT(5X,'INPUT THE HEAT OF COMBUSTION OF THE WASTE SLUDGE'
     1 ,'(BTU/HR)')
   94 FORMAT(5X,'INPUT THE HEAT OF COMBUSTION OF THE WASTE SLUDGE'
     1,'(KJ/KG)')
      READ*, ZSLHT
 3035 WRITE(6,100)
  100 FORMAT(5X,'FOR THE SLUDGE FEED INPUT THE WEIGHT FRACTION OF',
     1' VOLITLES')
      READ*, WTPVOL
      WRITE(6,120)
  120 FORMAT( 5X,'INPUT THE WEIGHT FRACTION OF FREE H2O IN THE SLUDGE',
     1' FEED.')
      READ*, WTPH2O
      WTTOT=WTPVOL+WTPH2O
      IF(WTTOT.GT.1.05) WRITE(6,3034)
 3034 FORMAT(10X,'THE SUM OF THE OVERALL COMPOSITION IS GREATER THAN',
     1 ' ONE. PLEASE RESPECIFY.')
      IF(WTTOT.GT.1.0) GOTO 3035
 2000 FORMAT(6A5)
  870 WRITE(6,871)
  871 FORMAT(10X,'SELECT ONE OF THE FOLLOWING'/
     1 15X, '1 - WASTE IS NON-VOLATILE'/
     2 15X, '2 - WASTE IS VOLATILE'/
     3 15X, '3 - WASTE IS VOLATILE AND COMBUSTABLE')
      READ*, ITEMP
      IF(ITEMP.GT.3.OR.ITEMP.LT.1) GOTO 870
      VOLTIL=.FALSE.
      CMBST=.FALSE.
      IF(ITEMP.EQ.2) VOLTIL=.TRUE.
      IF(ITEMP.EQ.3) VOLTIL=.TRUE.
      IF(ITEMP.EQ.3) CMBST=.TRUE.
      IF(METRIC)  WRITE(6,71)
      IF(ENGL)WRITE(6,70)
   71 FORMAT(5X,'ENTER PRESSURE OF INLET AIR(ATM)')
   70 FORMAT(5X,'ENTER PRESSURE OF INLET AIR(PSIA)')
      READ*,  PINC
      IF(METRIC)WRITE(6,76)
      IF(ENGL)WRITE(6,75)
   75 FORMAT(5X,'ENTER AMBIENT TEMPERATURE(DEGREES FAHENHEIT) ')
   76 FORMAT(5X,'ENTER AMBIENT TEMPERATURE(DEGREES CELCIUS)')
      READ*, TA
      WRITE(6,350)
  350 FORMAT(5X,'ENTER THE ELEVATION OF THE FACILITY(ABOVE SEA LEVEL)'/
     1 5X,'IN FEET')
      READ*, ELEVAT
      IF(ENGL)WRITE(6,91)
   91 FORMAT(5X,'INPUT THE FEED RATE OF THE WASTE STREAM(LB/HR)')
      IF(METRIC)WRITE(6,92)
   92 FORMAT(5X,'INPUT THE FEED RATE OF THE WASTE STREAM(KG/HR)')
      READ*, MASSSL
  145 WRITE(6,140)
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 140 FORMAT(5X,'ENTER 1 FOR FACILITY DESIGN ONLY.  ENTER 2 IF'/
    15X,'DESIGN AND COST ANALYSIS IS DESIRED')
     READ*, TEMPER
     IF(TEMPER.EQ.1) LCOST=.FALSE.
     IF(TEMPER.EQ.2) LCOST=.TRUE.
     IF(TEMPER.LT.1.OR.TEMPER.GT.2) WRITE(6,141)
 141 FORMAT(5X,'A VALUE BETWEEN 1 AND 2 MUST BE SELECTED')
     IF(TEMPER.LT.1.OR.TEMPER.GT.2) GOTO 145
     WRITE(6,146)
 146 FORMAT(5X,'HOW MANY UNITS ARE TO BE DESIGNED')
     READ*, NUNIT
     IF(FEDPT) GOTO 230
     I=0
4016 I=I+1
     IF(AFTINC.OR.INCIP.OR.QUNCH.OR.HTEIN.OR.VININ.OR.ININ.OR.PCIN.OR.
    1 STKIN) I=JJ
     IF(I.GT.NUNIT) GOTO 21
     IF(INCIP) GOTO 220
     IF(AFTINC) GOTO 210
     IF(QUNCH) GOTO 223
     IF(HTEIN) GOTO 222
     IF(VININ) GOTO 224
     IF(ININ)  GOTO 225
     IF(PCIN)  GOTO 226
     IF(STKIN) GOTO 227
     WRITE(6,147)
 147 FORMAT(15X,'1 - INCINERATOR',15X,'2 - AFTERBURNER'/
    1       15X,'3 - HEAT RECOVERY UNIT',8X,'4 - QUENCH '/
    2       15X,'5 - VENTURI SCRUBBER',10X,'6 - INDUCTION FAN'/
    3       15X,'7 - PACKED BED ABSORBER',7X,'8 - EXHAUST STACK ')
 155 WRITE(6,150)I
 150 FORMAT(5X,'SELECT UNIT NUMBER ',I2)
     READ*, NUMUN
     IF(NUMUN.LT.1.OR.NUMUN.GT.8) WRITE(6,156)
 156 FORMAT(5X,'UNIT NUMBER NOT WITHIN RANGE. RESPECIFY')
     IF(NUMUN.LT.1.OR.NUMUN.GT.8) GOTO 155
     IF(NUMUN.EQ.3) GOTO 559
 103 WRITE(6,101)
 101 FORMAT(10X,'SELECT TYPE OF  MATERIAL TO CONSTRUCT UNIT',
    1 ' :'/15X,'1 - INCONEL CLAD'/15X,'2 - STAINLESS STEEL 316'/
    2 15X,'3 - CARBON STEEL')
     READ*, TEMPER
     IF(TEMPER.GT.4.0.OR.TEMPER.LT.1) WRITE(6,99)
  99 FORMAT(10X,'CHOICE MUST BE BETWEEN 1 AND  4, RESPECIFY')
     IF(TEMPER.EQ.1.) MATL(I)='IC'
     IF(TEMPER.EQ.2.0) MATL(I)='SS'
     IF(TEMPER.EQ.3.) MATL(I)='CS'
     IF(TEMPER.GT.3.0.OR.TEMPER.LT.1.0) WRITE(6,102)
 102 FORMAT(10X,'MATERIAL SELECTION OUT OF RANGE. RESPECIFY')
     IF(TEMPER.GT.3.0.OR.TEMPER.LT.1.) GOTO 103
 559 IF(NUMUN.EQ.1) GOTO 220
     IF(NUMUN.EQ.2) GOTO 210
     IF(NUMUN.EQ.3) GOTO 222
     IF(NUMUN.EQ.4) GOTO 223
     IF(NUMUN.EQ.5) GOTO 224
     IF(NUMUN.EQ.6) GOTO 225
     IF(NUMUN.EQ.7) GOTO 226
     IF(NUMUN.EQ.8) GOTO 227
           GOTO 155
 180 WRITE(6,181)
 181 FORMAT(10X,'TRAYBED ABSORPTION COLUMN DESIGN PROCEDURE NOT ',
    1 'COMPLETE')
     GOTO 20
 220 WRITE(6,161)
     ROTARY=.FALSE.
     FLUID=.FALSE.
     LIQI=.FALSE.
     PLASMA=.FALSE.
     ADIA=.FALSE.
     IF(INCIP) GOTO 8002
     UNIT(I)='INC'
 161 FORMAT(10X,'****INPUT DESIGN PARAMETERS FOR INCINERATOR****'///)
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8002 WRITE(6,162)
 162 FORMAT(5X,'INPUT THE TYPE INCINERATOR TO BE DESIGNED')
 166 WRITE(6,163)
 163 FORMAT(15X,'1 - ROTARY KILN',10X,'2 - LIQUID INJECTION'/
    115X,'3 - FLUIDIZED BED',8X,'4 - PLASMA ARC PYROLYSIS')
     READ*, TEMPER
     IF(TEMPER.EQ.1) ROTARY=.TRUE.
     IF(TEMPER.EQ.2) LIQI=.TRUE.
     IF(TEMPER.EQ.3) FLUID=.TRUE.
     IF(TEMPER.EQ.4) PLASMA=.TRUE.
        IF(TEMPER.GT.4.0.OR.TEMPER.LT.1.0) WRITE(6,164)
 164 FORMAT(5X,'*** NUMBER NOT IN RANGE. RESPECIFY ***')
        IF(TEMPER.GT.4.0.OR.TEMPER.LT.1.)GOTO 166
 874 WRITE(6,875)
 875 FORMAT(10X,'SELECT ONE OF THE FOLLOWING'/
    1 15X,'1 - WASTE IS A SOLID'/
    2 15X,'2 - WASTE IS A PUMPABLE LIQUID')
     READ*, ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 874
     SLD=.FALSE.
     LQD=.FALSE.
      IF(ITEMP.EQ.1) SLD=.TRUE.
      IF(ITEMP.EQ.2) LQD=.TRUE.
 503 WRITE(6,501)
 501 FORMAT(10X,'WASTE FEED MECHANISM'/15X,'1 - WASTE FEED BURNERS'/
    1 15X,'2 - BARREL FEED'/15X,'3 - SCREW FEED')
     READ*, ITEMP
     IF(ITEMP.LT.1.OR.ITEMP.GT.3) WRITE(6,502)
 502 FORMAT(10X,'SELECTION OUT RANGE, RESPECIFY')
     IF(ITEMP.LT.1.OR.ITEMP.GT.3) GOTO 503
     BRN=.FALSE.
     BARREL=.FALSE.
     SCRW=.FALSE.
     IF(ITEMP.EQ.1) BRN=.TRUE.
     IF(ITEMP.EQ.2) BARREL=.TRUE.
     IF(ITEMP.EQ.3) SCRW=.TRUE.
 167 WRITE(6,96)
  96 FORMAT(10X,'SELECT 1 OF THE 2 OPTIONS'/15X,'1 - SET OUTLET TEMP',
    1 'ERATURE'/15X,'2 - ADIABATIC COMBUSTION')
     READ*,TEMPER
        IF(TEMPER.GT.4.0.OR.TEMPER.LT.1.0) WRITE(6,164)
        IF(TEMPER.GT.4.0.OR.TEMPER.LT.1.)GOTO 167
     IF(TEMPER.EQ.2)  ADIA=.TRUE.
     IF(.NOT.ADIA.AND.ENGL) WRITE(6,97)
  97 FORMAT(10X,'INPUT EXIT TEMPERATURE IN DEGREES FAHRENHEIT')
     IF(.NOT.ADIA.AND.METRIC) WRITE(6,98)
  98 FORMAT(10X,'INPUT TEMPERATURE IN DEGREES CELCIUS')
     IF(.NOT.ADIA)READ*, TTMP(I)
 551 WRITE(6,550)
 550 FORMAT(25X,'SPECIFY ONE OF THE FOLLOWING'/
    1 10X,'1 - INCLUDE A 10 PERCENT HEAT LOSS'/
    2 10X,'2 - NO HEAT LOSSES INCLUDED')
     READ*, ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 551
     IF(ITEMP.EQ.1) HTLS=.TRUE.
     IF(ITEMP.EQ.2) HTLS=.FALSE.
     WRITE(6,115)
 115 FORMAT(10X,'INPUT THE EXCEES AIR REQUIRED(FRACTION BETWEEN 0',
    1 ' AND 1)')
     READ*, EXCESS(I)
     WRITE(6,877)
 877 FORMAT(10X,'INPUT THE EXCEES FUEL REQUIRED(FRACTION BETWEEN 0',
    1 ' AND 1)')
     READ*, EXFUEL(I)
     WRITE(6,113)
 113 FORMAT(10X,'INPUT ESTIMATE OF THE RATIO OF LENGTH TO DIAMETER'/
    110X, 'RATIO(A VALUE BETWEEN 2  AND 9 IS GENERALLY SELECTED)')
     READ*,RLD(I)
     WRITE(6,114)
 114 FORMAT(10X,'INPUT RETENTION  TIME OF INCINERATOR (SECONDS)')
     READ*, RETIM(I)
     WRITE(6,380)
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 380 FORMAT(5X,'EXTRA COSTS FOR INCINERATOR(PERCENT OF EQUIPMENT COST')
     READ*, PREXTI
     IF(PREXTI.GT.2.0) PREXTI=PREXTI/100.0
     IF(INCIP) GOTO 4032
     CALL STAND(I)
     GOTO 20
 210 WRITE(6,261)
     IF(AFTINC) GOTO 8001
     UNIT(I)='AFT'
 261 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR AFTERBURNER'///)
8001 IF(METRIC) WRITE(6,98)
     IF(ENGL) WRITE(6,97)
     READ*, TTMP(I)
     WRITE(6,114)
     READ*, RETIM(I)
     WRITE(6,113)
     READ*,RLD(I)
     WRITE(6,115)
     READ*, EXCESS(I)
     WRITE(6,380)
     READ*, PREXT
     IF(AFTINC) GOTO 4015
     CALL STAND (I)
     GOTO 20
 222 WRITE(6,361)
     FXH=.FALSE.
     KRB=.FALSE.
     UTB=.FALSE.
     S316=.FALSE.
     S304=.FALSE.
     S347=.FALSE.
     NI200=.FALSE.
     MO400=.FALSE.
     IN600=.FALSE.
     IN825=.FALSE.
     TI=.FALSE.
     HS=.FALSE.
     UNIT(I)='HTE'
 361 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR HEAT RECOVERY UNIT'///)
     IF(ENGL)WRITE(6,97)
     IF(METRIC) WRITE(6,98)
     READ*, TTMP(I)
 126 WRITE(6,125)
 125 FORMAT(10X,'SPECIFY THE COST ESTIMATION METHOD FOR THE HEAT',
    1 ' RECOVERY BOILERS'//
    2 15X,'1 - GENERALIZED COST ESTIMATION METHOD'/
    3 15X,'2 - COST METHOD FOR BOILERS FOR THE INCINERATION INDUSTRY')
     READ*, ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 126
     IF(ITEMP.EQ.1) HM2=.TRUE.
     IF(ITEMP.EQ.2) HM1=.TRUE.
8003  WRITE(6,194)
 194 FORMAT(25X,'TYPE OF HEAT RECOVERY SYSTEM'//
    1 10X,'1 - FIXED HEAD                 2 - KETTLE REBOILER '/
    1 10X,'              3 - U-TUBE')
     READ*,ITEMP
     IF(ITEMP.GT.3.OR.ITEMP.LT.1) WRITE(6,195)
 195 FORMAT(10X,'SELECTION IF OUT OF RANGE. RESPECIFY')
     IF(ITEMP.GT.3.OR.ITEMP.LT.1) GOTO 8003
     IF(ITEMP.EQ.1) FXH=.TRUE.
     IF(ITEMP.EQ.2) KRB=.TRUE.
     IF(ITEMP.EQ.3) UTB=.TRUE.
 765 WRITE(6,673)
 673 FORMAT(25X,'MATERIALS OF CONSTRUCTION'//
    1 10X,'1 - STAINLESS STEEL 316      2 - STAINLESS STEEL 304'/
    2 10X,'3 - STAINLESS STEEL 347      4 - NICKEL 200'/
    3 10X,'5 - MONEL 400                6 - INCONEL 600'/
    4 10X,'7 - INCONEL 825              8 - TITANIUM'/
    5 10X,'            9 - HASTELLOY                ')
     READ*, ITEMP
     IF(ITEMP.GT.9.OR.ITEMP.LT.1) WRITE(6,764)
 764 FORMAT(10X,'NUMBER IS OUT OF RANGE. RESPECIFY')
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      IF(ITEMP.GT.9.OR.ITEMP.LT.1) GOTO 765
      IF(ITEMP.EQ.1) S316=.TRUE.
      IF(ITEMP.EQ.2) S304=.TRUE.
      IF(ITEMP.EQ.3) S347=.TRUE.
      IF(ITEMP.EQ.4) NI200=.TRUE.
      IF(ITEMP.EQ.5) MO400=.TRUE.
      IF(ITEMP.EQ.6) IN600=.TRUE.
      IF(ITEMP.EQ.7) IN825=.TRUE.
      IF(ITEMP.EQ.8) TI=.TRUE.
      IF(ITEMP.EQ.8) HS=.TRUE.
      WRITE(6,8004)
 8004 FORMAT(10X,'INPUT THE OVERALL HEAT TRANSFER COEFFICIENT'/10X,
     1 '(SHOULD RANGE FROM 1 TO 3 BTU/HR/FT°2 FAHRENHEIT)')
      READ*,HTC
      IF(HTEIN) GOTO 174
      CALL STAND(I)
      GOTO 20
  223 WRITE(6,461)
       QTEMP=0.0
       QSAT=0.0
      UNIT(I)='QUE'
  461 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR QUENCH UNIT'///)
      WRITE(6,370)
  370 FORMAT(5X,'SELECT ONE OF THESE OPTIONS'//
     1 10X,'1 - SPECIFY OUTLET TEMPERATURE'/
     2 10X,'2 - SATURATED GAS OUTLET')
      READ*, ICONV
      IF(ICONV.EQ.1) QTEMP=1
      IF(ICONV.EQ.2) QSAT=1
      IF(ENGL)WRITE(6,97)
      IF(METRIC) WRITE(6,98)
      READ*,TTMP(I)
      IF(QUNCH) GOTO 171
      CALL STAND(I)
      GOTO 20
  224 WRITE(6,561)
      DO 251 IJ=1,100
          DIAPT(IJ)=0.0
          WTPRT(IJ)=0.0
  251 CONTINUE
      NPRTS=0
      PRI=.FALSE.
      UNIT(I)='VEN'
  561 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR VENTURI SCRUBBER'///)
      IF(ENGL)WRITE(6,97)
      IF(METRIC) WRITE(6,98)
      READ*,TTMP(I)
  563 WRITE(6,562)
  562 FORMAT(10X,'VENTURI THROAT CONTROL MECHANISM'/15X,'1 - AUTOMATIC'
     1 /15X,'2 - MANUAL')
      READ*, ITEMP
      IF(ITEMP.EQ.1) VENAUT=.TRUE.
      IF(ITEMP.EQ.2) VENAUT=.FALSE.
      IF(ITEMP.LT.1.OR.ITEMP.GT.2) GOTO 563
      WRITE(6,353)
  353 FORMAT(5X,'WATER RATE IN VENTURI SCRUBBER(LB H2O/1000 FT°3 GAS)')
      READ*, VENWAT
  355 WRITE(6,354)
  354 FORMAT(5X,'SELECT ON OF THE FOLLOWING'//
     1  10X,'1 - PARTICULATE REMOVAL EFFICIENCY FROM EXPERIMENTAL DATA'/
     2  10X,'2 - DIRECT SPECIFICATION OF VENTURI PRESSURE DROP')
     READ*, INUM
      IF(INUM.GT.2.OR.INUM.LT.1) WRITE(6,141)
      IF(INUM.GT.2.OR.INUM.LT.1) GOTO 355
      IF(INUM.EQ.1) PRI=.TRUE.
      IF(INUM.EQ.2) PRI=.FALSE.
      IF(PRI) GOTO 356
      WRITE(6,357)
  357 FORMAT(5X,'SPECIFIY OVERALL REMOVAL EFFICIENCY(LB/ACF)')
      READ*, FEDRG2
      IF(INUM.EQ.2) WRITE(6,358)
  358 FORMAT(5X,'SPECIFY VENTURI SCRUBBER TOTAL PRESSURE DROP(IN H2O)')
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      IF(INUM.EQ.2) READ*, DPTOT
      GOTO 366
  356 WRITE(6,196)
  196 FORMAT(5X,'INPUT PARTICULATE DISTRIBUTION'//
     1  10X,'SPECIFY NUMBER OF DATA POINTS')
      READ*, NPRTS
      WRITE(6,362)
  362 FORMAT(10X,'SPECIFY THE PARTICULATE DIAMETER AND WEIGHT PERCENT')
      DO 363 IJ=1,NPRTS
        READ*, DIAPT(IJ),WTPRT(IJ)
  363 CONTINUE
  366 WRITE(6,364)
  364 FORMAT(5X,'SELECT THE FOLLOWING OPTION'/10X,'1 - FIBERGLASS LINED'
     1 ,' THROAT'/10X,'2 - UNLINED THROAT')
      READ*, ITEMP
      IF(ITEMP.LT.1.OR.ITEMP.GT.2) GOTO 366
      IF(ITEMP.EQ.1) FG=.TRUE.
      IF(ITEMP.NE.1) FG=.FALSE.
      IF(VININ) GOTO 177
      CALL STAND(I)
      GOTO 20
  225 WRITE(6,197)
      UNIT(I)='IND'
  197 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR THE INDUCTION FAN'///)
      WRITE(6,351)
  351 FORMAT(5X,'ENTER THE PRESSURE HEAD FOR THE TOTAL COMPRESSION'/
     1 5X,' PROCESS')
      READ*, TOTDP
      IF(ENGL)WRITE(6,97)
      IF(METRIC) WRITE(6,98)
      READ*,TTMP(I)
      FANCLS=4.0
      IF(ININ) GOTO 640
      CALL STAND(I)
      GOTO 20
  226 WRITE(6,761)
      IF(ENGL)WRITE(6,97)
      IF(METRIC) WRITE(6,98)
      READ*,TTMP(I)
      UNIT(I)='PCK'
      WRITE(6,762)
  762 FORMAT(10X,'INPUT MAJOR CAUSTIC TO BE SCRUBBED BY THE ABSORPTION',
     1 ' COLUMN')
      READ*, SCRNME(1)
      WRITE(6,381)
  381 FORMAT(5X,'CAUSTIC REMOVAL EFFICIENCY(PERCNET)')
      READ*, HCLRM
 2003 FORMAT(6A5)
      WRITE(6,763)
  763 FORMAT(10X,'INPUT THE RELATIVE WATER FEED RATE TO THE PACKED BED',
     2 ' SCRUBBER'/15X,'VALUE MUST BE BETWEEN 15 - 30 GALLON H2O PER',
     3 ' 1000 FT°3 OF GAS FLOW')
      READ*, PAKH2O
  761 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR THE PACKED BED'///)
  766 WRITE(6,198)
  198 FORMAT(10X,'INPUT PACKING TYPE'/15X,'1 - BERL SADDLES'/15X,
     1 '2 - RASCHIG RINGS')
      READ*, TEMPER
      IF(TEMPER.GT.2.0.OR.TEMPER.LT.1.0) WRITE(6,199)
  199 FORMAT(10X,'SELECTION OUT OF RANGE RESPCIFY')
      IF(TEMPER.GT.2.0.OR.TEMPER.LT.1.0) GOTO 766
      IF(TEMPER.EQ.1) PCKCHS(1)='BERL'
      IF(TEMPER.EQ.1) PCKCHS(2)=' SAD'
      IF(TEMPER.EQ.1) PCKCHS(3)='DLES'
      IF(TEMPER.EQ.1) PCKCHS(4)='    '
      IF(TEMPER.EQ.2) PCKCHS(1)='RASC'
      IF(TEMPER.EQ.2) PCKCHS(2)='HIG '
      IF(TEMPER.EQ.2) PCKCHS(3)='RING'
      IF(TEMPER.EQ.2) PCKCHS(4)='S   '
  769 WRITE(6,767)
  767 FORMAT(10X,'INPUT THE SIZE OF THE PACKING USED'/15X,
     1 '1 - 0.5 INCH PACKING      2 - 1.0 INCH PACKING ',/15X,
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   2 '3 - 1.5 INCH PACKING      4 - 2.0 INCH PACKING ')
     READ*, ITEMPR
     IF(ITEMPR.GT.4.OR.ITEMPR.LT.1.0) WRITE(6,768)
 768 FORMAT(10X,'SELECTION OUT OF RANGE, RESPICIFY.')
     IF(ITEMPR.GT.4.0.OR.ITEMPR.LT.1.0) GOTO 769
     IF(ITEMPR.EQ.1) PCKSIZ=0.5
     IF(ITEMPR.EQ.2) PCKSIZ=1.0
     IF(ITEMPR.EQ.3) PCKSIZ=1.5
     IF(ITEMPR.EQ.4) PCKSIZ=2.0
     WRITE(6,770)
 770 FORMAT(10X,'INPUT THE EFFECTIVE ABSORPTION FACTOR(BETWEEN 1'
    1 ,' AND 2).')
     READ*, EFFABS
     WRITE(6,771)
 771 FORMAT(10X,'INPUT THE PERCENT FLOODING IN THE PACKED BED'/
    1 '(BETWEEN 0 AND 100)')
     READ*, PRCFLD
     WRITE(6,772)
 772 FORMAT(10X,'INPUT THE NUMBER OF ABSORPTION TRANSFER UNITS',
    1'(OBTAINED FROM EQUILIBRIUM DIAGRAM)')
     READ*, NTU
     WRITE(6,774)
 774 FORMAT(10X,'INPUT THE SLOPE OF THE EQUILIBRIUM CURVE')
     READ*, SLPABS
     WRITE(6,775)
 775 FORMAT(10X,'INPUT THE DIFFUSION COEFFICIENT FOR THE CAUSTIC IN',
    1 ' THE GAS PHASE')
     READ*, DFHCLG
     WRITE(6,776)
 776 FORMAT(10X,'INPUT THE DIFFUSION COEFFICIENT FOR THE CAUSTIC IN',
    1 ' THE LIQUID PHASE')
     READ*, DFHCLL
     WRITE(6,773)
 773 FORMAT(10X,'INPUT THE SCHMIDT NUMBER FOR THE ABSORPTION PROCESS',
    1 '(INPUT 1.0 IF NOT KNOWN)')
     READ*, SCHMDT
     CALL STAND(I)
     IF(PCIN) GOTO 643
     GOTO 20
 227 WRITE(6,861)
     UNIT(I)='STK'
     IF(ENGL)WRITE(6,97)
     IF(METRIC) WRITE(6,98)
     READ*,TTMP(I)
 861 FORMAT(10X,'INPUT DESIGN PARAMETERS FOR THE EXHAUST STACK'///)
     WRITE(6,8050)
8050 FORMAT(10X,'INPUT HEIGHT OF EXHAUST STACK')
     READ*, HEIGHT
     IF(STKIN) GOTO 646
     GOTO 20
  20 CONTINUE
     GOTO 4016
  21 CONTINUE
     WRITE(6,1000)
1000 FORMAT(10X,'THE FOLLOWING INPUT REQUIREMENTS PERTAIN TO THE ',
    1 'ECONOMIC ANALYSIS OF THE FACILITY'///)
     WRITE(6,660)
 660 FORMAT(10X,'YEAR TO DATE THE CAPITAL COST OF THE FACILITY')
     READ*, IYEAR
     WRITE(6,552)
 552 FORMAT(10X,'HOW MANY HOURS PER DAY IS THE INCINERATOR '
    1 ,'OPERATING?')
     READ*, DAY
     WRITE(6,553)
 553 FORMAT(10X,'HOW MANY DAYS PER YEAR IS THE INCINERATOR IN ',
    1 'OPERATION?')
     READ*,YEAR
     WRITE(6,655)
 655 FORMAT(10X,'REVENUE GENERATED FOR WASTE INCINERATION($/TON)')
     READ*, REVLB
     WRITE(6,656)
 656 FORMAT(10X,'LENGTH OF PROCESS LIFE(YEARS)')
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      READ*, YRNUM
  657 WRITE(6,654)
  654 FORMAT(10X,'SELECT ONE OF THE FOLLOWING OPTIONS'/
     1  15X,'1 - INPUT AVERAGE COST INDEX FOR EQUIPMENT COST'/
     2  15X,'2 - INPUT SPECIFIC COST INDEX FACTORS FROM CHEMICAL '/
     3  19X,'ENGINEERING EQUIPMENT COST FACTORS')
      READ*, ITEMP
      IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 657
      IF(ITEMP.EQ.2) GOTO 658
      WRITE(6,659) IYEAR
  659 FORMAT(10X,'INPUT AVERAGE EQUIPMENT COST UPDATE FACTOR FOR THE'/
     1 13X,'YEAR ',I4)
      READ*, FACSUM
      FACCES=FACSUM
      FACMSC=FACSUM
      FACCEE=FACSUM
      FACCEF=FACSUM
      FACCEB=FACSUM
      GOTO 248
  658 WRITE(6,1010)
 1010 FORMAT(10X,'INPUT COST UPDATE FACTOR FOR'
     1 ,' EQUIPMENT MACHINERY AND SUPPORTS')
      READ*, FACCES
      WRITE(6,1003)
 1003 FORMAT(10X,'INPUT COST UPDATE FACTOR FOR'
     1 ,'FOR ELECTRICAL EQUIPMENT')
      READ*, FACCEE
      WRITE(6,1004)
 1004 FORMAT(10X,'INPUT THE COST UPDATE FACTOR FOR'
     1 , 'FABRICATED EQUIPMENT')
      READ*, FACCEF
      WRITE(6,1005)
 1005 FORMAT(10X,'INPUT THE COST UPDATE FACTOR FOR'
     1 ,'STRUCTURAL SUPPORTS AND MISC.')
      READ*, FACMSC
      WRITE(6,1006)
 1006 FORMAT(10X,'INPUT THE COST UPDATE FACTOR FOR ',
     1 'BUILDING COSTS')
      READ*, FACCEB
      WRITE(6,1015)
 1015 FORMAT(10X,'INPUT THE COST FACTOR FOR'
     1 ,' PIPES, VALVES & FITTINGS')
      READ*, FACPVF
      WRITE(6,1016)
 1016 FORMAT(10X,'INPUT THE COST FACTOR FOR'
     1 ,' PUMPS AND COMPRESSORS')
      READ*, PACPC
      WRITE(6,1017)
 1017 FORMAT(10X,'INPUT THE COTS FACTOR FOR'
     1 ,'PROCESS INSTRUMENTS')
      READ*, FACPI
      WRITE(6,1018)
 1018 FORMAT(10X,'INPUT THE COST FACTOR FOR'
     1 , ' ENGINEERING & SUPERVISION')
      READ*, FACENG
      WRITE(6,1019)
 1019 FORMAT(10X,'INPUT THE COST FACTOR FOR'
     1, ' CONSTRUCTION LABOR')
      READ*, FACLAB
      WRITE(6,1020)
 1020 FORMAT(10X,'INPUT THE COST FACTOR FOR'
     1, ' PROCESS MACHINERY')
      READ*, FACPRS
  248 CONTINUE
      WRITE(6,554)
  554 FORMAT(10X,'SPECIFY THE PERCENTAGE OF EQUIPMENT COST FOR THE ',
     1 'CONTENGENCY COSTS.')
      READ*, CONTEN
  230 CONTINUE
        IF(ECLOG) GOTO 1217
C
C
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C     CHECK INPUT BEFORE PRINTING TO OUTPUT FILE.
C
C
      FEDPT=.FALSE.
      WRITE(6,182) WSTNME(1)
  182 FORMAT(25X,'INPUT DATA FOR'/22X,A20)
      WRITE(6,183)
  183 FORMAT(10X,'GENERAL PHYSICAL PROPERTIES OF WASTE FEED'/)
      WRITE(6,184) MASSSL,WTPVOL,WTPH2O,ZSLHT
  184 FORMAT(15X,'WASTE FEED RATE=                  ',F9.2,' LB/HR'/
     1       15X,'WEIGHT PERCENT VOLATILES=         ',F9.6,/
     2       15X,'WEIGHT PERCENT H2O=               ',F9.6/
     3       15X,'HEAT CONTENT OF WASTE=            ',F9.0)
       IF(LQD) WRITE(6,930)
       IF(SLD) WRITE(6,931)
  930 FORMAT(10X,'WASTE FEED IS A LIQUID')
  931 FORMAT(10X,'WASTE FEED IS A SOLID')
      IF(CMBST) WRITE(6,185)
      IF(VOLTIL) WRITE(6,186)
  185 FORMAT(15X,'WASTE FEED IS COMBUSTABLE')
  186 FORMAT(15X,'WASTE FEED HAS SIGNIFICANT QUATITIES'/
     1 18X,'OF VOLATILES')
      WRITE(6,187) (XXSLUD(IJK),IJK=1,9),(XXFUEL(IJK),IJK=1,9),
     1             (XXAIR(IJK), IJK=1,9)
  187 FORMAT(25X,'COMPOSITON OF WASTE FEED, FUEL'/
     1       25X,'   AND AIR(WEIGHT PERCENT      '//
     2 5X,'  STREAM      H     C     O     N     CL    S     F     P     NE  '//
     3 5X,'WASTE FEED',9(2X,F5.3)/
     4 5X,'   FUEL   ',9(2X,F5.3)/
     5 5X,'    AIR   ',9(2X,F5.3))
      WRITE(6,188) ELEVAT,TA,PINC,FEDRG2
  188 FORMAT(10X,'AMBIENT CONDITIONS'/15X,
     1     'FACILITY CONDITONS=          ',F6.0,' FEET'/
     2 15X,'TEMPERATURE=                 ',F6.0,' FAHRENHEIT'/
     3 15X,'PRESSURE=                    ',F6.0,' PSIA'/
     4 15X,'PARTICULATE EMISSION LIMIT=  ',E15.5,'LB/ACF')
      IF(BRN) WRITE(6,932)
      IF(SCRW) WRITE(6,933)
      IF(BARREL) WRITE(6,934)
      IF(.NOT.BARREL) WRITE(6,935)
  932 FORMAT(10X,'BURNERS ARE USED FOR THE WASTE FEED SYSTEM')
  933 FORMAT(10X,'A SCREW AND CART SYSTEM IS USED FOR WASTE FEED')
  934 FORMAT(10X,'A BARREL BARN IS SPECIFIED TO STORE THE WASTE FEED')
  935 FORMAT(10X,'STORAGE TANKS ARE USED TO STORE WASTE')
  170 WRITE(6,4013)
      READ*, ITEMP
      IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 170
      IF(ITEMP.EQ.1) GOTO 189
          FEDPT=.TRUE.
          GOTO 200
  189 JJ=0
 5000 JJ=JJ+1
      CS=.FALSE.
      SS=.FALSE.
      IC=.FALSE.
      IF(MATL(JJ).EQ.MATLC(1)) CS=.TRUE.
      IF(MATL(JJ).EQ.MATLC(2)) SS=.TRUE.
      IF(MATL(JJ).EQ.MATLC(3)) IC=.TRUE.
      WRITE(6,231) JJ,UNIT(JJ)
  231 FORMAT(I3,2X,A5)
      IF(SUNIT(8).EQ.UNIT(JJ)) GOTO 4015
      IF(SUNIT(2).EQ.UNIT(JJ)) GOTO 171
      IF(SUNIT(1).EQ.UNIT(JJ)) GOTO 4032
      IF(SUNIT(4).EQ.UNIT(JJ)) GOTO 177
      IF(SUNIT(5).EQ.UNIT(JJ)) GOTO 640
      IF(SUNIT(6).EQ.UNIT(JJ)) GOTO 643
      IF(SUNIT(3).EQ.UNIT(JJ)) GOTO 174
      IF(SUNIT(9).EQ.UNIT(JJ)) GOTO 646
      GOTO 5001
 4032 WRITE(6,4000)
      INCIP=.FALSE.
 4000 FORMAT(10X,'INCINERATOR INPUT DATA')
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      IF(ROTARY) WRITE(6,4001)
      IF(FLUID)  WRITE(6,4002)
      IF(LIQI)   WRITE(6,4003)
      IF(PLASMA) WRITE(6,4004)
 4001 FORMAT(25X,'ROTARY KILN INCINERATOR')
 4002 FORMAT(25X,'FLUIDIZED BED INCINERATOR')
 4003 FORMAT(25X,'LIQUID INJECTION INCINERATOR')
 4004 FORMAT(25X,'PLASMA ARC PYROLYSIS PROCESS')
      IF(ADIA) WRITE(6,4005)
      IF(.NOT.ADIA) WRITE(6,4006) TTMP(JJ)
 4005 FORMAT(10X,'ADIABATIC COMBUSTION PROCESS')
 4006 FORMAT(10X,'OUTLET TEMPERATURE FROM INCINERATOR= ',F6.1)
      WRITE(6,4007) RETIM(JJ)
 4007 FORMAT(10X,'RETENTION TIME OF THE COMBUSTED GAS(SECONDS)= ',F6.1)
      WRITE(6,4008) EXCESS(JJ)
 4008 FORMAT(10X,'EXCESS AIR FOR COMBUSTION PROCESS= ',F6.1,'PERCENT')
      WRITE(6,936) EXFUEL(JJ)
  936 FORMAT(10X,'EXCESS FUEL FOR COMBUSTION PROCESS=',F6.1,'PERCENT')
      WRITE(6,4009) RLD(JJ)
 4009 FORMAT(10X,'LENGTH TO DIAMETER RATIO= ',F6.1)
      IF(IC) WRITE(6,4010)
 4010 FORMAT(10X,'MATERIAL OF CONSTRUCTION IS INCONEL')
      IF(SS) WRITE(6,4011)
 4011 FORMAT(10X,'MATERIAL OF CONSTRUCTION IS STAINLESS STEEL')
      IF(CS) WRITE(6,4012)
 4012 FORMAT(10X,'MATERIAL OF CONSTRUCTION IS CARBON STEEL')
      WRITE(6,937) PREXTI
  937 FORMAT(10X,'EXTRA COSTS INCLUDED WITH INCINERATOR= ',F6.3,
     1 ' PERCENT OF EQUIPMENT COST')
      IF(FLUID.AND.VALVE) WRITE(6,938)
      IF(FLUID.AND.SIEVE) WRITE(6,939)
  938 FORMAT(10X,'VALVES TRAYS USED TO COST ESTIMATE FLUIDIZED BED ',
     1 'SUPPORT TRAYS')
  939 FORMAT(10X,'SIEVE TRAYS USED TO COST EXTIMATE FLUIDIZED BED ',
     1 'SUPPORT TRAYS')
 4014 WRITE(6,4013)
 4013 FORMAT(10X,'IF THE DATA HAS BEEN ENTERED CORRECTLY, ENTER 1;'
     1 /10X,'IF CHANGES ARE NEEDED ENTER 2')
      READ*, TEMPER
      IF(TEMPER.GT.2.OR.TEMPER.LT.1) GOTO 4014
      IF(TEMPER.EQ.1) GOTO 5001
         INCIP=.TRUE.
         GOTO 4016
 4015 WRITE(6,4017)
      AFTINC=.FALSE.
 4017 FORMAT(25X,'AFTERBURNER INPUT DATA')
      IF(METRIC) WRITE(6,4018)TTMP(JJ)
      IF(ENGL)   WRITE(6,4019) TTMP(JJ)
 4018 FORMAT(10X,'OUTLET TEMPERATURE= ',F6.1,' CELCIUS')
 4019 FORMAT(10X,'OUTLET TEMPERATURE= ',F6.1,'FAHRENHEIT')
      WRITE(6,4020) RETIM(JJ)
 4020 FORMAT(10X,'RETENTION TIME OF AFTERBURNER=',F6.1,' SECONDS')
      WRITE(6,4021) EXCESS(JJ)
      WRITE(6,4022) EXFUEL(JJ)
      WRITE(6,4023) RLD(JJ)
      WRITE(6,878) PREXT
  878 FORMAT(10X,'CONTENGENCY COST FACTOR= ',F6.3)
 4021 FORMAT(10X,'EXCESS AIR= ',F5.1,'PERCENT')
 4022 FORMAT(10X,'EXCESS FUEL= ',F5.1,' PERCENT')
 4023 FORMAT(10X,'LENGTH TO DIAMETER RATIO= ',F5.1)
      IF(IC) WRITE(6,4024)
      IF(SS) WRITE(6,4025)
      IF(CS) WRITE(6,4026)
 4024 FORMAT(10X,'AFTERBURNER MATERIALS IN INCONEL CLAD')
 4025 FORMAT(10X,'AFTERBURNER MATERIALS IS STAINLESS STEEL')
 4026 FORMAT(10X,'AFTERBURNER MATERIALS IS CARBON STEEL')
 4030 WRITE(6,4013)
      READ*, ITEMP
      IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 4030
      IF(ITEMP.EQ.1) GOTO 4031
      AFTINC=.TRUE.
      GOTO 4016
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171 WRITE(6,172)
    QUNCH=.FALSE.
172 FORMAT(25X,'QUENCH CHAMBER INPUT DATA')
    IF(CS) WRITE(6,4012)
    IF(SS) WRITE(6,4011)
    IF(IC) WRITE(6,4010)
     IF(QSAT.EQ.1.0) WRITE(6,940)
     IF(QTEMP.EQ.1.0) WRITE(6,941) TTMP(JJ)
940 FORMAT(10X,'EMISSION GASES COOLED TO SATURATION')
941 FORMAT(10X,'GASS COOLED TO EXIT TEMPERATURE= ',F9.2,' FAHRENHEIT')
173 WRITE(6,4013)
    READ*, ITEMP
    IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 173
    IF(ITEMP.EQ.1) GOTO 5001
        QUNCH=.TRUE.
        GOTO 4016
174 WRITE(6,175)
175 FORMAT(25X,'INPUT DATA FOR HEAT RECOVERY BOILER')
    IF(CS) WRITE(6,4012)
    IF(SS) WRITE(6,4011)
    IF(IC) WRITE(6,4010)
    HTEIN=.FALSE.
    IF(FXH) WRITE(6,942)
    IF(KRB) WRITE(6,943)
    IF(UTB) WRITE(6,944)
942 FORMAT(10X,'HEAT ROCOVERY BOILER IS A FIXED-HEAD EXCHANGER')
943 FORMAT(10X,'HEAT ROCOVERY BOILER IS A KETTLE EXCHANGER')
944 FORMAT(10X,'HEAT ROCOVERY BOILER IS A U-TUBE EXCHANGER')
    WRITE(6,945) TTMP(JJ)
945 FORMAT(10X,'OUTLET TEMPERATURE FROM REBOILER IS=',F9.2,
   1 ' FAHRENHEIT')
    IF(S316) WRITE(6,946)
    IF(S304) WRITE(6,947)
    IF(S347) WRITE(6,948)
    IF(NI200) WRITE(6,949)
    IF(MO400) WRITE(6,950)
    IF(IN600) WRITE(6,951)
    IF(IN825) WRITE(6,952)
    IF(TI) WRITE(6,953)
    IF(HS) WRITE(6,954)
946 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF STAINLESS STEEL 316')
947 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF STAINLESS STEEL 304')
948 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF STAINLESS STEEL 347')
949 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF NICKEL 200')
950 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF MOLYEBDENUM 300')
951 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF INCONEL 600')
952 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF INCONEL 825')
953 FORMAT(10X,'HEAT EXCHANGER CONSTRUCTED OF TITANIUM')
954 FORMAT(10X,'HEAT EXHANGER CONSTRUCTED OF HASTELLOY')
    WRITE(6,955) HTC
955 FORMAT(10X,'HEAT TRANSFER COEFFICIENT=    ',F9.3,' BTU/FT°2/HR',
   1 '/FAHRENHEIT')
176 WRITE(6,4013)
    READ*, ITEMP
    IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 176
    IF(ITEMP.EQ.1) GOTO 5001
         HTEIN=.TRUE.
         GOTO 4016
177 WRITE(6,178)
    VININ=.FALSE.
178 FORMAT(25X,'INPUT DATA FOR VENTURI SCRUBBER ')
    IF(CS) WRITE(6,4012)
    IF(SS) WRITE(6,4011)
    IF(IC) WRITE(6,4010)
    WRITE(6,956) VENWAT
956 FORMAT(10X,'WATER RATE IN THE VENTURI SCRUBBER= ',F9.2,' LB H2O/'
   1 ,' 1000 ACF OF GAS')
    IF(FG) WRITE(6,957)
957 FORMAT(10X,'FIBERGLASS IS USED TO LINE THE SCRUBBER THROAT')
    IF(VENAUT) WRITE(6,958)
    IF(.NOT.VENAUT) WRITE(6,959)
958 FORMAT(10X,'AUTOMATIC PRESSURE DROP THROAT ADJUSTMENT IS SPECIFIED
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     1')
 959 FORMAT(10X,'MANUAL PRESSURE DROP THROAT ADJUSTMENT IS SPECIFIED')
     IF(PRI) WRITE(6,960)
     IF(.NOT.PRI) WRITE(6,961) DPTOT
 960 FORMAT(10X,'PRESSURE DROP IS CALCULATED FROM EXPERIMENTAL DATA')
 961 FORMAT(10X,'PRESSURE DROP IS SPECIFIED DIRECTLY=',F9.2,
    1 'INCHES OF H2O')
     IF(.NOT.PRI) GOTO 962
     WRITE(6,963)
 963 FORMAT(15X,'PARTICLE DIAMETER                WEIGHT'/
    1       15X,'    (MICRONS)                  (PERCENT)')
     DO 964 IL=1,NPRTS
        WRITE(6,965) DIAPT(IL),WTPRT(IL)
 965 FORMAT(18X,F10.2,14X,F9.6)
 964 CONTINUE
 962 CONTINUE
 192 WRITE(6,4013)
     READ*,ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 192
     IF(ITEMP.EQ.1) GOTO 5001
           VININ=.TRUE.
           GOTO 4016
 640 WRITE(6,641)
     ININ=.FALSE.
 641 FORMAT(25X,'INPUT DATA FOR INDUCTION FANS')
     IF(CS) WRITE(6,4012)
     IF(SS) WRITE(6,4011)
     IF(IC) WRITE(6,4010)
     WRITE(6,966) TOTDP
 966 FORMAT(10X,'TOTAL PRESSURE HEAD THROUGH INDUCTION FAN=',F9.2,
    1 'INCHES H2O')
 642 WRITE(6,4013)
     READ*, ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 642
      IF(ITEMP.EQ.1) GOTO 5001
          ININ=.TRUE.
          GOTO 4016
 643 WRITE(6,644)
 644 FORMAT(25X,'INPUT DATA FOR PACKED BED ABSORBER')
     IF(CS) WRITE(6,4012)
     IF(SS) WRITE(6,4011)
     IF(IC) WRITE(6,4010)
     WRITE(6,970) SCRNME(1)
     WRITE(6,971) HCLRM
     WRITE(6,972) PAKH2O
     WRITE(6,973) (PCKCHS(IJK),IJK=1,4)
     WRITE(6,974) PCKSIZ
 970 FORMAT(10X,'CAUSTIC TO BE SCRUBBED IS ',A15)
 971 FORMAT(10X,'OVERALL REMOVAL EFFICIENCY= ',F12.8)
 972 FORMAT(10X,'ABSORPTION WATER FEED RATE= ',F9.2,'GALLONS H2O/',
    1 ' 1000 FT°3 OF GAS')
 973 FORMAT(10X,'TYPE OF PACKING USED IS ',4(A4))
 974 FORMAT(10X,'SIZE OF PACKING IS= ',F6.1,' INCHES')
     WRITE(6,975) EFFABS,PRCFLD,NTU,SLPABS
 975 FORMAT(10X,'ABSORPTION PARAMETERS'/
    1       15X,'ABSORPTION EFFICIENCY=          ',F9.2,' OF IDEAL'/
    1       15X,'PERCENT FLOODING=               ',F9.2,' PERCENT'/
    2       15X,'NUMBER OF TRANSFER UNITS=       ',I4/
    3       15X,'SLOPE OF EQUILIBRIUM CURVE=     ',F6.1/
    4)
     WRITE(6,976) DFHCLG,DFHCLL
 976 FORMAT(15X,'DIFFUSION COEFFICIENT OF CAUSTIC IN GAS= ',F9.2,
    1 ' FT°2/SECOND'/
    2       15X,'DIFFUSION COEFFICIENT OF CAUSTIC IN LIQUID=',F9.2,
    3 ' FT°2/SECOND')
 645 WRITE(6,4013)
     PCIN=.FALSE.
     READ*, ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 645
     IF(ITEMP.EQ.1) GOTO 5001
          PCIN=.TRUE.
          GOTO 4016
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 646 WRITE(6,647)
     STKIN=.FALSE.
 647 FORMAT(25X,'INPUT DATA FOR EXHAUST STACK DESIGN')
     IF(CS) WRITE(6,4012)
     IF(SS) WRITE(6,4011)
     IF(IC) WRITE(6,4010)
     WRITE(6,977) HEIGHT
 977 FORMAT(10X,'HEIGHT OF THE EXHAUST STACK= ',F9.2,' FEET')
 648 WRITE(6,4013)
     READ*,ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 648
     IF(ITEMP.EQ.1) GOTO 5001
          STKIN=.TRUE.
          GOTO 4016
4031 CONTINUE
5001 CONTINUE
     IF(JJ.LE.NUNIT) GOTO 5000
 650 WRITE(6,649)
 649 FORMAT(25X,'INPUT DATA FOR DUCTWORK DESIGN'/
    1 10X,'  UNIT   MATERIALS   LENGTH(FEET)  # OF ELBOWS')
     DO 233 J=1,NUNIT
      IJ=J+1
     WRITE(6,651) J,IJ,DCMATL(J),DCTLEN(J),ELBNUM(J)
 651 FORMAT(10X,I2,' TO ',I2,5X,A5,2X,F9.2,2X,F9.2)
 233 CONTINUE
 652 WRITE(6,4013)
     READ*, ITEMP
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 652
     IF(ITEMP.EQ.1) GOTO 653
     DO 234 J=I,NUNIT
        CALL STAND(J)
 234 CONTINUE
 653 CONTINUE
1217 WRITE(6,1210) IYEAR,DAY,YEAR,REVLB,YRNUM
     WRITE(6,1211) FACCES,FACMSC,FACCEE,FACCEF,FACCEB,FACPVF,FACPC,
    1 FACPI
1210 FORMAT(25X,'ECONOMIC DATA FOR THE INCINERATION FACILITY'/
    1        25X,'              FOR THE YEAR ',I4/
    2 10X,'DAILY OPERATION=          ',F5.1/
    3 10X,'YEARLY OPERATION=         ',F5.1/
    4 10X,'COST FOR INCINERATION=  ',F6.1/
    5 10X,'TOTAL PROCESS LIFE=       ',F5.1/)
1211 FORMAT(25X,'COST FACTORS FROM CHEMICAL PROCESS INDUSTRY'/
    1        25X,'                 FOR ',I4/
    2 10X,'COST FACTOR FOR EQUIPMENT, MACHINERY, AND SUPPORTS=      ',
    2       F5.1/
    3 10X,'COST FACTOR FOR STRUCTURAL SUPPORTS AND MISCELLANIOUS=  ',
    3       F5.1/
    4 10X,'COST FACOTR FOR ELECTRICAL EQUIPMENT=                   ',
    4       F5.1/
    5 10X,'COST FACTOR FOR FABRICATED EQUIPMENT=                  ',
    5       F5.1/
    6 10X,'COST FACTOR FOR BUILDING=                             ',
    6       F5.1/
    7 10X,'COST FACTOR FOR PIPES, VALVES, AND FITTINGS=          ',
    7       F5.1/
    8 10X,'COST FACTOR FOR PUMPS AND COMPRESSORS=                ',
    8       F5.1/
    9 10X,'COST FACTOR FOR PROCESS INSTRUMENTS=                  ',
    9       F5.1)
     WRITE(6,1234) FACENG,FACLAB,FACPRS
1234 FORMAT(
    A 10X,'COST FACTOR FOR ENGINEERING AND SUPERVISION=         ',
    A       F5.1/
    B 10X,'COST FACTOR FOR CONSTRUCTION LABOR=                  ',
    B       F5.1/
    C 10X,'COST FACTOR FOR PROCESS MACHINERY=                   ',
    C       F5.1)
1215 WRITE(6,4013)
     READ*, ITEMP
     ECLOG=.FALSE.
     IF(ITEMP.GT.2.OR.ITEMP.LT.1) GOTO 1215
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      IF(ITEMP.EQ.2) ECLOG=.TRUE.
      IF(ITEMP.EQ.2) GOTO 21
      CCONT=CONTEN*100.0
      WRITE(6,127) CCONT
 127  FORMAT(10X,'CONTENGENCY COST FACTOR      =',F6.2,' PERCENT')
      CALL WRIT
      STOP
      END
      SUBROUTINE STAND(II)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,PRI,SLD,LQD,PLASMA,BRN,ADIA
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*20
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
      CHARACTER MATLC*2,SCRNME*20,FLNAM*15
      DIMENSION MATLC(4)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9);DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,EXFUEL(9),FEDRG2
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC
     1,AOP,WTPVOL,WTPH2O,WATRAT,NTU,AOQ,CSTSTO,SCHMDT,PRCFLD
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,PREXTI,DPTOT,PREXT,ELEVAT,TOTDP,QSET,QTEMP,HCLRM
     2 ,CSTIIN,CSTSTR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  VENWAT,DIAPT(100),WTPRT(100),FINCRG,REFINS,THCKIN,EQFVIN
       COMMON/UPDATE/ FACSUM,FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1 ,FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NPRTS,NUMBRN
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK,SCRNME(6)
     2,WSTNME(6),BNMFR(6),BNMIN(6),FLNAM
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC
     2,SLD,SCRW,VENAUT,PLASMA,BRN,ADIA,PRI,FG,LQD
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
C
      III=II+1
      WRITE(6,103) II,III
 103  FORMAT(10X,'FOR DUCTWORK DETWEEN UNITS',I2,' AND ',I2)
      IF(ENGL) WRITE(6,104)
      IF(METRIC) WRITE(6,107)
 104  FORMAT(10X,'INPUT THE LENGTH OF THE DUCTWORK ',
     1 '(FEET)')
 107  FORMAT(10X,'INPUT THE LENGTH OF THE DUCTWORK FROM UNIT',
     1 ' TO THE NEXT UNIT(M)')
      READ*, DCTLEN(II)
      WRITE(6,105)
 105  FORMAT(10X,'INPUT THE NUMBER OF BENDS IN THE DUCTWORK')
      READ*, ELBNUM(II)
 112  WRITE(6,106)
 106  FORMAT(10X,'INPUT THE MATERIAL USED FOR DUCTWORK'/15X,'1 - IC'/
     1 15X,'2 - SS'/15X,'3 - CS'/15X,'4 - WATER COOLED')
      READ*, TEMPER
      IF(TEMPER.EQ.1) DCMATL(II)='IC'
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      IF(TEMPER.EQ.2) DCMATL(II)='SS'
      IF(TEMPER.EQ.3) DCMATL(II)='CS'
      IF(TEMPER.EQ.4) DCMATL(II)='WC'
      IF(TEMPER.GT.4.0.OR.TEMPER.LT.1.0) WRITE(6,111)
  111 FORMAT(10X,'SELECTION OUT OF RANGE. RESPECIFY')
      IF(TEMPER.GT.4.0.OR.TEMPER.LT.1.0) GOTO 112
      RETURN
      END
      SUBROUTINE DEFALT
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,PRI,SLD,LQD,PLASMA,BRN,ADIA
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*20
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
      CHARACTER MATLC*2,SCRNME*20,FLNAM*15
      DIMENSION MATLC(4)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,EXFUEL(9),FEDRG2
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC
     1,AOP,WTPVOL,WTPH2O,WATRAT,NTU,AOQ,CSTSTO,SCHMDT,PRCFLD
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,PREXTI,DPTOT,PREXT,ELEVAT,TOTDP,QSET,QTEMP,HCLRM
     2 ,CSTIIN,CSTSTR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  VENWAT,DIAPT(100),WTPRT(100),FINCRG,REFINS,THCKIN,EQFVIN
       COMMON/UPDATE/ FACSUM,FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1 ,FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NPRTS,NUMBRN
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK,SCRNME(6)
     2,WSTNME(6),BNMFR(6),BNMIN(6),FLNAM
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC
     2,SLD,SCRW,VENAUT,PLASMA,BRN,ADIA,PRI,FG,LQD
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
C
   50  WRITE(6,100)
  100 FORMAT(10X,'SELECT TYPE OF AUXILLARY HEAT '/15X,'1 - NATURAL GAS'/
     1 15X,'2 - FUEL OIL #2')
      READ*,INTER
      IF(INTER.NE.1) GOTO 20
          FLNAM='NATURAL GAS'
          ZFLHT=1020*16.044*10.73 *(459.96+60.0)/14.696
          GOTO 40
   20 IF(INTER.NE.2) GOTO 30
          FLNAM='FUEL OIL#2'
          ZFLHT=13970.0
          GOTO 40
   30 WRITE(6,300)
  300 FORMAT(10X,'SELECTION OUT OF RANGE. RESPECIFY')
      GOTO 50
   40 CONTINUE
      TEKC=7.0
      SECC=7.0
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      SUPC=8.0
      DO 10 I=1,8
         XXAIR(I)=0.0
         XXFUEL(I)=0.0
   10 CONTINUE
      XXFUEL(1)=0.0130
      XXFUEL(2)=0.9870
      XXAIR(3)=0.2332
      XXAIR(4)=0.7672
      FACMSC=796.7
      FACCEE=347.6
      FACCEF=337.9
      FACCEB=302.4
      FACCES=345.6
      TEKC=7.00
      SECC=7.00
      SUPC=8.00
      DAY=24.0
      YEAR=260.0
      RETURN
      END
      SUBROUTINE WRIT
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,PRI,SLD,LQD,PLASMA,BRN,ADIA
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*20
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
      CHARACTER MATLC*2,SCRNME*20,FLNAM*15
      DIMENSION MATLC(4)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,EXFUEL(9),FEDRG2
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC
     1,AOP,WTPVOL,WTPH2O,WATRAT,NTU,AOQ,CSTSTO,SCHMDT,PRCFLD
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,PREXTI,DPTOT,PREXT,ELEVAT,TOTDP,QSET,QTEMP,HCLRM
     2 ,CSTIIN,CSTSTR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  VENWAT,DIAPT(100),WTPRT(100),FINCRG,REFINS,THCKIN,EQFVIN
       COMMON/UPDATE/ FACSUM,FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1 ,FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NPRTS,NUMBRN
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK,SCRNME(6)
     2,WSTNME(6),BNMFR(6),BNMIN(6),FLNAM
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC
     2,SLD,SCRW,VENAUT,PLASMA,BRN,ADIA,PRI,FG,LQD
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
C     OPEN(UNIT=12,FILE='ANS',STATUS='NEW')
      WRITE(12,205) DAY,YEAR
  205 FORMAT(1X,F4.1,1X,F5.1)
       WRITE(12,71) WSTNME(1)
   71 FORMAT(1X,A20)
      WRITE(12,70)(XXSLUD(I),I=1,9)
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      WRITE(12,70)(XXFUEL(I),I=1,9)
      WRITE(12,70)(XXAIR(I),I=1,9)
   70 FORMAT(1X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4
     1,2X,F6.4,2X,F6.4)
      WRITE(12,20) MASSSL,ZSLHT
      WRITE(12,207) FLNAM,ZFLHT
  207 FORMAT(1X,A15,F7.1)
   20 FORMAT(1X,2F11.4)
      WRITE(12,76) BRN,SCRW,BARREL,RECT,SLD,LQD,CMBST
   76 FORMAT(1X,L1)
      WRITE(12,73) WTPH2O,WTPVOL
      WRITE(12,30) METRIC,ENGL,LCOST
   73 FORMAT(1X,F9.7)
      WRITE(12,90) NUNIT
   90 FORMAT(1X,I2)
      TTMP(NUNIT+1)=TA
      WRITE(12,110) TTMP(NUNIT+1),PINC,ELEVAT,FEDRG2
  110 FORMAT(1X,F10.2)
      WRITE(12,100) (UNIT(I),MATL(I),TTMP(I)
     1,DCTLEN(I),ELBNUM(I),DCMATL(I),I=1,NUNIT)
      DO 130 I=1,NUNIT
  100 FORMAT(1X,A3,1X,A2,F10.2,F10.5,F4.1,1X,A2)
            IF(UNIT(I).EQ.SUNIT(1)) GOTO 700
            IF(UNIT(I).EQ.SUNIT(2)) GOTO 713
            IF(UNIT(I).EQ.SUNIT(3)) GOTO 710
            IF(UNIT(I).EQ.SUNIT(4)) GOTO 712
            IF(UNIT(I).EQ.SUNIT(5)) GOTO 711
            IF(UNIT(I).EQ.SUNIT(6)) GOTO 707
            IF(UNIT(I).EQ.SUNIT(7)) GOTO 130
            IF(UNIT(I).EQ.SUNIT(8)) GOTO 708
            IF(UNIT(I).EQ.SUNIT(9)) GOTO 709
            GOTO 130
  700 WRITE(12,30) ROTARY,FLUID,LIQI,HTLS
   30 FORMAT(1X,L1)
      WRITE(12,40) RETIM(I),RLD(I),EXCESS(I),EXFUEL(I)
      WRITE(12,73) PREXTI
      WRITE(12,76) ADIA,SIEVE,VALVE
       GOTO 130
  711 WRITE(12,110) TOTDP
      GOTO 130
  712 WRITE(12,110) VENWAT,DPTOT
      WRITE(12,76) PRI
      IF(.NOT.PRI) GOTO 241
      WRITE(12,31) NPRTS
   31 FORMAT(1X,I3)
      DO 32 IJ=1,NPRTS
         WRITE(12,33) DIAPT(IJ),WTPRT(IJ)
   32 CONTINUE
  241 WRITE(12,222) FEDRG2
  222 FORMAT(1X,E15.5)
      WRITE(12,76) VENAUT,FG
      GOTO 130
  713 WRITE(12,221) QSAT,QTEMP
  221 FORMAT(1X,2F3.1)
   33 FORMAT(1X,F9.5)
      GOTO 130
  707 WRITE(12,720) (PCKCHS(JJ),JJ=1,4),PCKSIZ,EFFABS,NTU,SCHMDT,PRCFLD
       WRITE(12,208) WATRAT,SLPABS,HCLRM
  208 FORMAT(1X,F6.3,F6.2,F8.4)
      WRITE(12,209) SCRNME(1)
  209 FORMAT(1X,A20)
      WRITE(12,211) DFHCLL,DFHCLG
  211 FORMAT(1X,F10.2)
   40 FORMAT(1X,F10..2)
  720 FORMAT(1X,4A4,F6.2,F10.8,I3,F6.3,F6.2)
      GOTO 130
  708 WRITE(12,134) RLD(I)
      WRITE(12,134) RETIM(I)
  134 FORMAT(1X,F10.5)
      WRITE(12,223) PREXT
  223 FORMAT(1X,F9.7)
      GOTO 130
```

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  709 WRITE(12,212) HEIGHT
  212 FORMAT(1X,F5.1)
      WRITE(12,76) VOLTIL
      GOTO 130
  710 WRITE(12,76) FXH,KRB,UTB,HM1,HM2
      WRITE(12,76) S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
      WRITE(12,110) HTC
  130 CONTINUE
      WRITE(12,200) FACMSC,FACCEE,FACCEF,FACCEB,FACCES,
     1 FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS,IYEAR
  200 FORMAT(2X,11F6.1,I5)
      WRITE(12,210) YRNUM,RTINST,REVLB,CONTEN
  210 FORMAT(1X,F4.1,F4.1,F8.3,F8.3)
C     CLOSE(12)
      RETURN
       END
      SUBROUTINE INPT(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,PRI,SLD,LQD,PLASMA,BRN,ADIA
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
      LOGICAL INCIP,AFTINC
      LOGICAL FEDPT,QUNCH,HTEIN,VININ,ININ,PCIN,STKIN
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*20
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
      CHARACTER MATLC*2,SCRNME*20,FLNAM*15
      CHARACTER ELEMNT*10
      DIMENSION MATLC(4),ELEMNT(9)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,EXFUEL(9),FEDRG2
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC
     1,AOP,WTPVOL,WTPH2O,WATRAT,NTU,AOQ,CSTSTO,SCHMDT,PRCFLD
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,PREXTI,DPTOT,PREXT,ELEVAT,TOTDP,QSET,QTEMP,HCLRM
     2 ,CSTIIN,CSTSTR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  VENWAT,DIAPT(100),WTPRT(100),FINCRG,REFINS,THCKIN,EQVFIN
       COMMON/UPDATE/ FACSUM,FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1 ,FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NPRTS,NUMBRN
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK,SCRNME(6)
     2,WSTNME(6),BNMFR(6),BNMIN(6),FLNAM
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL
     1,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC
     2,SLD,SCRW,VENAUT,PLASMA,BRN,ADIA,PRI,FG,LQD
     3 ,KRB,FXH,UTB,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
     2 , HT1,HT2,HT3,VALVE,SIEVE,CMBST,HM1,HM2,ECLOG
C
C WATER RATE BETWEEN 15 AND 35 GAL/FT GAS  FLOW
      BRN=.FALSE.
      ELEVAT=20000.0
      VENWAT= 0.003
      QSAT=0.0
      QTEMP=1.0
      PRI=.FALSE.
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      NPRTS=0.0
      FEDRG2=1.142E-05
C   LB/ACF
        PREXT=0.10
        PREXTI = 0.10
C     PERCENT EXTRA COST
      ADIA=.FALSE.
        PLASMA=.FALSE.
        SIEVE=.FALSE.
        VALVE=.TRUE.
      WATRAT=15.
      VOLTIL=.FALSE.
      VENAUT=.FALSE.
      FG=.FALSE.
      FANCLS=4.0
      IF(IDEBUG.GT.25) WRITE(6,79)
   79 FORMAT(10X,'*****  1SUMMARY OF INPUT DATA *****')
      RTINST=0.10
      TOTDP=60.0
      YRNUM=10.0
      REVLB=400.0/2000.0
      FINCRG=12.0
      AOP=0.24
      AOQ=3.725
      WSTNME(1)='TEST '
      WSTNME(2)='SLUDG'
      WSTNME(3)='E NUM'
      WSTNME(4)='BER 1'
      WSTNME(5)='     '
      WSTNME(6)='     '
        CONTEN=20.0
      SLD=.FALSE.
        LQD=.TRUE.
      HEIGHT=100.0
      FACMSC=796.7
      FACCEE=347.6
      FACCEF=337.9
      FACCEB=302.4
      FACCES=345.6
      TEKC=7.00
      SECC=7.00
      SUPC=8.00
      DAY=24.0
      YEAR=300.0
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE INPT')
      IJKLM=1
      IF(IJKLM.EQ.1) GOTO 1200
      READ(4,12)
      READ(4,10) (CP(1,J),CP(2,J),CP(3,J),CP(4,J),CP(5,J),CP(6,J),
     1 PRDMW(J),J=1,NPRD)
   11 FORMAT(1X,6E11.4)
   12 FORMAT(/////)
   10 FORMAT(1X,6E11.4,F10.5)
      DO 60 J=1,8
      READ(4,50)(BRIKNM(I,J),I=1,6), TLIM(J),TKOND(J),NRES(J),BCOST(J)
   50 FORMAT(1X,6(A4),2X,F9.4,2X,F8.4,2X,I1,2X,F9.4)
      IF(IDEBUG.GT.10)WRITE(6,50)(BRIKNM(I,J),I=1,6), TLIM(J),TKOND(J)
     1 ,NRES(J),BCOST(J)
   60 CONTINUE
      READ(4,81)
   81 FORMAT(///)
      DO 140 J=1,1
      READ(4,74) (FUELNM(I,J),I=1,5),PRICE,HTCNT,FULC,ZFLHT
   74 FORMAT(1X,5A3,F7.2,F10.2,2E11.4)
  140 CONTINUE
      READ(4,215)
  215 FORMAT(/////)
      DO 220 J=1,7
         READ(4,210) (PCKNAM(J,JJ),JJ=1,4),PSIZE(J),CSTPK(J)
     1 ,(CONST(J,JJ),JJ=1,3),(PAKRAG(J,JJ),JJ=1,4),(CONST(J,JJ),JJ=4,7)
      IF(IDEBUG.LT.10) GOTO 220
```

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      IF(IDEBUG.GT.5)WRITE(6,210) (PCKNAM(J,JJ),JJ=1,4),PSIZE(J),CSTP
     1K(J),(CONST(J,JJ),JJ=1,3),(PAKRAG(J,JJ),JJ=1,4),(CONST(J,JJ),JJ=4
     2,7)
  210 FORMAT(1X,4A4,F4.1,2F6.2,2F5.2,3F2.0,F3.0,F8.5,F5.2,F7.2,F8.5)
  220 CONTINUE
      READ(4,75) STMCST,WTRCST,DSPCST,CSTFUL,CSTELC,CSTLME
   75 FORMAT(/1X,F11.6,F11.6,F11.6,F11.6,F11.6,F11.6)
      IF(IDEBUG.GT.25)WRITE(6,78) STMCST,WTRCST,DSPCST,CSTFUL,CSTELC
   78 FORMAT(10X,'COST OF RECOVERED STEAM = ',3X,F8.6,' $/LB'/
     1 10X,'COST OF WATER = ',14X,F8.6,' $/LB'/
     2 10X,'COST OF WASTE ASH AND WATER = ',F8.2,' $/LB TREATED'/
     3 10X,'COST OF FUEL = ',12X,F8.6,' $/LB'/
     4 10X,'COST OF ELECTRICITY =',4X,F8.6,'$/KWH')
      READ(4,76) HSTVAP
 1200 CONTINUE
      HSTVAP=HSTVAP*1000.0
   76 FORMAT(1X,F10.5)
      READ(14,732) DAY,YEAR
  732 FORMAT(1X,F4.1,1X,F5.1)
      READ(14,4000) WSTNME(1)
 4000 FORMAT(1X,A20)
      READ(14,70)(XXSLUD(I),I=1,9)
      READ(14,70)(XXFUEL(I),I=1,9)
      READ(14,70)(XXAIR(I),I=1,9)
      READ(14,72) MASSSL,ZSLHT
      CLMS = MASSSL*XXSLUD(5)
      READ(14,734) FLNAM,ZFLHT
  734 FORMAT(1X,A15,F7.1)
      READ(14,733) BRN,SCRW,BARREL,RECT,SLD,LQD,CMBST
  733 FORMAT(1X,L1)
   72 FORMAT(1X,2F11.4)
   70 FORMAT(1X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4
     1,2X,F6.4,2X,F6.4)
      IF (IDEBUG.GT.5) WRITE(6,55)
   55 FORMAT('         BRICK TYPE      ,    TLIM    , THERM COND  , CL?, COS
     1T')
     IF(IDEBUG.GT.5) WRITE(6,76) HSTVAP
     IF(IDEBUG.GT.5) WRITE(6,77) PRICE,HTCNT,FULC
     1,ZFLHT
   77 FORMAT(5X,'PRICE= ',E15.5,'HEAT CONTENT= ',E15.5, 'FUEL COST',
     1'= ',E15.5/10X,'HEAT OF COMBUSTION= ',E15.5)
      IF(IDEBUG.GT.5)WRITE(6,456) ZFLHT
  456 FORMAT(10X,'HEAT OF COMBUSTION (IN INPUT UNITS)= ',E15.5)
      READ(14,73) WTPH2O,WTPVOL
      READ(14,30) METRIC,ENGL,LCOST
   73 FORMAT(1X,F9.7)
      FREH2O=WTPH2O*MASSSL
      VOLIT=WTPVOL*MASSSL
      ASH=MASSSL-FREH2O-VOLIT
      READ(14,90) NUNIT
   90 FORMAT(1X,I2)
      READ(14,110) TTMP(NUNIT+1),PINC,ELEVAT,FEDRG2
  110 FORMAT(1X,F10.2)
      TA=TTMP(NUNIT+1)
      READ(14,100) (UNIT(I),MATL(I),TTMP(I)
     1,DCTLEN(I),ELBNUM(I),DCMATL(I),I=1,NUNIT)
      DO 130 I=1,NUNIT
      IF(IDEBUG.GT.5) WRITE(6,100) UNIT(I),MATL(I),TTMP(I+1)
     1,DCTLEN(I),ELBNUM(I),DCMATL(I)
  100 FORMAT(1X,A3,1X,A2,F10.2,F10.5,F4.1,1X,A2)
            IF(UNIT(I).EQ.SUNIT(1)) GOTO 700
            IF(UNIT(I).EQ.SUNIT(2)) GOTO 804
            IF(UNIT(I).EQ.SUNIT(3)) GOTO 801
            IF(UNIT(I).EQ.SUNIT(4)) GOTO 803
            IF(UNIT(I).EQ.SUNIT(5)) GOTO 802
            IF(UNIT(I).EQ.SUNIT(6)) GOTO 707
            IF(UNIT(I).EQ.SUNIT(7)) GOTO 130
            IF(UNIT(I).EQ.SUNIT(8)) GOTO 708
            IF(UNIT(I).EQ.SUNIT(9)) GOTO 800
            GOTO 130
  700 READ(14,30) ROTARY,FLUID,LIQI,HTLS
   30 FORMAT(1X,L1)
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      READ(14,40) RETIM(I),RLD(I),EXCESS(I),EXFUEL(I)
      READ(14,73) PREXTI
      READ(14,30) ADIA,SIEVE,VALVE
        GOTO 130
  707 READ(14,720) (PCKCHS(JJ),JJ=1,4),PCKSIZ,EFFABS,NTU,SCHMDT,PRCFLD
      READ(14,736) WATRAT,SLPABS,HCLRM
  736 FORMAT(1X,F6.3,F6.2,F8.4)
      READ(14,737) SCRNME(1)
  737 FORMAT(1X,A20)
      READ(14,911) DFHCLL,DFHCLG
  911 FORMAT(1X,F10.2)
  730 FORMAT(1X,F10.2)
  720 FORMAT(1X,4A4,F6.2,F10.7,I3,F6.3,F6.2)
      IF(IDEBUG.GE.25)
     1 WRITE(6,43) (PCKCHS(JJ),JJ=1,4),PCKSIZ,EFFABS,NTU,SCHMDT,PRCFLD
   43 FORMAT(10X,'PACKING TYPE CHOSEN= ',4(A4),'PACKING SIZE(IN)= ',
     1 F9.2/10X,'EFFECTIVE ABSOPTION = ',F9.0,'NTU= ',I5/
     2 10X,'SCHMIDT NUMBER= ',E15.5,'PERCENT OF FLOODING= ',F9.2)
      GOTO 130
  708 READ(14,134) RLD(I)
      READ(14,134) RETIM(I)
  134 FORMAT(1X,F10.5)
      READ(14,73) PREXT
      GOTO 130
  800 READ(14,1) HEIGHT
    1 FORMAT(1X,F5.1)
      READ(14,30) VOLTIL
      GOTO 130
  801 READ(14,30) FXH,KRB,UTB,HM1,HM2
      READ(14,30) S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
      READ(14,110) HTC
      GOTO 130
  802 CONTINUE
      READ(14,110) TOTDP
        GOTO 130
  803 READ(14,110) VENWAT,DPTOT
      READ(14,30) PRI
      IF(.NOT.PRI) GOTO 34
      READ(14,31) NPRTS
   31 FORMAT(1X,I3)
      DO 32 IJ=1,NPRTS
         READ(14,33) DIAPT(IJ),WTPRT(IJ)
   33 FORMAT(1X,2F9.5)
   32 CONTINUE
   34 READ(14,813) FEDRG2
  813 FORMAT(1X,E15.5)
      READ(14,30) VENAUT,FG
        GOTO 130
  804 READ(14,221) QSAT,QTEMP
  221 FORMAT(1X,2F3.1)
        GOTO 130
  130 CONTINUE
      READ(14,731) FACMSC,FACCEE,FACCEF,FACCEB,FACCES,
     1 FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS,IYEAR
  731 FORMAT(2X,11F6.1,I5)
      READ(14,742) YRNUM,RTINST,REVLB,CONTEN
  742 FORMAT(1X,F4.1,F4.1,F8.3,F8.3)
      DO 200 II=1,NUNIT
        IF(EXCESS(II).GT.1.0) WRITE(6,71) II
   71 FORMAT(2X,'WARNING! EXCESS AIR IS GREATER THAN 1 IN UNIT',F5.1)
  200 CONTINUE
   40 FORMAT(1X,F10.2)
      IF(IDEBUG.GT.5) WRITE(6,30) ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HT
     1LS
      IF(IDEBUG.GT.5) WRITE(6,41) PINC
   41 FORMAT(10X,'INLET PRESSURE TO INCINERATOR = ',F6.2,' PSIA')
        IF(IDEBUG.LT.10) GOTO 765
      WRITE(6,150) (CP(1,J),CP(2,J),CP(3,J),CP(4,J),CP(5,J),CP(6,J),
     1 PRDMW(J),J=1,NPRD)
  150 FORMAT(1X,'SPEC.        A     ,       B      ,     C    , ,     D     ,
     A TLOW  , THIGH   ,    MW'              //
     1 3X,'H2O   ',4E11.3,4X,2F7.2,F9.4/3X,'HCL   ',4E11.3,4X,2F7.2,F9.4/
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     2 3X,'CO2  ',4E11.3,4X,2F7.2,F9.4/3X,'CO   ',4E11.3,4X,2F7.2,F9.4/
     3 3X,'N2   ',4E11.3,4X,2F7.2,F9.4/3X,'O2   ',4E11.3,4X,2F7.2,F9.4/
     4 3X,'NO   ',4E11.3,4X,2F7.2,F9.4/3X,'NO2  ',4E11.3,4X,2F7.2,F9.4/
     5 3X,'CL2  ',4E11.3,4X,2F7.2,F9.4/3X,'SO2  ',4E11.3,4X,2F7.2,F9.4/
     6 3X,'H2SO4',4E11.3,4X,2F7.2,F9.4/3X,'F2   ',4E11.3,4X,2F7.2,F9.4/
     7 3X,'HF   ',4E11.3,4X,2F7.2,F9.4/3X,'P2O6 ',4E11.3,4X,2F7.2,F9.4/
     8 3X,'NE   ',4E11.3,4X,2F7.2,F9.4)
   765 CONTINUE
       IF(IDEBUG.GT.5)WRITE(6,38) (XXSLUD(I),XXFUEL(I),XXAIR(I),I=1,9)
    38 FORMAT(////25X,'MASS FRACTION OF FEED STREAMS'//13X,'SPECIES     S
     1LUDGE        FUEL        AIR'/15X,'   H    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'   C    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'   O    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'   N    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'  CL    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'   S    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'   F    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'   P    ',2X,F7.5,5X,F7.5,5X,F7.5/
     1 15X,'  NE    ',2X,F7.5,5X,F7.5,5X,F7.5/)
       PEXT=PINC
       IF(IDEBUG.GE.25) WRITE(6,82)
    82 FORMAT(10X,'**************************************************')
       RETURN
       END
```

PROGRAM HWSTBRN

```
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      CHARACTER MATLC*2
      DIMENSION MATLC(4)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
        COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C
C     INITIALIZE VARIABLES
C
      IDEBUG=0
       DO 1200 I=1,100
       DIAPT(I)=0.0
       WTPRT(I)=0.0
 1200 CONTINUE
      VISCG=0.0
      VISCL=0.0
      TOCOST=0.0
      TOTCAP=0.0
      SUNIT(1)='INC'
      SUNIT(2)='QUE'
      SUNIT(3)='HTE'
      SUNIT(4)='VEN'
      SUNIT(5)='IND'
      SUNIT(6)='PCK'
      SUNIT(7)='TRA'
      SUNIT(8)='AFT'
      SUNIT(9)='STK'
      SUNIT(10)='ADI'
      SUNIT(11)='   '
      MATLC(1)='IC'
      MATLC(2)='SS'
      MATLC(3)='CS'
```

```
      MATLC(4)='WC'
      FLTOT=0.0
      CSTSTC=0.0
      CSTEM=0.0
      AFTINC=0.0
      CSTMTB=0.0
      CSTPAK=0.0
      CSTHTR=0.0
      CSTQUE=0.0
      CSTFAN=0.0
      CSTSTK=0.0
      TOTLAB=0.0
      TTMAIN=0.0
      CSTSIT=0.0
      CSTIIN=0.0
      CSTSTR=0.0
      CSTSPR=0.0
      CSTCRT=0.0
      CSTENG=0.0
      CSTINT=0.0
      TOTELC=0.0
      TOTH2O=0.0
      TTFUEL=0.0
      TTWSTD=0.0
      TTCAUS=0.0
      TTOPR=0.0
      CSTCNT=0.0
      CSTVEN=0.0
      DCTTST=0.0
      IYEAR=1985
      WTRTOT=0.0
      TOTMAN=0.0
      DO 60 III=1,9
      DESVOL(III)=0.0
         MSTOT(III)=0.0
         DIA(III)=0.0
         AREA(III)=0.0
         VOLRAT(III)=0.0
         INCLEN(III)=0.0
         EXCESS(III)=0.0
         RLD(III)=0.0
         DO 11 I=1,9
            DCDIA(I)=0.0
            DSDIA(I)=0.0
            DCTBCS(I)=0.0
            TDCTCS(I)=0.0
            MSSLUD(I,III)=0.0
             MLPRDT(I,III)=0.0
            MSFUEL(I,III)=0.0
            MSAIR(I,III)=0.0
            XXSLUD(I)=0.0
            XXFUEL(I)=0.0
            XXAIR(I)=0.0
            TKOND(I)=0.0
            TTMP(I)=0.0
            IF(I.GE.9) GOTO 11
               TLIM(I)=0.0
               BCOST(I)=0.0
               NRES(I)=0
               DO 12 L=1,6
                   BRIKNM(L,I)='    '
12             CONTINUE
11       CONTINUE
60    CONTINUE
      IC=.FALSE.
      SSG=.FALSE.
      BARREL=.FALSE.
      VOLTIL=.FALSE.
      LOC=2
      ROTARY=.FALSE.
      FLUID=.FALSE.
      LIQI=.FALSE.
```

```
      METRIC=.FALSE.
      ENGL=.FALSE.
      LCOST=.FALSE.
      PMPHP=0.0
      HPTOT=0.0
      DPTOT=0.0
      BLWHP=0.0
      DIABRK=0.0
      MASSSL=0.0
      MASSFL=0.0
      ZFLHT=0.0
      ZSLHT=0.0
      PINC=0.0
      PEXT=0.0
      T1=0.0
      T2=0.0
      HTCOMB=0.0
      BAL=.TRUE.
      SEMI=.FALSE.
      DO 13 JJ=1,20
          UNIT(JJ)='    '
          MATL(JJ)='    '
          IF(JJ.GE.16) GOTO 13
          PRDMW(JJ)=0.0
          DO 14 JJJ=1,6
             CP(JJJ,JJ)=0.0
   14     CONTINUE
   13 CONTINUE
       SHLCST=0.0
       DRVCST=0.0
       TBRNTT=0.0
       BRKTOT=0.0
       ASHCST=0.0
       NUMIT=0
       HTLS=.FALSE.
       RECT=.FALSE.
       NREAC=9
       NPRD=15
       RETIM(III)=0.0
       ZLOSS=0.0
C
C  READ IN PHYSICAL DESIGN AND COST DATA
C
      CALL INPT(NREAC,NPRD)
  234 FORMAT(3E15.4)
      MUNIT=NUNIT+1
C
C  DEBUG OUTPUT TO CHECK INPUTDATA
C
       DO 50  III=1,NUNIT
       IC=.FALSE.
       SS=.FALSE.
       CS=.FALSE.
       DIC=.FALSE.
       DSS=.FALSE.
       DCS=.FALSE.
       DWC=.FALSE.
       IF(IDEBUG.GT.25)WRITE(6,110) UNIT(III)
  110 FORMAT(10X,'UNIT IN QUESTION IS  ',A10)
      IF(MATL(III).EQ.MATLC(1)) IC=.TRUE.
      IF(MATL(III).EQ.MATLC(2)) SS=.TRUE.
      IF(MATL(III).EQ.MATLC(3)) CS=.TRUE.
      IF(DCMATL(III).EQ.MATLC(1)) DIC=.TRUE.
      IF(DCMATL(III).EQ.MATLC(2)) DSS=.TRUE.
      IF(DCMATL(III).EQ.MATLC(3)) DCS=.TRUE.
      IF(DCMATL(III).EQ.MATLC(4)) DWC=.TRUE.
           T1=TTMP(III)
           T2=TTMP(III+1)
           PINC=PEXT
           IF(UNIT(III).EQ.SUNIT(1)) CALL INCDES(NREAC,NPRD)
           IF(UNIT(III).EQ.SUNIT(2)) CALL QUENCH(NREAC,NPRD)
           IF(UNIT(III).EQ.SUNIT(3)) CALL HTEXCH(NREAC,NPRD)
```

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        IF(UNIT(III).EQ.SUNIT(4)) CALL VENTUR(NREAC,NPRD)
        IF(UNIT(III).EQ.SUNIT(5)) CALL INDFAN(NREAC,NPRD)
        IF(UNIT(III).EQ.SUNIT(6)) CALL PCKBD(NREAC,NPRD)
        IF(UNIT(III).EQ.SUNIT(7)) CALL TRABED(NREAC,NPRD)
        IF(UNIT(III).EQ.SUNIT(8)) CALL AFTER(NREAC,NPRD)
        IF(UNIT(III).EQ.SUNIT(9)) CALL STACK(NPRD)
        IF(UNIT(III).EQ.SUNIT(10)) CALL ADIAB(NREAC,NPRD)
        IF(FLGPAS) CALL DUCT(NPRD)
   CALL OUTP7(NPRD)
50    CONTINUE
   CALL OUTP3(NPRD)
   CALL STOREG(NREAC,NPRD)
   CALL CAPTAL
   CALL OUTP2(NPRD)
   CALL OPERAT
   CALL EQIV
   CALL DCFRR(TOTTOT,TTOPR,YRNUM,MASSSL,DAY,YEAR,REVLB)
   STOP
   END
    SUBROUTINE ADIAB(NREAC,NPRD)
   REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
  1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
   LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
  1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
  2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
  4,CUTVN,CMBST,TCH
  3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
    CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
  1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
  2 ,SCRNME*20
   COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
  1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
  2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
   COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
  1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
   COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
  1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
  2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
  3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
   COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
  1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
   COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
  1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
  2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
  3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
   COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
  1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
  2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
  3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
  4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
  5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
  6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
    COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
  1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
   COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
   COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
   COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
   COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
  1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
  2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
   COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
  1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
  2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
  3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
   MASSFL=0.0
    IF(ENGL) CALL METRC(NREAC,NPRD)
200 CONTINUE
    DELTAH=0.0
   IF(IDEBUG.GT.25) WRITE(6,500)
500 FORMAT(10X,'SUBROUTINE ADIAB')
    DTTEMP=100.0
    FFF=0
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```
      FF=1
     IF(IDEBUG.GT.25) WRITE(6,40) MASSSL,MASSFL,MASSAR
  40 FORMAT(2X,'MASSSL ',E15.5,2X,'MASSFL ',E15.5,2X,'MASSAR ',E15.5)
     DO 13 I=1,NREAC
         MSSLUD(I,III)=VOLIT*XXSLUD(I)
  13 CONTINUE
      HTCOMB=VOLIT*ZSLHT
      CALL HTMSBL(NREAC,NPRD)
  11  IF(IDEBUG.GT.25) WRITE(6,500)
     CALL DTHEAT(NPRD)
      IF(IDEBUG.GT.25) WRITE(6,998) DELTAH,HTCOMB
 998  FORMAT(4X,'HEAT FOR GAS=  ',E15.5/4X,'HEAT OF COMBUSTION= ',
    1 E15.5)
      IF(ABS(DELTAH-HTCOMB).LT.(.001*DELTAH)) GOTO 19
      IF(DELTAH.GT.HTCOMB) GOTO 15
      T2=T2+DTTEMP
      IF(FF.EQ.0) DTTEMP=DTTEMP/2.0
      IF(FFF.EQ.0) FFF=1
      IF(FFF.EQ.1) GOTO 11
      FF=0
      GOTO 11
  15  T2=T2-DTTEMP
      IF(FF.EQ.0) DTTEMP=DTTEMP/2.0
      IF(FFF.EQ.0) FFF=-1
      IF(FFF.EQ.-1) GOTO 11
      FF=0
      GOTO  11
  19 IF(IDEBUG.GT.10)WRITE(6,50) T2
     TTMP(III+1)=T2
  50 FORMAT(10X,'THE ABIABATIC TEMPERATURE OF THE COMBUSTION PROCESS='
    1,F10.3,'DEGREES CELCIUS')
       IF(METRIC) CALL ENG(NREAC,NPRD)
     RETURN
     END
      SUBROUTINE HTMS(NREAC,NPRD)
     REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
    1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
     LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
    1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
    2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
    4,CUTVN,CMBST,TCH
    3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
    1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
    2 ,SCRNME*20
     LOGICAL FUEL
     COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
    1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
    2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
     COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
    1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
     COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
    1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
    2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
    3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
     COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
    1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
     COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
    1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
    2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
    3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
     COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
    1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
    2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
    3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
    4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
    5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
    6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
      COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
    1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
     COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
     COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
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```
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        DELTAH=0.0
        MASSAR=0.0
        MASSFL=0.0
        FUEL=.TRUE.
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE HTMS')
        DTFUEL=2000.0*453.96
        FFF=0
        FF=1
      IF(IDEBUG.GT.50) WRITE(6,40) MASSSL,T2,MASSAR
   40 FORMAT(2X,'MASSSL ',E15.5,2X,'T2 ',E15.5,2X,'MASSAR ',E15.5)
   11 CONTINUE
      IF(MASSFL.LT.0.0) FUEL=.FALSE.
        IF(FUEL) GOTO 12
        CALL ADIAB(NREAC,NPRD)
        GOTO 60
   12 DO 10 I=1,NREAC
      IF(IDEBUG.GT.50) WRITE(6,30) I,XXSLUD(I),XXFUEL(I),XXAIR(I)
   30 FORMAT(2X,'COMP. ',I3,2X,'XXSLUD ',F6.4,2X,'XXFUEL ',F6.4,
     12X,'XXAIR ',F6.4)
          MSSLUD(I,III)=VOLIT*XXSLUD(I)
          MSFUEL(I,III)=MASSFL*XXFUEL(I)
   10 CONTINUE
        HTCOMB=MASSFL*ZFLHT+VOLIT*ZSLHT
        CALL HTMSBL(NREAC,NPRD)
      CALL DTHEAT(NPRD)
        IF(IDEBUG.GT.25) WRITE(6,500)
        IF(IDEBUG.GT.25) WRITE(6,998) DELTAH,HTCOMB,MASSFL
  998   FORMAT(4X,'HEAT FOR GAS=  ',E15.5/4X,'HEAT OF COMBUSTION= ',
     1  E15.5/4X,'MASS RATE OF FUEL',5(E15.5 ))
        IF(ABS(DELTAH-HTCOMB).LT.(.001*DELTAH)) GOTO 19
        IF(DELTAH.LT.HTCOMB) GOTO 15
        MASSFL=MASSFL+DTFUEL
        IF(FF.EQ.0) DTFUEL=DTFUEL/2.0
        IF(FFF.EQ.0) FFF=1
        IF(FFF.EQ.1) GOTO 11
        FF=0
        GOTO 11
   15   MASSFL=MASSFL-DTFUEL
        IF(FF.EQ.0) DTFUEL=DTFUEL/2.0
        IF(FFF.EQ.0) FFF=-1
        IF(FFF.EQ.-1) GOTO 11
        FF=0
        GOTO  11
   19   IF(IDEBUG.GT.1)WRITE(6,999)MASSFL,MASSAR
  999 FORMAT(4X,'  FINAL MASS RATE OF FUEL= ',E15.5/2X,'  FINAL AIR FLOW
     1RATE(GRAMS/HR)= ',E15.3)
      MSTOT(III)=0.0
      DO 20 I=1,NREAC
          MSAIR(I,III)=MASSAR*XXAIR(I)
          MSTOT(III)=MSTOT(III)+MSSLUD(I,III)+MSFUEL(I,III)+MSAIR(I,III)
   50 FORMAT(10X,'FOR UNIT  ',I2,'MASS FLOW RATE =',E15.5,'G/HR')
   20 CONTINUE
          IF(IDEBUG.GT.25)WRITE(6,50) III,MSTOT(III)
      FLTOT=FLTOT+MASSFL
   60   RETURN
        END
      SUBROUTINE HTMSBL(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
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     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      REAL MLFEED(9),FD(9),MLFED(9)
C
C
C     THIS SUBROUTINE WILL CALCULATE A MASS/HEAT BALANCE FROM A  GIVEN S
C GIVEN SLUDGE,FUEL, AND AIR FLOWRATE PROVIDED.
C
C
C23456789
      INTEGER BLORD(15)
      DIMENSION FDPAR(9,3),HEAT(15)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      DATA FD/1.00797,12.01115,15.9994,14.0067,35.453,32.064,18.9984
     1 ,30.9738,20.183/
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE HTMSBLC')
C
C   ALL REACTANT DIMENSIONS CATALOG
C   1-H,   2-C,   3-O,   4-N,   5-CL,   6-S,   7-F,   8-P,   9-NE
C
C
C     ALL PRD** DIM'S CATALOG
C     1- H2O,   2-HCL,    3-CO2,  4-CO,   5-N2,   6-O2,   7-NO
C     8-NO2,    9-CL2,    10-SO2, 11-H2SO4,12-F2,  13-HF,    14-P2O6
C    15-NE
      IF(UNIT(III).EQ.SUNIT(8)) GOTO 62
    5 CONTINUE
      DO 40 I=1,NPRD
          MLPRDT(I,III)=0.0
          MSFUEL(I,III)=MASSFL*XXFUEL(I)
   40 CONTINUE
      DO 10 J= 1 , NREAC
          IF(UNIT(III).EQ.SUNIT(8)) MLFEED(J)=(ZLFD2(J,III-1)
     1 + MSFUEL(J,III))/FD(J)
      IF(UNIT(III).NE.SUNIT(1)) GOTO 63
          MLFEED(J)=(MSSLUD(J,III)+MSFUEL(J,III))/FD(J)
```

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   63 ZLFD2(J,III)=MLFEED(J)
  510 FORMAT(2X,'TOTAL MOLE RATE OF ELEMENT ',I2,' = ',E15.5/
     1 2X,'INLET FLOW OF SLUDGE G/HR= ',E15.5,' INLET AIR RATE G/HR= ',
     2 E15.5/2X,'INLET FUEL FLOW RATE G/HR= ',E15.5,'ELEMENT ATOMIC WEI
     3GHT= ',F9.4)
   10 CONTINUE
      AMEET=(MLFEED(1)-MLFEED(5))/4.0/0.2099+MLFEED(2)/0.2099
     1+MLFEED(6)/0.2099/2.0*6.0
      MASSAR=AMEET*29.0*(EXCESS(III)+1.0)
      DO 65 K=1,NREAC
         MSAIR(K,III)=MASSAR*XXAIR(K)
         MLFEED(K)=MLFEED(K)+MSAIR(K,III)/FD(K)
      IF(IDEBUG.GT.50) WRITE(6,510)K, MLFEED(K),MSSLUD(K,III),MSAIR(K,II
     1I),MSFUEL(K,III),FD(K)
   65 CONTINUE
      GOTO 70
   62 CONTINUE
      IF(NSET.EQ.1) GOTO 81
         NSET=1
         MLFED(1)=MLPRDT(1,III-1)*2.0+MLPRDT(2,III-1)+MLPRDT(11,III-1)+
     1              MLPRDT(13,III-1)
         MLFED(2)=MLPRDT(3,III-1)+MLPRDT(4,III-1)
         MLFED(3)=MLPRDT(1,III-1)+MLPRDT(3,III-1)*2.+MLPRDT(4,III-1)+
     1 MLPRDT(6,III-1)*2.+MLPRDT(7,III-1)+MLPRDT(8,III-1)*2.+
     2 MLPRDT(10,III-1)*2.+MLPRDT(11,III-1)*4.+MLPRDT(14,III-1)
      MLFED(4)=MLPRDT(5,III-1)*2.+MLPRDT(7,III-1)+MLPRDT(8,III-1)*2.
      MLFED(5)=MLPRDT(2,III-1)+MLPRDT(9,III-1)
      MLFED(6)=MLPRDT(10,III-1)+MLPRDT(11,III-1)
      MLFED(7)=MLPRDT(12,III-1)*2.+MLPRDT(13,III-1)
      MLFED(8)=MLPRDT(14,III-1)*2.
   81 DO 80 I=1,NREAC
         MLFEED(I)=MLFED(I)+MASSFL*XXFUEL(I)/FD(I)
   80 CONTINUE
      DATA BLORD/3,10,4,5,2,7,1,8,9,12,11,13,14,15,6/
   70     DO 30 I=1,NPRD
      IF(BLORD(I).EQ.4.OR.BLORD(I).EQ.7.OR.BLORD(I).EQ.8.OR.BLORD(I)
     1 .EQ.9.OR.BLORD(I).EQ.11.OR.BLORD(I).EQ.12.
     2 OR.BLORD(I).EQ.13.OR.BLORD(I).EQ.14.OR.BLORD(I).EQ.15) GOTO  30
          IF(BLORD(I).EQ.3) GOTO 22
          IF(BLORD(I).EQ.5)  GOTO 23
          IF(BLORD(I).EQ.2)  GOTO 24
          IF(BLORD(I).EQ.1)  GOTO 25
          IF(BLORD(I).EQ.6)  GOTO 26
          IF(BLORD(I).EQ.10)  GOTO 27
          GOTO 20
   22 CONTINUE
C
C     BALANCE FOR CARBON DIOXIDE (100 % CONVERSION)
C
      MLPRDT(3,III)=MLFEED(2)/1.0
      MLFEED(3)=MLFEED(3)-MLPRDT(3,III)*2.0
      MLFEED(2)=MLFEED(2)-MLPRDT(3,III)*1.0
      GOTO 20
C
C     BALANCE FOR SULFUR DIOXIDE (100 % CONVERSION)
C
   27 MLPRDT(10,III)=MLFEED(6)/1.0
      MLFEED(3)=MLFEED(3)-MLPRDT(10,III)*2.0
      MLFEED(6)=MLFEED(6)-MLPRDT(10,III)*1.0
      GOTO 20
C
C   MASS BALANCE FOR HYDROGEN CHLORIDE
C
   24 MLPRDT(2,III)=MLFEED(5)*1.0
      MLFEED(1)=MLFEED(1)-MLPRDT(2,III)*1.0
      MLFEED(5)=MLFEED(5)-MLPRDT(2,III)
      GOTO 20
C
C   MASS BALANCE FOR NITROGEN GAS
C
   23  MLPRDT(5,III)=MLFEED(4)/2.0
      MLFEED(4)=MLFEED(4)-MLPRDT(5,III)*2.0
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      GOTO 20
C
C   MASS BALANCE FOR WATER
C
   25 MLPRDT(1,III)=MLFEED(1)/2.0
      MLFEED(1)=MLFEED(1)-MLPRDT(1,III)*2.0
      MLFEED(3)=MLFEED(3)-MLPRDT(1,III)*1.0
      IF(III.EQ.1)MLPRDT(1,III)=MLPRDT(1,III)+FREH2O/18.01
      GOTO 20
C
C   MASS BALANCE FOR OXYGEN
C
   26 MLPRDT(6,III)=MLFEED(3)/2.0
      MLFEED(3)=MLFEED(3)-MLPRDT(6,III)*2.0
C
   20    CONTINUE
        FEED(BLORD(I))=MLPRDT(BLORD(I),III)*PRDMW(BLORD(I))
        IF(IDEBUG.GT.50) WRITE(6,60) BLORD(I)
      IF(IDEBUG.NE.25) GOTO 66
        WRITE(6,61) FEED(BLORD(I)),MLPRDT(BLORD(I),III),PRDMW(BLORD(I))
   61   FORMAT(10X,'FEED RATE= ',E15.5,'MOLE RATE',E15.5,'MOLE WEIGHT',
     1E15.5)
   66 CONTINUE
   60 FORMAT(10X,'BALANCING SPECI',I3)
   30 CONTINUE
      ZLOSS=0.0
C
      DO 85 I=1,NREAC
         IF(MLFEED(I).LT.0.0) WRITE(6,95) I,MLFEED(I)
   95 FORMAT(5X,'REACTANT',I3,' WAS LESS THAN ZERO',F10.3,
     1 'CHECK BALANCE OF EQUATION')
   85 CONTINUE
      RETURN
      END
      SUBROUTINE DTHEAT(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      DIMENSION HEAT(15)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
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      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      DELTAH=0.0
      IF(IDEBUG.GT.25) WRITE(6,110) T1,T2
  110 FORMAT(2X,'INLET TEMP DEG C=',F9.3,'OUTLET TEMP= ',F9.3)
      DO 100 I=1,NPRD
        HEAT(I)=0.0
        HEAT(I)=CP(1,I)*(T2-T1)+CP(2,I)/2.*(T2**2.-T1**2.)
     1  +CP(3,I)/3.*(T2**3.-T1**3.)+CP(4,I)/4.*(T2**4.-T1**4.)
        HEAT(I)=HEAT(I)*MLPRDT(I,III)
        DELTAH=HEAT(I)+DELTAH
        IF(IDEBUG.GT.50) WRITE(6,51) I,HEAT(I),MLPRDT(I,III)
   51   FORMAT(2X,'FOR SPECI',I2,'DELTA ENTH(J/HR)',E15.5,'MOLE RATE OF
     1 PRODUCT',E15.5)
  100 CONTINUE
C     HEAT TO VAPORIZE FREE WATER  INSLUDGE
        PRTH2O=HSTVAP*FREH2O/18.00
         IF(III.EQ.1)DELTAH=DELTAH+PRTH2O
      IF(IDEBUG.GT.25.AND.UNIT(III).EQ.SUNIT(III)) WRITE(6,230) PRTH2O
     1,FREH2O
  230 FORMAT(10X,'HEAT OF VAPORIZATION OF WATER=',E15.5/10X,'INLET FLOW'
     1,' RATE= ',E15.5)
        ZLOSS=DELTAH*0.10
       HTASH=0.26*ASH/78.0*(T2-T1)
       IF(HTLS) DELTAH=DELTAH+ZLOSS
       IF(III.EQ.1) DELTAH=DELTAH+HTASH
       RETURN
       END
       SUBROUTINE VLRATE(TVOL,PVOL,NPRD)
       REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
       LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
     1,TOTML
       COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
       COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
       COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
       COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
       COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
       COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
        COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
       COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
       COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
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      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE VLRATE')
       RG=10.73
       TK=459.96
      TTL(III)=0.0
      MSTOT(III)=0.0
      DO 10 I=1,NPRD
          TTL(III)=TTL(III)+MLPRDT(I,III)
          MSTOT(III)=MSTOT(III)+MLPRDT(I,III)*PRDMW(I)
   10 CONTINUE
      VOLRAT(III)=TTL(III)*RG*(TVOL+TK)/PVOL
      IF(IDEBUG.GT.10)WRITE(6,20) VOLRAT(III),TTL(III),MSTOT(III)
   20 FORMAT(10X,'VOLUME RATE= ',E15.5,'FT°3/HR.   MOLE RATE ',E15.5,
     1'LBMOLE/HR    MASS RATE= ',E15.5,' LB/HR')
  100 RETURN
      END
      SUBROUTINE INPT(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTCT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C      TCH IS A LOGICAL VAR TO SPECFY REFRACTORY THICK CALCULATED FROM
C    IDUSTRIAL PROCTICE.
      TCH=.TRUE.
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      CUTVN=.FALSE.
C WATER RATE BETWEEN 15 AND 35 GAL/FT GAS  FLOW
      WRITE(6,79)
   79 FORMAT(10X,'*****   SUMMARY OF INPUT DATA FILE   *****')
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE INPT')
      READ(4,12)
      READ(4,10) (CP(1,J),CP(2,J),CP(3,J),CP(4,J),CP(5,J),CP(6,J),
     1 PRDMW(J),J=1,NPRD)
   11 FORMAT(1X,6E11.4)
   12 FORMAT(/////)
   10 FORMAT(1X,6E11.4,F10.5)
      DO 60 J=1,8
      READ(4,50)(BRIKNM(I,J),I=1,6), TLIM(J),TKOND(J),NRES(J),BCOST(J)
   50 FORMAT(1X,6(A4),2X,F9.4,2X,F8.4,2X,I1,2X,F9.4)
      IF(IDEBUG.GT.10)WRITE(6,50)(BRIKNM(I,J),I=1,6), TLIM(J),TKOND(J)
     1 ,NRES(J),BCOST(J)
   60 CONTINUE
      READ(4,81)
   81 FORMAT(///)
      DO 140 J=1,1
      READ(4,74) (FUELNM(I,J),I=1,5),PRICE,HTCNT,FULC,ZFLHT
   74 FORMAT(1X,5A3,F7.2,F10.2,2E11.4)
  140 CONTINUE
      READ(4,215)
  215 FORMAT(/////)
      DO 220 J=1,7
         READ(4,210) (PCKNAM(J,JJ),JJ=1,4),PSIZE(J),CSTPK(J)
     1 ,(CONST(J,JJ),JJ=1,3),(PAKRAG(J,JJ),JJ=1,4),(CONST(J,JJ),JJ=4,7)
      IF(IDEBUG.LT.10) GOTO 220
         IF(IDEBUG.GT.5)WRITE(6,210) (PCKNAM(J,JJ),JJ=1,4),PSIZE(J),CSTP
     1K(J),(CONST(J,JJ),JJ=1,3),(PAKRAG(J,JJ),JJ=1,4),(CONST(J,JJ),JJ=4
     2,7)
  210 FORMAT(1X,4A4,F4.1,2F6.2,2F5.2,3F2.0,F3.0,F8.5,F5.2,F7.2,F8.5)
  220 CONTINUE
      READ(4,75) STMCST,WTRCST,DSPCST,CSTFUL,CSTELC,CSTLME
   75 FORMAT(/1X,F11.6,F11.6,F11.6,F11.6,F11.6)
      IF(IDEBUG.GT.25)WRITE(6,78) STMCST,WTRCST,DSPCST,CSTFUL,CSTELC
   78 FORMAT(10X,'COST OF RECOVERED STEAM = ',3X,F8.6,' $/LB'/
     1 10X,'COST OF WATER = ',14X,F8.6,' $/LB'/
     2 10X,'COST OF WASTE ASH AND WATER = ',F8.2,' $/LB TREATED'/
     3 10X,'COST OF FUEL = ',12X,F8.6,' $/LB'/
     4 10X,'COST OF ELECTRICITY =',4X,F8.6,'$/KWH')
      READ(4,76) HSTVAP
      HSTVAP=HSTVAP*1000.0
   76 FORMAT(1X,F10.5)
      READ(15,732) DAY,YEAR
      WRITE(6,732) DAY,YEAR
  732 FORMAT(1X,F4.1,1X,F5.1)
      READ(15,4000) WSTNME(1)
      WRITE(6,4000) WSTNME(1)
 4000 FORMAT(1X,A20)
      READ(15,70)(XXSLUD(I),I=1,9)
      WRITE(6,70)(XXSLUD(I),I=1,9)
      READ(15,70)(XXFUEL(I),I=1,9)
      WRITE(6,70)(XXFUEL(I),I=1,9)
      READ(15,70)(XXAIR(I),I=1,9)
      WRITE(6,70)(XXAIR(I),I=1,9)
      READ(15,72) MASSSL,ZSLHT
      WRITE(6,72) MASSSL,ZSLHT
      CLMS = MASSSL*XXSLUD(5)
      READ(15,734) FLNAM,ZFLHT
      WRITE(6,734) FLNAM,ZFLHT
  734 FORMAT(1X,A15,F7.1)
      READ(15,733) BRN,SCRW,BARREL,RECT,SLD,LQD,CMBST
      WRITE(6,733) BRN,SCRW,BARREL,RECT,SLD,LQD,CMBST
  733 FORMAT(1X,L1)
   72 FORMAT(1X,2F11.4)
   70 FORMAT(1X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4
     1,2X,F6.4,2X,F6.4)
      IF (IDEBUG.GT.5) WRITE(6,55)
   55 FORMAT('        BRICK TYPE      ,    TLIM    , THERM COND   , CL?, COS
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     1T')
      IF(IDEBUG.GT.5) WRITE(6,76) HSTVAP
      IF(IDEBUG.GT.5) WRITE(6,77) PRICE,HTCNT,FULC
     1,ZFLHT
   77 FORMAT(5X,'PRICE= ',E15.5,'HEAT CONTENT= ',E15.5, 'FUEL COST',
     1'= ',E15.5/10X,'HEAT OF COMBUSTION= ',E15.5)
      IF(IDEBUG.GT.5)WRITE(6,456) ZFLHT
  456 FORMAT(10X,'HEAT OF COMBUSTION (IN INPUT UNITS)= ',E15.5)
      READ(15,73) WTPH2O,WTPVOL
      WRITE(6,73) WTPH2O,WTPVOL
      READ(15,30) METRIC,ENGL,LCOST
      WRITE(6,30) METRIC,ENGL,LCOST
   73 FORMAT(1X,F9.7)
      FREH2O=WTPH2O*MASSSL
      VOLIT=WTPVOL*MASSSL
      ASH=MASSSL-FREH2O-VOLIT
      READ(15,90) NUNIT
      WRITE(6,90) NUNIT
   90 FORMAT(1X,I2)
      READ(15,110) TTMP(NUNIT+1),PINC,ELEVAT,FEDRG2
      WRITE(6,110) TTMP(NUNIT+1),PINC,ELEVAT,FEDRG2
  110 FORMAT(1X,F10.2)
      TA=TTMP(NUNIT+1)
      TTMP(1)=TA
      READ(15,100) (UNIT(I),MATL(I),TTMP(I+1)
     1,DCTLEN(I),ELBNUM(I),DCMATL(I),I=1,NUNIT)
      WRITE(6,100) (UNIT(I),MATL(I),TTMP(I+1)
     1,DCTLEN(I),ELBNUM(I),DCMATL(I),I=1,NUNIT)
      DO 130 I=1,NUNIT
      IF(IDEBUG.GT.5) WRITE(6,100) UNIT(I),MATL(I),TTMP(I+1)
     1,DCTLEN(I),ELBNUM(I),DCMATL(I)
  100 FORMAT(1X,A3,1X,A2,F10.2,F10.5,F4.1,1X,A2)
            IF(UNIT(I).EQ.SUNIT(1)) GOTO 700
            IF(UNIT(I).EQ.SUNIT(2)) GOTO 804
            IF(UNIT(I).EQ.SUNIT(3)) GOTO 801
            IF(UNIT(I).EQ.SUNIT(4)) GOTO 803
            IF(UNIT(I).EQ.SUNIT(5)) GOTO 802
            IF(UNIT(I).EQ.SUNIT(6)) GOTO 707
            IF(UNIT(I).EQ.SUNIT(7)) GOTO 130
            IF(UNIT(I).EQ.SUNIT(8)) GOTO 708
            IF(UNIT(I).EQ.SUNIT(9)) GOTO 800
            GOTO 130
  700 READ(15,30) ROTARY,FLUID,LIQI,HTLS
      WRITE(6,30) ROTARY,FLUID,LIQI,HTLS
   30 FORMAT(1X,L1)
      READ(15,40) RETIM(I),RLD(I),EXCESS(I),EXFUEL(I)
      WRITE(6,40) RETIM(I),RLD(I),EXCESS(I),EXFUEL(I)
      READ(15,73) PREXTI
      WRITE(6,73) PREXTI
      READ(15,30) ADIA,SIEVE,VALVE
      WRITE(6,30) ADIA,SIEVE,VALVE
       GOTO 130
  707 READ(15,720) (PCKCHS(JJ),JJ=1,4),PCKSIZ,EFFABS,NTU,SCHMDT,PRCFLD
      WRITE(6,720) (PCKCHS(JJ),JJ=1,4),PCKSIZ,EFFABS,NTU,SCHMDT,PRCFLD
      READ(15,736) WATRAT,SLPABS,HCLRM
      WRITE(6,736) WATRAT,SLPABS,HCLRM
  736 FORMAT(1X,F6.3,F6.2,F8.4)
      READ(15,737) SCRNME(1)
      WRITE(6,737) SCRNME(1)
  737 FORMAT(1X,A20)
      READ(15,911) DFHCLL,DFHCLG
      WRITE(6,911) DFHCLL,DFHCLG
  911 FORMAT(1X,F10.2)
  730 FORMAT(1X,F10.2)
  720 FORMAT(1X,4A4,F6.2,F10.8,I3,F6.3,F6.2)
      IF(IDEBUG.GE.25)
     1 WRITE(6,43) (PCKCHS(JJ),JJ=1,4),PCKSIZ,EFFABS,NTU,SCHMDT,PRCFLD
   43 FORMAT(10X,'PACKING TYPE CHOSEN= ',4(A4),'PACKING SIZE(IN)= ',
     1 F9.2/10X,'EFFECTIVE ABSOPTION = ',F9.0,'NTU= ',I5/
     2 10X,'SCHMIDT NUMBER= ',E15.5,'PERCENT OF FLOODING= ',F9.2)
      GOTO 130
  708 READ(15,134) RLD(I)
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      WRITE(6,134) RLD(I)
      READ(15,134) RETIM(I)
      WRITE(6,134) RETIM(I)
  134 FORMAT(1X,F10.5)
      READ(15,73) PREXT
      WRITE(6,73) PREXT
      GOTO 130
  800 READ(15,1) HEIGHT
      WRITE(6,1) HEIGHT
    1 FORMAT(1X,F5.1)
      READ(15,30) VOLTIL
      WRITE(6,30) VOLTIL
      GOTO 130
  801 READ(15,30) FXH,KRB,UTB,HM1,HM2
      WRITE(6,30) FXH,KRB,UTB,HM1,HM2
      READ(15,30) S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
      WRITE(6,30) S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS
      READ(15,110) HTC
      WRITE(6,110) HTC
      GOTO 130
  802 CONTINUE
      READ(15,110) TOTDP
      WRITE(6,110) TOTDP
        GOTO 130
  803 READ(15,110) VENWAT,DPTOT
      WRITE(6,110) VENWAT,DPTOT
      READ(15,30) PRI
      WRITE(6,30) PRI
      IF(.NOT.(PRI.AND.CUTVN)) GOTO 34
      READ(15,31) NPRTS
      WRITE(6,31) NPRTS
   31 FORMAT(1X,I3)
      DO 32 IJ=1,NPRTS
         READ(15,33) DIAPT(IJ),WTPRT(IJ)
         WRITE(6,33) DIAPT(IJ),WTPRT(IJ)
   33 FORMAT(1X,2F9.5)
   32 CONTINUE
   34 READ(15,813) FEDRG2
      WRITE(6,813) FEDRG2
  813 FORMAT(1X,E15.5)
      READ(15,30) VENAUT,FG
      WRITE(6,30) VENAUT,FG
       GOTO 130
  804 READ(15,221) QSAT,QTEMP
      WRITE(6,221) QSAT,QTEMP
  221 FORMAT(1X,2F3.1)
       GOTO 130
  130 CONTINUE
      READ(15,731) FACMSC,FACCEE,FACCEF,FACCEB,FACCES,
     1 FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS,IYEAR
      WRITE(6,731) FACMSC,FACCEE,FACCEF,FACCEB,FACCES,
     1 FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS,IYEAR
  731 FORMAT(2X,11F6.1,I5)
      READ(15,742) YRNUM,RTINST,REVLB,CONTEN
      WRITE(6,742) YRNUM,RTINST,REVLB,CONTEN
  742 FORMAT(1X,F4.1,F4.1,F8.3,F8.3)
      DO 200 II=1,NUNIT
       IF(EXCESS(II).GT.1.0) WRITE(6,71) II
   71 FORMAT(2X,'WARNING! EXCESS AIR IS GREATER THAN 1 IN UNIT',F5.1)
  200 CONTINUE
   40 FORMAT(1X,F10.2)
      IF(IDEBUG.GT.5) WRITE(6,30) ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HT
     1LS
      IF(IDEBUG.GT.5) WRITE(6,41) PINC
   41 FORMAT(10X,'INLET PRESSURE TO INCINERATOR = ',F6.2,' PSIA')
       IF(IDEBUG.LT.10) GOTO 765
      WRITE(6,150) (CP(1,J),CP(2,J),CP(3,J),CP(4,J),CP(5,J),CP(6,J),
     1 PRDMW(J),J=1,NPRD)
  150 FORMAT(1X,'SPEC.        A     ,       B      ,     C      ,     D     ,
     A TLOW , THIGH  ,    MW'          //
     1 3X,'H2O   ',4E11.3,4X,2F7.2,F9.4/3X,'HCL   ',4E11.3,4X,2F7.2,F9.4/
     2 3X,'CO2   ',4E11.3,4X,2F7.2,F9.4/3X,'CO    ',4E11.3,4X,2F7.2,F9.4/
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    3 3X,'N2    ',4E11.3,4X,2F7.2,F9.4/3X,'O2    ',4E11.3,4X,2F7.2,F9.4/
    4 3X,'NO    ',4E11.3,4X,2F7.2,F9.4/3X,'NO2   ',4E11.3,4X,2F7.2,F9.4/
    5 3X,'CL2   ',4E11.3,4X,2F7.2,F9.4/3X,'SO2   ',4E11.3,4X,2F7.2,F9.4/
    6 3X,'H2SO4',4E11.3,4X,2F7.2,F9.4/3X,'F2    ',4E11.3,4X,2F7.2,F9.4/
    7 3X,'HF    ',4E11.3,4X,2F7.2,F9.4/3X,'P2O6  ',4E11.3,4X,2F7.2,F9.4/
    8 3X,'NE    ',4E11.3,4X,2F7.2,F9.4)
765 CONTINUE
    IF(IDEBUG.GT.5)WRITE(6,38) (XXSLUD(I),XXFUEL(I),XXAIR(I),I=1,9)
 38 FORMAT(////25X,'MASS FRACTION OF FEED STREAMS'//13X,'SPECIES      S
   1LUDGE         FUEL          AIR'/15X,'    H     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'    C     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'    O     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'    N     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'   CL     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'    S     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'    F     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'    P     ',2X,F7.5,5X,F7.5,5X,F7.5/
   1 15X,'   NE     ',2X,F7.5,5X,F7.5,5X,F7.5/)
    PEXT=PINC
    IF(IDEBUG.GE.25) WRITE(6,82)
 82 FORMAT(10X,'****************************************************')
    RETURN
    END
    SUBROUTINE BLOCK(NREAC,NPRD)
    REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
   1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
    LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
   1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
   2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
   4,CUTVN,CMBST,TCH
   3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
     CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
   1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
   2  ,SCRNME*20
    COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
   1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
   2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
    COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
   1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
    COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
   1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
   2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
   3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
    COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
   1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
    COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
   1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
   2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
   3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
    COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
   1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
   2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
   3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
   4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
   5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
   6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
     COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
   1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
    COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
    COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
    COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
    COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
   1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
   2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
    COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
   1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
   2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
   3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
    BRKTOT=0.0
    IF(IDEBUG.GT.25) WRITE(6,500)
500 FORMAT(10X,'SUBROUTINE BLOCK')
    DDSVOL=DESVOL(III)
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      TD2=TTMP(III+1)
      TD1=TTMP(III)
    9 CONTINUE
C23456789
      REFINS=1.0+(4.0-1.0)/(3000.-1800.)*(TD2-1800)
      THCKIN=4.0+(12.0-4.0)/(3000.-1800.)*(TD2-1800.)
      IF(TD2.GT.3000.) THCKIN=12.0
      IF(TD2.LT.1800.) THCKIN=4.0
      IF(TD2.LT.1800.)REFINS=1.0
      IF(TD2.GT.3000.)REFINS=4.0
      ARINS=3.1416*(DIA(III)+REFINS*2./12.+THCKIN*2./12.)*INCLEN(III)
      ARREF=3.1416*(DIA(III)+THCKIN*2./12.)*INCLEN(III)
      DIA(III)=DIA(III)+REFINS*2./12.+2.*THCKIN/12.
      DIABRK=DIA(III)
      SHELVL=DIABRK**2.*3.1416/4.0*INCLEN(III)
      DTLGM=(TD2-TD1)/LOG(TD2/TD1)
      NCOR=0
      NCHOSE=0
      MCHOSE=0
C
C  CHOOSE REFRACTORY MATERIAL
C

      IF(XXSLUD(5).GT.0.005) NCOR=1
      DO 10 I=1,3
          IF(NCOR.GT.NRES(I)) GOTO 10
          IF(TD2.GT.TLIM(I)) GOTO 10
         RBCOST=BCOST(I)
         DO 300,II=1,6
             BNMFR(II)=BRIKNM(II,I)
  300 CONTINUE
         NCHOSE=I
         GOTO 15
   10 CONTINUE
      RBCOST=BCOST(3)
      DO 304 IJ=1,6
         BNMFR(IJ)=BRIKNM(IJ,6)
  304 CONTINUE
   15 DO 20 I=4,8
         IF(NCOR.GT.NRES(I)) GOTO 20
         IF(TD2.GT.TLIM(I)) GOTO 20
         ZIBCOS=BCOST(I)
         DO 301,II=1,6
             BNMIN(II)=BRIKNM(II,I)
  301 CONTINUE
         MCHOSE=I
         GOTO 25
   20 CONTINUE
      ZIBCOS=BCOST(8)
      DO 303 IJ=1,6
         BNMIN(IJ)=BRIKNM(IJ,6)
  303 CONTINUE
   25 CONTINUE
      IF(.NOT.HTLS) GOTO 30
      IF(TCH) GOTO 30
      THCKIN=(-(TD2-TA)/ZLOSS+REFINS/TKOND(NCHOSE)/ARINS)*TKOND(MCHOSE)*
     1 ARREF
      IF(DCTFLG) DSDIA(III)=DIA(III)*12.0+(THCKIN+REFINS)*2.0
      IF(THCKIN.LT.0.125) THCKIN=3.0
   30  IF(IDEBUG.GT.25)WRITE(6,110) RBCOST,ZIBCOS,DIABRK,INCLEN(III)
     1 ,TKOND(NCHOSE),ZLOSS
  110  FORMAT(2X,'COST OF REFRACTORY INSULATION ($/FT**2IN)= ',F9.2/
     1 2X,'COST OF INSULATION ($/FT**2)=',F9.2/10X,'DIAMETER OF UNIT ',
     2'WITH BRICK COVERING(FT)= ',F9.2,
     3 '    LENGTH OF INCINERATOR(FT)= ',F12.2,
     4 /1X,'THERMAL CONDUCTIVITY= ',F10.2,E15.5)
      BRKCOS=(RBCOST*THCKIN*ARREF+ZIBCOS*REFINS*ARINS)
     1  *FACMSC/318.7
      BRKINS=BRKCOS*1.0
      BRKSHP=BRKCOS*0.30
      IF(.NOT.DCTFLG) BRKTOT=BRKCOS+BRKINS+BRKSHP
      IF(DCTFLG) DCBRIK=BRKCOS+BRKINS+BRKSHP
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      IF(FLUID.AND.(.NOT.DCTFLG)) BRKMAN=BRKTOT*0.150
      IF(LIQI.AND.(.NOT.DCTFLG)) BRKMAN=BRKTOT*0.050
      IF(FLUID.AND.DCTFLG) BRKMAN=DCBRIK*0.150
      IF(LIQI.AND.DCTFLG) BRKMAN=DCBRIK*0.050
      IF(ROTARY) BRKMAN=BRKTOT*0.10
      IF(IDEBUG.LE.25) GOTO 40
          WRITE(6,100) ARINS,TD2,REFINS,THCKIN,(BNMIN(I)
     1 ,
     1I=1,6)
     1,    (BNMFR(I),I=1,6),SHELVL,BRKCOS,BRKINS,BRKSHP
100       FORMAT(30X,'DATA USED IN SUBROUTINE BLOCK'//
     1/5X,'    SURFACE AREA(III)(FT**3)',F9.2/5X,
     1'TEMPERATURE(F)= ',
     2F9.2/5X,'INSULATING THICKNESS(IN.)= ',F7.2,'    REFRACTORY THICKNE
     3SS(IN.)=',F7.2/
     5 5X,'INSULATION USED= ',6(A4),'    REFRACTORY USED',6(A4
     4)/10X,'SHELL VOLUME (FT**3)= ',F9.2/20X,'COST OF BRICKS AND',
     5 ' INSULATION'//10X,'BRICK COST =   ',10X,F12.2/
     610X,'INSTALLATION COSTS =   ',2X,F12.2/
     710X,'SHIPPING COSTS =   ',6X,F12.2/
     8 10X,      '-----------------------------------')
      IF(.NOT.DCTFLG) WRITE(6,641) BRKTOT
      IF(DCTFLG) WRITE(6,641) DCBRIK
641   FORMAT(
     1 10X,'TOTAL BRICK COST=   ',5X,F12.2)
 40   RETURN
      END
      SUBROUTINE INCDES(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK.CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR.TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
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      HPBLWR=0.0
      DRVHP=0.0
      CSTSCR=0.0
      CSTLOD=0.0
      SKRCST=0.0
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE INCDES')
      IF(ENGL) CALL METRC(NREAC,NPRD)
      CALL HTMS(NREAC,NPRD)
       IF(METRIC) CALL ENG(NREAC,NPRD)
      PVOL=PINC
      TVOL=T2
       CALL VLRATE(TVOL,PVOL,NPRD)
       RHO=MSTOT(III)/VOLRAT(III)
      DESVOL(III)=VOLRAT(III)*RETIM(III)/3600.0
      IF(IDEBUG.GT.1)WRITE(6,600) RETIM(III),VOLRAT(III),DESVOL(III)
  600 FORMAT(10X,'RETENTION TIME=   ',F7.4,'    VOLUME RATE=',F12.2
     1,'    DESIGN VOLUME=',F12.2)
      IF(ROTARY) AREA(III)=5.76*DESVOL(III)**0.67
      IF(LIQI) AREA(III)=5.76*DESVOL(III)**0.67
       HTCOMB=(MASSFL*ZFLHT+VOLIT*ZSLHT)/1.E6
        DIA(III)=5.2385+0.54878*HTCOMB-5.284E-3*HTCOMB**2.+
     1 2.655E-5*HTCOMB**3.
      IF(.NOT.FLUID)DIA(III)=(DESVOL(III)*4.0/3.1416/RLD(III))**(1./3
     1.)
      INCLEN(III)=DIA(III)*RLD(III)
       AREA(III)=3.141596*DIA(III)**2./4.0*INCLEN(III)
       IF(.NOT.FLUID) INCLEN(III)=DESVOL(III)/3.14159/DIA(III)**2.0*4.0
      IF(RECT)  AREA(III)=0.30*DESVOL(III)+149.0
      IF(IDEBUG.LT.25) GOTO 782
      WRITE(6,300) DESVOL(III),DIA(III),INCLEN(III),AREA(III),VOLRAT(
     1III)
  300 FORMAT(2X,'DESIGN VOLUME (FT**3)= ',E15.5/2X,'INCINERATOR DIAMETE
     1 R (FT)= ',E15.5,'INCINERATOR LENGTH (FT)= ',E15.5/2X,
     2 ' SURFACE AREA(III) OF INCINERATOR (FT**2)= ',E15.5/2X,'GAS FLOW'
     3, ' RATE (FT**3/HR)= ',E15.5)
  782 IF(UNIT(III).EQ.SUNIT(8)) LIQI=.TRUE.
        CALL BLOCK(NREAC,NPRD)
        CALL SHELL(NREAC,NPRD)
        CALL BURNER(NREAC,NPRD)
       DIABED=DIA(III)
      MTL=1
      IF(SS) MTL=2
      IF(IC) MTL=2
       XASH=ASH/MASSSL
      IF(FLUID) TRACST=TRAYCS(SIEVE,VALVE,DIABED,MTL)*FACCEF/329.1
       ASHGAS=ASH*PERUPT
       IF(XASH.GT.0.02) CALL ASHUN
      CSTLOD=0.0
      IF(SLD) CSTLOD=LOADR(HTCOMB/1E6,BARREL)*FACCES/308.4
      IF(SLD.AND.SCRW) CSTSCR=SCRFED(HTCOMB/1.E6)*FACCES/308.4
      SKRCST=10000.0
      EXTRA1 = 0.0
      IF(ASH.GT.1.0) CALL ASHUN
      IF(ROTARY) SKRCST=10000.0
      EXTRA1=(BRKTOT+CSTSCR+CSTLOD+SHLCST+TBRNTT+ASHCST+SKRCST)*PREXTI
      CSTINC=BRKTOT+SHLCST+TBRNTT+ASHCST+CSTSCR+CSTLOD+EXTRA1+SKRCST
        IF(ROTARY) CSTINC=CSTINC+DRVCST
       IF(ROTARY) CSTINS=2.0*CSTINC
       IF(FLUID) CSTINS=CSTINC*1.0
      IF(LIQI) CSTINS=CSTINC*0.5
      GAL=MASSFL/60.0/47.0
      IF(ROTARY) CSTMAN=CSTINC*0.20
      IF(LIQI) CSTMAN=CSTINC*0.09
      IF(FLUID) CSTMAN=CSTINC*0.07
      TOTMAN=TOTMAN+CSTMAN
      IF(ROTARY) DRVHP=0.22*MASSSL/500.0
      FLPMHP=0.036*GAL
      IF(FLUID) HPBLWR=PINC/14.696*33.9*12.0/60.0/4464.0*MASSAR
      IF(.NOT.FLUID) GOTO 200
          TOTDP=5.0*33.9*12.0/14.696
          VLHOLD=VOLRAT(III)
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         VOLRAT(III)=MASSAR*10.73*(TA+460.)/29.0/PINC
              CALL INDFAN(NREAC,NPRD)
         VOLRAT(III)=VLHOLD
200 CONTINUE
        PEXT= PEXT- PRESSR(MSTOT(III),RHO,DIA(III),INCLEN(III))
     TOTELC=TOTELC+(DRVHP/0.80*0.746+0.746*HPBLWR/0.80)*DAY*YEAR
     TOTELC=FLPMHP*0.746/0.80+TOTELC
     HPTOT=HPTOT+(DRVHP+HPBLWR)/0.80
    1 * DAY*0.746
     CSTIIN=CSTIIN+CSTINS
     CALL OUTP1(NPRD)
     CALL OUTP6(NPRD)
     IF(NUNIT.NE.III) FLGPAS=.TRUE.
100 RETURN
     END
     SUBROUTINE AFTER(NREAC,NPRD)
     REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
    1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
     LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
    1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
    2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
    4,CUTVN,CMBST,TCH
    3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
    1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
    2 ,SCRNME*20
     COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
    1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
    2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
     COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
    1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
     COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
    1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
    2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
    3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
     COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
    1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
     COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
    1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
    2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
    3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
     COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
    1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
    2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
    3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
    4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
    5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
    6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
      COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
    1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
     COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
     COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
     COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
     COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
    1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
    2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
     COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
    1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
    2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
    3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      AASH=ASH
      SHLCST=0.0
      BRKTOT=0.0
      ASHCST=0.0
      VVOLIT=VOLIT
      FFREE=FREH2O
     ASH=0.0
     VOLIT=0.0
     FREH2O=0.0
     DO 30 I=1,NPRD
        MLPRDT(I,III)=MLPRDT(I,III-1)
 30 CONTINUE
```

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      PVOL=PINC
      TVOL=T2
       CALL VLRATE(TVOL,PVOL,NPRD)
      IF(T1.GT.T2) GOTO 80
      IF(IDEBUG.GT.25)WRITE(6,90) T1,T2
   90 FORMAT(5X,'INLET TEMP IN AFTER =',F7.2,'CELCIUS. OUTLET TEMP= ',
     1F7.2,'CELCIUS')
      IF(IDEBUG.GT.25) WRITE(6,500)
  500 FORMAT(10X,'SUBROUTINE AFTER')
      IF(LIQI) AFT=1.
      IF(ROTARY) AFT=2.
      IF(FLUID) AFT=3.
      NSET =0
      IF(.NOT.LIQI) LIQI=.TRUE.
      FLUID=.FALSE.
      ROTARY=.FALSE.
        BAL=.TRUE.
        IF(ENGL) CALL METRC(NREAC,NPRD)
         VVOLIT=VOLIT
         VOLIT=0.0
         VMSAIR=MASSAR
         MASSAR=0.0
       CALL HTMS(NREAC,NPRD)
        ISST=0
        IF(ISST.EQ.1) STOP
       IF(METRIC) CALL ENG(NREAC,NPRD)
      PVOL=PINC
      TVOL=T2
       CALL VLRATE(TVOL,PVOL,NPRD)
       RHO=MSTOT(III)/VOLRAT(III)
      DESVOL(III)=VOLRAT(III)*RETIM(III)/3600.0
      IF(IDEBUG.LT.25) GOTO 60
      WRITE(6,600) RETIM(III),VOLRAT(III),DESVOL(III)
  600 FORMAT(10X,'RETENTION TIME=  ',F7.4,'VOLUME RATE=',E15.5
     1,'DESIGN VOLUME=',E15.5)
   60 AREA(III)=5.76*DESVOL(III)**0.67
      DIA(III)=(DESVOL(III)*4.0/3.1416/RLD(III))**(1./3.)
      INCLEN(III)=DIA(III)*RLD(III)
      IF(IDEBUG.NE.1) GOTO 70
      WRITE(6,300) DESVOL(III),DIA(III),INCLEN(III),AREA(III),VOLRAT(
     1III)
  300 FORMAT(2X,'DESIGN VOLUME (FT**3)= ',E15.5/2X,'INCINERATOR DIAMETE
     1 R (FT)= ',E15.5,'INCINERATOR LENGTH (FT)= ',E15.5/2X,
     2 ' SURFACE AREA(III) OF INCINERATOR (FT**2)= ',E15.5/2X,'GAS FLOW'
     3, ' RATE (FT**3/HR)= ',E15.5)
   70 IF(UNIT(III).EQ.SUNIT(8)) LIQI=.TRUE.
        CALL BLOCK(NREAC,NPRD)
        CALL SHELL(NREAC,NPRD)
        CALL BURNER(NREAC,NPRD)
        EXTRA2 = (BRKTOT+SHLCST+TBRNTT)*PREXT
        AFTINC=BRKTOT+SHLCST+TBRNTT
        AFTINC=AFTINC+(EXTRA2)
      FULCST=MASSFL*ZFLHT*FULC
      GAL=MASSFL/60.0*ZFLHT/HTCNT
       CSTMAN=AFTINC*0.09
      TOTMAN=TOTMAN+CSTMAN
      FLPMHP=0.036*GAL
      TOTELC=TOTELC+(FLPMHP*DAY*YEAR*0.746/0.80)
      CSTIIN=CSTIIN+AFTINC*.30
      CALL OUTP1(NPRD)
      CALL OUTP6(NPRD)
      LIQI=.FALSE.
      IF(AFT.EQ.1) LIQI=.TRUE.
      IF(AFT.EQ.2) ROTARY=.TRUE.
      IF(AFT.EQ.3) FLUID=.TRUE.
      IF(NUNIT.NE.III) FLGPAS=.TRUE.
      GOTO 100
   80 WRITE(6,400)T1,T2
      FLGPAS=.FALSE.
  400 FORMAT(10X,'THE INLET TEMPERATURE OF THE INCINERATOR ',F7.2,
     1' OUTLET  TEMPERATURE IS ',F7.2,' DEGREES FAHRENHEIT')
  100 ASH=AASH
```

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      VOLIT=VVOLIT
      FREH2O=FFREE
         PEXT= PEXT- PRESSR(MSTOT(III),RHO,DIA(III),INCLEN(III))
      RETURN
      END
      SUBROUTINE BURNER
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3.MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
        COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        TBRNTT=0.0
        BRNSCT=0.0
        BRNCST=0.0
        IF(ZSLHT.LT.4000.) GOTO 10
      NUM=0
      ZNUM=0.
C  ONLY ONE FUEL BURNER REQUIRED
        IF(IDEBUG.GT.25) WRITE(6,35) ZFLHT,MASSFL,HTFLCB
   35 FORMAT(2X,'HEAT CONTENT OF FUEL(BTU/LB)= ',E15.2,'MASS RATE OF FUE
     1L (LB/HR)= ',E15.2/2X,'HEAT OUTPUT FROM FUEL(BTU/HR) =',E15.2)
C
         HTFLCB=ZFLHT*MASSFL
          IF(HTFLCB.GT.1.5E6) GOTO 20
C  FOR SMALL BURNERS ($1,200. DOLLARS EACH FOR 1.5E6 MAX BTU/HR HT RATE
      ZNUM=HTFLCB/1.2E6
       NUM=ZNUM
        IF(ZNUM.GT.NUM) NUM=NUM+1
         ZNUM=NUM
          BRNCST=ZNUM*1200.00
           GOTO 40
   20 IF(HTFLCB.GT.5.0E6) GOTO 30
      ZNUM=HTFLCB/4.0E6
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        NUM=ZNUM
         IF(ZNUM.GT.NUM) NUM=NUM+1
         ZNUM=NUM
          BRNCST=ZNUM*5000.0
           GOTO 40
   30 ZNUM=HTFLCB/10.0E6
        NUM=ZNUM
        IF(ZNUM.GT.NUM) NUM=NUM+1
        ZNUM=NUM
        BRNCST=ZNUM*10000.
        IF(NUM.GT.8) WRITE(6,34) NUM
   34 FORMAT(2X,'HEAT LOAD IS TOO LARGE  FOR BURNER SYSTEMS'/I5,'  BURNE
     1RS ARE REQUIRED')
         GOTO 40
   10 CONTINUE
C  TWO FUEL BURNERS REQUIRED
C
         HTFLCB=ZFLHT*MASSFL/2.
          IF(HTFLCB.GT.1.5E6) GOTO 21
C  FOR SMALL BURNERS ($1,200. DOLLARS EACH FOR 1.5E6 MAX BTU/HR HT RATE
       ZNUM=HTFLCB/1.2E6*2
    .   NUM=ZNUM
         IF(ZNUM.GT.NUM) NUM=NUM+1
         ZNUM=NUM
          BRNCST=ZNUM*1200.00
          GOTO 40
   21 IF(HTFLCB.GT.5.0E6) GOTO 32
       ZNUM=HTFLCB/4.0E6*2.
        NUM=ZNUM
         IF(ZNUM.GT.NUM) NUM=NUM+1
         ZNUM=NUM
          BRNCST=ZNUM*5000.0
          GOTO 40
   32 ZNUM=HTFLCB/10.0E6*2.
        NUM=ZNUM
        IF(ZNUM.GT.NUM) NUM=NUM+1
        IF(NUM.GT.8) WRITE(6,31) NUM
   31 FORMAT('HEAT LOAD IS TOO LARGE  FOR BURNER SYSTEMS'/I5,'  BURNERS
     1 ARE REQUIRED')
   40 CONTINUE
C
        IF(.NOT.BRN) GOTO 60
        IF(III.NE.1) GOTO 60
C    WASTE FUEL BURNER SELECTION
C
       HTWSCB=ZSLHT*MASSSL
       IF(HTWSCB.LT.2.30E7) GOTO 50
       BRNSCT=HTWSCB*3.248E-4+30029.6
       GOTO 60
   50 BRNSCT=HTWSCB*5E-4+26000.
   60 CONTINUE
       TBRNTT=(BRNSCT+BRNCST)/344.9*FACPVF
       IF(IDEBUG.LT.25) GOTO 70
          WRITE(6,100) ZSLHT,HTWSCB,BRNSCT,ZFLHT,HTFLCB,BRNCST,NUM
  100 FORMAT(10X,'DATA USED IN SUBROUTINE BURNER'///10X,'SLUDGE ',
     1'BURNER CALCULATIONS'/ 1X,'SLUDGE HEAT OF COMBUSTION(BTU/LB)=',
     2E15.3,'TOTAL SLUDGE HEAT LOAD(BTU/HR)= ',E15.3/1X,'COST OF ',
     3'SLUDGE BURNER SYSTEM (JUNE 1981 DOLLARS)= ',E15.2//10X,
     4'FUEL BURNER CALCULATIONS'/ 1X,'FUEL HEAT OF COMBUSTION (BTU/LB)='
     5,E15.2,'TOTAL HEAT LOAD (BTU/HR)= ',E15.3/1X,'COST OF FUEL BURNER'
     6,' SYSTEM (JUNE 1981 DOLLARS)= ',E15.2,'NUMBER OF NOZZLES USED FOR
     7','FUEL COMBUSITON= ',I2)
   70 CONTINUE
       NUMBRN=NUM
       RETURN
        END
       SUBROUTINE QUENCH(NREAC,NPRD)
       REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
       LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
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     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2  ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1  ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1  ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2  ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3  ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4   TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5   TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6   EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1,  FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      DO 10 I=1,NPRD
          MLPRDT(I,III)=MLPRDT(I,III-1)
   10 CONTINUE
      MASSFL=0.0
      AASH=ASH
      VVOLIT=VOLIT
      FFREE=FREH2O
      ASH=00.0
      VOLIT=0.0
      FREH2O=0.0
      IF(ENGL) CALL METRC(NREAC,NPRD)
      CALL HTMSQ(NREAC,NPRD)
      FREH2O=0.0
      IF(METRIC) CALL ENG(NREAC,NPRD)
      TVOL=T1
      PVOL=PINC
      CALL VLRATE(TVOL,PVOL,NPRD)
      FACLEN = 3.0
      VEL=10.0
C       FEET / SECOND
          RHO=MSTOT(III)/VOLRAT(III)
          ARRA=MSTOT(III)/RHO/VEL/3600.0
          DIA(III)= (ARRA/3.1416*4.0)**(0.5)
          INCLEN(III)= DIA(III)*FACLEN
          DESVOL(III)= 3.1416*DIA(III)**2.0/4.0*INCLEN(III)
          IF(QTEMP.EQ.1.0) CSTQUE=0.235*VOLRAT(III)/60.0 + 43000.0
       IF(IDEBUG.EQ.100) WRITE(6,900) QTEMP,VOLRAT(III),CSTQUE
  900 FORMAT(10X,'QTEMP=',F4.1,'VOLUME RATE(FT°3/HR)= ',E15.5/
     1 10X,'COST OF QUENCH CHAMBER= ',E15.5)
          IF(QSAT.EQ.1.0) CSTQUE=0.220*VOLRAT(III)/60.0 +  8000.0
          IF(T1.GT.600.0.AND.CS) CALL BLOCK(NREAC,NPRD)
          IF(T1.GT.900.0.AND.SS) CALL BLOCK(NREAC,NPRD)
          IF(T1.GT.1100.0.AND.IC) CALL BLOCK(NREAC,NPRD)
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      ASH=AASH
      VOLIT=VVOLIT
      FREH2O=FFREE
     CSTQUE=CSTQUE/308.4*FACCES
     CSTIIN=CSTIIN+CSTQUE*0.67
        PEXT= PEXT- PRESSR(MSTOT(III),RHO,DIA(III),INCLEN(III))
     WRITE(6,400)
400  FORMAT('1',25X,'QUENCH CHAMBER DESIGN SPECIFICATIONS'///)
     WRITE(6,401) T2,DIA(III),INCLEN(III),H2OM,VAPNO
401  FORMAT(10X,'QUENCH TEMPERATURE = ',F6.1,' FAHRENHEIT'/
    1 10X,'QUENCH DIAMETER = ',2X,F7.1,' FEET'/
    2 10X,'QUENCH LENGTH =   ',2X,F7.1,' FEET'/
    3 10X,'WATER RATE =   ',2X,E10.3,' LB/HR'/
    4 10X,'WATER OUT  =  .',2X,E10.3,' LB/HR'/
    1 10X,'OPTIONS IN EFFECT'/)
      IF(IC) WRITE(6,300)
300  FORMAT(15X,'INCONEL WAS SELECTED AS THE MATERIAL OF CONSTRUCTION')
     IF(SS) WRITE(6,301)
     IF(CS) WRITE(6,302)
301  FORMAT(15X,'STAINLESS STEEL WAS SELECTED AS THE MATERIAL OF ',
    1 'CONTRUCTION.')
     IF(T2.GT.600.0.AND.CS) WRITE(6,304) (BNMIN(I),I=1,6),THCKIN,(BNMFR
    1 (I),I=1,6),REFINS
     IF(T2.GT.900.0.AND.SS) WRITE(6,304) (BNMIN(I),I=1,6),THCKIN,(BNMFR
    1 (I),I=1,6),REFINS
     IF(T2.GT.1100.0.AND.IC) WRITE(6,304) (BNMIN(I),I=1,6),THCKIN,(BNMF
    1 R(I),I=1,6),REFINS
304  FORMAT(15X,'REFRACTORY SELECTED FOR QUENCH = ',6(A4),' THICKNESS '
    1 ,'=',F3.1/15X,'INSULATION SELECTED FOR QUENCH = ',6(A4),
    2 ' THICKNESS = ',F3.1)
302  FORMAT(15X,'CARBON STEEL WAS SELECTED AS THE MATERIAL OF ',
    1 'CONSTRUCTION ')
      IF(QTEMP.EQ.1) WRITE(6,402)
402  FORMAT(15X,'QUENCH CHAMBER DESIGNED FOR SPECIFIC OUTLET',
    1 ' TEMPERATURE')
     IF(QSAT.EQ.1) WRITE(6,403)
403  FORMAT(15X,'QUENCH CHAMBER DESIGNED TO COOL GAS TO SATURATED',
    1 'TEMPERATURE')
     IF(NUNIT.NE.III) FLGPAS=.TRUE.
     TOTMAN=TOTMAN+CSTQUE*0.10
     TOTELC=TOTELC+0.746*DAY*YEAR*0.036*H2OM/62.4/35.45*264.35
     RETURN
     END
     SUBROUTINE HTEXCH(NREAC,NPRD)
     REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
    1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
     LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
    1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
    2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
    4,CUTVN,CMBST,TCH
    3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
    1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
    2 ,SCRNME*20
     COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL.
    1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
    2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
     COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
    1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
     COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
    1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
    2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
    3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
     COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
    1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
     COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
    1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
    2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
    3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
     COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
    1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
    2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
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     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      PSTM=185.0
      DO 20 I=1,NPRD
         MLPRDT(I,III)=MLPRDT(I,III-1)
   20 CONTINUE
      IF(ENGL) CALL METRC(NREAC,NPRD)
      CALL DTHEAT(NPRD)
      IF(METRIC) CALL ENG(NREAC,NPRD)
C     BOILER STEAM CHARACTERITICS
C         P=150 PSIA
C         T=366.0 FAHRENHEIT
C         DH(VAP)= 857.4 BTU/LB
C
      STMRT= -DELTAH/857.41
      STMREC=STMCST*STMRT*0.80
      TVOL=60.0
      PVOL=14.696
      CALL VLRATE(TVOL,PVOL,NPRD)
      IF(HM2) GOTO 30
      AR=ABS(DELTAH/HTC/(T2-T1))
   33 CONTINUE
      CSTHTR= (28800.*AR**(-0.440))*EXP(0.0672*LOG(AR)**2.0)
      IF(AR.LT.200.0.AND.AR.GT.50000.0) WRITE(6,303) AR
  303 FORMAT(10X,'**ERROR- AREA MUST RANGE BETWEEN 200 AND 50000
     1 SQUARE FEET FOR CALCULATION ACCURACY.'/10X,'AREA USED IS',F9.1,
     2 'FT**2')
      IF(IDEBUG.GT.1) WRITE(6,10)  STMRT,STMREC,CSTHTR
   10 FORMAT(10X,'RATE OF STEAM FORMATION (GRAMS/HR)',E15.5/10X,
     1'REVENUE FROM RECOVERED STEAM ($/HR WITH 80% EFFICIENCY)',F7.2,
     2/10X,'HEAT EXCHANGER COST(U.S. DOLLARS)',F12.2)
      IF(METRIC) CALL ENG(NREAC,NPRD)
      IF(IC) CSTHTR=CSTHTR*3.0
      IF(T2.GT.800.0) CSTHTR=CSTHTR*1.2
      CSTHTR=CSTHTR/308.4*FACCES
      IF(NUNIT.NE.III) FLGPAS=.TRUE.
        PEXT=PINC-0.872*(ABS(DELTAH/HTCOMB)*100.0)-1.920
         IF(PEXT.GT.PINC) PEXT=PINC - 2.0/12.0/33.9*14.696
      WRITE(6,400)
  400 FORMAT(30X,'HEAT RECOVERY SYSTEM DESIGN')
      WRITE(6,402) STMRT,STMREC
  402 FORMAT(10X,'CHARACTERISTICS OF STEAM PRODUCED'/
     1 15X,'PRESSURE OF STEAM FORMED=                185. PSIA '/
     2 15X,'QUANTITY OF STEAM PRODUCED = ',9X,F12.0,' LB/HR'/
     3 15X,'COST RECOVERED FROM STEAM PRODUCTION = ',F12.2,' U.S. ',
     4 ' DOLLARS/HR'/10X,'MATERIALS OF CONSTRUCTION')
      IF(IC) WRITE(6,500)
  500 FORMAT(15X,'MATERIAL OF CONSTRUCTION IS INCONEL')
      IF(T2.GT.800.0) WRITE(6,501)
  501 FORMAT(15X,'DESIGN IS FOR HIGH TEMPERATURE PERFORMANCE')
      GOTO 31
   30 AR=ABS(DELTAH/HTC/(T2-T1))
      CB=EXP(8.551 - 0.30863 * LOG(AR) + 0.06811 * LOG(AR)**2.0)
      IF(FXH) FD=EXP(-1.1156 + 0.0906 * LOG(AR))
      IF(KRB) FD=1.35
      IF(UTB) FD=EXP(-0.9816 + 0.0830 * LOG(AR))
      IF(PSTM.GE.100.0.AND.PSTM.LE.300.0) FP=0.7771+0.04981*LOG(AR)
      IF(PSTM.GT.300.0.AND.PSTM.LE.600.0) FP=1.0305+0.07140*LOG(AR)
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      IF(PSTM.GT.600.0.AND.PSTM.LE.900.0) FP=1.1400+0.12088*LOG(AR)
      IF(PSTM.GE.100.0.OR.PSTM.LE.900.0) GOTO 34
      IF(PSTM.LT.100.0) WRITE(6,301) PSTM
  301 FORMAT(10X,'PRESSURE OF HEAT EXCHANGER IS TOO SMALL FOR ESTIMATION
     1 AT ',F10.3,'PSIA. METHOD 1 IS USED')
      IF(PSTM.GT.900.0) WRITE(6,302) PSTM
  302 FORMAT(10X,'PRESSURE OF HEAT EXCHANGER IS TOO LARGE FOR ESTIMATION
     1 AT ',F10.3,'PSIA. METHOD 1 IS USED')
   34 IF(AR.LT.150.0.AND.AR.GT.12000.0) WRITE(6,304) AR
  304 FORMAT(10X,'AREA OF HEAT TRANSFER(',F7.1,' FT°2) IS OUT OF RANGE'
     1/10X,'METHOD 1 IS USED')
      IF(AR.LT.150.0.AND.AR.GT.12000.0) GOTO 33
      IF(.NOT.S316) GOTO 600
          G1=0.8608
          G2=0.23296
  600 IF(.NOT.S304) GOTO 601
          G1=0.8193
          G2=0.15984
  601 IF(.NOT.S347) GOTO 602
          G1=0.6116
          G2=0.22186
  602 IF(.NOT.NI200) GOTO 603
          G1=1.5092
          G2=0.60859
  603 IF(.NOT.MO400) GOTO 604
          G1=1.2989
          G2=0.43377
  604 IF(.NOT.IN600) GOTO 605
          G1=1.2040
          G2=0.50764
  605 IF(.NOT.IN825) GOTO 606
          G1=1.1854
          G2=0.49706
  606 IF(.NOT.TI) GOTO 607
          G1=1.5420
          G2=0.42913
  607 IF(.NOT.HS) GOTO 608
          G1=0.1549
          G2=1.51774
  608 CONTINUE
      FM=G1+G2*(LOG(AR))
      CSTHTR=(CB*FD*FP*FM)*FACCES/332.3
      CSTIIN=CSTIIN+CSTHTR*1.00
      WTRTOT=WTRTOT+STMRT
      TOTMAN=TOTMAN+CSTHTR*0.10
   31 RETURN
      END
      SUBROUTINE VENTUR(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
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     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C
      ICONV=0
      PSTPAT=0.0
      FFF=0
      FF=1
      DO 30 I=1,NPRD
         MLPRDT(I,III)=MLPRDT(I,III-1)
   30 CONTINUE
       CALL VLRATE(T2,PINC,NPRD)
       IF(.NOT.(PRI.AND.CUTVN)) GOTO 60
      VENDP=20.0
   20 VENREM=0.0
      VENBEF=0.0
      DO 10 I=1,NPRTS
         VEN1=ASHGAS*WTPRT(I)
         VEN2=(1.0-WTPPRT(DIAPT(I),VENDP))
               VEN3=VEN2*VEN1
         VENREM=VENREM+VEN3
         VENBEF=VENBEF+VEN1
         IF(IDEBUG.GE.25) WRITE(6,29) VENDP
   29 FORMAT(20X,'PRESSURE DROP = ',F10.4)
   10 CONTINUE
      PREPAT=ASHGAS/VOLRAT(III)
      PSTPAT=VENREM/VOLRAT(III)
      IF(PSTPAT.GT.FEDRG2) VENDP=VENDP+10.0
      IF(VENDP.GT.100) GOTO 61
      IF(PSTPAT.GT.FEDRG2) GOTO 20
      DPTOT=VENDP
      IF(METRIC) CALL ENG(NREAC,NPRD)
      DO 200 I=1,NPRD
         MLPRDT(I,III)=MLPRDT(I,III-1)
  200 CONTINUE
   60 VOLUME=VOLRAT(III)/60.0/1000.0
      IF(.NOT.CUTVN) GOTO 61
       VENDP=20.
  420 VENREM=0.0
      VENBEF=0.0
      CTDI=LOG(VENDP) * (-0.519) +(-.856)
      CTDI=EXP(CTDI)
      A=2.00
      C=0.50/EXP(A*CTDI**2.0)
      DO 410 I=1,NPRTS
      PT=C*EXP(2.0*DIAPT(I))
         VENBEF=ASHGAS*WTPRT(I)+VENBEF
         VENREM=ASHGAS*WTPRT(I)*PT+VENREM
           IF(IDEBUG.EQ.25) WRITE(6,29) VENDP
  410 CONTINUE
      PREPAT=ASHGAS/VOLRAT(III)
      PSTPAT=VENREM/VOLRAT(III)
      IF(PSTPAT.GT.FEDRG2) VENDP=VENDP+1.0
      IF(VENDP.GT.100) GOTO 61
      IF(PSTPAT.GT.FEDRG2) GOTO 420
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      DPTOT=VENDP
   61 CONTINUE
  300 FORMAT(10X,'VOLUME RATE (FT°3/MIN/1000)= ',10X,E15.5/10X,
     1 'VOLUME RATE (FT°3/HR) = ',10X,E15.5/10X,'VENTURI COST= ',
     2 10X,F12.0,'1979 DOLLARS')
      CSTVEN=7117.0+408.*VOLUME-0.85*VOLUME**2.
      IF(IDEBUG.GE.25) WRITE(6,300) VOLUME,VOLRAT(III),CSTVEN
      BCONST=LOG(VOLUME) - 1.0*LOG(ABS(PINC/14.695*33.9*12.0
     1 - 33.9*12.0))
      IF(BCONST.GT.5.0) THCK=1./8.
      IF(BCONST.GT.3.0.AND.BCONST.LT.5.00) THCK=3.0/16.
      IF(BCONST.GT.2.9.AND.BCONST.LT.3.00) THCK=1./4.
      IF(BCONST.GT.2.48.AND.BCONST.LT.2.9) THCK=3./8.
      IF(BCONST.GT.2.3.AND.BCONST.LT.2.48) THCK=7./16.
      IF(BCONST.LT.2.3) THCK=1./2.
      IF(THCK.LT.0.25.AND.VOLUME.GT.100000.) VENFAC=5.8
       VVV=VOLRAT(III)/60.0/1000.0
      DO 600 IL=1,7
          ICONT= THICK(DPTOT,VVV,IL)
          IF(ICONT.LT.1) GOTO 600
          IF(IL.EQ.1) VNCST=1.0
          IF(IL.EQ.2) VNCST=-7.00E-3*VVV+1.57
          IF(IL.EQ.3) VNCST=-6.25E-3*VVV+1.9625
          IF(IL.EQ.4) VNCST=-0.0121*VVV+3.221
          IF(IL.EQ.5) VNCST=-0.0175*VVV+4.8255
          IF(IL.EQ.6) VNCST=-0.021*VVV+6.457
          IF(IL.EQ.7) VNCST=-0.003*VVV+8.3
          IF(IL.EQ.7.AND.VVV.GT.90.0) VNCST=5.6
          IF(IL.EQ.7.AND.VVV.GT.90.0) VNCST=5.6
          IF(IL.EQ.6.AND.VVV.GT.100.0) VNCST=4.75
          IF(IL.EQ.5.AND.VVV.GT.100.0) VNCST=3.4
          IF(IL.EQ.4.AND.VVV.GT.90.0) VNCST=2.2
          IF(IL.EQ.3.AND.VVV.GT.60.0) VNCST=1.6
          IF(IL.EQ.2.AND.VVV.GT.60.0) VNCST=1.2
            GOTO 601
  600 CONTINUE
  601 CSTVEN=CSTVEN*VNCST
      IF(IC) CSTVEN=CSTVEN*3.5
      IF(SS) CSTVEN=CSTVEN*3.2
      IF(VENAUT) CSTVEN=CSTVEN+6350.0
      IF(.NOT.VENAUT) CSTVEN=CSTVEN+3450.0
      IF(FG) CSTVEN=CSTVEN*1.15
      INCLEN(III)=8.0+0.250*VOLUME-0.00048*VOLUME**2.
      DIA(III)=5.0+0.11*VOLUME-0.00024*VOLUME**2.
      IF(NUNIT.NE.III) FLGPAS=.TRUE.
      VENH2O=VENWAT*VOLRAT(III)/1000.0
C LBH2O/HR
      CSTIIN=CSTIIN+CSTVEN*.40
      CSTVEN=CSTVEN/308.4*FACCES
      WTRTOT=WTRTOT+VENH2O*0.25
      TOTMAN=TOTMAN+CSTVEN*0.10
      GAL=VENH2O/62.4/35.45*264.17
      WTRHP=0.036*GAL
      CSEL=WTRHP/0.80*0.746
      TOTELC=TOTELC+CSEL
      WRITE(6,501)
  501 FORMAT('1',30X,'VENTURI SCRUBBER DESIGN OUTPUT'/)
      WRITE(6,500) DPTOT,VENH2O,THCK,FEDRG2,PSTPAT
  500 FORMAT(15X,'TOTAL PRESSURE DROP=          ',F10.0,' INCHES H2O'/
     1       15X,'WATER FEED RATE=          ',E15.5,     'LB/HR'/
     2       15X,'VENTURI SHELL THICKNESS=      ',F10.2,'  INCHES'/
     3       15X,'FEDERAL PARTICULATE LEVELS=   ',E15.5,'LB/ACF'/
     4       15X,'CALCULATED EMISSION LEVELS=   ',E15.5,'LB/ACF')
      WRITE(6,320)  INCLEN(III),DIA(III)
  320 FORMAT(15X,'LENGTH OF VENTURI SEPARATOR(FT)= ',F9.0,/
     1 15X,'DIAMETER OF VENTURI SEPARATOR(FT)= ',F9.0)
      WRITE(6,503)
  503 FORMAT(15X,'OPTIONS SELECTED')
      IF(PRI) WRITE(6,504)
  504 FORMAT(20X,'PRESSURE DROP CALCULATED '/20X,'FROM EXPERIMENTAL DATA
     1')
      IF(.NOT.PRI) WRITE(6,505)
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505 FORMAT(20X,'PRESSURE DROP DIRECTLY SPECIFIED')
    IF(VENAUT) WRITE(6,506)
506 FORMAT(20X,'AUTOMATIC THROAT CONTROL SPECIFIED')
    IF(.NOT.VENAUT) WRITE(6,507)
507 FORMAT(20X,'MANUAL THROAT CONTROL SPECIFIED')
    IF(FG) WRITE(6,508)
508 FORMAT(20X,'THROAT LINED WITH FIBERGLASS')
    IF(IC) WRITE(6,509)
509 FORMAT(20X,'VENTURI CONSTRUCTED OF INCONEL')
    IF(SS) WRITE(6,510)
510 FORMAT(20X,'VENTURI SCRUBBER CONSTRUCTED OF STAINLESS STEEL')
    IF(CS) WRITE(6,511)
511 FORMAT(20X,'VENTURI SCRUBBER CONSTRUCTED OF CARBON STEEL')
    RETURN
    END
    SUBROUTINE INDFAN(NREAC,NPRD)
    REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
   1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
    LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
   1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
   2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
   4,CUTVN,CMBST,TCH
   3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
    LOGICAL ELC
     CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
   1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
   2  ,SCRNME*20
    COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
   1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
   2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
    COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
   1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
    COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
   1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
   2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
   3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
    COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
   1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
    COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
   1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
   2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
   3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
    COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
   1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
   2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
   3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
   4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
   5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
   6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
     COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
   1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
    COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
    COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
    COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
    COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
   1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
   2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
    COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
   1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
   2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
   3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
    IF(METRIC) CALL ENG(NREAC,NPRD)
    ELC=.FALSE.
    DO 400 I=1,NPRD
       MLPRDT(I,III)=MLPRDT(I,III-1)
400 CONTINUE
    PEXT=PINC+TOTDP/12.0/33.9*14.696
    T2=(T1+459.6)*(PEXT/PINC)**((1.4-1.0)/1.4)-459.6
    TVOL=T2
    PVOL=PINC
    IF(UNIT(III).NE.SUNIT(1)) CALL VLRATE(TVOL,PVOL,NPRD)
    BCRPM=-1.45E-3
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      CCRPM= 0.50
      DPSTG= 20.0
      NMSTM=1
      VOLFAN=VOLRAT(III)/60.0
      VOLFN=VOLFAN
   30 CONTINUE
      DO 63 I=1,9
         LGC=RPM(DPSTG,I,VOLFN)
         IF(LGC.LT.1) GOTO 65
            IF(I.EQ.9) RPMEST=300.0
            IF(I.EQ.8) RPMEST=500.0
            IF(I.EQ.7)RPMEST=750.0
            IF(I.EQ.6) RPMEST=1000.0
            IF(I.EQ.5) RPMEST=1500.0
            IF(I.EQ.4) RPMEST=2000.0
            IF(I.EQ.3) RPMEST=2500.0
            IF(I.EQ.2) RPMEST=3000.0
            IF(I.EQ.1) RPMEST=3500.0
            GOTO 64
   65 CONTINUE
   63 CONTINUE
           IF(RPMEST.GT.3600.0)  DPSTG=DPSTG-1.0
           IF(RPMESE.LT.300.) GOTO 40
      WRITE(6,66)
   66 FORMAT(10X,'**ERROR - AFTER 10 ITERATIONS, RPM"S WAS ',
     1 'NOT SOLVED.')
      ELC=.TRUE.
   64 CONTINUE
           IF(IDEBUG.GE.25) WRITE(6,603) VOLFAN,DPSTG,C1,RPMEST
  603 FORMAT(10X,'VOLUME RATE OF FAN (FT**3/MIN/1000)= ',F10.2/
     110X,'PRESSURE CHANGE PER FAN STAGE (IN H2O)= ',F10.2/
     210X,'C1 CONSTANT=',F12.2/
     310X,'ESTIMATE OF RPMS',F12.2)
               GOTO 50
   40 NMSTM=NMSTM+1.0
      VOLFN=VOLFAN/NMSTM
      GOTO 30
   50 NUMFAN=TOTDP/DPSTG
      IF(DPSTG.GT.2.5) GOTO 51
      FANCLS=1.0
      GOTO 56
   51 IF(DPSTG.GT.4.25) GOTO 52
      FANCLS=2.0
      GOTO 56
   52 IF(DPSTG.GT.6.75) GOTO 53
      FANCLS=3.0
      GOTO 56
   53 FANCLS=4.0
   56 CONTINUE
      IF(IDEBUG.GT.25) WRITE(6,350) RPMEST,C1,DPSTG,VOLFAN,NUMFAN
  350 FORMAT(10X,'RPM ESTIMATE= ',F9.2,3X,'CONST 1= ',E15.5,
     1' PRESSURE DROP PER STAGE= ',E15.5,'IN H2O'
     2/ 10X,'VOLUME RATE PER FAN TRAIN',E15.5,' FT°3/HR'
     3, 'NUMBER OF FANS=',I3)
      IF(NUMFAN.GT.ABS(NUMFAN)) NUMFAN=NUMFAN+1
C          CALCULATE HORSEPOWER FOR INDUCTION
      DO 60 ISTRM=1,10
      VOLFN=VOLRAT(III)/60.0
         VOLFN=VOLFN/ISTRM
         NMSTM=ISTRM
        LGC=0
        DO 61 I=1,9
           LGC=FX4(DPSTG,I,VOLFN)
           IF(LGC.LT.1) GOTO 61
               IF(I.EQ.1) HPFAN=1.0
               IF(I.EQ.2) HPFAN=2.0
               IF(I.EQ.3) HPFAN=5.0
               IF(I.EQ.4) HPFAN=10.0
               IF(I.EQ.5) HPFAN=20.0
               IF(I.EQ.6) HPFAN=50.0
               IF(I.EQ.7) HPFAN=100.00
               IF(I.EQ.8) HPFAN=200.0
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                IF(I.EQ.9) HPFAN=500.0
                GOTO 32
   61 CONTINUE
   60 CONTINUE
      WRITE(6,62)
   62 FORMAT(10X,'**ERROR - AFTER 10 ITERATIONS HORSEPOWER WAS',
     1 ' NOT SOLVED')
   32 CONTINUE
      THPFAN=HPFAN*NMSTM
      IF(HPFAN.GT.500.0) WRITE(6,100) HPFAN
  100 FORMAT(10X,'HORSE POWER  IS TOO LARGE AT ',F13.3,'HORSE POWER')
        GOTO 80
   70 CONTINUE
      THPFAN=HPFAN*NMSTM
      IF(HPFAN.GT.50.0) WRITE(6,110) HPFAN
  110 FORMAT(10X,'HORSEPOWER IS TOO LARGE TOO BE USED BY THIS EQUATION')
C         SELECT MOTOR SIZE
   80 IF(RPMEST.LT.4000.0) GOTO 310
      WRITE(6,200) RPMEST
  200 FORMAT(10X,'RPM IS TOO HIGH AT ',E15.5)
  310 IF(RPMEST.LT.2400.0) GOTO 320
         RPMEST=3600.0
         GOTO 380
  320 IF(RPMEST.LT.1400.0) GOTO 330
         RPMEST=1800.0
         GOTO 380
  330 IF(RPMEST.LT.1000.) GOTO 335
      RPMEST=900.0
      GOTO 380
  335 IF(RPMEST.LT.400.) WRITE(6,340) RPMEST
  340 FORMAT(10X,'RPMS ARE  TOO LOW AT ',F9.2,'SET TO  600 RPMS')
  380 CSTMOT=FANFXN(HPFAN,RPMEST)
      IF(IDEBUG.GE.25) WRITE(6,355) C2,HPFAN,RPMEST,CSTMOT
  355 FORMAT(10X,'CONST 2= ',E15.5,'FAN HORSEPOWER= ',E15.5,'HP'/
     110X,'RPM ESTIMATE= ',E15.5,'  COST OF MOTOR= ',E15.5,'US DOLLARS')
      VOLFAN=VOLFAN/1000.0
      C3=LOG(VOLFAN)-0.5012*LOG(DPSTG)
      IF(C3.LT 0.0) C3=0.0
      DIAIMP=9.765 + 13.42*C3 - 3.490 * C3**2. + 1.34 * C3**3.
      IF(DIAIMP.GT.18.0) GOTO 205
         IF(FANCLS.EQ.1) CSTUF=  800.0
         IF(FANCLS.EQ.2) CSTUF= 1000.0
         IF(FANCLS.EQ.3) CSTUF= 1900.0
         IF(FANCLS.EQ.4) CSTUF= 2200.0
         DPRCST=(.39+.86)*1000.0
         GOTO 250
  205 IF(DIAIMP.GT.27.0) GOTO 210
         IF(FANCLS.EQ.1) CSTUF= 1500.0
         IF(FANCLS.EQ.2) CSTUF= 2000.0
         IF(FANCLS.EQ.3) CSTUF= 3500.0
         IF(FANCLS.EQ.4) CSTUF= 4000.0
         DPRCST=(0.5+1.)*1000.0
         GOTO 250
  210 IF(DIAIMP.GT.40.0) GOTO 220
         IF(FANCLS.EQ.1) CSTUF= 2800.0
         IF(FANCLS.EQ.2) CSTUF= 3700.0
         IF(FANCLS.EQ.3) CSTUF= 5800.0
         IF(FANCLS.EQ.4) CSTUF= 7000.0
         DPRCST=(0.87+1.5)*1000.0
         GOTO 250
  220 IF(DIAIMP.GT.60.0) GOTO 230
         IF(FANCLS.EQ.1) CSTUF= 6000.0
         IF(FANCLS.EQ.2) CSTUF= 6000.0
         IF(FANCLS.EQ.3) CSTUF=10200.0
         IF(FANCLS.EQ.4) CSTUF=10500.0
         DPRCST=(1.7+2.5)*1000.0
         GOTO 250
  230 IF(DIAIMP.GT.80.0) GOTO 240
         IF(FANCLS.EQ.1) CSTUF=10000.0
         IF(FANCLS.EQ.2) CSTUF=10400.0
         IF(FANCLS.EQ.3) CSTUF=20000.0
         IF(FANCLS.EQ.4) CSTUF=25000.0
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         DPRCST=(1.8+4.1)*1000.0
         GOTO 250
  240 IF(DIAIMP.GT.98.0) GOTO 250
         IF(FANCLS.EQ.1) CSTUF=16000.0
         IF(FANCLS.EQ.2) CSTUF=20100.0
         IF(FANCLS.EQ.3) CSTUF=30000.0
         IF(FANCLS.EQ.4) CSTUF=38000.0
         DPRCST=(4.0+7.5)*1000.0
  250 IF(T2.GT.250.0.AND.T2.LT.600.0) CSTUF=CSTUF*1.03
      IF(T2.GT.600.0) WRITE(6,358)
  358 FORMAT(10X,'TEMPERATURE IS TOO HIGH FOR FANS')
      IF(SS) CSTUF=CSTUF*2.50
      IF(IC) CSTUF=CSTUF*3.0
      IF(IDEBUG.GE.25) WRITE(6,357)  DIAIMP,C3,CSTUF,NUMFAN
  357 FORMAT(10X,'DIAMETER OF IMPELLOR(IN)= ',F9.2,' CONST 3= ',E15.5
     1/10X,'COST OF EACH FAN= ',F10.2,'US DOLLARS.  THERE ARE',I2,'FANS'
     2)
        CSTFAN=CSTFAN/226.70*FACCES*NMSTM*NUMFAN
        CSTMOT=CSTMOT/226.70*FACCES
        DPRCST=DPRCST/226.70*FACPVF
      CSTFAN= CSTUF*NUMFAN*NMSTM+(DPRCST+CSTMOT)*NMSTM
      IF(NUNIT.NE.III) FLGPAS=.TRUE.
      CSTINS=CSTINS+CSTFAN*0.50
      WRITE(6,500)
  500 FORMAT('1',30X,'INDUCED DRAFT FAN DESIGN'//)
      WRITE(6,501)TOTDP
  501 FORMAT(10X,'TOTAL PRESSURE DROP(INCLUDING ADJUSTMENT FOR ',
     1 'ELEVATION) = ',F7.2,' IN H2O')
      WRITE(6,800) ELEVAT
  800 FORMAT(10X,'ELEVATION OF FACILITY=              ',F7.0,' FEET')
      WRITE(6,502) DPSTG
  502 FORMAT(10X,'PRESSURE DROP PER STAGE = ',F7.2,' IN H2O')
      WRITE(6,503) VOLFAN
  503 FORMAT(10X,'VOLUME RATE PER PARALLEL FEED = ',F7.2,'FT**3/MIN/',
     1'1000')
      WRITE(6,504) NUMFAN
  504 FORMAT(10X,'NUMBER OF FANS PER STAGE = ',I3)
      WRITE(6,505) RPMEST
  505 FORMAT(10X,'MOTOR RPMS = ',F9.2)
      WRITE(6,506) THPFAN
      WRITE(6,512) NMSTM
  512 FORMAT(10X,'NUMBER OF INLET STREAMS=',I3)
  506 FORMAT(10X,'TOTAL HORSEPOWER REQUIRED TO COMPRESS GAS = ',F10.2,
     1 ' HP')
      WRITE(6,507) DIAIMP
  507 FORMAT(10X,'DIAMETER OF IMPELLOR = ',F7.0,' INCHES ')
      WRITE(6,611)
  611 FORMAT(10X,'OPTIONS SELECTED')
      IF(IC) WRITE(6,508)
  508 FORMAT(15X,'MATERIAL OF CONSTRUCTION FOR FANS IS INCONEL ')
      IF(SS) WRITE(6,509)
  509 FORMAT(15X,'MATERIAL OF CONSTRUCTION OF THE FANS IS STAINLESS',
     1 ' STEEL')
      IF(CS) WRITE(6,600)
  600 FORMAT(15X,'MATERIAL OF CONSTRUCTION OF THE FANS IS CARBON',
     1 ' STEEL')
      WRITE(6,804)
  804 FORMAT(15X,'CLASS 4 FANS ARE SPECIFIED(HIGH PERFORMANCE)')
      CSTUFF=CSTUF*NUMFAN*NMSTM
      IF(IDEBUG.GE.25) WRITE(6,806) CSTUFF,DPRCST,CSTMOT,CSTFAN
  806 FORMAT(//29X,'COST OF INDUCTION FANS'/
     1 15X,'COST OF FANS=           ',F10.0,'   U.S. DOLLARS'/
     2 15X,'COST OF DAMPERS=        ',F10.0,'   U.S. DOLLARS'/
     3 15X,'COST OF MOTORS=         ',F10.0,'   U.S. DOLLARS'/
     4 15X,'----------------------------------'/
     5 15X,'TOTAL INDUCTION FAN COST=',F8.0,'   U.S. DOLLARS')
      CSTIIN=CSTIIN+CSTFAN*0.50
      TOTELC=TOTELC+(THPFAN/0.80*0.746+0.746*0.0/0.80)*DAY*YEAR
      TOTMAN=TOTMAN+CSTFAN*0.10
      RETURN
      END
      SUBROUTINE PCKBD(NREAC,NPRD)
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      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      LOGICAL FLAG
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C
      JPIK=0
      IDEBUG=26
      DO 30 I=1,NPRD
         MLPRDT(I,III)=MLPRDT(I,III-1)
   30 CONTINUE
       NPSTM=1
      GC= 32.174
      COSTP=0.0
        DO 10 I=1,7
           IF(PCKCHS(1).NE.PCKNAM(I,1)) GOTO 10
               IF(PSIZE(I).GT.PCKSIZ) COSTP=CSTPK(I)
                 JPIK=I
              IF(COSTP.GT.0.01) GOTO 20
   10 CONTINUE
   20 CONTINUE
      COSTP=CSTPK(2)
      IF(JPIK.LE.4) FLAG=.TRUE.
      PAKFAC = FXPACK(PCKSIZ,FLAG)
      IF(METRIC) CALL ENG(NREAC,NPRD)
      DO 200 I=1,NPRD
         MLPRDT(I,III)=MLPRDT(I,III-1)
  200 CONTINUE
      CALL VLRATE(60.0,PINC,NPRD)
      GSMS=MSTOT(III)
      PAKH2O=VOLRAT(III)*35.45*62.4/264.35*WATRAT/1000.0
      RHO= MSTOT(III)/VOLRAT(III)
```

```
      RHOL= 62.4
      FLOLIQ=(PAKH2O/MSTOT(III))*(RHO/RHOL)**0.5
      VISCL=0.1167*(RHOL*0.1603)**(0.5) *10.**(0.552*(1.-(T2+460.)
     1/1165.3))/((T2+459.0)/1165.3)
      TPFXN=1.058*((T2+460.)/1165.5)**0.645-0.261/((1.9*(T2+460.)/1165.3
     1))**(0.9*2.3*LOG(1.9*(T2+460.)/1165.3))
      VISCG=33.3*(18.011*647.5)**0.5/56.0**0.667*TPFXN
      VISCG=VISCG*1E-4*2.42
  700 DIAMTR=PAKDIA(VISCL,RHOL,RHO,PAKFAC,GSMS,PAKH2O)/EFFABS*100.0
      DIAMTR=DIAMTR*12.0
      IF(DIAMTR.GT.100.0) GOTO 500
      IF(DIAMTR.LT.6.0) DIAMTR=6.0
      GOTO 505
  500 WRITE(6,600) DIAMTR
  600 FORMAT(10X,'THE DIAMETER OF THE PACKED BED IS TOO LARGE',
    1 ' FOR COST CALCULATIONS'/10X,'DIAMETER(IN)= ',F10.0,
     2 ' NUMBER OF INLET STREAMS INCREASED BY ONE')
      NPSTM=NPSTM+1
      GSMS=GSMS/NPSTM
      PAKH2O=VOLRAT(III)/NPSTM*35.45*62.4/264.35*WATRAT/1000.0
      GOTO 700
  505 AREA(III)=3.1416*(DIAMTR/12.0)**2.0/4.0
      GMASS=MSTOT(III)/AREA(III)
       IF(IDEBUG.GE.25)
     1WRITE(6,234) GMASS,RHO,RHOL,PAKFAC,VISCL,EFFABS,DIAMTR
  234 FORMAT(10X,'GMASS= ',E15.5,'ROHO= ',E15.5/
    1 'RHOL= ',E15.5,'PAKFAC= ',E15.5,'VISCL=',E15.5/
     2 'EFFABS= ',E15.5,'DIAMTR= ',E15.5)
      CALL NNTU
      IF(Z.LT.10.0) Z=10.0
      IF(Z.GT.100.0) Z=100.0
      PVV=(DIAMTR/12.0)**2.0*3.14/4.00*Z
      CPAK=0.0
      CPAK=COSTP*PVV*FACCES/100.0
      CINSTL=FX3(DIAMTR)*FACCES/100.0
      WRITE(6,710) CINSTL,CPAK,CSTPAK
  710 FORMAT(10X,'COST OF ABSORBER COLUMN =      ',F12.2/
    1       10X,'COST OF ABORBER PACKING =      ',F12.2/
     2      10X,'TOTAL ABSORBER COST =          ',F12.2)
      DIAMTR=DIAMTR/12.0
      CSTPAK=(CINSTL*Z+CPAK)*NPSTM
      DP(III)=CONST(JPIK,6)*1.0E-08*10.**(CONST(JPIK,8)*PAKH2O/AREA(III)
     1/RHOL)*(GMASS*3600.0)**2.0/RHO*NTU
      IF(NUNIT.NE.III) FLGPAS=.TRUE.
      IF(METRIC) CALL ENG(NREAC,NPRD)
      WTRTOT=WTRTOT+PAKH2O*0.25
      CSTIIN=CSTIIN+CSTPAK*0.50
      CLMM=1.04*CLMS
      WRITE(6,800) DIAMTR,Z,CSTPAK,PAKH2O,AREA(III),NTU,CLMM
  800 FORMAT('1',30X,'PACKED BED DESIGN PARAMETERS'/15X,'DIAMETER',
    1  ' OF COLUMN(FT)= ',F10.2,'  TOTAL HEIGTH OF COLUMN(FT)= ',
     2 F10.2
     3 /15X,'CALCULATED COST OF COLUMN= ',F10.2,' U.S. DOLLARS'/
     4 15X, 'CALCULATED FEED RATE=         ',F10.2/
     5 15X, 'AREA OF BED=                  ',F10.2, 'FT**2'/
     6 15X, 'NUMBER OF MASS TRANSFER UNITS=',I9/
     7 15X, 'AMOUNT OF LIME ADDED=          ',F10.2,'LB/HR'/)
      WRITE(6,678)
  678 FORMAT(15X,'OPTIONS SELECTED')
      WRITE(6,610) (PCKCHS(I),I=1,4),PCKSIZ
  610 FORMAT(20X,'PACKING SELECTED IS ',4A4/20X,'PACKING SIZE IS ',
     1 F4.1,' INCHES')
      IF(IC) WRITE(6,570)
  570 FORMAT(10X,'PACKED COLUMN IS CONSTRUCTED OF INCONEL')
      IF(CS) WRITE(6,571)
  571 FORMAT(10X,'PACKED COLUMN IS CONSTRUCTED OF CARBON STEEL')
      MLPRDT(2,III)=MLPRDT(2,III)*(1.0-HCLRM/100.00)
      CSTBAS=CSTLME/2000.0*CLMS*1.04
      TOTMAN=TOTMAN+CSTPAK*0.05
      WHP=0.036*PAKH2O/62.4/35.45*264.17
      TOTELC=TOTELC+0.746*WHP*DAY*YEAR
      IDEBUG=0
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      RETURN
      END
      SUBROUTINE NNTU
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      IF(IDEBUG.GE.25) WRITE(6,10) VISCL,VISCG,T2,MSTOT(III),AREA(III)
   10 FORMAT(10X,'LIQUID VISCOSITY( CP)= ',E15.5,'   GAS  VISCOSITY(LB',
     1 '/FT/HR)= ',E15.5/10X,'TEMPEATURE (F)= ',F9.2/10X,'MASS FLOW RATE
     2(LB/HR)= ',E15.5,'AREA(FT**2)=  ',E15.5)
C
C   CHANGE VISCOSITY TO LB/HR/FT**2
      VISCL=VISCL*2.4191
      ACONST=VISCL/EXP(0.522/293.3)
      VISCOR=ACONST*EXP(0.522/((T2-32.0)/1.8+273.96))/VISCL
      BCONST=VISCG/((T2+460.)**1.5/((T2+460.)+1.47*(672)))
      CORVIS=BCONST*((T2+460.)**1.5/((T2+460.)+1.47*672))/VISCG
      VELMSG=MSTOT(III)/AREA(III)
      VELMSL=PAKH2O/AREA(III)
      HG=CONST(JPIK,1)*VELMSG**CONST(JPIK,2)/VELMSL**CONST(JPIK,3)
C     EQUATION 2-23MASS TRANSFER BY HINES
      HG=HG*(VISCG/RHO/DFHCLG*CORVIS)**0.5
      SCMIDL=(VISCL/RHOL/DFHCLL*VISCOR/((T2+460.0)/528.0))
      HL=CONST(JPIK,4)*(PAKH2O/AREA(III)/VISCL)**CONST(JPIK,5)*SCMIDL
     1 **0.50
      HOG=HG+SLPABS*(TTL(III)/(PAKH2O/18.011))*HL
      Z=HOG*NTU
      IF(IDEBUG.GE.25) WRITE(6,20) Z,HOG,NTU,HG,HL,SCMIDL,PAKH2O,VELMSG,
     1VELMSL
   20 FORMAT(10X,'TOTAL HEIGHT OF BED(FT)= ',E15.5,'HEIGHT OF ',
     1 'ONE TRANSFER UNIT(FT)= ',E15.5,'NUMBER OF TRANSFER'
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     1,' UNITS= ',I5/
     110X,'HG= ',E15.5,'HL= ',E15.5,'SCHMIDT NUMBER= ',E15.5/
     2 10X,'WATER RATE(LB/HR)= ',E15.5,'MASS VELOCITY GAS= ',E15.5,
     3 'MASS VELOCITY LIQUID= ',E15.5)
      IF(IDEBUG.GE.25)
     1 WRITE(6,234) SLPABS,(CONST(JPIK,I),I=1,4),VISCOR,DFHCLL, DFHCLG
 234 FORMAT(10X,'SLOPE OF EQUILIBRIUM CURVE= ',E15.5/
     1 10X,'CONSTANTS OF EQUATIONS'/
     2 4(10X,E15.5/),10X,'VISCOR= ',E15.5,'DIFFUSION COEFFICENTS',
     3 ' FOR LIQUID AND GAS= ',2E15.5)
      RETURN
      END
      SUBROUTINE TRABED(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,M0400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      WRITE(6,10)
  10 FORMAT(2X,'THIS SUBROUTINE (TRABED) IS NOT WORKING')
      RETURN
      END
      SUBROUTINE DUCT(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,M0400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH20,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH20,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,M0400,IN600,IN825,TI,HS,UTB,HM1,HM2
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      IF(METRIC) CALL ENG(NREAC,NPRD)
      IF(IDEBUG.GT.5.AND.DIC) WRITE(6,16) III
      IF(IDEBUG.GT.5.AND.DSS) WRITE(6,12)III
      IF(IDEBUG.GT.5.AND.DCS) WRITE(6,13) III
      IF(IDEBUG.GT.5.AND.DWC) WRITE(6,14) III
   16 FORMAT(10X,'FOR UNIT',I2,'DUCTWORK IS MADE OF INCONEL')
   12 FORMAT(10X,'FOR UNIT',I2,'DUCTWORK IS MADE OF STAINLESS STEEL')
   13 FORMAT(10X,'FOR UNIT',I2,'DUCTWORK IS MADE OF CARBON STEEL')
   14 FORMAT(10X,'FOR UNIT',I2,'DUCTWORK IS WATER COOLDED')
      DCTCST(III)=0.0
      DCTFLG=.TRUE.
      DCBRIK=0.0
       DCTVEL(III)=9000.0*60.0
      CALL VLRATE(TTMP(III+1),PINC,NPRD)
      RHO=MSTOT(III)/VOLRAT(III)
      IF(IDEBUG.GT.1)WRITE(6,70)RHO,MSTOT(III),VOLRAT(III),T2,PINC
   70 FORMAT(5X,'DENSITY OF GAS = ',E15.5,'LB/FT**3','TOTAL MASS RATE',
     1' IN =',E15.5,'LB/HR'/10X,'VOLUME RATE OF THE GAS',E15.5,'FT**3',
     2'/HR','T2= ',F9.2,'PINC= ',F9.2)
   15 DCDIA(III)=(MSTOT(III)/RHO/DCTVEL(III)/3.1416*4.0)**0.5*12.0
      IF(IDEBUG.GT.1) WRITE(6,11) DCDIA(III),DCTVEL(III)
   11 FORMAT(10X,'ESTIMATED DUCT DIAMETER(INCHES)',F10.4,'GAS VELOCITY(F
     1T/HR',F14.4)
      IF(DCDIA(III).GT.170.0) GOTO 51
      IF(DCDIA(III).LT.20) GOTO 52
      IF(.NOT.DCS) GOTO 10
      IF(T2.LT.1100) GOTO 41
      ZHOLD=INCLEN(III)
      INCLEN(III)=DCTLEN(III)
        DHOLD=DIA(III)
        ZHOLD=INCLEN(III)
        DIA(III)=DCDIA(III)/12.0
        INCLEN(III)=DCTLEN(III)
        CALL BLOCK(NREAC,NPRD)
        INCLEN(III)=ZHOLD
        DCDIA(III)=DIA(III)*12.0
        DIA(III)=DHOLD
   41 CONTINUE
      IF(DCDIA(III).GT.80) GOTO 20
        DCTCST(III)=(-1.46+1.09*DCDIA(III))*DCTLEN(III)
        DCTCST(III)=DCTCST(III)+(12.07*DCDIA(III)+0.176*DCDIA(III)**2.0)
     1*ELBNUM(III)
        GOTO 100
   20 IF(DCDIA(III).GT.130.) GOTO 21
        DCTCST(III)=(-1.76+1.37*DCDIA(III))*DCTLEN(III)
        DCTCST(III)=DCTCST(III)+(-9.83*DCDIA(III)+0.205*DCDIA(III)**2.0
     1  +16.76*DCDIA(III))
     1*ELBNUM(III)
        GOTO 100
   21 IF(DCDIA(III).GT.140) GOTO 22
        DCTCST(III)=(-2.05+1.77*DCDIA(III))*DCTLEN(III)
        DCTCST(III)=DCTCST(III)+(-8.21*DCDIA(III)+0.240*DCDIA(III)**2.0
     1+ 18.41*DCDIA(III))
     1*ELBNUM(III)
        GOTO 100
   22 IF(DCDIA(III).GT.150) GOTO 23
        DCTCST(III)=(-2.93+2.38*DCDIA(III))*DCTLEN(III)
        DCTCST(III)=DCTCST(III)+(-12.89*DCDIA(III)+0.450*DCDIA(III)**2.0
     1 +21.1*DCDIA(III))
     1*ELBNUM(III)
        GOTO 100
   23 IF(DCDIA(III).GT.170) GOTO 24
        DCTCST(III)=(-3.86+3.01*DCDIA(III))*DCTLEN(III)
        DCTCST(III)=DCTCST(III)+(-16.41*DCDIA(III)+0.480*DCDIA(III)**2.0
     1 +24.71*DCDIA(III))
     1*ELBNUM(III)
      GOTO 100
   24 DCTVEL(III)=DCTVEL(III)*1.20
      IF(IDEBUG.GT.1)WRITE(6,101) DCTVEL(III)
  101 FORMAT(10X,'DUCT DIAMETER TOO LARGE. ADJUSTED GAS VELOCITY T
     1O',5X,F10.3,3X,'FEET/MINUTES')
      GOTO 15
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10 IF(DWC) GOTO 50
   IF(T2.LT.1300.AND.DSS) GOTO 42
   IF(T2.LT.1400.AND.DIC) GOTO 42
   ZHOLD=INCLEN(III)
   INCLEN(III)=DCTLEN(III)
     DHOLD=DIA(III)
     ZHOLD=INCLEN(III)
     DIA(III)=DCDIA(III)/12.0
     INCLEN(III)=DCTLEN(III)
     CALL BLOCK(NREAC,NPRD)
     INCLEN(III)=ZHOLD
     DCDIA(III)=DIA(III)*12.0
     DIA(III)=DHOLD
42 CONTINUE
   IF(DCDIA(III).GT.75.) GOTO 31
     DCTCST(III)=(-4.22+3.83*DCDIA(III))*DCTLEN(III)
     DCTCST(III)=DCTCST(III)+(19.04*DCDIA(III)+0.703*DCDIA(III)**2.0)
  1*ELBNUM(III)
     GOTO 100
31 IF(DCDIA(III).GT.130.) GOTO 32
     DCTCST(III)=(-21.73+5.75*DCDIA(III))*DCTLEN(III)
     DCTCST(III)=DCTCST(III)+(17.6*DCDIA(III)+1.05*DCDIA(III)**2.0
  1  +124)
  1*ELBNUM(III)
     GOTO 100
32 IF(DCDIA(III).GT.150) GOTO 33
     DCTCST(III)=(-26.84+7.54*DCDIA(III))*DCTLEN(III)
     DCTCST(III)=DCTCST(III)+(19.3*DCDIA(III)+1.46*DCDIA(III)**2.0
  1+ 134.0)
  1*ELBNUM(III)
     GOTO 100
33 IF(DCDIA(III).GT.160) GOTO 34
     DCTCST(III)=(-42.17+10.86*DCDIA(III))*DCTLEN(III)
     DCTCST(III)=DCTCST(III)+(23.7*DCDIA(III)+2.10*DCDIA(III)**2.0
  1 +199.0)
  1*ELBNUM(III)
     GOTO 100
34 DCTVEL(III)=DCTVEL(III)*1.20
   WRITE(6,110) DCTVEL(III)
110 FORMAT(10X,'DIAMETER MUST BE INCREASED BY INCREASE THE VELOCITY
  1TO ',5X,F10.2,2X,'FEET/MINUTE')
      GOTO 15
50   DCTCST(III)=51.84+4.45*DCDIA(III)
   DCTCST(III)=DCTCST(III)+(-12.89+21.10*DCDIA(III)+0.45*DCDIA(III))*
  1ELBNUM(III)
   GOTO 100
51 DCTVEL(III)=DCTVEL(III)*1.20
   GOTO 15
52 DCTVEL(III)=DCTVEL(III)/1.20
   GOTO 15
100 AUTODP=.TRUE.
    DMPCST=554.85+96.54*DCDIA(III)-0.394*DCDIA(III)**2.
  1+5.81E-3*DCDIA(III)**3.
    DAMPT(III)=DMPCST*FACPVF/228.0
    DCIBC(III)=DCBRIK/228*FACPVF
    DCTFLG= .FALSE.
   DCTCST(III)=DCTCST(III)/228.0*FACPVF
   CSTINS=CSTINS+DCTCST(III)*0.12
      PEXT= PEXT- PRESSR(MSTOT(III),RHO,DCDIA(III),DCTLEN(III))
   FLGPAS=.FALSE.
    TDCTCS(III)=DAMPT(III)+DCTCST(III)+DCIBC(III)
    TOTMAN=TOTMAN+DCTCST(III)*0.05
   DCTTST=DCTTST+TDCTCS(III)
   RETURN
   END
    SUBROUTINE HTMSQ(NREAC,NPRD)
   REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
  1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
   LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
  1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
  2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
  4,CUTVN,CMBST,TCH
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     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C         ANTOINE'S CONSTANTS FOR WATER
C         PRESSURE IN TERMS OF  MMHG(CHANGED TO ATM)
C
      ICONV=0
      SATH2O=0.0
      FREH2O=0.0
      AA=7.96681
      AB=1668.21
      AT=228.0
      PVH2O=10.0**(AA-AB/(AT+T2))/760.0
      IF(IDEBUG.GE.25)WRITE(6,200) PVH2O,T2,PINC
  200 FORMAT(10X,'VAPOR PRESSURE OF WATER IS ',F9.2,' ATM AT A TEMPERATU
     1RE OF ',F9.2,' CELCIUS. ' /10X,'TOTAL PRESSURE= ',F9.2)
       DELTAH=0.0
       H2O=0.0
      TTVOL=T2*1.8+32.0
      PVOL= PINC*14.696
      CALL VLRATE(TTVOL,PVOL,NPRD)
      IF(METRIC) VOLRAT(III)=VOLRAT(III)/35.453
      VOLTEM=VOLRAT(III)
      RC2=8.206E-05
       CALL DTHEAT(NPRD)
      DELTAH=-DELTAH
      IF(IDEBUG.GE.25) WRITE(6,401) DELTAH
  401 FORMAT(10X,'AMOUNT OF HEAT REQUIRED TO COOL GAS',E15.5,'JOULES/HR'
     1)
       DTH2O=2000.0*453.96
       FFF=0
       FF=1
       HTLIQ=75.4*(T2-TA)
        HEAT=0.0
        HEAT1=0.0
        HEAT1=CP(1,1)*(T2-T1)+CP(2,1)/2.*(T2**2.-T1**2.)
     1  +CP(3,1)/3.*(T2**3.-T1**3.)+CP(4,1)/4.*(T2**4.-T1**4.)
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      HEAT=CP(1,1)*(T2-TA)+CP(2,1)/2.*(T2**2.-TA**2.)
     1 +CP(3,1)/3.*(T2**3.-TA**3.)+CP(4,1)/4.*(T2**4.-TA**4.)
      IF(IDEBUG.GT.1) WRITE(6,20) HEAT,T2,TA,CP(1,1)
   11 CONTINUE
      ICONV=ICONV+1
      IF(ICONV.GE.100) WRITE(6,402)
  402 FORMAT(15X,'VENTURI SAT NOT RESOLVED')
      IF(ICONV.GE.100) GOTO 19
      ICONV=ICONV+1
      PRTH2O=(MLPRDT(1,III)+H2O)*RC2*(T2+273.15)/VOLTEM
   20 FORMAT(10X,'HEAT TO RAISE H2O FROM TA TO T1= ',E15.5,'OUTLET TEMP'
     1,F9.2,' AMBIENT TEMPERATURE(CELC)',F9.2/'HEAT CAPACITY OF H2O ',
     2E15.5)
       VAPNO=0.0
       DIFH2O=H2O
      IF(PRTH2O.LT.PVH2O) GOTO 50
          SATH2O=(PVH2O)*VOLTEM/RC2/(T2+273.15)
          DIFH2O= SATH2O - MLPRDT(1,III)
          VAPNO= H2O - DIFH2O
   50 CONTINUE
        COLDH=H2O*HTLIQ+DIFH2O*HSTVAP
       IF(IDEBUG.GE.25)
     1  WRITE(6,400) COLDH,H2O,MLPRDT(1,III),SATH2O,DIFH2O,VAPNO
  400 FORMAT(10X,'HEAT FROM H2O TO COOL GAS= ',E15.5,' JOULES/HR'/
     1        10X,'TOTAL AMOUNT OF WATER ADDED=',E13.5,' GMOLES/HR'/
     2        10X,'H2O IN WASTE GAS=            ',E13.5,'GMOLES/HR'/
     2        10X,'MAXIMUM AMOUNT OF H2O=      ',E15.5,' GMOLES/HR'/
     3        10X,'H2O VAPORIZED=              ',E15.5,' GMOLES/HR'/
     4        10X,'H2O NOT VAPORIZED=          ',E15.5,' GMOLES/HR')
      IF(ICONV.GT.100) WRITE(6,403)
  403 FORMAT(10X,'QUENCH WATER CONVERGENCE CALCULATION HAS NOT CONVERGED
     1')
       IF(ICONV.GT.700.0) STOP
      IF(IDEBUG.GT.1)WRITE(6,300)DIFH2O,COLDH,PRTH2O
  300 FORMAT(10X,'H2O  ABOVE SATURATION(GMOLES/HR)',E15.5,
     1'TOTAL HEAT TRANSFERRED ',E15.5/10X,'TOTAL PARTIAL PRESSURE OF H2O
     2',E15.5)
      IF(IDEBUG.GT.1) WRITE(6,120) H2O,DIFH2O,HSTVAP,HEAT1
  120 FORMAT(10X,'ESTIMATED H2O(GMOLES/HR) ',E15.5,' H2O NOT VAPORIZED '
     1,E15.5/' HEAT OF VAPORIZATION JOULES/GM ',E15.5,' HEAT USED
     2TO RAISE H2O FROM T1 TO T2 ',E15.5)
       IF(ABS(DELTAH-COLDH).LT.(.001*DELTAH)) GOTO 19
       IF(DELTAH.LT.COLDH) GOTO 15
       H2O=H2O+DTH2O
       IF(FF.EQ.0) DTH2O=DTH2O/2.0
       IF(FFF.EQ.0) FFF=1
       IF(FFF.EQ.1) GOTO 11
       FF=0
       GOTO 11
   15  H2O = H2O -DTH2O
       IF(FF.EQ.0) DTH2O=DTH2O/2.0
       IF(FFF.EQ.0) FFF=-1
       IF(FFF.EQ.-1) GOTO 11
       FF=0
       GOTO  11
   19  IF(IDEBUG.GT.1)WRITE(6,999)H2O
  999 FORMAT(4X,'  FINAL MOLE RATE OF QUENCH WATER= ',E15.5)
      FREH2O=FFRH2O
      MLPRDT(1,III)= MLPRDT(1,III)+H2O
      FEED(1)= FEED(1)+DIFH2O*18.011
      H2OM=H2O*18.011
      WTRTOT=WTRTOT + (H2OM-VAPNO*18.011)/453.96
      IF(IDEBUG.GT.1) WRITE(6,150) H2O,MLPRDT(1,III),MLPRDT(1,III-1)
  150 FORMAT(10X,'AFTER',E15.5,'WATER',E15.5,'H2O MOLE AFTER',
     1E15.5,'H2O MOLE BEFORE')
      VAPNO=VAPNO*18.011
       RETURN
       END
       SUBROUTINE SHELL(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
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     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C   THIS SUBROUTINE PROVIDES THE COST FOR A CYLINDRICAL
C      SHAPED  INCIENRATOR
C   ROTARY DRIVE IS ALSO CALCULATED FOR THE ROTARY KILN.
      THKSL=2./12.
      SHLCST=0.0
C
C23456789
      SHLARA=(DIA(III)+THKSL)*3.1416*INCLEN(III)
     1 + 3.1416*(DIA(III)**2.0 / 4.0 *1.5)
       IF(ROTARY) DRVCST=100.*SHLARA
       SHLCST= 75.*SHLARA
C
C   COST FACTORS FOR DIFFERENT MATERIALS
C       INCONEL= 3.3
C       STAINLESS STEEL 316= 2.7
C       MONEL= 3.3
C       NICKEL= 3.5
C
       IF(IC) SHLCST=SHLCST*3.3
       IF(SS)  SHLCST=SHLCST*2.7
       IF(IDEBUG.GT.1) GOTO 10
       IF(IDEBUG.GT.1)WRITE(6,20) SHLARA,DIABRK,THKSL,SHLCST
   20 FORMAT(2X,'SURFACE AREA(III) OF INCINERATOR(FT**2)= ',E15.3,'DIAME
     1TER    (FT)= ',E15.3/2X,'THICKNESS OF SHELL(IN)= ',F9.2,
     2 'COST OF SHELL ($)=',E15.2)
   10 SHLCST=SHLCST/305.9*FACCEF
      DRVCST=DRVCST/305.9*FACCEF
       RETURN
       END
      SUBROUTINE STOREG(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
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     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2   SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      INTEGER BNUM
C
      CSTNIT=0.0
      CSTN2=0.0
      CSTCON=0.0
      BNUM=0.
      MNUM=0.
      LNUM=0
      ARACST=0.0
      CSTSTO=0.0
      STRCST=0.0
       FLAG=0
      SDENS=47.1
       CSTFAC=1.0
      IF(IC) CSTFAC=3.3
      IF(SSB) CSTFAC=2.7
      VOL=(MASSSL/SDENS*24.*3.0*7.48)*1.20
      TOTVOL=VOL
      IF(BARREL) GOTO 60
      IF(FLAG.GT.0) GOTO 20
C
C   COST THE 3 POSSIBLE WASTE STORAGE CONTAINERS.
C
      SMLTAN=8000.*CSTFAC+3000.+6000.+10000.+8000.+3000.+1000.+5000.
      MEDTAN=10000*CSTFAC+5000.+8000.+11000.+10000.+5000.+2000.+7000.
      BIGTAN=23000*CSTFAC+12000.+9000.+24000.+13000.+13000.+5000.+13000.
      FLAG=0
   20 DO 50I=1,100
      IF(VOL.LE.1000.) GOTO 51
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      IF(VOL.GT.25000.) GOTO 30
      IF(VOL.GT.10000.) GOTO 40
      STRCST=STRCST+SMLTAN
      VOL=VOL-5000.
      LNUM=LNUM+1
      GOTO 50
   40 STRCST=STRCST+MEDTAN
      VOL=VOL-10000.
      MNUM=MNUM+1
      GOTO 50
   30 STRCST=STRCST+BIGTAN
      VOL=VOL-25000.
      BNUM=BNUM+1
   50 CONTINUE
   51 CONTINUE
      CSTSTO=STRCST
      IF(.NOT.VOLTIL) GOTO 101
      IF(VOLTIL.AND.(.NOT.CMBST)) GOTO 102
      TOTNUM=MNUM+BNUM+LNUM
      CSTNIT=TOTNUM*2500./305.9*FACCES
      CSTN2=TOTVOL*1000./310.1*FACMSC/2500.
  102 CSTCON=10000.*305.9/FACCEF
      CSTSTO=(CSTSTO+CSTNIT+CSTN2+CSTCON)/305.9*FACCEF
  101 WRITE(6,300) BNUM,MNUM,LNUM,STRCST,CSTNIT,CSTN2,CSTCON
  300 FORMAT('1',25X,'LIQUID WASTE STORAGE FACILITY'///
     1 15X,'NUMBER OF 25,000 GALLON TANKS = ',I3/
     2 15X,'NUMBER OF 10,000 GALLON TANKS = ',I3/
     3 15X,'NUMBER OF  1,000 GALLON TANKS = ',I3/
     4 15X,'TOTAL STORAGE TANK COST=          ',F9.0,'   U.S. DOLLARS'/
     5 15X,'CSTNIT=                           ',F9.0,'   U.S. DOLLARS'/
     6 15X,'NITROGEN BLANKET SYSTEM=          ',F9.0,'   U.S. DOLLARS'/
     7 15X,'CONDENSOR COST=                   ',F9.0,'   U.S. DOLLARS'/)
      GOTO 100
C
C     CALCULATION OF BARREL STORAGE FACILITIES
C
   60 BRLNUM=VOL/55.*24.*3.
      BRLARA=BRLNUM/75.
      ARACST=40.0*BRLARA
      ARACST=ARACST*FACCEB/257.2
      WRITE(6,200) BRLNUM,BRLARA,ARACST
  200 FORMAT('1',25X,'COST PARAMETERS FOR BARREL STORAGE FACILITY'/
     1 15X,'NUMBER OF BARRELS FOR ',I2,' DAYS OF STORAGE= ',F9.2/
     2 15X,'AREA OF STORAGE FACLITY = ',F9.2, ' FT°2'/
     3 15X,'COST OF BARREL STORAGE FACILITY(INSTALLED)= ',F9.2,
     4 'U.S. DOLLARS'/)
  100  TOTMAN=TOTMAN+ARACST*0.05+CSTSTO*0.05
      RETURN
      END
      SUBROUTINE ASHUN
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
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 1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
 2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
 3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
  COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
 1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
 2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
 3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
 4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
 5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
 6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
   COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
 1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
  COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
  COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
  COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
  COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
 1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
 2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
  COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
 1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
 2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
 3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
  SEMI=.FALSE.
  ASHCST=0.0
  IF(HTCOMB.GT.20.0E6) GOTO 60
  IF(.NOT.SEMI) GOTO 60
     ASHCST=15000.0
     GOTO 50
60 IF(HTCOMB.GT.15E6) GOTO 20
     ASHCST=7000.0
     GOTO 50
20 IF(HTCOMB.GT.75.E6) GOTO 30
     ASHCST=10000.0
     GOTO 50
30 ASHCST=22000.0
50 ASHCST=ASHCST*FACCES/308.4
  IF(IDEBUG.GT.1) WRITE(6,70) ASHCST
70 FORMAT(2X,'COST OF ASH HANDLING SYSTEM($)= ',E15.5)
  ASHCST=ASHCST/308.4*FACCEE
  RETURN
  END
   SUBROUTINE OUTP1(NPRD)
  REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
 1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
  LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
 1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
 2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
 4,CUTVN,CMBST,TCH
 3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
   CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
 1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
 2 ,SCRNME*20
  COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
 1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
 2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
  COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
 1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
  COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
 1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
 2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
 3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
  COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST.,STMCST,DCTCST(9)
 1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
  COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
 1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
 2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
 3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
  COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
 1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
 2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT.CSTENG,DCDIA(9),CSTINT
 3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
 4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
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     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      PREFD=0.0
      IF(UNIT(III).NE.SUNIT(1)) PREFD=MSTOT(III-1)
       EEXCES=EXCESS(III)*100.0
       EEXFUL=0.0
       RYEAR=365.0-YEAR
       RYEAR= 365.0-YEAR
       WRITE(6,10)
   10 FORMAT('1',25X,'INCINERATOR DESIGN AND COST FOR')
      IF(III.EQ.2) WRITE(6,16)
      IF(UNIT(III).EQ.SUNIT(8)) GOTO 17
      IF(ROTARY) WRITE(6,12)
      IF(LIQI) WRITE(6,13)
      IF(FLUID) WRITE(6,14)
   12 FORMAT(34X,'ROTARY KILN')
   13 FORMAT(34X,'LIQUID INJECTION')
   14 FORMAT(34X,'FLUIDIZED BED')
   16 FORMAT(27X,'LIQUID INJECTION AFTERBURNER')
   53 FORMAT(//)
   17 WRITE(6,53)
      WRITE(6,20)
   20 FORMAT(25X,'****INPUT STREAM CHARACTERISTICS****'/)
      WRITE(6,21) MSTOT(III),ASH,VOLIT,FREH2O,MASSFL,EEXCES,MASSAR
   21 FORMAT(15X,'COMBUSTED GAS EXIT RATE',16X,F11.2,' LB/HR '/15X,'ASH
     1FEED RATE ',26X,F10.2,' LB/HR'/15X,'VOLITILES FEED RATE',21X,F10.2
     2,' LB/HR'/15X,'FREE WATER IN SLUDGE FEED',15X,F10.2,' LB/HR'/15X
     3,'FUEL FEED RATE',21X,F15.2,' LB/HR'/15X,'AIR FEED RATE (AT ',F6.2
     4,'% EXCESS)',2X,F15.2,' LB/HR')
      IF(UNIT(III).NE.SUNIT(1)) WRITE(6,23) PREFD
   23 FORMAT(15X,'GAS FEED FROM PREVIOUS UNIT',12X,F10.2,' LB/HR ')
      WRITE(6,40) EEXCES,EEXFUL,T2,TA,DAY,YEAR,RYEAR,RETIM(III),RLD(III)
   40 FORMAT(///29X,'PROCESS DESIGN VARIABLES'//15X,'PERCENT EXCESS AIR
     1IS ',
     1 19X,F5.2,' PERCENT',/15X,'PERCENT EXCESS FUEL IS ',18X,F5.2,
     1 ' PERCENT.'
     2 /15X,'INCINERATOR TEMPERATURE ',15X,F7.2,' DEG. FAHRENHEIT'
     3/15X,'AMBIENT TEMPERATURE      ',15X,F7.2,' DEG. FAHRENHEIT.'
     4/15X,'DAILY USE                ',15X,F7.2,' HOURS/DAY.'
     5/15X,'LENGTH OF PROCESS RUN    ',15X,F7.2,' DAYS/YEAR.'
     6/15X,'SHUTDOWN LENGTH          ',15X,F7.2,' DAYS/YEAR.'
     7/15X,'RETENTION TIME           ',15X,F7.2,' SECONDS    '
     8/15X,'LENGTH TO DIAMETER RATIO ESTIMATE',6X,F7.2)
      RETURN
      END
      SUBROUTINE OUTP7(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
       DIMENSION FEDD(15)
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      CHARACTER MATLC*2
      DIMENSION MATLC(4)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
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    1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
    2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
     COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
    1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
     COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
    1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
    2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
    3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
     COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
    1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
     COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
    1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
    2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
    3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
     COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
    1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
    2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
    3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
    4   TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
    5   TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
    6   EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
    1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
     COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
     COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
     COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
     COMMON/ALPHA/MATL(20),BRIKNM(6,8);FUELNM(4,5),UNIT(20),SUNIT(11)
    1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
    2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
     COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
    1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
    2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
    3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
     DO 165 I= 1,NPRD
        FEDD(I)=0.0
165 CONTINUE
     IF(III.EQ.1) GOTO 166
     DO 150 I=1,NPRD
        FEDD(I)=MLPRDT(I,III-1)*PRDMW(I)
150 CONTINUE
166 CONTINUE
 56 FORMAT('1'//)
     WRITE(6,56)
     WRITE(6,140) T1,T2,PINC,PEXT
140 FORMAT(25X,'PROCESS STREAM CONDITIONS AND COMPOSITION'///5X,
    1'INPUT STREAM T= ',F7.2,' FAHRENHEIT',7X,'OUTPUT STREAM T= ',
    2F7.2,' FAHENHEIT'/18X,'P= ',F7.2,' PSIA',27X,'P= ',F7.2,' PSIA'//
    322X,'LB/HR',31X,'LB/HR'/22X,'-----',31X,'-----')
     IF(UNIT(III).EQ.SUNIT(1).OR.UNIT(III).EQ.SUNIT(8))
    1 WRITE(6,110)MASSFL
110 FORMAT(5X,' FUEL  ',5X,F10.2,32X,'0.00')
     IF(UNIT(III).EQ.SUNIT(1).OR.UNIT(III).EQ.SUNIT(8))
    1 WRITE(6,120)MASSAR
120 FORMAT(5X,'  AIR  ',5X,F10.2,32X,'0.00')
     IF(UNIT(III).EQ.SUNIT(1))
    1 WRITE(6,130) MASSSL
130 FORMAT(5X,' WASTE ',5X,F10.2,32X,'0.00')
     IF(UNIT(III).EQ.SUNIT(1))
    1 WRITE(6,135) ASH
135 FORMAT(5X,'  ASH   ',10X,'0.00',26X,F10.2)
     WRITE(6,50) (FEDD(II),FEED(II),II=1,15)
 50 FORMAT(
    2 5X,'   H2O   ',5X,F10.2,26X,F10.2/
    B 5X,'   HCL   ',5X,F10.2,26X,F10.2/
    2 5X,'   CO2   ',5X,F10.2,26X,F10.2/
    C 5X,'   CO    ',5X,F10.2,26X,F10.2/
    3 5X,'   N2    ',5X,F10.2,26X,F10.2/
    D 5X,'   O2    ',5X,F10.2,26X,F10.2/
    4 5X,'   NO    ',5X,F10.2,26X,F10.2/
    E 5X,'   NO2   ',5X,F10.2,26X,F10.2/
    5 5X,'   CL2   ',5X,F10.2,26X,F10.2/
    F 5X,'   SO2   ',5X,F10.2,26X,F10.2/
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     6 5X,' H2S04 ',5X,F10.2,26X,F10.2/
     7 5X,'  F2   ',5X,F10.2,26X,F10.2/
     8 5X,'  HF   ',5X,F10.2,26X,F10.2/
     9 5X,' P206  ',5X,F10.2,26X,F10.2/
     A 5X,'  NE   ',5X,F10.2,26X,F10.2/)
       WRITE(6,300)
   300 FORMAT('1')
       RETURN
       END
       SUBROUTINE OUTP6(NPRD)
       REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
       LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
         CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
       CHARACTER MATLC*2
       DIMENSION MATLC(4)
       COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
       COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
       COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
       COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
       COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
       COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
         COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
       COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
       COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
       COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
       COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
       COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       IF(CONTEN.GT.1.0) EXTRA= TOTCAP*(100.+CONTEN)/100.0
       HTWAST=MASSSL*ZSLHT
       WRITE(6,60) DIA(III),INCLEN(III),(BNMFR(I),I=1,6),REFINS
     1,(BNMIN(I),I=1,6),THCKIN,AREA(III),DESVOL(III),NUMBRN
    60 FORMAT(//25X,'INCINERATOR PROCESS DESIGN SPECIFICATIONS'//
     110X,'INCINERATOR DIAMETER (FT)= ',13X,F10.4/
     210X,'INCINERATOR LENGTH (FT)= ',15X,F10.4/
     310X,'MATERIALS OF CONTRUCTION FOR THE INCINERATOR'/15X,'REFRACTORY
     3 SELECTED = ',6(A4),9X,'THICKNESS = ',F5.1,' INCHES'/
     3 15X,'INSULATION SELECTED = ',6(A4),9X,'THICKNESS = ',F5.1
     3, ' INCHES '/
     310X,'INCINERATOR SURFACE AREA (FT**2)',8X,F10.4/
     410X,'INCINERATOR VOLUME        (FT**3) ',6X,F10.4/
     510X,'INCINERATOR BURNER DATA'/15X,'NUMBER OF FUEL BURNERS',
     6 ' = ',I3 )
       IF(LQD.AND.UNIT(III).EQ.SUNIT(1)) WRITE(6,117) HTWAST
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117 FORMAT(15X,'WASTE FEED BURNER HEAT LOAD = ',E10.3,' BTU/HR')
    WRITE(6,110)
110 FORMAT(10X,'OPTIONS IN EFFECT')
    IF(HTLS) WRITE(6,111)
111 FORMAT(10X,'A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED)',
   1 ' IS INCLUDED IN THE HEAT/MASS BALANCE CALCULATIONS')
    IF(SLD.AND.III.EQ.1) WRITE(6,112)
112 FORMAT(10X,'FEED IS A SOLID.  AN ASH REMOVAL SYSTEM AND A',
   1 ' BULK FEED SYSTEM ARE SELECTED')
    IF(LQD.AND.III.EQ.1) WRITE(6,113)
    IF(SLD.AND.III.EQ.1) WRITE(6,114)
114 FORMAT(15X,'WASTE FEED IS A SOLID. RAM LOADER USED')
113 FORMAT(15X,'WASTE FEED IS A LIQUID.  WASTE BURNERS ARE SELECTED')
    IF(IC) WRITE(6,711)
711 FORMAT(15X,'INCONEL WAS SELECTED TO CONTRUCT THE SHELL')
    IF(SS) WRITE(6,712)
    IF(CS) WRITE(6,713)
712 FORMAT(15X,'STAINLESS STEEL WAS SELECTED TO CONTRUCT THE SHELL')
713 FORMAT(15X,'CARBON STEEL WAS SELECTED TO CONTRUCT THE SHELL')
    WRITE(6,70) BRKTOT,SHLCST,TBRNTT
 70 FORMAT(//25X,'INCINERATOR COST BREAKDOWN'//
   110X,'TOTAL BRICK COST $',10X,F9.2/
   210X,'TOTAL SHELL COST $',8X,F11.2/
   A10X,'COST OF BURNER SYSTEM $',3X,F11.2)
    IF(III.NE.1) GOTO 200
    IF(SLD.AND.BARREL) WRITE(6,116) CSTLOD
116 FORMAT(10X,'55-GAL BARREL WASTE LOADER $',8X,F11.2)
300 FORMAT(10X,'RAM WASTE LOADER $',8X,F11.2)
     IF(SLD.AND.(.NOT.BARREL)) WRITE(6,300) CSTLOD
    IF(SLD.AND.SCRW)WRITE(6,118) CSTSCR
118 FORMAT(10X,'SCREW FEEDER TO RAM $',5X,F11.2)
    IF(.NOT. LIQI) WRITE(6,80) ASHCST
    IF(ROTARY) WRITE(6,85) DRVCST
 80 FORMAT(10X,'COST OF ASH SYSTEM $',8X,F9.2)
 85 FORMAT(10X,'COST OF DRIVE SYSTEM $',6X,F9.2)
    IF(ROTARY) WRITE(6,90) SKRCST
 90 FORMAT(10X,'COST OF SKIRTING $',10X,F9.2)
200 IF(III.EQ.1) WRITE(6,95) EXTRA1
    IF(III.EQ.2) WRITE(6,95) EXTRA2
 95 FORMAT(10X,'EXTRA COSTS $',15X,F9.2/10X,'-------------------------
   1----------------')
    IF(UNIT(III).EQ.SUNIT(1))WRITE(6,100) CSTINC
100 FORMAT(10X,'TOTAL INCINERATOR COST  ',F13.2)
    IF(UNIT(III).EQ.SUNIT(8))WRITE(6,100) AFTINC
    RETURN
    END
    SUBROUTINE OUTP2(NPRD)
    REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
   1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
    LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
   1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
   2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
   4,CUTVN,CMBST,TCH
   3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
     CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
   1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
   2 ,SCRNME*20
    COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
   1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
   2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
    COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
   1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
    COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
   1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
   2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
   3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
    COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
   1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
    COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
   1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
   2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
   3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
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      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
        COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      CALL CAPTAL
      CONFEE=CONTEN*TOTCAP
      IF(CSTPAK.GT.10000000.) CSTPAK=0.0
      TOTIND= CSTIIN+CSTSTR+CSTSPR+CSTCRT+CSTENG+CSTINT+CONFEE
      TOTTOT= TOTCAP+TOTIND
      WRITE(6,10)
   10 FORMAT('1',32X,'TOTAL CAPITAL COST'/21X,'-----------------')
      WRITE(6,20) IYEAR,CSTINC,AFTINC
      WRITE(6,30) CSTHTR
      WRITE(6,40) CSTQUE,CSTVEN,CSTPAK
      WRITE(6,50) CSTFAN
      NHEIGH=HEIGHT
      WRITE(6,60) NHEIGH,CSTSTK
      WRITE(6,81) WASCAP
      WRITE(6,61) CSTSTO
      WRITE(6,70) DCTTST
      WRITE(6,80) CSTMTB
      WRITE(6,90) CSTSIT
      WRITE(6,100) CSTSTC
      WRITE(6,110) CSTEM
      WRITE(6,120) CSTCNT
      WRITE(6,130) TOTCAP
      WRITE(6,150) CSTIIN,CSTSTR,CSTSPR,CSTCRT,CSTENG,CSTINT,CONFEE,
     1 TOTIND
      WRITE(6,160) TOTTOT
   20 FORMAT(10X,'COMBUSTION CHAMBERS:',30X,I4,' $'/59X,'---------'/
     115X,'PRIMARY COMBUSTOR',24X,F12.2/15X,'SECONDARY COMBUSTOR',22X
     A,F12.2)
   30 FORMAT(10X,'ENERGY ROCOVERY BOILER',24X,F12.2)
   40 FORMAT(10X,'AIR POLLUTION CONTROL SYSTEM'/15X,'QUENCH CHAMBER ',
     126X,F12.2/15X,'VENTURI SCRUBBER AND SEPARATOR',11X,F12.2/
     215X,'PACKED BED SCRUBBER',22X,F12.2)
   50 FORMAT(10X,'INDUCTION FAN',33X,F12.2)
   60 FORMAT(10X,'EXHAUST STACK(',I3,' FEET HIGH)',18X,F12.2)
   81 FORMAT(10X,'WASTE WATER TREATMENT FACILITY',15X,F12.1)
   61 FORMAT(10X,'STORAGE TANK FACILITY',25X,F12.2)
   70 FORMAT(10X,'TOTAL DUCTWORK',32X,F12.2)
   80 FORMAT(10X,'METAL BUILDING',32X,F12.2)
   90 FORMAT(10X,'SITEWORK AND FOUNDATIONS',22X,F12.2)
  100 FORMAT(10X,'STUCTURAL STEEL',31X,F12.2)
  110 FORMAT(10X,'ELECTRICAL MATERIAL',27X,F12.2)
  120 FORMAT(10X,'INSTRUMENTS AND CONTROLS',22X,F12.2/55X,'-------------
     A-')
  130 FORMAT(20X,'TOTAL-----',26X,F12.2//)
  150 FORMAT(10X,'TOTAL INSTALLATION COST',23X,F12.2/
     1       10X,'START-UP (10 % OF EQUIPMENT COST)',13X,F12.2/
     2       10X,'SPARE PARTS (8 % OF EQUIPMENT COST)',11X,F12.2/
     3       10X,'CERTIFICATION (10 % OF EQUIPMENT COST)',8X,F12.2/
     4       10X,'ENGINEERING (7 % OF EQUIPMENT COST)',11X,F12.2/
     5       10X,'INSTRUMENTATION (20 % OF EQUIPMENT COST)',6X,F12.2/
     7       10X,'CONTENGENCY FEE (20 % OF EQUIPMENT COST)',6X,F12.2/
     6       55X,'---------------'/10X,'TOTAL INDIRECT COSTS',26X,F12.2)
  160 FORMAT(//10X,'***** TOTAL CAPITAL COST= ',20X,F12.2///)
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      RETURN
      END
      SUBROUTINE OUTP3(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTI-IN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      WRITE(6,200)
  200 FORMAT(20X,'DUCTWORK DESIGN OUTPUT'//
     1 4X,'         OUTER        BRICK  MATERIALS OF   DUCT        NUM'
     2,'BER OF'/
     3 4X,'UNITS  DIAMETER  DIAMETER CONSTRUCTION  LENGTH      ELBOWS')
      DO 10 I=1,NUNIT
      MUNIT=I+1
      WRITE(6,100) I,MUNIT,DCDIA(I),DSDIA(I),DCMATL(I),DCTLEN(I)
     1 ,ELBNUM(I)
  100 FORMAT(2X,I2,' TO',I2,3X,F5.1,2X,F9.2,5X,A4,6X,F6.2,9X,F3.0)
   10 CONTINUE
      WRITE(6,310)
  310 FORMAT(///32X,'COST OF DUCTWORK'//
     1 17X,'DUCTWORK      FIREBRICK         DAMPERS          TOTAL '/
     2 5X,'   COST        COST             COST             COST         '
     3,'COST'
     3 //)
      MUNIT=0.0
      DO 20 I=1,NUNIT
      MUNIT=I+1
      WRITE(6,300) I,MUNIT,DCTCST(I),DCIBC(I),DAMPT(I),TDCTCS(I)
  300 FORMAT(5X,I2,' TO ',I2,3X,F7.1,8X,F7.1,9X,F7.1,9X,F7.1)
   20 CONTINUE
      RETURN
      END
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      SUBROUTINE OUTP4(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      WRITE(6,20) TOTLAB,TTMAIN,TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS
      WRITE(6,130) TTOPR
   20 FORMAT(10X,'LABOR',30X,F12.2/10X,'MAINTENENCE',30X,F12.2/
     110X,'UTILITIES'/
     215X,'ELECTRICITY',30X,F12.2/15X,'WATER',36X,F12.2/
     315X,'FUEL',30X,F12.2/15X,'SOLID WASTE DISPOSAL',30X,F12.2/
     415X,'CAUSTIC LIME',30X,F12.2)
  130 FORMAT(10X,'***TOTAL - ',30X,F12.2)
      RETURN
      END
      SUBROUTINE OUTP5(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
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     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
        COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      ANSWER =EQVREV-EQVOPR-EQVCAP
      TOT= TTOPR+DEPREC+TAX+ZINSUR
      WRITE(6,10) TOTTOT,TTOPR,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT
      WRITE(6,20) EQVOPR,EQVREV,EQVCAP,EQVFIN
      WRITE(6,30) ANSWER
   10 FORMAT(10X,'CAPITAL COST',20X,F12.2/10X,'------------'//
     1 10X,'OPERATING COST',20X,F12.2/10X,'DEPRICIATION COST',15X,
     2 F12.2/10X,'TAXES(2% OF CAPITAL COTS)',20X,F12.2/
     3 10X,'INSURANCE(.6% OF CAPTIAL COST)',20X,F12.2//
     4 15X,'TOTAL COST- ',20X,F12.2)
   20 FORMAT(10X,'ANNUALIZED OPERATING COST',20X,F12.2/
     1 10X,'ANNUALIZED REVENUES',20X,F12.2/ 10X,'ANNUALIZED EQUIPMENT',
     2 ' COST',20X,F12.2/10X,'FINANCE CHARGES',20X,F12.2)
   30 FORMAT(10X,'ANNUAL EQUIVALENT',20X,F12.2/10X,'REVENUES GENERATED')
      RETURN
      END
      SUBROUTINE LABOR
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCCMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
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     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
      COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      PSUPS=0.0
      TEKC=7.00
      SECC=7.00
      SUPC=8.00
      PCHEMS=0.0
      ZTOT=0.0
       YARDS=0.0
      IF(MASSSL.GT.1000.0) GOTO 10
C     SALARY    BASE SALARY  # REQUIRED  OPER(HR/DAY)   PERCENT     BENIFIT
C        $         $/HR      WHEN OPER.  *(DAY/YR)      TIME NEEDED FACTOR
        LTEKS=   TEKC*        1.0*          8.0*YEAR*     1.00*    1.20
        COPERS=  SUPC*        0.0*          DAY*YEAR*     0.50*    1.19
        OPERS=   TEKC*        1.0*          DAY*YEAR*     1.00*    1.20
        YARDS=   TEKC*        1.0*         8.00*YEAR*     1.00*    1.44
        SECS =   SECC*        1.0*           8.0*YEAR*     0.50*   1.44
            ZTOT=LTEKS+COPERS+OPERS+YARDS+SECS
            PSUPS=ZTOT*0.20
            NTEK=1.0
            NOPER=1.0
            NYARD=1.0
            NSEC=1.0
            GOTO 50
   10 IF(MASSSL.GT.10000.) GOTO 20
        LTEKS=   TEKC*        1.0*          8.0*YEAR*     1.00*    1.20
        COPERS=  SUPC*        1.0*         365.*DAY *     0.50*    1.19
        OPERS=   TEKC*        2.0*         365.0*DAY *     1.00*    1.20
        YARDS=   TEKC*        2.0*          8.0*YEAR*     1.00*    1.44
        SECS =   SECC*        1.5*          8.0*YEAR*     0.50*    1.44
        ZTOT= LTEKS+COPERS+OPERS+YARDS+SECS
        PSUPS=ZTOT*0.20
        NTEK=1.0
        NOPER=2.0
        NYARD=2.0
        NSEC=1.5
        PCHEMS=ZTOT*0.20
        GOTO 50
   20 CONTINUE
        LTEKS=   TEKC*        2.0*          8.0*YEAR*     1.00*    1.20
        COPERS=  SUPC*        1.0*         365.*DAY *     0.50*    1.19
        OPERS=   TEKC*        4.0*         365.0*DAY *     1.00*    1.20
        YARDS=   TEKC*        3.0*          8.0*YEAR*     1.00*    1.44
        SECS =   SECC*        2.0*          8.0*YEAR*     0.50*    1.44
        ZTOT= LTEKS+COPERS+OPERS+YARDS+SECS
        PSUPS=ZTOT*0.20
        NTEK=2
        NOPER=4
        NYARD=3
        NSEC=2
        PCHEMS=ZTOT*0.20
   50 CONTINUE
      LTEKS=LTEKS*268.50/268.5
      COPERS=COPERS*268.50/268.5
      YARDS=YARDS*268.50/268.5
      SECS=SECS*268.50/268.5
      OPERS=OPERS*268.50/268.5
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      PCHEMS=PCHEMS*268.50/268.5
      ZTOT=ZTOT*268.50/268.5
      SUPP= ZTOT*0.20*268.50/268.5
      PAYEXP=ZTOT*0.30*268.50/268.5
      IF(IDEBUG.GT.1) WRITE(6,100) TEKC,SUPC,SECC,MASSSL,DAY,YEAR
      TOTLAB=ZTOT+PCHEMS+SUPP+PAYEXP
100   FORMAT(5X,'OPERATING LABOR DEBUG OUTPUT FOR INPUT DATA'/8X,
     1'BASE TECHNICIAN SALARY ($/HR)= ',F7.2,5X,'SUPERVISORS BASE SALARY
     2($/HR)= ',F7.2,5X/8X,'SECRETARY SALARY ($/HR)= ',F7.2/8X,
     3'MASS RATE OF INLET SLUDGE (LB/HR)= ',E15.4/8X,'OPERATING HOURS PE
     4 R DAY= ',F7.2,5X,'OPERATING DAYS PER YEAR= ',F7.2)
      WRITE(6,201)
201   FORMAT('1')
      WRITE(6,200) PSUPS,PCHEMS,LTEKS,NTEK,COPERS,OPERS,NOPER,YARDS
     1,NYARD,SECS,NSEC,PAYEXP,SUPP,TOTLAB
200   FORMAT(25X,'OPERATING LABOR OUTPUT'//10X,'SUPERVISOR SALARY($/YR)=
     1 ',15X,F9.0/10X,'LABORATORY SUPERVISOR($/YR)= ',11X,F9.0/
     2 10X,'LABORATORY TECHNICIANS SALARY($/YR) =   ',F9.0,1X,'FOR',I2,
     3 ' LAB TECHNICIANS'/10X,'CHIEF OPERATORS SALARY($/YR) = ',9X,F9.0/
     410X, 'OPERATORS SALARY($/YR) = ',15X,F9.0,' FOR',I2,' OPERATORS
     4.'/
     5 10X,'YARD WORKERS SALARY($/YR) = ',12X,F9.0,' FOR',I2,' WORKERS.
     5'/
     6 10X,'SECRETARIES SALARY($/YR) = ',13X,F9.0,' FOR',I2,' SECRETAR'
     6,'IES'/
     7 10X,'PAYROLL EXPENSES(20% OF LABOR=',10X,F9.0/10X,'COST IN $/YR)
     7 '/
     8 10X,'SUPPLIES AND OTHER MISC.($/YR)= ',8X,F9.0/
     8 10X,'-------------------',
     9'--------------------------'/10X,'TOTAL EXPENSES($/YR)= ',18X,F9.0/
     A//)
      RETURN
      END
      SUBROUTINE OPERAT
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
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     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      CSTBAS=CSTBAS*DAY*YEAR
      WSTOPR=-0.00018*WTRTOT/62.4/35.45*264./60.0+2.15
      WSTOPR=WSTOPR*WTRTOT/62.4/35.45*264./1000.0*DAY*YEAR
      CSTST=(CSTINC+AFTINC)*0.02+(CSTHTR+CSTQUE+CSTVEN+CSTPAK)*0.01
     1 +(CSTFAN+CSTSTK)*0.01
C
      CSTFUL=FLTOT*CSTFUL*DAY*YEAR
      CSTH2O=WTRTOT*WTRCST*DAY*YEAR
      CSTDSP=ASH*DSPCST*DAY*YEAR
      CALL LABOR
      TAX=TOTTOT*0.02
      ZINSUR=TOTTOT*0.006
      CSTLEC=TOTELC*CSTELC
C
C    EPA HAZARDOUS  WASTE INCINERATION TESTS
C    COST 20000 DOLLARS PER RUN LASTING 22 HOURS
C
      RECSTM=STMREC*DAY*YEAR*(-1.0)
      TTOPR= TOTLAB+CSTLEC+CSTFUL+CSTH2O+CSTDSP+ZINSUR+RECSTM
     1         +TOTMAN+CSTSTR+CSTBAS+DEPREC+WSTOPR
      WRITE(6,10)
   10 FORMAT('1',30X,'ANNUAL OPERATING COSTS')
      WRITE(6,20) (WSTNME(I),I=1,6)
   20 FORMAT(30X,6(A5))
      WRITE(6,30)MASSSL
   30 FORMAT(30X,'FEED RATE ',F7.0,' LB/HR'//)
      WRITE(6,40) TOTLAB
   40 FORMAT(10X,'LABOR ',32X,F12.0/)
      WRITE(6,50) CSTLEC,CSTFUL,CSTH2O,CSTDSP,CSTBAS
   50 FORMAT(10X,'UTILITIES'/15X,'---------'/15X,
     1 'ELECTRICITY ',21X,F12.0/
     2 15X,'FUEL',29X,F12.0/
     3 15X,'WATER',28X,F12.0/
     4 15X,'WASTE DISPOSAL',19X,F12.0/
     5 15X,'BULK LIME',24X,F12.0/)
      WRITE(6,101) WSTOPR
  101 FORMAT(15X,'WASTE WATER TREATMENT',12X,F12.0/)
      WRITE(6,100) CSTSTR
  100 FORMAT(10X,'STARTUP COSTS ',24X,F12.0/)
  110 FORMAT(10X,'ANNUAL MAINTENENCE',20X,F12.0)
      WRITE(6,111) ZINSUR
  111 FORMAT(10X,'INSURANCE COST'
     1, 24X,F12.0//)
      WRITE(6,110) TOTMAN
      IF(ROTARY) WRITE(6,120)
      IF(FLUID) WRITE(6,130)
      IF(LIQI) WRITE(6,140)
  120 FORMAT(15X,'ROTARY KILN (10% EQUIPMENT',/15X,'COST)'/)
  130 FORMAT(15X,'FLUIDIZED BED   (7% EQUIPMENT'/15X,'COST)')
  140 FORMAT(15X,'LIQUID INJECTION INCINERATOR (5%'/15X,'COST)')
      WRITE(6,150) RECSTM
  150 FORMAT(10X,'HEAT RECOVERY UNIT',20X,F12.0/15X,'(80% EFFICIENCY)')
      WRITE(6,160)  TTOPR
  160 FORMAT(40X,'----------------------'/10X,'TOTAL OPERATING COST',18X
     1 ,F12.0///)
      RETURN
      END
      SUBROUTINE STACK(NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
        CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
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     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2  ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1  ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1  ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2  ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3  ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4   TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5   TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6   EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
        COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY;YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
C
C     INITIALIZE VARIABLES
      IF(METRIC) CALL ENG(NREAC,NPRD)
      DO 45 I=1,NPRD
       MLPRDT(I,III)=MLPRDT(I,III-1)
   45 CONTINUE
      CALL VLRATE(T1,PINC,NPRD)
C   VEL IN FT/MIN
      VEL=9000.0
      STKMAS=MSTOT(III)
         RHO=MSTOT(III)/VOLRAT(III)
         DIA(III)=(STKMAS/60.0*4.0/RHO/VEL)**(0.5)
         HEIGHT=100.0
         ZNUM=1.0
         DIA(III)=DIA(III)*12.0
       IF(HEIGHT.GT.200.0) GOTO 550
  105   IF(DIA(III).LT.60.0) GOTO 100
      IF(IDEBUG.GT.5) WRITE(6,200) DIA(III)
  200      FORMAT(10X,'STACK DIA(III)METER IS TO LARGE AT ',F7.2,'INCHES
     1')
          ZNUM=ZNUM+1.
         STKMAS=MSTOT(III)/ZNUM
  210      FORMAT(10X,F3.0,'STACKS WILL BE DESIGNED')
          WRITE(6,210) ZNUM
      GOTO 105
  100 IF(DIA(III).LE.54.0) GOTO 115
        CSTSTK=1265.0+87.4*HEIGHT
         GOTO 500
  115 IF(DIA(III).LE.48.0) GOTO 120
        CSTSTK=1265.0+83.9*HEIGHT
         GOTO 500
  120 IF(DIA(III).LE.42.0) GOTO 125
        CSTSTK=1035.+79.3*HEIGHT
         GOTO 500
  125 IF(DIA(III).LE.36.0) GOTO 130
        CSTSTK=977.+70.0*HEIGHT
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      GOTO 500
130 IF(DIA(III).LE.30.0) GOTO 135
      CSTSTK=862.+65.5*HEIGHT
      GOTO 500
135 IF(DIA(III).LE.24.0) GOTO 140
      CSTSTK=862.+59.8*HEIGHT
        GOTO 500
140 CSTSTK=862.0+49.4*HEIGHT
     GOTO 500
550 DIA(III)=DIA(III)/12.0
560 IF(DIA(III).LE.40.0) GOTO 145
      ZNUM=ZNUM+1
      WRITE(6,220)  DIA(III),ZNUM
220   FORMAT(10X,'DIA(III)METER OF SATACK IS TOO LARGE AT',F10.2,'AND
    1 ',F3.0,'STACKS WILL BE DESIGNED')
     GOTO 560
145 IF(DIA(III).LE.30.0) GOTO 150
      CSTSTK=1000.0*(0.0097*HEIGHT+1.14)
      GOTO 500
150 IF(DIA(III).LE.20.) GOTO 155
      CSTSTK=1000.0*(0.083*HEIGHT-1.063)
      GOTO 500
155 IF(DIA(III).LE.15) GOTO 160
      CSTSTK=1000.0*(0.0085*HEIGHT-1.30)
      GOTO 500
160 CSTSTK=1000.0*(0.0051125*HEIGHT-0.7725)
500 CSTSTK=CSTSTK*ZNUM
    NNUM=ZNUM
    CSTSTK=CSTSTK/228.0*FACCES
    FLGPAS=.FALSE.
    CSTIIN=CSTIIN+0.57*CSTSTK
    IF(IDEBUG.GT.5)WRITE(6,620) CSTSTK,DIA(III),HEIGHT,NNUM
620 FORMAT(10X,'THE TOTAL COST OF THE STACK IS '/10X,F12.2,'U.S.',
   1' DOLLARS DIAMETER OF STACK IS ',F12.2,'INCHES'/10X,
   2'HEIGHT OF STACK IS',F12.2,'AND ',I3,' STACKS ARE DESIGNED')
    DIA(III)=DIA(III)/12.0
    WRITE(6,300) HEIGHT,DIA(III),STKMAS,NNUM,VEL
300 FORMAT(35X,'EXHAUST STACK DESIGN DATA OUTPUT'/
   1 15X,'HEIGHT OF EXHAUST STACK=          ',F10.2,' FEET'/
   2 15X,'DIAMETER OF EXHAUST STACK=        ',F10.2,' FEET'/
   3 15X,'MASS OF STACK=                    ',F10.2,' LBS'/
   4 15X,'NUMBER OF STACKS=                 ',I4/
   5 15X,'EXIT VELOCITY OF GAS IN STACK=    ',F10.2,'FEET/MINUTE')
    TOTMAN=TOTMAN+CSTSTK*0.05
    RETURN
    END
    SUBROUTINE METRC(NREAC,NPRD)
    REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
   1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
    LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
   1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
   2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
   4,CUTVN,CMBST,TCH
   3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
   1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
   2  ,SCRNME*20
    COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
   1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
   2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
    COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO.VISCL
   1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
    COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
   1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
   2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
   3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
    COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
   1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
    COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
   1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
   2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
   3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
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      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
          MASSSL=MASSSL/2.20467*1000.0
          H2OM=H2OM/2.20467*1000.0
          VAPNO=VAPNO/2.20467*1000.0
           MASSFL=MASSFL/2.20467*1000.0
          FLTOT=FLTOT/2.20467*1000.0
           WTRTOT=WTRTOT/2.20467*1000.0
           MASSAR=MASSAR/2.20467*1000.0
           VOLIT=VOLIT/2.20467*1000.0
           ASH=ASH/2.20467*1000.0
           FREH2O=FREH2O/2.20467*1000.0
           ZFLHT=ZFLHT/0.453/1000.0/9.486E-4
           ZSLHT=ZSLHT/0.453/1000.0/9.486E-4
            PINC=PINC/14.696
C    CONVERT HEAT OF VAPORIZATION OF H2O FROM BTU/LB(INPUT)
C     TO J/G.
      DELTAH=DELTAH/9.486E-4
      HTCOMB=HTCOMB/9.486E-4/453.96
      T1=(T1-32.0)/1.8
      T2=(T2-32.)/1.8
      TA=(TA-32.0)/1.80
      DO 20 J=1,NUNIT
C     CONVERT VOLRAT FROM FT°3/TIME  TO M°3/TIME
              VOLRAT(J)=VOLRAT(J)*0.028317
C
               TTMP(J)=(TTMP(J)-32.)/1.8
               MSTOT(III)=MSTOT(III)*453.96
         DO 10 I=1,NPRD
             MLPRDT(I,J)=MLPRDT(I,J)*453.96
   10 CONTINUE
   20 CONTINUE
      DO 40 JJ=1,NPRD
         FEED(JJ)=FEED(JJ)*453.96
   40 CONTINUE
      ENGL=.FALSE.
      METRIC=.TRUE.
      RETURN
      END
      SUBROUTINE ENG(NREAC,NPRD)
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
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      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
          MASSSL=MASSSL*2.20467/1000.0
          H2OM=H2OM*2.20467/1000.0
          VAPNO=VAPNO*2.20467/1000.0
           MASSFL=MASSFL*2.20467/1000.0
          FLTOT=FLTOT*2.20467/1000.0
           WTRTOT=WTRTOT*2.20467/1000.0
           MASSAR=MASSAR*2.20467/1000.0
           VOLIT=VOLIT*2.20467/1000.0
           ASH=ASH*2.20467/1000.0
           FREH2O=FREH2O*2.20467/1000.0
           ZFLHT=ZFLHT*0.453*1000.0*9.486E-4
           ZSLHT=ZSLHT*0.453*1000.0*9.486E-4
            PINC=PINC*14.696
          DELTAH=DELTAH*9.486E-4
            HTCOMB=HTCOMB*9.486E-4*453.96
      T1=T1*1.8+32.
      T2=T2*1.80+32.0
      TA=TA*1.80+32.0
      DO 20 J=1,NUNIT
         TTMP(J)=TTMP(J)*1.8+32.0
          VOLRAT(J)=VOLRAT(J)/0.028317
          MSTOT(III)=MSTOT(III)/453.96
      DO 10 I=1,NPRD
          MLPRDT(I,J)=MLPRDT(I,J)/453.96
   10 CONTINUE
   20 CONTINUE
      DO 40 JJ=1,NPRD
         FEED(JJ)=FEED(JJ)/453.96
   40 CONTINUE
      METRIC=.FALSE.
      ENGL=.TRUE.
      RETURN
      END
      FUNCTION FXPACK(X,Y)
      LOGICAL Y
      IF(Y) GOTO 10
C   BERL SADDLE PACKING FACTOR
        FXPACK=9558.4-37171.2*X+50495.3*X**2.0-28383.5*X**3.0
     1  +5620.97*X**4.0
      RETURN
   10 FXPACK=3714.4-17151.2*X+34461.1*X**2.-34065.6*X**3.+14944.*X**4.
     1 -278.7*X**5.-1866.2*X**6.+364.04*X**7.+69.6*X**8.-19.18*X**9.
      RETURN
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      END
      FUNCTION FX1(X)
C   LOBO CORELATION FROM MODERN POLLUTION CONTROL TECHNOLOGY 23.41
C   FIG 145.
      IF(X.GT.1.0.AND.X.LE.8.0) FX1=0.0236-7.42E-2*X+5.94E-4*X**2.
      IF(X.GT.0.10.AND.X.LE.1.0) FX1=0.112-0.219*X+0.131*X**2.
      IF(X.GT.0.01.AND.X.LE.0.1) FX1=0.2827-3.981*X+22.91*X**2.
      IF(X.GT.8.0.OR.X.LE.0.01) FX1=.05
      RETURN
      END
      FUNCTION FX3(X,Y)
      LOGICAL Y
      IF(X.LT.5.0.OR.X.LT.100.0) WRITE(6,20)
   20 FORMAT(10X,'PACK BED DIAMETER IS OUT OF RANGE FOR ACCURATE CALCS')
      IF(Y) GOTO 10
         FX3=24.285+7.707*X-3.546E-4*X**2.+3.095E-4*X**3.
      RETURN
   10    FX3=28.91+22.027*X-0.16561*X**2.+2.92E-3*X**4.
C   COST OF PACKED TOWER PER FT OF HEIGHT.
C     FROM M.P.C.T. VOL 1, 23.40 FIGURE 144
      RETURN
      END
      FUNCTION FANFXN(X,Y)
      A=LOG(X)
      IF(Y.LT.1800.0) GOTO 10
      B=4.546+0.125*A+0.103*A**2.0
      FANFXN=EXP(B)
      GOTO 100
   10 IF(Y.LT.1200) GOTO 20
      B=4.721+0.225*A+0.093*A**2.0
      FANFXN=EXP(B)
      GOTO 100
   20 IF(Y.LT.900)  GOTO 30
      B=5.924-0.185*A+0.159*A**2.0
      FANFXN=EXP(B)
      GOTO 100
   30 IF(Y.LT.600) WRITE(6,200)
  200 FORMAT(10X,'RPM SPEED IS TOO LOW IN THE FUNCTION')
       B=4.337+0.088*A+0.0965*A**2.0
       GOTO 100
  100 FANFXN=EXP(B)
      IF(IDEBUG.GE.0) WRITE(6,300) Y,X,FANFXN
  300 FORMAT(10X,'MOTOR RPMS= ',F10.2/
     1        10X,'GAS VOLUME RATE= ',F10.2,'FT°3/MIN/1000'/
     2        10X,'COST OF MOTOR=   ',F10.2,'U.S. DOLLARS')
      RETURN
      END
      SUBROUTINE CAPTAL
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1   ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
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     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      X=MASSSL/1000.0
C   COST OF WASTE WATER TREATMENT PLANT
      WATER=WTRTOT/62.4/35.45*264.4/60.0
C23456
      WASCAP=1000*(1.221*WATER-11.00)*FACCES/320.0
      TOTCAP=CSTINC+AFTINC+CSTHTR+CSTQUE+CSTVEN+CSTPAK+CSTFAN+CSTSTK
     1 +DCTTST+CSTMTB+CSTSIT+CSTSTC+CSTEM+CSTCNT+CSTSTO+WASCAP
C
C  THIS SUBROUTINE CALCULATES ADDITIONAL CAPITAL INFORMATION  FOR SITEWO
C  SITEWORK, STRUCTURAL STEEL, METAL BUILDING,ELECTRICAL MATERIALS,
C  AND INSTRUMENTS AND CONTROLS
C
C
C        THIS EQUATION CONVERTS THE WASTE  FEED RATE TO
C        UNITS CURVFIT FROM DATA OBTAINED IN LITERATURE.
C
C
C       THIS SECTION OF THE SUBROUTINE CALCULATES THE COST OF  A METAL
C       BUILDING.  REF.
C                      LEPEAU,MATEO,"EVALUATING HEAT RECOVERY FROM
C                      BURNING REFUSE",CHEMICAL ENGINEERING, MARCH 21
C                      ,1983.
C
      IF(MASSSL.GT.13000.) GOTO 100
        IF(MASSSL.GT.11000.) GOTO 110
          CSTMTB = 220000.0
  110   IF(CSTMTB.LT. 9000.) GOTO 120
          CSTMTB = 180000.0
          GOTO 200
  120   IF(CSTMTB.LT.750.) GOTO 130
          CSTMTB= 73.95+17.81*X+2.721*X**2.+0.2323*X**3.
          GOTO 200
  130     CSTMTB=90000.0
          GOTO 200
  100 WRITE(6,300)
  300 FORMAT(5X,'*** ERROR *** THE FEED RATE OF WASTE IS TOO LARGE',
     1 ' FOR ACCURATE PREDICTION OF METAL BUILDING COSTS')
      GOTO 120
  200 CONTINUE
      CSTMTB=CSTMTB*FACCEB /232.7
C
C         THIS SECTION OF THE SUBROUTINE CALCULATES THE COST OF SITEWORK
C         AND FOUNDATION COST FOR  AN INCINERATION FACILITY
C         REF
C            SAME AS METAL BUILDING
C
C
      IF(MASSSL.GT.9500.) GOTO 210
        IF(MASSSL.GT.750.0) GOTO 220
          CSTSIT=90000.
          GOTO 305
  220   IF(MASSSL.GT.7500.0) GOTO 221
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      CSTSIT=67.8571+34.643*X-2.50*X**2.
        GOTO 305
  221 CSTSIT=264.73+1.756*X+0.387*X**2.
        GOTO 305
  210   WRITE(6,310)
  310 FORMAT(5X,'*** ERROR *** THE FEED RATE OF WASTE IS TOO LARGE',
     1 'FOR ACCURATE PREDICTION OF SITEWORK COST')
      CSTSIT=520000.0
  305 CONTINUE
      CSTSIT=CSTSIT*FACCEB/232.7
C          THIS SECTION OF  THE  SUBROUTINE CALCULATES THE COST OF
C          THE STRUCTURAL STEEL NEEDED FOR AN  INCINERATION FACILITY.
C          REF
C             SAME AS METAL BUILDING COST
C
C
      IF(MASSSL.GT.8000.0) GOTO 340
        IF(MASSSL.LT.1000.0) GOTO 350
        CSTSTC= 30000.0
        GOTO 400
  350   CSTSTC= 25000.0
        GOTO 400
  340   IF(MASSSL.GT.10000.0) GOTO 360
        CSTSTC= 50000.0
        GOTO 400
  360   CSTSTC= 60000.0
  400 CONTINUE
      CSTSTC=CSTSTC*FACCES/281.2
      CSTCNT=(51.182 - 2.544*X+1.053*X**2.)*1000.000
       IF(X.GT.7) GOTO 501
      CSTEM= (32.+ 3.57*X)*1000.0
      GOTO 500
  501  IF(X.GT.11) GOTO 502
       CSTEM=(-582.94+137.09*X-6.57*X**2.)*1000.0
       GOTO 500
  502 IF(X.GT.16) GOTO 503
      CSTEM=(-1300.+203.33*X-6.67*X**2.)*1000.0
      GOTO 500
  503 WRITE(6,600) MASSSL
  600 FORMAT(10X,'THE FACILITY WASTE FEED RATE IS TOO LARGE FOR ',
     1 'ACCURATE CALCULATION FROM DATA AVAILABLE',F12.0,'LB/HR')
  500 CONTINUE
C   THIS SECTION IS DEVOTED TO THE CALCLATION OF INDIRECT CAPITAL
C   EXPENDITURES
C       VARIABLES ARE:
C                      CSTIIN- INSTALLATION COST OF FACILITY
C                      CSTSTR- FIRST TIME START-UP COSTS
C                      CSTSPR- COST OOF SPARE  PARTS STOCK REQUIRED
C                      CSTCRT- COST OF CERTIFICATION FOR HAZARDOUS WASTE
C
C
C
C         CALCULATION OF FACILITY INSTALLATION
      CSTSTR = TOTCAP *0.10
      CSTSPR = TOTCAP * 0.08
      CSTCRT = TOTCAP * 0.10
      CSTENG = TOTCAP * 0.07
      CSTINT = TOTCAP * 0.20+64000.0*2.
      RETURN
      END
      FUNCTION PRESSR(TOTMS,RHO,DIA,X)
      FRIC=0.0045
      PRESSR= 2.0*FRIC*(TOTMS/(DIA**2.0*3.1416/4.0))**0.5/RHO/DIA*X
      PRESSR= PRESSR *12.0*33.9/14.696/3600.0/32.074
      RETURN
      END
      SUBROUTINE EQIV
      REAL MSSLUD,MSTOT,MLPRDT,TTMP,MSFUEL,MSAIR,XXSLUD
     1 ,XXFUEL,XXAIR,MASSSL,MASSFL,MASSAR,INCDIA,INCLEN,LTEKS
      LOGICAL ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1 ,IC,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,AUTODP,
     2  SSB,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,FLGPAS,SLD,LQD
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     4,CUTVN,CMBST,TCH
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
       CHARACTER BRIKNM*4,UNIT*3,MATL*4,FUELNM*3,PCKCHS*4,WSTNME*5
     1  ,BNMFR*4,BNMIN*4,SUNIT*3,PCKNAM*4,MTLDCT*3,MTLBRK*3,DCMATL*2
     2 ,SCRNME*20
      CHARACTER MATLC*2
      DIMENSION MATLC(4)
      COMMON/MASS/ MSSLUD(9,9),MSFUEL(9,9),MSAIR(9,9),MASSSL,MASSFL,
     1 MASSAR,ZFLHT,ZSLHT,T1,T2,XXSLUD(9),XXFUEL(9),XXAIR(9),HSTVAP
     2,VOLIT,ASH,FREH2O,HTCNT,FULC,FEED(15),TA,DELTAH,ZLFD2(9,9)
      COMMON/PCKBED/ PSIZE(7),PCKSIZ,CSTPK(7),PAKH2O,RHOL,RHO,VISCL
     1,VISCG,EFFABS,TOCOST,CONST(7,8),SLPABS,PAKRAG(7,4),Z,CSTINS,TBRNTT
      COMMON/DES/RLD(9),DESVOL(9),TKOND(9),EXCESS(9),DP(9),TTL(9),HTC
     1 ,BCOST(8),TLIM(8),ZLOSS,TTMP(9),DIABRK,CSTTRT,RETIM(9),FANCLS
     2,HTCOMB,AREA(9),VOLRAT(9),REPCST,HPTOT,TOTCAP,STMREC,YRNUM,RTINST
     3,INCLEN(9),MSTOT(9),MLPRDT(15,9),PINC,PEXT,WTRTOT,FLTOT,TOTMAN
      COMMON/COST/ SHLCST,DRVCST,BRKTOT,ASHCST,STMCST,DCTCST(9)
     1,CSTFUL,DFHCLL,DFHCLG,EXTRA,CSTINC,WTPRT(100),EXFUEL(9)
      COMMON/INPUT/ CP(6,15),PRDMW(15),HEIGHT,WTRCST,DSPCST,CSTELC,DPTOT
     1,AOP,WATRAT,TOTDP,NTU,AOQ,CSTSTO,ASHGAS,PERUPT,FEDRG2,DIAPT(100)
     2,QTEMP,WASCAP,H2OM,VENWAT,CLMS,HCLRM,ELEVAT,CSTLME
     3,QSAT,VENH2O,DAMPT(10),DCIBC(10),CSTBAS,EXTRA2,DIFH2O,VAPNO
      COMMON/OUTPUT/ AFTINC,CSTHTR,CSTQUE,CSTVEN,CSTPAK,CSTFAN,CSTSTK
     1 ,DCTTST,CSTMTB,CSTSIT,CSTSTC,CSTEM,CSTCNT,PREXT,PREXTI,SKRCST
     2 ,CSTIIN,EXTRA1,CSTSTR,CSTSCR,CSTSPR,CSTCRT,CSTENG,DCDIA(9),CSTINT
     3 ,DSDIA(9),CSTLOD,DCTBCS(9),TDCTCS(9),TOTLAB,TTMAIN,
     4  TOTELC,TOTH2O,TTFUEL,TTWSTD,TTCAUS,TTOPR,
     5  TOTTOT,DEPREC,EQVPFT,REVLB,CONTEN,ZINSUR,TOT,EQVOPR,EQVREV,
     6  EQVCAP,FINCRG,REFINS,THCKIN,EQVFIN,DCBRIK
       COMMON/UPDATE/ FACCES,FACMSC,FACCEE,FACCEF,FACCEB
     1, FACPVF,FACPC,FACPI,FACENG,FACLAB,FACPRS
      COMMON/SALARY/TEKC,SUPC,SECC,DAY,YEAR,ZTOT,SUPP,PAYEXP
      COMMON/DCT/ ELBNUM(9),DCTLEN(9),DCTVEL(9),DIA(9)
      COMMON/INT/IDEBUG,NRES(8),NUNIT,III,NSET,JPIK,IYEAR,NUMBRN,NPRTS
      COMMON/ALPHA/MATL(20),BRIKNM(6,8),FUELNM(4,5),UNIT(20),SUNIT(11)
     1,PCKCHS(4),PCKNAM(7,4),DCMATL(9),MTLDCT,MTLBRK
     2,WSTNME(6),BNMFR(6),BNMIN(6),SCRNME(6)
      COMMON/LOGIC/ROTARY,FLUID,LIQI,METRIC,ENGL,LCOST,HTLS,RECT,BAL,PRI
     1,IC,TCH,SSG,VOLTIL,BARREL,SEMI,DCTFLG,SS,CS,DIC,DSS,DCS,DWC,FLGPAS
     2,SLD,SCRW,VENAUT,FG,BRN,ADIA,PLASMA,SIEVE,VALVE,CMBST,LQD,CUTVN
     3,KRB,FXH,S316,S304,S347,NI200,MO400,IN600,IN825,TI,HS,UTB,HM1,HM2
      REVNUE= +MASSSL*DAY*YEAR*REVLB
      EQVOPR=0.0
      EQVREV=0.0
      EQVOPR=-TTOPR*AOQ
      EQVREV=REVNUE*AOQ
      EQVFIN=-FINCRG*AOQ*TOTTOT/100.0
      EQVCAP=-TOTTOT*AOP
      EQVPFT=EQVREV+EQVOPR+EQVFIN+EQVCAP
      EQVLB=EQVPFT/(MASSSL*DAY*YEAR)
      WRITE(6,10)
   10 FORMAT(21X,'*******  FUTURE WORTH COST ANALYSIS  *******')
      WRITE(6,20) (WSTNME(I),I=1,6),MASSSL
   20 FORMAT(////32X,'ANNUAL EQUIVALENT PROFIT'/32X,6(A5)/30X,'FEED RATE
     1 ',2X,F6.0,'LB/HR')
      IF(ROTARY) WRITE(6,200)
      IF(FLUID)  WRITE(6,210)
      IF(LIQI)   WRITE(6,220)
  200 FORMAT(32X,'ROTARY KILN')
  220 FORMAT(29X,'LIQUID INJECTION'//)
  210 FORMAT(30X,'FLUIDIZED BED')
      WRITE(6,300) EQVCAP,AOP
  300 FORMAT(//15X,'ANNUALIZED EQUIVALENT' ,28X,F12.2/15X,'CAPITAL COST'
     1/15X,
     1 '(',F5.2,' ANNUALIZING FACTOR)'/)
      WRITE(6,310) EQVOPR,AOQ
  310 FORMAT(15X,'ANNUALIZED OPERATING COST',24X,F12.2/15X,'(',F5.2
     1 ,' ANNUALIZING FACTOR)'/)
      WRITE(6,320) EQVREV,AOQ
  320 FORMAT(15X,'ANNUALIZED REVENUE EARNINGS',22X,F12.2/15X,
     1 '(',F4.1,' ANNUALIZING FACTOR)'/)
      WRITE(6,330)  EQVFIN,AOQ
```

```
  330 FORMAT(15X,'ANNUALIZED FINANCE CHARGES',22X,F13.2/15X,'(',
     1 F4.2,' ANNUALIZING FACTOR)'/15X,'---------------------------------
     2-------------------------------------')
      WRITE(6,340)EQVPFT
  340 FORMAT(15X,'ANNUALIZED EQUIVALENT REVENUES',19X,F12.2/)
      WRITE(6,350) EQVLB
  350 FORMAT(15X,'REVENUE GENERATED PER POUND',21X,F13.2)
      RETURN
      END
      FUNCTION LOADR(X,C)
      LOGICAL C
      IF(C) GOTO 10
      LOADR=(X+1.1667)/0.3667*1000.0
      RETURN
   10 IF(X.GT.90.) GOTO 20
C   DRUM LOADER
C
      LOADR=175000.0
      RETURN
   20 LOADR=300000.0
      RETURN
      END
      FUNCTION SCRFED(X)
C
C  COST OF SCREQ FEED SYSTEM INCLUDES
C     INCLUDES:
C               5 FT LENGTH SCREW
C               CONVEYOR WITH TROUGH
C               FEED  HOPPER
C               DRIVE  AND MOTOR
C
      IF(X.GT.15.) GOTO 10
        SCRFED=7000.0
        RETURN
   10 IF(X.GT.75.) GOTO 20
        SCRFED=10000.0
        RETURN
   20 SCRFED=22000.0
      RETURN
      END
      FUNCTION TRAYCS(A,B,C,D)
      LOGICAL A,B
      IF(A.AND.B) WRITE(6,10)
   10 FORMAT(10X,'ONLY ONE TYPE OF PACKING IS SELECTED')
      IF(A.AND.B) B=.FALSE.
      IF(A) GOTO 100
      IF(D.EQ.1) TRAYCS=1.0*(2.00+0.157*C+0.111*C**2.)
      IF(D.EQ.2) TRAYCS=1.0*(2.91-0.185*X+0.212*X**2.)
      GOTO 200
  100 IF(D.EQ.1) TRAYCS=1.0*(2.813-0.462*C+0.103*C**2.)
      IF(D.EQ.2) TRYACS=1.0*(1.28+0.589*C-0.066*C*2.+7.52E-3*C**3.)
  200 RETURN
      END
      FUNCTION WTPPRT(Z,PD)
      IF(PD.GT.20.) GOTO 30
          WTPPRT=1.0*(67.6+8.9)*Z
          IF(Z.GT.4.5) WTPPRT=1.0
          GOTO 90
   30 IF(PD.GT.30) GOTO 35
          WTPPRT=1.0*(51.496+67.07*Z-32.9*Z**2.+5.35*Z**3.)
          IF(Z.GT.3.0) WTPPRT=1.0
          GOTO 90
   35 IF(PD.GT.40) GOTO 40
          WTPPRT=1.0*(62.2+84.71*Z-64.857*Z**2.+16.0*Z**3.)
          IF(Z.GT.2.0) WTPPRT=1.0
          GOTO 90
   40 IF(PD.GT.60) GOTO 42
          WTPPRT=1.0*(98.1+9.2*Z)
          IF(Z.GT.1.5) WTPPRT=1.
          GOTO 90
   42 IF(PD.GT.80.) GOTO 45
          WTPPRT=1.0*(95.0+5.0*Z)
```

```
          IF(Z.GT.1.0) WTPPRT=1.0
          GOTO 90
   45 WTPPRT=1.0
   90 RETURN
      END
      FUNCTION PAKDIA(U,RL,RG,F,GM,WL)
      FF=1
      FFF=0.0
      DD=1.0
      DDIA=7.0
   11 AT=3.1416*DDIA**2.0/4.0
      RES1=((28.6*GM/60.0*AT/RG/(RL/RG)**0.50)*(F*U**0.2))**(1./3.)
      RES2= (WL/60.0*AT/62.40/(RL/RG)**0.50*(F*U**0.20))**(1./3.)
      RES=RES1+RES2
      IF(ABS(18.91-RES).LT.0.005) GOTO 50
      IF(RES.GT.18.91) GOTO 20
      DDIA=DDIA+DD
      IF(FF.EQ.0) DD=DD/2.0
      IF(FFF.EQ.0) FFF=1
      IF(FFF.EQ.1) GOTO 11
      FF=0.
      GOTO 11
   20 DDIA=DDIA-DD
      IF(FF.EQ.0) DD=DD/2.0
      IF(FFF.EQ.0) FFF=-1
      IF(FFF.EQ.-1) GOTO 11
      FF=0.
      GOTO 11
   50 CONTINUE
      PAKDIA=DDIA
      RETURN
      END
      SUBROUTINE DCFRR(TOTTOT,TTOPR,YRNUM,MASSSL,DAY,YEAR,REVLB)
       DIMENSION ACRS(16,4),DEP(16),TXABLE(16),TAX(16),OPR(16)
     1 ,ATXINC(16),CSHFLW(16),ZINC(16),ADJCST(16)
      REAL MASSSL
      ICONV=0
      IDEBUG=0.0
       NYR=YRNUM
       NNN=3
       TOTTOT=TOTTOT/1000000.0
       RINC=MASSSL*DAY*YEAR*400.0/2000.0/1000000.0
      TXRT = 0.50
      IF(NYR.LE.4) NNN= 1
      IF(NYR.GT.4.AND.NYR.LE.8) NNN=2
      IF(NYR.GT.8.AND.NYR.LE.12) NNN=3
      IF(NYR.GE.12) NNN=4
C INPUT ACRS DEPRECTION RATE VALUES
C    *****    3 YR DEPRECTIATTION
      DATA ACRS/0,.25,.38,.37,0,0.0,0,0,0,0,0,0,0,0,0,
     1          0,.15,.22,.21,.21,0,0,0,0,0,0,0,0,0,0,0,
     2          0,.08,.14,.12,.10,.10,.10,.09,.09,.09,.09,0,0,0,0,0,
     3          0,.05,.10,.09,.08,.07,.06,.06,.06,.06,.06,.06,.06,.06,
     3          .06,.06/
      NYR = YRNUM
      IF(IDEBUG.GE.25) WRITE(6,320) MASSSL,DAY,YEAR,REVLB,RINC
  320 FORMAT(5X,'MASSSL,DAY,YEAR,REVLB',5F10.2)
      TOTINC = RINC * YRNUM
       DO 5 I = 1,16
          DEP(I) = 0.0
          TXABLE(I) = 0.0
          TAX(I) = 0.0
          OPR(I) = 0.0
          ATXINC(15) = 0.0
           CSHFLW(I) = 0.0
           ZINC(I)=0.0
    5 CONTINUE
      IF(IDEBUG.GE.25) WRITE(6,200) ((ACRS(J,I),I=1,4),J=1,16)
  200 FORMAT(5X,4F10.3)
      DO 10 I = 1,NYR+1
C  I IS THE NUMBER OF YEARS STARTING WITH YEAR 0.
      IF(I.NE.1) GOTO 11
```

```
      CSHFLW(I) = - TOTTOT
      IF(IDEBUG.GE.25) WRITE(6,330) CSHFLW(I)
  330 FORMAT(10X,'CASH FLOW YEAR ZERO',F9.4)
      GOTO 10
   11 CONTINUE
      OPR(I) =TTOPR/1000000.0
      ZINC(I) = RINC
      IF(IDEBUG.GE.25) WRITE(6,340)ZINC(I),RINC,NNN
  340 FORMAT(5X,'ZINC(I) AND RINC',2F9.3)
      DEP(I) = TOTTOT*ACRS(I,NNN)
      TXABLE(I) = ZINC(I)-OPR(I)-DEP(I)
      IF(TXABLE(I).GT.0.0) TAX(I) = TXABLE(I)*TXRT
      ATXINC(I)=TXABLE(I) - TAX(I)
      CSHFLW(I) = ATXINC(I) + DEP(I)
      IF(IDEBUG.GE.25) WRITE(6,310) ZINC(I),OPR(I),DEP(I),TXABLE(I)
     1,TAX(I),ATXINC(I),
     1 CSHFLW(I)
  310 FORMAT((3X,F6.3))
   10 CONTINUE
      FFF= 0
      FF = 1
      DTRTI = 0.10
      RTI=0.50
   30 CONTINUE
      SUMCST = 0.0
      SUMCSH=0.0
       ICONV=ICONV+1
       IF(ICONV.GE.100) STOP
      DO 20 I=2,NYR+1
          SUMCST=SUMCST+CSHFLW(I)/EXP(I*RTI)
           SUMCSH=SUMCSH+CSHFLW(I)
          ADJCST(I) = CSHFLW(I)/EXP(I*RTI)
           EXPFAC=EXP(I*RTI)
           IF(IDEBUG.GE.25) WRITE(6,390) ADJCST(I),SUMCST,EXPFAC,I,RTI
  390 FORMAT(5X,'ADJCST',F6.2,'SUMCST',F6.2,'EXPFAC',F6.2,I2,F6.2)
   20 CONTINUE
       SUMCSH=SUMCSH  +CSHFLW(1)
       IF(IDEBUG.GE.25)  WRITE(6,300) RTI,DTRTI
  300 FORMAT(5X,'INTEREST RATE= ',F9.5,'DTRTI= ',F9.4)
          RESID = SUMCST+CSHFLW(1)
      IF(ABS(RESID).LT.(-CSHFLW(1)*0.010)) GOTO 500
       IF(SUMCST.LT.-CSHFLW(1)) GOTO 15
       RTI=RTI+DTRTI
       IF(FF.EQ.0) DTRTI=DTRTI/2.0
       IF(FFF.EQ.0) FFF=1
       IF(FFF.EQ.1) GOTO 30
       FF=0
       GOTO 30
   15  RTI = RTI -DTRTI
       IF(FF.EQ.0) DTRTI=DTRTI/2.0
       IF(FFF.EQ.0) FFF=-1
       IF(FFF.EQ.-1) GOTO 30
       FF=0
       GOTO  30
C INTERVAL HALVING METHOD TO DETERMINE DISCOUNTED CASH FLOW RATE OF
C RETURN INTEREST FACTOR.
  500 CONTINUE
      WRITE(6,876)
  876 FORMAT('1',22X,'DISCOUNTED CASH FLOW RATE OF RETURN'/35X,
     1 'ANALYSIS OUTPUT'/27X,'(MILLIONS OF U.S. DOLLARS)' //)
  999 FORMAT(20X,'DISCOUNTED CASH FLOW RATE OF RETURN = ',F5.1,'%')
      WRITE(6,100) (I,I=0,NYR)
  100 FORMAT(1X,'YEAR     ',11(4X,I2))
      WRITE(6,130)
      WRITE(6,110)(ZINC(I),I=1,NYR+1)
  110 FORMAT(1X,'INCOME    ',11(1X,F5.1))
      WRITE(6,120)(OPR(I),I=1,NYR+1)
  120 FORMAT(1X,'OPERATE   ',11(1X,F5.1))
       WRITE(6,165)(DEP(I),I=1,NYR+1)
  165 FORMAT(1X,'DEPREC.   ',11(1X,F5.1))
      WRITE(6,130)
  130 FORMAT(1X,'------------------------------------------------------',
```

```
     1 '--------------------------')
       WRITE(6,140)(TXABLE(I),I=1,NYR+1)
   140 FORMAT(1X,'TAXABLES ',11(1X,F5.1))
       WRITE(6,150)(TAX(I),I=1,NYR+1)
   150 FORMAT(1X,'TAXES    ',11(1X,F5.1))
       WRITE(6,130)
       WRITE(6,160)(ATXINC(I),I=1,NYR+1)
   160 FORMAT(1X,'NET INC. ',11(1X,F5.1))
        WRITE(6,165)(DEP(I),I=1,NYR+1)
       WRITE(6,170)CSHFLW(1)
   170 FORMAT(1X,'CAPITAL  ',F5.1,'     -     -     -     -     -     -',
     1 '     -     -     -     -')
       WRITE(6,130)
       WRITE(6,190) (CSHFLW(I),I=1,NYR+1)
   190 FORMAT(1X,'CASH FLW ',11(1X,F5.1))
       WRITE(6,410) SUMCSH
   410 FORMAT(//20X,'THE TOTAL CASH FLOW =  ',F6.2,' MILLION DOLLARS')
       RTI=RTI*100.0
        WRITE(6,999)RTI
        WRITE(6,987)
   987 FORMAT(/////)
       STOP
       END
       FUNCTION RPM(A1,I,C)
       A=LOG(A1)
       RPM=0.0
        IF(I.EQ.9) Y=1.416423* A +10.04325
        IF(I.EQ.8) Y=1.44121 * A + 8.98720
        IF(I.EQ.7) Y=1.4764*A+ 8.00637
        IF(I.EQ.6) Y=1.4412*A+7.60090
        IF(I.EQ.5) Y=1.73115*A+5.97017
        IF(I.EQ.4) Y=1.571183*A+5.838497
        IF(I.EQ.3) Y=1.440643*A+5.58771
        IF(I.EQ.2) Y=1.24444*A+5.5406
        IF(I.EQ.1) Y=1.44904*A+4.898956
        Y=EXP(Y)
        IF(Y.GE.C) RPM=1.0
        IF(Y.LT.C) RPM=0.0
        IF(IDEBUG.GE.50) WRITE(6,100) A1,Y,C
   100 FORMAT(10X,'PRESSURE DROP= ',F12.2,'INCHES H2O'/
     1        10X,'ESTIMATED RPMS=',E12.2/
     2        10X,'ACTUAL VOLUME RATE=',E15.5,'FT°3/MIN/1000')
        RETURN
        END
       FUNCTION FX4(A1,I,C)
       A=LOG(A1)
       FX4=0.0
        IF(I.EQ.9) Y=-1.08*A+14.88
        IF(I.EQ.8) Y=-1.00*A+13.8155
        IF(I.EQ.7) Y=-1.00*A+13.12236
        IF(I.EQ.6) Y=-1.08*A+12.4292
        IF(I.EQ.5) Y=-1.00*A+11.5129
        IF(I.EQ.4) Y=-1.00*A+10.81978
        IF(I.EQ.3) Y=-1.06*A+10.12663
        IF(I.EQ.2) Y=-1.00*A+9.21034
        IF(I.EQ.1) Y=-0.999*A+8.5172
        Y=EXP(Y)
        IF(Y.GE.C) FX4=1.0
        IF(Y.LT.C) FX4=0.0
        IF(IDEBUG.EQ.50) WRITE(6,100) A1,Y,C
   100 FORMAT(10X,'PRESURE DROP=',F12.2,' INCHES H2O'
     1/ 10X,'CALCULATED VOLUME RATE=',E15.5,'FT°3/MIN/1000'/
     2  10X,'ACTUAL VOLUME RATE=     ',E15.5,'FT°3/MIN/1000')
        RETURN
        END
       FUNCTION THICK(A,B,I)
       IF(I.EQ.7) Y=-0.9302*LOG(B)+9.796
       IF(I.EQ.1) Y=-1.0*LOG(B)+6.6846
       IF(I.EQ.2) Y=-1.0*LOG(B)+7.6009
       IF(I.EQ.3) Y=-1.0455*LOG(B)+8.535
       IF(I.EQ.4) Y=-1.0*LOG(B)+8.8882
       IF(I.EQ.5) Y=-0.9910*LOG(B)+9.294
```

```
IF(I.EQ.6) Y=-0.9562*LOG(B)+9.509
 Y2=EXP(Y)
 IF(Y2.GE.A) THICK=1.0
 IF(Y2.LT.A) THICK=0.0
 RETURN
 END
```

APPENDIX E

OPERATING MANUAL

PROGRAM HWSTBRN OPERATING MANUAL

By

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Overview

Introduction

The HWSTBRN program is designed to aid the engineer in the design, cost estimation and economic comparision of a hazardous waste incineration facility. This program provides, as an option, a selection of combustor and pollution control process equipment. Also, included in the package, is an interactive program to view existing data sets or create new ones. The main program HWSTBRN is run as a batch.

The capabilities of this program include;

1) Selection of rotary kiln, fluidized bed or liquid injection combustors for the primary incineration process.
2) Selection of a quench chamber, a heat recovery boiler, venturi scrubber, induction fan, packed bed absorber, and exhaust stack for emission controls.
3) Provide several different levels of output depending on the user's requirements.
4) Provide alternate methods for the design and cost estimation of the process equipment.

The objectives of this program are made possible with a minimum amount of physical and technical data.

Operation of Programs

Operation of the computer package requires the use of 4 computer programs. These programs are called INCIN, INPUT, KILN, and HWSTBRN. Physical data for the program is listed in the data file CP(See Appexdix D). Each of these programs will be discussed separately.

Program INCIN controls the selection of the names of the files to be created by program INPUT for use by program HWSTBRN. Program INCIN allows the use of program INPUT interactively on the IBM 3081D system. When the user selects the name(s) of the data sets to be used, program INPUT is called to create a new input file.

Program INPUT allows the user to read old data files already created or allows the user to create new data files. The program INPUT is used in the interactive mode. Further discussion of program is included in the Input section.

Once a new file has been created and checked by the user, program KILN can be accessed. The name of the input data file accessed by program HWSTBRN must be specified in program KILN(See Figure 1 line 1000). This must be done by entering the edit mode with program KILN. Program KILN is used to control the input and output files and the calling of program HWSTBRN. Program KILN request the user number and password for computer charges. Program HWSTBRN is then run as a batch job. All design and cost calculations for the incineration process are controlled by program HWSTBRN. When this program has run, the output is stored on hard-disk and can be retrieved using the Interactive Output Files (IOF) system. Information on using IOF files can be obtained from the University Computer Center.

Input For Program HWSTBRN

Information that must be provided for the program is divided into four categories. These include:

1) Waste Feed Characteristics
2) Process Facility Variables
3) Design and Cost Data Particular to each Process Unit.
4) Information for Economic Analysis

When all of the data has been input by the user, the program reprints all of the data for inspection before it is written to an output file. Inspection of files already created is also possible. Changes can also be made if required. When all changes are complete, an output file is created. This file is used to input data to program HWSTBRN.

Figure 1

```
//U15500AC  JOB (7,XXX-XX-XXXX),'XXX',TIME=(0,10),CLASS=A,
//  REGION=3000K,MSGCLASS=X,NOTIFY=*,MSGLEVEL=(1,1)
/*PASSWORD ?
/*JOBPARM ROOM=E
// EXEC FORTVCLG,FVREGN=3000K,GOREGN=3000K,FVLNSPC='3200,(100,20)'
//FORT.SYSIN DD DSN=U15500D.FACIL.CNTL,DISP=SHR
//GO.FT04F001 DD DSN=U15500D.CP.DATA,DISP=SHR
//GO.FT15F001 DD DSN=U15500D.KODAK.DATA,DISP=SHR
//GO.SYSIN DD *
//GO.FT10F001 DD UNIT=STORAGE,DISP=(OLD,CATLG),
// SPACE=(TRK,(100,25),RLSE),
// DCB=(LRECL=80,BLKSIZE=7440,RECFM=FB),
// DSN=U15500D.CCP.DATA
//
```

This figure presents the controlling computer program used to design and cost estimate a hazardous waste incineration facility. In this program, program FACIL is the main program. Program CP contains all of the physical data used by program FACIL. Program FINAL is the data set for a specific facility.

PROGRAM INPUT

Introduction

Creating an input file is handled by program INPUT. Different types of data are reqired depending the the process selected. If the program prompts the user to enter letter characters, they must be in single quotes. Samples of the inputs are provided below.

Inputs

Program HWSTBRN first requires the user to specify the names of the files that will be used. This is requested by printing:

IS THIS A NEW PROBLEM ?

The user should respond by typing YES or NO. If Yes, the program asks for the name of the new file(including .data). If no, the program asks for the name of the old file to be retained and the name of a new file for the output.

SELECT METRIC(ENTER 1) OR ENGLISH(ENTER 2) SYSTEM OF MEASUREMENTS

The user responds by entering 1 or 2.

The next section of input corresponds to the characteristics of the waste feed to be incinerated. The program begins by printing:

INPUT THE WASTE FEED IDENTIFICATION NAME

This will label the output with a name or phrase identifying the facility to be designed. The name should not exceed 20 characters.

FOR THE WASTE FEED
INPUT THE WEIGHT FRACTION OF HYDROGEN IN WASTE FEED

Input a number between 0 and 1. This process is repeated for Carbon, Oxygen, Nitrogen, Chlorine, Sulphur, Fluorine, and Phosphorous. If the total weight percent of the waste exceeds one, the process must be repeated. If the total weight percent of the waste is less than 0.98, then the components are normalized to one.

INPUT THE HEAT OF COMBUSTION OF THE WASTE SLUDGE

Input the heat value of the waste feed. This should range from 4,000 Btu/lb to 12,000 Btu/lb.

FOR THE WASTE FEED, INPUT THE WEIGHT FRACTION OF VOLATILES

This value should range between 0 and 1.0. It includes all the combustable or volatile components in the waste feed. This value does not include water in the waste

INPUT THE WEIGHT FRACTION OF FREE H2O IN THE WASTE

This value should range between 0 and 1.0.

SELECT ONE OF THE FOLLOWING
1 - WASTE IS NON-VOLATILE
2 - WASTE IS VOLATILE
3 - WASTE IS VOLATILE AND COMBUSTABLE

This input is used primarily for determination of storage tank costs and accessories. If the user specifies non-volatile, no special accessories are included. If the user indicates that the waste is volatile, a nitrogen blanketing system is included in the design. If the waste is volatile and combustable, a nitrogen blanketing system and special condensors are included as accessories.

The next section of input is for the facility process variables

ENTER PRESSURE OF INLET AIR(PSIA)

The user should respond by entering the ambient pressure at the facility site.

ENTER AMBIENT TEMPERATURE(FAHRENHEIT)

The user should respond by entering the ambient temperature at the facility site.

ENTER THE ELEVATION OF THE HWSTBRNITY(ABOVE SEA LEVEL)

Enter the height above sea level, in feet, to determine the extra compression requirements for the induction fan design.

INPUT THE FEED RATE OF THE WASTE STREAM(LB/HR)

Enter the mass rate at which the waste is fed to the incinerator. Program HWSTBRN is designed to handle waste feed rates between 100 and 10,000 lb/hour.

The next section of input is to determine the amount and type of output required from program HWSTBRN.

ENTER 1 FOR HWSTBRNITY DESIGN ONLY. ENTER 2 IF DESIGN AND COST ANALYSIS DESIRED.

If 1 is entered, the output of all cost data is supressed. If 2 is entered by the user, all major design and cost data is printed.

The next section of input pertains to the particular piece of process equipment selected by the user. First, the user is asked to select a piece of equipment (up to 9 units). The program responds with questions pertaining to that specific unit. The user must select an incinerator as the first unit. After that, any piece of equipment may be specified. For the incinerator, the input program asks the following questions.

INPUT THE TYPE OF INCINERATOR TO BE DESIGNED
1 - ROTARY KILN   2 - LIQUID INJECTION
3 - FLUIDIZED BED

One of these units must be selected by entering the appropriate number.

SELECT ONE OF THE FOLLOWING
1 - WASTE IS A SOLID
2 - WASTE IS A PUMPABLE LIQUID

This question is used for the selection of the waste feed mechanism and in limiting the type of incinerator that may be selected.

WASTE FEED MECHANISM
1 - WASTE FEED BURNERS 2 - BARREL FEED
3 - SCREW FEED SYSTEM

Here, the waste feed system for the incinerator is selected.

SELECT ON OF THE FOLLOWING
1 - SET THE OUTLET INCINERATOR TEMPERATURE
2 - ADIABATIC COMBUSTION

If the user selects 1, the heat balance in program HWSTBRN will calculate the fuel requirements to incinerate the waste feed at the specified temperature. If the combustion of the waste exceeds this temperature, the program will determine the adiabatic combustion temperature. If the user selects 2, the heat balance will directly calculate the temperature at which the waste feed combusts without the aid of fuel.

SPECIFY ONE OF THE FOLLOWING
1 - INCLUDE A 10 PERCENT HEAT LOSS
2 - NO HEAT LOSSES INCLUDED

This question determines if a heat loss factor of 10 percent is included in the heat balance of the primary and secondary combustor.

INPUT THE EXCESS AIR REQUIRED

This prompts the user to specify the excess air for the combustion of the waste. This number should be a fraction between 0 and 1(0 to 100 percent).

INPUT EXCESS FUEL REQUIRED

This prompts the user to specify the amount of excess fuel that is added to the combustor over the required amount. This number should be a fraction between 0 and 1(0 to 100 percent).

INPUT AN ESTIMATE OF THE LENGTH TO DIAMETER RATIO

The user should respond by entering a number between 2 and 9.

INPUT THE RETENTION TIME OF THE INCINERATOR(SECONDS)

Input the time in which the combusted gas should remain within the incinerator(usually 2 seconds for hazardous waste).

EXTRA COSTS FOR INCINERATOR

The user should input a factor(between 0 and 0.50) for extra costs required with the combustor. This factor is multiplied by the total equipment cost of the combustor.

This section includes the input requirements for an afterburner combustor.

INPUT THE EXIT TEMPERATURE OF THE COMBUSTOR

This prompts the user to input the combustion temperature in the afterburner(Fahrenheit).

INPUT THE RETENTION TIME OF COMBUSTOR

Input the retention time of the afterburner in seconds.

INPUT THE EXTRA COSTS FOR INCINERATOR

Input a contengency fee factor for the afterburner. This cost is a percentage of the afterburner equipment cost and should range bewteen 0.0 to 0.50.

This section of input pertains to the design and cost of heat recovery boilers.

TYPE OF HEAT RECOVERY BOILER

1 - FIXED HEAT 2 - KETTLE REBOILER

3 - U-TUBE

The user should select one of these types of heat exchanger for the production of steam. A kettle reboiler is suggested as the best choice.

MATERIALS OF CONSTRUCTION

1 - STAINLESS STEEL 316	2 - STAINLESS STEEL 304
3 - STAINLESS STEEL 347	4 - NICKEL 200
5 - MONEL 400	6 - INCONEL 600
7 - INCOLOY 825	8 - TITANIUM
9 - HASTALLOY	

Select one of these materials for the construction of the heat recovery boilers.

INPUT THE OVERALL HEAT TRANSFER COEFFICIENT

Specify the heat transfer coefficient for the heat recovery boiler for the waste gas and boiling water at 360 Fahrenheit. This value should range between 1 and 5 Btu/Hr/ft°2/Fahrenheit.

This section includes the input requirements for quench chambers.

SPECIFY ONE OF THESE OPTIONS
1 - Specify outlet temperature
2 - Saturated outlet temperature

The type of quench chamber must be specified. If option number one is selected, a heat balance is used to calculate the amount of water required to cool the stream to a specific temperature. If option two is specified, water will be added to cool the gas stream to the saturation temperature.

Specification of the design parameters for the venturi scrubber begins with the prompt:

SELECT THE VENTURI THROAT MECHANISM
1 - Automatic throat control
2 - Manual throat control

If option one is selected, an automatic throat adjustment(for a specific pressure drop) is specified for the design. If option two is selected, manual throat adjustment is included.

INPUT THE WATER RATE TO THE VENTURI SCRUBBER

This prompts the user to specify the flow rate of water(used to remove particulates in the gas stream). The recommended range, for high energy scrubbers is 3 to 10 lb H2O / 1000 cubic feet of gas.

SELECT ONE OF THE FOLLOWING
1 - PARTICULATE REMOVAL EFFICIENCY FROM EXPERIMENTAL DATA
2 - DIRECT SPECIFICATION OF VENTURI SCRUBBER PRESSSURE DROP
3 - PARTICULATE REMOVAL EFFICIENCY USING EXPERIMENTAL DATA AND THE CUT-DIAMETER METHOD.

If option two is selected, the pressure drop is specified by the user. This value should range between 40 - 100 in H2O. With this option, no particulate distribution is specified. If option one is selected, experimental data for removal efficiency versus particulate diameter is impelemented. Data is available at pressure drops of 40, 60, and 80 inches H2O. If option 3 is selected, the cut-diameter for a given pressure drop is determined. This data is also generated from experimental data.

SPECIFY THE OVERALL REMOVAL EFFICIENCY

This prompts the user to indicate the maximum particulate concentration allowed to exit the venturi scrubber. Present federal regulations specify a maximum concentration of 0.0005 lb particulates per actual cubic feet of gas. This print is not required if the venturi scrubber pressure is directly specified.

INPUT THE NUMBER OF DATA POINTS FOR THE PARTICULATE DISTRIBUTION.

This prompts the user to indicate the number of data points for the particulate distribution. This input is only required if the pressure drop is not directly specified. The maximum allowed number of data points is 100.

SPECIFY THE AVERAGE DIAMETER AND WEIGHT PERCENT FOR THE PARTICULATE DISTRIBUTION

Here the user inputs the average particulate diameter(of a specific range) and the weight percent of the total. Repeat this for the number of data points specified.

SELECT THE FOLLOWING OPTIONS
1 - FIBERGLASS LINED THROAT
2 - UNLINED THROAT

Option one is specified for highly corrosive environments. For relatively mild conditions, the unlined throat is acceptable.

This section of the input pertains to the design of Induction fans.

ENTER THE PRESSURE HEAD FOR THE COMPRESSION PROCESS

Input the pressure head in inches of water. A recommended range is from 40 to 80 inches of H2O.

This section of input is used to input the variables for a packed bed absorber.

INPUT MAJOR CAUSTIC TO BE SCRUBBED BY THE ABSORPTION COLUMN

This prompts the user to name the chemical absorbed for identification of the diffusion coefficients. The name should not exceed 20 characters, and must be enclosed in single quotes.

INPUT THE CAUSTIC REMOVAL EFFICIENCY

Specify the percent removal of the caustic to be scrubbed. The value should range from 0 to 100.

INPUT THE RELATIVE WATER FEED RATE TO THE PACKED BED ABSORBER.

Specify the water rate(in gallons of water per 1000 cubic feet of gas flow) added to the absorber. The rate should range from 15 to 30 gallons of water per 1000 cubic feet of gas flow.

INPUT THE PACKING TYPE
1 - Berl Saddles
2 - Raschig Rings

Two types of packing are available. One of these must be specified to select absorption data.

INPUT SIZE OF PACKING USED
1 - 0.50 inch packing   2 - 1.0 inch packing
3 - 1.50 inch packing   4 - 2.0 inch packing

One of these packing sizes must be specified.

INPUT THE EFFECTIVE ABSORPTION FACTOR

This prompts the user to specify an efficiency factor for the packed bed absorber. This value should range from 0.10 to 1.0.

INPUT THE PERCENT FLOODING IN THE PACKED BED

The user should specify the percent flooding in the packed bed absorber.

INPUT THE NUMBER OF ABSORPTION TRANSFER UNITS

This print prompts the user to specify the number of mass transfer units required to absorb the caustic. This value is determined from an equilibrium diagram(See figure 2).

INPUT THE SLOPE OF THE EQUILIBRIUM CURVE

Input the slope of the equilibrium curve at the outlet concentration. Figure 2 represents the equilibrium curve for hydrogen chloride. For pollution control with high caustic removal, the slope of this curve is approximated by zero.

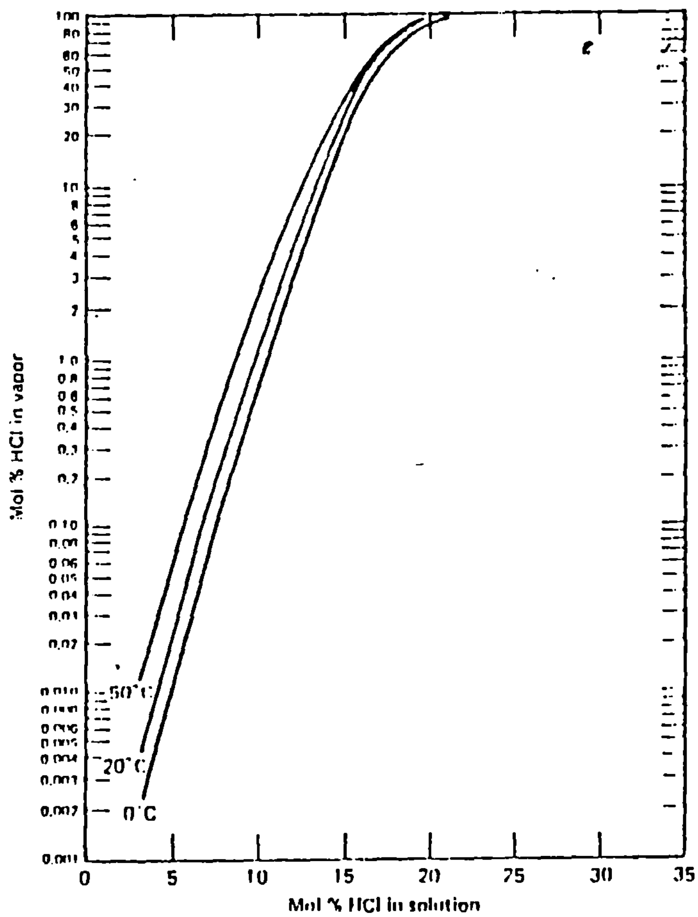


Figure 2 - Vapor liquid equilibrium curve used to calculate the slope(m) for absorption calculations(85).

INPUT THE DIFFUSION COEFFICIENT FOR THE CAUSTIC IN THE GAS PHASE

Input the diffusion coefficient in square feet per second. For hydrogen chloride, this value is 30.0 square feet per second.

INPUT THE DIFFUSION COEFFICIENT FOR THE CAUSTIC IN THE LIQUID PHASE

Input the diffusion coefficient in square feet per second. For hydrogen chloride, this value is 0.05 square feet per second.

INPUT THE SCHMIDT NUMBER FOR THE ABSORPTION PROCESS

The schmidt number is a dimensionless number. If unknown, input 1.0.

The next section of input pertains to exhaust stack design.

INPUT THE HEIGHT OF THE EXHAUST STACK

The height of the stack must be specified(in feet).

The following input requirements pertain to the economic analysis of the facility.

YEAR TO DATE THE CAPITAL COST OF THE HWSTBRNITY

Input the year when the construction of the facility will take place. This is the year to which the cost update factors are specified.

HOW MANY HOURS PER DAY IS THE INCINERATOR IN OPERATION

Specify the hours per day(including reheat time if used less than 24 hours per day) that the facility is in operation. This number is almost always 24 hours per day.

HOW MANY DAYS PER YEAR IS THE HWSTBRNITY IN OPERATION

Specify the number of days per year for operation. This value can range up to 300 days per year. The balance of the year is required for facility maintanence and start-up.

REVENUE GENERATED FROM INCINERATOR OPERATION

Specify the amount of revenue generated from incineration of the waste. This value can range from 20 to 1,200 U.S. Dollars per ton of waste feed; depending on the type of waste incinerated.

LENGTH OF PROCESS LIFE

Specify the total process life of the incineration facility. This value is recommended to be 3,5,10 or 15 years(for depreciation purposes).

INPUT THE SPECIFIC COST INDEX FACTORS FROM CHEMICAL ENGINEERING EQUIPMENT COST FACTORS

For the year to date for the incineration facility, cost update factors must be specifed from Chemical Engineering magazine (See Table I for 1986 cost factors). These factors are requested individually.

INPUT THE COST UPDATE FACTOR FOR EQUIPMENT MACHINERY AND SUPPORTS

INPUT THE COST UPDATE FACTOR FOR ELECTRICAL EQUIPMENT

INPUT THE COST UPDATE FACTOR FOR FABRICATED EQUIPMENT

INPUT THE COST UPDATE FACTOR FOR STRUCTURAL SUPPORTS AND OTHER MISCELLANIOUS COSTS

INPUT THE COST UPDATE FACTOR FOR BUILDING COSTS

INPUT THE COST FACTOR FOR PIPES VALVES & FITTINGS

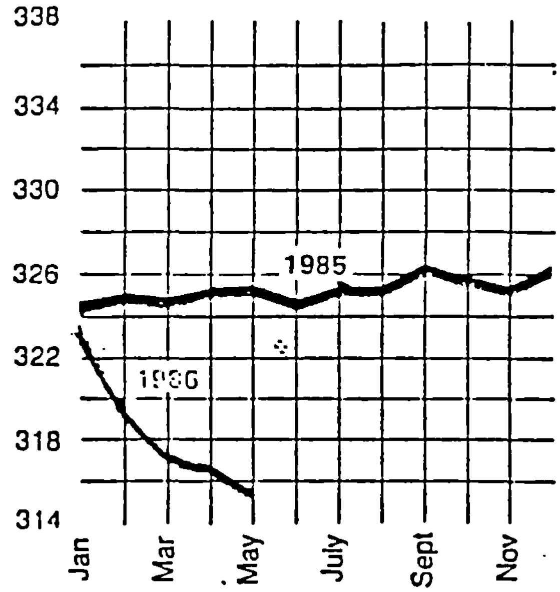
INPUT THE COST FACTOR FOR PUMPS AND COMPRESSORS

INPUT THE COST FACTOR PROCESS INSTRUMENTS

INPUT THE COST FACTOR FOR ENGINEERING & SUPERVISION

INPUT THE COST FACTOR FOR CONSTRUCTION LABOR

Table I



Annual index
1975 = 182.4†
1976 = 192.1†
1977 = 204.1†
1978 = 218.8†
1979 = 238.7†
1980 = 261.2†
1981 = 297.0†
1982 = 314.0*
1983 = 316.9*
1984 = 322.7*
1985 = 325.3*

CE plant cost index

(1957-59 = 100)	May '86 Prelim.	Apr.'86 Final	Mar.'86 Final	May '85 Final
	315.2	316.7	317.4	325.4
Equipment, machinery, supports	332.1	334.4	336.9	347.0
Construction labor	260.8	261.3	257.9	265.8
Buildings	303.7	303.5	301.9	305.3
Engineering & supervision	339.8	339.7	339.7	338.9
Fabricated equipment	305.1	310.6	317.0	336.0
Process machinery	324.6	324.6	326.3	331.0
Pipe, valves & fittings	373.0	374.7	375.1	386.5
Process instruments	324.1	323.2	325.6	323.5
Pumps & compressors	425.1	425.1	419.8	417.5
Electrical equipment	252.9	252.9	252.2	252.3
Structural supports & misc.	340.3	340.9	341.2	345.6

*Revised: productivity factor = 1.75.
†Unrevised: productivity factor = 2.50.
See "CE Plant Cost Index—Revised," Apr. 19, 1982, p. 153. For description of original Index, see Feb. 18, 1963 issue. For past annual averages of CE Plant Cost Index and M&S Equipment Cost Indexes, refer to issues of Apr. 25, 1966, May 5, 1969, Nov. 13, 1972, Apr. 28, 1975, May 8, 1978, Apr. 19, 1982 and Apr. 29, 1985. For reprint containing all foregoing articles, request Reprint No. 122 on order form in back of any issue.

This table represents an example of the cost updating factors from CHEMICAL ENGINEERING magazine for the engineering plant cost index. This example was obtained from the July 21, 1986 issue.

INPUT THE COST FACTOR FOR PROCESS MACHINERY

Each of these cost update factors are represented under a specific category for cost updating factors(See Table I).

SPECIFY THE PERCENTAGE OF EQUIPMENT COST FOR THE CONTENGENCY COSTS

This print requests a factor(between 0 and 1.0) to estimate the contengency fees that are required for facility construction. A value of 0.20 is recommended.

Program HWSTBRN Output

Different levels of output are available, depending on the users specifications. This section provides examples of the different levels of output.

Output for the incineration process are listed in Table II. This printout is provided with every run and cannot be switched off. Table III shows an example of the design and cost breakdown for the combustor(in this case the primary combustor). The cost breakdown is an optional printout and is not shown if the user specifies no cost estimation.

Output for the pollution control components are listed in Table IV. Design output for ductwork connecting these units and waste storage for the facility is presented in Table V. From the above output, a summary table of the Total Capital Cost is printed(See Table VI). To view this table, the cost estimation option must be specified by the user(See the section on INPUT). Also, if specified, the operating costs are presented. If an economic analysis is requested by the user, a table representing the present value discounted rate of return factor is calculated. An example of this output is listed in Table VII.

Table II

INCINERATOR DESIGN AND COST FOR
ROTARY KILN

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE	189708.69 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLITILES FEED RATE	9000.00 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	3252.70 LB/HR
AIR FEED RATE (AT 50.00% EXCESS)	177514.50 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	50.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT.
INCINERATOR TEMPERATURE	2000.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.
DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	289.00 DAYS/YEAR.
SHUTDOWN LENGTH	76.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	5.00

This table represents the output printed for incineration facility design parameters.

Table III

```
                INCINERATOR PROCESS DESIGN SPECIFICATIONS

INCINERATOR DIAMETER (FT)=                        12.8267
INCINERATOR LENGTH (FT)=                          58.4393
MATERIALS OF CONTRUCTION FOR THE INCINERATOR
     REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK               THICKNESS =   1.5 INCHES
     INSULATION SELECTED = INSULATING FIREBRICK                THICKNESS =   5.3 INCHES
INCINERATOR SURFACE AREA (FT**2)               6269.8516
INCINERATOR VOLUME        (FT**3)              6269.8789
INCINERATOR BURNER DATA
     NUMBER OF FUEL BURNERS =   5
     WASTE FEED BURNER HEAT LOAD =  0.810E+08 BTU/HR
OPTIONS IN EFFECT
A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED IN THE HEAT/MASS BALANCE
     WASTE FEED IS A LIQUID.  WASTE BURNERS ARE SELECTED
     INCONEL WAS SELECTED TO CONTRUCT THE SHELL


                INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $             197151.25
TOTAL SHELL COST $             409029.87
COST OF BURNER SYSTEM $         70604.44
COST OF ASH SYSTEM $                0.00
COST OF DRIVE SYSTEM $         165264.56
COST OF SKIRTING $              10000.00
EXTRA COSTS $                  137357.06
----------------------------------------
TOTAL INCINERATOR COST         989407.19
```

Output sample of the combustor process design specifications and cost breakdown.

Table IV

```
                HEAT RECOVERY SYSTEM DESIGN
CHARACTERISTICS OF STEAM PRODUCED
     PRESSURE OF STEAM FORMED=                      185. PSIA
     QUANTITY OF STEAM PRODUCED =                 71252. LB/HR
     COST RECOVERED FROM STEAM PRODUCTION =         287.29 U.S.  DOLLARS/HR
MATERIALS OF CONSTRUCTION
     MATERIAL OF CONSTRUCTION IS INCONEL
```

```
                  QUENCH CHAMBER DESIGN SPECIFICATIONS

        QUENCH TEMPERATURE =   180.0 FAHRENHEIT
        QUENCH DIAMETER =       10.6 FEET
        QUENCH LENGTH =         31.7 FEET
        WATER RATE =       0.111E+05 LB/HR
        WATER OUT  =       0.000E+00 LB/HR
        OPTIONS IN EFFECT

             INCONEL WAS SELECTED AS THE MATERIAL OF CONSTRUCTION
             QUENCH CHAMBER DESIGNED FOR SPECIFIC OUTLET TEMPERATURE
```

```
                      VENTURI SCRUBBER DESIGN OUTPUT

            TOTAL PRESSURE DROP=                      60. INCHES H2O
            WATER FEED RATE=                  0.21106E+05LB/HR
            VENTURI SHELL THICKNESS=                0.50  INCHES
            FEDERAL PARTICULATE LEVELS=          0.50000E-04LB/ACF
            CALCULATED EMISSION LEVELS=          0.00000E+00LB/ACF
            LENGTH OF VENTURI SEPARATOR(FT)=          16.
            DIAMETER OF VENTURI SEPARATOR(FT)=          9.
            OPTIONS SELECTED
                 PRESSURE DROP DIRECTLY SPECIFIED
                 AUTOMATIC THROAT CONTROL SPECIFIED
                 THROAT LINED WITH FIBERGLASS
                 VENTURI CONSTRUCTED OF INCONEL
```

Table IV cont.

INDUCED DRAFT FAN DESIGN

```
TOTAL PRESSURE DROP(INCLUDING ADJUSTMENT FOR ELEVATION) =   60.00 IN H20
ELEVATION OF FACILITY=                   9000. FEET
PRESSURE DROP PER STAGE =   20.00 IN H20
VOLUME RATE PER PARALLEL FEED =   36.60FT**3/MIN/1000
NUMBER OF FANS PER STAGE =   3
MOTOR RPMS =   1800.00
TOTAL HORSEPOWER REQUIRED TO COMPRESS GAS =     200.00 HP
NUMBER OF INLET STREAMS=  1
DIAMETER OF IMPELLOR =     35. INCHES
OPTIONS SELECTED
     MATERIAL OF CONSTRUCTION FOR FANS IS INCONEL
     CLASS 4 FANS ARE SPECIFIED(HIGH PERFORMANCE)
                         COST OF INDUCTION FANS
     COST OF FANS=              63000.   U.S. DOLLARS
     COST OF DAMPERS=            3917.   U.S. DOLLARS
     COST OF MOTORS=             4865.   U.S. DOLLARS
     ---------------------------------
     TOTAL INDUCTION FAN COST=  71783.   U.S. DOLLARS
```

PACKED BED DESIGN PARAMETERS

```
DIAMETER OF COLUMN(FT)=        2.65  TOTAL HEIGTH OF COLUMN(FT)=      10.00
CALCULATED COST OF COLUMN=   64307.96 U.S. DOLLARS
CALCULATED FEED RATE=              0.00
AREA OF BED=
OPTIONS SELECTED
     PACKING SELECTED IS BERL SADDLES
     PACKING SIZE IS  0.5 INCHES
PACKED COLUMN IS CONSTRUCTED OF CARBON STEEL
```

EXHAUST STACK DESIGN

```
HEIGHT OF EXHAUST STACK=                 100.00 FEET
DIAMETER OF EXHAUST STACK=                 3.67 FEET
MASS OF STACK=                        125467.12 LBS
NUMBER OF STACKS=                          1
EXIT VELOCITY OF GAS IN STACK=          9000.00FEET/MINUTE
```

This table represents a sample of the output provided by program FACIL to indicate some of the important design parameters determined.

Table V

DUCTWORK DESIGN OUTPUT

UNITS	OUTER DIAMETER	BRICK DIAMETER	MATERIALS OF CONSTRUCTION	DUCT LENGTH	NUMBER OF ELBOWS
1 TO 2	75.6	0.00	IC	10.00	1.
2 TO 3	81.8	0.00	IC	10.00	2.
3 TO 4	38.8	0.00	IC	10.00	0.
4 TO 5	39.0	0.00	CS	10.00	1.
5 TO 6	39.0	0.00	CS	15.00	3.
6 TO 7	39.0	0.00	CS	15.00	3.
7 TO 8	0.0	0.00	CS	0.00	0.

COST OF DUCTWORK

COST	DUCTWORK COST	FIREBRICK COST	DAMPERS COST	TOTAL COST
1 TO 2	11628.8	16310.2	8143.1	36082.0
2 TO 3	21746.4	21935.2	9030.3	52711.8
3 TO 4	1448.8	0.0	4061.2	5509.9
4 TO 5	1152.9	0.0	4080.4	5233.2
5 TO 6	2841.8	0.0	4081.5	6923.3
6 TO 7	2841.9	0.0	4081.5	6923.4
7 TO 8	0.0	0.0	0.0	0.0

LIQUID WASTE STORAGE FACILITY

NUMBER OF 25,000 GALLON TANKS =	4	
NUMBER OF 10,000 GALLON TANKS =	2	
NUMBER OF 1,000 GALLON TANKS =	1	
TOTAL STORAGE TANK COST=	608000.	U.S. DOLLARS
CSTNIT=	0.	U.S. DOLLARS
NITROGEN BLANKET SYSTEM=	0.	U.S. DOLLARS
CONDENSOR COST=	0.	U.S. DOLLARS

The table represents a sample of the output for the design specifications and cost of the ductwork connecting the combustor and pollution control process units. Also shown, is output representing the number of storage tanks and the cost of a waste storage facility.

Table VI

TOTAL CAPITAL COST

COMBUSTION CHAMBERS:	1976 $
PRIMARY COMBUSTOR	989407.19
SECONDARY COMBUSTOR	1006837.00
ENERGY RECOVERY BOILER	149723.69
AIR POLLUTION CONTROL SYSTEM	
QUENCH CHAMBER	45399.73
VENTURI SCRUBBER AND SEPARATOR	91359.50
PACKED BED SCRUBBER	4691.82
INDUCTION FAN	179274.37
EXHAUST STACK(0 FEET HIGH)	0.00
WASTE WATER TREATMENT FACILITY	173989.2
STORAGE TANK FACILITY	608000.00
TOTAL DUCTWORK	113383.56
METAL BUILDING	143025.25
SITEWORK AND FOUNDATIONS	247.82
STUCTURAL STEEL	35935.28
ELECTRICAL MATERIAL	118699.69
INSTRUMENTS AND CONTROLS	113578.75
TOTAL-----	3773546.00
TOTAL INSTALLATION COST	2459029.00
START-UP (10 % OF EQUIPMENT COST)	377354.69
SPARE PARTS (8 % OF EQUIPMENT COST)	301883.56
CERTIFICATION (10 % OF EQUIPMENT COST)	377354.69
ENGINEERING (7 % OF EQUIPMENT COST)	264148.19
INSTRUMENTATION (20 % OF EQUIPMENT COST)	882709.12
CONTENGENCY FEE (20 % OF EQUIPMENT COST)	754709.12
TOTAL INDIRECT COSTS	5417186.00
***** TOTAL CAPITAL COST=	9190732.00

This table represents the output generated by program FACIL listing the total capital cost of the incineration facility.

Table VII

DISCOUNTED CASH FLOW RATE OF RETURN
ANALYSIS OUTPUT
(MILLIONS OF U S. DOLLARS)

YEAR	0	1	2	3	4	5	6	7	8	9	10
INCOME	0.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
OPERATE	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
DEPREC.	0.0	0.7	1.3	1.1	0.9	0.9	0.9	0.8	0.8	0.8	0.8
TAXABLES	0.0	7.8	7.2	7.4	7.6	7.6	7.6	7.7	7.7	7.7	7.7
TAXES	0.0	3.9	3.6	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8
NET INC.	*****	3.9	3.6	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8
DEPREC.	0.0	0.7	1.3	1.1	0.9	0.9	0.9	0.8	0.8	0.8	0.8
CAPITAL	-9.2	-	-	-	-	-	-	-	-		-
CASH FLW	-9.2	4.6	4.9	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7

THE TOTAL CASH FLOW = 38.00 MILLION DOLLARS
DISCOUNTED CASH FLOW RATE OF RETURN = 30.6%

This table represents an example of the Discounted Cash Flow Rate of Return (DCFRR) analysis generated by program FACIL. The rate of return(in this case 30.6 percent) of different facilities can be compared to determine the most profitable option. The greater the rate of return, the greater the profitablity.

APPENDIX F

EXAMPLES OF PROGRAM HWSTBRN OUTPUT

```
          *****   SUMMARY OF INPUT DATA FILE   *****

24.0 300.0

0.0300  0.7000  0.0700  0.0000  0.2000  0.0000  0.0000  0.0000  0.0000
0.0130  0.9870  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.2332  0.7672  0.0000  0.0000  0.0000  0.0000  0.0000
 10000.0000  6000.0000
               13970.0
T
F
F
F
F
T
F
0.0000000
1.0000000
F
T
T
 8
     80.00
     14.70
   3000.00
      0.00
INC IC    1800.00   10.00000 1.0 IC
AFT IC    2000.00   15.00000 2.0 IC
HTE        500.00   10.00000 0.0 CS
QUE IC     180.00   10.00000 1.0 CS
VEN CS     180.00   15.00000 3.0 CS
IND CS     180.00   15.00000 3.0 CS
PCK CS     180.00    0.00000 0.0 CS
STK CS     180.00    0.00000 0.0
T
F
F
T
      2.00
      3.00
      0.50
      0.50
0.2000000
F
F
T
   7.00000
   2.00000
0.2000000
F
T
F
F
F
F
F
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F
F
T
F
F
F
      2.50
0.01.0
      8.00
     60.00
F
    0.50000E-03
T
F
     60.00
```

```
BERL SADDLES       0.500.50000000 10 1.000 70.00
18.000  0.00 99.9900
HCL
      0.03
     30.00
100.0
T
  308.4 212.3 305.9 257.2 310.9 344.9 368.6 265.5 232.3 214.3 287.2 1986
10.0 0.0 400.000   0.000
         ********************************************

 HEAT LOAD IS TOO LARGE  FOR BURNER SYSTEMS
  12  BURNERS ARE REQUIRED
1                       INCINERATOR DESIGN AND COST FOR
                                ROTARY KILN
```

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE ·	299910.19 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLATILES FEED RATE	9999.99 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	8381.95 LB/HR
AIR FEED RATE (AT 50.00% EXCESS)	281619.44 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	50.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT.
INCINERATOR TEMPERATURE	1800.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.
DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	300.00 DAYS/YEAR.
SHUTDOWN LENGTH	65.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	3.00

INCINERATOR PROCESS DESIGN SPECIFICATIONS

```
INCINERATOR DIAMETER (FT)=                 16.5191
INCINERATOR LENGTH (FT)=                   47.0572
MATERIALS OF CONSTRUCTION FOR THE INCINERATOR
     REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK
     THICKNESS =    1.0 INCHES
     INSULATION SELECTED = INSULATING FIREBRICK
     THICKNESS =   4.0 INCHES
INCINERATOR SURFACE AREA (FT**2)         9093.4102
INCINERATOR VOLUME        (FT**3)        9093.4375
INCINERATOR BURNER DATA
     NUMBER OF FUEL BURNERS =  12
     WASTE FEED BURNER HEAT LOAD =  0.600E+08 BTU/HR
OPTIONS IN EFFECT
     A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED
        IN THE HEAT/MASS BALANCE CALCULATIONS
     WASTE FEED IS A LIQUID.  WASTE BURNERS ARE SELECTED
     INCONEL WAS SELECTED TO CONSTRUCT THE SHELL
```

INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $	230925.31
TOTAL SHELL COST $	690082.75
COST OF BURNER SYSTEM $	169517.44
COST OF ASH SYSTEM $	0.00
COST OF DRIVE SYSTEM $	278821.25
COST OF SKIRTING $	10000.00
EXTRA COSTS $	220104.94

TOTAL INCINERATOR COST 1599450.00

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 80.00 FAHRENHEIT P= 14.70 PSIA

OUTPUT STREAM T= 1800.00 FAHRENHEIT P= 14.69 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	8381.95	0.00
AIR	281619.44	0.00
WASTE	9999.99	0.00
ASH	0.00	0.00
H2O	0.00	3144.05
HCL	0.00	2054.53
CO2	0.00	55915.13
CO	0.00	0.00
N2	0.00	215929.87
O2	0.00	22866.70
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

1

INCINERATOR DESIGN AND COST FOR LIQUID INJECTION AFTERBURNER

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE	301481.25 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLATILES FEED RATE	0.00 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	1571.62 LB/HR
AIR FEED RATE (AT 0.00% EXCESS)	0.00 LB/HR
GAS FEED FROM PREVIOUS UNIT	299910.19 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	0.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT.
INCINERATOR TEMPERATURE	2000.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.
DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	300.00 DAYS/YEAR.
SHUTDOWN LENGTH	65.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	7.00

INCINERATOR PROCESS DESIGN SPECIFICATIONS

INCINERATOR DIAMETER (FT)= 13.3097
INCINERATOR LENGTH (FT)= 85.1958
MATERIALS OF CONSTRUCTION FOR THE INCINERATOR
REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK
THICKNESS = 1.5 INCHES
INSULATION SELECTED = INSULATING FIREBRICK

```
     THICKNESS =   5.3 INCHES
INCINERATOR SURFACE AREA (FT**2)        2740.5830
INCINERATOR VOLUME         (FT**3)      9911.7500
INCINERATOR BURNER DATA
     NUMBER OF FUEL BURNERS =   3
OPTIONS IN EFFECT
     A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED
        IN THE HEAT/MASS BALANCE CALCULATIONS
     INCONEL WAS SELECTED TO CONSTRUCT THE SHELL
```

INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $	447886.19
TOTAL SHELL COST $	944377.87
COST OF BURNER SYSTEM $	30000.00
EXTRA COSTS $	284452.56
TOTAL INCINERATOR COST	1706715.00

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 1800.00 FAHRENHEIT P= 14.69 PSIA — OUTPUT STREAM T= 2000.00 FAHRENHEIT P= 14.65 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	1571.62	0.00
AIR	0.00	0.00
H2O	3144.05	3326.48
HCL	2054.53	2054.53
CO2	55915.12	61594.08
CO	0.00	0.00
N2	215929.69	215929.75
O2	22866.68	18576.51
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

HEAT RECOVERY SYSTEM DESIGN

```
CHARACTERISTICS OF STEAM PRODUCED
     PRESSURE OF STEAM FORMED=                     185. PSIA
     QUANTITY OF STEAM PRODUCED =                182134. LB/HR
     COST RECOVERED FROM STEAM PRODUCTION =        734.36 U.S.  DOLLARS/HR
MATERIALS OF CONSTRUCTION
```

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 2000.00 FAHRENHEIT P= 14.65 PSIA — OUTPUT STREAM T= 500.00 FAHRENHEIT P= 11.36 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	3326.48	3326.48
HCL	2054.53	2054.53
CO2	61594.09	61594.05
CO	0.00	0.00
N2	215929.56	215929.69
O2	18576.50	18576.50

NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P206	0.00	0.00
NE	0.00	0.00

1
1 QUENCH CHAMBER DESIGN SPECIFICATIONS

QUENCH TEMPERATURE = 180.0 FAHRENHEIT
QUENCH DIAMETER = 19.2 FEET
QUENCH LENGTH = 57.6 FEET
WATER RATE = 0.282E+05 LB/HR
WATER OUT = 0.000E+00 LB/HR
OPTIONS IN EFFECT

INCONEL WAS SELECTED AS THE MATERIAL OF CONSTRUCTION
QUENCH CHAMBER DESIGNED FOR SPECIFIC OUTLET TEMPERATURE

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 500.00 FAHRENHEIT P= 11.36 PSIA
OUTPUT STREAM T= 180.00 FAHRENHEIT P= 11.36 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	3326.47	31539.01
HCL	2054.53	2054.53
CO2	61594.08	61594.01
CO	0.00	0.00
N2	215929.44	215929.62
O2	18576.49	18576.50
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P206	0.00	0.00
NE	0.00	0.00

1
1 VENTURI SCRUBBER DESIGN OUTPUT

TOTAL PRESSURE DROP= 60. INCHES H2O
WATER FEED RATE= 0.55594E+05LB/HR
VENTURI SHELL THICKNESS= 0.50 INCHES
FEDERAL PARTICULATE LEVELS= 0.50000E-03LB/ACF
CALCULATED EMISSION LEVELS= 0.00000E+00LB/ACF
LENGTH OF VENTURI SEPARATOR(FT)= 31.
DIAMETER OF VENTURI SEPARATOR(FT)= 15.
OPTIONS SELECTED

PRESSURE DROP DIRECTLY SPECIFIED
AUTOMATIC THROAT CONTROL SPECIFIED
VENTURI SCRUBBER CONSTRUCTED OF CARBON STEEL

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT
OUTPUT STREAM T= 180.00 FAHRENHEIT

	P= 11.36 PSIA	P= 11.36 PSIA
	LB/HR	LB/HR
H2O	31546.85	31539.01
HCL	2054.53	2054.53
CO2	61594.08	61594.01
CO	0.00	0.00
N2	215929.44	215929.62
O2	18576.49	18576.50
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

MOTOR RPMS= 900.00
GAS VOLUME RATE= 500.00FT°3/MIN/1000
COST OF MOTOR= 55000.06U.S. DOLLARS

1 INDUCED DRAFT FAN DESIGN

TOTAL PRESSURE DROP(INCLUDING ADJUSTMENT FOR ELEVATION) = 60.00 IN H2O
ELEVATION OF FACILITY= 3000. FEET
PRESSURE DROP PER STAGE = 20.00 IN H2O
VOLUME RATE PER PARALLEL FEED = 121.75FT**3/MIN/1000
NUMBER OF FANS PER STAGE = 3
MOTOR RPMS = 900.00
TOTAL HORSEPOWER REQUIRED TO COMPRESS GAS = 1000.00 HP
NUMBER OF INLET STREAMS= 2
DIAMETER OF IMPELLOR = 64. INCHES
OPTIONS SELECTED
MATERIAL OF CONSTRUCTION OF THE FANS IS CARBON STEEL
CLASS 4 FANS ARE SPECIFIED(HIGH PERFORMANCE)

1

PROCESS STREAM CONDITIONS AND COMPOSITION

	INPUT STREAM T= 180.00 FAHRENHEIT P= 11.36 PSIA	OUTPUT STREAM T= 212.73 FAHRENHEIT P= 13.52 PSIA
	LB/HR	LB/HR
H2O	31546.85	31539.01
HCL	2054.53	2054.53
CO2	61594.08	61594.01
CO	0.00	0.00
N2	215929.44	215929.62
O2	18576.49	18576.50
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)= 261. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)= 185. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS

DIAMETER(IN)= 151. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)= 131. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)= 117. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)= 107. NUMBER OF INLET STREAMS INCREASED BY ONE
PACK BED DIAMETER IS OUT OF RANGE FOR ACCURATE CALCS
COST OF ABSORBER COLUMN PER FOOT = 3358.31
COST OF ABORBER PACKING = 10746.12
TOTAL ABSORBER COST = 310304.81

1 PACKED BED DESIGN PARAMETERS

DIAMETER OF COLUMN(FT)= 8.23
TOTAL HEIGHT OF COLUMN(FT)= 10.00
CALCULATED COST OF COLUMN= 310304.81 U.S. DOLLARS
CALCULATED FEED RATE= 102024.62
AREA OF BED= 53.20FT**2
NUMBER OF MASS TRANSFER UNITS= 10
AMOUNT OF LIME ADDED= 2080.00LB/HR

OPTIONS SELECTED
PACKING SELECTED IS BERL SADDLES
PACKING SIZE IS 0.5 INCHES
PACKED COLUMN IS CONSTRUCTED OF CARBON STEEL

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT P= 13.52 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT P= 13.52 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	31546.85	31539.01
HCL	2054.53	2054.53
CO2	61594.08	61594.01
CO	0.00	0.00
N2	215929.44	215929.62
O2	18576.49	18576.50
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1 EXHAUST STACK DESIGN DATA OUTPUT

HEIGHT OF EXHAUST STACK= 200.00 FEET
DIAMETER OF EXHAUST STACK= 6.56 FEET
MASS OF STACK= 327647.00 LBS
NUMBER OF STACKS= 1
EXIT VELOCITY OF GAS IN STACK= 9000.00FEET/MINUTE

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT P= 13.52 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT P= 13.52 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	31546.85	31539.01
HCL	0.21	2054.53

CO2	61594.08	61594.01
CO	0.00	0.00
N2	215929.44	215929.62
O2	18576.49	18576.50
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

**** WARNING. THE EXHAUST STACK EXIT PRESSURE IS LESS THAN THE AMBIENT FACILITY PRESSURE

DUCTWORK DESIGN OUTPUT

UNITS	OUTER DIAMETER	BRICK DIAMETER	MATERIALS OF CONSTRUCTION	DUCT LENGTH	NUMBER OF ELBOWS
1 TO 2	84.5	0.00	IC	10.00	1.
2 TO 3	91.5	0.00	IC	15.00	2.
3 TO 4	48.7	0.00	CS	10.00	0.
4 TO 5	48.6	0.00	CS	10.00	1.
5 TO 6	48.6	0.00	CS	15.00	3.
6 TO 7	48.6	0.00	CS	15.00	3.
7 TO 8	44.4	0.00	CS	0.00	0.
8 TO 9	0.0	0.00		0.00	0.

COST OF DUCTWORK

COST	DUCTWORK COST	FIREBRICK COST	DAMPERS COST	TOTAL COST
1 TO 2	20818.3	31247.8	14238.0	66304.0
2 TO 3	43286.5	67410.9	15943.9	*******
3 TO 4	780.6	0.0	7550.4	8331.0
4 TO 5	2293.0	0.0	7531.8	9824.8
5 TO 6	5713.5	0.0	7534.0	13247.5
6 TO 7	5713.5	0.0	7534.1	13247.6
7 TO 8	0.0	0.0	6918.2	6918.2
8 TO 9	0.0	0.0	0.0	0.0

1

LIQUID WASTE STORAGE FACILITY

NUMBER OF 25,000 GALLON TANKS =	5	
NUMBER OF 10,000 GALLON TANKS =	1	
NUMBER OF 1,000 GALLON TANKS =	1	
TOTAL STORAGE TANK COST=	662000.	U.S. DOLLARS
CSTNIT=	0.	U.S. DOLLARS
NITROGEN BLANKET SYSTEM=	0.	U.S. DOLLARS
CONDENSOR COST=	10000.	U.S. DOLLARS

*** ERROR *** THE FEED RATE OF WASTE IS TOO LARGEFOR ACCURATE PREDICTION OF SITEWORK C

*** ERROR *** THE FEED RATE OF WASTE IS TOO LARGEFOR ACCURATE PREDICTION OF SITEWORK C

1

TOTAL CAPITAL COST

COMBUSTION CHAMBERS:	1986 $
PRIMARY COMBUSTOR	1599450.00
SECONDARY COMBUSTOR	1706715.00
ENERGY ROCOVERY BOILER	539945.69
AIR POLLUTION CONTROL SYSTEM	
QUENCH CHAMBER	84481.50
VENTURI SCRUBBER AND SEPARATOR	101700.69
PACKED BED SCRUBBER	310304.81
INDUCTION FAN	318808.25
EXHAUST STACK(200 FEET HIGH)	14996.14

WASTE WATER TREATMENT FACILITY	82579.50
STORAGE TANK FACILITY	671999.81
TOTAL DUCTWORK	244514.37
METAL BUILDING	198951.31
SITEWORK AND FOUNDATIONS	574748.44
STRUCTURAL STEEL	55280.93
ELECTRICAL MATERIAL	130960.94
INSTRUMENTS AND CONTROLS	131041.19
TOTAL-----	6766471.00

TOTAL INSTALLATION COST	4130972.00
START-UP (10 % OF EQUIPMENT COST)	676647.25
SPARE PARTS (8 % OF EQUIPMENT COST)	541317.56
CERTIFICATION (10 % OF EQUIPMENT COST)	676647.25
ENGINEERING (7 % OF EQUIPMENT COST)	473652.87
INSTRUMENTATION (20 % OF EQUIPMENT COST)	1481294.00
CONTENGENCY FEE (20 % OF EQUIPMENT COST)	0.00
TOTAL INDIRECT COSTS	7980529.00

***** TOTAL CAPITAL COST= 14747000.00

1

OPERATING LABOR OUTPUT

SUPERVISOR SALARY($/YR)=	55111.	
LABORATORY SUPERVISOR($/YR)=	55111.	
LABORATORY TECHNICIANS SALARY($/YR) =	20160.	FOR 1TECHNICIANS
CHIEF OPERATORS SALARY($/YR) =	41698.	
OPERATORS SALARY($/YR) =	147168.	FOR 2 OPERATORS
YARD WORKERS SALARY($/YR) =	48384.	FOR 2 WORKERS.
SECRETARIES SALARY($/YR) =	18144.	FOR 1 SECRETARIES
PAYROLL EXPENSES(20% OF LABOR= COST IN $/YR)	82666.	
SUPPLIES AND OTHER MISC.($/YR)=	55111.	
TOTAL EXPENSES($/YR)=	468440.	

1

ANNUAL OPERATING COSTS

FEED RATE 10000. LB/HR

LABOR	468440.
UTILITIES	
ELECTRICITY	421295.
FUEL	5310783.
WATER	71040.
WASTE DISPOSAL	0.
BULK LIME	250848.
WASTE WATER TREATMENT	72434.
STARTUP COSTS	676647.
INSURANCE COST	88482.
ANNUAL MAINTENENCE ROTARY KILN (10% EQUIPMENT COST)	577788.
HEAT RECOVERY UNIT	-5287423.

(80% EFFICIENCY)

TOTAL OPERATING COST 2650332.

1

DISCOUNTED CASH FLOW RATE OF RETURN
ANALYSIS OUTPUT
(MILLIONS OF U.S. DOLLARS)

YEAR	0	1	2	3	4	5	6	7	8	9	10
INCOME	0.0	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
OPERATE	0.0	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
DEPREC.	0.0	1.2	2.1	1.8	1.5	1.5	1.5	1.3	1.3	1.3	1.3
TAXABLES	0.0	10.6	9.7	10.0	10.3	10.3	10.3	10.4	10.4	10.4	10.4
TAXES	0.0	5.3	4.8	5.0	5.1	5.1	5.1	5.2	5.2	5.2	5.2
NET INC.	0.0	5.3	4.8	5.0	5.1	5.1	5.1	5.2	5.2	5.2	5.2
DEPREC.	0.0	1.2	2.1	1.8	1.5	1.5	1.5	1.3	1.3	1.3	1.3
CAPITAL	-14.7	-	-	-	-	-	-	-	-	-	-
CASH FLW	-14.7	6.5	6.9	6.8	6.6	6.6	6.6	6.5	6.5	6.5	6.5

THE TOTAL CASH FLOW = 51.37 MILLION DOLLARS
DISCOUNTED CASH FLOW RATE OF RETURN = 27.8%

```
          *****    SUMMARY OF INPUT DATA FILE    *****

24.0 300.0

0.0300  0.7000  0.0700  0.0000  0.2000  0.0000  0.0000  0.0000  0.0000
0.0130  0.9870  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.2332  0.7672  0.0000  0.0000  0.0000  0.0000  0.0000
  5000.0000  6000.0000
               13970.0
T
F
F
F
F
T
F
0.0000000
1.0000000
F
T
T
 8
     80.00
     14.70
   3000.00
      0.00
INC IC    1800.00  10.00000 1.0 IC
AFT IC    2000.00  15.00000 2.0 IC
HTE        500.00  10.00000 0.0 CS
QUE IC     180.00  10.00000 1.0 CS
VEN CS     180.00  15.00000 3.0 CS
IND CS     180.00  15.00000 3.0 CS
PCK CS     180.00   0.00000 0.0 CS
STK CS     180.00   0.00000 0.0
F
T
F
T
      2.00
      1.50
      0.50
      0.50
0.2000000
F
F
T
   7.00000
   2.00000
0.2000000
F
T
F
F
F
F
F
F
F
F
T
F
F
F
      2.50
0.01.0
      8.00
     60.00
F
    0.50000E-03
T
F
     60.00
```

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BERL SADDLES       0.500.50000000 10 1.000 70.00
18.000  0.00 99.9900
HCL
     0.03
    30.00
100.0
T
  308.4 212.3 305.9 257.2 310.9 344.9 368.6 265.5 232.3 214.3 287.2 1986
10.0 0.0 400.000   0.000
         ****************************************

         MOTOR RPMS=     1800.00
         GAS VOLUME RATE=     200.00FT°3/MIN/1000
         COST OF MOTOR=      3293.54U.S. DOLLARS
1                             INDUCED DRAFT FAN DESIGN


         TOTAL PRESSURE DROP(INCLUDING ADJUSTMENT FOR ELEVATION) =138.40 IN H2O
         ELEVATION OF FACILITY=                3000. FEET
         PRESSURE DROP PER STAGE =    20.00 IN H2O
         VOLUME RATE PER PARALLEL FEED =   31.90FT**3/MIN/1000
         NUMBER OF FANS PER STAGE =    6
         MOTOR RPMS =    1800.00
         TOTAL HORSEPOWER REQUIRED TO COMPRESS GAS =     200.00 HP
         NUMBER OF INLET STREAMS=  1
         DIAMETER OF IMPELLOR =     33. INCHES
         OPTIONS SELECTED
              MATERIAL OF CONSTRUCTION FOR FANS IS INCONEL
              CLASS 4 FANS ARE SPECIFIED(HIGH PERFORMANCE)
1                        INCINERATOR DESIGN AND COST FOR
                                 FLUIDIZED BED


                        ****INPUT STREAM CHARACTERISTICS****

              COMBUSTED GAS EXIT RATE                     149954.94 LB/HR
              ASH FEED RATE                                    0.00 LB/HR
              VOLATILES FEED RATE                           5000.00 LB/HR
              FREE WATER IN SLUDGE FEED                        0.00 LB/HR
              FUEL FEED RATE                                4190.97 LB/HR
              AIR FEED RATE (AT  50.00% EXCESS)           140809.75 LB/HR


                              PROCESS DESIGN VARIABLES

              PERCENT EXCESS AIR IS                      50.00 PERCENT
              PERCENT EXCESS FUEL IS                      0.00 PERCENT.
              INCINERATOR TEMPERATURE                    80.00 DEG. FAHRENHEIT
              AMBIENT TEMPERATURE                        80.00 DEG. FAHRENHEIT.
              DAILY USE                                  24.00 HOURS/DAY.
              LENGTH OF PROCESS RUN                     300.00 DAYS/YEAR.
              SHUTDOWN LENGTH                            65.00 DAYS/YEAR.
              RETENTION TIME                              2.00 SECONDS
              LENGTH TO DIAMETER RATIO ESTIMATE           1.50

                        INCINERATOR PROCESS DESIGN SPECIFICATIONS

         INCINERATOR DIAMETER (FT)=                    31.6678
         INCINERATOR LENGTH (FT)=                      46.2518
         MATERIALS OF CONSTRUCTION FOR THE INCINERATOR
              REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK
              THICKNESS =    1.0 INCHES
              INSULATION SELECTED = INSULATING FIREBRICK
              THICKNESS =    4.0 INCHES
         INCINERATOR SURFACE AREA (FT**2)               0.0000
         INCINERATOR VOLUME         (FT**3)          4546.7148
         INCINERATOR BURNER DATA
              NUMBER OF FUEL BURNERS =    6
              WASTE FEED BURNER HEAT LOAD =  0.300E+08 BTU/HR
```

OPTIONS IN EFFECT
A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED
IN THE HEAT/MASS BALANCE CALCULATIONS
WASTE FEED IS A LIQUID. WASTE BURNERS ARE SELECTED
INCONEL WAS SELECTED TO CONSTRUCT THE SHELL

INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $	437143.87
TOTAL SHELL COST $	1437269.00
COST OF BURNER SYSTEM $	99773.44
COST OF SUPPORT TRAYS $	18475.59
COST OF ASH SYSTEM $	0.00
EXTRA COSTS $	400532.12
TOTAL INCINERATOR COST	2403192.00

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 80.00 FAHRENHEIT P= 14.70 PSIA
OUTPUT STREAM T= 80.00 FAHRENHEIT P= 14.70 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	4190.97	0.00
AIR	140809.75	0.00
WASTE	5000.00	0.00
ASH	0.00	0.00
H2O	0.00	1572.02
HCL	0.00	1027.27
CO2	0.00	27957.56
CO	0.00	0.00
N2	0.00	107964.81
O2	0.00	11433.36
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1
1

INCINERATOR DESIGN AND COST FOR
LIQUID INJECTION AFTERBURNER

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE	150740.50 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLATILES FEED RATE	0.00 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	785.81 LB/HR
AIR FEED RATE (AT 0.00% EXCESS)	0.00 LB/HR
GAS FEED FROM PREVIOUS UNIT	149954.94 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	0.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT.
INCINERATOR TEMPERATURE	2000.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.

DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	300.00 DAYS/YEAR.
SHUTDOWN LENGTH	65.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	7.00

INCINERATOR PROCESS DESIGN SPECIFICATIONS

INCINERATOR DIAMETER (FT)= 10.7967
INCINERATOR LENGTH (FT)= 67.6045
MATERIALS OF CONSTRUCTION FOR THE INCINERATOR
REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK
THICKNESS = 1.5 INCHES
INSULATION SELECTED = INSULATING FIREBRICK
THICKNESS = 5.3 INCHES
INCINERATOR SURFACE AREA (FT**2) 1721.6831
INCINERATOR VOLUME (FT**3) 4952.4687
INCINERATOR BURNER DATA
NUMBER OF FUEL BURNERS = 2
OPTIONS IN EFFECT
A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED IN THE HEAT/MASS BALANCE CALCULATIONS
INCONEL WAS SELECTED TO CONSTRUCT THE SHELL

INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $	287080.62
TOTAL SHELL COST $	610282.50
COST OF BURNER SYSTEM $	20000.00
EXTRA COSTS $	183472.56
TOTAL INCINERATOR COST	1100835.00

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 1800.00 FAHRENHEIT, P= 14.70 PSIA
OUTPUT STREAM T= 2000.00 FAHRENHEIT, P= 14.66 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	785.81	0.00
AIR	0.00	0.00
H2O	1572.02	1663.24
HCL	1027.27	1027.27
CO2	27957.55	30797.04
CO	0.00	0.00
N2	107964.75	107964.75
O2	11433.35	9288.27
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P206	0.00	0.00
NE	0.00	0.00

1

HEAT RECOVERY SYSTEM DESIGN

CHARACTERISTICS OF STEAM PRODUCED
PRESSURE OF STEAM FORMED= 185. PSIA
QUANTITY OF STEAM PRODUCED = 91067. LB/HR
COST RECOVERED FROM STEAM PRODUCTION = 367.18 U.S. DOLLARS/HR
MATERIALS OF CONSTRUCTION

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 2000.00 FAHRENHEIT P= 14.66 PSIA

OUTPUT STREAM T= 500.00 FAHRENHEIT P= 11.38 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	1663.24	1663.24
HCL	1027.27	1027.27
CO2	30797.02	30797.04
CO	0.00	0.00
N2	107964.69	107964.69
O2	9288.26	9288.27
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

1 QUENCH CHAMBER DESIGN SPECIFICATIONS

QUENCH TEMPERATURE = 180.0 FAHRENHEIT
QUENCH DIAMETER = 13.6 FEET
QUENCH LENGTH = 40.7 FEET
WATER RATE = 0.141E+05 LB/HR
WATER OUT = 0.000E+00 LB/HR
OPTIONS IN EFFECT

INCONEL WAS SELECTED AS THE MATERIAL OF CONSTRUCTION
QUENCH CHAMBER DESIGNED FOR SPECIFIC OUTLET TEMPERATURE

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 500.00 FAHRENHEIT P= 11.38 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT P= 11.37 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	1663.24	15769.50
HCL	1027.26	1027.27
CO2	30797.01	30797.03
CO	0.00	0.00
N2	107964.62	107964.62
O2	9288.25	9288.26
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

1 VENTURI SCRUBBER DESIGN OUTPUT

TOTAL PRESSURE DROP= 60. INCHES H2O
WATER FEED RATE= 0.27759E+05LB/HR
VENTURI SHELL THICKNESS= 0.50 INCHES

```
FEDERAL PARTICULATE LEVELS=        0.50000E-03LB/ACF
CALCULATED EMISSION LEVELS=        0.00000E+00LB/ACF
LENGTH OF VENTURI SEPARATOR(FT)=       21.
DIAMETER OF VENTURI SEPARATOR(FT)=       11.
OPTIONS SELECTED
     PRESSURE DROP DIRECTLY SPECIFIED
     AUTOMATIC THROAT CONTROL SPECIFIED
     VENTURI SCRUBBER CONSTRUCTED OF CARBON STEEL
```

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT P= 11.37 PSIA — OUTPUT STREAM T= 180.00 FAHRENHEIT P= 11.37 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	15773.42	15769.50
HCL	1027.26	1027.27
CO2	30797.01	30797.03
CO	0.00	0.00
N2	107964.62	107964.62
O2	9288.25	9288.26
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

```
MOTOR RPMS=     1800.00
GAS VOLUME RATE=      500.00FT°3/MIN/1000
COST OF MOTOR=      10947.02U.S. DOLLARS
```

1

INDUCED DRAFT FAN DESIGN

```
TOTAL PRESSURE DROP(INCLUDING ADJUSTMENT FOR ELEVATION) =138.40 IN H20
ELEVATION OF FACILITY=             3000. FEET
PRESSURE DROP PER STAGE =   20.00 IN H20
VOLUME RATE PER PARALLEL FEED =   64.17FT**3/MIN/1000
NUMBER OF FANS PER STAGE =    6
MOTOR RPMS =   1800.00
TOTAL HORSEPOWER REQUIRED TO COMPRESS GAS =      500.00 HP
NUMBER OF INLET STREAMS=  1
DIAMETER OF IMPELLOR =     46. INCHES
OPTIONS SELECTED
     MATERIAL OF CONSTRUCTION OF THE FANS IS CARBON STEEL
     CLASS 4 FANS ARE SPECIFIED(HIGH PERFORMANCE)
```

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT P= 11.37 PSIA — OUTPUT STREAM T= 250.18 FAHRENHEIT P= 16.37 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	15773.42	15769.50
HCL	1027.26	1027.27
CO2	30797.01	30797.03
CO	0.00	0.00
N2	107964.62	107964.62
O2	9288.25	9288.26
NO	0.00	0.00

NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

```
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)=       193. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)=       136. NUMBER OF INLET STREAMS INCREASED BY ONE
THE DIAMETER OF THE PACKED BED IS TOO LARGE FOR COST CALCULATIONS
DIAMETER(IN)=       111. NUMBER OF INLET STREAMS INCREASED BY ONE
PACK BED DIAMETER IS OUT OF RANGE FOR ACCURATE CALCS
COST OF ABSORBER COLUMN PER FOOT =          3240.59
COST OF ABORBER PACKING =          10252.13
TOTAL ABSORBER COST =          170632.06
```

1 PACKED BED DESIGN PARAMETERS

```
DIAMETER OF COLUMN(FT)=        8.04
TOTAL HEIGHT OF COLUMN(FT)=      10.00
CALCULATED COST OF COLUMN=  170632.06 U.S. DOLLARS
CALCULATED FEED RATE=          73743.44
AREA OF BED=                      50.76FT**2
NUMBER OF MASS TRANSFER UNITS=       10
AMOUNT OF LIME ADDED=            1040.00LB/HR

OPTIONS SELECTED
     PACKING SELECTED IS BERL SADDLES
     PACKING SIZE IS  0.5 INCHES
PACKED COLUMN IS CONSTRUCTED OF CARBON STEEL
```

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT, P= 16.37 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT, P= 16.37 PSIA

	LB/HR	LB/HR
H2O	15773.42	15769.50
HCL	1027.26	1027.27
CO2	30797.01	30797.03
CO	0.00	0.00
N2	107964.62	107964.62
O2	9288.25	9288.26
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1 EXHAUST STACK DESIGN DATA OUTPUT

```
HEIGHT OF EXHAUST STACK=              100.00 FEET
DIAMETER OF EXHAUST STACK=              4.22 FEET
MASS OF STACK=                     163823.37 LBS
NUMBER OF STACKS=                     1
EXIT VELOCITY OF GAS IN STACK=       9000.00FEET/MINUTE
```

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT
P= 16.37 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT
P= 16.37 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	15773.42	15769.50
HCL	0.10	1027.27
CO2	30797.01	30797.03
CO	0.00	0.00
N2	107964.62	107964.62
O2	9288.25	9288.26
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

DUCTWORK DESIGN OUTPUT

UNITS	OUTER DIAMETER	BRICK DIAMETER	MATERIALS OF CONSTRUCTION	DUCT LENGTH	NUMBER OF ELBOWS
1 TO 2	52.7	0.00	IC	10.00	1.
2 TO 3	68.7	0.00	IC	15.00	2.
3 TO 4	34.4	0.00	CS	10.00	0.
4 TO 5	34.3	0.00	CS	10.00	1.
5 TO 6	34.3	0.00	CS	15.00	3.
6 TO 7	34.3	0.00	CS	15.00	3.
7 TO 8	28.5	0.00	CS	0.00	0.
8 TO 9	0.0	0.00		0.00	0.

COST OF DUCTWORK

COST	DUCTWORK COST	FIREBRICK COST	DAMPERS COST	TOTAL COST
1 TO 2	7463.5	0.0	8168.7	15632.3
2 TO 3	19862.5	50061.2	10905.5	80829.2
3 TO 4	545.2	0.0	5516.3	6061.5
4 TO 5	1483.7	0.0	5503.7	6987.3
5 TO 6	3636.9	0.0	5505.1	9142.0
6 TO 7	3636.9	0.0	5505.2	9142.1
7 TO 8	0.0	0.0	4725.7	4725.7
8 TO 9	0.0	0.0	0.0	0.0

1 LIQUID WASTE STORAGE FACILITY

NUMBER OF 25,000 GALLON TANKS =	2	
NUMBER OF 10,000 GALLON TANKS =	1	
NUMBER OF 1,000 GALLON TANKS =	2	
TOTAL STORAGE TANK COST=	370000.	U.S. DOLLARS
CSTNIT=	0.	U.S. DOLLARS
NITROGEN BLANKET SYSTEM=	0.	U.S. DOLLARS
CONDENSOR COST=	10000.	U.S. DOLLARS

1 TOTAL CAPITAL COST

	1986 $
COMBUSTION CHAMBERS:	
PRIMARY COMBUSTOR	2403192.00
SECONDARY COMBUSTOR	1100835.00
ENERGY ROCOVERY BOILER	280848.31
AIR POLLUTION CONTROL SYSTEM	

QUENCH CHAMBER	63886.80
VENTURI SCRUBBER AND SEPARATOR	51383.38
PACKED BED SCRUBBER	170632.06
INDUCTION FAN	86292.69
EXHAUST STACK(100 FEET HIGH)	13165.51
WASTE WATER TREATMENT FACILITY	49353.11
STORAGE TANK FACILITY	379999.87
TOTAL DUCTWORK	132519.94
METAL BUILDING	198951.31
SITEWORK AND FOUNDATIONS	197.37
STRUCTURAL STEEL	33168.55
ELECTRICAL MATERIAL	49849.93
INSTRUMENTS AND CONTROLS	64786.85
TOTAL-----	5079055.00

TOTAL INSTALLATION COST	2999661.00
START-UP (10 % OF EQUIPMENT COST)	507905.56
SPARE PARTS (8 % OF EQUIPMENT COST)	406324.31
CERTIFICATION (10 % OF EQUIPMENT COST)	507905.56
ENGINEERING (7 % OF EQUIPMENT COST)	355533.81
INSTRUMENTATION (20 % OF EQUIPMENT COST)	1143810.00
CONTENGENCY FEE (20 % OF EQUIPMENT COST)	0.00
TOTAL INDIRECT COSTS	5921138.00

***** TOTAL CAPITAL COST= 11000193.00

1

OPERATING LABOR OUTPUT

SUPERVISOR SALARY($/YR)=	55111.	
LABORATORY SUPERVISOR($/YR)=	55111.	
LABORATORY TECHNICIANS SALARY($/YR) =	20160.	FOR 1TECHNICIANS
CHIEF OPERATORS SALARY($/YR) =	41698.	
OPERATORS SALARY($/YR) =	147168.	FOR 2 OPERATORS
YARD WORKERS SALARY($/YR) =	48384.	FOR 2 WORKERS.
SECRETARIES SALARY($/YR) =	18144.	FOR 1 SECRETARIES
PAYROLL EXPENSES(20% OF LABOR= COST IN $/YR)	82666.	
SUPPLIES AND OTHER MISC.($/YR)=	55111.	
TOTAL EXPENSES($/YR)=	468440.	

1

ANNUAL OPERATING COSTS

FEED RATE 5000. LB/HR

LABOR	468440.
UTILITIES	
ELECTRICITY	352741.
FUEL	2655397.
WATER	45732.
WASTE DISPOSAL	0.
BULK LIME	125424.
WASTE WATER TREATMENT	46739.
STARTUP COSTS	507906.
INSURANCE COST	66001.

ANNUAL MAINTENENCE FLUIDIZED BED (7% EQUIPMENT COST)		330886.
HEAT RECOVERY UNIT (80% EFFICIENCY)		-2643707.
TOTAL OPERATING COST		1955557.

1

DISCOUNTED CASH FLOW RATE OF RETURN
ANALYSIS OUTPUT
(MILLIONS OF U.S. DOLLARS)

YEAR	0	1	2	3	4	5	6	7	8	9	1C
INCOME	0.0	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
OPERATE	0.0	2.0	2.0	2.0	2.C	2.0	2.0	2.0	2.0	2.0	2.0
DEPREC.	0.0	0.9	1.5	1.3	1.1	1.1	1.1	1.0	1.0	1.0	1.0
TAXABLES	0.0	4.4	3.7	3.9	4.1	4.1	4.1	4.3	4.3	4.3	4.3
TAXES	0.0	2.2	1.9	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1
NET INC.	0.0	2.2	1.9	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1
DEPREC.	0.0	0.9	1.5	1.3	1.1	1.1	1.1	1.0	1.0	1.0	1.0
CAPITAL	-11.0	-	-	-	-	-	-	-	-	-	-
CASH FLW	-11.0	3.1	3.4	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.1

THE TOTAL CASH FLOW = 20.72 MILLION DOLLARS
DISCOUNTED CASH FLOW RATE OF RETURN = 18.4%

***** SUMMARY OF INPUT DATA FILE *****

```
24.0 300.0

0.0300  0.7000  0.0700  0.0000  0.2000  0.0000  0.0000  0.0000  0.0000
0.0130  0.9870  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.2332  0.7672  0.0000  0.0000  0.0000  0.0000  0.0000
  1000.0000  6000.0000
              13970.0
T
F
F
F
F
T
F
0.0000000
1.0000000
F
T
T
 8
     80.00
     14.70
   3000.00
      0.00
INC IC   1800.00  10.00000 1.0 IC
AFT IC   2000.00  15.00000 2.0 IC
HTE       500.00  10.00000 0.0 CS
QUE IC    180.00  10.00000 1.0 CS
VEN CS    180.00  15.00000 3.0 CS
IND CS    180.00  15.00000 3.0 CS
PCK CS    180.00   0.00000 0.0 CS
STK CS    180.00   0.00000 0.0
F
F
T
T
      2.00
      5.00
      0.50
      0.50
0.2000000
F
F
T
   7.00000
   2.00000
0.2000000
F
T
F
F
F
F
F
F
F
F
T
F
F
F
      2.50
0.01.0
      8.00
     60.00
F
    0.50000E-03
T
F
     60.00
```

```
BERL SADDLES      0.500.5000000C 1C 1.000 70.00
18.000  C.00 99.9900
HCL
     0.03
    30.00
100.0
T
  308.4 212.3 305.9 257.2 310.9 344.9 368.6 265.5 232.3 214.3 287.2 1986
10.0 0.0 400.000   0.000
         ******************************************
```

1

INCINERATOR DESIGN AND COST FOR
LIQUID INJECTION

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE	29815.66 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLATILES FEED RATE	1000.00 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	828.81 LB/HR
AIR FEED RATE (AT 50.00% EXCESS)	27995.92 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	50.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT.
INCINERATOR TEMPERATURE	1800.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.
DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	300.00 DAYS/YEAR.
SHUTDOWN LENGTH	65.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	5.00

INCINERATOR PROCESS DESIGN SPECIFICATIONS

```
INCINERATOR DIAMETER (FT)=                   6.9621
INCINERATOR LENGTH (FT)=                    30.6440
MATERIALS OF CONSTRUCTION FOR THE INCINERATOR
     REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK
     THICKNESS =    1.0 INCHES
     INSULATION SELECTED = INSULATING FIREBRICK
     THICKNESS =    4.0 INCHES
INCINERATOR SURFACE AREA (FT**2)            904.0422
INCINERATOR VOLUME        (FT**3)           904.0449
INCINERATOR BURNER DATA
     NUMBER OF FUEL BURNERS =    2
     WASTE FEED BURNER HEAT LOAD =  0.600E+07 BTU/HR
OPTIONS IN EFFECT
     A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED
        IN THE HEAT/MASS BALANCE CALCULATIONS
     WASTE FEED IS A LIQUID.  WASTE BURNERS ARE SELECTED
     INCONEL WAS SELECTED TO CONSTRUCT THE SHELL
```

INCINERATOR COST BREAKDOWN

```
TOTAL BRICK COST $            62532.44
TOTAL SHELL COST $           183992.31
COST OF BURNER SYSTEM $       48999.99
EXTRA COSTS $                 61104.93
----------------------------------------
TOTAL INCINERATOR COST       366629.56
```

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 80.00 FAHRENHEIT   OUTPUT STREAM T= 1800.00 FAHRENHEIT
P= 14.70 PSIA   P= 14.69 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	828.81	0.00
AIR	27995.92	0.00
WASTE	1000.00	0.00
ASH	0.00	0.00
H2O	0.00	313.32
HCL	0.00	205.45
CO2	0.00	5557.61
CO	0.00	0.00
N2	0.00	21465.68
O2	0.00	2273.61
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

REACTANT 3 WAS LESS THAN ZERO -0.004CHECK BALANCE OF EQUATION

1 INCINERATOR DESIGN AND COST FOR
LIQUID INJECTION AFTERBURNER

****INPUT STREAM CHARACTERISTICS****

COMBUSTED GAS EXIT RATE	29971.99 LB/HR
ASH FEED RATE	0.00 LB/HR
VOLATILES FEED RATE	0.00 LB/HR
FREE WATER IN SLUDGE FEED	0.00 LB/HR
FUEL FEED RATE	156.38 LB/HR
AIR FEED RATE (AT 0.00% EXCESS)	0.00 LB/HR
GAS FEED FROM PREVIOUS UNIT	29815.66 LB/HR

PROCESS DESIGN VARIABLES

PERCENT EXCESS AIR IS	0.00 PERCENT
PERCENT EXCESS FUEL IS	0.00 PERCENT.
INCINERATOR TEMPERATURE	2000.00 DEG. FAHRENHEIT
AMBIENT TEMPERATURE	80.00 DEG. FAHRENHEIT.
DAILY USE	24.00 HOURS/DAY.
LENGTH OF PROCESS RUN	300.00 DAYS/YEAR.
SHUTDOWN LENGTH	65.00 DAYS/YEAR.
RETENTION TIME	2.00 SECONDS
LENGTH TO DIAMETER RATIO ESTIMATE	7.00

INCINERATOR PROCESS DESIGN SPECIFICATIONS

INCINERATOR DIAMETER (FT)= 6.7774
INCINERATOR LENGTH (FT)= 39.4693
MATERIALS OF CONSTRUCTION FOR THE INCINERATOR
REFRACTORY SELECTED = 90%-ALUMINA FIREBRICK
THICKNESS = 1.5 INCHES
INSULATION SELECTED = INSULATING FIREBRICK
THICKNESS = 5.3 INCHES
INCINERATOR SURFACE AREA (FT**2) 583.6919
INCINERATOR VOLUME (FT**3) 985.5383
INCINERATOR BURNER DATA

NUMBER OF FUEL BURNERS = 1

OPTIONS IN EFFECT

A 10 PERCENT HEAT LOSS (OF TOTAL HEAT RELEASED) IS INCLUDED IN THE HEAT/MASS BALANCE CALCULATIONS

INCONEL WAS SELECTED TO CONSTRUCT THE SHELL

INCINERATOR COST BREAKDOWN

TOTAL BRICK COST $	103806.19
TOTAL SHELL COST $	226498.87
COST OF BURNER SYSTEM $	5000.00
EXTRA COSTS $	67060.94
TOTAL INCINERATOR COST	402365.94

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 1800.00 FAHRENHEIT P= 14.69 PSIA

OUTPUT STREAM T= 2000.00 FAHRENHEIT P= 14.66 PSIA

	INPUT LB/HR	OUTPUT LB/HR
FUEL	156.38	0.00
AIR	0.00	0.00
H2O	313.32	331.47
HCL	205.45	205.45
CO2	5557.61	6122.68
CO	0.00	0.00
N2	21465.68	21465.68
O2	2273.60	1846.72
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

1

HEAT RECOVERY SYSTEM DESIGN

CHARACTERISTICS OF STEAM PRODUCED

PRESSURE OF STEAM FORMED= 185. PSIA

QUANTITY OF STEAM PRODUCED = 18107. LB/HR

COST RECOVERED FROM STEAM PRODUCTION = 73.01 U.S. DOLLARS/HR

MATERIALS OF CONSTRUCTION

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 2000.00 FAHRENHEIT P= 14.66 PSIA

OUTPUT STREAM T= 500.00 FAHRENHEIT P= 11.38 PSIA

	INPUT LB/HR	OUTPUT LB/HR
H2O	331.47	331.47
HCL	205.45	205.45
CO2	6122.68	6122.68
CO	0.00	0.00
N2	21465.67	21465.68
O2	1846.72	1846.72
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00

H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P206	0.00	0.00
NE	0.00	0.00

1

1 QUENCH CHAMBER DESIGN SPECIFICATIONS

QUENCH TEMPERATURE = 180.0 FAHRENHEIT
QUENCH DIAMETER = 6.0 FEET
QUENCH LENGTH = 18.1 FEET
WATER RATE = 0.281E+04 LB/HR
WATER OUT = 0.000E+00 LB/HR
OPTIONS IN EFFECT

INCONEL WAS SELECTED AS THE MATERIAL OF CONSTRUCTION
QUENCH CHAMBER DESIGNED FOR SPECIFIC OUTLET TEMPERATURE

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 500.00 FAHRENHEIT
P= 11.38 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT
P= 11.37 PSIA

	LB/HR	LB/HR
H2O	331.47	3136.89
HCL	205.45	205.45
CO2	6122.68	6122.68
CO	0.00	0.00
N2	21465.66	21465.67
O2	1846.72	1846.72
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P206	0.00	0.00
NE	0.00	0.00

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1 VENTURI SCRUBBER DESIGN OUTPUT

TOTAL PRESSURE DROP= 60. INCHES H2O
WATER FEED RATE= 0.55197E+04LB/HR
VENTURI SHELL THICKNESS= 0.50 INCHES
FEDERAL PARTICULATE LEVELS= 0.50000E-03LB/ACF
CALCULATED EMISSION LEVELS= 0.00000E+00LB/ACF
LENGTH OF VENTURI SEPARATOR(FT)= 11.
DIAMETER OF VENTURI SEPARATOR(FT)= 6.
OPTIONS SELECTED
PRESSURE DROP DIRECTLY SPECIFIED
AUTOMATIC THROAT CONTROL SPECIFIED
VENTURI SCRUBBER CONSTRUCTED OF CARBON STEEL

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT
P= 11.37 PSIA

OUTPUT STREAM T= 180.00 FAHRENHEIT
P= 11.37 PSIA

LB/HR	LB/HR

H2O	3137.67	3136.89
HCL	205.45	205.45
CO2	6122.68	6122.68
CO	0.00	0.00
N2	21465.66	21465.67
O2	1846.72	1846.72
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

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MOTOR RPMS= 3600.00
GAS VOLUME RATE= 100.00FT**3/MIN/1000
COST OF MOTOR= 1489.25U.S. DOLLARS

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INDUCED DRAFT FAN DESIGN

TOTAL PRESSURE DROP(INCLUDING ADJUSTMENT FOR ELEVATION) = 60.00 IN H2O
ELEVATION OF FACILITY= 3000. FEET
PRESSURE DROP PER STAGE = 20.00 IN H2O
VOLUME RATE PER PARALLEL FEED = 12.09FT**3/MIN/1000
NUMBER OF FANS PER STAGE = 3
MOTOR RPMS = 3600.00
TOTAL HORSEPOWER REQUIRED TO COMPRESS GAS = 100.00 HP
NUMBER OF INLET STREAMS= 1
DIAMETER OF IMPELLOR = 21. INCHES
OPTIONS SELECTED
MATERIAL OF CONSTRUCTION OF THE FANS IS CARBON STEEL
CLASS 4 FANS ARE SPECIFIED(HIGH PERFORMANCE)

1

PROCESS STREAM CONDITIONS AND COMPOSITION

INPUT STREAM T= 180.00 FAHRENHEIT P= 11.37 PSIA

OUTPUT STREAM T= 212.69 FAHRENHEIT P= 13.54 PSIA

	LB/HR	LB/HR
H2O	3137.67	3136.89
HCL	205.45	205.45
CO2	6122.68	6122.68
CO	0.00	0.00
N2	21465.66	21465.67
O2	1846.72	1846.72
NO	0.00	0.00
NO2	0.00	0.00
CL2	0.00	0.00
SO2	0.00	0.00
H2SO4	0.00	0.00
F2	0.00	0.00
HF	0.00	0.00
P2O6	0.00	0.00
NE	0.00	0.00

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PACK BED DIAMETER IS OUT OF RANGE FOR ACCURATE CALCS
COST OF ABSORBER COLUMN PER FOOT = 2581.02
COST OF ABORBER PACKING = 7481.01
TOTAL ABSORBER COST = 33291.25

1

PACKED BED DESIGN PARAMETERS

DIAMETER OF COLUMN(FT)= 6.87
TOTAL HEIGHT OF COLUMN(FT)= 10.00
CALCULATED COST OF COLUMN= 33291.25 U.S. DOLLARS

THE AMBIENT FACILITY PRESSURE
DUCTWORK DESIGN OUTPUT

UNITS	OUTER DIAMETER	BRICK DIAMETER	MATERIALS OF CONSTRUCTION	DUCT LENGTH	NUMBER OF ELBOWS
1 TO 2	33.5	0.00	IC	10.00	1.
2 TO 3	38.2	0.00	IC	15.00	2.
3 TO 4	20.2	0.00	CS	10.00	0.
4 TO 5	20.1	0.00	CS	10.00	1.
5 TO 6	20.1	0.00	CS	15.00	3.
6 TO 7	20.1	0.00	CS	15.00	3.
7 TO 8	20.1	0.00	CS	0.00	0.
8 TO 9	0.0	0.00		0.00	0.

COST OF DUCTWORK

COST	DUCTWORK COST	FIREBRICK COST	DAMPERS COST	TOTAL COST
1 TO 2	4036.2	11946.8	5393.9	21376.9
2 TO 3	8530.8	26887.6	6039.4	41457.8
3 TO 4	310.5	0.0	3614.3	3924.8
4 TO 5	784.5	0.0	3607.1	4391.6
5 TO 6	1889.9	0.0	3607.9	5497.8
6 TO 7	1889.9	0.0	3607.9	5497.8
7 TO 8	0.0	0.0	3611.9	3611.9
8 TO 9	0.0	0.0	0.0	0.0

1 LIQUID WASTE STORAGE FACILITY

NUMBER OF 25,000 GALLON TANKS =	0	
NUMBER OF 10,000 GALLON TANKS =	1	
NUMBER OF 1,000 GALLON TANKS =	1	
TOTAL STORAGE TANK COST=	102000.	U.S. DOLLARS
CSTNIT=	0.	U.S. DOLLARS
NITROGEN BLANKET SYSTEM=	0.	U.S. DOLLARS
CONDENSOR COST=	10000.	U.S. DOLLARS

1 TOTAL CAPITAL COST

COMBUSTION CHAMBERS:	1986 $
PRIMARY COMBUSTOR	366629.56
SECONDARY COMBUSTOR	402365.94
ENERGY ROCOVERY BOILER	78659.87
AIR POLLUTION CONTROL SYSTEM	
QUENCH CHAMBER	47432.45
VENTURI SCRUBBER AND SEPARATOR	18192.60
PACKED BED SCRUBBER	33291.25
INDUCTION FAN	16324.46
EXHAUST STACK(100 FEET HIGH)	9329.72
WASTE WATER TREATMENT FACILITY	34489.83
STORAGE TANK FACILITY	111999.87
TOTAL DUCTWORK	85758.31
METAL BUILDING	198951.31
SITEWORK AND FOUNDATIONS	110.53
STRUCTURAL STEEL	27640.46
ELECTRICAL MATERIAL	35569.98
INSTRUMENTS AND CONTROLS	49690.99
TOTAL-----	1516432.00

TOTAL INSTALLATION COST	373148.37
START-UP (10 % OF EQUIPMENT COST)	151643.19
SPARE PARTS (8 % OF EQUIPMENT COST)	121314.50
CERTIFICATION (10 % OF EQUIPMENT COST)	151643.19
ENGINEERING (7 % OF EQUIPMENT COST)	106150.19
INSTRUMENTATION (20 % OF EQUIPMENT COST)	431286.37

CONTENGENCY FEE (20 % OF EQUIPMENT COST)	0.00
TOTAL INDIRECT COSTS	1335185.00
***** TOTAL CAPITAL COST=	2851617.00

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OPERATING LABOR OUTPUT

SUPERVISOR SALARY($/YR)=	23386.	
LABORATORY SUPERVISOR($/YR)=	0.	
LABORATORY TECHNICIANS SALARY($/YR) =	20160.	FOR 1TECHNICIANS
CHIEF OPERATORS SALARY($/YR) =	0.	
OPERATORS SALARY($/YR) =	60480.	FOR 1 OPERATORS
YARD WORKERS SALARY($/YR) =	24192.	FOR 1 WORKERS.
SECRETARIES SALARY($/YR) =	12096.	FOR 1 SECRETARIES
PAYROLL EXPENSES(20% OF LABOR= COST IN $/YR)	35078.	
SUPPLIES AND OTHER MISC.($/YR)=	23386.	
TOTAL EXPENSES($/YR)=	175392.	

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ANNUAL OPERATING COSTS

FEED RATE 1000. LB/HR

LABOR	175392.
UTILITIES	
ELECTRICITY	102560.
FUEL	525135.
WATER	34411.
WASTE DISPOSAL	0.
BULK LIME	25085.
WASTE WATER TREATMENT	35206.
STARTUP COSTS	151643.
INSURANCE COST	17110.
ANNUAL MAINTENENCE LIQUID INJECTION INCINERATOR (5% COST)	86007.
HEAT RECOVERY UNIT (80% EFFICIENCY)	-525657.
TOTAL OPERATING COST	626890.

1

DISCOUNTED CASH FLOW RATE OF RETURN
ANALYSIS OUTPUT
(MILLIONS OF U.S. DOLLARS)

YEAR	0	1	2	3	4	5	6	7	8	9	10
INCOME	0.0	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
OPERATE	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
DEPREC.	0.0	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
TAXABLES	0.0	0.6	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
TAXES	0.0	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3

NET INC.	0.0	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
DEPREC.	0.0	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
CAPITAL	-2.9	-	-	-	-	-	-	-	-	-	-
CASH FLW	-2.9	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5

THE TOTAL CASH FLOW = 2.64 MILLION DOLLARS
DISCOUNTED CASH FLOW RATE OF RETURN = 10.9%

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VITA

Jeffrey Dean Mathis

Candidate for the Degree of

Master of Science

Thesis: A COMPUTER PROGRAM FOR THE DESIGN AND COST ESTIMATION OF HAZARDOUS WASTE INCINERATION FACILITIES

Major Field: Chemical Engineering

Biographacal:

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Education: Graduated from Edmond Memorial High School, Edmond Oklahoma, in May, 1980; received Bachelor of Science Degree from Oklahoma State University in May, 1984; completed requirements for the Master of Science degree at Oklahoma State University, December, 1986.

Professional Experience: Teaching Assistant, Introduction to Computer Science Fortran 77 for freshman engineering students, Oklahoma State University, January 1985, to May 1986; Research Assistant, Department of Chemical Engineering, in the field of biochemical engineering, Oklahoma State University, September, 1982 to August, 1986; Organic Chemistry Storeroom Manager, Organic Chemistry Department, Oklahoma State University, September, 1982 to January 1985.