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EFFECT OF GAS TEMPERATURE GRADIENTS AND RADIANT HEAT TRANSMISSION ON KINETIC MODEL BEHAVIOR

by

RICHARD W. J. ROBERTSON

A DISSERTATION

PRESENTED IN PARTIAL FULFILLMENT OF

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FOR

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FACULTY COMMITTEE

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ABSTRACT

EFFECT OF GAS TEMPERATURE GRADIENTS AND RADIANT HEAT TRANSMISSION ON KINETIC MODEL BEHAVIOR

by

Richard W. J. Robertson

Satisfactory methods to predict radiant heat transmission in enclosures containing a radiating gas at uniform temperature are available. These methods have been traditionally used in solutions of kinetic models.

Kinetic models are strongly temperature dependent with a difference of 10°K able to double the reaction rate. In the present investigation, calculation techniques which make allowance for the non-uniformity of gas temperatures in an en losure are applied to the kinetic models. The furnace problem considers only the radiation section with the assumption that detailed knowledge of combustion and fluid flow pattern within the enclosure is available.

If the gas space in the enclosure and the bounding walls are divided into zones, a zone being taken small enough so that it may be considered isothermal, then for steady-state operation one can write an energy balance on each zone. For any specific problem, every term in these equations with the

exception of the net wall fluxes may be written as a function of unknown temperatures only; furthermore the number of equations is exactly equal to the number of unknown temperatures and wall fluxes so that a solution is possible, though exceedingly difficult due to the existing non-linearities.

The net wall fluxes are calculated by the kinetic model, the flux at any point being a function of the overall heat transfer coefficient, the extent of reaction, and the temperature of the reacting gases, each of which in turn is a complex function of reaction gas composition and velocity.

The chief problem of this investigation was one of evaluating the emission from both a gas zone and a surface zone and the radiant interchange between all zones, making due allowance for absorption along every path from one zone to another.

The primary result of this dissertation has been the application of radiant dominant heat transmissions in enclosures (which make allowances for temperature non-uniformity in gas mass) to a pyrolysis reactor. The result of this reactor-furnace hybrid model is the ability to determine optimum tube placement, furnace size, and fuel consumption, while accounting for the effect of carbon

deposition in the reactor.

The methods developed in this dissertation were instrumented on an IBM 370-15 computer. This machine made it possible to make parametoric studies which predict the effect of changing furnace and reactor variables.

The high severity steam cracking furnace results in the greatest production per pound of fuel consumed. A yield of 73% represents maximum fuel economy. However, the associated problems of coke formation and high tube metal temperature must first be overcome before these yields can be realized.

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Chapter I

SUMMARY

An increased understanding of the basic principles underlying heat transfer processes has forced a realization of the importance of radiation as the dominant mode of heat transfer in high-temperature industrial furnaces. It is, therefore, desirable to be able to predict rates of radiant dominant heat transmission with confidence for both design and performance calculations. Methods which predict the net interchange between a radiating gas at a uniform temperature (a one gas zone furnace) with the walls forming the enclosure are available in the literature.

For many industrial furnaces, however, it is not permissable to assign a uniform temperature to the radiating gas, particularly when the distribution of heat flux within the enlcoure as well as the over-all performance is desired. When endothermic fluid phase reactions take place within the process fluid of the reactor a detailed knowledge of the local temperature gradient on the tube wall becomes important in that it affects the extent of reaction. The relatively large deviation from the true temperature profile produced by assuming one zone furnace

results in solutions which, though valid, are poor in engineering application. In the present investigation, therefore, the work of applying calculational techniques for predicting radiant dominant transmission has been continued, with the specific aim of making allowance for the non-uniformity of gas temperature in a fixed reactor. It was decided to limit the scope of the project by focusing attention on the radiation section of the fired heater problem and assuming that a description of the other phenomena necessary to the formulation, namely fuel-air combustion and internal flow patterns are available for use.

If the gas space in the enclosure and the bounding walls are divided up into zones, a zone being taken small enough so that it may be considered isothermal, then for steady-state operation it is possible to write an energy balance for each zone. For a gas zone the sum of the radiant energy received from all zones in the system (both gas and surface) plus the net convection to it from adjacent gas or surface elements plus the net enthalpy flux (chemical and sensible) to it due to bulk flow must equal the radiant energy originating within the gas zone. Similarly, for a surface, the sum of the radiant energy

received from all zones (gas and surface) plus the net convection to it must equal the emission from the surface plus the net flux through the surface. Every term in these equations with the exception of the net wall fluxes may be written as a function of unknown temperatures only and the number of equations is exactly equal to the number of unknown temperatures and wall fluxes. A solution of a set of these non-linear equations, once written for each zone in the enclosure, would yield the desired distribution of temperature and energy flux throughout the system.

One problem of this investigation, therefore, was one of evaluating the emission from either a gas zone or a surface zone and the radiant interchange between any two of these zones, making due allowance for absorption along every path from one zone to another and for partial diffuse reflection of every path at every surface ad infinitum. The furnace was subdivided into a set of isothermal zones. Each zone extended the entire length of the furnace and end effects were neglected. Sets of these furnaces can be set up one next to the other to produce a three-dimensional furnace of any degree of complexity. Some error will result due to the assumption that no interaction takes place between any furnace and its neighbor.

The results produced, however, are still an improvement over most computational techniques.

A computational technique developed by Cohen [18] is able to handle zoning along the length of the reactor as well as across and vertically. His methods, however, were principally graphic, and do not lend themselves to the digital computer.

The emission rate from a gas volume of Area A is given by the following equation:

$$E_g = 4(kL)\ (A) \cdot \phi \cdot \sigma T_g^4 \qquad (1\text{-}1)$$

where E_g is the rate of emission in energy per unit time, kL is the absorption coefficient of the gas times its path length, and ϕ is the fraction of the energy originating within the volume which leaves the boundaries of the volume. The escape factor, ϕ , is a function of kL only and has been obtained by multiple numerical integrations as described in a later Chapter.

The emission rate from a surface area of Area A is given by:

$$E_s = \varepsilon_s\ (A)\ \sigma T_s^4 \qquad (1\text{-}2)$$

where ε_s is the emissivity of the surface.

The interchange between any two zones in the system is more complex, involving not only the direct radiant flux between the two zones, but also the sum of the infinite number of reflected beams within the enclosure due to energy originating at either of the zones under consideration with due allowance for multiple attenuation. It is profitable to consider first only the direct interchange between the two zones; i.e. the interchange in a black-walled system.

The one-way radiation flux - surface to surface, surface to gas, gas to surface, and gas to gas respectively may be written as:

$$q_{ss}/(\sigma T_s^4) = ss \qquad (1\text{-}3)$$

$$q_{sg}/(\sigma T_s^4) = sg \qquad (1\text{-}4)$$

$$q_{gs}/(\sigma T_g^4) = gs \qquad (1\text{-}5)$$

$$q_{gg}/(\sigma T_g^4 = gg \qquad (1\text{-}6)$$

where the terms ss, sg, gs, and gg, designated as direct interchange factors, also termed in the literature as interchange areas due to the dimensional units. These factors may be thought of as the product of a radiation

factor f, having any of the subscript combinations indicated on the right-hand sides of equations (1-3) through (1-6) with the first subscript representing the source of the energy and the second the receiver, which represents the fraction of the energy originating in any zone in the enclosure which reaches and is absorbed by any other zone, and a radiating-ability factor, (area)·(emissivity) for a surface zone and 4 X (volume) X (absorption coefficient) for a gas zone. Values of these radiation factors have been evaluated. These factors are functions of the path length and k, where k is the absorption coefficient of the gas. It is to be noted that these factors have been evaluated assigning a uniform k to each characteristic gas, a characteristic gas being a mathematical representation of a gas, which, in conjunction with other characteristic gases predicts the properties of gases in the system. The details of this technique, involving evaluation of determinants of order equal to the number of surface zones and of volume zones in the system, are given in Chapter 3.

With all the interchange factors for the system evaluated, it is possible to return to the original energy balances and solve for the temperature and flux distribution in the "two-dimensional enclosure." It will be

recalled that the details of the fuel-air combustion, convection, and internal flow patterns are assumed known so that all terms in the energy balances have been evaluated and only temperatures or net wall fluxes appear as unknowns. Unfortunately, the set of equations contains unknown temperature in mixed first and fourth powers. For obtaining numerical solutions, these equations were linearized in T^4 by forcing the convection and enthalpy flux terms into a fourth-power law; this technique necessitates an iterative solution since the coefficients on the convection and enthalpy flux terms are now strong functions of temperature. The sets of equations are solved iteratively until the assumed values are verified.

The use of the digital computer enables a parametoric study of furnace conditions and designs criterions. The results were an optimization of a pyrolysis reactor which maximizes the ratio of product to fuel consumption. The results are given in Chapter (4).

The over-all performance of the furnace (i.e., the total amount of energy transferred from the gas) as calculated by the method presented in this thesis was found to give good agreement with the performance as calculated by existing techniques in the literature. (49) The distribution

of the heat flux within the enclosure, however, was found to be very different.

The technique developed in this dissertation is capable of giving far more detailed information as to the radiant interchange within the enclosure than has been possible up to the present time. Its chief weaknesses are:

1. Finite sized zones, assumed to be isothermal, have been chosen so as to facilitate numerical solutions.
2. It has been assumed that detailed knowledge of the combustion and mixing pattern is available. This is not actually the case for most enclosures.
3. It has been assumed that no interaction takes place between furnace subsections along the reactor length.
4. The furnace is assumed to be of infinite length. This assumption can be eliminated with moderate additional complexity.

The furnace model was used in connection with a reactor model. The reactor model is able to handle large numbers of interrelated chemical reactions. The model is set up to accept any set of reactions so long as the

kinetic data of reactions and the physical properties of the components are known.

From this initial data, the heat of reaction, heat of formation and the equilibrium constants are defined as functions of temperature. These functions are later evaluated to give point conditions in the reaction fluids.

The reactor is sectioned off into increment sections. Simultaneous material, momentum, and energy balances are performed on each section.

The temperature, pressure and composition of reaction fluids at the inlet of an incremental section are known from previous calculation. The temperature of the outside of the reactor wall is supplied by the furnace model. A temperature, pressure and composition are assumed at the end of the increment. A better estimate is made by calculating the reaction rates at the two ends and averaging the result. This procedure is continued until agreement is reached between two successful estimates.

The increment of heat flow to the reactor is calculated by summing the sensible heat gain of the reaction mass and the heat of reaction of each competing reaction. This must equal the net heat flux through the walls. The

increment heat flux is then summed over the length of each reactor section.

The reactor model also calculates the coke buildup as a function of reaction rates. The reaction rates are assumed to be invariant over the time span during which the carbon is deposited. New reactor conditions are then used during each additional time span of carbon deposition. The coke's chief effect on reactor conditions is a decrease in overall reaction rate due to the following effects:

1. A decrease in the net heat flux through the wall of the reactor due to the presence of a coke layer.
2. A reduction in reactor volume and hence, reactor mean residence time.
3. A larger pressure drop throughout the reactor length necessitating a higher inlet pressure, adversely affecting equilibrium.

The reactor model results in a new temperature profile for the reactor. The new profile is then mapped into three corresponding process temperature profiles which is then transferred into the furnace model.

The furnace model and the reactor model are solved repeatedly until good agreement is reached between assumed and calculated temperature profiles. The net heat flux

through the wall is also forced to converge. The net heat flux into the reactor is solved by the relationship

$$Q = UA \Delta T \qquad (1\text{-}7)$$

The overall heat transfer coefficient (U_R) used by the reactor model, is a function of the thickness of the reactor wall, the thicknesss, if any, of the coke layer and the inside film coefficient (H_i). H_i is in turn a function of the reaction mixture velocity, thermal conductivity and composition.

The overall heat transfer coefficient used by the furnace model (U_F) to calculate the outside wall temperature from the known temperature of the process fluid must be mapped into the tube plane. The mapping is necessary due to the pseudo two dimensional nature of the furnace model. The mapping is done through a net heat flux balance on the reactor wall. The value of U_F is thus mapped by forcing agreement between the overall heat flux calculated by the furnace model and the heat flux calculated by the reactor model. U_F does not correspond with U_R calculated by the reactor model.

Since both the reactor and furnace models were set up in a computer program it was possible to make a parametoric

study on the complete system. Thus the effect of tube placement, oil fired rate, furnace dimensions, reactor length, reactor composition can be correlated to design a furnace of optimum yield with minimum fuel consumption. One of the major contributions of this thesis is to correlate these quantities to predict optimum furnace and reactor design.

CHAPTER II

1. The Furnace Model

A. Introduction

This analysis depends on the development of two unrelated, but interdependent models. These two models are then coupled together and form an effective method to predict optimum furnace design.

One model, the furnace model, will be discussed is Chapter II-1. The other model, the kinetic model, will be discussed in Chapter II-2. The coupling model is then explained in Chapter II-3.

An increased understanding of the basic principles underlying heat transfer processes has forced a realization of the inportance of thermal radiation as the dominant mode of heat transfer in high temperature industrial furnaces. High installation and maintenance costs as well as the competitive market of today call for the design of furnaces or heaters which will perform efficiently and economically. Furthermore, because of variations in process conditions one would like to be able to predict the effect of such variations on furnace operation. To these ends, therefore, considerable effort has been extended to put the calculation and prediction of radiant heat interchange on a firm engineering basis.

The model makes use of work done by Cohen [18] and Roche [63] which allows for the non-uniformity of gas temperatures in an enclosure.

B. Fundamental Laws Governing Surface and Gas Radiation

1. Radiation from Solid Surfaces

All solids, at any temperature other than absolute zero, emit and absorb radiant energy. Both the magnitude of the emission and its quality (i.e., its spectral distribution) depend primarily on the temperature of the material, but also, to a lesser extent, on the particular nature of its surface. The rate of emission from a perfect radiator (defined as a black body) is given by the familiar Stefan-Boltzmann Law: the emitted flux (energy per unit time per unit area) is proportional to the fourth power of the absolute temperature. The spectral distribution of black-body radiation is a function of temperature only and is given by Planck's Law. Any real surface always emits less than black-body radiation, and if its spectral distribution is the same as the Planck distribution, the body is said to be gray. The ratio of the energy emitted by any gray body at a fixed temperature to black-body emission at the same temperature is termed the

emissivity; by the very nature of its definition, numerical values of emissivity must always lie between zero and unity.

For a further review of surface emissivities and radiation from solids Jakob[36], McAdams[49] and Hottel and Sarofim[33] or other standard references on heat transfer may be consulted.

2. Radiation from Gases

In addition to surfaces, certain gases absorb and emit energy when heated. Of greatest interest to the furnace designer are water vapor and carbon dioxide, the primary products of combustion. Data on the radiating and absorbing characteristics exist for both carbon dioxide and water vapor.[32], [35], [49] Somewhat more limited data are available for carbon monoxide, sulfur dioxide and ammonia.[16], [26], [59], [88]

Gas radiation differs from surface radiation in one important respect. Gas radiation is by no means gray, rather these gases exhibit very strong emission and absorption bands in certain spectral regions and are practically transparent in others. This non-grayness of real gases leads to enormous complications in furnace design calculations if it is to be allowed for rigorously. Fortunately, approximation techniques exist for handling the real-gas case; they will be discussed in later sections of this

chapter.

C. Techniques Available for Predicting Radiant Heat Interchange in Furnace Enclosures

The calculation of the radiant interchange in a furnace enclosure may be resolved into three different, though not completely separable, problems:

1. Allowance for the geometry of the system.
2. Emission of radiation from the gas and its absorption and/or reflection at the various surfaces.
3. Absorption by the gas of radiation emitted by or reflected at the different surfaces.

A little thought will show that a completely rigorous calculation of the interchange in an enclosure would be exceedingly complex, and, in fact, a perfectly rigorous solution appears to be almost impossible to attain. One of the most important reasons for this complexity is the fact that in a radiating system, what goes on at any point is influenced by every other point in the system. That is, one must write an integral equation to express the heat transfer rates everywhere, instead of a differential expression expressing the local rate dependent only upon local conditions, as is possible for convective and conductive heat transfer. For this reason certain simplifications have been

made which have enormously decreased the complexity of the calculations but which nevertheless yield answers for certain cases of sufficient accuracy for engineering use. A brief review, without any derivations or elaborate explanations, of the methods presently available for calculating radiant heat transfer appears below.

A. Interchange in Gray Enclosures Containing Non-Absorbing Media

The radiant interchange in a gray furnace enclosure, of any degree of complexity so long as it does not contain any absorbing gas, is calculable by the method presented by Hottel[46]. The net transfer by radiation between any two surfaces such as A_1 and A_2 is given as:

$$q_{A_1 \to A_2} = A_1 \mathcal{F}_{12} \sigma (T_1^4 - T_2^4) \qquad (2\text{-}1)$$

(A portion of the enclosure may be grouped together as a surface, e.g., A_1, when it has a substantially uniform temperature and when all portions of it have substantially the same "view" of the remainder of the enclosure.) The term $A_1 \mathcal{F}_{12}$ is dependent upon the geometry of the entire system as well as the emissivities (equal to the absorptivities for a gray system) of all surfaces, but it is not a function of the temperatures of any surfaces so long as their emissivities are themselves independent of temperature.

B. Interchange in Gray Enclosures Containing a Gray Isothermal Gas Mass

If now, the enclosure is filled with a gray gas of uniform temperature, the interchange between the gas and any surface or between any two surfaces separated by gas, may be calculated by a slight nodification of the above method. Gas-surface interchange is defined by the following equation:

$$q_{G_1 \rightarrow A_1} = A_1 \mathcal{F}_{1G} \sigma (T_G^4 - T_1^4) \qquad (2\text{-}2)$$

The surface-to-surface heat transfer is exactly the same as given in equation (2-1) with the modification, however, that the interchange factor $A_1 \mathcal{F}_{12}$ has been adjusted so as to allow for the fact that on each pass from surface A_1 to surface A_2, directly or via any surface forming the enclosure, a portion of the energy is absorbed by the gas.

The interchange factors for this case, as before, are dependent upon the geometry of the entire system as well as the emissivities of all surfaces, and in addition are dependent upon the gas emissivity. For opaque surfaces, the emissivity is equal to the absorptivity and the complement of the reflectivity: that is $\varepsilon = \alpha = (1-\rho)$ They are not functions of any temperature in the system,

so long as the emissivities of the system, both gas and surface, are independent of temperature.

D. Allowance for a Real Gas

Non-luminous gas radiation, particularly radiation from carbon dioxide and water vapor, which are of greatest importance to the furnace designer, is not gray. The transmissivity of such a gas is not only a function of the gas properties, but is also very markedly influenced by the spectral distribution of the energy which is being absorbed. For example, the absorption of very high-temperature radiation by carbon dioxide, with its strong absorption bands in the long wavelength region would be very low because the source of radiation would be predominantly of short wavelength; but the absorption of lower temperature gray radiation, with a consequent larger fraction of the incident energy in the same spectral region as the gas absorption bands, would be much higher. In the treatment of the gray gas system mentioned in subsection 2, it was assumed that the absorptivity of the gas for surface radiation was independent of the quality of that incident radiation, and for this reason the gray-gas formulation is in error if applied directly to a real system.

Hottel and Sarofim[33] have shown it is possible to

approximate very closely real-gas radiation, without losing the mechanics of the gray-gas formulation. Since for the gray gas the transmittance of a gas beam of length x with a gas pressure P_G is given by:

$$\tau_x = e^{-K' P_G X} \qquad (2-3)$$

where k' is the absorption coefficient of the gas and is independent of wavelengths, the emissivity and absorptivity are equal and may be expressed as:

$$\varepsilon_x = a_x = 1 - \tau_x = 1 - e^{-K' P_G X} \qquad (2-4)$$

It is, of course, possible to fit the $\tau_x = f(P_G x)$ curve for a real gas to any degree of precision by a series of exponential type terms such as:

$$\varepsilon_x = a\, e^{-K'_a P_G X} + b\, e^{-K'_b P_G X} + c\, e^{-K'_c P_G X} \ldots (2-5)$$

This equation indicates that the transmissivity of a real gas may be thought of as a weighted sum of a number of gray-gas transmissivities, each applicable over a different spectral region. The sum of the weighting factors, a,b, c,..... must be unity, since the emissivity of a gray gas having no thickness (x=0) must be unity. The interchange in an enclosure, therefore, can be thought of as equivalent to the sum of the interchanges of a number of gray-gas systems each weighted in porportion to that fraction of the spectral region over which it acts. It is

to be noted that the gray gas in each region has a different absorption coefficient and hence a different emissivity.

In the limit, as one considers an infinite number of spectral regions each obeying the gray-gas formulation, the answer of course, must be exact. For engineering calculations, however, this type of approach would be extraordinarily complex if one had to consider a large number of zones. Numerical analysis of typical problems has indicated, fortunately, that if the $e^{-k'X}$ curve is to be fitted anew for each numerical problem, it is in general sufficient to consider only two spectral regions, a and b, where the fraction "a" consists of a gray gas with a finite absorption coefficient k_a and the fraction "b" (the complement of "a") consists of a gas with a zero absorption coefficient (i.e., a clear gas which neither absorbs nor emits). Again, space limitations prohibit a more adequate discussion of this problem and, for details, the reader is referred to Hottel[49] and Hottel and Sarofim.[33]

E. Limitations on the Calculational Techniques

Recapitulating, it has been shown that one is able to handle satisfactorily an enclosure made up of any number of gray surfaces and filled with a real isothermal gas mass. In actual practice it may be difficult to obtain a numerical

solution for a very complicated case; however, the principles governing the interchange in such enclosures and the technique for obtaining solutions have been formulated and are generally available. [49]

Perhaps the most servious limitation to the calculational methods outlined above is the fact that the gas temperature and composition have been assumed to be uniform throughout the enclosure. Obviously, this assumption is never completely true for any industrial furnace, and in a good many cases it may be very seriously in error. If the furnace chamber is roughly cubical in shape, and if turbulence and mixing are present to a high degree, then the gas temperature will be nearly uniform and equal to the temperature of the exit gas so that the above methods apply directly. Even if these conditions apply only approximately, that is, if the gas temperature and composition at the inlet and outlet of the furnace are not too different from each other, then some mean of the two temperatures ought to give a reasonably accurate answer. Unfortunately, few industrial furnaces fall in this category.

If, on the other hands, the furnace is very long compared to the dimensions of the cross-section normal to the direction of gas flow, and if combustion is rapid at the furnace entrance, the temperature of the gas falls continu-

ously as it passes through the furnace. In the limiting case of a furnace with length infinitely great relative to the transverse dimensions, allowance for this drop in gas temperature can be made by calculating local heat transfer rates at several points and graphically integrating along the furnace length. Long furnaces have been handled adequately by this technique, which in effect ignores radiant flux in the direction of gas flow, as long as there is a definitive negative temperature gradient from the botton of the combustion chamber to the top. This tedious process, which applies only to one very special type of furnace, has been performed for a wide range of furnace variables, and a simplified method of predicting a mean gas temperature to give the answer in a single step is available.(17) (49)

In this thesis a furnace model of the infinite length relative to the transverse dimension is considered. However, the model incorporates radiant flux consideration in both transverse directions. Radiant flux along the infinite axis is also calculated, but ignores end conditions along the infinite axis. This makes it possible to section the model along the long axis and consider each section independently of the others. Some error is introduced

in that the model can not show any net heat flux between adjacent sections despite the existence of temperature gradients between sections. The errors thus generated are minimal due to the relatively small difference of temperature and the low value of the heat transfer due to eddy diffusion.

While one is able to handle the two limiting cases of furnaces mentioned above quite simply, it is rather unfortunate that most industrial furnaces fall into a category somewhere in between them. At the present time, only the method developed by Cohen[18] allows one to take into account the fact that in actual furnaces, very substantial gas temperature gradients exist, both in the direction of gas flow and transverse to it. The method, however, is very tedious, and does not easily lend itself to computer calculations due to the graphical techniques or methodology employed.

Simply to illustrate the magnitude of the temperature gradients, a few numerical examples will be given.

1. Data obtained by Smith[73] and reported by Cohen[18] on a scaled-down model of a steel-reheating furnace, using premixed air and gaseous fuel, have indicated that a drop of about 300-400 Centigrade degrees between the

gas temperature near the refractory roof and the cool floor sink, a total distance of about one foot in his equipment, is not at all unusual.

2. The large-scale furnace (about 6 feet by 6 feet by 20 feet) used by the International Flame Radiation Research Committee, and fired with either gaseous or liquid fuel in a burner jet, has shown temperature drops between the hot combustion zone near the center of the flame and the refractory wall of as much as 600 Centigrade degrees in a distance of about three feet.[37]

These figures have been quoted merely for illustrative purposes. However, when one considers that gas emission is roughly proportional to the second or third power of absolute gas temperature, it seems likely that the consequences of these large gradients might be extremely important.

It is possible for one to handle rigorously the simplest possible case of allowing for temperature non-uniformity in the gas. This method has been presented by Hottel[49] for the case of energy reception by a black wall adjacent to a gas mass having a known one-dimensional temperature gradient.

F. Methods Used to Solve Furnace Model

There are, of course, two fundamentally different approaches that one might use in attacking this problem. The first is completely theoretical and involves the development of calculational techniques to enable the prediction of the effect of temperature gradients on radiant heat interchange. Since basically the processes occuring within a furnace are determined solely by the fundamental laws of heat transfer, fluid flow, and combustion kinetics, the problem reduces itself to one of expressing the interrelationships of the various mechanisms interacting with one another in such a way that it becomes possible to obtain a numerical solution. The second technique would be to determine experimentally heat transfer rates under a wide variety of conditions with the hope of obtaining some sort of correlation which would enable one to predict the operation of furnaces other than those studied.

The first method of attack was felt to be the more profitable one in this case, and accordingly a purely calculational approach was used. The advent of the high speed digital computer has allowed implementation of this approach to handle far more complex systems than heretofor have been attempted. The speed of computation also allows

for solution of many furnace models with the ultimate objective of being able to simplify the result into some generalized empirical relationship. The solution has been to set up in the most general terms possible, that is, in such a form that if one had specific knowledge of combustion and mixing, he would be able to incorporate such information directly into the recommended technique.

In all fairness to the reader, it must be pointed out that the combination of processes occuring in a furnace is extremely complex. The extent to which the method developed in this dissertation might be used by an engineer is dependent solely upon the amount of time which he is justified in spending on any particular problem. For one wishing only an approximate answer, it would be uneconomical to go through the costly and involved processes described later. On the other hand, if it is really important that one has the right answer, the author sees no alternative to following the methods recommended in this dissertation or their equivalent. Their use to prove the validity of engineering shortcuts is an interesting application, but not the subject of this dissertation. The use of the computer in handling the model will make it feasible for an investigator to find such simplified approaches.

2. The Reactor Model

A. Introduction

To perform an optimization one needs some sort of plant description to form an objective function such as production rate or profit margin which must be optimized in terms of the independent variables.

Historically, plant data were used in deriving mathematical models by regression analysis. Some plants had even been deliberately disturbed in order to obtain enough data to determine the independent variables into which the plant was being fitted.

This method has many drawbacks such as noise in the plant data causing unreliability in the reading and a limited range of conditions under which the data is collected. Conditions outside of the range of those specifically studied must be calculated by the relatively unreliable method of extrapolation.

An alternative method is to simulate the plant based on the physical and chemical conditions. This simulated model can then be perturbed to determine the effect on the function to be optimized.

In order to describe plant conditions as thoroughly and accurately as possible, a model should consider the entire plant, including recycle streams, separators and peripheral equipment as well as the reactor. This is not

the intent of this study.

It was decided that the optimization of fuel consumption would be most meaningful and would give optimum conditions close to the optimum based on an overall profit objective function.

The purpose of this disseration is to develop an algorithm which successfully predicts the behavior of a reactor-furnace. In order to be able to verify the results a reaction system was chosen which has been extensively reported in the literature. The reaction system thus decided upon was the cracking of ethane to form ethylene.

B. Pyrolysis of Ethane Process

Ethylene is a basic raw material used in the manufacture of polyethylene and polyethylene copolymers and as an intermediate in the synthesis of many organic compounds, with plant sizes ranging between 50 to 250 million pounds per year. The pyrolysis of ethane is very profitable becuase the raw material, ethane, would have a minimum value as a fuel gas. Ethylene is produced by "cracking" of the feed stock in fired reactors at temperatures up to 1250^{o}K.

Almost all larger petrochemical facilities have several

furnaces which operate with different feed stocks, notably various proportions of ethane, propane, butane and "naphtha". The reactor pressure and temperature profiles and feed rates are also varied. The products from these different streams are generally combined into one stream after "quenching" to terminate the production of unwanted byproducts.

The reactor model is able to handle each set of feed stocks independently and perform separate optimizations for each furnace. In this study, the cases of pure ethane, propane, and combinations, each mixed with steam, were considered. The steam provides a chemical mechanism to minimize the rate of coke deposition. The model is also capable of optimizing the production of acetylene by increasing the residence time.

C. Carbon Deposition

Carbon is one of the byproducts of the pyrolysis reactions. Carbon is deposited on the wall of the reactor and results in a continuously decreasing reactor radius. This results in larger pressure drops occuring within the reactor tube. Eventually the pressure drop reaches a value which is too high to keep the system operating, and the reactor must be shut down for cleaning. Another effect of the carbon deposition is to reduce the overall heat

heat transfer coefficient making the fired heater less efficient.

An increase in reactor outlet temperature increases both the yield of ethylene and the rate of carbon deposition, hence causing an increase in the frequency of reactor shutdown for cleaning. As fuel consumption in the furnace increases, so does the reactor yield. The function of reactor yield divided by fuel consumption plotted against fuel consumption goes through a maximum which represents an optimum operating condition for any given set of furnace and reactor parameters, i.e.

$$\text{Yield/Fuel Consumption} = f(\text{reactor parameters, furnace parameters})/\text{fuel consumption} \quad (2\text{-}4)$$

The reactor-furnace model developed in this dissertation is able to determine this ideal operating point for most existing furnaces. The model also lends itself to the determination of the optimum design of most new furnace-reactor systems.

D. Chemistry of Pyrolysis

The chief products from thermal cracking furnaces-reactors vary from feed to feed. For the feed considered in this study, the chief products were ethane, ethylene,

acetylene, methane, propane, propene, hydrogen and coke. Small amounts of aromatics were also formed. As an approximation these were defined to have the properties of C4's and C6's alpha olefins.

The eight equations considered in this study are:[71]

	Order Forward	Order Reverse	
$C_2H_6 \rightleftharpoons C_2H_4 + H_2$	1	1-1	(2-5)
$C_2H_6 \rightleftharpoons CH_4 + \frac{1}{2}C_2H_4$	1	1-1	(2-6)
$C_2H_4 \rightleftharpoons C_2H_2 + H_2$	1	1-1	(2-7)
$C_2H_2 \rightleftharpoons 2C + H_2$	2	1-1	(2-8)
$2C_2H_2 \rightleftharpoons C_4H_4$ (i.e.) C4's	1	1	(2-9)
$C + H_2O \rightleftharpoons CO + H_2$	1-0	1-1	(2-10)
$C_3H_8 \rightleftharpoons C_3H_6 + H_2$	1	1-1	(2-11)
$C_3H_8 \rightleftharpoons C_3H_4 + CH_4$	1	1-1	(2-12)

A detailed explanation of the kinetic reactor model can be found in the M.S. Thesis of Robertson.[62] It was necessary to modify Robertson's model in order to incorporate the calculation of the net heat flux through the wall of the reactor when the details of the pointwise temperature

distribution are known.

Further detail may be found in the following references:

1. Use of computers in pyrolysis - see Reference Numbers (3, 9, 12, 23, 25, 44, 45, 53, 60, 62, 65, 68, 69, 70, 86, 95)
2. Chemistry of Pyrolysis (2, 38)
3. Reaction Rate (80, 81)
4. Equilibrium Rate (40)
5. Heat of Reaction (71)
6. Heat Transfer (13, 76)
7. Carbon Deposition (10, 14, 20, 28, 55, 57, 82)
8. Furnace Construction (15, 37, 48, 67, 74, 78)
9. Supersonic Oxidative Pyrolysis (90)
10. Sub-sonic Oxidative Pyrolysis (89)
11. Pyrolysis of Heavy Feed Stock (79, 86)

3. The Mapping Function

The development of the kinetic model and the furnace model are independent of each other. In order to make the two models interdependent it was necessary to develop a third model which could communicate between the first two models. This third or mapping model is the author's specific contribution in this dissertation. It was utilized to investigate the product yield, fuel consumption geometry and tube placement of the reactor-furnace. The firing patterns produced by different tips on the burners can also be studied with the idea of designing a firing tip which would yield an optimum firing pattern.

The mapping model has to take into account a number of inconsistencies which include:

1. The furnace model assumes that there is no variation in temperatures along its infinite axes. The kinetic model, however, shows a continuous increase in temperature as the reaction mass flows through the reactor tube, which has vertical as well as longitudinal variations in geometry.

2. The furnace model "views" the furnace wall as a continuous semi-porous plane, a pprtion of which

is a heat sink to the ambient (through the insulating walls of the furnace). The kinetic model considers itself a discreet section of tubing with a radial uniform outside surface temperature.

3. The furnace model was picked to have a height of 28' feet. The reactor model was 400 feet long. This made it necessary to fold the reactor tube into a series of "u" bends which run up and down along the wall of the furnace.
4. The furnace model considered itself infinitely long with no end effects due to the presence of walls at both ends of the furnace. The reactor model was clearly finite in length.

Methods used to handle each of these inconsistencies will be discussed later in this section.

In order to make the models compatable, both temperature and net heat flux profiles through the reactor wall had to be in agreement. As each of these quantities is calculated independently by both models, a trial and error type of solution was developed.

The temperature profile of the outer reactor wall was assumed. With this assumed profile, the kinetic calculations

were completed. The kinetic calculations included a reactor fluid temperature profile and a net heat flux. The furnace calculations were then performed and yielded a new outer reactor wall temperature profile and a net heat flux to the reaction fluids.

This new outer wall temperature profile was then used to repeat the kinetic calculations. This process was then repeated until the maximum difference between old and new reactor fluid temperatures was less than 1.25°K and the net heat fluxes calculated by the two models were within 2% of each other.

A. Temperature Variations Along Reactor Length

The temperature of the reaction fluids increases continuously as the reactions take place. The net heat flux into the reactor results in two net effects:

1. An increase in the temperature of the reaction mass due to a sensible heat gain.
2. A change in reactor mass composition due to chemical change. (The principal reaction being endothermic).

In the initial stage of reaction the mixture has an insufficient temperature for any appreciable reaction to take place, hence, most of the heat flux results in a sensible heat gain.

In a second portion of the reactor the reaction mass is at reaction temperature with large quantities of unreacted species present. A majority of the heat flux goes to supplying the reaction mass with the necessary heat of reaction, with some sensible heat gain still occurring.

A final portion of the reactor consists of an ever declining portion of the net heat flux contributing to the heat of reaction;

It becomes possible to take advantage of these tendencies by splitting the furnace into three zones. In the first zone there is considerable increase in the temperature of the reaction mass. This in turn results in rapidly changing wall flux. However, since in this section of the reactor little reaction takes place, an averaging technique of the the temperature flux along the infinite axis for each isothermal wall zone will not seriously affect the kinetic model.

In the second zone the kinetic model predicts large extent of reaction but only mild increasing temperatures. Again an averaging technique for each isothermal wall zone along the inifinite axis lives temperature distributions which can be used by the kinetic model, since only relatively small temperature differences exist.

In the third zone both relatively extensive amounts of reaction and fairly large reactor fluid temperature changes take place. By minimizing the size of this section, the averaging technique is again applicable.

The reader should note that considerable flue gas temperature gradients exist between each isothermal zone in adjoining sections. This would suggest that a subdivision of each section into two or more sub-sections would result in still more precise results. However, the additional computational time required by the computer for such an undertaking would be prohibitively large.

B. Mapping the "Plane Into A Reactor Tube

The furnace model views the wall of the furnace as a continuous plane with isotherms running along the horizontal and discreet temperatures of radiation running along the vertical. The plane is porous in that it "views" the furnace wall and reactor tubing simultaneously, differentiating between them as the ratio of their respective areas. The furnace model does not distinguish individual sections of tube and wall, rather "considers" the two as the wall of the furnace.

The kinetic model "uses" the outer skin temperature of the reactor to calculate the net heat flux to the reaction mixture. In a furnace tube there would be some radial

temperature distribution since the side of the tube facing the wall of the furnace would have a lower temperature than the side facing the bulk of the hot flue gases. The net temperature difference is not too great since the major resistance to heat flow is the result of the inside film heat transfer coefficient. (The resistance to heat flow through the coke layer would also be large, but this quantity is a variable, depending on the length of time the coke has been forming and the particular location in the reactor tube). The ratio of heat resistance in the tube metal to that caused by the inside film coefficient is an order of magnitude greater than 10 to 1, as was calculated by Robertson.(62)

In order to make some allowance for this effect, the net heat transfer coefficient calculated from reaction mixture to outer tube wall temperature used by the furnace was adjusted in such a fashion that the net heat flux as calculated from the furnace equation was equal to the net heat flux as calculated from the reactor equations.

The net heat transfer coefficient found by the reaction equation was calculated from considerations of physical properties of the reactor tube, the thickness of the coke layer and the chemical composition and physical properties

of the reaction mass.(62)

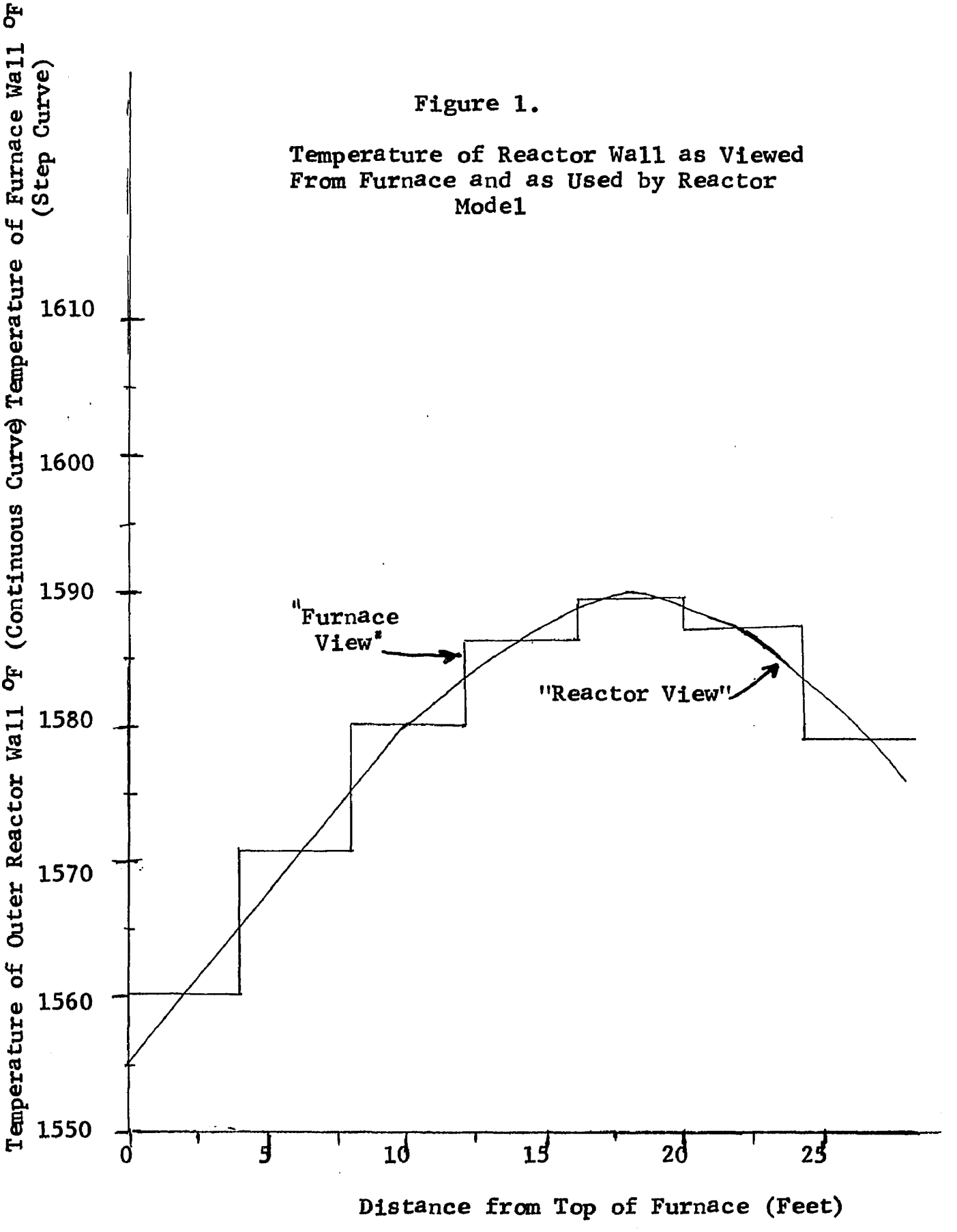
C. Placement of Reactor Tube

The reactor being 400 feet of continuous tubing which is hung in the vertical direction (to avoid gradual bending of the tube near its center if the tube were placed in a horizontal position due to the excessive heat required for pyrolysis) would not fit into a furnace 20 feet in height. It was therefore placed in the furnace in a series of "U" bends running first from top to bottom and then bottom to top. A total of 14 such bends was required to accomodate the entire reactor length. A total of 14 such reactors can be placed in the 40 foot length of the furnace, seven on each side of the flame wall. The "U" bends provide mechanical support while allowing for thermal expansion.

Within the series of 14 "U" bends, the furnace was further subdivided into three distinct reactor zones discussed earlier in this Chapter. The mapping model had to be able to distinguish in which furnace zone the corresponding reactor segment lay. It is also necessary to know whether the tube was running up the furnace or down. The temperature profiles used by the furnace and the reactor are illustrated in Figure 1.

Figure 1.

Temperature of Reactor Wall as Viewed From Furnace and as Used by Reactor Model



The smooth curve shown in Figure 1 was calculated by fitting a fourth power polynomial of $T - f(Z) = a + bZ + cZ^2 + dZ^3 + eZ^4$ using the midpoint of each discreet furnace zone temperature as calculated by the furnace model. These discreet temperature zones were adjusted at the end of each furnace calculation and smooth curves were refitted for each of the three furnace zones recalculated.

Figures 2 and 3 show the actual location of the tubing in the furnace as well as the placement of the isothermal zones. The bridge wall extends on half the distance along the top of the furnace, the remaining half being the opening into the convection section and the stack.

D. End Effects

The furnace model studied in this thesis was considered to be infinitely long and end effects were ignored. As the dominant mode of heat transfer is radiation, an estimate of the distance necessary to completely absorb all incident radiation was made for the gray gases consisting of the flow gas. It was determined that for beam lengths of 65 feet, less than one part per million of the original radiation was still present in the beam. The clear gas contribution was somewhat higher.

The furnace model was further complicated by assuming

subdivisions along the reactor length (See Figure 2). Each subdivision assumes that its unique properties exist unchanged through neighbor subdivisions in the horizontal plane. In the furnace model studied, which was 70 feet long, there occurred 21 subdivisions. There were, however, only three distinct furnace subdivisions which had to be calculated.

Figure 2
Front and Side View of a "Zoned" Furnace with 3 Subsections

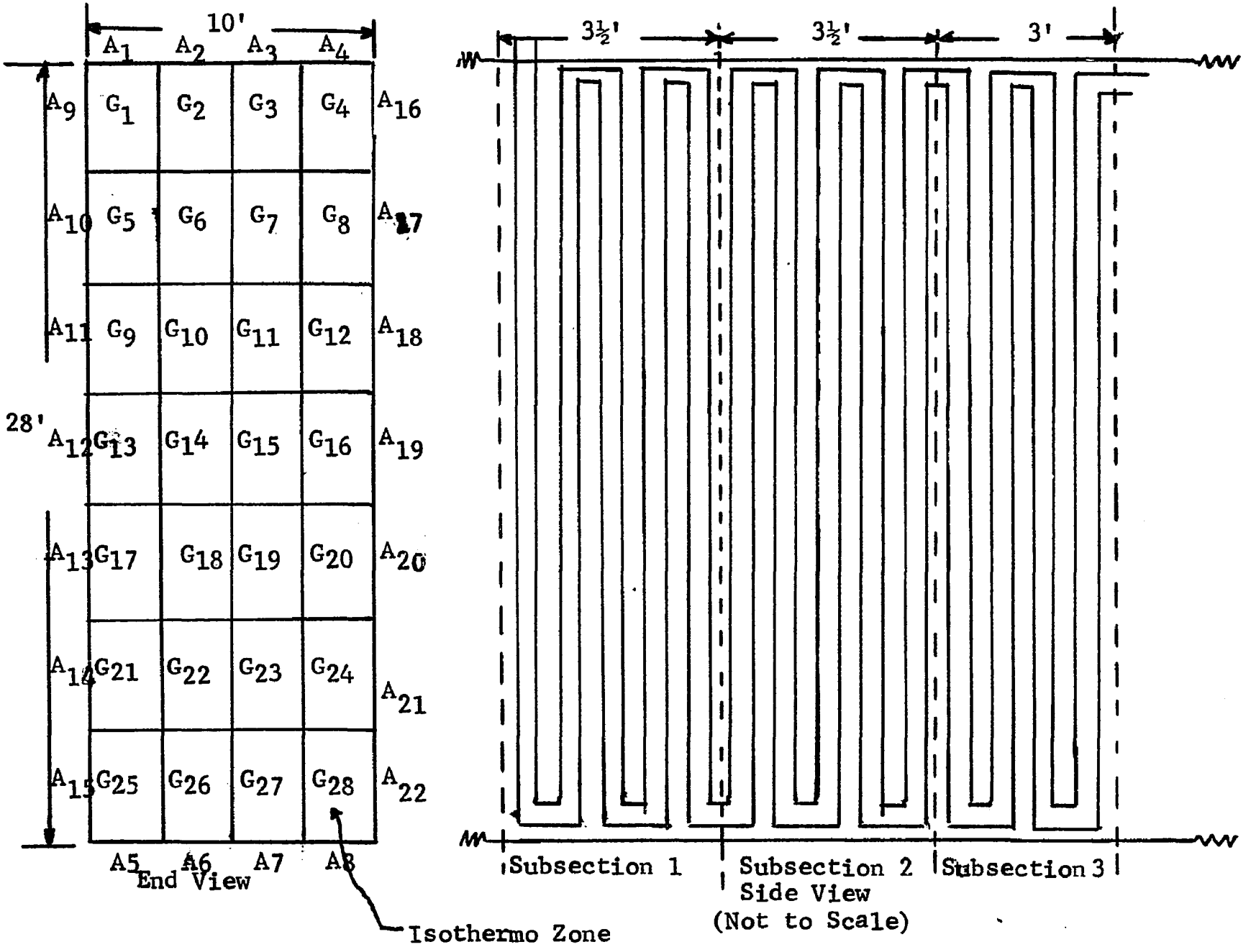
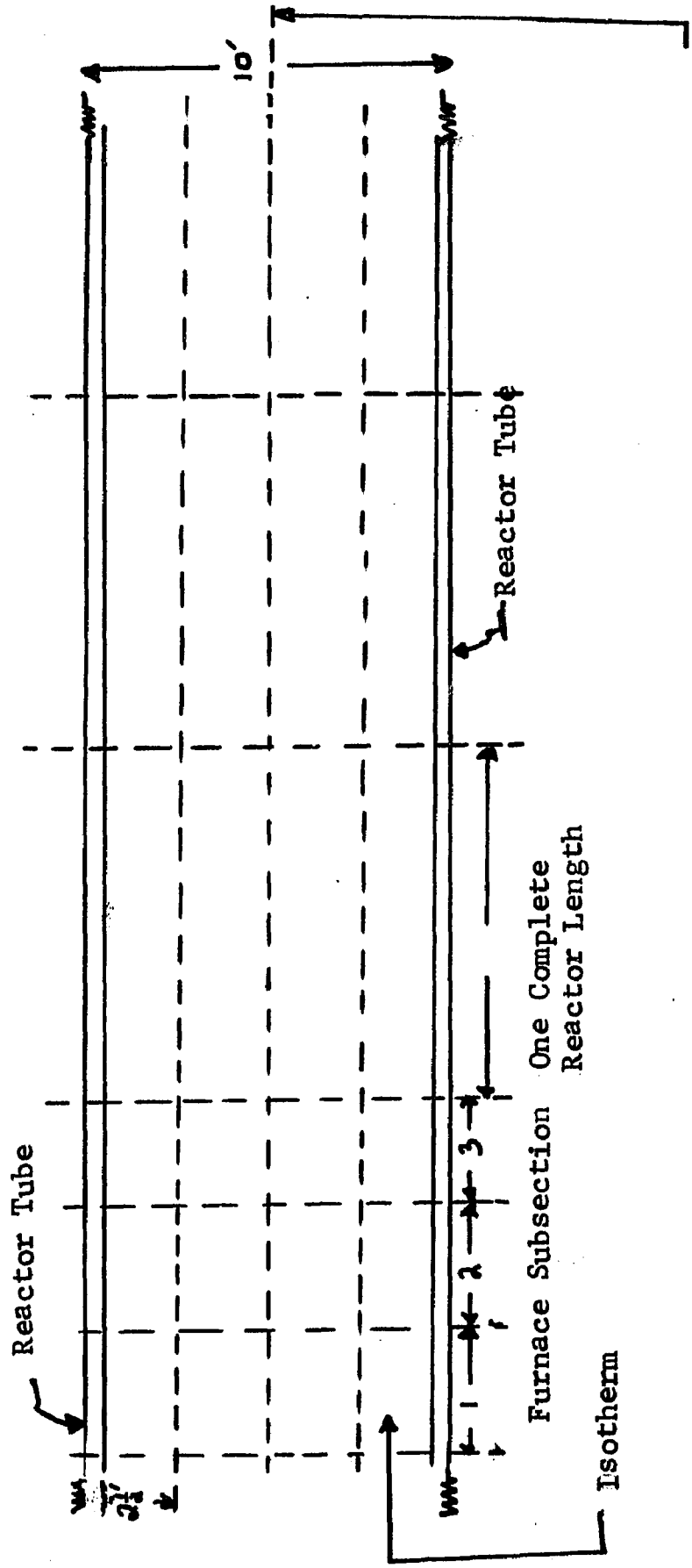


Figure 3

Top View of Furnace-Reactor Showing Isotherm Zone Placement



Chapter III

Procedures Used in Solution of the Zoned Furnace-Reactor Model

1. The Furnace Model

This Chapter will discuss in detail the mechanism used in the solution of each of the problems handled in this study. The furnace model will be discussed in Chapter III-1, the kinetic model in Chapter III-2, and the mapping model in Chapter III-3. In addition, Chapter III-4 will show the computational procedure used in order to arrive at the solution which comprises this study. In the remainder of this dissertation, all discussion will be limited to steady-state conditions in an enclosure.

In this study the furnace was zoned into isothermal gas volumes and surfaces areas. The volumes run through the entire length of the furnace and are in fact treated as infinite in length; the height and width of each of these zones being finite. Likewise the surface areas are infinite in length and finite in width if in the horizontal plane, or in height if in the vertical plane. The model does not consider any plane or volume which is not either mutually parallel or perpendicular to the infinite axis (see Figures 2, 3, 4). These limitations should be kept in mind for all future references to surface area and gas

volumes.

The furnace was further subdivided along the infinite axis in order to make allowance for the nonuniformity along that axis. However, for the calculation, each subdivision is treated as if those conditions in that subdivision existed along the entire length of the furnace. This precedure allows the handling of each subdivision as an independent calculation, greatly reducing the complexities of the calculation procedure.

The general approach to be used consists of dividing the space enclosed and the bounding surfaces into zones, each zone being taken small enough so that it may be considered isothermal.

An energy balance may be written for each zone in the system, and when this is done it will be found that the series of equations contains only gas temperatures, surface temperatures or wall fluxes as unknowns. Futhermore, the number of unknowns will be found to equal exactly the number of equations. In principle then, one can solve either for the temperature at any given point in the system or the flux through the wall.

A. Energy Balances on the System

Consider the enclosure to be made up of isothermal volumes of space containing a gray gas, and designated as

g_1, g_2, g_3 ..... and isothermal areas of bounding surface (either heat sinks or refractory) designated as s_1, s_2, s_3..... . The surface areas will coincide exactly with the gas volumes that touch them.

The conventions of naming the various surfaces and gas volumes used in this dissertation are as follows: (Refer to Figure 2, cross section view).

1. The gas volumes are numbered from left to right, starting in the upper left hand corner and working down as each row is completed. Hence the first gas volume in the upper left hand corner would be g_1.
2. The surface areas are numbered from left to right along the floor of the furnace. The sides of the furnace are then enumerated from top to bottom going down the right wall, then from top to bottom going down the left wall. Hence the last surface area, number 22, would be on the bottom of the right side of the vertical wall of the furnace and would be called s_{22}.

Since the temperature of the gas in any volume g (a volume defined as fixed in space) will remain unchanged once steady state has been reached, an energy balance on any volume such as g_1 may be written as follows:

Total outward radiation in all directions through the bounding walls of volume g_1	= Radiation absorbed by g_1 from all volumes both direct and by multiple reflections at the walls	+	Radiation absorbed by volume g_1, from all surface elements, both direct and by multiple reflections
	+ Net energy to volume g_1 by bulk transport of the flowing gas stream	+	Net energy to volume g_1 by convection from adjacent gas volumes or surface elements

(3-1)

Rewriting in terms of symbole, where the various terms correspond directly:

$$E_{g_1} = \sum_i q_{g_i g_1} + \sum q_{s_j g_1} + q_{B_{g_1}} + q_{C_{g_i}} \quad (3\text{-}2)$$

In the above and all subsequent equations a double set of subscripts such as gg, gs or ss indicates the direction of the energy transfer, the first subscript denoting the source of the energy and the second the receiver. Subscripts on the last 2 terms refer to bulk transport B or convection C, with an additional subscript to indicate which single gas or surface element is involved.

Similarly, writing an energy balance on any surface s_1:

Total outward radiation in all directions from surface s_1	=	Radiation absorbed by s_1 from all volumes both direct and by multiple reflections at the walls.	+ Radiation absorbed by surface s_1 from all surface elements both direct and by multiple reflections.
	+	Net energy to surface s_1 by convection from adjacent gas cubes	- Energy flux through wall s_1

(3-3)

Rewriting again in symbols:

$$E_{s1} = \sum_i q_{gi} S_1 + \sum_j q_{sj} S_1 + q_{cs_1} - q_{ws_1} \qquad (3\text{-}4)$$

A little consideration of equations (3-2) and (3-4) will show that all the terms with the exception of wall-flux $q_{w_{s_1}}$ may be written as functions of temperatures, the coefficients on the temperature terms being functions of the geometry, heat capacities, flow rates and emissivities (and absorptivities) of the system. If it may be assumed that these temperature coefficients can all be evaluated at some mean temperature for the system, then there will result a total of g + s equations on g unknown gas temperatures and s unknown wall temperatures or wall fluxes.

It is to be noted at this point that, most unfortunately, the resulting series of simultaneous equations is

neither linear in temperature nor in any power of temperature. If one is willing to assign to the temperature coefficients mean values for the system then the radiation terms will be proportional to the fourth power of temperature while the convection and bulk flow terms are proportional to the first power of temperature. In order to simplify the final solution of the equations, it is advisable to linearize them by forcing the convection and bulk flow terms into a fourth power law. It would also be possible to force the radiant terms into the first power law. However, this alternate procedure does not reflect the radiant dominant nature of the fired heater or furnace. Using the first method means that the coefficients on these terms are very strong functions of temperature and hence of the solution to the equations, necessitating an iterative procedure in solution. Details of this technique will be presented later in this section.

B. Radiant Interchange in a Black Enclosure Containing a Gray Gas

To simplify the problem of determining the radiant interchange factors in the most general case, it was decided to determine them first for this simple case: An enclosure containing black walls (and thus no multiple

reflections) and filled with a gray gas. In the case of a single-temperature gas zone as was described in Chapter 2, it was found possible to build up the interchange factor which allows for multiple reflections from the much simpler one of direct interchange only; a similar situation is found in the multi-gas zone cases. Futhermore, the technique for allowance for a real gas as the weighted sums of a number of gray gases also applies. For these reasons, the direct interchange factors for the gray-gas case will be evaluated first; then the method of building up solutions to the more complex situation of gray walls and a real gas will be indicated.

1. Emission from a Volume of Gas

The rate of emission of energy from an isothermal gas volume, if there were no attenuation of radiation within the volume, would be equal to the gas emissivity per unit volume multiplied by the volume and by "black body" emission at the same temperature:

$$E_g^* = \mathcal{V} \cdot V_g \cdot \sigma T^4 \qquad (3\text{-}5)$$

where E_g^* is the rate of emission if no attenuation occurs

$\mathcal{V}$ is the gas emissivity on a volume base

V_g is the volume of the gas

σT^4 is the Stefan-Boltzmann Constant times the temperature to the fourth power

Since the gas volume is infinite in length, some distance (such as the actual length of the furnace) is used in calculating this volume.

It may readily be shown that the gas emissivity on a volume basis is equal to 4k, where k is the absorption coefficient for a characteristic gas such that the gas emissivity, g, is equal to $(1 - e^{-kx})$. (18) (33)

Since for any restricted volume of gas there will be attenuation of energy originating within the volume, the actual emission will be less than that given by equation (3-5).

2. Emission from a Surface Area

There is no problem involved in the formulation of the total rate of energy emission from a surface which is simply equal to the surface emissivity multiplied by black radiation at the temperature of the surface. The values of emissivity for a wide variety of materials encountered in industrial practice are available in the literature.(34, 45)

3. Interchange Between Two Surfaces

The one-way radiation from surface s_1 to surface s_2 is given by the following equation which may be considered a definition of the factor $f_{s_1 s_2}$:

$$q_{s_1 s_2} = f_{s_1 s_2} A_{s_1} \sigma T_{s_1}^4 \qquad (3\text{-}6)$$

The factor $f_{s_1 s_2}$ plainly represents the fraction of the energy leaving surface s_1 that is intercepted by surface s_2 and is a function of the areas and geometrical configurations of the two surfaces as well as the absorption coefficient of the intervening gas mass. For evaluation of the factors of the type f_{ss} it will be assumed that the intervening gas has constant absorption properties, that is, a constant absorption coefficient k, no matter how far apart the surfaces are. This is in accordance with an earlier statement that it is desirable to evaluate the coefficients on the temperature terms in the energy balances, equations (3-2) and (3-4) at some mean temperature for each isothermic gas volume.

Consider two differential areas dA_1 and dA_2 separated by distances Δx, Δy and Δz measured on the three coordinate axes and therefore separated by a center-to-center distance r, where:

$$r = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2} \qquad (3\text{-}7)$$

The one-way radiation between the two differential areas is plainly proportional to the areas of each as viewed from the other, inversely proportional to the square of the separating distance, and must be diminished by the transmissivity of the intervening gas of absorption coefficient k and path length r. Expressing this methematically and putting in the proportionality constant $1/\pi$ which has been established elsewhere,[46] one obtains:

$$dq_{12} = \frac{dA_1 \cos\phi_1 \cdot dA_2 \cos\phi_2}{\pi r^2} \cdot e^{-kr} \sigma T_1^4 \qquad (3\text{-}8)$$

It is now necessary to integrate this expression over the two finite areas A_{s_1} and A_{s_2} to obtain the interchange, and combining this result with equation (3-6) one can evaluate the factors $f_{s_1 s_2}$. Due to the presence of both an exponential term and a polynomial it is not possible to integrate equation (3-8) analytically. At this point it is adequate to point out that two distinct cases of interchange between surfaces must be handled - surfaces in parallel planes and surfaces in perpendicular planes. Considering these two cases only for the parallel and

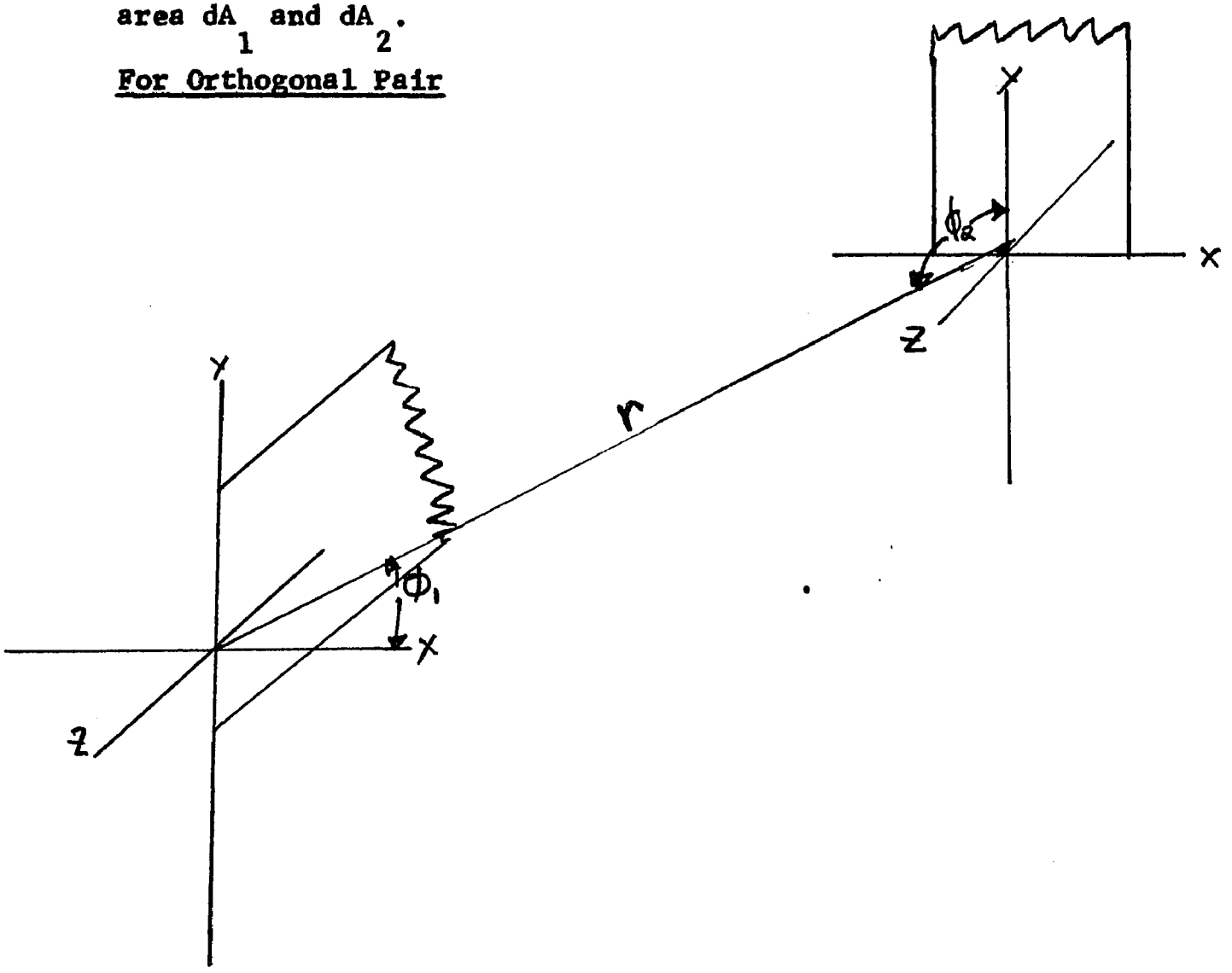
orthogonal cases, one arrives at the two following expressions to be numerically integrated to obtain the F_{ss}:

$$F_{ss} = \frac{\mathcal{G}_{s_1 \to s_2}}{6T^4} = f_{ss} A_s$$

$$f_{ss} = \int_{A_1} \int_{A_2} \frac{e^{-Kh}}{\pi r^2} \cos\phi_1 \cos\phi_2 \, dA_1 \, dA_2 \quad (3\text{-}9)$$

where r is the distance separating the incremental area dA_1 and dA_2.

<u>For Orthogonal Pair</u>



$\cos\phi_1 = \frac{y}{r}$ $\qquad$ $\cos\phi_2 = \frac{x}{r}$

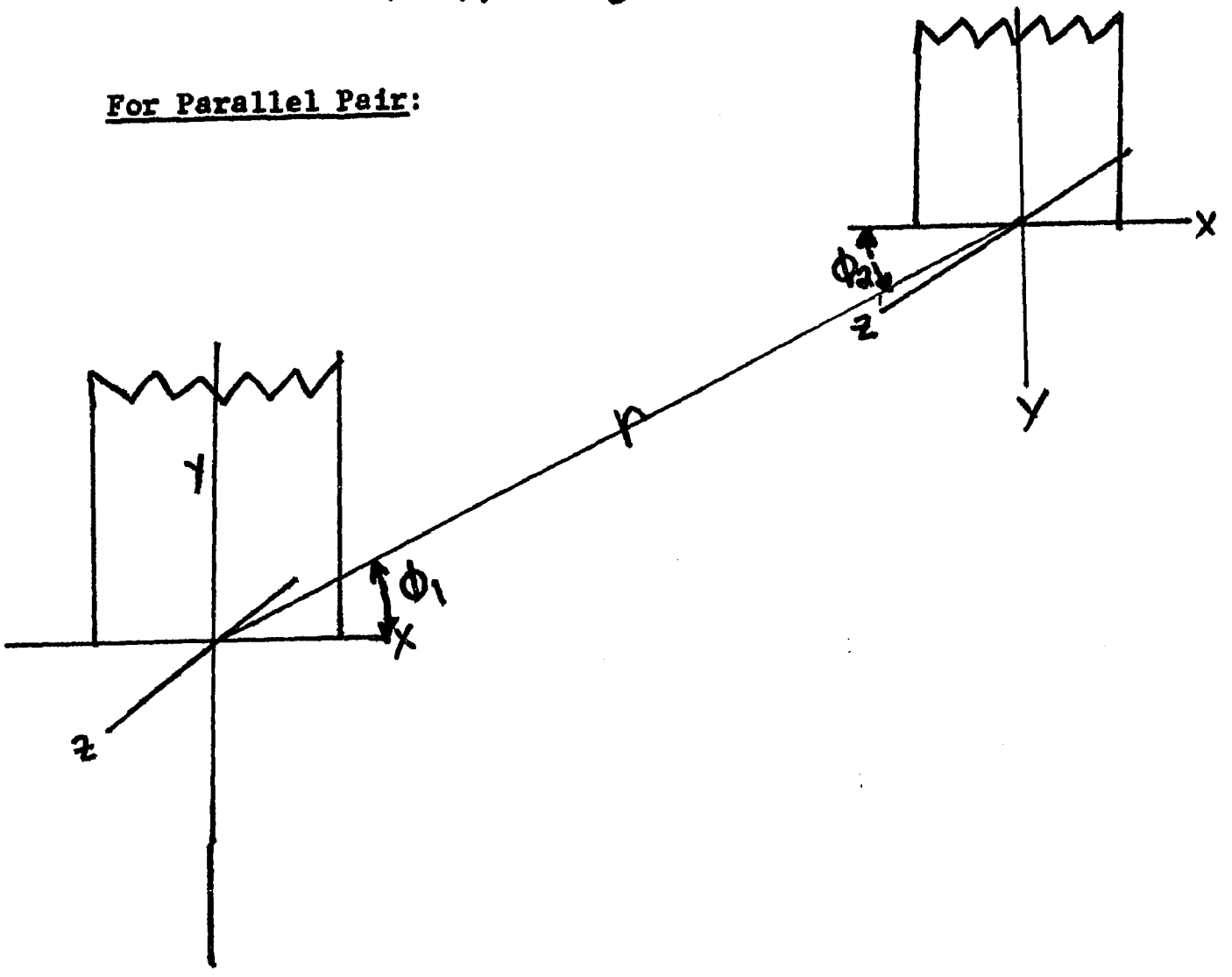
$dA_1 = dy\ dz$ $\qquad$ $dA_2 = dx\ dz$

$$r = \sqrt{\Delta x_a^2 + \Delta y^2 + \Delta z^2}$$

$$f_{ss} = \int\int\int\int e^{-kh/h^2} \cdot \frac{y}{h}\ \frac{x}{h}\ dz_R\, dy\, dx\, dz_E$$

$$= \int_0^L \int_{x_1}^{x_2} \int_{y_1}^{y_2} \int_{-\infty}^{+\infty} xy\, e^{-\pi h/h} + dz_R\, dy\, dx\, dz_E$$

For Parallel Pair:



$\cos \phi_1 = y/r$ $\qquad$ $\cos \phi_2 = /r$

$dA_1 = dy\, dz$ $\qquad$ $dA_2 = dx\, dz$

$$f_{ss} = \int\int\int\int \frac{e^{-kh}}{r^2} \frac{y_1}{r} \frac{y_2}{h} dz_R\, dy_1\, dy_2\, dz$$

oh

(3-12)

$$f_{ss} = \int_0^L \int_{y_1'}^{y_1''} \int_{y_2'}^{y_2''} \int_{-\infty}^{\infty} \frac{e^{-kr}}{r^4} y^2\, dz_R\, dy_1\, dy_2\, dz_E$$

(3-13)

Similar relationships exist for the other possible orientations, but will not be given here. It now becomes possible to perform numerical integration on equations (3-10) and (3-11) and any of the other required orientations.

The method of Gaussian quadratures was combined with Simpson's integration[1] to yield the numerical results.

All of the possible orientations were of the following form:

$$f_{ss} = \int_0^L \int_{\varphi_1'}^{\varphi_1''} \int_{\varphi_2'}^{\varphi_2''} f(x,y) \int_{-\infty}^{\infty} \frac{e^{-k\sqrt{U^2+Z^2}}}{(U^2+Z^2)^2} dz_R\, d\varphi_1\, d\varphi_2\, dz_E$$

Where

$$U = \sqrt{x^2 + y^2}$$

and f(x,y) takes into account the particular orientation being evaluated, the function can be brought outside of the two innter integrals because it is independent of z.

The limits of integration Q_1 and Q_2 are either both x, or both y, or x and y, again depending on the orientation of the surfaces under evaluation.

Evaluating the two indefinite integrals using Simpson's integration of the following form: (1)

$$\int_a^b f(x)dx = \frac{h}{3}\left[f(a) + 4f(a+h) + 2f(a+2h) + 4f(a+3h) + + 4f(a+(2m-1)h) + f(b)\right] \quad (3\text{-}15)$$

where $h = (b - a)/2m$

and m is the number of subdivisions used.

Considering the inner integral of (3-14) and allowing $U^2 = \sqrt{x^2 + y^2}$ and $r = \sqrt{x^2 + y^2 + z^2}$ results in:

$$\int_{-\infty}^{\infty} e^{-Kr}\frac{dz}{r^4} = \int_{-\infty}^{\infty} \frac{e^{-KU\sqrt{1+z^2/U^2}}}{U^4(1+z^2/U^2)^2}dz \quad (3\text{-}16)$$

Letting w = z/u or dz = udw yields:

$$\int_{-\infty}^{\infty} \frac{e^{-KU\sqrt{1+w^2}}}{U^4(1+w^2)^2}U\,dw = \frac{1}{U^3}\int_{-\infty}^{\infty} \frac{e^{-KU\sqrt{1+w^2}}}{(1+w^2)^2}dw \quad (3\text{-}17)$$

Defining:

$$F(KU) = \int_{-\infty}^{\infty} \frac{e^{-KU\sqrt{1+w^2}}}{(1+w^2)^2}\, dw \tag{3-18}$$

Noting:

$$F(KU) = 2\int_{0}^{\infty} \frac{e^{-KU\sqrt{1+w^2}}}{(1+w^2)^2}\, dw \tag{3-19}$$

$$\approx \int_{0}^{40} \frac{e^{-KU\sqrt{1+w^2}}}{(1+w^2)^2}\, dw$$

Equation (3-19) can now be evaluated from equation (3-15).

The replacement of the upper limit in equation (3-19) to a value of 40 was justified by evaluating (3-19) for a value of KU = 0, since when this substitution is made, equation (3-19) can be evaluated analytically yielding a value of $\pi/2$.

$$F(0) = 2\int_{0}^{\infty} \frac{dw}{(1+w^2)^2}$$

$$= 2\left[\frac{w}{2(1+w^2)} + \tfrac{1}{2}\,\mathrm{Tan}^{-1}(w)\right]_{0}^{\infty} = \pi/2. \tag{3-20}$$

The numerical evaluation of (3-19) using the upper limit of 40 and using h = .05 i.e. evaluating 800 terms

in the Simpson integration) resulted in a value of F(0) = 1.570795 (= π/2).

It is important to note that KU will always be positive, so that the evaluation of (3-19) by Simpson's Rule will result in numerical values smaller than for K = 0 (a clear gas).

Setting KU = 0 to evaluated F(KU) results in the largest numerical deviation from the correct value of the function.

The value of F(KU) can now be evaluated separately for various values of KU. This procedure was carried out for values of KU varying between 0 and 20, as shown on Figure 4. Above 20 the contributions of the terms constituting the numerical equivalent of the integral made no significant contribution to the calculation of the view factor and thus was taken as 0. This would correspond to a beam length of approximately 60 feet. The value being discarded results in an error less than one part in a million. Previous to this, graphical integration techniques could only yield results that were accurate to one part in a hundred.[18]

The function of F(KU) versus log (KU) was then fitted to a 7th order polynomial. In order to get the best possible fit, the function was broken down into four ranges,

a separate polynomial being used for each interval. The results of these curve fits can be found in Appendix B which gives the Fortran listing of the calculation procedure. The results are shown in Function W.[19]

Once the value of F(KU) is determined, it is necessary to evaluate the rest of the equation (3-14). This is done by using Gaussian quadratures,[1] the relationship is:

$$\int_{-1}^{1} f(x)\,dx = \sum_{i=1}^{N} W_i \cdot f(x_i) \qquad (3\text{-}21)$$

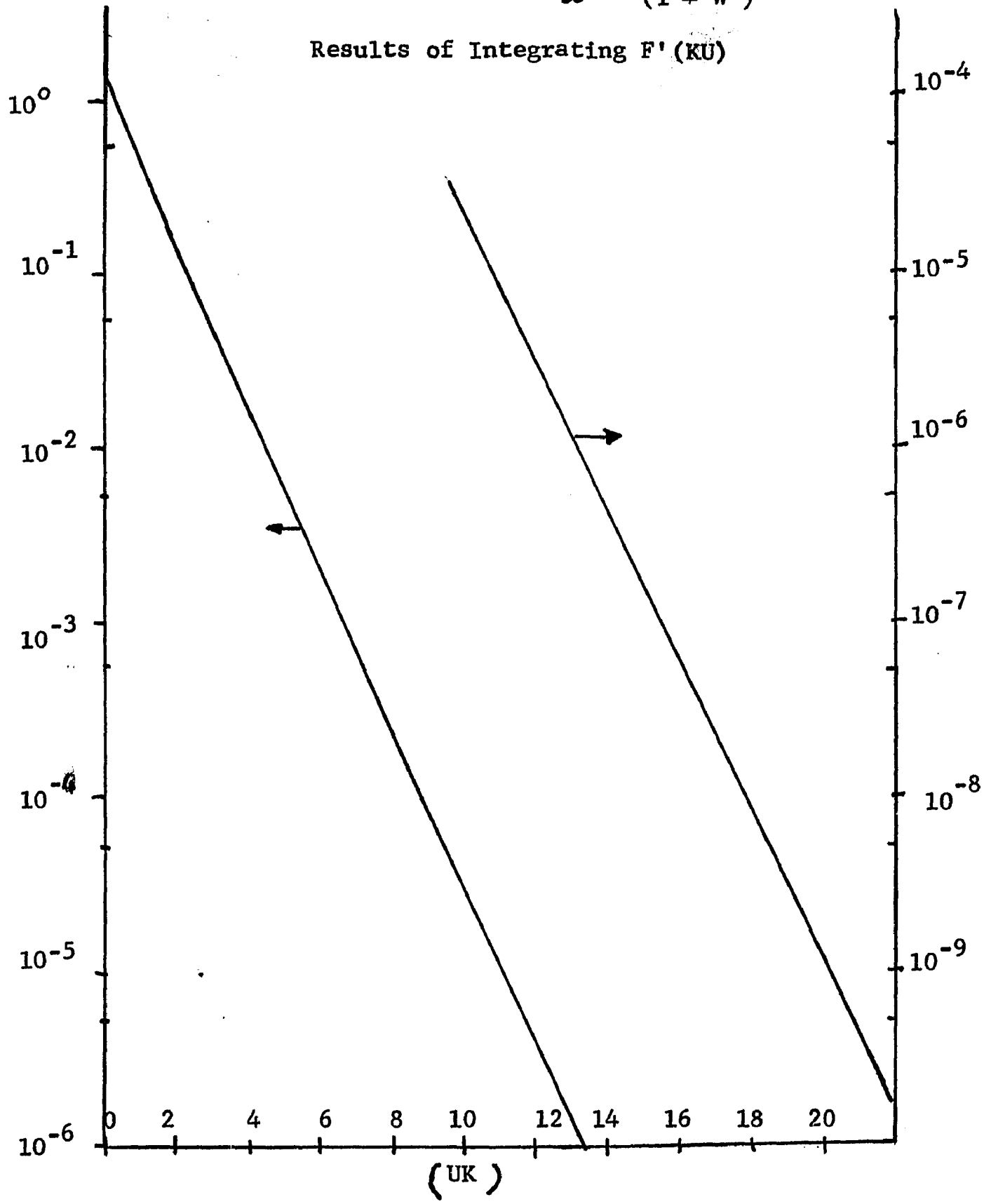
Where W_i is the weight factor different from W_i used by the Hermite integrations

X_i is the associated value of the independent variable

Figure 4.

$$F(UK) = \int_{-\infty}^{\infty} \frac{e^{-KU\sqrt{1+W^2}}}{(1+W^2)^2}\, dW$$

Results of Integrating F'(KU)



This relationship is applied twice to equation (3-14) to yield:

$$f_{ss} = \sum_{i}^{N} W_i \sum_{j}^{N} W_j \, f(x_i, y_i) \cdot F(UK) \tag{3-22}$$

In doing the calculation it was decided to use a value of 9 for N, resulting in 81 calculations for the determination of each F_{ss} term. The value of 9 for N was selected as a compromise between accuracy and time required to perform the calculation.

4. Interchange Between a Volume of Gas and a Bounding Surface

The defining equations for the one-way radiation, gas to surface or surface to gas, are as follows:

$$q_{sg} = A_s \cdot f_{sg} \cdot \sigma T_s^4 \tag{3-23}$$

$$q_{gs} = 4KV_g \cdot f_{gs} \, \sigma T_g^4 \tag{3-24}$$

As T_s approaches T_g, that is as the temperatures of the two elements approach each other, the values of q must likewise approach each other and it follows that:

$$A_s f_{sg} = 4KV_g \cdot f_{gs} \tag{3-25}$$

Formerly, when the values of F_{ss} were calculated by techniques with an estimated error in one part per hundred, the difference between the six values was small in comparison to the magnitude of the solution. By using the computer this problem has been eliminated, and the error reduced to approximately one part in a million.

In our two dimensional model the radiation entering and leaving the infinite areas can not be "viewed" by the surface. This means that only a total of four values of f_{ss} need to be calculated and summed together with the appropriate sign to yield the desired value of f_{sg}.

In instrumenting this procedure on the computer, great care must be taken in the determination of the correct orientation. Once this is accomplished, it becomes possible to use the already existing procedures for the calculations of the values of f_{ss}. The reader is referred to the Fortran listing of the calculation procedures and specifically to FUNCTION SG, on page 96 of Appendix B.

5. Interchange Between Two Gas Volumes

The defining equation for this final case of one-way radiation exchange, that is the energy transfer from one volume to another in the system may be written as:

$$q_{gg} = 4K\nu_g f_{gg} \cdot \sigma T_g^4 \qquad (3\text{-}26)$$

The meaning of this type of interchange areas, as before, is the fraction of the radiation originating in one element that reaches and is absorbed by any other in the system. If the two subscripts g refer to the same gas volume, q represents the radiation originating in the volume q_{gg} and absorbed by itself before reaching the boundary surface.

Once again the factor f_{gg} is function of the geometry of the system and the absorption coefficient of the gas. Just as it was possible to obtain f_{sg} by properly adding up six values of f_{ss} it is also possible to calculate f_{gg} by the appropriate addition of six values of f_{gs} in a system where the gas volumes have finite length. Plainly, f_{gg} must equal the sum of the f_{gs} values to the near faces of the second volume, minus the sum of the f_{gs} values seen dimly through the volume.

In the two dimensional model being developed in this study, only four values of f_{gs} need to be computed, the two edges at the end of the finite axis being unable to view each other.

The evaluation of f_{gs} again requires the evaluation of four f_{ss} terms. This means for each f_{gg} term calculated, a total of sixteen f_{ss} terms need to be evaluated. With the orientation determined, the evaluation of f_{gg} is accomplished by using FUNCTION SG which in turn uses FUNCTION SS.

C. Calculation of Direct Energy Transfer

It will be useful at this point to define a new type of interchange factor - one that when multiplied by σT^4 the black emissive power of a unit surface at the temperature of the radiating zone will yield directly the rate of energy absorption by any other zone in the system. Again the reacer is reminded that discussion is presently restricted to one in which all surfaces are perfect absorbers. These factors, in simplified nomenclature, will always be written as two letters - either ss, sg, gs or gg - where g and s stand for gas and surface respectively. Furthermore each of the letters will have a numerical subscript to identify which particular volume or surface is under consideration. For example the energy transferred from surface 2 to gas volume 4 is equal to $s_2g_4 \cdot W_{s2}$; similarly, the transfer from gas volume 4 to surface 2 is $g_4s_2 \cdot W_{g4}$, where W_{sn} is equal to the rate of emission from unit area of a black body at a temperature

indicated by subscript (i.e. temperature of surface n). Since, as the temperature of the gas zone and the surface zone approach each other (i.e. as the values of W approach each other) the net transfer between the two zones must be zero; the only way that this can happen is for $s_2 g_4$ to equal $g_4 s_2$, and thus, in this type of formulation the order in which two zones are mentioned is immaterial. This same reasoning applies to both surface-surface and gas-gas radiation.

The use of four symbols to describe interchange areas - two to indicate the types of zones involved (gas or surface) and two to indicate the particular zones - is a necessary consequence of having more than one gas zone in the enclosure.

It is noted that the total of all the interchange areas from any one zone to all other zones in the enclosure including itself must add up to the energy originating from that same area per unit emissive power. Expressed mathematically:

$$S_1 S_1 + S_1 S_2 + S_1 S_3 + + \cdots S_1 g_1 + S_1 g_2 + S_1 g_3 + \cdots = A_{S1} \tag{3-27}$$

or

$$\sum_i S_1 S_i + \sum S_1 g_i = A_{S_1} \tag{3-28}$$

and $g_1 g_1 + g_1 g_2 + g_1 g_3 + \cdots g_1 s_1 + g_1 s_2 + g_1 s_3 + \cdots$

$$= 4K V g_1 \qquad (3\text{-}29)$$

or $$\sum_i g_1 g_i + \sum g_1 s_i = 4K V g_1 \qquad (3\text{-}30)$$

D. Allowance for Grayness of Walls

The discussion which follows summarizes the work of Hottel[33-A] and Cohen [18]

All discussion up to this point has been concerned with a system in which all walls were perfect absorbers so that any energy which reached a wall surface was not reflected back into the system, hence total or perfect absorption took place. In general, however, the walls of a furnace are not black but are capable of reflecting some of the energy incident upon them. This reflected energy is distributed among all the gas and all the surfaces in accordance with the geometrical configuration of the various surfaces and the absorbing power of the gas; and that portion incident on the surface is again partially absorbed and partially reflected to repeat the process ad infinitum. The result is an extremely complex situation necessitating a condiseration of all possible beams of original energy and the results of an infinite number of reflections at the walls.

The technique for making allowance for this complicated problem to be given here is simply an extension of the one presented by Hottel[49] for the one-gas zone, multi-surfaced enclosure. As in Hottel's treatment where the direct interchange between two zones was equal to A_1F_{1G} or A_1F_{12} multiplied by the difference in emissive powers, so in the present case it is equal to a factor g_1g_2, s_2s_3, etc. Similarly, if one allows for the multiple reflections within the enclosure, defined as G_1G_2, G_1S_1 or S_1S_1, one can evaluate such factors as GS, GG, or SS from the direct factors gs, gg or ss. Note that the factors GG, GS, and SS like their lower-case counterparts all have the dimensions of area.

It is plain that the interchange area between any two zones in the enclosure cannot be a function of temperature as long as the physical properties of the system (emissivities and absorptivities) are independent of temperature. Therefore one is justified in evaluating the interchange areas at any convenient temperature and the results will be completely general. The problem of evaluating the interchange areas is very much simplified if one causes the temperature of <u>every surface and gas zone except one</u> to be maintained at absolute zero and as a consequence the emissive powers of every zone except one area are

all zero. This necessitates some sort of energy withdrawal from all zones, including the gas zones, by means unspecified but not interfering with transmission. Furthermore, one can let the temperature of the one emitting zone be such that its black emissive power is unity; i.e. such that σT^4 is unity. As a result of maintaining the temperature at $\sigma T^4 = 1$ at the single surface or gas zone, there will be a radiant flux at and toward every surface in the system, and at and away from it as well due solely to original emission from the one zone and to the multiple reflections within the enclosure. In a black system this reflected flux would, of course, be equal to zero. The terminology to describe this outgoing flux density will be R with a presubscript designating the original source of the energy and a final subscript, the reflecting surface. Thus if gas zone g_1 were the only emitter in the system, the flux density at surfaces s_1, s_2,..... would be indicated by $g_1R_{s_1}$, $g_1R_{s_2}$,..... . Similarly if surface s_1 were the only original emitter the flux density at surfaces s_2, s_3,..... would be $s_1R_{s_2}$, $s_1R_{s_3}$, ... but the flux density at surface s_1 would be equal to $s_1R_{s_1}$ due to reflections corrected for ε_{s_1} to allow for original emission from the surface.

i. Original Emitter is a Gas Zone

If, for example, gas zone g_1 is the sole original emitter then the total radiant flux at and away from any surface such as s_1 in the system is designated as $g_1 R_{s_1} \cdot A_{s_1} \cdot \sigma T^4$. Since this is the reflected flux, if one multiplies it by the ratio of the absorptivity (equal to emissivity) of the surface to the reflectivity of the surface (the complement of absorptivity) the result will be the absorbed energy at the surface, and since the value of σT^4 of the original emitter was made equal to unity, this must by definition be identical with the desired factor $G_1 s_1$. Expressing this statement more generally by considering the i-th gas zone and the j-th surface zone:

$$G_i S_j = S_j G_i = g_i R_{s_j} \cdot \frac{A_{s_j} \varepsilon_{s_j}}{\varphi_{s_j}} \qquad (3\text{-}31)$$

In order to determine the value of the reflected flux R at any surface one can write an energy balance on each surface. The total rate of energy impingement on surface s_1 is equal to the contributions from all the surfaces in the system including itself plus the energy it receives directly from the single gas zone which is the original emitter. If the sum of all these terms is then multiplied

by the surface reflectivity, then the result which is the reflected flux must be equal to ${}_{g_i}R_{s_i} \cdot A_{s_i}$. This summation can be carried out for every surface in the system yielding a set of equations, one for each surface, as follows:

$$\left[S_1 S_1 \cdot g_i R_{s_i} + S_1 S_2 \cdot g_i R_{s_2} + \cdots g_i S_1\right] P_{s_1} = A_{s_1} \cdot g_i R_{s_1}$$

$$\left[S_1 S_2 \; g_i R_{s_1} + S_2 S_2 \cdot g_i R_{s_2} + \cdots g_i S_2\right] P_{s_2} = A_{s_2} g_i R_{s_2}$$

$$\left[S_1 S_3 \; g_i R_{s_1} + S_3 S_2 \cdot g_i R_{s_2} + \cdots g_i S_3\right] P_{s_3} = A_{s_3} \cdot g_i R_{s_3}$$

(3-32)

It is apparent that the total number of equations in set (3-32) is exactly equal to the number of unknown reflected-flux densities R_s.

Expression (3-32) in matrix form:

$$\left|D\right| \cdot \left| g_i R_{s_L} \right| = \left| -g_i S_L \right| \qquad (3\text{-}33)$$

$$D = \begin{vmatrix} S_1S_2 - A_{s_1}/\rho_{s_1} & S_1S_2 & S_1S_3 & \cdots \\ S_1S_2 & S_2S_2 - A_{s_2}/\rho_{s_2} & S_2S_3 & \cdots \\ S_1S_3 & & S_3S_3 - A_{s_3}/\rho_{s_3} & \cdots \\ & S_2S_3 & & \\ \bullet & \bullet & \bullet & \cdots \\ \bullet & \bullet & \bullet & \cdots \\ \bullet & \bullet & \bullet & \cdots \end{vmatrix}, {}^{g_i}R_{s_L} \begin{vmatrix} {}^{g_i}R_{s_1} \\ {}^{g_i}R_{s_2} \\ {}^{g_i}R_{s_3} \\ \bullet \\ \bullet \\ \bullet \end{vmatrix}, {}^{-g_1}s_L = \begin{vmatrix} -{}^{g_i}s_1 \\ {}^{g_i}s_2 \\ {}^{g_i}s_3 \\ \bullet \\ \bullet \\ \bullet \end{vmatrix}$$

(3-33A)

Equation (3-33) can then be solved by taking the matrix inverse:

$$|g_i R_{s_L}| = |D|^{-1} \cdot |-g_i s_L| \qquad (3\text{-}34)$$

The reader is again referred to Apprendix B to SUBROUTINE INVERT page 104 to get the details of the inversion procedure. The invert algorithm takes advantage of the fact that D is a diagonally dominant matrix.

From the values of the reflected flux density at the various surfaces it is also possible to calculate the total interchange factor between any two gas cubes. If gas zone g_1 is the original emitter, then the total reception at any other gas zone g_2 is equal to the direct radiation from g_1 to g_2 (equal to $g_1 g_2$) plus the sum of the products of the reflected flux at each surface in the system multiplied by the fraction of that flux which reaches and is absorbed by gas zone g_2. Again, since the black-body emission from zone g_1 has been set at unity this sum represents the desired factor $G_1 G_2$. The general expression for this factor between any two gas zones m and n then becomes:

$$G_m G_n = g_m g_n + \sum_i (g_m R_{s_i}) \cdot (\varepsilon_i g_n) \qquad (3\text{-}35)$$

ii. Original Emission in a Surface Zone

In order to obtain the one remaining factor - interchange between two surfaces - it is necessary to let one of the surface zones be at such a temperature that its black body emission would be equal to unity and to let all other surfaces as well as all gas zones be at absolute zero. One can again write energy balances on each surface in the system, the only changes being that there will be no direct radiation from the gas and that the surface that is the original emitter will send out, in addition to the reflected flux term, an amount of energy per unit area equal to its emissivity. The set of resultant equations for this case where surface s_1 is the sole original emitter is:

$$\left[S_1 S_1 (g_1 R_{s_1} + \varepsilon_{s_1}) + S_1 S_2 \cdot {}_{s_1}R_{s_2} + \cdots\right] \Psi_{s_1} = A_{s_1} \cdot {}_{s_1}R_{s_1}$$

$$\left[S_1 S_2 ({}_{s_1}R_{s_1} + \varepsilon_{s_1}) + S_2 S_2 \cdot {}_{s_1}R_{s_2} + \cdots\right] \Psi_{s_2} = A_{s_2} \cdot {}_{s_1}R_{s_2}$$

$$\left[S_1 S_3 ({}_{s_1}R_{s_1} + \varepsilon_{s_1}) + S_3 S_2 \cdot {}_{s_1}R_{s_2} + \cdots\right] \Psi_{s_3} = A_{s_3} \cdot {}_{s_1}R_{s_2}$$

(3-36)

Just as before the total number of equations is equal to the total number of unknown reflected flux densities and the solution for any one of them may be written as:

$$|g_i R s_L| = |D|^{-1} \cdot |S_i S_L| \qquad (3\text{-}37)$$

where D is exactly the same as the expression obtained earlier and given in equation (3-33).

Hottel[46] and Cohen[18] demonstrate that

$$S_i S_j = S_j S_i \qquad (3\text{-}38)$$

E. Allowance for a Real Gas

It has already been shown in Chapter 2, that it is possible to approximate the behavior of a real gas in a system by considering it to be a weighted sum of gray gases and one clear gas, each weighted in proportion to the energy fraction of the spectrum that it occupies. Furthermore, since in most systems it is the first beam that is the important one all successive beams undergo double attenuation by the gas and the surface on each pass, an adequate approximation to the real gas is the simple sum of two characteristic gases - one having an absorption coefficient k and occupying the fraction "a"

of the spectrum, the second being a clear gas (absorption coefficient equals zero) and occupying the fraction "1-a" of the spectrum.

One is cautioned that such an approximation would not be valid in a system where the K_1 is so low that the gas transmissivity is very high and where the walls are highly reflective. For the single-gray + clear-gas case the emissivity and absorptivity are then related to the path length x as follows:

$$\varepsilon_x = a\left(1-e^{-Kx}\right) \tag{3-39}$$

If one then fits the above exponential to the actual emissivity versus path length curve for a real gas, at a path length equal to the primary path length for the system, and at twice this value, mathematical manipulation leads to the following expression for "a", the fraction of the spectrum occupied by the gray portion:

$$a = \frac{\varepsilon_1^2}{2\varepsilon_1 - \varepsilon_2} \tag{3-40}$$

The value of kL for this case is then equal to:

$$KL = LN\left(\frac{\varepsilon_1}{\varepsilon_2 - \varepsilon_1}\right) = LN\left(\frac{1}{1-\varepsilon_1/a}\right) \tag{3-41}$$

In both the above expressions ε_1 refers to the gas emissivity evaluated at the characteristic path length for the system L, and ε_2 is the emissivity evaluated at twice that path length.

Since ε_x is a function of temperature, it is now possible to find a series of "ε" at different temperatures and calculate the corresponding values of "a". The resulting values of "a" can now be fitted to polynomials in temperature resulting in:

$$a = b_0 + b_1 T + b_2 T^2 + b_3 T^3 + b_4 T^4 + b_5 T^5 \tag{3-42}$$

The value of ε_x was calculated from a regression fit of the emissivity data reported by Hottel in McAdams Chapter 4.[49] The regressed data fit considers carbon dioxide, sulfur dioxide and water vapor. The calculation procedures are presented in the Fortran program in Appendix B FUNCTION EMISS. The regressed curve fit takes into

consideration the partial pressure of the components, the total pressure of the system and the temperature of the gas system being determined.

Once the value of "a" has been determined as a function of temperature it can be applied to the following equation:

$$SS = a\,[SS]_{KL} + (1-a)[SS]_{KL=0} \tag{3-43}$$

The value of $[ss]_{kL\,=\,0}$ represents the value of the interchange area evaluated for a clear gas.

$$GS = a\,[GS]_{KL} \tag{3-44}$$

$$GG = a\,[GG]_{KL} \tag{3-45}$$

It is to be noted that, as a result of this real-gas approximation, several important changes have been made:

1. In addition to the factos SS, SG and GG evaluated at kL by the methods of the previous sections, one must evaluate a new set of the SS-factors for the clear gas portion; i.e. at kL = 0.
2. As before, the sum of the total interchange factos from any surface to all surface and gas zones is

equal to the surface emissivity times the area. The sum of the factors from one gas zone to all zones, however, is now given by:

$$\sum_j G_i G_j + \sum_j G_i S_j = 4 K a V_{g_1} \qquad (3\text{-}46)$$

The values of the partial pressure of CO_2, SO_2 and H_2O are calculated via a flue gas analysis. No attempt was made to calculate the values of partial pressure within each isotherm, the flow patterns being assumed known throughout the system.

In evaluating the total interchange areas within a given zone, each in turn was considered to be the original emitter. This enabled the evaluation of the set of factors at the KU of the emitting zone. This means that G_1G_2 no longer is equal to G_2G_1, since each is now based on evaluations at different temperatures.

It was necessary first to estimate all the temperatures in the system and then, after the final solution to the problem, revise the estimates of temperature and repeat the computational procedure. This procedure was continued until the difference between the guessed values and the actual values was less than $.5^{\circ}$ Rankin.

This procedure, however, is not completely rigorous since one should allow for that fact that the k_L of the gas is constantly changing with path length. It is conceivable that one could, for each individual problem, start at the beginning and repeat the numerical integrations, allowing for the fact that the absorption coefficient was changing as one moved along a path length. It should be stated that the computer time involved in such a technique would be absolutely prohibitive for engineering calculations.

F. Energy Balance of Gas Volumes

The energy balance on the gas volumes and the surface area have been decoupled . This procedure has two chief advantages:

1. It reduces the computational magnitude of the energy balances to more manageable size.
2. It takes advantage of wall temperature being relatively stable due to the presence of sinks (i.e. the reactor).

The disadvantage of the procedure is that the convergence procedure has to be repeated for the surface and volume energy balances.

The term q_B in the energy balance on a gas zone in equation (3-2) represents the net energy transferred to the

zones by the bulk flow of the gas stream. It is equal to the total enthalpy above any arbitrary base temperature of all entering streams minus the total enthalpy above the same base temperature of all leaving streams. In order to formulate this enthalpy flux vorrectly, one would need to know the details of the gas flow pattern within the enclosure. Unfortunately, for most enclosures one does not have a detailed description of the flow pattern.

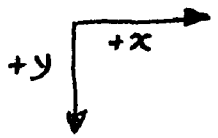
Some studies have been carried out utilizing the use of metal filings being introduced into the flow stream. Stop action photography techniques are then employed to determine actual flow distribution. The results of one such study were reported by Yeich[93] and are used in this study. The details of this flow pattern are presented in Appendix A.

The flow patterns were defined for an infinite furnace, hence no flow is permissable along the infinite axis. The flow in the plane perpendicular to the infinite axis was resolved into the flow along the other two mutually perpendicular directions. Flow from the eighteen gas volumes would thus be represented as $(GM_{x_{18}}, GM_{y_{18}})$.

A computational check was performed to verify that the gas volume had neither a positive or a negative accumulation term. It should be noted that GM_{xj} is a vector quantity

and is used in the same sense as are the gas volume orientations, as shown in Figure 2.

i.e. the coordinate system is:



It now becomes possible to write an energy balance on the gas volume:

Note the subscript I refers to inlet conditions

o refers to outlet conditions

$$\text{Heat In} - \text{Heat Out} + \text{Sources} = 0 \qquad (3\text{-}47)$$

$$\left[\text{Enthalpy}_I - \text{Enthalpy}_O\right]_{\text{Bulk Flow}} + \left[\text{Heat}_I - \text{Heat}_O\right]_{\text{Convection}}$$

$$+ \left[\text{Radiant Energy}_I - \text{Radiant Energy}_O\right] + \text{Heat Release}$$

$$\text{by Combustion} = 0 \qquad (3\text{-}48)$$

Equation (3-48) can now be rewritten for gas volume i

$$[GM_{x_I} \cdot H(T_{j_1}) - GM_{x_I} H(T_{j_2})] + [GM_{y_I} \cdot H(T_{j_3}) - GM_{y_0} \cdot H(T_{j_4})$$
$$+ [h_{x_1} A_{x_I} ({}_sT_{x_I} - T_i) - h_{x_0} A_{y_0} (T_i - {}_sT_{x_0})]$$
$$+ [h_{y_1} A_{y_I} ({}_sT_{y_I} - T_i) - h_{y_0} A_{y_0} (T_i - {}_sT_{y_0})]$$
$$+ \sigma [\sum_j G_j G_i \cdot T_j^4 + \sum_j S_j G_i \cdot T_j^4 - T_i^4 (\sum_j G_i G_j + \sum_j G_i S_j)$$
$$+ E_T \cdot \phi (X_i, Y_i) = 0 \qquad (3\text{-}49)$$

where

H(T) is the enthalpy of the flue gas and is calculated by integrating $C_p(T) = c_0 + c_1 T + c_2 T^2 + c_3 T^3$ between absolute 0 and T

$$H(T) = c_0 T + \tfrac{1}{2} c_1 T^2 + \tfrac{1}{3} c_2 T^3 + \tfrac{1}{4} T^4 \qquad (3\text{-}50)$$

h_{X_I} is converted heat transfer coefficient between the gas and the gas surface with contact area A_{X_I} and ${}_sT_{X_I}$ is the surface temperature in contact with the volume.

$\phi (X_i\ Y_i)$ is the fraction of the total heat released within the isothermal gas volume by combustion

E_T is the total heat released within the furnace.

$$a_{ii}\,\sigma T_i^4 + \sum_j b_{ij}\,T_j^4 + 1/4\,\frac{\alpha}{T_{x_I}^3}\,T_{x_I}^4 + \frac{1}{4}\frac{\beta}{T_{x_I}^3}\,T_{y_I}^4 + \frac{1}{4}\,\frac{\gamma'''}{T_{x_0}}\,T_{x_0}^4 + \frac{\delta'''}{T_{y_0}^3}\,T_{y_0}^4 = C_i \qquad (3\text{-}51)$$

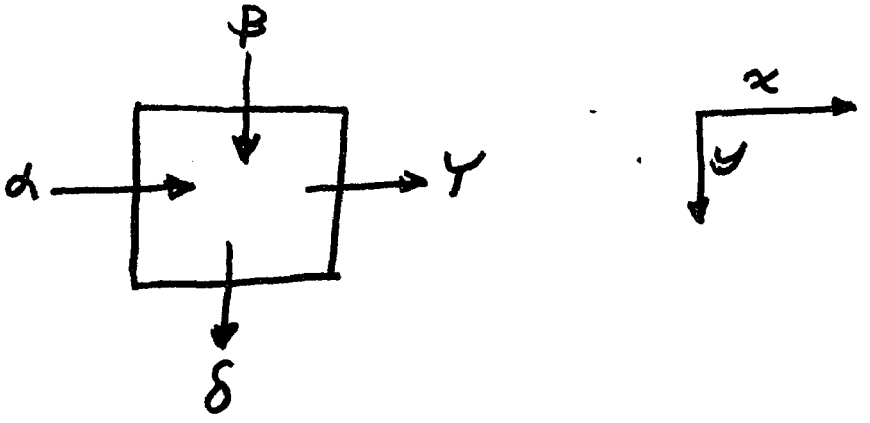
Where

$$a_{ii} = -\sigma\left[\sum_j G_i G_j + \sum_j G_j S_i\right] + 1/4\left[H_{x_I} A_{x_I} - h_{y_I} A_{y_I} - h_{x_0} A_{x_0} - h_{y_0} A_{y_0}\right]\frac{1}{T_i^3} + 1/4\left[\alpha'' + \beta'' + \gamma'' + \delta'\right]\cdot\frac{1}{T_i^3}$$

$$b_{ij} = \sigma F_j G_i$$

$$C_i = \left[-\sigma\sum_j G_i G_j \cdot T_j^4 + \left(-h_{x_I} A_{x_I}\, {}_sT_{x_I} - h_{y_I} A_{y_I}\, {}_sT_{y_I} - h_{y_0} A_{y_0}\, {}_sT_{x_0} - h_{y_0} A_{y_0}\, {}_sT_{y_0}\right) - E_T\,\phi(x,y) + \alpha'' + \beta''' + \gamma''' + \delta'''\right] - 3/4\left[\alpha' T_{x_I} + \alpha'' T_i + \beta' T_{y_I} + \beta'' T_i + \gamma' T_i + \gamma'' T_{x_0} + \delta' T_i + \delta'' T_{y_0}\right] + HT_{\infty} T_i$$

Where $\alpha, \beta, \gamma, \delta$ are the bulk flow terms from the four sides of the isotherm under consideration.



The single prime on the bulk flow term indicates that there is a sensible heat flow from the facing isotherm. The double prime on the bulk flow term indicates the sensible heat flow from within the isotherm. The triple prime of the bulk flow term indicates the enthalpy gain within the isotherm.

The bulk flow terms are evaluated as follows: (3-51a)

$GM_{x_I} = 0$

No Area Contact	Area Contact
$q' = GM_{x_I} \cdot c_p(T_{o_{x_I}})$	$q' = 0.0$
$q'' = 0.0$	$q'' = 0.0$
$q''' = -GM_{x_I}[H(T_{o_{x_I}}) - c_p(T_{o_{x_I}}) \cdot T_{o_{x_I}}]$	$q''' = -GM_{x_I} \cdot H(T_{Fa}$

$GM_{x_I} < 0.0$	$GM_{x_I} = 0.0$
$q' = 0.0$	$q' = 0.0$
$q'' = GM_{x_I} \cdot c_p(T_{o_i})$	$q'' = 0.0$
$q''' = -GM_{x_I}(-H(T_{o_i}) - c_p(T_{o_i}) \cdot T_{o_{x_I}})$	$q''' = 0.0$

$$q = q' + q'' + q'''$$

$GM_{y_I} > 0$

No Area Contact	Area Contact
$\beta' = GM_{y_I} \cdot c_p(T_{o_{y_I}})$	$\beta' = 0.0$
$\beta'' = 0.0$	$\beta'' = 0.0$
$\beta''' = -GM_{y_I}[H(T_{o_{y_I}}) - c_p(T_{o_{x_I}}) \cdot T_{o_{y_I}}]$	$\beta''' = -GM_y \cdot H(T_{h_2})$

$GM_{y_I} < 0$

$\beta' = 0$

$\beta'' = GM_{y_I} \cdot c_p(T_{o_i})$

$\beta''' = -GM_{y_I} \cdot [H(T_{o_i}) - c_p(T_{o_i}) \cdot T_{o_i}]$

$GM_{y_I} = 0.0$

$\beta' = 0.0$

$\beta'' = 0.0$

$\beta''' = 0.0$

$$\beta = \beta' + \beta'' + \beta'''$$

$GM_{x_o} > 0$	$GM_{x_o} = 0$
$\gamma' = 0$	$\gamma' = 0.0$
$\gamma'' = GM_{y_I} \cdot c_p(T_{o_i})$	$\gamma'' = 0.0$
$\gamma''' = -GM_{y_I}[H(T_{o_i}) - c_p(T_{o_i}) \cdot T_{o_i}]$	$\gamma''' = 0.0$

$GM_{x_o} < 0$

No Area Contact

$\gamma' = 0.0$

$\gamma'' = GM_{x_o} \cdot c_p(T_{o_{x_o}})$

$\gamma''' = GM_{x_o} \cdot [H(T_{o_{x_o}}) - c_p(T_{o_{x_o}})]$

$GM_{x_o} < 0$

Area Contact

$\gamma' = 0.0$

$\gamma'' = 0.0$

$\gamma''' = GM_{x_o}[H(T_{Fa})]$

$\gamma = \gamma' + \gamma'' + \gamma'''$

$GM_{y_o} > 0$

$\delta' = 0$

$\delta'' = -GM_{x_o} c_p(T_{o_{x_o}})$

$\delta''' = GM_{x_o} [H(T_{o_{x_o}}) \cdot T_{o_{x_o}}]$

$GM_{y_o} < 0$

Area Contact

$\delta' = 0.0$

$\delta'' = 0.0$

$\delta''' = -GM_{y_o} H(T_{Fa})$

$GM_{y_o} < 0$

No Area Contact

$\delta' = 0.0$

$\delta'' = -GM_{x_o} \cdot c_p(T_{o_{x_o}})$

$\delta''' = GM_{y_o} [H(T_{o_{y_o}}) - c_p(T_{o_{y_o}}) \cdot T_{o_{y_o}}]$

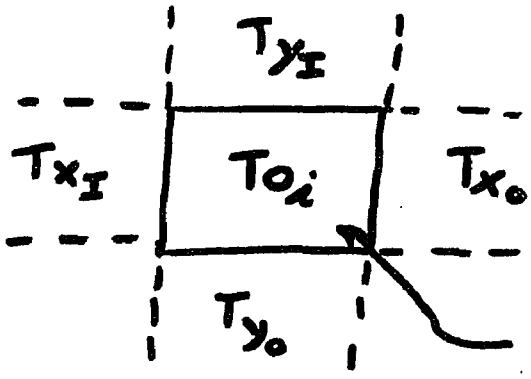
$GM_{y_o} = 0$

$\delta' = 0.0$

$\delta'' = 0.0$

$\delta''' = 0.0$

$\delta = \delta' + \delta'' + \delta'''$



The relationship used in equation (3-51) can be changed by reference to the above figure. The gas volume i has a temperature T_{O_i}. The temperature for the isotherm to the left is T_{X_I}. The subscript I refers to inlet temperatures in reference to positve X axis. Similarly, the 0 in T_{X_O} refers to outlet temperature. The T_{Y_I} and T_{Y_O} have similar meanings in reference to the positive Y area. The temperature T_{FA} refers to the fuel-air temperature of the incoming fuel. The reader should note that all possible burner locations are accounted for by the four special cases of area contact. To illustrate this point, consider the case for and GM_X 0. If $GM_X = 0$, no fuel-air mixture could enter since no bulk flow term is present. If GM_X 0 the bulk flow would have to go in the direction of the furnace wall and since the gas volume is in contact with the wall, there could clearly be no flow. Consideration of the other three cases leads to similar results.

Temperature terms which have a presubscript s such as ${}_sT_{X_I}$ would refer to a surface temperature of the enclosing furnace wall. The subscript X_I would have the same meaning as previously discussed.

Equation (3-51) may now be written for every gas volume with the number of unknown gas volume temperatures equal to the number of equations. The matrix is again diagonally dominant and can be solved by the methods of Gauss-Jordan without double pivoting. The matrix contains surface area temperatures which are assumed constant in the solution of the gas volume temperature. In the next section the surface area temperature balance will be made assuming known gas volume temperature. This procedure allows for seperation of the surface energy balance from the gas volume energy balance.

The two energy balances are then solved repeatedly (adjusting the total interchange area for the newly calculated temperature) using the Newton-Raphson technique.

G. Energy Balance on Surface Area

The heat balance on the surface is expressed as:

$$\text{Heat In} - \text{Heat Out} = 0 \qquad (3\text{-}52)$$

or

Heat release due to combustion + Radiant Energy In - Radiant Energy Out + Heat Transfer In - Heat Transfer Out by convection - Heat Loss to Ambient Surroundings = 0 (3-53)

The enthalpy consideration is zero as a result of considering heat transfer due to bulk flow to have occurred before flue gas has passed through the "porous membrane."

i. The Source Term

The source term accounts for burner heat release that is very near the furnace. It is assumed that the detailed information of such heat release is known. This term is presented as:

$$H_S = E_{Total}\ \Psi(x,y) \qquad (3\text{-}54)$$

where $\Psi(X,Y)$ = fractions of total heat released at surface area.

ii. Radiant Energy Term

The radiant energy term accounts for all radiation in the system. Radiant energy from all the surface zones and all of the gas volumes over surface i may be expressed as

$$R = \left[\sum_j G_j G_i \sigma T_j^4 + \sum_j S_j S_i \sigma T_j^4 \right]$$

$$+ \left[- \sum_j S_i G_j \sigma T_i^4 - \sum_j S_i S_j \sigma T_i^4 \right]$$

(3-55)

iii. Convective Heat Transfer

Convective heat transfer can take place in the bounding wall aa well as internal heat transfer surface.

If the heat transfer takes place in the bounding wall, the net convected heat transfer becomes:

$$= h_c (T_G - T_i) A_i - h_c'' (T_i - T_{sink}) A_i - h_c' (T_i - T_{proc}) A_i \quad (3\text{-}56)$$

where

T_G is the temperature of the adjoining gas volume

T_i is the temperature of Area A_i

T_{sink} is the temperature of ambient

T_{proc} is the temperature of the process fluid

h_c is the adjusted overall heat transfer coefficient between surface i and the flue gas

h'_c is the adjusted overall heat transfer coefficient between the area A_i and the process fluid

h_c'' is the adjusted overall heat transfer coefficient between the area A_i and the ambient temperature

The net convected heat transfer for internal surface becomes:

$$h_c(T_G - T_i)A_i\Big|_{Left} + h_c(T_G - T_i)A_i\Big|_{Right} - h_c'(T_i - T_{proc})A_i \quad (3\text{-}57)$$

Note internal surfaces always have a vertical orientation.

iv. Net Heat Absorbed by a Surface

The net heat absorbed by a surface can be expressed as:

$$[E_{Total} \cdot \psi(x,y)] + [h_c(T_G - T_i)A_i]$$
$$+ \left[\sum_j G_i G_j \sigma T_j^4 + \sum_j S_j S_i \sigma T_j^4 - \sigma T_i^4 \left(\sum_j S_i G_j + \sum_j S_i S_j\right)\right] \quad (3\text{-}53)$$

The overall heat balance on surface zone i

$$E_T \psi(x,y) + \sum_j G_j S_i \sigma T_j^4 + \sum_j S_j S_i \sigma T_j^4$$
$$- \sigma T_i^4 \left[\sum_j S_i G_j + \sum_j S_i S_j\right] + h_c(T_G - T_i)A_i$$
$$- h_c'(T_i - T_{proc})A_i - h_c''(T_i - T_{sink})A_i \quad (3\text{-}59)$$
$$= 0$$

It ia now possible to write (3-59) for each surface area and linearize it in terms of T^4. The resulting equation can be solved for T_i^4 by assuming the gas volume temperature as constant. The equation has the form:

$$A_{ii}\, T_i^4 + \sum_j b_{ij}\, T_j^4 = C_i \qquad (3\text{-}60)$$

where

$$A_{ii} = \sigma\left[\sum_j S_j S_i - \sum_j S_i G_j\right] - \left[(h_c + h_c' + h_c'')\, A_i \frac{1}{T_i^3}\right]^{1/4}$$

$$B_{ij} = \sigma\, S_j S_i$$

$$C_i = -\sigma \sum_j G_j S_i T_j^4 - (h_c T_G + h_c' T_{proc} + h_c'' T_{sink})\, A_i - E_T\, \psi(\alpha, y) + \left[(h_c + h_c' + h_c'')\, A_i T_i\right]^{3/4}$$

The reader should note that T_i is treated as a constant and the equation is then solved. The solution is then used to resolve the equation. This procedure is repeated until the maximum difference between two successive T_i's is less than some abstract small quantity. 1° R was used as the criterion for convergence in this study.

2. The Kinetic Model

The complete description of the kinetic model is given by Robertson[62] and will not be repeated here.

A brief discussion, however, will be presented and the method of incorporating the pointwise temperature distribution of the reactor wall will be explained.

A. Description of Reactor

The reactor is a tube 400 feet long placed in a furnace in a series of U bends. The tube runs up and down in the reactor to prevent bending of the tube in the center which would occur if it was strung out in an elongated position.

The tube itself is 3.640 inches in inside radius and the walls are .226 inches thick (a nominal four inch tube). The tube is assumed to have scale both on its inner and outer walls that add to the resistance of heat flow. The reactor tube was considered to be free of coke deposit. All initial design considerations did not consider the effect of coke on overall performance. However, a coke profile was calculated and later used to determine its effect on reactor yield.

The reactor inlet pressure was adjusted to give an

outlet pressure of two atmospheres. The initial reactor feed comsisted of steam, ethane and propane. It is possible to include other material as long as the various mechanisms of reaction are known. The user would have to input kinetic and thermo-dynamic data. These however, were not included as a part of this study.

B. The Material Balance

Considering any incremental length of reactor the material balance can be written as:

IN = OUT + Change By Reaction + Accumulation (3-61)

Since steady state is assumed, the only accumulation term involved in this study was the deposition of carbon on the reactor wall. When (3-61) is rewritten in

$$\text{syn}\sum_i N_i\Big|_{INLET} = \sum_i \left[N_i\Big|_{OUTLET} + \sum_j A_{ij} N_{ij}\Big|_{INLET} \cdot \Delta X \right]$$

$$\sum_i N_i\Big|_{INLET} = \sum_i \left[N_i\Big|_{OUTLET} + \sum_j A_{ij} N_{ij}\Big|_{INLET} \cdot \Delta X_j \right] + A_{cc} \qquad (3\text{-}62)$$

where

N_i = number of molar flow rate into incremental reactor

A_{ij} = stoichiometric coefficient of the i^{th} chemical component in the j^{th} reaction

N_{ij} = the molar flow rate of the j^{th} reaction of the i^{th} component

ΔX_j = the incremental conversion calculated within the incremental length

A_{cc} = accumulation term

Equation (3-62) can be written for the i^{th} component to yield a component balance.

C. Calculation of Incremental Conversion

For the plug flow reactor the space time is defined by

$$\tau = \frac{1}{s} = C_{A_0} \int_{x_0}^{x_2} dX_A / -r_A \qquad (3\text{-}63)$$

where

τ = is the reactor space time =

dX_a = differential conversion of A component

$-r_A$ = rate of reaction

C_{A_0} = initial concentration of component A

V = reactor volume =

F_a = volumetric flow rate

S = space time

Considering finite differences in equation (3-63) and solving for $X_a = X_2 - X_1$ results in:

$$\Delta X_A = -r_A \Delta \tau / C_{A_0} \tag{3-64}$$

Equation (3-64) can now be expressed in terms of flow rates:

$$\Delta X_A = \pi R^2 / F_{A_0} (-r_A) \Delta L \tag{3-65}$$

Where ΔL = the incremental reactor length under consideration.

Defining the reaction rate ($-r_A$) in terms of the Arrhenius rate law:

$$(-r_A) = e^{-E_A^*/RT} \left[K_o \prod_j C_{A_i}^{N_{A_i}} - K \prod_j C_{A_i}^{N_{A_i}} \right] \tag{3-66}$$

Where

K_o = the Arrhenius frequency factor

E_A^* = the Arrhenius energy of reactivation

R = gas constant

T = absolute temperature

N_{A_i} = order of reaction j of the i^{th} component

K = equilibrium constant

C_{a_i} = concentration of component

The reader should note π_j refers to the Pi product of the concentration terms. The concentration terms can be calculated from the ideal gas law:

$$C_a = P_a / R'T \qquad (3\text{-}67)$$

where

P_a = Pressure of component a

R' = Gas constant

D. Calculation of Pressure Profile

In order to calculate the pressure at the end of the incremental reactor section a momentum balance was performed using the Bernouli equation.(51)

$$\Delta P = \left[\frac{V_1 + V_2}{2} \Delta W F \Delta L / R + V_2^2 - V_1^2 \right] / 2g \qquad (3\text{-}68)$$

where

P = Pressure drop

V_1, V_2 = Reactor gas velocity at inlet, outlet conditions

F = Friction factor

L/R = Incremental length of reactor radius ratio

g = Gravitational constant

E. Calculation of Temperature Profile

In order to calculate the temperature at the end of the reactor increment, a heat balance was performed on the incremental reactor segment.

Heat flux in = sensible heat gain + heat of reaction (3-69)

$$UA\Delta T_1 = \sum_j F_j C_{P_j} \Delta T_2 + \sum_i \Delta H_i F_{K(i)} \Delta X_i \quad (3-70)$$

where

- U = to the overall heat transfer coefficient from reactor tube outer wall to reaction fluid
- A = the area through which heat flux is transmitted = $2\ R\ L$
- T_1 = The temperature between outside wall and reaction fluid
- T_2 = Temperature difference between reaction fluid at start of increment and end of increment
- H_i = Heat of reaction i
- $F_{K(i)}$ = Molar flow rate of key component K(i) of the i^{th} reaction
- X_i = Extent of i^{th} reaction between the start and end of reactor increment
- CP_j = Heat capacity of the j^{th} component.

The reaction rate ($-r_A$) was determined by calculating its value at both ends of the incremental portion of the reactor and averaging the results. The average value was then used to recalculate the reactor conditions at the far end of the increment. This procedure was repeated until good values were obtained between the assumed end conditions and the actual end conditions. Thus an implicit method of solving differential equations was combined with Euler's method.

The convergence of reaction rate ($-r_A$) took place simultaneously with convergence of the pressure profile. The concentration profile and the temperature profile converged through repeated applications of momentum, component, overall material and energy balances.

F. Calculation of Overall Heat Transfer Coefficient

The previous discussion has been condensed; readers who are interested in more details are again referred to Robertson.[62]

However, more detailed information will be given on the calculation of U the overall heat transfer coefficient, as the concept was not fully developed in Robertson's work. The overall heat transfer coefficient from outer wall to reaction mass can be defined as:

$$\frac{1}{UA} = \sum_{i} R_i = \frac{R_o}{A_o} + \frac{\Delta X_{ST}}{K_{St} A_{St}} + \frac{R_I}{A_I} + \frac{\Delta X_c}{K_c A_c} + \frac{1}{h_I A_I} \qquad (3\text{-}71)$$

where

R_i = Resistance to heat flow

R_o, R_I = Scale resistance to heat flow on outside and inside of reactor tube = .001 $\frac{\text{hr. ft}^2\ ^\circ\text{F}}{\text{BTU}}$

.001 from Ludvig (44A)

X_{ST} , X_C = Thickness of heat resisting material

ST = steel reactor tube thickness

C = coke thickness

K_{ST} , K_C = Thermal conductivity, BTU/hr. ft^2($^\circ$F/ft.)

K_{ST} = 26., K_C = 2.90 (44-A)

A, A_C, A_I = Average area of heat transfer area

$A_{ST} = 2\ L\ (r_o - r_i) / \ln (r_o/r_I)$

$A_C = 2\ L\ (r_I - r_C) / \ln (r_I/r_C)$

$A_I = 2\ L\ r_C$

and where

r_o = radius of reactor tube (center to outer wall)

r_i = radius of reactor tube (center to inner wall)

r_c = radius of coke deposit (center of tube to coke surface)

h_I = heat transfer coefficient from coke surface to reaction fluid.

The value of h_I is a function of reaction fluid temperature, pressure, composition, velocity and temperature and can be calculated from the Seiden Tate equation since the clow is maintained in the turbulent re to minimize residence time and product degradation via carbon deposition.

$$\frac{h_o D_i}{K} = 0.023 (N_{Re})^{.8} (N_{Pr})^{1/3} \left(\frac{\mu}{\mu_1}\right)^{.14} \quad (3\text{-}72)$$

$$h = 0.023 \frac{K}{2r_i} \left(\frac{2r_i V \rho}{\mu}\right)^{.8} \left(\frac{C_p \mu}{K}\right)^{1/3} \left(\frac{\mu}{\mu_1}\right)^{.14} \quad (3\text{-}73)$$

where

V = velocity of reaction fluid

P = density of reactor fluid

= viscosity of reaction fluid

μ_1 = viscosity of reaction fluid at wall temperature

C_p = heat capacity of reaction fluid

K = thermal conductivity of the fluid

N_{Re} = Reynold's number

N_{Pr} = Prandtl's number

D_i = Diameter of the reactor radius after i increments of coke deposition

The methods of calculating C_p, μ, V and P are discussed in Robertson's Thesis[62]. However, the calculation of the thermal conductivity has not been discussed.

The Mason equation was used:[11, 91]

$$K_{mix} = \sum_i \frac{x_i K_i}{\sum_j x_j \phi_{ij}} \qquad (3\text{-}74)$$

where

$$\phi_{ij} = \frac{1}{\sqrt{8}} \left[\left(1 + \frac{M_i}{M_j}\right) \right]^{-1/2} \left[1 + \left(\frac{\mu_i}{\mu_j}\right)^{1/2} \left(\frac{M_j}{M_i}\right)^{1/2} \right]$$

M = molecular weight of the compoent

X = mole fraction of the component

The value of K_i was calculated from Eucken's[19-A] development of handling energy exchange in polyatomic gases and is given by

$$K_i = \left(c_{p_i} + 5/4 \frac{R'}{M_i} \right) \mu_i \qquad (3\text{-}75)$$

The method used to calculate the viscosity utilizes the Lennard Jones equation.[11]

$$\mu_i = 2.6693 * 10^{-5} \sqrt{M_i T} / \sigma_i \Omega_\mu \qquad (3\text{-}76)$$

where

σ_i is the characteristic of collision diameter of the molecule

Ω_μ is a slowly varying function of the dimensionless temperature KT/ϵ

σ_i and K/ϵ are commonly known as the Lennard Jones constants. The reader is referred to Robertson's Thesis[62] for the details of the evaluation of Ω_μ .

The reactor model now is able to calculate an increment of conversion but requires the outer tube metal temperature. This calculation procedure is repeated for the entire length of the reactor.

3. The Mapping Models

A. Furnace Model to Reactor Model

The furnace model supplies the furnace plane wall temperature. This plane wall temperature is split into m isothermal temperature areas. In addition there were n sets of these isothermal zones, one for each subdivision of the furnace-reactor model.

It would be possible to use these discreet isothermal zones as the tube metal temperature used by the reactor. However, it was felt that a better approximation of the net heat flux could be obtained by considering the m isothermal temperatures as m points in a continuous curve. The location of each point would be the mid point of the isothermal zone. These points are then fitted to a fourth order polynomial in Y (the furnace height). The fit is accomplished by a linear least square fit (function FITIT), which is given in Appendix B. An actual fit is illustrated in Figure 2 of Chapter I.

This procedure is repeated for the other n-1 furnace subsections. In order to determine what the reactor tube

wall temperature is at any point, all that is required is to determine which subsection of the furnace the reactor tube is located in, and what height that location lies relative to the furnace wall. This can be determined by the following relationship:

$$Y_i = Z_i - \text{Integer}(Z_i/L_i) * L_i \qquad (3\text{-}76)$$

where L_i is twice the furnace height

Integer implies that the result of $Z_i/56$ is rounded off to the lower whole number. That is, the result of Integer (51.9971) 51

Z_i is the position of the reactor tube being evaluated for the tube metal temperatures.

If the value of Y is greater than $(L_i/2)$ Y is redefined in terms of the original Y by

$$Y_i = L_i - Y_{original} \qquad (3\text{-}77)$$

The furnace subsection the tube is in is easily determined by knowing the length of each reactor subdivision.

The standard deviation of the temperature as function of wall height was approximately one half of a Farenheit degree.

By using the method described, it is possible to take into account the fluctuation of temperature with wall height. Variations along the long axes are handled as a set of three discontinuous isotherms.

One method would entail the determination of some continuous and smooth functions which would yield the temperature as a function Y and Z, which is:

$$T = f(Y, Z) \qquad (3\ 78)$$

One such method would be to determine the best straight line, or the best second order polynomial through the three temperatures for the value of X and then determine the value for the particular location above the long or Z axis.

This procedure was not incorporated in this study, but it is recommended that consideration be given to it in any future refinement of this work.

B. Reactor Model to Furnace Model

It was necessary to map the reactor process fluid temperature into a set of (n X m) isothermals. This was accomplished by considering each one of the n subdivisions seperately. The temperature of the reactor process fluid was recorded at m furnace height for every up and down pass

of the reactor tube in the furnace. It then became possible to sum the temperatures for any given furnace height and average the result. Thus:

$$\overline{T_{PF_i}} = \frac{\sum_i (T_{PF_i})}{\eta} \qquad (3\text{-}79)$$

Where T_{PF_i} = average temperature of process fluid for isotherm at height Y

(T_{PF}) = successive temperatures of the process plane each time the tube passes through the height .

η = number of times the reactor tube passes through the height

Referring to Figure 5 for example, to calculate the temperature of isothermal zone being in isotherm 4, X_4 would result in:

$$\overline{T_{I(I,4)}} = \frac{\sum_{I=1}^{5} (T_{I(I,4)})}{5} = \frac{T_4 + T_{11} + T_{18} + T_{26} + T_{32}}{5} \qquad (3\text{-}80)$$

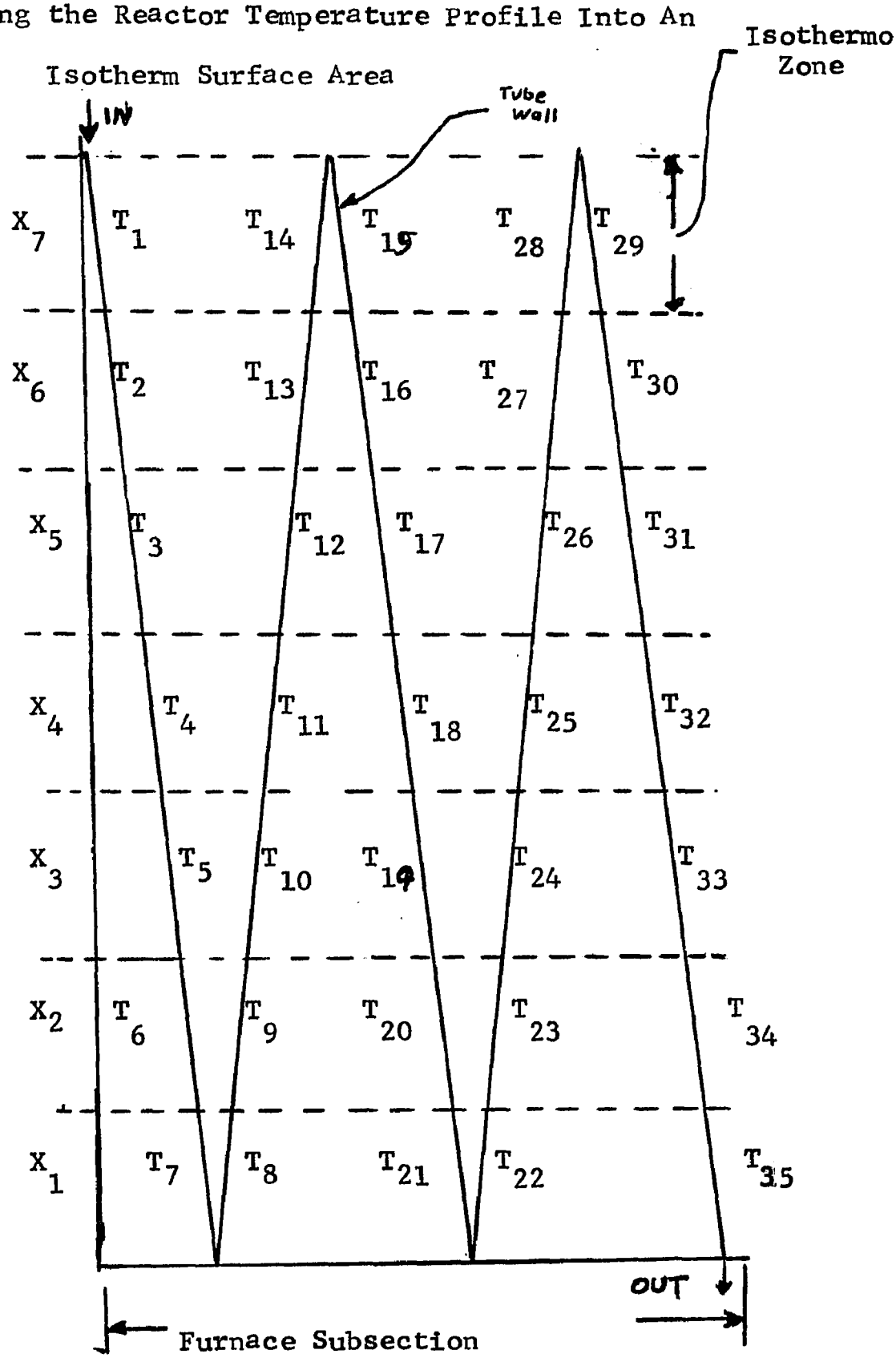
In order to determine the value of $\overline{T_{I(I,4)}}$ it was necessary to manually determine which temperature lay in which isotherm. This procedure was repeated for each of the furnace subsections under investigation. The

temperature locations were then stored as a part of the computer program (Apprendix B).

Any further user who had a different set of furnace or reactor conditions or who desired to zone the furnace in a different way would have to redo these determinations and rewrite the main program. No changes in any subroutines or functions (with the exception of TEMP) would have to be performed.

Figure 5

Mapping the Reactor Temperature Profile Into An Isotherm Surface Area



The average process temperature can thus be calculated from any set of isotherms for any furnace subsection.

The overall heat transfer coefficient from tube plane to process fluid plane will not be the same coefficient calculated from outer tube wall to process fluid in the reactor model. This is due to the differences in geometry between the two models. It was decided to allow the models themselves to do the mapping between the two geometries.

This mapping was accomplished by calculating the net heat flux Q_R through the reactor tube via the method described in Chapter III-2 for each furnace subsection. The furnace model then uses a fuessed value for the overall heat transfer U_F to calculate the net heat flux Q_F to the process fluid.

At the next repeat of the furnace calculation the value of the overall heat transfer is adjusted according to:

$$U_F = U'_F (D + Q_R/Q_F)/(D+1.)$$

(3-81)

Where U'_F = former guessed value of the overall heat transfer coefficient

D = Damping factor

It was necessary to damp the change in the value of U_F as the undamped change i.e.:

$$U_F = U_F' Q_R / Q_F \qquad (3\text{-}82)$$

results in divergent oscillation of the solution around the solution. The value of U_F was calculated independently for each furnace subsection.

4. Calculation "Flow"

A. Introduction

This section is an attempt to give the reader a "feel" for the computational sequence. Thr reader is reminded that the calculations were carried out on a high speed computer so some references will be made to data "input" and "output".

It would be extremely complicated to give detailed calculations of each step. In order to avoid this difficulty, whole groups of calculations will be referred to by a few descriptibe words. It would also be difficult to give a "flow diagram" but reference will be made referring back to previous steps. This will be accomplished by numbering the various steps.

B. The "Flow"

STEP I. Input Furnace Data

1. Total heat release distribution
2. Fuel-excess air analysis
3. Geometry of furnace
4. Bulk flow pattern
5. Furface properties
   a. Transmissivity
   b. Emissivity
   c. Heat transfer coefficient
6. Surface boundary conditions

STEP II. Preliminary Furnace Calculations

1. Flue gas analysis
2. Specific heat enthalpy data
3. Initial temperature profile (if not inputted)
4. Characteristic flue gas by clear-gray gas combintation. (isolate temperature dependence)

STEP III. Calculate Direct Interchange Area

1. Surface to surface - ss (clear gas . gray gas(es))
2. Surface-gas/ gas-surface, sg, gs (gray gas(es))
3. Gas - gas gg (gray gas(es))

STEP IV. Account for Surface Reflectivity

1. Reflection with gas volume as the emitter.

   Solve for $_{g}R_{s}$ (gray gas(es))

2. Reflection with surface area as the emitter

   Solve for $_{s}R_{s}$ (gray gas(es))

STEP V. Calculate Total Interchange Area - for a Characteristic Gas (Temperature Independent)

1. Gas to gas $GG = gg + \sum {}_{g}R_{s} \cdot g$ (Gray gas(es)

2. Gas to surface/surface to gas

   $GS = {}_{g}R_{s} \cdot \frac{AE}{P}$ (Gray gas(es))

3. Surface to Surface

   a. $SS_c = {}_{s}R_{s_c} \; AE/P$ (Clear Gas)

   b. $SS = {}_{s}R_{s_c} \; AE/P$ (Gray gas(es))

STEP VI. Input Reaction Data

1. Initial Tube Wall Temperature (Guessed)
2. Description of Reactions
3. Description of Reactor
4. Initial Reactant Concentration
5. Physical Data
   a. Heat Capacity
   b. Arrhenius Kinetic Data
   c. Enthalpy
   d. Entropy

e. Reaction Equilibrium

f. Lennard - Jones Constants

6. Miscellaneous Control Parameter

STEP VII. Calculate Parameter Needed for Reactor Calculation as a Function of Temperature

STEP VIII. Output the Reaction System and Generate Parameters

STEP IX. Calculate Reactor Pressure, Component, Temperature, Heat Flux and Carbon Deposition Profiles

1. Determine the Temperature Profiles for Each Furnace Subsection

2. Determine Rates for Beginning of Increment (All Conditions Known)

3. Guess or Update Temperature, Composition and Pressure at End of Increment and Determine Reaction Rates at End of Increment

4. Calculate Average Reaction Rates

5. Using Average Rates do:

A. Material Balance

i. Component Balance

ii. Pressure Drop Calculation

iii. Material Balance

B. Heat Balance

i. Sensible Heat Gain

ii. Heat Flux Calculation Using T=f(z)

6. Compare End Conditions. (if in agreement with set used (go to Step IX-7) otherwise (go to Step IX-3)

7. Calculate Next Reactor Increment Using End Conditions as Initial Conditions

a. If Finished the Length of the Reactor, Go to Step X.

b. Otherwise - Step IX-3

STEP X Using the Reactor Fluid Temperature Profile, Calculated in Step IV, Calculate Isothermal Area Temperature for Each Isotherm in each Furnace Subsection.

STEP XI Calculate New Surface and Gas Volume Temperatures Using the Isothermal Temperature Calculated in Step X or Step XI-3

1. Total interchange area for real gas (temperature dependent) 1 corrected for intermediate surface if any transmissivity

a. Surface to Gas $SG=\left[\sum_n A_n \cdot SG_n\right]\tau$

b. Surface to Surface $SS=\left[\sum_n a_n \cdot SS_n + (1-\sum_n a_n)SS_c\right]\tau$

2. Total interchange area for real gas (temperature dependent) 2 Corrected for intermediate surface, if any transmissivity

a. Gas to Gas GG = $\left[\sum_n GG_n\right]\tau$

b. Gas to Surface GS = $\left[\sum_n \cdot GG_n\right]\tau$

3. Gas Volume Heat Balance

a. Surface area temperatures are assumed constant

b. Heat Balance

i. Bulk Flow

ii. Radiation

iii. Source

iv. Convection

c. Linear Heat Balance Equation Using Iterated Newton-Raphson

d. Solve for T

e. Update Gas Volume Temperature

f. Test the Size of the Max T

4. Surface Area Heat Balance

a. Gas Volume Temperatures are Assumed Constant

b. Heat Balance

i. Radiation

ii. Sources

iii. Convection

c. Linearize Heat Balance Equation Using Iterated Newton-Raphson (as in Step XI-3c)

Chapter IV

Results and Conclusions

The calculation procedures described in the first three chapters were used to make a parameter study of a typical large scale industrial furnace producing ethylene and propylene (as a secondary product).

The chief parameters which were adjusted were the fuel rate and the wall to wall separation. The results obtained were compared with plant observations. It should be realized that an exact matching of the two is difficult in view of the errors in plant measurements and the uncertainties in the value of kinetic data, emissivities, and other physical properties of furnace and reactor.

The values of yeilds obtained have good agreement with data obtained with adjusted of the Arrhenius frequency factor (A_i). As these adjustments were in the unimportant side reactions, it was decided to perform the optimization with the unadjusted constants.

Comparing the overall furnace performances was somewhat more difficult as these results are highly dependent on the physical properties of the furnace being studied. The author was unable to locate any data from industrial furnaces with sufficient amount of detail to duplicate the calculations. However, excellent agreement was found with general operating

conditions of industrial plants. The point of optimum operation determined in this study corresponds to actual operating conditions found in existing furnaces.

1. Verification of Results

The results from this study were compared with results reported by two other investigators, Shah[70] and Nelson.[54]

Shah had simulated a reactor system using the method of Lobo[46] to calculate the outer tube wall temperature. Shah then adjusted the Arrhenius rate constant to force agreement of his results with data he had available.

Nelson reported data from a variety of industrial furnaces. As a result, the individual furnace characteristics are not available.

Table I shows a comparison of Shah, Nelson and results from this study. It should be noted that good agreement exists between Shah's results and the results reported in this study. There is some disparity in the reported outlet temperature. The two cases reported in this table represent different rates of firing. The two rates bracket the firing rates found in some industrial furnaces is in excellent agreement.

The operating point of the industrial furnaces as reported by Nelson was in agreement with the optimum operating report as developed in this study.

TABLE I

COMPARISON OF RESULTS OF THIS STUDY WITH SHAH[70] AND NELSON [54]

	Shah's Results	Nelson Reports	Robertson Case 1	Robertson Case 2
Heat Availability 10^6 BTU/Hr.-Foot Furnace	-	-	2.86	3.22
Total Feed (lb/ moles/hr.)	171	-	280	280
Steam-Feed Ratio	.363	.3 - 1.1	.35	.35
Inlet Pressure (atm.)	4.43		6.6	6.6
Outlet Pressure (atm.)	?	1.2 - 3	2.0	2.2
Reactor Length (feet)	394	-	400	400
Tube Radius (inches)	?	-	4	4
Gas Inlet Temperature °F	1010°	-	1012°	1012°
Gas Outlet Temperature °F	1400°	1515-1525°	1544°	1560°
Mole % Ethylene Yield	47.6%	58 - 62%	52.48%	60.05%
Mole Ratio Methane/Ethane (+)	.0177	.025-.067	.0142	.0157
Mole Ratio Acetylene/Ethane (+)	.00053	.0014	.00101	.00145
Thermo Efficiency Ratio BTU to Reactor/ BTU Fired	-	-	.350	.315

2. Furnace Temperature Driving Force

Figure 6 shows a typical temperature driving force calculated by the procedure outlined in this study.

It should be noted that fluctuations ranging up to 790°F are found between adjoining gas zone isotherms. Differences of 1100°F exist between the highest and the lowest isothermal temperature zones.

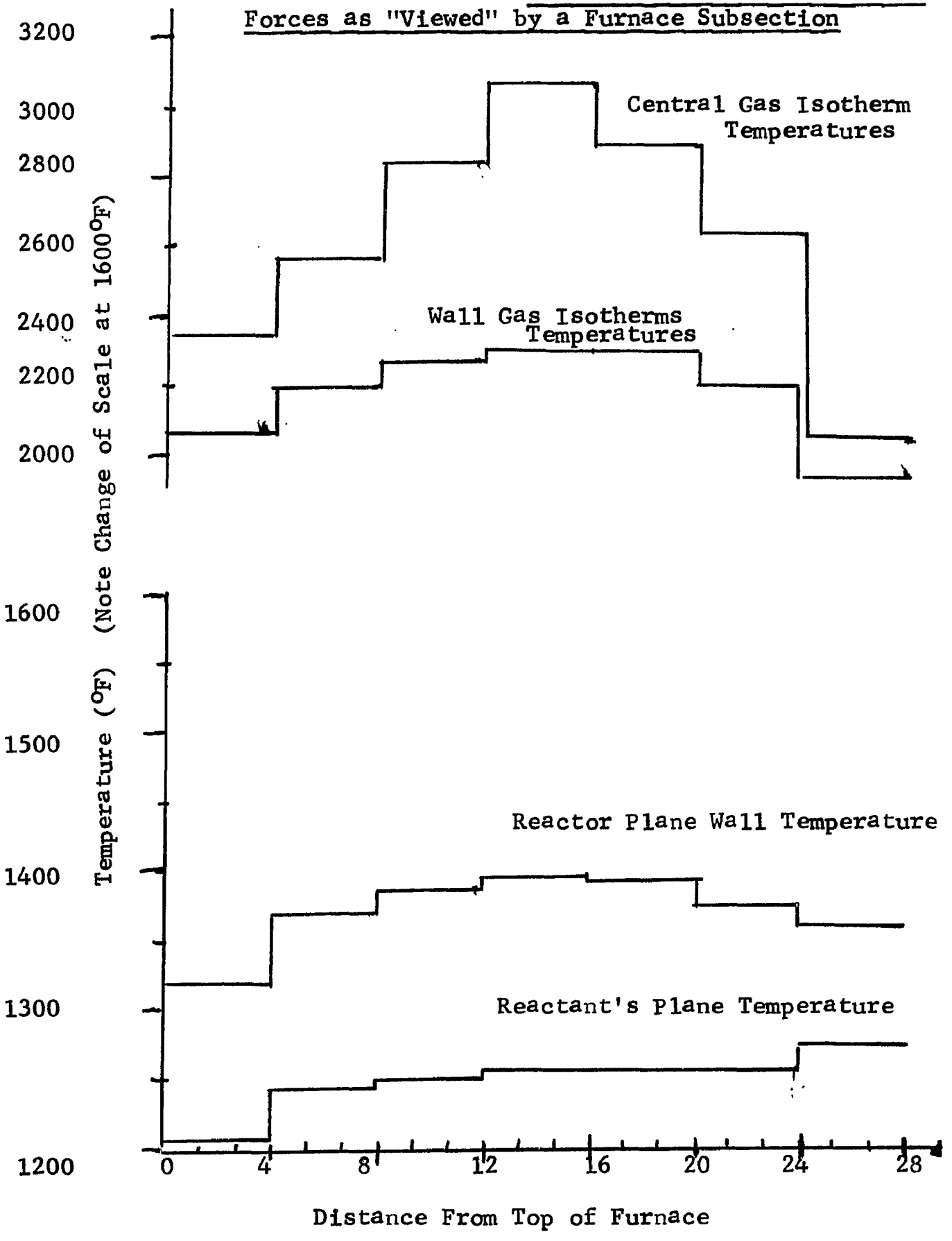
The large differences calculated are a strong justification for the use of this complex procedure, expecially when highly temperature dependent calculations are being used.

It is also interesting to note that the temperature driving force between the tube wall "plane" and the process "plane" is not constant, but is dependent on tube height.

Normally the process plane temperature would be nearly constant at the average temperature of the process fluid. However, in this example there is an increase near the bottom of the furnace due to an uneven number of tubes in this subsection.

Figure 7 is a numerical example of the temperature driving force in each of the three furnace subsections.

Figure 6. Typical Temperature Driving Forces as "Viewed" by a Furnace Subsection



Each subsection represents only half of the plane of the furnace subsection (the missing half would be symmetrical to that shown).

Several interesting observations may be drawn from this figure:

1. Once again, considerable temperature differences exist between adjoining isothermal zones in different furnace subsections.

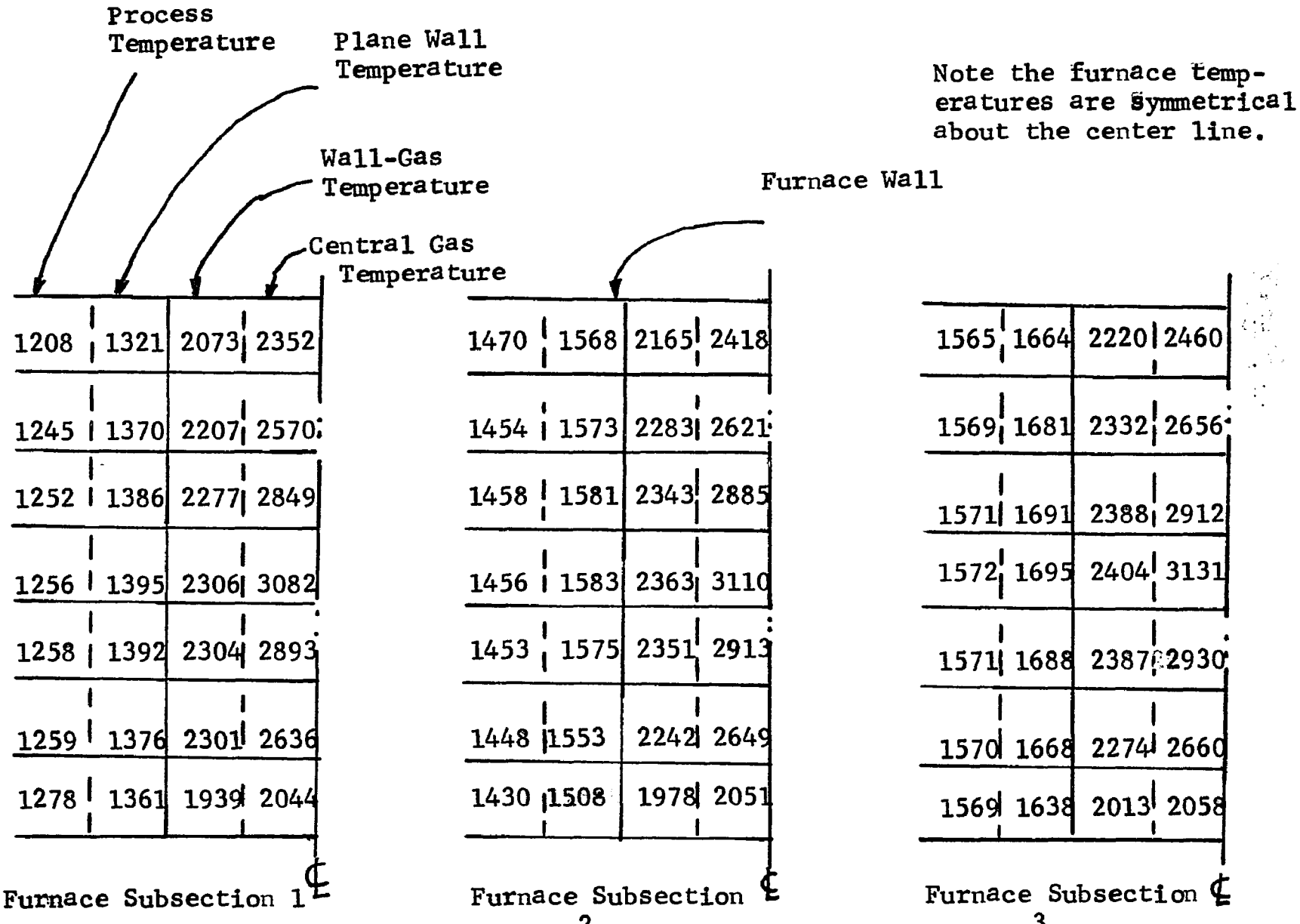
2. The temperature of the central isothermal zone shows only relatively small variation from subsection to subsection.

3. Considerably larger temperature fluctuations exist in those isotherms abutting the furnace wall. This is important as these isotherms act as the chief driving force for convective heat transfer. It has been generally accepted that radiation is the dominant mode of heat transfer in the fire box. The results of this study suggest that convection also plays a significant role. It should be given consideration in the design of an "optimum furnace."

The use of a single gas isotherm for the entire furnace zone would do a poor job at estimating the importance of the convected heat transfer.

Figure 7

Temperature Profile in Furnace Subsection in (^{o}F)



3. Convected Heat Transfer in the Radiant Section of the Furnace

In order to dramatize the effect of convected heat transfer, a series of calculations were made which varied the wall to wall separation. During the first set of calculations, no correction was made to the gas to surface heat transfer coefficient. (Normally as the walls of the furnace get closer together retaining the same fuel consumption rate, the convected heat transfer coefficient would increase according to the .8 power of the bulk flow rates.)

The result (See Figure 8 and Table 2) was an increase in reactor yield with increasing wall separation. The result is a representation of an isolation of the radiative heat transfer rate which would increase as the surface area is able to view larger sections of the flame boundary at less oblique angles.

If the distance separating the wall continued to increase, the rate would ultimately drop off as the area would "view" a line source of radiation.

In the second set of calculations, the surface to gas volume heat transfer coefficient was corrected for bulk flow consideration. (See Figure 9 and Table 3 .) The results were reversed, with the closer the wall to wall separation, the higher the yield for the same amount of fuel fired.

Table 2

Effect of Wall Separation on Reactor Yield Radiation Effects Isolated by Using Uncorrected Surface to Gas Heat Transfer Coefficient

Heat Availability $2.142*10^6$ BTU/hr.-foot(furnace)

Wall-Wall Separation Feet	% Yield Ethylene	Uncorrected Heat Transfer Coefficient Area Base BTU/hr ^oF/ft
6	32.27	3.14
8	32.52	3.14
10	33.20	3.14
50	37.16	3.14

Table 3

Effect of Wall Separation on Reactor Yield Using Corrected Surface to Gas Heat Transfer Coefficient

Heat Availability $2.142 * 10^6$ BTU/hr.- foot/furnace

Wall-Wall Separation Feet	% Yield Ethylene	Corrected Heat Transfer Coefficient (Area Bases) BTU/hr ^oF/ft
6	34.35	4.73
8	33.83	3.76
10	33.20	3.14
14	31.95	2.40
18	31.59	1.96

Figure 8.

Effect of Wall to Wall Separation on Ethylene Yield (Radiant Effect Isolated - No Adjustment of Gas to Wall Heat Transfer Coefficient)

Heat Available $2.142 * 10^6$ BTU/Hour - Foot Furnace

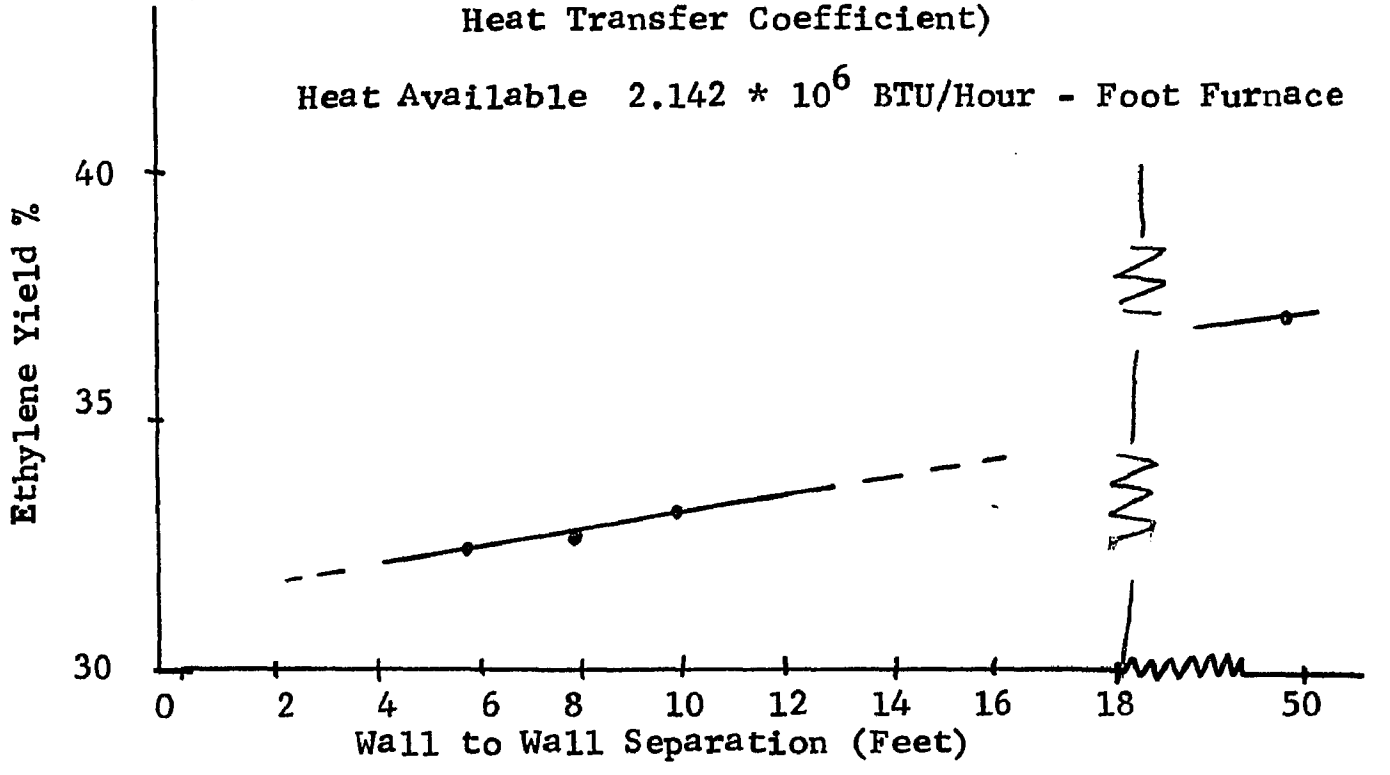
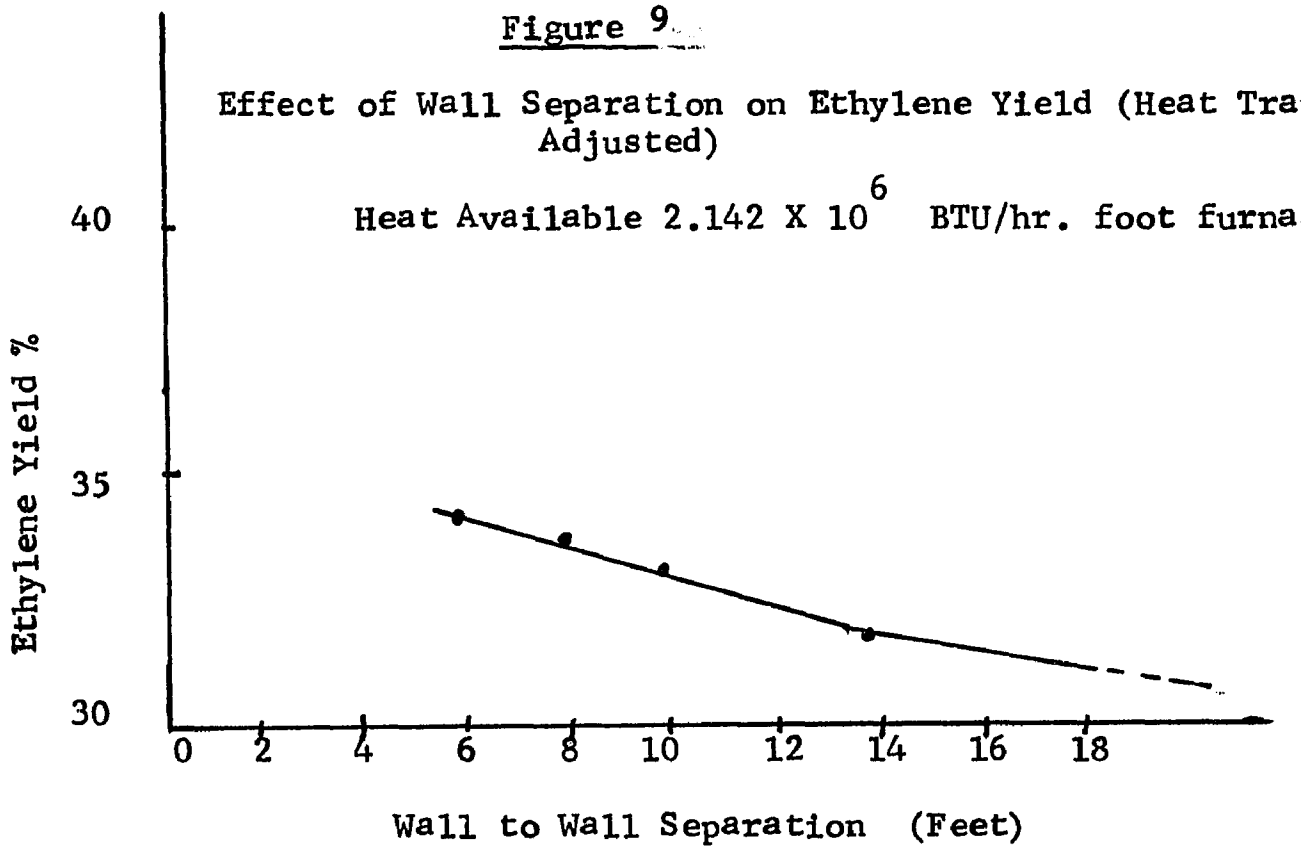


Figure 9

Effect of Wall Separation on Ethylene Yield (Heat Transfer Adjusted)

Heat Available 2.142×10^6 BTU/hr. foot furnace



This would suggest that optimum furnace construction should have the walls as close as possible while allowing sufficient volume for the complete combustion of the fuel.

The above discussion did not allow for the introduction of more isothermal zones as the wall separation was increased. It is likely that if such a procedure had been followed, the effects would have been less pronounced, but still valid.

4. Optimization of the Furnace-Reactor as a Function of Fuel Rate

Several sets of calculations were performed varying the net heat availability (E_t). The ethylene yield was then plotted as a function of net heat availability (Figure 9). The wall to wall separation was kept constant at 10 feet, 10 ft. separation being used as a basis for all variations.

Figure 10 and Table 4 predict the possibility of ethylene yields in excess of 70% per pass. There are, however, two main reasons why this yield is not practical.

The first reason is illustrated in Figure 10 which shows the rate of ethylene production in terms of pounds of ethylene produced/pound of fuel consumed versus net heat availability of the furnace. The plot goes through a

Table 42

Effect of Heat Availability on Reactor Yield for 10 Foot Wall - Wall Separation

Heat Availability BTU/hr. Foot Furnace X 10^6	% Ethylene Yield	Surface to Gas Heat Transfer Coefficient* Adjusted Area Bases BTU/hr. ^oF/ft.
1.79	23.18	2.72
2.14	33.20	3.14
2.50	43.42	3.55
2.86	52.48	3.95
3.22	60.05	4.35
3.57	66.67	4.73
3.93	72.14	5.10

*Adjustment takes into consideration increase in flue gas velocity due to increase in fuel fired.

Figure 10

Ethylene Yield as a Function of Heat Availability

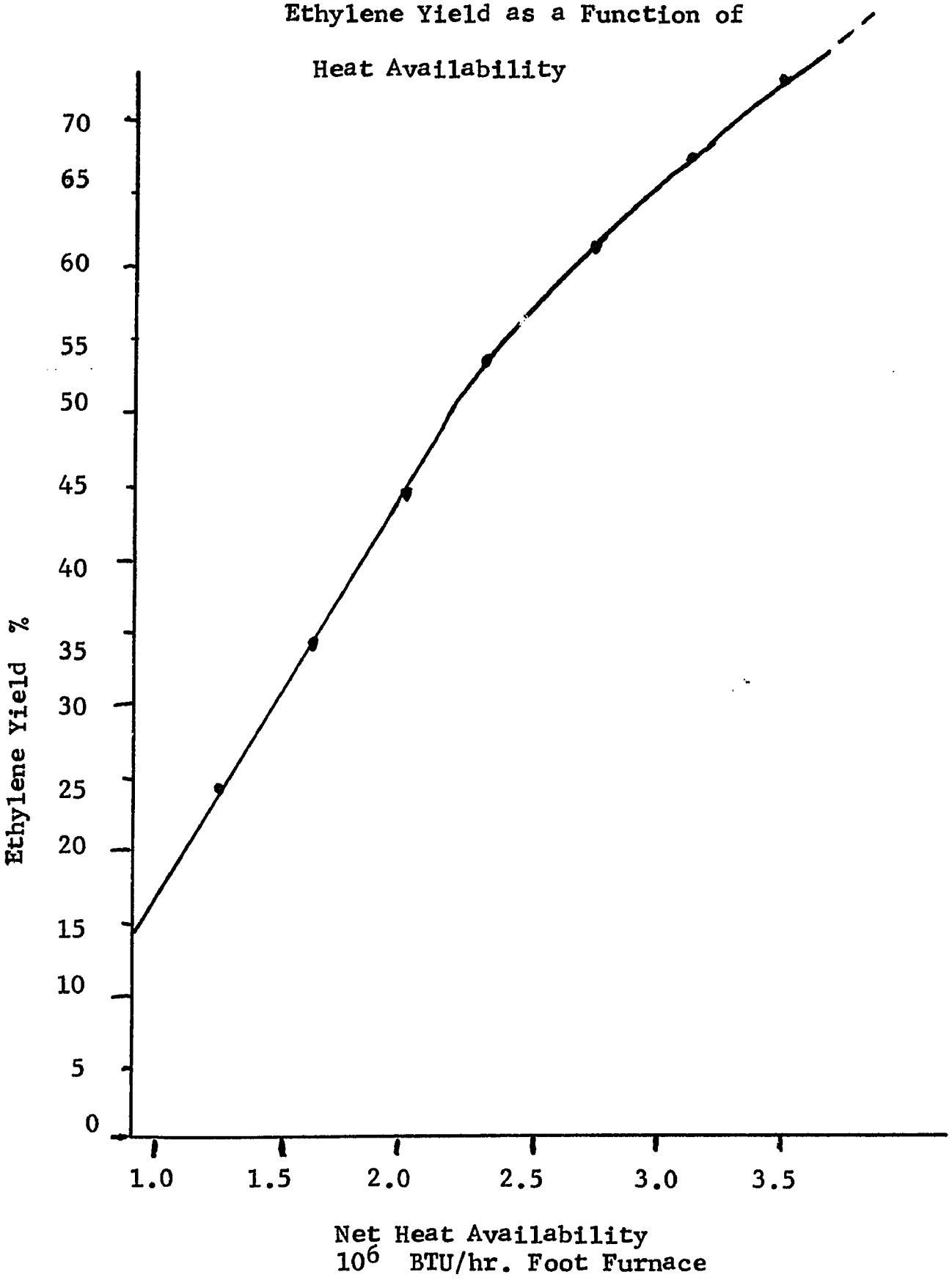


Figure 11

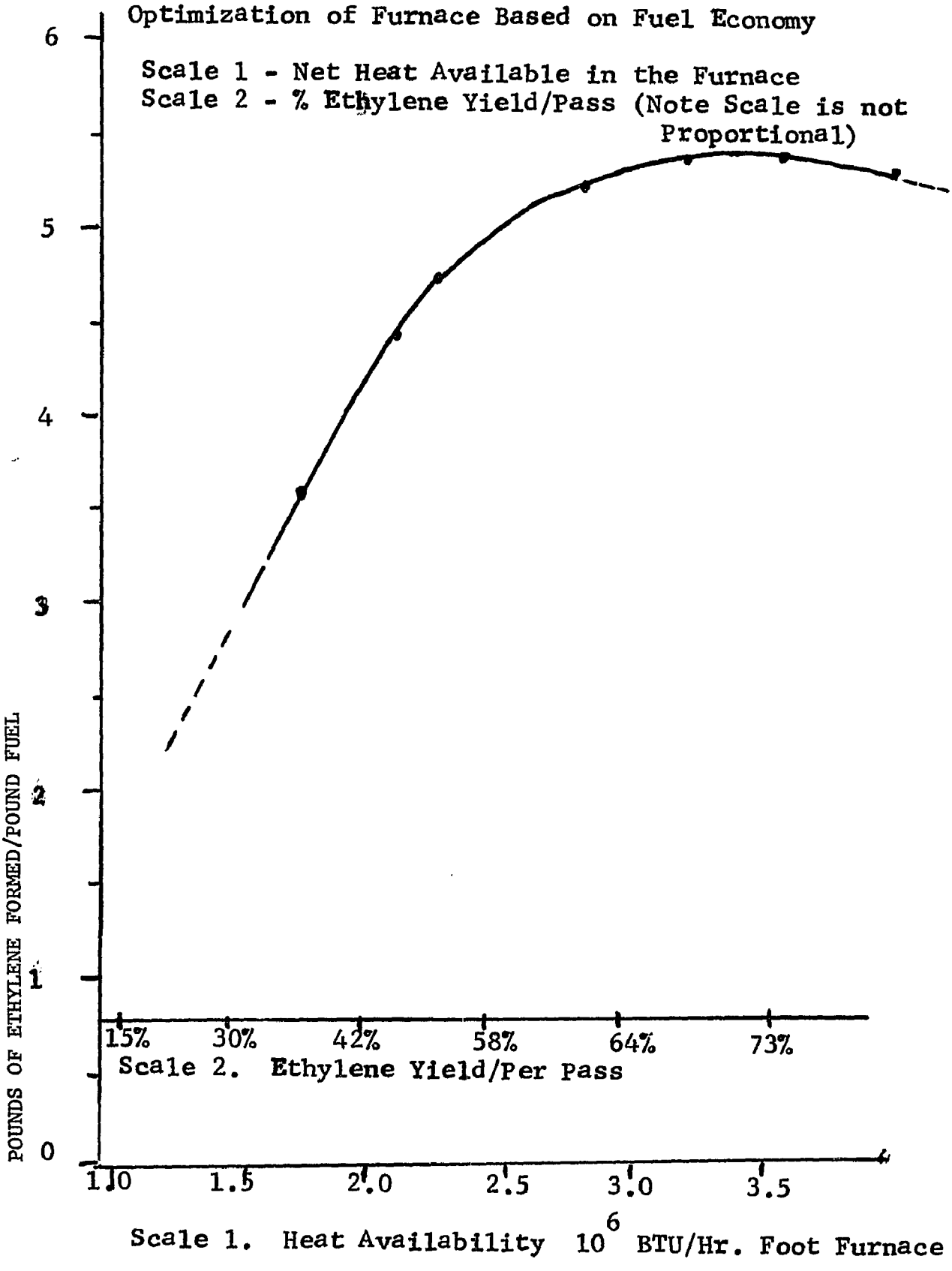
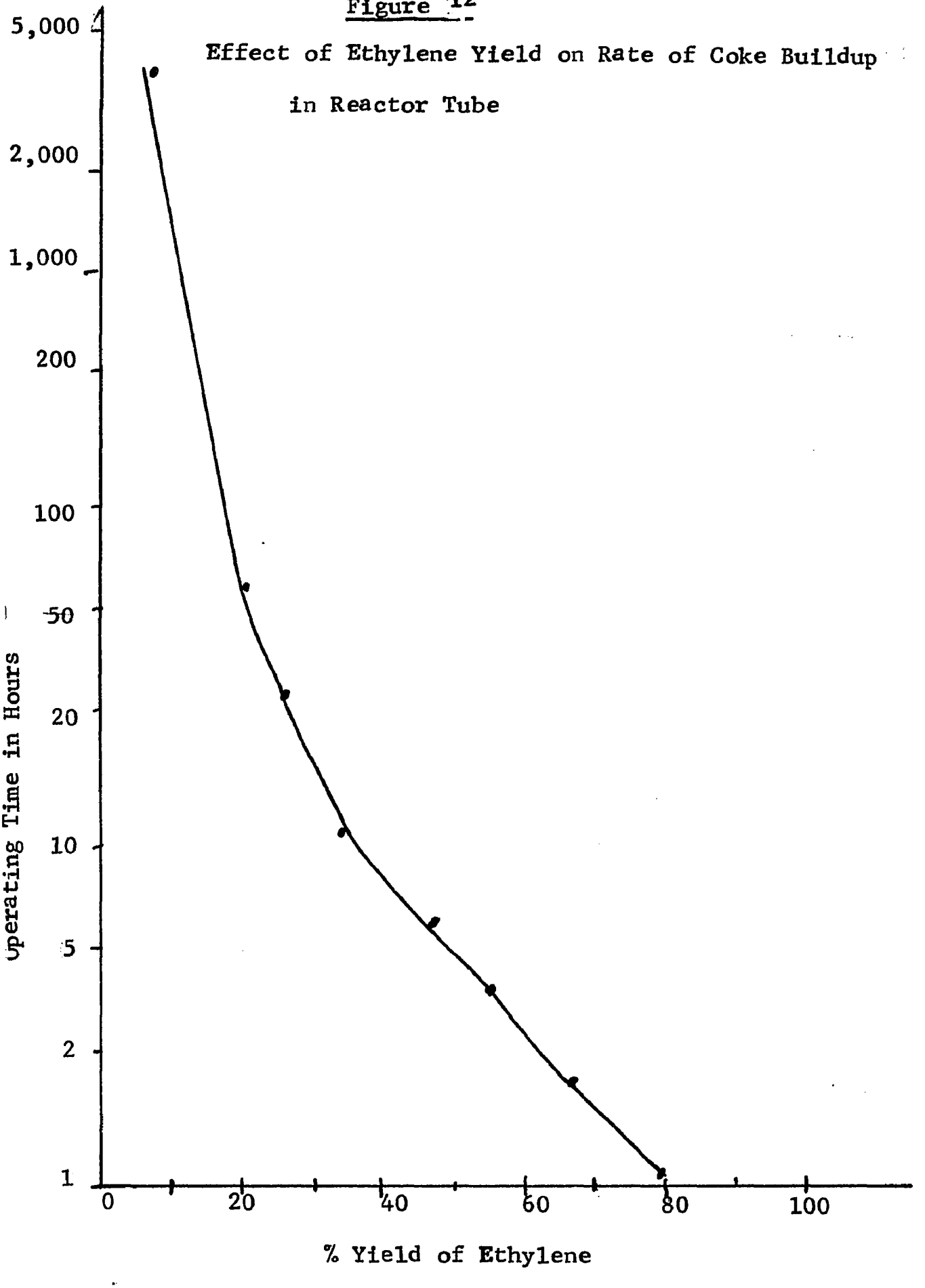

Optimization of Furnace Based on Fuel Economy
Scale 1 - Net Heat Available in the Furnace
Scale 2 - % Ethylene Yield/Pass (Note Scale is not Proportional)
POUNDS OF ETHYLENE FORMED/POUND FUEL
0
1
2
3
4
5
6
15%
30%
42%
58%
64%
73%
Scale 2. Ethylene Yield/Per Pass
1.0
1.5
2.0
2.5
3.0
3.5
Scale 1. Heat Availability 10^6 BTU/Hr. Foot Furnace

Figure 12

Effect of Ethylene Yield on Rate of Coke Buildup in Reactor Tube



maximum. The curve is flat near the top, however, and at first consideration it would be possible to assume yield of 65-70% would be possible. This would correspond with an optimum fuel economy of 5.4 pounds of ethylene/pound of fuel consumed.

Figure 12 however, shows that the rate of coke buildup in the pyrolysis tubes becomes very rapid when large yields of ethylene are desired. A yield of 65-70% would necessitate the cleaning of the reactor every 3-4 days. A 40% yield with a corresponding fuel economy of 4.1 pounds of ethylene/pound of fuel would result in a reactor requiring cleaning only every 18 - 20 days.

If a manufacturer wishes to obtain the higher fuel economy predicted in this study, clearly something would have to be done about the coke buildup. One possible solution lies in the supersonic oxidative pyrolysis of Vasil'ev [90] or his subsonic oxidative pyrolysis [89] which incorporated the introduction of oxygen into the reactant stream. This resulted in a blocking of the coke reaction and 58% yields of ethylene.

Chapter V

Recommendations

The computational procedures developed in this study are very extensive, enabling the handling of complex furnace-reactor design. The furnace design utilizes the complex method of Hottel and Cohen in handling zoned furnaces. It incorporates several suggestions of Cohen, notably the evaluation of the gas emissivities and absorption at individual zone temperatures instead of a system mean temperature.

There are, however, important limitations:

1. The furnace was assumed to be infinite in length, thus no end effects were taken into consideration. The subdivision of the furnace into furnace subsections enabled the handling of variable wall fluxes, but allowed no interreaction between subsections.

2. The zones in the system have been assumed to be isothermal. The solution could only become exact as the size of the zones are shrunk to infinitessimal size.

3. The reactor model calculates coke deposit as a function of reaction rate. No mechanism was supplied to to allow a portion of the coke to be carried out of the furnace. The exact mechanism of coke formation is not known. It has been considered to be catalytic in nature.

This depends on whether sufficient deposition takes place on the bare metal of the reactor or on other coke deposits.

4. The reactor increments were to have uniform average properties. The solution could only become exact as the increments are shrunk to infinitessimal size.

It is therefore recommended:

1. To take end effect into consideration in order to make a "true" three dimensional model.

2. To determine the exact nature of the coke formation.

3. To apply the calculation procedure to a large variety of furnaces with the objective of formulating a general correlation which would allow for rapid estimation of design criterion.

4. To apply the calculation procedure to the optimization of existing furnace-reactor structures.

5. To design optimum furnace configurations by repeated application of the calculation procedures.

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APPENDIX A

TABLE OF NOMENCLATURE

Area of a surface, square feet; A_1, A_2 area of a source-sink surface; A_{s_1}, A_{s_2}, ... area of surface zones s_1, s_2, ...

AMWT Average molecular weight of reacting system

B Normal distance between differential radiating volume elements and a plane, feet

B(I,K) Coefficient of component in K^{th} position I^{th} reaction

BB(I,K) Order of reaction of component in I^{th} position K^{th} reaction

C Convective-flux coefficient, square feet, C_g evaluated at T_g, C_s evaluated at T_s

c Exponent on temperature ratio in obtaining G from G' dimensionless

c Heat capacity, B.t.u./lb.,^{o}F.

C(J) Concentration of J^{th} component (lb. moles/ft.^{3})

CF Temporary constant used in calculating the product of concentration raised to order of reaction components in the forward direction

CLJ(J,1) Constant of Lennard and Jones - collision diameter ($\overset{o}{A}$) J^{th} component

CLJ(J,2) Constant of Lennard and Jones - /K-(^{o}K)J^{th} component

CP(J,1-4) Heat capacity data for J^{th} component C_p=CP(J,1) + CP(J,2)*T+CP(J,3)*T^2+CP(J,4)*T^3 (BTU/lb. mole ^{o}F)

CR Temporary constant used in calculating the products of concentration raised to the order of reaction of each reaction component in the reverse direction

CT = C(J) (lb. moles/$ft.^3$)

D =MAX(ABS(DXA(I))) i.e. the max of the absolute incremental change of reaction

D Basic determinant for the system of simultaneous equations used to obtain total interchange factors

$g_i D_{s_j}$ Determinant formed by replacing the s_j-column of D by a column of g_i-functions

d $\ln_G$ / ln PL, dimensionless

$$DCP(I,1\text{-}4) = \sum_{K=SF(I)+1}^{SR(I)} \frac{B(I,K)}{B(I,1)} CP(I,1\text{-}4) - \sum_{K=1}^{SF(1)} \frac{B(I,K)}{B(I,1)} CP(I,1\text{-}4) \quad \text{(BTU/lb. mole } ^{o}\text{F)} \qquad (1)$$

(i.e.) Summation of heat capacity of products - heat capacity of reactants

DF(I) Summation of free energy of products - free energy of reactants I^{th} reaction (BTU/lb. mole)

DH(I) Summation of heat of formation of products - heat of formation of reactants (BTU/lb. mole)

DS(I) Summation of entropy of products - entropy of reactants (BTU/lb. mole)

EA(I) Arrhenius frequency factor of I^{th} reaction

EE(I) Arrhenius activation energy of I^{th} reaction (cal/m)

E Radiation-emission rate, energy per unit time; E_{g_1}, E_{g_2}, ... from surface zone s_1, s_2, ...

E Eddy diffusivity, square feet per hour

F View Factor = Fraction of radiation from one surface zone intercepted by another surface zone in the presence of a non-absorbing medium, dimensionless; $F_{s_1 s_2}$ from surface s_1 to s_2

F Fraction of energy from a point radiating source absorbed by a sphere of gas, dimensionless; F_1 intercepted by a portion of spherical surface F_2 absorbed by a portion of a spherical shell

f Fraction of radiation originating in one zone which reaches and is absorbed by another zone in a black-walled enclosure, dimensionless; f_{ss} between two

surface zones; f_{gg} between two gas zones, f_{sg} from a surface zone to a gas zone; f_{gs} from a gas zone to a surface zone

F(J) — Factor by which the Arrhenius frequency factor is changed - assumed to be one

FI(I) — Constant of integration used in calculating the equilibrium constant

GC — Gas constant = 1.341 At/lb mole ^{o}K

G_m — Molal flow rate per unit area mols/hr. sq. ft.

GG — Total interchange factor between any two gas zones including reflections at all surfaces, square ft.; G_1G_2 (G_2G_1) is equal to $q_{g_1g_2}/W_{g_1}$ or $q_{g_2g_1}/W_{g_2}$

GS — Total interchange factor between any gas and surface zone including reflections at all surfaces, square feet; G_1S_1 (S_1G_1) is equal to $q_{g_1s_1}/W_{g_1}$ or $q_{g_2g_1}/W_{s_1}$

g — Gas zone with a numerical subscript to designate the particular zone under consideration

gg — Direct interchange factor between any two gas zones, square feet; g_1g_2 (g_2g_1) is equal to $(q_{g_ig_2})_{direct}/W_{g_i}$ or $(q_{g_2g_1})_{direct}/W_{g_2}$

gs — Direct interchange factor between any gas and surface zone, square feet; g_1s_1 (s_1g_1) is equal to $(q_{g_1s_1})$ direct/W_{g_1} or $(q_{s_1g_1})$direct/W_{s_1}

H_{ex} — Total enthalpy of entering fuel and air per unit time, B.t.u./hr.

H_g — Enthalpy-flux coefficient evaluated at T_g, square ft.

h_c, h_c', h_c'', h_c''' — Convective coefficient of heat transfer, B.t.u./hr. sq. ft. ^oF

h — Enthalpy content, B.t.u./mol; h_s sensible enthalpy; h_{ch} chemical enthalpy

HR — Number of hours in which carbon has been accumulating

HT(J) — Heat of reaction of the (J) component (BTU/lb. mole)

I — Temporary storage to denote I^{th} reaction

IA(I,K) — Used to identify J in the reaction species in the I^{th} reaction the K^{th} position (i.e. J=IA(J,K)

IB — Number of increments the reactor will calculate before it is forced off

K,K' — Correction factors by which to multiply $T_{avg.}$, dimensionless.

k — Absorption coefficient of a gas, $ft.^{-1}$

L — Mean beam length for gas radiation, feet.

P — Pressure, atmospheres; P_w partial pressure of water vapor; P_c partial pressure of carbon dioxide; P_G gas pressure

P — Dimensionless ratio r/β for evaluating f_P

P(J) — Pressure of J component (at.)

PD — Pressure drop increment (in at.)

PDIP — Initial incremental pressure change used in convergence (at.)

PI — Pressure into reactor (at.)

P OUT — Pressure out of reactor (at.)

PPI(J) — Initial pressure of J^{th} component (at.)

Pr — Prandtl Number $/k$, dimensionless

Heat transfer rate, B.t.u. per hour; $q_{1\ 2}$ net between surfaces 1 and 2; $q_{1\ G}$ net between surface 1 and the gas; $q_{g_i g_1}$ one-way from g_i to g_1; $q_{s_j g_1}$ one-way from g_i to s_1; $q_{B_{g_1}}$ net to g_1 by bulk transport; $q_{C_{g_1}}$ net to g_1 by convection; $q_{C_{s_1}}$ net to s_1 by convection; $q_{w_{s_1}}$ net through surface s_1.

R — Relative flux density, dimensionless; $_{s_1}R_{s_2}$, flux density away from s_2, due solely to radiation originating at s_1, and expressed as a ratio to W_{s_1}; $_{g_1}R_{s_2}$, same, but due to radiation originating in gas zone g_1.

R — Gas constant 1.987 cal/gram mole ^{o}K

r — Linear distance between two elements (feet)

RA — Rate of reaction

RAD — Radius of the reactor (feet)

RADD(I) Radius of reactor at 1% temporary storage

RADF(I) Radius of reactor at 1% previously calculated

RADI(I) Radius of reactor at 1% presently being calculated

RADU Original radius of clean reactor (feet)

RAF Original radius of clean reactor (feet)

RATE Total rate of reaction

Re Reynolds Number DG/ , dimensionless

SS Total interchange factor between any two surface zones including reflections at all surfaces, sq. ft. S_1G_1 (G_1 S_1) is equal to $q_{s_i g_1}/W_{s_1}$ or $q_{g_1 s_1}/W_{g_1}$

s Surface zone with a numerical subscript to designate the particular zone under consideration

sg Direct interchange factor between any surface and gas zone, sq. ft; s_1g_1 (g_1s_1) is equal to $(q_{s_1g_1})$ direct/W_{s_1} or $(q_{g_1s_1})$ direct/W_{g_1}

ss Direct interchange factor between any two surfaces, sq. ft.; s_1s_2 (s_2s_1) is equal to $(q_{s_1s_2})$ direct W_{s_1} or $(q_{s_2s_1})$ direct W_{s_2}

SR(I) (Integer) number of components in I^{th} reverse reaction

T Temperature, ^{o}R; T_{g_1}, T_{g_2}, of gas zone g_1, g_2, ... ; T_{s_1}, T_{s_2}, ... of surface zone s_1, s_2, ...; T_G and T_S of gas and surface respectively; T_1 and T_2 of surfaces 1 and 2

T Temperature of reactor (any point) (^{o}F)

TIN Temperature of inlet conditions (^{o}F)

TMPH Total moles per hour (lb moles/hour)

TMPHI Initial molar flow rate (lb. moles/hour)

U Over-all coefficient of heat transfer through a wall, based on inside surface and outside air temperatures, B.t.u./hr. sq. ft.^{o}F

V Gas volume cubic feet

VELI Velocity of gas at any point in reactor (ft/sec)

VC(J,L) Concentration of component J at L% into reactor

W Rate of emission from a unit area of a black-body at the temperature indicated by a subscript (W_{g_1} at the temperature of g_1), B.t.u./hr. sq. ft.

WDZA(I,L) Rate of reaction I at distance L% into reactor

WPJ(L) Pressure L% into reactor (At)

WT(L) Temperature L% into reactor (^{o}F)

WTM(J,L) Total mole/hour of component J, L% into reactor

WTMPH(L) Total mole/hour L% into reactor

WVELI(L) Velocity ft/sec L% into reactor

WZIC(L) Length ft L% into reactor

X Used as temporary in calculating heat of reaction, heat capacity

XN Used to calculate temperature profile in reactor

x_1, x_2 Thickness of gas layers, feet.

x,y,z Linear dimensions along the three coordinate axes, ft

α Absorptivity, dimensionless, $_{GS}$ of a gas for surface radiation; $_{x}$ of a gas of path length x, $_{s}$ of a surface.

$\alpha, \beta, \delta, \gamma$ Positional parameter indicating the magnitude and direction of bulk flow heat exchange between gas volumes

γ Factor by which to multiply center-to-center distance between two zones to obtain correct mean beam length between them for radiation, dimensionless.

γ Emission coefficient, sq. ft. $\gamma_g = 4kaV_g$; $\gamma_s = \epsilon_s A_s$

Δ Denotes a difference

$\mathcal{D}$ Determinant formulation of energy balances

ϵ Emissivity, dimensionless; ϵ_s of a surface; ϵ_G or ϵ_g of a gas; $\epsilon_{T_{avg}}$ evaluated at the arithmetic mean of the gas and surface temperatures; ϵ_x of path

length x; ε_1, ε_2, ... of a gas at PL_1, PL_2, ...

$\mathcal{F}$ Overall interchange factor, dimensionless; $\mathcal{F}_{1G}$ = radiation reaching gas and $\mathcal{F}_{12}$ radiation reaching surface A_2, due to original emission from A_1 only, but including assistance given by reflection at all surfaces, expressed as a ratio to σT^4

ϕ Angle between line joining centers of two zones and the normal to a surface, radians.

ϕ_1, ϕ_2 Angles used in evaluation of f_p, radians

μ Viscosity, lb/ft. hr.

ν Emissivity of a gas on a volume basis, ft.$^{-1}$

ρ Density, lb/cu. ft.

ρ_s Reflectivity of a surface, dimensionless

σ Stefan-Boltzmann constant = 0.1713×10^{-8} B.t.u./hr. sq. ft. $^{o}R^4$

τ Gas transmissivity, dimensionless; $_x$ of path length x

ψ Escape factor for radiation from a cube of gas (ratio of energy leaving boundaries to energy originating within volume), dimensionless

θ_1, θ_2 Angles between radiant beam and normals to a surface, radians

ω Solid angle, steradians

Appendix B

Computer Program

```
      PROGRAM MAIN                                                      MAIN  1
      COMMON/ZZREAD/ID                                                  MAIN  2
      COMMON/TAPE2/IND,TX(100),QT(4),QPF                                MAIN  3
      COMMON/ARRAY1/TP1(60),TP2(60),TP3(60),T1(60),T2(60),T3(60)        MAIN  4
     1 ,H1(60),H2(60),H3(60)                                            MAIN  5
      COMMON//DUMMY(400),NPRNT                                          MAIN  6
      DIMENSION ID(105),TXF(85),TXFOLD(85),TXOLD(85),QF(4)              MAIN  7
      DEFINE FILE 20(2400,61,U,ID),21(480,61,U,ID),22(480,61,U,ID),     MAIN  8
     1 23(8,401,U,ID),24(2400,61,U,ID),25(480,61,U,ID)                  MAIN  9
      DATA ID    /1,13,25,90,100,2,12,14,24,26,3,11,15,23,27,4,10,16,   MAIN 10
     1            22,28,5,9,17,21,29,6,8,18,20,30,7,19,31,100,100,     MAIN 11
     2            37,49,61,100,100,36,38,48,50,60,35,39,47,51,59,34,40,MAIN 12
     3          46,52,58,33,41,45,53,57,32,42,44,54,56,31,43,55,100,100,MAIN 13
     4            61,73,85,100,100,62,72,74,84,100,63,71,75,83,100,64,70MAIN 14
     5,         76,82,100,65,69,77,81,100,66,68,78,80,100,67,79,100,100MAIN 15
     6,100/                                                             MAIN 16
C     CALL ERRSET(209,,,1,0.0,0)                                        MAIN 17
      CALL READ(4,'START',DUMMY(1),400)                                 MAIN 18
      CALL PZERO(TP1(1),540)                                            MAIN 19
      READ(5,904)(T1(I),I=1,22),(T2(I),I=1,22),(T3(I),I=1,22)           MAIN 20
C   T1 T2 T3 ARE THE THREE ASSUMED OUTER WALL REACTOR TEMPERATURE PROFILMAIN 21
      PI=3.1415926/2.                                                   MAIN 22
      READ(5,904)DTREC                                                  MAIN 23
C   DTREC IS THE CONVERGENCE CRITERAM FOR THE REACTOR IN KELVIN DEGREES MAIN 24
      CALL FURN                                                         MAIN 25
      IND=1                                                             MAIN 26
      NPRNT=1                                                           MAIN 27
      NSURF=22                                                          MAIN 28
      CALL WRITE(3,'TEM1',T1(1),60)                                     MAIN 29
      CALL WRITE(3,'TEM2',T2(1),60)                                     MAIN 30
      CALL WRITE(3,'TEM3',T3(1),60)                                     MAIN 31
      CALL RYBD                                                         MAIN 32
      CALL READ(2,'HCP ',H1(1),60)                                      MAIN 33
      CALL READ(2,'HCP ',H2(1),60)                                      MAIN 34
      CALL READ(2,'HCP ',H3(1),60)                                      MAIN 35
      DO 1000 I000=1,10                                                 MAIN 36
      IJ=1                                                              MAIN 37
      DO 10 I=1,85                                                      MAIN 38
      TXOLD(I)=TX(I)                                                    MAIN 39
10    TXF(I)=TX(I)*1.3                                                  MAIN 40
      WRITE(6,901)TXF                                                   MAIN 41
      TX(100)=0.0                                                       MAIN 42
      J1=0                                                              MAIN 43
      DO 2 J=9,15                                                       MAIN 44
      X1=0.                                                             MAIN 45
      X2=0.                                                             MAIN 46
      X3=0.                                                             MAIN 47
      DO 1 K=1,5                                                        MAIN 48
      J1=J1+1                                                           MAIN 49
      I1=ID(J1)                                                         MAIN 50
```

```
      I2=ID(J1+35)                                                    MAIN  51
      I3=ID(J1+70)                                                    MAIN  52
      IF(I1.NE.100)X1=X1+1.                                           MAIN  53
      IF(I2.NE.100)X2=X2+1.                                           MAIN  54
      IF(I3.NE.100)X3=X3+1.                                           MAIN  55
      TP1(J)=TP1(J)+TX(I1)                                            MAIN  56
      TP2(J)=TP2(J)+TX(I2)                                            MAIN  57
1     TP3(J)=TP3(J)+TX(I3)                                            MAIN  58
      TP1(J)=TP1(J)/X1*1.8                                            MAIN  59
      TP1(J+7)=TP1(J)                                                 MAIN  60
      TP2(J)=TP2(J)/X2*1.8                                            MAIN  61
      TP2(J+7)=TP2(J)                                                 MAIN  62
      TP3(J)=TP3(J)/X3*1.8                                            MAIN  63
2     TP3(J+7)=TP3(J)                                                 MAIN  64
      CALL WRITE(2,'TEMP',TP1(1),60)                                  MAIN  65
      CALL WRITE(2,'HCP ',H1(1),60)                                   MAIN  66
      CALL FURN1                                                      MAIN  67
      QF(IJ)=OFF                                                      MAIN  68
      CALL READ(2,'TEMS',T1(1),60)                                    MAIN  69
      DO 11 I=1,60                                                    MAIN  70
11    T1(I)=T1(I)/1.8                                                 MAIN  71
      WRITE(6,909)IJ,(T1(I),I=1,NSURF)                                MAIN  72
      CALL WRITE(3,'TEM1',T1(1),60)                                   MAIN  73
      CALL WRITE(2,'HCP ',H2(1),60)                                   MAIN  74
      CALL WRITE(2,'TEMP',TP2(1),60)                                  MAIN  75
      IJ=IJ+1                                                         MAIN  76
      WRITE(6,902)IJ,(TP2(I),I=1,NSURF)                               MAIN  77
      CALL FURN1                                                      MAIN  78
      QF(IJ)=OFF                                                      MAIN  79
      CALL READ(2,'TEMS',T2(1),60)                                    MAIN  80
      DO 12 I=1,60                                                    MAIN  81
12    T2(I)=T2(I)/1.8                                                 MAIN  82
      WRITE(6,900)IJ,(T2(I),I=1,NSURF)                                MAIN  83
      CALL WRITE(3,'TEM2',T2(1),60)                                   MAIN  84
      CALL WRITE(2,'TEMP',TP3(1),60)                                  MAIN  85
      CALL WRITE(2,'HCP ',H3(1),60)                                   MAIN  86
      IJ=IJ+1                                                         MAIN  87
      WRITE(6,902)IJ,(TP3(I),I=1,NSURF)                               MAIN  88
      CALL FURN1                                                      MAIN  89
      QF(IJ)=OFF                                                      MAIN  90
      CALL READ(2,'TEMS',T3(1),60)                                    MAIN  91
      DO 13 I=1,60                                                    MAIN  92
13    T3(I)=T3(I)/1.8                                                 MAIN  93
      WRITE(6,900)IJ,(T3(I),I=1,NSURF)                                MAIN  94
      CALL WRITE(3,'TEM3',T3(1),60)                                   MAIN  95
      IND=1                                                           MAIN  96
      CALL PYRO1                                                      MAIN  97
      DO 101 I=1,22                                                   MAIN  98
      T1(I)=T1(I)/1.8                                                 MAIN  99
      T2(I)=T2(I)/1.8                                                 MAIN 100
```

```
101 101   T3(I)=T3(I)/1.8                                                    MAIN 101
102       A=400./84.                                                         MAIN 102
103       IND=2                                                              MAIN 103
104       DO 4 I=1,85                                                        MAIN 104
105       ZIC=A*FLOAT(I)-A                                                   MAIN 105
106 4      CALL TEMPT(TXF(I),ZIC,IND)                                        MAIN 106
107       WRITE(6,903)TXF                                                    MAIN 107
108       DO 3 IJ=1,3                                                        MAIN 108
109       N1=(IJ-1)*60+1                                                     MAIN 109
110       N2=N1+NSURF-1                                                      MAIN 110
111 3     WRITE(6,902)IJ,(TP1(I),I=N1,N2)                                    MAIN 111
112       DT=0.0                                                             MAIN 112
113       DO 5 IJ=1,85                                                       MAIN 113
114       DT=AMAX1(DT,ABS(TX(IJ)-TXOLD(IJ)))                                 MAIN 114
115 5      TXOLD(IJ)=TX(IJ)                                                  MAIN 115
116       IF(DT.LT.DTREC)GO TO 6                                             MAIN 116
117       IF(DT.LT.1.0)GO TO 6                                               MAIN 117
118       CALL PZERO(TP1(1),360)                                             MAIN 118
119       WRITE(6,907)DT,I000                                                MAIN 119
120       DO 100 IJ=1,NSURF                                                  MAIN 120
121       H1(IJ)=H1(IJ)*QT(1)/(QF(1)*5./3.)                                  MAIN 121
122       H2(IJ)=H2(IJ)*QT(2)/(QF(2)*5./3.)                                  MAIN 122
123       H3(IJ)=H3(IJ)*QT(3)/(QF(3)*5./3.)                                  MAIN 123
124 100   CONTINUE                                                           MAIN 124
125       WRITE(6,908)H1(9),H2(9),H3(9)                                      MAIN 125
126 1000  CONTINUE                                                           MAIN 126
127       WRITE(6,905)DT                                                     MAIN 127
128       GO TO 7                                                            MAIN 128
129 6      WRITE(6,906)I000,DT                                               MAIN 129
130 900   FORMAT(///1H1,20X,'SURFACE TEMPERATURE PROFILE FOR FURNACE SEGMENTMAIN 130
131      1',I10,'  DEG K'//20X,60('-')///(25X,6F15.1))                       MAIN 131
132 901   FORMAT(///1H1,20X,'REACTOR PROCESS TEMPERATURE PROFILE'/20X,35('-MAIN 132
133      1'),20X,'DEG R'///(25X,6F15.1))                                     MAIN 133
134 902    FORMAT(//20X,'PROCESS TEMPERATURE PROFILE FOR FURNACE SEGMENT',I1MAIN 134
135      1,'  DEG F'//20X,60('-')///(25X,6F15.1))                           MAIN 135
136 903   FORMAT(///1H1,20X,'REACTOR OUT WALL TEMPERATURE PROFILE'/20X,35('-MAIN 136
137      1'),20X,'DEG K'///(25X,6F15.1))                                     MAIN 137
138 904   FORMAT(2(3(7F10.0/),F10.0/),3(7F10.0/),F10.0)                      MAIN 138
139 905   FORMAT('  INSIDE TEMPERATURE PROFILE DID NOT CONVERGE AFTER 10 TRAMAIN 139
140      1ILS MAX TEMPERATURE= ',F10.3,' DEG K'/' ',90('-'))                 MAIN 140
141 906    FORMAT(' INSIDE  TEMPERATURE PROFILE CONVERGED AFTER',I3,'TRAILS MMAIN 141
142      1AX TEMPERATURE DIFERENCE= ',F10.3,' DEG K'/' ',95('-'))           MAIN 142
143 907    FORMAT(20X,'MAXIUM TEMPRATURE DIFERENCE CALCULATED= ',F16.3,'  AFTMAIN 143
144      1ER',I5,2X,'TRAILS')                                              MAIN 144
145 908    FORMAT('0ADJUSTED HEAT TRANSFER COEFFICIENT PROCESS FLUID TO OUTSIDMAIN 145
146      1E TUBE WALL BTU/(HR FOOT OF FURNACE LENGTH)',///' ',20X,3F20.3)   MAIN 146
147 7      CALL WRITE(4,'STAR',DUMMY(1),400)                                 MAIN 147
148       STOP                                                               MAIN 148
149       END                                                                MAIN 149
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      SUBROUTINE PYRO                                                   PYRO 150
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)  PYRO 151
     1,EA(25),EE(25),RAD,AU                                             PYRO 152
      COMMON/TUBE2/IMD,TX(100)                                          PYRO 153
      COMMON/PYRO3/Z(11),ZTT,C(25),CP(25,4)                             PYRO 154
     1,DH(25),DS(25),DF(25)                                             PYRO 155
C                                                                       PYRO 156
      COMMON/EE/DCP(25,4),HT(25),ST(25),FT(25),EI(25),HD(25)            PYRO 157
      COMMON/PU/P(25),DN,SMWT(25),CLJ(25,2),VI(25),AMWT,VEL1,HI         PYRO 158
      COMMON/PT2/TI,RN1,RN2,VIS                                         PYRO 159
      COMMON/TM/TMPH,RADI(100),DE(25),ZIC                               PYRO 160
      COMMON/SET/MY,MB,IB,IPLOT,DLS                                     PYRO 161
      DIMENSION DXA(25),TM(25),PPI(25),RADF(100),CARD(80)               PYRO 162
      COMMON/W/ ZIC(5,),WT(50),TMPH(50),WPT(50),WVEL1(50),WC(25,50),WTPYRO 163
     1M(25,50),WDXA(25,50),RADD(100,50)                                 PYRO 164
      DIMENSION RA(25),E(25),INAME(50),IDAT8(240)                       PYRO 165
      DATA DXA/25*0./,F/25*1./                                          PYRO 166
        INTEGER IDATA(43)/1A1,1B1,1C1,1D1,1E1,1F1,1G1,1H1,1I1,1J1,1K1,1L1PYRO 167
     1,1M1,1N1,1O1,1P1,1Q1,1R1,1S1,1T1,1U1,1V1,1W1,1X1,1Y1,1Z1,1=>1,1+1 PYRO 168
     2,1 1,1-1,1*1,1/1,1(1,1)1,1=1,1$1/                                 PYRO 169
      INTEGER IDATP(9)/1 1N1,12N1,13N1,14N1,15N1,16N1,17N1,18N1,19N1/    PYRO 170
      INTEGER IDATB(50)/1 N1,1 N1,1RN1,1EN1,1AN1,1CN1,1TN1,1ON1,1RN1,   PYRO 171
     1 1N1,1PN1,1ON1,1SN1,1IN1,1TN1,1IN1,1ON1,1NN1,1 N1,1FN1,1EN1,1EN1,1PYRO 172
     2TN1,1 N1,1 N1,25*1 N1/                                            PYRO 173
      IDATP(1)=IDATP(1)                                                 PYRO 174
      REAL*4 LOG                                                        PYRO 175
      IB=1                                                              PYRO 176
      IGOTO=1                                                           PYRO 177
C     F(ID)=CHANGE IN ARRHENIUS FREQUENCY FACTOR FROM                   PYRO 178
C     PUBLISHED DATA ,CHANGE IS MADE FOR CHEMICAL SPECIES REACTION ID   PYRO 179
  107 READ(5,953) ID,FFF                                                PYRO 180
      F(ID)=FFF                                                         PYRO 181
      IF(ID,EQ.25)GO TO 100                                             PYRO 182
      GO TO 107                                                         PYRO 183
C      IR  IS TOTAL NUMBER OF REACTIONS                                 PYRO 184
C     IS IS TOTAL NUMBER OF CHEMICAL SPECIES INCLUDING INERTS           PYRO 185
  100 READ(5,900,END=99)IR,IS                                           PYRO 186
C IR=TOTAL NUMBER OF REACTIONS,IS=TOTAL NUMBER OF CHEMICAL SPECIES      PYRO 187
C     IGOW 1READ IN NEW DATA SET                                        PYRO 188
C          2RETAIN PRESENT DATA SET READ IN NEW TEMPERATURE PROFILE     PYRO 189
C          3NO NEW CASES OR TEMPERATURES TO FOLLOW COMPUTER  STOPS      PYRO 190
C                                                                       PYRO 191
C     Z(II) TEMPERATURE PROFILE IN 10% INCREMENTS INCLUDING 0 AND 100   PYRO 192
      READ(5,943)IGOW,(Z(II),II=1,11)                                   PYRO 193
C     CARD CONTAINS UP TO 80 ALPHANUMERIC IDENTIFATION OF SYSTEM BEING  PYRO 194
C     CALCULATED                                                        PYRO 195
      READ(5,950)CARD                                                   PYRO 196
C     IB TIME INCREMENTS USED TO CALCULATE CARBON DEPOSITION            PYRO 197
C     IZZ MAX ALLAWABLE TRIALS FOR CONVERGENCE                          PYRO 198
C     IPLOT                                                             PYRO 199
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C        1      PLOT RESULTS      DO NOT WRITE DETAILED CALCULATIONS      PYRO 200
C        2      PLOT RESULTS      WRITE OUT DETAILED CALCULATIONS         PYRO 201
C        3      PLOT NOT DONE     WRITE OUT DETAILED CALCULATIONS         PYRO 202
C        4      PLOT NOT DONE     DO NOT WRITE DETAILED CALCULATIONS      PYRO 203
      READ(5,958)IB,IZZ,IPLOT                                             PYRO 204
C     T IS TEMPERATURE AT INLET Z(1)                                       PYRO 205
C     PT IS INITIAL PRESSURE AT STARTUP                                    PYRO 206
C     PRESS IS MAX ALLOWABLE PRESSURE AT INLET                             PYRO 207
C     POUT IS DESIRED PRESSURE AT OUTLET                                   PYRO 208
C     ALL PRESSURES IN ATMOSPHERES                                         PYRO 209
C      ZT IS TOTAL REACTOR LENGTH FEET                                     PYRO 210
C     DL IS INCREMENT OF LENTH USED TO CALCULATE REACTOR CONDICITIONS      PYRO 211
      READ(5,919)T,PT,PRES,ZT,DL,POUT                                      PYRO 212
      DLS=DL                                                               PYRO 213
      TIN=T                                                                PYRO 214
C IA(I,M)=IDENTITY OF CHEMICAL SPECIES IN CHEMICAL REACTION POSITION M     PYRO 215
      GC=1.3143                                                            PYRO 216
C     KE(I) IS NUMBER OF REACTANTS IN REACTION I                           PYRO 217
C     KR(I) IS NUMBER OF PRODUCTS IN REACTION I                            PYRO 218
      READ(5,911)(KE(I),KR(I),I=1,IR)                                      PYRO 219
      DO 1 I=1,IR                                                          PYRO 220
      IT=KE(I)+KR(I)                                                       PYRO 221
C     IA(I,M) REPRESENTS THE CHEMICAL SPECIES IA IN REACTION I             PYRO 222
C           POSITION M                                                     PYRO 223
      READ(5,901)ID,(IA(I,M),M=1,IT)                                       PYRO 224
      IF (ID.NE.I)GO TO 101                                                PYRO 225
1     CONTINUE                                                             PYRO 226
C B(I,M)COEFFICIENT OF M CHEMICAL SPECIES IN REACTION I                    PYRO 227
      DO 2 I=1,IR                                                          PYRO 228
      IT=KE(I)+KR(I)                                                       PYRO 229
C     B(I,M) IS THE STOCIMETRIC COEFFICIENT REACTION I                     PYRO 230
C          POSITION M                                                      PYRO 231
C     BB(I,M) IS THE PSEUDO  ORDER OF REACTION REACTION I                  PYRO 232
C          POSITION M                                                      PYRO 233
      READ(5,903)ID,(B(I,M),M=1,IT),(BB(I,M),M=1,IT)                       PYRO 234
      IF(ID.NE.I)GO TO 102                                                 PYRO 235
2     CONTINUE                                                             PYRO 236
C C(J) IS THE INITIAL CONCENTRATION OF THE J CHEMICAL SPECIES (8 PER CARD  PYRO 237
      READ(5,904)(P(J),J=1,IS)                                             PYRO 238
      PTT=0.0                                                              PYRO 239
      DO 220 I=1,IS                                                        PYRO 240
220   PTT=PTT+P(I)                                                         PYRO 241
      DO 18 I=1,IS                                                         PYRO 242
      PPI(I)=P(I)*PT/PTT                                                   PYRO 243
      P(I)=PPI(I)                                                          PYRO 244
18    C(I)=P(I)/GC/T                                                       PYRO 245
C INAME(I)IS THE NAME OF EACH CHEMICAL SPECIES (MAX 20 LETTERS) 4 PER CARD PYRO 246
      IT=IS*20                                                             PYRO 247
C     INAME(J) IS THE ALPANUMERIC IDENTIFCATION OF CHEMICAL                PYRO 248
C     SPECIES J                                                            PYRO 249
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      READ(5,905)(INAME(J),J=1,IT)                                      PYRO 250
      DO 3 J=1,IS                                                       PYRO 251
C     CP(J,M) IS THE HEAT CAPACITY OF CHEMICAL SPECIES J                PYRO 252
C           EXPRESSED AS A 3-RD POWER POLYNOMIAL IN TEMPERATURE         PYRO 253
      READ(5,906) (CP(J,M),M=1,4),ID                                    PYRO 254
      IF(ID.NE.J)GO TO 103                                              PYRO 255
3     CONTINUE                                                          PYRO 256
      DO 4 I=1,IR                                                       PYRO 257
C     EA(I) IS ARRHENIUS FREQUENCY FACTOR OF REACTION I                 PYRO 258
C     EE(I) IS THE ARRHENIUS ACTIVATION ENERGY OF REACTION I            PYRO 259
C          CAL/MOLE OK                                                  PYRO 260
      READ(5,907)ID,EA(I),EE(I)                                         PYRO 261
      EA(I)=EA(I)*F(I)                                                  PYRO 262
      IF (ID.NE.I)GO TO 104                                             PYRO 263
4     CONTINUE                                                          PYRO 264
      DO5 J=1,IS                                                        PYRO 265
C     DS(J) IS THE ENTOPY OF CHEMICAL SPECIES J 25 C                    PYRO 266
C     DH(J) IS THE ENTHALPY OF CHEMICAL SPECIES J 25 C                  PYRO 267
C     DF(J) IS GIBBS FREE ENERGY OF CHEMICAL SPECIES J 25 C             PYRO 268
      READ(5,908) ID,DS(J),DH(J),DE(J)                                  PYRO 269
      IF(ID.NE.J) GO TO 105                                             PYRO 270
5     CONTINUE                                                          PYRO 271
      DO 21 J=1,IS                                                      PYRO 272
C     CLJ(J,M) ARE THE CONSTANTS OF LENNARD & JONES                     PYRO 273
C     M                                                                 PYRO 274
C     1 COLLISION PARAMETER                                             PYRO 275
C     2 E/K                                                             PYRO 276
C     SMWT(J) IS THE MOLECULAR WEIGHT OF THE JTH CHEMICAL SPECIES       PYRO 277
C     DE(J) IS THE DENSITY OF SOLID CHEMICAL SPECIES J                  PYRO 278
      READ(5,911) ID,(CLJ(J,M),M=1,2),SMWT(J)                          PYRO 279
      IF(CLJ(J,2).EQ.0.)READ(5,940)DE(J)                                PYRO 280
      IF(ID.NE.J)GO TO 106                                              PYRO 281
21    CONTINUE                                                          PYRO 282
      DO 6 I=1,IR                                                       PYRO 283
      DO 7 L=1,4                                                        PYRO 284
7     DCP(I,L)=0.                                                       PYRO 285
      I1=KF(I)+1                                                        PYRO 286
      I2=KR(I)+KF(I)                                                    PYRO 287
      DO 8 M=I1,I2                                                      PYRO 288
      J=IA(I,M)                                                         PYRO 289
      DO 8 L=1,4                                                        PYRO 290
8     DCP(I,L)=DCP(I,L)+B(I,M)*CP(J,L)/B(I,1)                           PYRO 291
      I2=KF(I)                                                          PYRO 292
      DO 6 M=1,I2                                                       PYRO 293
      J=IA(I,M)                                                         PYRO 294
      DO 6 L=1,4                                                        PYRO 295
6     DCP(I,L)=DCP(I,L)-B(I,M)*CP(J,L)/B(I,1)                           PYRO 296
C  TEMPERATURE                                                          PYRO 297
      R1=1.987                                                          PYRO 298
      DO 9 I=1,IR                                                       PYRO 299
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      FT(I)=0.                                                          PYRO 300
      ST(I)=0                                                           PYRO 301
      HT(I)=0                                                           PYRO 302
      I1=KF(I)+1                                                        PYRO 303
      I2=KR(I)+KF(I)                                                    PYRO 304
      DO 10 M=I1,I2                                                     PYRO 305
      J=IA(I,M)                                                         PYRO 306
      ST(I)=ST(I)+B(I,M)*DS(J)/B(I,1)                                   PYRO 307
      FT(I)=FT(I)+B(I,M)*DF(J)/B(I,1)                                   PYRO 308
   10 HT(I)=HT(I)+B(I,M)*DH(J)/B(I,1)                                   PYRO 309
      I2=KF(I)                                                          PYRO 310
      DO 9 M=1,I2                                                       PYRO 311
      J=IA(I,M)                                                         PYRO 312
      FT(I)=FT(I)-B(I,M)*DF(J)/B(I,1)                                   PYRO 313
      ST(I)=ST(I)-B(I,M)*DS(J)/B(I,1)                                   PYRO 314
    9 HT(I)=HT(I)-B(I,M)*DH(J)/B(I,1)                                   PYRO 315
      TO=298.15                                                         PYRO 316
      DO19 I=1,IR                                                       PYRO 317
      READ(5,908)IJ,TT,FI(I)                                            PYRO 318
      HO(I)=HT(I)                                                       PYRO 319
      DO 29 M=1,4                                                       PYRO 320
      X=M                                                               PYRO 321
   29 HO(I)=HO(I)-DCP(I,M)/X*TO**M                                      PYRO 322
      IF(FI(I).GT.0.)FI(I)=LOG(FI(I))                                   PYRO 323
      IF(FI(I).LE.0.0)FI(I)=-FT(I)/TO/R1                                PYRO 324
   19 FI(I)=HO(I)/R1/TT+FI(I)-DCP(I,1)/R1*LOG(TT)-DCP(I,2)/2./R1*T      PYRO 325
     1T-DCP(I,3)/6./R1*TT**2-DCP(I,4)/12./R1*TT**3                      PYRO 326
C  NOW WE HAVE THE REACTION SYSTEM, IT WILL BE PRINTED OUT.             PYRO 327
C CHEMICAL SPECIES IDENTIFICATION                                       PYRO 328
      WRITE(6,909)                                                      PYRO 329
      WRITE(6,910)                                                      PYRO 330
      DO 11 J=1,IS                                                      PYRO 331
      JJ1=1+20*(J-1)                                                    PYRO 332
      JJ2=20*J                                                          PYRO 333
   11 WRITE(6,912)(INAME(JJ),JJ=JJ1,JJ2),IDATA(J),J,(CP(J,M),M=1,4),DH(JPYRO 334
     1),DS(J),DF(J)                                                     PYRO 335
      IGOTO=1                                                           PYRO 336
      WRITE(6,920)                                                      PYRO 337
      DO 17 J=1,IS                                                      PYRO 338
      JJ1=1+20*(J-1)                                                    PYRO 339
      JJ2=20*J                                                          PYRO 340
   17 WRITE(6,917)(INAME(JJ),JJ=JJ1,JJ2),IDATA(J),J,(CLJ(J,M),M=1,2),SHPYRO 341
     1T(J),C(J)                                                         PYRO 342
      WRITE(6,913)                                                      PYRO 343
      DO 12 I=1,IR                                                      PYRO 344
      II=2                                                              PYRO 345
      IF (EE(I).EQ.0.)II=1                                              PYRO 346
      I2=KF(I)                                                          PYRO 347
      DO 14 M=1,I2                                                      PYRO 348
      J=IA(I,M)                                                         PYRO 349
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      MM=M*3-1                                                          PYRO 350
      IDATB(MM)=IDATA(J)                                                PYRO 351
      J=P(I,M)+29.01                                                    PYRO 352
      MM=M*3-2                                                          PYRO 353
      IDATB(MM)=IDATA(J)                                                PYRO 354
      MM=M*3                                                            PYRO 355
   14 IDATB(MM)=IDATA(28)                                               PYRO 356
      MM=KF(I)*3                                                        PYRO 357
      KK=40                                                             PYRO 358
      GO TO (122,121),II                                                PYRO 359
  121 IDATB(MM)=IDATA(KK)                                               PYRO 360
      MM=MM+1                                                           PYRO 361
  122 KK=KK+1                                                           PYRO 362
      IDATB(MM)=IDATA(KK)                                               PYRO 363
      MM=MM+1                                                           PYRO 364
      KK=KK+1                                                           PYRO 365
      IDATB(MM)=IDATA(KK)                                               PYRO 366
      I1=KF(I)+1                                                        PYRO 367
      I2=KF(I)+KP(I)                                                    PYRO 368
      DO 15 M=I1,I2                                                     PYRO 369
      J=IA(I,M)                                                         PYRO 370
      MM=M*3-1 +II                                                      PYRO 371
      IDATB(MM)=IDATA(J)                                                PYRO 372
      J=P(I,M)+29.01                                                    PYRO 373
      MM=M*3-2+II                                                       PYRO 374
      IDATB(MM)=IDATA(J)                                                PYRO 375
      MM=M*3+II                                                         PYRO 376
   15 IDATB(MM)=IDATA(28)                                               PYRO 377
      DO 16 J=MM,44                                                     PYRO 378
   16 IDATB(J)=IDATA(29)                                                PYRO 379
   12 WRITE(6,915)I,(IDATB(M),M=1,40),EA(I),EE(I),(DCP(I,M),M=1,4)      PYRO 380
      WRITE(6,927)                                                      PYRO 381
      DO 28 J=1,IR                                                      PYRO 382
      I2=KF(J)+KP(J)                                                    PYRO 383
      DO 32 I=1,I2                                                      PYRO 384
      I3=IA(J,I)                                                        PYRO 385
   32 IDATB(I)=IDATA(I3)                                                PYRO 386
   28 WRITE(6,926)J,FI(J),FI(J),(IDATB(I),BB(J,I),I=1,I2)               PYRO 387
C     RAD IS THE RADIUS OF THE INSIDE OF THE REACTOR TUBE               PYRO 388
C     AO IS THE RADIUS OF THE OUTSIDE OF THE REACTOR TUBE               PYRO 389
C     TMPH IS THE MOLAR FLOW RATE IN LB MOLES ORE HOUR                  PYRO 390
C     KEYR IS THE KEY REACTANT                                          PYRO 391
C     KEYP IS THE KEY PRODUCT                                           PYRO 392
      READ(5,902) RAD,AO,TMPH                                           PYRO 393
      READ(5,900)KEYR,KEYP                                              PYRO 394
      TMPH1=TMPH                                                        PYRO 395
      RADU=RAD                                                          PYRO 396
      ZTT=ZT                                                            PYRO 397
      IGOTO=1                                                           PYRO 398
      PDP=.2                                                            PYRO 399
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      PSAVE=PT                                                          PYRO 400
      IF(KEYR.EQ.0)GO TO 92                                             PYRO 401
      WRITE(6,918)                                                      PYRO 402
      DO 205 I=1,IR                                                     PYRO 403
      MM=0                                                              PYRO 404
      IFIN=1                                                            PYRO 405
      I1=1                                                              PYRO 406
      I2=KF(I)                                                          PYRO 407
      GO TO 206                                                         PYRO 408
207   I1=KF(I)+1                                                        PYRO 409
      I2=KF(I)+KP(I)                                                    PYRO 410
      IFIN=2                                                            PYRO 411
206   DO 214 M=I1,I2                                                    PYRO 412
      JJ1=1+29*(IA(I,M)-1)                                              PYRO 413
      JJ2=JJ1+19                                                        PYRO 414
      DO 208 I3=JJ1,JJ2                                                 PYRO 415
      IF(INAME(I3).EQ.INAME(20).AND.INAME(I3+1).EQ.INAME(20))GO TO 209  PYRO 416
208   CONTINUE                                                          PYRO 417
      GO TO 210                                                         PYRO 418
209   JJ2=I3                                                            PYRO 419
210   J=B(I,M)+29.01                                                    PYRO 420
      MM=MM+1                                                           PYRO 421
      IDATB(MM)=IDATA(J)                                                PYRO 422
      MM=MM+1                                                           PYRO 423
      IDATB(MM)=IDATA(29)                                               PYRO 424
      DO 211 I3=JJ1,JJ2                                                 PYRO 425
      MM=MM+1                                                           PYRO 426
211   IDATB(MM)=INAME(I3)                                               PYRO 427
      IF(M.EQ.I2)GO TO 214                                              PYRO 428
      MM=MM+1                                                           PYRO 429
      IDATB(MM)=IDATA(28)                                               PYRO 430
214   CONTINUE                                                          PYRO 431
      IF(IFIN.EQ.2)GO TO 205                                            PYRO 432
      DO 212 I3=1,3                                                     PYRO 433
      MM=MM+1                                                           PYRO 434
      KK=39+I3                                                          PYRO 435
212   IDATB(MM)=IDATA(KK)                                               PYRO 436
      GO TO 207                                                         PYRO 437
205   WRITE(6,971)(IDATB(I3),I3=1,MM)                                   PYRO 438
      ENTRY PYRO1                                                       PYRO 439
110   WRITE(6,916)                                                      PYRO 440
      HR=0.                                                             PYRO 441
      HAZE=1                                                            PYRO 442
      KK=1                                                              PYRO 443
C T=GAS TEMPERATURE AT ENTRANCE, PRES=PRESSURE OF GAS, ZT=LENGTH OF TUBEPYRO 444
      HR=0.                                                             PYRO 445
C DZ=INCREMENTAL CHANGE IN REACTOR,CI=CONCENTRATION OF INERTS, A=T=A(1) PYRO 446
C A(2)Z + A(3) Z**L + A(4)*Z**3                                         PYRO 447
900   FORMAT(2I2)                                                       PYRO 448
901   FORMAT(4I2)                                                       PYRO 449
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  301 902   FORMAT(3F10.5)                                                    PYRO 450
  302 903   FORMAT(I2,2F3.2)                                                  PYRO 451
  303 904   FORMAT(12F6.5)                                                    PYRO 452
  304 905   FORMAT(60A1)                                                      PYRO 453
  305 906   FORMAT(4E16.8,I7)                                                 PYRO 454
  306 907   FORMAT(I2,E7.1,F10.4)                                             PYRO 455
  307 908   FORMAT(I2,3F9.2)                                                  PYRO 456
  308 909   FORMAT('1  PROGRAM PYRO',/,' PROGRAMMER RICHARD ROBERTSON',/,' ADVPYRO 457
      309      1ISORS',/,' DR ROCHE ',/,' DR HANESIAN',/,' AS PARITIAL FULFILMENT PYRO 458
      310      2OF PHD THESIS',/,' NEWARK COLLEGE OF ENGINEERING')              PYRO 459
  311 910   FORMAT (1H1,T45,'IDENTIFICATION OF REACTION SYSTEM',///,T5,'COMPONPYRO 460
      312      1ENT',T22,'CO  NO.',T44,'HEAT CAPACITY DATA',T81,'DELTA-H',T98,'DELPYRO 461
      313      2TA-S',T116,'LOG(K) ',//,T33,'A',T44,'B',T56,'C',T68,'D')        PYRO 462
  314 911   FORMAT(I2,3X,3E5.0)                                                PYRO 463
  315 912   FORMAT(' ',20A1,1X,1A1,1X ,I2,4(2X,1PE10.3),3(3X,1PE15.8))        PYRO 464
  316 913   FORMAT(1H1,T45,'REACTION SYSTEM',//,' EQUATION',T45,'ARRHENIUS  EAPYRO 465
      317      1TE CONTANT',T75,'DELTA HEAT CAPACITY  DATA FOR REACTION',/1H ,T71,PYRO 466
      318      2 'DELTA-A',T93,'DELTA B',T95,'DELTA C',T107,'DELTA D',T51,'K(O)',TPYRO 467
      319      361,'E')                                                         PYRO 468
  320 915   FORMAT(1H ,I2,2X,40A1,6(1PE10.3,2X))                               PYRO 469
  321 916   FORMAT(1H )                                                       PYRO 470
  322 917   FORMAT(' ',21A1,I2,5X,F5.3,5X,F5.1,5X,F7.2,1PE12.4)               PYRO 471
  323 918   FORMAT(1H1)                                                       PYRO 472
  324 919   FORMAT(6E12.5)                                                    PYRO 473
  325 920   FORMAT('0  COMPONET',T22,'CO NO',T36,'LENNARD-JONES  MOL. WT.',T62PYRO 474
      326      1,'INITAL ',/,T36,'PARAMETERS',/,T58,'CONCENTRATION',/,T31,'(A)  PYRO 475
      327      2  (DEG-K)')                                                     PYRO 476
  328 921   FORMAT('1COMPONENT    IDENTIFICATION',I2,' OUT OF PLACE',I5,' ID')PYRO 477
  329 922   FORMAT('1COEFFICIENT  IDENTIFICATION',I2,' OUT OF PLACE',I5,' ID')PYRO 478
  330 923   FORMAT('1CP(HEAT CAP) IDENTIFICATION',I2,' OUT OF PLACE',I6,' ID')PYRO 479
  331 924   FORMAT('1ARRHENIUS    IDENTIFICATION',I2,' OUT OF PLACE',I5,' ID')PYRO 480
  332 925   FORMAT('1ENTHALPHY    IDENTIFICATION',I2,' OUT OF PLACE',I5,' ID')PYRO 481
  333 926   FORMAT(' ',I2,2(5X,1PE12.5),5X,6(5X,1A1,'**(',0PF3.1,')'))        PYRO 482
  334 927   FORMAT('0E',T13,'LOG(K)',9X,'CONSTANT ',10X,'ORDER OF REACTIOPYRO 483
      335      1N BY COMPONENT',/,T11,'REACTION',T29,'INTEGERATION')            PYRO 484
  336 928   FORMAT(' ',I2,1PE14.4,E14.4,E14.4)                                PYRO 485
  337 929   FORMAT(' ITERATION NUMBER-',I3,/,' NO CONCENTRATION      TMPH     PYRO 486
      338      1   DXA')                                                       PYRO 487
  339 930   FORMAT('0 DL CHANGED  TO',1PE15.5,5X,'ZIC=',1PE14.5)              PYRO 488
  340 931   FORMAT(1   ALL DXA= 0, SYSTEM MUST BE CHANGED TO ALLOW REACTION') PYRO 489
  341 932   FORMAT (' I=',I2,2X,'PA=',1PE14.5,2X,'DXA(I)=',1PE14.5,2X,'CF,CR='PYRO 490
      342      1,2E14.5,2X,'REQC=',1PE14.5,/,5HORATE,'=',1PE14.5)               PYRO 491
  343 933   FORMAT(' ', 25(1PE14.5,5X,I2/,' '))                               PYRO 492
  344 934   FORMAT(' ',I2,1PE12.5)                                            PYRO 493
  345 935   FORMAT('1',' LENNARD JONES CONSTANTS',I2,'CARD ID',I2,',INTERNAL')PYRO 494
  346 936   FORMAT('0',3(5X,1PE16.7))                                         PYRO 495
  347 937   FORMAT('1REACTOR IS ',F10.2,' FEET LONG AND ',F6.3,' FEET IN RADIUPYRO 496
      348      1S',/,' TOTAL MOLES  / HOUR ARE',F6.1,'POUND MOLES  AT PRESSURE',F8PYRO 497
      349      2.3,'A  VELOCITY OF ',1PE12.5,' AT TEMPERATURE',0PF8.1,'DEG K',//,' PYRO 498
      350      3INITIAL REACTOR INCREMENT(DL',1PE12.5,'FEET)')                  PYRO 499
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  351 938   FORMAT(' ',I2,14X,1PE14.4)                                          PYRO 500
  352 939   FORMAT(' ',I2,1PE14.5,E14.5)                                        PYRO 501
  353 940   FORMAT(F10.0)                                                       PYRO 502
  354 942   FORMAT(' PRESSURE IS',1PE14.5,'    VELOCITY',1PE14.4,'FEET/SEC.') PYRO 503
  355 943   FORMAT(I3,11F7.2)                                                   PYRO 504
  356 944   FORMAT(' ',1PE11.6)                                                 PYRO 505
  357 945   FORMAT('1',T25,'REACTOR RADIUS PROFILE AFTER ',F9.2,' HOURS',//)    PYRO 506
  358 946   FORMAT(' ',I2,'=',1A1,2X,20A1,1PE14.5,5X,E14.5)                     PYRO 507
  359 948   FORMAT(' ',I2,1PE14.4,E14.4)                                        PYRO 508
  360 949   FORMAT('0,1 UNSTABLE TEMPERATURE PROFILE NEW CASE')                 PYRO 509
  361 950   FORMAT(80A1)                                                        PYRO 510
  362 951   FORMAT(' ',80A1)                                                    PYRO 511
  363 952   FORMAT('0VELOCITY OF GAS GREATER THAN SOUND')                       PYRO 512
  364 953   FORMAT(I2,F8.2)                                                     PYRO 513
  365 954   FORMAT('0 REACTOR TUBE COMPLETELY BLOCKED WITH CARBON')             PYRO 514
  366 955   FORMAT(' REACTOR RADIUS PROFILE FROM START TO CLOSE DOWN')          PYRO 515
  367 956   FORMAT(T20,',TEMPERATURE  REACTANT  PRODUCT PROFILES')              PYRO 516
  368 958   FORMAT(3I3)                                                         PYRO 517
  369 960   FORMAT(T16,'0%',T36,'20%',T56,'40%',T76,'60%',T96,'80%',T116,'10    PYRO 518
  370      10%')                                                                PYRO 519
  371 961   FORMAT(' ',F4.0,'FT')                                               PYRO 520
  372 962   FORMAT(T16,'/',T26,'/',T36,'/',T46,'/',T56,'/',T66,'/',T76,'/',T10PYRO 521
  373      16,'/',T86,'/',T116,'/')                                             PYRO 522
  374 963   FORMAT(T20,'R=MOLE REACTANT/(INITIAL MOLE REACTANT)',T60,'E=MOLE PPYRO 523
  375      1RODUCT/(INITIAL MOLE REACTANT)*S.C.',/,T20,'T=TEMPERATURE/(T(I)- TPYRO 524
  376      2(F)',T56,'P=PRESSURE/(P(MAX)-P(MIN))',/,T20,'ELAPSED REACTOR RUNPYRO 525
  377      3 TIME',F7.2,'HOURS')                                                PYRO 526
  378 964   FORMAT(' TROUBLE IN PRESSURE DROP')                                 PYRO 527
  379 965   FORMAT('0CONVERSION OF ',20A1,'TO ',20A1,'IS',F6.2,'%')             PYRO 528
  380 966   FORMAT('+ 0. FT',T66,'/',/,T65,'CL')                                PYRO 529
  381 967   FORMAT(///,25X,80A1)                                                PYRO 530
  382 968   FORMAT(' ',F8.2,' FT',T65,'CL',/,T66,'/')                           PYRO 531
  383 969   FORMAT(' ',I4,3X,3(' ',1PE11.4,9E11.4,/))                           PYRO 532
  384 970   FORMAT('1TEMP      EQUILIBRUM CONSTANTS',/,'0',T30,'EQUATIONS NUPYRO 533
  385      1MBER',/,5X,10(5X,I2,5X))                                            PYRO 534
  386 971   FORMAT(' ',3(120A1/),' '))                                          PYRO 535
  387 972   FORMAT('1TEMP      HEAT OF REACTION',/31X,'EQUATION NUMBER',/5X,10(5PYRO 536
  388      1X,I2,5X))                                                           PYRO 537
  389 973   FORMAT(' ',I5,4X,13(F7.3,2X))                                       PYRO 538
  390 974   FORMAT('+',7X,F5.1)                                                 PYRO 539
  391 975   FORMAT('1TEMP      HEAT CAPACITY DATA',/31X,'COMPONENT NUMBER',/5X,5PYRO 540
  392      10(3X,I3,3X))                                                        PYRO 541
  393 9934  FORMAT(' REACTOR POSITION',1PE14.5,'FEET',/,' TEMPERTURE',0PF8.2,'PYRO 542
  394      1,DEGREE-K  MOLAR FLOW RATE',1PE14.5,'POUND MOLES PER HOUR')        PYRO 543
  395 C     DENC= DENSITY OF CARBON AT UI 1200DEG, F                            PYRO 544
  396 C TEMPERTURE ON OUTSIDE WALL OF REACTOR  WILL BE ASSUMED CONSTANT         PYRO 545
  397 CC  RAD=RADIUS OFPIPE IN FEET                                            PYRO 546
  398       ISS=MAXO(IR,IS)                                                    PYRO 547
  399       IM=MINO(IR,IS)                                                     PYRO 548
  400       IGO=1                                                              PYRO 549
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401          IF(IR.EQ.IS)IGO=3                                          PYRO 550
402          IF(IR.LT.IS)IGO=2                                          PYRO 551
403          RAD=RADO                                                   PYRO 552
404          DO 48 I=1,100                                              PYRO 553
405          RADF(I)=RAD                                                PYRO 554
406 48       RADI(I)=RAD                                                PYRO 555
407          ITEST=1                                                    PYRO 556
408 58       MA=1                                                       PYRO 557
409          TMPH=TMPHI                                                 PYRO 558
410          PT=0.                                                      PYRO 559
411          DO 57 I=1,IS                                               PYRO 560
412 57       PT=PT+P(I)                                                 PYRO 561
413          DO 60 I=1,100                                              PYRO 562
414 60       RADI(I)=RADF(I)                                            PYRO 563
415          RAD=RADF(1)                                                PYRO 564
416          T=TIN                                                      PYRO 565
417          PI=PT                                                      PYRO 566
418          VEL1=1.1620929600E-4*TMPH*T/PT/RAD**2                      PYRO 567
419          WRITE(6,937)ZT,RAD,TMPH,PT,VEL1,T,DL                       PYRO 568
420          R=1.967                                                    PYRO 569
421          ZT=ZTT                                                     PYRO 570
422          ZIC=0.                                                     PYRO 571
423          MB=0                                                       PYRO 572
424          MMM=1                                                      PYRO 573
425          MZ=0.                                                      PYRO 574
426          ZICI=0.                                                    PYRO 575
427          CALL TUBE(T,TMPH)                                          PYRO 576
428          IF(MB.GE.1000)GO TO 200                                    PYRO 577
429          IWMZ=MB                                                    PYRO 578
430          DO 93 I=1,IS                                               PYRO 579
431          TM(I)=WTM(I,MB)                                            PYRO 580
432 93       C(I)=WC(I,MB)                                              PYRO 581
433          IZZ=1                                                      PYRO 582
434          GO TO 65                                                   PYRO 583
435 200      MB=MB/1000                                                 PYRO 584
436          GO TO(201,201,204,202,203,300),MB                          PYRO 585
437 201      WRITE(2,964)                                               PYRO 586
438          GO TO 213                                                  PYRO 587
439 202      WRITE(2,952)                                               PYRO 588
440 213      DL=DLS                                                     PYRO 589
441          GO TO 49                                                   PYRO 590
442 203      WRITE(2,954)                                               PYRO 591
443 204      MB=20                                                      PYRO 592
444          STOP                                                       PYRO 593
445 300      CONTINUE                                                   PYRO 594
446          MB=MB+1                                                    PYRO 595
447 25       CONTINUE                                                   PYRO 596
448          IF(MA.GT.9)GO TO 55                                        PYRO 597
449          ZIC=ZIC+DL                                                 PYRO 598
450          IF(ZIC.GE.ZTT)GO TO 33                                     PYRO 599
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      XN=ZIC/ZTT*10.+1.                                                 PYRD 600
      IIN=XN                                                            PYRD 601
      XXN=IIN                                                           PYRD 602
      TR=Z(IIN)+(Z(IIN+1)-Z(IIN))*(XN-XXN)                              PYRD 603
      RAF=RAD                                                           PYRD 604
      IJ=100.001-(ZTT-ZIC)/ZTT*99.                                      PYRD 605
      RIJ=IJ                                                            PYRD 606
      RJ=100.000-(ZTT-ZIC)/ZTT*99.                                      PYRD 607
      IF(IJ.LE.99)RAD=KADF(IJ)+(RADF(IJ+1)-RADF(IJ))*(RIJ-RJ)           PYRD 608
      IF(IJ.GE.100)RAD=RADF(100)                                        PYRD 609
      TT=T                                                              PYRD 610
      T=TR                                                              PYRD 611
      DO34 I=1,IR                                                       PYRD 612
      NO=0                                                              PYRD 613
      I1=1                                                              PYRD 614
      I2=KF(I)                                                          PYRD 615
      K=IA(I,1)                                                         PYRD 616
      CF=1.                                                             PYRD 617
      DO 35 M=I1,I2                                                     PYRD 618
      J=IA(I,M)                                                         PYRD 619
       IF(CLJ(J,2).EQ.0.)NO=I                                           PYRD 620
      IF(BB(I,M).NE.0.)CF=CF*C(J)**BB(I,M)                              PYRD 621
   35 CONTINUE                                                          PYRD 622
      CR=1                                                              PYRD 623
      I1=KF(I)+1                                                        PYRD 624
      I2=KR(I)+KF(I)                                                    PYRD 625
      DO 36 M=I1,I2                                                     PYRD 626
      J=IA(I,M)                                                         PYRD 627
       IF(CLJ(J,2).EQ.0.)NO=I                                           PYRD 628
      IF(BB(I,M).NE.0.)CR=CR*C(J)**BB(I,M)                              PYRD 629
   36 CONTINUE                                                          PYRD 630
      EA(I)=EA(I)*EXP(-EE(I)/R/T)*(CF-CR*REQC(T,I))                     PYRD 631
      IF(P(K).NE.0.)DXA(I)=1.130973355E4*DL*RA(I)*RAD**2/TMPH*PT/P(K)   PYRD 632
      IF(P(K).EQ.0.)DXA(I)=0.                                           PYRD 633
      IF(NO.NE.0)GO TO 54                                               PYRD 634
      GO TO 68                                                          PYRD 635
   54 IF((ABS(DXA(I)).GE.1.E-2).AND.(F(I).LE.9.))GO TO 20               PYRD 636
   68 IF(DXA(NO).LE.0.)DXA(NO)=0.                                       PYRD 637
      IF(DXA(I).GE..1)DXA(I)=DXA(I)*.1                                  PYRD 638
      IF(DXA(I).GE..1)GO TO 20                                          PYRD 639
   34 CONTINUE                                                          PYRD 640
      GO TO 23                                                          PYRD 641
   20 ZIC=ZIC-DL                                                        PYRD 642
      DL=ABS(DL*.005/DXA(I))                                            PYRD 643
      REQ=REQC(T,I)                                                     PYRD 644
      RATE=EA(I)*EXP(-EE(I)/R/T)                                        PYRD 645
      WRITE(6,930)DL,ZIC                                                PYRD 646
      WRITE(6,932)I,RA(I),DXA(I),CF,CR,REQ,RATE                         PYRD 647
      MA=MA+1                                                           PYRD 648
      GO TO 25                                                          PYRD 649
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      DN=0.                                                              PYRO 650
      PT2=PRR(IS)                                                        PYRO 651
      DO 39 I=1,IR                                                       PYRO 652
      K=IA(I,1)                                                          PYRO 653
      I1=1                                                               PYRO 654
      I2=KF(I)                                                           PYRO 655
      DO 38 M=I1,I2                                                      PYRO 656
      J=IA(I,M)                                                          PYRO 657
      DN=DN+B(I,M)/B(I,1)*C(K)*DXA(I)                                    PYRO 658
   38 P(J)=P(J)+B(I,M)/B(I,1)*P(K)*DXA(I)                                PYRO 659
      I1=KF(I)+1                                                         PYRO 660
      I2=KR(I)+KF(I)                                                     PYRO 661
      DO 39 M=I1,I2                                                      PYRO 662
      J=IA(I,M)                                                          PYRO 663
      DN=DN+B(I,M)/B(I,1)*C(K)*DXA(I)                                    PYRO 664
   39 P(J)=P(J)+B(I,M)/B(I,1)*P(K)*DXA(I)                                PYRO 665
      CT=0.                                                              PYRO 666
      DO 37 I=1,IS                                                       PYRO 667
      C(I)=P(I)/T/GC                                                     PYRO 668
   37 CT=CT+C(I)                                                         PYRO 669
      RN1=CT                                                             PYRO 670
      RN2=CT-DN                                                          PYRO 671
      TMPH=TMPH*DN*GC*T/PT+TMPH                                          PYRO 672
      DN=TMPH                                                            PYRO 673
      PD=PRESD(T)                                                        PYRO 674
      PT=PRR(IS)                                                         PYRO 675
      IF(MB.EQ.5000)GO TO 72                                             PYRO 676
      IF(MB.EQ.3000)GO TO 71                                             PYRO 677
      IF(MB.EQ.2000)PT=.5                                                PYRO 678
      IF(PT.LE.(POUT-.2))GO TO 69                                        PYRO 679
      DO 40 J=1,IS                                                       PYRO 680
   40 TM(J)=TMPH*P(J)/PT                                                 PYRO 681
      D=0.                                                               PYRO 682
      DO 43 IX=1,IR                                                      PYRO 683
   43 D=AMAX1(ABS(DXA(IX)),D)                                            PYRO 684
      IF(D.EQ.0.)GO TO 26                                                PYRO 685
      IF(D.GE..0010)GO TO 24                                             PYRO 686
   27 IF(DL.GE..01*ZTT)GO TO  24                                         PYRO 687
      DL=ABS(DL*.005/D)                                                  PYRO 688
      IF(DL.GE..01*ZTT)DL=.01001*ZTT                                     PYRO 689
      WRITE(6,930)DL,ZIC                                                 PYRO 690
      WRITE(6,933)(DXA(I),I,I=1,IR)                                      PYRO 691
   24 IF(MB.NE.1)GO TO 31                                                PYRO 692
      WRITE(6,942)PT,VEL                                                 PYRO 693
      WRITE(6,928)(J,C(J),TM(J),DXA(J),J=1,IM)                           PYRO 694
      GO TO(46,47,31),IGO                                                PYRO 695
   46 II=IS+1                                                            PYRO 696
      WRITE(6,936)(J,DXA(J),J=II,IR)                                     PYRO 697
      GO TO 31                                                           PYRO 698
   47 II=IR+1                                                            PYRO 699
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      WRITE(6,939)(J,C(J),TM(J),J=II,IS)                                PYRO 700
31    CONTINUE                                                          PYRO 701
      ZICI=ZICI+DL                                                      PYRO 702
      IF(ZICI.LE.(ZTT/25.))GO TO 30                                     PYRO 703
      ZICI=0.                                                           PYRO 704
      MZ=MZ+1                                                           PYRO 705
      WZIC(MZ)=ZIC                                                      PYRO 706
      WT(MZ)=T                                                          PYRO 707
      WTMPH(MZ)=TMPH                                                    PYRO 708
      WPT(MZ)=PT                                                        PYRO 709
      WVEL1(MZ)=VEL1                                                    PYRO 710
      DO 70 J=1,ISS                                                     PYRO 711
      WC(J,MZ)=C(J)                                                     PYRO 712
      WTM(J,MZ)=TM(J)                                                   PYRO 713
70    WDXA(J,MZ)=DXA(J)                                                 PYRO 714
30    GO TO 300                                                         PYRO 715
33    PT=PT2                                                            PYRO 716
69    IWMZ=MZ                                                           PYRO 717
      WRITE(6,914)                                                      PYRO 718
      WRITE(6,951)CARD                                                  PYRO 719
      WRITE(6,9934)ZIC,T,TMPH                                           PYRO 720
      PTTE=PT                                                           PYRO 721
      IF(MAZE.EQ.2)PT=2.                                                PYRO 722
      WRITE(6,942)PT,VEL1                                               PYRO 723
      PT=PTTE                                                           PYRO 724
      DO 64 I=1,IS                                                      PYRO 725
64    P(I)=PPI(I)                                                       PYRO 726
      IF((PT.GE.(POUT-.2)).AND.(PT.LE.(POUT+.2)))GO TO 65               PYRO 727
      IF(KK.EQ.2)PDP=PDP/2                                              PYRO 728
      IF(KK.EQ.2)GO TO 63                                               PYRO 729
      IF((PT.GE.POUT+.2).AND.(ITEST.EQ.2))PDP=PDP/2.                    PYRO 730
      IF((MAZE.EQ.2).AND.(PT.GE.(POUT-.2)))GO TO 65                     PYRO 731
      IF(MAZE.EQ.2)GO TO 63                                             PYRO 732
      IF((PT.LE.POUT-.2).AND.(ITEST.EQ.3))PDP=PDP/2.                    PYRO 733
      IF((PT.GE.POUT+.2).AND.(ITEST.EQ.2))KK=2                          PYRO 734
      IF((PT.LE.POUT-.2).AND.(ITEST.EQ.3))KK=2                          PYRO 735
      GO TO 63                                                          PYRO 736
71    MAZE=2                                                            PYRO 737
      PT=.5                                                             PYRO 738
      WRITE(6,952)                                                      PYRO 739
      GO TO 69                                                          PYRO 740
65    IF(IPLOT.GT.2)GO TO 91                                            PYRO 741
      WRITE(6,918)                                                      PYRO 742
      WRITE(6,951)CARD                                                  PYRO 743
      WRITE(6,963)HR                                                    PYRO 744
      WRITE(6,960)                                                      PYRO 745
      WRITE(6,962)                                                      PYRO 746
      DO 81 I=14,116                                                    PYRO 747
81    CALL PLOT(I,'*N')                                                 PYRO 748
      CALL PLOT(1,' ')                                                  PYRO 749
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      DO 82 I1=1,IWMZ                                                    PYRO 750
      I=IWMZ+1-I1                                                        PYRO 751
      J1=WTM(KEYP,I)/WTM(KEYR,1)*100.+15.                                PYRO 752
      J2=WTM(KEYP,I)/WTM(KEYR,1)*100.+15.                                PYRO 753
      J3=(WT(I)-WT(1))/(WT(IWMZ)-WT(1))*100.+15.                         PYRO 754
      J4=(WPT(I))/6.*100.+15                                             PYRO 755
      WRITE(6,974)WZIC(I)                                                PYRO 756
   82 CALL PLOT(14.,'*N',.5,IDATE(I1),J1,'EN',J2,'RN',J3,'TN',J4,'PN',116.PYRO 757
     1'*0')                                                              PYRO 758
      DO 83 I=14,116                                                     PYRO 759
   83 CALL PLOT(I,'*N')                                                  PYRO 760
      CALL PLOT(1,'  ')                                                  PYRO 761
      WRITE(6,918)                                                       PYRO 762
   91 KK=1                                                               PYRO 763
      IF((IPLOT.GT.3).OR.(IPLOT.LT.2))GO TO 90                           PYRO 764
      MMM=2                                                              PYRO 765
      DO 75 I=1,IWMZ                                                     PYRO 766
      PT=WPT(I)                                                          PYRO 767
      VEL1=WVEL1(I)                                                      PYRO 768
      ZIC=WZIC(I)                                                        PYRO 769
      T=WT(I)                                                            PYRO 770
      TMPH=WTMPH(I)                                                      PYRO 771
      DO 76 J=1,ISS                                                      PYRO 772
      C(J)=WC(J,I)                                                       PYRO 773
      TM(J)=WTM(J,I)                                                     PYRO 774
   76 DXA(J)=WDX(J,I)                                                    PYRO 775
      MMM=MMM+1                                                          PYRO 776
      IF(MMM.LE.1)GO TO 41                                               PYRO 777
      MMM=0                                                              PYRO 778
      WRITE(6,918)                                                       PYRO 779
      WRITE(6,951)CARD                                                   PYRO 780
   41 WRITE(6,2934)ZIC,T,TMPH                                            PYRO 781
      YIELD=TM(KEYP)/TMPHI/PPI(KEYR)*PI*100.                             PYRO 782
      J2=KEYR*20                                                         PYRO 783
      J1=J2-19                                                           PYRO 784
      J4=KEYP*20                                                         PYRO 785
      J3=J4-19                                                           PYRO 786
      WRITE(6,965)(INAME(L),L=J1,J2),(INAME(L),L=J3,J4),YIELD            PYRO 787
      WRITE(6,942)PT,VEL1                                                PYRO 788
      WRITE(6,929)I                                                      PYRO 789
      WRITE(6,926)(J,C(J),TM(J),DXA(J),J=1,IM)                           PYRO 790
      GO TO(42,45,75),IGO                                                PYRO 791
   42 II=IS+1                                                            PYRO 792
      WRITE(6,933)(J,DXA(J),J=II,IR)                                     PYRO 793
      GO TO 75                                                           PYRO 794
   45 II=IR+1                                                            PYRO 795
      WRITE(6,939)(J,C(J),TM(J),J=II,IS)                                 PYRO 796
   75 WRITE(6,916)                                                       PYRO 797
      WRITE(6,916)                                                       PYRO 798
   90 WRITE(6,951)CARD                                                   PYRO 799
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      MB=1                                                              PYRO 800
      MY=1                                                              PYRO 801
      MZ=1                                                              PYRO 802
      WRITE(6,916)                                                      PYRO 803
      DO 59 I=1,IR                                                      PYRO 804
59    PRETT=PRESC(T,I)                                                  PYRO 805
      WRITE(6,916)                                                      PYRO 806
C     PRETT=PRESD(I)                                                    PYRO 807
      DO 51 I=1,IS                                                      PYRO 808
      I1=1+(I-1)*20                                                     PYRO 809
      I2=I*20                                                           PYRO 810
51    WRITE(6,946)I,IDATA(I),(INAME(J),J=I1,I2),C(I),TM(I)              PYRO 811
      YIELD=TM(KEYP)/TMPHI/PPI(KEYR)*PI*100.                            PYRO 812
      J2=KEYR*20                                                        PYRO 813
      J1=J2-19                                                          PYRO 814
      J4=KEYP*20                                                        PYRO 815
      J3=J4-19                                                          PYRO 816
      WRITE(6,965)(INAME(I),I=J1,J2),(INAME(I),I=J3,J4),YIELD           PYRO 817
      GO TO 50                                                          PYRO 818
63    PTI=PI                                                            PYRO 819
      IF(PT.LT.PDUT)GO TO 49                                            PYRO 820
      GO TO 61                                                          PYRO 821
49    PDIR=PI-PT                                                        PYRO 822
67    PTI=PI                                                            PYRO 823
      PI=PI+PDP                                                         PYRO 824
      IF(PI.GE.6.1)GO TO 56                                             PYRO 825
      DO 53 I=1,IS                                                      PYRO 826
      PPI(I)=PPI(I)*PI/PTI                                              PYRO 827
      P(I)=PPI(I)                                                       PYRO 828
53    C(I)=P(I)/T/GC                                                    PYRO 829
      ITEST=2                                                           PYRO 830
      GO TO 58                                                          PYRO 831
61    PTI=PI                                                            PYRO 832
      PI=PI-PDP                                                         PYRO 833
      DO 62 I=1,IS                                                      PYRO 834
      DO 62 I=1,IS                                                      PYRO 835
      PPI(I)=PPI(I)*PI/PTI                                              PYRO 836
62    P(I)=PPI(I)                                                       PYRO 837
      ITEST=3                                                           PYRO 838
      GO TO 58                                                          PYRO 839
50    T=TIN                                                             PYRO 840
      TMPH=TMPHI                                                        PYRO 841
      HR=HR+IB                                                          PYRO 842
      IGOTO=IGOTO+1                                                     PYRO 843
      WRITE(6,945)HR                                                    PYRO 844
      DO 52 I=1,ICO                                                     PYRO 845
      RADD(I,IGOTO)=RADI(I)                                             PYRO 846
52    RADE(I)=RADI(I)                                                   PYRO 847
      WRITE(6,944)RADI                                                  PYRO 848
      DO 66 I=1,IS                                                      PYRO 849
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      P(I)=PPI(I)                                                       PYRO 850
   66 C(I)=R(I)/SC/320.                                                 PYRO 851
      ITEST=1                                                           PYRO 852
      MA=1                                                              PYRO 853
      IF(IGOTO.GE.IZZ)GO TO 56                                          PYRO 854
      IF(PT.LT.PRES)GO TO 58                                            PYRO 855
      GO TO 56                                                          PYRO 856
   72 WRITE(6,954)                                                      PYRO 857
      IGOTO=IZZ                                                         PYRO 858
      GO TO 50                                                          PYRO 859
   55 WRITE(6,949)                                                      PYRO 860
   56 WRITE(6,919)                                                      PYRO 861
      IF(IPLOT.GT.2)GO TO 95                                            PYRO 862
      WRITE(6,955)                                                      PYRO 863
      WRITE(6,966)ZTT                                                   PYRO 864
      IGOTO=IGOTO+1                                                     PYRO 865
      DO 77 J=14,116                                                    PYRO 866
   77 CALL PLOT(J,'*N!')                                                PYRO 867
      CALL PLOT(1,'  !)                                                PYRO 868
      DO 78 J=2,100,2                                                   PYRO 869
      J1=102-J                                                          PYRO 870
      IJK=0.                                                            PYRO 871
      DO 79 I=1,IGOTO                                                   PYRO 872
      IJK=IJK+1                                                         PYRO 873
      IF(IJK.GT.9)IJK=1                                                 PYRO 874
      J2=RADD(J1,I)/RAD*50.+65.                                         PYRO 875
      J3=130-J2                                                         PYRO 876
   79 CALL PLOT(14,'*N!,J2,IDATP(IJK),J3,IDATP(IJK),116,'*N!)           PYRO 877
      IJ=(J+2)/4                                                        PYRO 878
      IF(FLOAT(J/4).EQ.FLOAT(J)/4.)IJ=1                                 PYRO 879
   78 CALL PLOT(5,IDATQ(IJ),65,'+ ')                                    PYRO 880
      DO 80 J=14,116                                                    PYRO 881
   80 CALL PLOT(J,'*N!')                                                PYRO 882
      CALL PLOT(1,'  !)                                                PYRO 883
      WRITE(6,966)                                                      PYRO 884
      WRITE(6,967)CARD                                                  PYRO 885
   95 CONTINUE                                                          PYRO 886
      IGOTO=1                                                           PYRO 887
      MA=1                                                              PYRO 888
      PT=0.                                                             PYRO 889
      DO 73 I=1,IS                                                      PYRO 890
   73 PT=PT+PPI(I)                                                      PYRO 891
      DO 74 I=1,IS                                                      PYRO 892
      PPI(I)=PPI(I)*PSAVE/PT                                            PYRO 893
   74 P(I)=PPI(I)                                                       PYRO 894
      IF(IND.NE.0)RETURN                                                PYRO 895
      READ(5,943)IGOW,(Z(II),II=1,11)                                   PYRO 896
      READ(5,950)CARD                                                   PYRO 897
      READ(5,958)IB,IZZ,IPLOT                                           PYRO 898
      GO TO(100,110,111),IGOW                                           PYRO 899
```

```
      CONTINUE                                                          PYRO 900
      WRITE(6,921)I,ID                                                  PYRO 901
      STOP111                                                           PYRO 902
102   CONTINUE                                                          PYRO 903
      WRITE(6,922)I,ID                                                  PYRO 904
      STOP112                                                           PYRO 905
103   CONTINUE                                                          PYRO 906
      WRITE(6,923)I,ID                                                  PYRO 907
      STOP113                                                           PYRO 908
104   CONTINUE                                                          PYRO 909
      WRITE(6,924)I,ID                                                  PYRO 910
      STOP114                                                           PYRO 911
105   CONTINUE                                                          PYRO 912
      WRITE(6,925)I,ID                                                  PYRO 913
      STOP115                                                           PYRO 914
111   CONTINUE                                                          PYRO 915
      WRITE(6,919)                                                      PYRO 916
92    WRITE(6,970)(I,I=1,IR)                                            PYRO 917
      DO 84 IT=800,1200,10                                              PYRO 918
      J=(IT-800)/10+1                                                   PYRO 919
      T=IT                                                              PYRO 920
      DO 85 N=1,IR                                                      PYRO 921
85    WC(J,N)=1./REQC(T,N)                                              PYRO 922
84    WRITE(6,969)IT,(WC(J,N),N=1,IR)                                   PYRO 923
      WRITE(6,972)(I,I=1,IR)                                            PYRO 924
      DO 86 IT=800,1200,10                                              PYRO 925
      J=(IT-800)/10+1                                                   PYRO 926
      T=IT                                                              PYRO 927
      DO 87 N=1,IR                                                      PYRO 928
87    WC(J,N)=HEATR(T,N)                                                PYRO 929
86    WRITE(6,969)IT,(WC(J,N),N=1,IR)                                   PYRO 930
      WRITE(6,975)(I,I=1,IS)                                            PYRO 931
      DO 88 IT=800,1200,10                                              PYRO 932
      J=(IT-800)/10+1                                                   PYRO 933
      T=IT                                                              PYRO 934
      DO 89 N=1,IS                                                      PYRO 935
89    WC(J,N)=HCP(T,N)                                                  PYRO 936
88    WRITE(6,973)IT,(WC(J,N),N=1,IS)                                   PYRO 937
99    RETURN                                                            PYRO 938
106   WRITE(6,935) ID,J                                                 PYRO 939
      STOP116                                                           PYRO 940
26    WRITE(6,931)                                                      PYRO 941
      WRITE(6,949)(J,C(J),DXA(J),J=1,IS)                                PYRO 942
      STOP26                                                            PYRO 943
      END                                                               PYRO 944
```

```
      FUNCTION PRR(IS)                                                  PRR  945
      COMMON/TUBE1/IR,IZ,KF(25),KR(25),R(25,10),RR(25,10),DL,IA(25,10)  PRR  946
     1,EA(25),EE(25),RAD,AD                                             PRR  947
      COMMON/PD/P(25),DN,SUMT(25),CLJ(25,2),VI(25),AMWT,VELL,HI         PRR  948
      COMMON/TH/TMPH,RADI(100),DE(25),ZIC                               PRR  949
      COMMON/PYRD3/Z(11),ZTT,C(25),CP(25,4)                             PRR  950
     1,DH(25),DS(25),DF(25)                                             PRR  951
      COMMON/SET/MY,MZ,IS,IPLOT,DLS                                     PRR  952
      DATA PI/3.1415926/                                                PRR  953
      PT=0.                                                             PRR  954
      PT2=0.                                                            PRR  955
      HRS=IS                                                            PRR  956
      DO 1 I=1,IS                                                       PRR  957
      IF(CLJ(I,1).NE.0.)PT2=PT2+P(I)                                    PRR  958
    1  PT=PT+P(I)                                                       PRR  959
      DO 2 I=1,IS                                                       PRR  960
      IF(CLJ(I,1).EQ.0.)GO TO 5                                         PRR  961
      GO TO 2                                                           PRR  962
    5 IJ=100.001-(ZTT-ZIC)/ZTT*99.                                      PRR  963
      IJJ=100.001-(ZTT-DL-ZIC)/ZTT*99.                                  PRR  964
      IF(IJJ.GT.100)IJJ=100                                             PRR  965
      XNC=ABS(FLOAT(IJ-IJJ))                                            PRR  966
      IF(XNC.LE.0.0)XNC=1.                                              PRR  967
      VOL=TMPH*SUMT(I)*P(I)/PT/DE(I)*HRS                                PRR  968
      DLR=ZTT/100.                                                      PRR  969
      IF((RADI(IJ)**2-VOL/DLR/XNC/PI).LE.0.)GO TO 1001                  PRR  970
      IF(MZ.EQ.5000)RETURN                                              PRR  971
      DO 3 IK=IJ,IJJ                                                    PRR  972
    3 RADI(IK)=SQRT(RADI(IK)**2-VOL/DLR/XNC/PI)                         PRR  973
      IF(CLJ(I,1).EQ.0.)P(I)=0.                                         PRR  974
      GO TO 2                                                           PRR  975
 1001 WRITE(2,9001)PRR,RADI(1),VOL                                      PRR  976
    2 P(I)=P(I)*PT/PT2                                                  PRR  977
      PRR=PT                                                            PRR  978
 9001 FORMAT(' FUNCTION PRR(IS)'/,' PR=',1PE14.5,5X,'RADI(1)=',1PE14.5PRR  979
     1,5X,'VOL=',1PE14.5)                                               PRR  980
      RETURN                                                            PRR  981
      END                                                               PRR  982
```

```
      FUNCTION REQC(T,I)                                                REQC 983
      COMMON/FE/DCP(25,4),HT(25),SO(25),FO(25),FI(25),HO(25)            REQC 984
      COMMON/SET/MY,MZ,IB,IPLOT,DLS                                     REQC 985
      REAL*4 LOG                                                        REQC 986
      DATA  R/1.987/                                                    REQC 987
      ELNK=HO(I)/R/T+DCP(I,1)/R*LOG(T)+DCP(I,2)/(2.*R)*T+DCP(I,3)/(6.*RREQC 988
     1)*T*T+DCP(I,4)/(12.*R)*T**3+FI(I)                                 REQC 989
      REQC=EXP(-ELNK)                                                   REQC 990
      RETURN                                                            REQC 991
      END                                                               REQC 992
```

```
      1       FUNCTION PRESD(T)                                                 PRES 993
      2       COMMON/RYRO3/Z(11),ZTT,C(25),CP(25,4)                             PRES 994
      3      1,DH(25),DS(25),DF(25)                                             PRES 995
      4       COMMON/TUBE1/IP,IS,KE(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)  PRES 996
      5      1,EA(25),EE(25),RAD,AD                                             PRES 997
      6       COMMON/PD/P(25),DN,SMWT(25),CLJ(25,2),VI(25),AMWT,VEL1,HI         PRES 998
      7       COMMON/PT2/TT,RN1,RN2,VIS                                         PRES 999
      8       COMMON/SET/MY,MZ,IB,IPLOT,DLS                                     PRES1000
      9       REAL*4 LOG                                                        PRES1001
     10       PT=PRR(IS)                                                        PRES1002
     11       IF(MZ.EQ.5000)RETURN                                              PRES1003
     12  C THIS SUBROUTINE CALULATES PRESSURE DROP FROM BERNOULIE LAW           PRES1004
     13  C MODIFIED TO TAKE FRICTION LOSS INTO CONSIDERATION                    PRES1005
     14       DATA MYY/1/                                                       PRES1006
     15       IF(MYY.NE.1)GO TO 1                                               PRES1007
     16       MYY=2                                                             PRES1008
     17       MAZE=1                                                            PRES1009
     18       PDR=.2                                                            PRES1010
     19       DATA A/.4398818/,BI/-.44245917/,CC/.86401820E-1/,D/.77484511E-2/  PRES1011
     20       DATA A1/2.6693E-5/,A2/1.1620929E-4/,A3/7.37495E4/                 PRES1012
     21       PRESDT=0.                                                         PRES1013
     22  11   DO 2 I=1,IS                                                       PRES1014
     23       IF(CLJ(I,1).EQ.0) GO TO 2                                         PRES1015
     24       E=LOG(T/CLJ(I,2))                                                 PRES1016
     25       VI(I)=A1*SQRT(SMWT(I)*T)/(CLJ(I,1)**2*EXP(A+BI*E+CC*E**2+D*E**3)) PRES1017
     26  2    CONTINUE                                                          PRES1018
     27       VIS=0.                                                            PRES1019
     28       DO 3 I=1,IS                                                       PRES1020
     29       IF(CLJ(I,1).EQ.0.)GO TO 3                                         PRES1021
     30       V=P(I)/PT*VI (I)                                                  PRES1022
     31       U=0.                                                              PRES1023
     32       DO 4 J=1,IS                                                       PRES1024
     33       IF(CLJ(J,1).EQ.0.)GO TO 4                                         PRES1025
     34       U=U+P(J)/PT*1./SQRT(8.)/(1.+SMWT(I)/SMWT(J))*(1.+(VI(I)/VI(J))**.5PRES1026
     35      1*(SMWT(J)/SMWT(I))**.25)**2                                       PRES1027
     36  4    CONTINUE                                                          PRES1028
     37       VIS=VIS+V/U                                                       PRES1029
     38  3    CONTINUE                                                          PRES1030
     39       VIS=VIS*.0672                                                     PRES1031
     40  1    AMWT=0.                                                           PRES1032
     41       VEL2=A2*T/(PT-PRESDT)/RAD**2*DN                                   PRES1033
     42       DO 5 I=1,IS                                                       PRES1034
     43  5    AMWT=P(I)/PT*SMWT(I)+AMWT                                         PRES1035
     44  C    GC IN AT.*FT**3  /(OK LB.MOLES)                                   PRES1036
     45       GC=1.3143                                                         PRES1037
     46       DEN=PT/(GC*T)*AMWT                                                PRES1038
     47       IF(DEN.LE.0.)GO TO 21                                             PRES1039
     48  6    VELA=(VEL1+VEL2)/2.                                               PRES1040
     49       RENU=2.*RAD*DEN*VELA/VIS                                          PRES1041
     50       IF(RENU.LE.0.)GO TO 19                                            PRES1042
```

```
      IF(RENU.LE.3500.)GO TO 20                                          PRES1043
      GO TO 10                                                           PRES1044
   20 F=64./RENU                                                         PRES1045
   10 F=0.00560+.5/(RENU**.32)                                           PRES1046
      GO TO 100                                                          PRES1047
  100 PRESD=DEN*(VELA**2*F*DL/RAD+VEL2**2-VEL1**2)/62.4/2116.8           PRES1048
      PRESD=ABS(PRESD)                                                   PRES1049
      P2=PT-PRESD                                                        PRES1050
      IF(P2.LE.0.)GO TO 21                                               PRES1051
      VEL2=A2*T/P2/RAD**2*DN                                             PRES1052
      IF(PRESD.EQ.0.)GO TO 7                                             PRES1053
      IF(ABS((PRESDT-PRESD)/PRESD).LE..001)GO TO 7                       PRES1054
      PRESDT=PRESD                                                       PRES1055
      DEN=(P2+PT)/(2.*GC*T)*AMWT                                         PRES1056
      GO TO 6                                                            PRES1057
    7 PT2=0.                                                             PRES1058
      DO 9 I=1,IS                                                        PRES1059
    9 PT2=PT2+P(I)                                                       PRES1060
      DO 8 I=1,IS                                                        PRES1061
    8 P(I)=P(I)*(PT2-PRESD)/PT2                                          PRES1062
      IF((IPLOT.EQ.2).OR.(IPLOT.EQ.3).AND.(MZ.EQ.1))GO TO 1001           PRES1063
      VEL1=VEL2                                                          PRES1064
      IF(VEL1.GE.1214.5)GO TO 22                                         PRES1065
      IF(VEL1.GE.SQRT(A3*P2/DEN))GO TO 22                                PRES1066
      RETURN                                                             PRES1067
   22 MZ=3000                                                            PRES1068
      PT=.5                                                              PRES1069
      RETURN                                                             PRES1070
 1001  WRITE(6,9001)RENU, VIS,DEN,F,VEL1,VEL2,VELA,T ,PRESD              PRES1071
      VEL1=VEL2                                                          PRES1072
      RETURN                                                             PRES1073
   19 WRITE(6,900)RAD,DEN,VELA,VIS,RENU                                  PRES1074
      WRITE(6,902)T,PT,(P(I),I=1,IS),GC,AMWT,P2                          PRES1075
      MZ=2000                                                            PRES1076
      RETURN                                                             PRES1077
   21 WRITE(6,902)T,PT,(P(I),I=1,IS),GC,AMWT,P2                          PRES1078
      MZ=2000                                                            PRES1079
      RETURN                                                             PRES1080
  900 FORMAT(' RAD=',1PE12.5,'DEN,VELA,VIS,RENU',4(2X,1PE12.5))          PRES1081
  901 FORMAT(' PRESSURE DROP =',1PE12.5,'DEN,VELA,DL,VEL1,VEL2,',5(2X,1PPRES1082
     1E12.5))                                                            PRES1083
  902 FORMAT(' T PT P(1)=P(12), GC AMWT ',10(1X,E8.2))                   PRES1084
 9001 FORMAT(' FUNCTION PRESD(T)',//,' RENU=',1PE14.5,5X,'VIS=',1PE14.5,5PRES1085
     1X,'DEN=',1PE14.5,/,' FRICTION FACTOR= ',1PE14.5,5X,'V1,V2,VA=',3(1PRES1086
     1PE14.5,5X),' TEMPERTURE=',0PF8.2     ,5X,'PRESSURE D=',1PE14.5)    PRES1087
      END                                                                PRES1088
```

```
      FUNCTION HCP(T,I)                                                 HCP 1089
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)  HCP 1090
     1,EA(25),EE(25),RAD,AD                                             HCP 1091
      COMMON/PYRO3/Z(11),ZTT,C(25),CP(25,4)                             HCP 1092
     1,DH(25),DS(25),DF(25)                                             HCP 1093
      HCP=CP(I,1)+CP(I,2)*T+CP(I,3)*T*T+CP(I,4)*T**3                    HCP 1094
      RETURN                                                            HCP 1095
      END                                                               HCP 1096
```

```
      SUBROUTINE RATE(C1,T,RA)                                          RATE1097
      DATA R/1.987/                                                     RATE1098
      DIMENSION RA(25),C1(25)                                           RATE1099
      COMMON/PD/SLURP(52),CLJ(25,2)                                     RATE1100
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)  RATE1101
     1,EA(25),EE(25),RAD,AC                                             RATE1102
C1                                                                      RATE1103
      DO34 I=1,IR                                                       RATE1104
      NO=0                                                              RATE1105
      I1=1                                                              RATE1106
      I2=KF(I)                                                          RATE1107
      CF=1.                                                             RATE1108
      DO 35 M=I1,I2                                                     RATE1109
      J=IA(I,M)                                                         RATE1110
       IF(CLJ(J,2).EQ.0.)NO=I                                           RATE1111
      IF(BB(I,M).NE.0.)CF=CF*C1(J)**BB(I,M)                             RATE1112
35    CONTINUE                                                          RATE1113
      CR=1.                                                             RATE1114
      I1=KF(I)+1                                                        RATE1115
      I2=KR(I)+KF(I)                                                    RATE1116
      DO 36 M=I1,I2                                                     RATE1117
      J=IA(I,M)                                                         RATE1118
      IF(CLJ(J,2).EQ.0.)NO=I                                            RATE1119
      IF(BB(I,M).NE.0.)CR=CR*C1(J)**BB(I,M)                             RATE1120
36    CONTINUE                                                          RATE1121
34    RA(I)=EA(I)*EXP(-EE(I)/R/T)*(CF-CR*REQC(T,I))                     RATE1122
      RETURN                                                            RATE1123
      END                                                               RATE1124
```

```
      SUBROUTINE MATB(RA1,RA2,BC2,DXA,X1,X2,T1,T2,PT1,PT2)                MATB1125
      DATA GC/1.3413/                                                     MATB1126
      DIMENSION DXA(25),X1(25),X2(25),BC2(25),RA1(25),RA2(25)             MATB1127
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)    MATB1128
     1,EA(25),EE(25),RAD,AO                                               MATB1129
      DN=0.0                                                              MATB1130
      DO 1 I=1,IR                                                         MATB1131
      K=IA(I,1)                                                           MATB1132
      RA=(RA1(I)+RA2(I))/2.                                               MATB1133
      IF(X1(K).NE.0.)DXA(I)=1.130973355E4*DL*RA*RAD**2/X1(K)              MATB1134
    5 CONTINUE                                                            MATB1135
      IF(X1(K).EQ.0.)DXA(I)=0.                                            MATB1136
    1 CONTINUE                                                            MATB1137
      DO 37 J=1,IS                                                        MATB1138
      X2(J)=X1(J)                                                         MATB1139
   37 CONTINUE                                                            MATB1140
      DO 39 I=1,IR                                                        MATB1141
      K=IA(I,1)                                                           MATB1142
      I1=1                                                                MATB1143
      I2=KF(I)                                                            MATB1144
      DO 38 M=I1,I2                                                       MATB1145
      J=IA(I,M)                                                           MATB1146
      DN=DN+B(I,M)/B(I,1)*X1(K)*DXA(I)                                    MATB1147
   38 X2(J)=X2(J)-B(I,M)/B(I,1)*X1(K)*DXA(I)                              MATB1148
      I1=KF(I)+1                                                          MATB1149
      I2=KR(I)+KF(I)                                                      MATB1150
      DO 39 M=I1,I2                                                       MATB1151
      J=IA(I,M)                                                           MATB1152
      DN=DN+B(I,M)/B(I,1)*X1(K)*DXA(I)                                    MATB1153
   39 X2(J)=X2(J)+B(I,M)/B(I,1)*X1(K)*DXA(I)                              MATB1154
      TMPH=0.0                                                            MATB1155
      DO 42 I=1,IS                                                        MATB1156
   42 TMPH=TMPH+X2(I)                                                     MATB1157
      CALL PRESC(T1,T2,PD,TMPH)                                           MATB1158
      XT2=0.0                                                             MATB1159
      DO 40 I=1,IS                                                        MATB1160
      XT2=XT2+X2(I)                                                       MATB1161
   40 CONTINUE                                                            MATB1162
      PT2=PT1-PD                                                          MATB1163
      DO 41 I=1,IS                                                        MATB1164
      BC2(I)=X2(I)/XT2*PT2/T2/GC                                          MATB1165
   41 CONTINUE                                                            MATB1166
      RETURN                                                              MATB1167
      END                                                                 MATB1168
```

```
      FUNCTION HEATR(T2,I)                                              HEAT1169
      COMMON/FE/DCP(25,4),HT(25),ST(25),FT(25),FI(25),HC(25)            HEAT1170
      COMMON/SET/MY,NB,IB,IPLOT,DLS                                     HEAT1171
      HEATR=HC(I)                                                       HEAT1172
      DO 1 L=1,4                                                        HEAT1173
      X=L                                                               HEAT1174
    1 HEATR=HEATR+DCP(I,L)*(T2**L/X)                                    HEAT1175
C     WRITE(2,9001)HEATR,T2,I                                           HEAT1176
      IF((IPLOT.EQ.2).OR.(IPLOT.EQ.3).AND.(MZ.EQ.1))GO TO 1001          HEAT1177
      RETURN                                                            HEAT1178
 1001  WRITE(6,9001)HEATR,T2,I                                          HEAT1179
      RETURN                                                            HEAT1180
 9001 FORMAT(' HEAT$_R$(T,I)=',1PE14.5,'(',0PF8.2,',',I2,')')          HEAT1181
      END                                                               HEAT1182
```

```
      SUBROUTINE HEATB(RADC,TB1,TB2,DXA,X1,X2,TB2C,Q,U)                 HEAT1183
      REAL*4 LOG                                                        HEAT1184
      COMMON/PD/P(25),DN,SHWT(25),CLJ(25,2),VI(25),AMWT,VEL1,HI         HEAT1185
      COMMON/TUBE1/IR,IS,KE(25),KR(25),A(25,10),BB(25,10),DL,IA(25,10)  HEAT1186
     1,EA(25),EE(25),RADI,RADO                                          HEAT1187
      COMMON/TUBE2/IND,TX(100)                                          HEAT1188
      COMMON/TH/TMPZ,RADZ(100),DE(25),ZIC                               HEAT1189
      DATA RO/.001/,RI/.001/,XKST/26./,TSKIN/1120./                     HEAT1190
     1,PI/3.1415926/,XKC/2.90/,IC/0/                                    HEAT1191
C     RO AND RI FOULING FACTORS FROM APPLIED PROCESS DESIGN FOR         HEAT1192
C     CHEMICAL AND PETROCHEMICAL PLANTS BY E.E. LUDWIG PAGES 55-59      HEAT1193
C     THERMOCONDUCTIVITY OF CARBON(GRAPHITE) XKC FROM                   HEAT1194
C     TRANSPORT PHENOMENA BIRD STUART AND LIGHTFOOT PAGE249             HEAT1195
      DIMENSION X1(25),X2(25),DXA(25)                                   HEAT1196
      IF(IND.EQ.0)GO TO 10                                              HEAT1197
      CALL TEMPT(TSKIN,ZIC,IND)                                         HEAT1198
10    TAVG=(TB2+TB1)/2.                                                 HEAT1199
      DT1=TSKIN-TAVG                                                    HEAT1200
      DT2=TB2-TB1                                                       HEAT1201
      DT2=TB2-TB1                                                       HEAT1202
      HR=0.0                                                            HEAT1203
      DO 1 I=1,IR                                                       HEAT1204
      K=IA(I,1)                                                         HEAT1205
1     HR=HR+HEATB(TAVG,I)*(X2(K)+X1(K))/2.*DXA(I)/1.8                   HEAT1206
      SH=0.0                                                            HEAT1207
      DO 2 I=1,IS                                                       HEAT1208
2     SH=SH+(X2(I)*HCP(TB2,I)+X1(I)*HCP(TB1,I))/2.*1.8                  HEAT1209
C     HI=F(VEL,COMP)                                                    HEAT1210
      AO=PI*DL*RADO*2.0                                                 HEAT1211
      AI=PI*RADI*DL*2.0                                                 HEAT1212
      AC=PI*RADC*DL*2.0                                                 HEAT1213
      AAVG=(AO-AI)/LOG(AO/AI)                                           HEAT1214
      RST=(RADO-RADI)/XKST                                              HEAT1215
      AAVGC=1.0                                                         HEAT1216
      IF(RADI.NE.RADC)AAVGC=(AI-AC)/LOG(AI/AC)                          HEAT1217
      RC=(RADI-RADC)/XKC                                                HEAT1218
      RU=RO+RST*AO/AAVG+RI*1./(HI*AC/AO)+RC*AI/AAVGC                    HEAT1219
      U=1./RU                                                           HEAT1220
4     TB2C=TB1+(U*AO*DT1-HR)/SH                                         HEAT1221
      HR=HR/DL                                                          HEAT1222
      Q=U*AO*DT1                                                        HEAT1223
      IC=IC+1                                                           HEAT1224
      IF(IC.LT.10)GO TO 5                                               HEAT1225
      IC=1                                                              HEAT1226
C     WRITE(2,901)Q,HR,SH,HI                                            HEAT1227
C901  FORMAT(' Q=',E14.5,'  HR=',E14.5,'  SH=',E14.5,'  HI=',E14.5)     HEAT1228
5     RETURN                                                            HEAT1229
      END                                                               HEAT1230
```

```
      SUBROUTINE TUBE(T1,TMPH)                                          TUBE1231
      COMMON/PYRO3/Z(11),ZTT,C(25),CP(25,4)                             TUBE1232
     1,DH(25),DS(25),DF(25)                                             TUBE1233
      COMMON/PD/P(25),DN,SMWT(25),CLJ(25,2),VI(25),AMWT,VEL1,HI         TUBE1234
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)  TUBE1235
     1,EA(25),EE(25),RAD,AD                                             TUBE1236
      COMMON/TUBE2/IND,TX(100),QT(4),QFF                                TUBE1237
      COMMON/TM/TMPZ,RADI(100),QE(25),ZIC                               TUBE1238
      COMMON/W/ WZIC(50),WT(50),WTMPH(50),WPT(50),WVEL1(50),WC(25,50),WTTUBE1239
     1M(25,50),WCXA(25,50),RADF(100,50)                                 TUBE1240
      COMMON/SET/MY,MZ,IB,IPLOT,DLS                                     TUBE1241
      DIMENSION X1(25),X2(25),RA1(25),RA2(25),BRA2(25), BC2(25)         TUBE1242
     1,BBC2(25),BXA(25),BDXA(25),RADF(100)                              TUBE1243
      DATA II/2/1/                                                      TUBE1244
      QTOT=0.0                                                          TUBE1245
      JN=0                                                              TUBE1246
      CALL PZERO(QT(1),4)                                               TUBE1247
      N3=1                                                              TUBE1248
      XN=1.                                                             TUBE1249
      Z85=ZTT/85.                                                       TUBE1250
      Z33=ZTT/3.                                                        TUBE1251
      PT=0.0                                                            TUBE1252
      DO 1 I=1,IS                                                       TUBE1253
      PT=PT+P(I)                                                        TUBE1254
    1 CONTINUE                                                          TUBE1255
      ISS=MAXO(IR,IS)                                                   TUBE1256
      ZICI=0.0                                                          TUBE1257
      MZ=0                                                              TUBE1258
      DO 7 I=1,IS                                                       TUBE1259
      X1(I)=TMPH*P(I)/PT                                                TUBE1260
    7 CONTINUE                                                          TUBE1261
      IF(II-2.GT.1)GO TO 9                                              TUBE1262
      DO 8 I=1,100                                                      TUBE1263
    8 RADF(I)=RAD                                                       TUBE1264
C     DL=10.                                                            TUBE1265
    9 ZIC=0.0                                                           TUBE1266
      T2=T1+10.                                                         TUBE1267
      DL=DLS                                                            TUBE1268
      CALL RATE(C,T1,RA1)                                               TUBE1269
    2 CALL RATE(C,T2,RA2)                                               TUBE1270
      T2OLD=T2                                                          TUBE1271
      ZIC=ZIC+DL                                                        TUBE1272
      ZICI=ZICI+DL                                                      TUBE1273
      IF(ZIC.LT.ZTT)GO TO 4                                             TUBE1274
      DL=ZTT-(ZIC-DL)                                                   TUBE1275
      IF(DL.LE.0)GO TO 10                                               TUBE1276
      ZIC=ZTT                                                           TUBE1277
      ZICI=ZTT                                                          TUBE1278
    4 CI=RADF(INT((ZTT-ZIC)/ZTT*99.+1.))                                TUBE1279
      IF(CI.LE.0.0)CI=RAD                                               TUBE1280
```

```
    51 C906  FORMAT('   I   J   K   M',3X,'X1(K)',5X,'X2(J)',4X,'DXA(I)',5X,'DXTUBE1281
    52 C     11,')                                                          TUBE1282
    53       CALL MATB(RA1,RA2,BC2,DXA,X1,X2,T1,T2,PT,PT2)                  TUBE1283
    54       CALL HEATB(CI,T1,T2,DXA,X1,X2,BT2,QINC,UINC)                   TUBE1284
    55       IF(MZ.GE.1000)RETURN                                           TUBE1285
    56       IC=0                                                           TUBE1286
    57 3     CALL RATE(BC2,BT2,BRA2)                                        TUBE1287
    58       CALL MATB(RA1,BRA2,BBC2,BDXA,X1,X2,T1,BT2,PT,PT2)              TUBE1288
    59       CALL HEATB(CI,T1,BT2,BDXA,X1,X2,BBT2,QINC,UINC)                TUBE1289
    60       IF(MZ.GE.1000)RETURN                                           TUBE1290
    61       IF(ABS((BBT2-BT2)/BBT2).GE.0.0001)GO TO 5                      TUBE1291
    62       GO TO 6                                                        TUBE1292
    63 5     BT2=(BBT2+BT2)/2.                                              TUBE1293
    64       IC=IC+1                                                        TUBE1294
    65       IF(IC.GE.25)STOP1000                                           TUBE1295
    66       DO 50 I=1,IS                                                   TUBE1296
    67       DO 50 I=1,IS                                                   TUBE1297
    68 50    BC2(I)=BBC2(I)                                                 TUBE1298
    69       GO TO 3                                                        TUBE1299
    70 6     DT=T2OLD-BBT2                                                  TUBE1300
    71       IF(ZIC.LE.0L)DT=0.0                                            TUBE1301
    72       T2=BBT2+(BBT2-T1)-DT                                           TUBE1302
    73       T1=BBT2                                                        TUBE1303
    74       TMPH=0.0                                                       TUBE1304
    75       DO 60 I=1,IS                                                   TUBE1305
    76       P(I)=P(I)*BT2/PT                                               TUBE1306
    77       C(I)=BBC2(I)                                                   TUBE1307
    78       X1(I)=X2(I)                                                    TUBE1308
    79       TMPH=TMPH+X1(I)                                                TUBE1309
    80 60    CONTINUE                                                       TUBE1310
    81       PT=PRR(IS)                                                     TUBE1311
    82       IF(MZ.GE.1000)RETURN                                           TUBE1312
    83       DO 61 I=1,IS                                                   TUBE1313
    84 61    P(I)=PT*X1(I)/TMPH                                             TUBE1314
    85       IF(ZIC.LT.Z85*XN)GO TO 63                                      TUBE1315
    86       XN=XN+1.                                                       TUBE1316
    87       JN=JN+1                                                        TUBE1317
    88       TX(JN)=T1                                                      TUBE1318
    89  63   CONTINUE                                                       TUBE1319
    90       IF(ZICI.LE.(ZTT/30.))GO TO 30                                  TUBE1320
    91 C     WRITE(2,901)T1,T2,PT,ZIC                                       TUBE1321
    92       ZICI=0.                                                        TUBE1322
    93       MZ=MZ+1                                                        TUBE1323
    94       WZIC(MZ)=ZIC                                                   TUBE1324
    95       WT(MZ)=T2                                                      TUBE1325
    96       WTMPH(MZ)=TMPH                                                 TUBE1326
    97       WPT(MZ)=PT                                                     TUBE1327
    98       WVEL1(MZ)=VEL1                                                 TUBE1328
    99       DO 70 J=1,ISS                                                  TUBE1329
   100       WC(J,MZ)=C(J)                                                  TUBE1330
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```
      WTM(J,NZ)=X2(J)                                                    TUBE1331
   70 WDXA(J,NZ)=DXA(J)                                                  TUBE1332
      IF(ZIC.GE.ZTT)GO TO 10                                             TUBE1333
  901 FORMAT(1X,'T1=',E10.3,'  T2=',E10.3,'  PT=',E10.3,'  ZIC=',E10.3)  TUBE1334
   30 QTOT=QTOT+QINC                                                     TUBE1335
      QT(N3)=QT(N3)+QINC                                                 TUBE1336
      IF(ZIC.LT.Z33*FLOAT(N3))GO TO 2                                    TUBE1337
      N3=N3+1                                                            TUBE1338
      GO TO 2                                                            TUBE1339
   10 DO 20 I=1,100                                                      TUBE1340
      RADD(I,1)=RADI(I)                                                  TUBE1341
   20 RADD(I)=RADI(I)                                                    TUBE1342
      WRITE(6,902)QTOT                                                   TUBE1343
      IF(JN.LT.85)GO TO 64                                               TUBE1344
      RETURN                                                             TUBE1345
   64 DO 65 I=JN,85                                                      TUBE1346
   65 TX(I)=T1                                                           TUBE1347
  902 FORMAT('       NET HEAT FLUX TO PROCESS FLUID ',E16.7,' BTU')      TUBE1348
      RETURN                                                             TUBE1349
      END                                                                TUBE1350
```

```
      FUNCTION VIS(T,TCOND)                                              VIS 1351
      REAL*4 LOG                                                         VIS 1352
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)   VIS 1353
     1,EA(25),EE(25),RAD,AO                                              VIS 1354
      COMMON/PYRO3/Z(11),ZTT,C(25),CP(25,4)                              VIS 1355
     1,DU(25),DS(25),DE(25)                                              VIS 1356
      COMMON/PO/P(25),ON,SMWT(25),CLJ(25,2),VI(25),AMWT,VEL1,HI          VIS 1357
      DATA A/.4398818/,BI/-.44245917/,CC/.86401820E-1/,D/.77484511E-2/   VIS 1358
      DATA A1/2.6693E-5/,TOLD/10./                                       VIS 1359
      IF(ABS(T-TOLD).LE.25.)GO TO 5                                      VIS 1360
      TOLD=T                                                             VIS 1361
      PT=0.0                                                             VIS 1362
      DO 1 I=1,IS                                                        VIS 1363
    1 PT=PT+P(I)                                                         VIS 1364
      PRESDT=0.                                                          VIS 1365
   11 DO 2 I=1,IS                                                        VIS 1366
      IF(CLJ(I,1).EQ.0) GO TO 2                                          VIS 1367
      E=LOG(T/CLJ(I,2))                                                  VIS 1368
      VI(I)=A1*SQRT(SMWT(I)*T)/(CLJ(I,1)**2*EXP(A+BI*E+CC*E**2+D*E**3))  VIS 1369
    2 CONTINUE                                                           VIS 1370
      VIS=0.                                                             VIS 1371
      TCOND=0.0                                                          VIS 1372
      DO 3 I=1,IS                                                        VIS 1373
      IF(CLJ(I,1).EQ.0.)GO TO 3                                          VIS 1374
      V=P(I)/PT*VI (I)                                                   VIS 1375
      TC=(4CP(T,I)+2.484)*VI(I)/SMWT(I)                                  VIS 1376
      U=0.                                                               VIS 1377
      DO 4 J=1,IS                                                        VIS 1378
      IF(CLJ(J,1).EQ.0.)GO TO 4                                          VIS 1379
      U=U+P(J)/PT*1./SQRT(8.)/(1.+SMWT(I)/SMWT(J))*(1.+(VI(I)/VI(J))**.5VIS 1380
     1*(SMWT(J)/SMWT(I))**.25)**2                                        VIS 1381
    4 CONTINUE                                                           VIS 1382
      VIS=VIS+V/U                                                        VIS 1383
      TCOND=TCOND+P(I)/PT*TC/U                                           VIS 1384
    3 CONTINUE                                                           VIS 1385
      VIS=VIS*.0672                                                      VIS 1386
      TCOND=TCOND*435.15                                                 VIS 1387
C     THERMOCONDUCTIVE IN BTU/(HR-FT**2/FT-DEG K)                        VIS 1388
C     WRITE(2,907)VIS,TCOND                                              VIS 1389
C907  FORMAT(' VIS=  ',E15.5,'   TCOND=',E15.5)                          VIS 1390
      RETURN                                                             VIS 1391
    5 VIS=VIS                                                            VIS 1392
      RETURN                                                             VIS 1393
      END                                                                VIS 1394
```

```
      SUBROUTINE PRESC(T1,T2,PD,TMPH)                                   PRES1395
      REAL*4 LOG                                                        PRES1396
      COMMON/PYRL3/Z(11),ZTT,C(25),CP(25,4)                             PRES1397
     1,DI(25),DS(25),DE(25)                                             PRES1398
      COMMON/TUBE1/IR,IS,KF(25),KR(25),B(25,10),BB(25,10),DL,IA(25,10)  PRES1399
     1,EA(25),EE(25),RAD,AO                                             PRES1400
      COMMON/PD/P(25),DH,SMWT(25),CLJ(25,2),VI(25),AMWT,VEL1,HI         PRES1401
      COMMON/PT2/TT,RN1,RN2,VISS                                        PRES1402
      COMMON/SET/MY,MZ,IB,IPLOT,DLS                                     PRES1403
C THIS SUBROUTINE CALULATES PRESSURE DROP FROM BERNOULIE LAW            PRES1404
C MODIFIED TO TAKE FRICTION LOSS INTO CONSIDERATION                     PRES1405
      DATA A2/1.1620925E-4/,A3/7.37495E4/                               PRES1406
      DATA PRESDT/0.0/,GC/1.3143/                                       PRES1407
      T=(T1+T2)/2.                                                      PRES1408
      VISS=VIS(T,TCOND)                                                 PRES1409
      PT=0.0                                                            PRES1410
      DO 2 I=1,IS                                                       PRES1411
    2 PT=PT+P(I)                                                        PRES1412
    1 AMWT=0.                                                           PRES1413
      HCPB=0.0                                                          PRES1414
      VEL2=A2*T2/(PT-PRESDT)/RAD**2*TMPH                                PRES1415
      DO 5 I=1,IS                                                       PRES1416
      HCPB=HCPB+HCP(T,I)*P(I)/PT/SMWT(I)                                PRES1417
    5 AMWT=P(I)/PT*SMWT(I)+AMWT                                         PRES1418
C     GC IN AT.*FT**3  /(OK LB,MOLES)                                   PRES1419
      DEN=PT/(GC*T)*AMWT                                                PRES1420
      IF(DEN.LE.0.)GO TO 21                                             PRES1421
    6 VELA=(VEL1+VEL2)/2.                                               PRES1422
      RENU=2.*RAD*DEN*VELA/VISS                                         PRES1423
      IF(RENU.LE.0.)GO TO 19                                            PRES1424
      IF(RENU.LE.3500.)GO TO 20                                         PRES1425
      GO TO 10                                                          PRES1426
   20 F=64./RENU                                                        PRES1427
      GO TO 100                                                         PRES1428
   10 F=0.00560+.5/(RENU**.32)                                          PRES1429
  100 PD=DEN*(VELA**2*F*DL/RAD+VEL2**2-VEL1**2)/62.4/2116.8             PRES1430
      PD=ABS(PD)                                                        PRES1431
      P2=PT-PD                                                          PRES1432
      IF(P2.LE.0.)GO TO 21                                              PRES1433
      VEL2=A2*T/P2/RAD**2*TMPH                                          PRES1434
      IF(PD.EQ.0.)GO TO 7                                               PRES1435
      IF(ABS((PRESDT-PD)/PD).LE..001)GO TO 7                            PRES1436
      PRESDT=PD                                                         PRES1437
      DEN=(P2+PT)/(2.*GC*T)*AMWT                                        PRES1438
      GO TO 6                                                           PRES1439
    7 PT2=0.                                                            PRES1440
      DO 9 I=1,IS                                                       PRES1441
    9 PT2=PT2+P(I)                                                      PRES1442
      IF((IPLOT.EQ.2).OR.(IPLOT.EQ.3).AND.(MZ.EQ.1))GO TO 1001          PRES1443
      VEL1=VEL2                                                         PRES1444
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      HI=.0207*TCOND/RAD*RENU**.8*(HCPE*VISS/TCOND*3600.*1.8)**.333333  PRES1445
C     HI IN BTU/(FT**2-HR-DK)                                           PRES1446
      IF(VEL1.GE.1214.5)GO TO 22                                        PRES1447
      IF(VEL1.GE.SQRT(A3*P2/DEN))GO TO 22                               PRES1448
31    CONTINUE                                                          PRES1449
      RETURN                                                            PRES1450
22    MZ=3000                                                           PRES1451
      PT=.5                                                             PRES1452
      RETURN                                                            PRES1453
1001  WRITE(2,9001)RENU, VISS,DEN,F,VEL1,VEL2,VELA,T ,PD                PRES1454
      VEL1=VEL2                                                         PRES1455
      RETURN                                                            PRES1456
19    WRITE(2,900)RAD,DEN,VELA,VISS,RENU                                PRES1457
      WRITE(2,902)T,PT,(P(I),I=1,IS),GC,AMWT,P2                         PRES1458
      MZ=2000                                                           PRES1459
      RETURN                                                            PRES1460
21    WRITE(2,902)T,PT,(P(I),I=1,IS),GC,AMWT,P2                         PRES1461
      MZ=2000                                                           PRES1462
      RETURN                                                            PRES1463
900   FORMAT(' RAD=',1PE12.5,'DEN,VELA,VIS,RENU',/4(2X,1PE12.5))        PRES1464
901   FORMAT(' PRESSURE DROP =',1PE12.5,'DEN,VELA,DL,VEL1,VEL2',/5(2X,1PPRES1465
     1E12.5))                                                           PRES1466
902   FORMAT(' T PT P(1)-P(IS), GC AMWT PT2 ',5(1X,F8.2)/)              PRES1467
9001  FORMAT(' FUNCTION PD(T)',//,' RENU=',1PE14.5,5X,'VISS=',1PE14.5,5X,PRES1468
     1 'DE=',1PE14.5,/,' FRICTION FACTOR= ',1PE14.5,5X,'V1,V2,VA=',3(1PEPRES1469
     114.5,5X),/,' TEMPERTURE=',0PF8.2,'PRESSURE D=',1PE14.5)           PRES1470
      END                                                               PRES1471
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```
      SUBROUTINE TEMPT(TSKIN,ZIC,IND)                                   TEMP1472
      COMMON/ANDY/T1(60),T2(60),T3(60),C1(10),C2(10),C3(10),ZX(7)       TEMP1473
      IF(IND.EQ.2)GO TO 5                                               TEMP1474
      ZX(1)=0.0                                                         TEMP1475
      DO 1 I=2,7                                                        TEMP1476
    1 ZX(I)=ZX(I-1)+14./3.                                              TEMP1477
      CALL PZERO(T1(1),210)                                             TEMP1478
      CALL READ(3,'TEM1',T1(1),60)                                      TEMP1479
      CALL READ(3,'TEM2',T2(1),60)                                      TEMP1480
      CALL READ(3,'TEM3',T3(1),60)                                      TEMP1481
      X1=FITIT(ZX(1),T1(9),7,5,C1(1),1,1.)                              TEMP1482
      X3=FITIT(ZX(1),T3(9),7,4,C3(1),1,1.)                              TEMP1483
      X2=FITIT(ZX(1),T2(9),7,4,C2(1),1,1.)                              TEMP1484
      WRITE(6,901)X1,X2,X3                                              TEMP1485
  901 FORMAT(' STANDRARD DEVIATION TEMPERATURE CURVE',3E16.7)           TEMP1486
      IND=2                                                             TEMP1487
    5 ZSE=ZIC-FLOAT(INT(ZIC)/56)*56.                                    TEMP1488
      IF(ZSE.GT.28.0)ZSE=56.-ZSE                                        TEMP1489
      IF(ZIC.LT.140.)GO TO 10                                           TEMP1490
      IF(ZIC.LT.220.)GO TO 15                                           TEMP1491
      TSKIN=EQUA(ZSE,C3(1))                                             TEMP1492
      GO TO 18                                                          TEMP1493
   10 TSKIN=EQUA(ZSE,C1(1))                                             TEMP1494
      GO TO 18                                                          TEMP1495
   15 TSKIN=EQUA(ZSE,C2(1))                                             TEMP1496
   18 IF(TSKIN.LT.700..OR.TSKIN.GT.1400.)GO TO 20                       TEMP1497
      RETURN                                                            TEMP1498
   20 WRITE(6,900)TSKIN                                                 TEMP1499
  900 FORMAT(' TEMPERATURE OF REACTOR WALL OUTSIDE OF RANGE T= ',E18.5)  TEMP1500
      TSKIN=1120                                                        TEMP1501
      RETURN                                                            TEMP1502
      END                                                               TEMP1503
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      SUBROUTINE FURN                                                   FURN1504
      COMMON // DUMMY(3),KK, ICODE, HCODE,                             FURN1505
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    FURN1506
     A TBRIDG, PRES, FLUET, FLUE(5), XHWX, TSINK,                       FURN1507
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    FURN1508
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     FURN1509
     A XSURFX(9), XD, YD, ZLONG, NCOL, NROW, NXSXN,                     FURN1510
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              FURN1511
     A K1, K2, RCRD(10), TDEP(100), PERM(200),NPRNT                     FURN1512
C                                                                       FURN1513
      COMMON /CPHV/ CPCP(11), HVHV(12)                                  FURN1514
C                                                                       FURN1515
C                                                                       FURN1516
      INTEGER SCODE, TCODE, RSTART, HCODE                               FURN1517
      EQUIVALENCE (DUMMY(1),KHTCL5), (DUMMY(2),KHTCL6),                FURN1518
     1 (PERM(99),DHTCL5), (PERM(200),DHTCL6)                            FURN1519
C                                                                       FURN1520
C                                                                       FURN1521
C                                                                       FURN1522
C                                                                       FURN1523
      CALL PZERO(DUMMY(1),400)                                          FURN1524
      K1=1                                                              FURN1525
      K2=6                                                              FURN1526
      WRITE(K2,876)                                                     FURN1527
  876 FORMAT (1H1)                                                      FURN1528
C   READ AND WRITE THREE TITLE CARDS HERE                               FURN1529
      DO 802 J=1,3                                                      FURN1530
      READ(K1,801)(PERM(N),N=1,18)                                      FURN1531
  801 FORMAT (18A4)                                                     FURN1532
      WRITE(K2,821)(PERM(N),N=1,18)                                     FURN1533
  821 FORMAT(15X,18A4)                                                  FURN1534
  802 CONTINUE                                                          FURN1535
C                                                                       FURN1536
      NOONE = 0                                                         FURN1537
C                                                                       FURN1538
C     RSTART ---- 0 NO RESTART                                          FURN1539
C                 1 GENERATE RESTART DISKS                            FURN1540
C                 2 CASE USES RESTART DISKS                           FURN1541
C                                                                       FURN1542
C     TCODE ----- 0 ALL VOL AND SURF TEMP TO BE READ IN                 FURN1543
C                 1 MIN MAX TEMP KNOWN                                FURN1544
C                 2 CALC MIN MAX TEMP FROM ADIABATIC FLAME TEMP       FURN1545
C                 3 USE TEMP DATA FROM RESTART DISKS                  FURN1546
C                                                                       FURN1547
C     SCODE ----- 0 VOL AND SURF TEMP ARE ALL VARIABLES                 FURN1548
C                 1 SOME VOL TEMP ARE TO BE HELD CONSTANT             FURN1549
C                 2 SOME SURF TEMP ARE TO BE HELD CONSTANT            FURN1550
C                 3 SOME VOL + SURF TEMP ARE TO BE HELD CONSTANT !    FURN1551
C     JHCHC ----- 0 MEANINGLESS                                         FURN1552
C                 1 REVISE HEAT TRANSFER COEFFICIENTS ONLY IF RSTART = 2 FURN1553
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      C                                                                      FURN1554
      C     NSTART --- 0 NEW CASE                                            FURN1555
      C                1 PREVIOUS CASES HAVE BEEN RUN - TREAT AS RESTART CASE FURN1556
      C                                                                      FURN1557
      C     NCASE --- 0 NO MORE CASES TO FOLLOW                              FURN1558
      C               1 ANOTHER CASE WILL FOLLOW                             FURN1559
      C                                                                      FURN1560
      C     NPRNT --- 0 DETAIL RESULTS PRINTED                               FURN1561
      C               1 DETAILED RESULTS NOT PRINTED                         FURN1562
      C                                                                      FURN1563
            READ(K1,2)RSTART,TCODE,SCODE,NGRAY,JHCHC,NSTART,NCASE,NPRNT      FURN1564
        2   FORMAT (8I10)                                                    FURN1565
      C                                                                      FURN1566
            IF ( NSTART .NE. 0 ) RSTART = 2                                  FURN1567
      C                                                                      FURN1568
            IF ( RSTART .EQ. 2 ) GO TO 6                                     FURN1569
        4   CONTINUE                                                         FURN1570
            GO TO 10                                                         FURN1571
        6    CALL READ(4,'START',DUMMY(1),400)                               FURN1572
            IF ( ZLONG .LE. 0.0 .OR. DUMMY(3) .LE. 0.0 .OR.                  FURN1573
           1 NCOL .LE. 0 .OR. NROW .LE. 0 .OR.                               FURN1574
           2 NSURF .LE. 0 .OR. NVOL .LE. 0 .OR.                              FURN1575
           3 NCR .LE. 0 ) GO TO 111                                          FURN1576
            RSTART=2                                                         FURN1577
            NSTART=1                                                         FURN1578
       10   READ (K1,11)NVNSM, NVMAX, NSMAX, KHTCL5, KHTCL6, DHTCL5, DHTCL6  FURN1579
       11   FORMAT ( 5I10,2F10.2 )                                           FURN1580
      C                                                                      FURN1581
            CALL CL1 ( NCASE, NSTART, NVNSM, NVMAX, NSMAX )                  FURN1582
      C                                                                      FURN1583
            IF ( RSTART .EQ. 2 ) GO TO 40                                    FURN1584
      C                                                                      FURN1585
            RETURN                                                           FURN1586
            ENTRY FURN0                                                      FURN1587
            CALL CL2                                                         FURN1588
       40   CALL CL3                                                         FURN1589
            RETURN                                                           FURN1590
            ENTRY FURN1                                                      FURN1591
            NDONE=0                                                          FURN1592
      C                                                                      FURN1593
            DO 60 N=1,NVNSM                                                  FURN1594
            WRITE (K2,2  1) N                                                FURN1595
        2   1 FORMAT (1H1,14X,35HENERGY BALANCE INTERMEDIATE RESULTS/15X,    FURN1596
           1 35(1H-)                                /15X,12HTRIAL NUMBER:I10) FURN1597
            HCODE = 0                                                        FURN1598
            ICODE = 0                                                        FURN1599
            CALL CL4                                                         FURN1600
      C                                                                      FURN1601
            DO 52 NV=1,NVMAX                                                 FURN1602
            WRITE (K2,2011) NV                                               FURN1603
```

```
  101  2011 FORMAT (/////15X,60HGAS VOLUME ENERGY BALANCE RESULTS, INTERMEDIAT FURN1604
  102     1E TRIAL NUMBER I10 )                                              FURN1605
  103       CALL CL5                                                         FURN1606
  104       IF ( HCODE .EQ. 2 .OR. NV .EQ. NVMAX ) GO TO 54                  FURN1607
  105    51 CONTINUE                                                         FURN1608
  106       HCODE = 10                                                       FURN1609
  107       CALL CL4                                                         FURN1610
  108       HCODE = 1                                                        FURN1611
  109    52 CONTINUE                                                         FURN1612
  110 C                                                                      FURN1613
  111    54 DO 56 NS=1,NSMAX                                                 FURN1614
  112       WRITE (K2,2021) NS                                               FURN1615
  113  2021 FORMAT (/////15X,62HSURFACE AREA ENERGY BALANCE RESULTS, INTERMEDI FURN1616
  114     1ATE TRIAL NUMBER I10)                                             FURN1617
  115       CALL CL6                                                         FURN1618
  116    55 IF ( ICODE .EQ. 2 .OR. NS .EQ. NSMAX ) GO TO 57                  FURN1619
  117       ICODE = 10                                                       FURN1620
  118       CALL CL4                                                         FURN1621
  119       ICODE = 1                                                        FURN1622
  120    56 CONTINUE                                                         FURN1623
  121 C                                                                      FURN1624
  122    57 IF ( HCODE .EQ. 2 .AND. NV .EQ. 1 .AND.                          FURN1625
  123      1 ICODE .EQ. 2 .AND. NS .EQ. 1 ) NDONE = 1                        FURN1626
  124       IF ( NDONE .EQ. 1 ) GO TO 70                                     FURN1627
  125    60 CONTINUE                                                         FURN1628
  126 C                                                                      FURN1629
  127    70 KK = NDONE                                                       FURN1630
  128       CALL CL7                                                         FURN1631
  129 C                                                                      FURN1632
  130 C                                                                      FURN1633
  131       RETURN                                                           FURN1634
  132    90 IF ( RSTART .EQ. 0 ) GO TO 999                                   FURN1635
  133       IF ( NCASE .NE. 0 ) GO TO 999                                    FURN1636
  134  111  WRITE(2,112)                                                     FURN1637
  135  112  FORMAT('1',20X,'RESTART NO GOOD CHECK DS23')                     FURN1638
  136  999  RETURN                                                           FURN1639
  137       END                                                              FURN1640
```

```
      SUBROUTINE CL1 ( NCASE, NSTART, NVNSM, NVMAX, NSMAX )                CL1 1641
C                                                                          CL1 1642
      COMMON // DUMMY(3), KK, ICODE, HCODE,                                CL1 1643
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                       CL1 1644
     A TBRIDG, PRES, FLUET, FLUE(5), XMMX, TSINK,                          CL1 1645
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                       CL1 1646
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                        CL1 1647
     A XSURFX(8), XQ, YQ, ZLONG, NCOL, NROL, NXSXN,                        CL1 1648
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                                 CL1 1649
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                              CL1 1650
C                                                                          CL1 1651
      INTEGER SCODE, TCODE, RSTART, HCODE                                  CL1 1652
      EQUIVALENCE (DUMMY(1),KHTCL5), (DUMMY(2),KHTCL6),                    CL1 1653
     1 (PERM(199),DHTCL5), (PERM(200),DHTCL6)                              CL1 1654
C                                                                          CL1 1655
      COMMON /ED/ A(10,5), B(12,7), C(11,7), GHW(7)                        CL1 1656
C                                                                          CL1 1657
      WRITE (K2,811) RSTART, TCODE, SCODE, JHCHC, NSTART, NCASE,           CL1 1658
     1 NVNSM, NVMAX, NSMAX, KHTCL5, KHTCL6, DHTCL5, DHTCL6                 CL1 1659
  811 FORMAT ( ///// 15X 13HPROBLEM CODES / 15X 13(1H-)                    CL1 1660
     A /// 20X 12HRESTART CODE I28                                         CL1 1661
     B / 20X 21HTEMPERATURE DATA CODE I19                                  CL1 1662
     C / 20X 23HTEMPERATURE CALCULATION CODE I12                           CL1 1663
     D / 20X 31HHEAT TRANSFER COEFFICIENT CODE I10                         CL1 1664
     E // 20X 18HPREVIOUS CASE CODE I22                                    CL1 1665
     F / 20X 20HSUBSEQUENT CASE CODE I20                                   CL1 1666
     G // 20X 33HNUMBER OF OVERALL ENERGY BALANCES I17                     CL1 1667
     H / 20X 36HNUMBER OF GAS VOLUME ENERGY BALANCES I14                   CL1 1668
     I / 20X 36HNUMBER OF SURFACE AREA ENERGY BALANCES I12                 CL1 1669
     M // 20X,68HNUMBER OF GAS VOLUME ENERGY BALANCES USING CURRENT INTEC  CL1 1670
     NRCHANGE AREAS,I12                                                    CL1 1671
     O / 20X 72HNUMBER OF SURFACE AREA ENERGY BALANCES USING CURRENT INTC  CL1 1672
     PERCHANGE AREAS,I10                                                   CL1 1673
     A // 20X 47HTOLERANCE ON GAS VOLUME ENERGY BALANCE, DEG. F.           CL1 1674
     L F13.3                                                               CL1 1675
     K / 20X 49HTOLERANCE ON SURFACE AREA ENERGY BALANCE, DEG. F.          CL1 1676
     L F11.3 )                                                             CL1 1677
C                                                                          CL1 1678
      KERR = 0                                                             CL1 1679
C                                                                          CL1 1680
C     DEFINE FURNACE GEOMETRY, AND HEAT RELEASE PATTERN                    CL1 1681
C                                                                          CL1 1682
   15 CALL AAA ( KERR )                                                    CL1 1683
C                                                                          CL1 1684
C     READ FUEL CODE, EXCESS AIR, FUEL TEMP, BRIDGE WALL TEMP,             CL1 1685
C     AND BOX PRES                                                         CL1 1686
C                                                                          CL1 1687
C     KFUEL ---- 0 OIL FIRING                                              CL1 1688
C                1 GAS FIRING                                              CL1 1689
C                                                                          CL1 1690
```

```
      IF ( RSTART .EQ. 2 ) GO TO 31                                      CL1 1691
   21 READ (K1,23) KFUEL, XAIR, FTEMP, TBRIDG, PRES                      CL1 1692
   23 FORMAT (I10,4F10.0)                                                CL1 1693
      IF ( FTEMP .EQ. 0.0 ) FTEMP = 60.0                                 CL1 1694
      IF ( TBRIDG .EQ. 0.0 ) TBRIDG = -460.0                             CL1 1695
      WRITE (K2,8020) KFUEL, XAIR, FTEMP                                 CL1 1696
 8020 FORMAT ( 1H1, 14X, 13HFUEL ANALYSIS / 15X, 13H-------------///     CL1 1697
     1 20X, 23HFUEL CODE (0=OIL,1=GAS) I25 / 20X, 20HEXCESS AIR, PER CENTCL1 1698
     2,    F28.2 / 20X, 30HFUEL-AIR MIXTURE TEMP., DEG. F F18.2)        CL1 1699
      FTEMP = FTEMP + 460.0                                              CL1 1700
      TBRIDG = TBRIDG + 460.0                                            CL1 1701
C                                                                        CL1 1702
C     COMPUTE FUEL ANALYSIS AND THE SPECIFIC HEAT + ENTHALPY DATA        CL1 1703
C                                                                        CL1 1704
   31 CALL BBB ( KERR )                                                  CL1 1705
C                                                                        CL1 1706
C     ESTABLISH TEMPERATURES                                             CL1 1707
C                                                                        CL1 1708
      IF ( RSTART .EQ. 2 .AND. TCODE .EQ. 3 ) GO TO 41                   CL1 1709
      CALL CCC                                                           CL1 1710
C                                                                        CL1 1711
C     ESTABLISH VOLUME AND SURFACE DATA                                  CL1 1712
   41 JUNK = 0                                                           CL1 1713
      IF ( RSTART .EQ. 2 .AND. JHCHC .EQ. 0 ) JUNK = 1                   CL1 1714
      IF ( RSTART .EQ. 2 .AND. JHCHC .EQ. 1 ) JUNK = 2                   CL1 1715
      CALL DDD ( JUNK, KERR )                                            CL1 1716
C                                                                        CL1 1717
C     CHARACTERIZE FLUE GAS                                              CL1 1718
C                                                                        CL1 1719
   51 IF ( RSTART .EQ. 2 ) GO TO 61                                      CL1 1720
      CALL EEE                                                           CL1 1721
C                                                                        CL1 1722
   61 IF ( KERR .EQ. 0 ) RETURN                                          CL1 1723
      STOP                                                               CL1 1724
      END                                                                CL1 1725
```

```
      SUBROUTINE AAA(KAPUT)                                              AAA 1726
      COMMON // DUMMY(3),KK, ICODE, HCODE,                               AAA 1727
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(6,3),                     AAA 1728
     A TORIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                        AAA 1729
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                     AAA 1730
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                      AAA 1731
     A XSURFX(9), XD, YD, ZLONG, NCOL, NROW, NXSXN,                      AAA 1732
     A RSTART, TCODE, SCODE, NGRAY, JHCNC,                               AAA 1733
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                            AAA 1734
C                                                                        AAA 1735
      INTEGER SCODE,TCODE,RSTART,HCODE                                   AAA 1736
      EQUIVALENCE (Z1(1), Z(1)),(Z2(1),Z( 61))                           AAA 1737
      DIMENSION Z(120),Z1( 60),Z2( 60)                                   AAA 1738
      KERR=0                                                             AAA 1739
      IF(RSTART.EQ.2) GO TO 30                                           AAA 1740
C     FURNACE GEOMETRY - - DIMENSIONS ARE IN FEET                        AAA 1741
      READ(K1,16) NCOL,NROW,XWIDE,YHIGH,ZLONG,XLX,(XSURFX(J),J=1,9)      AAA 1742
16    FORMAT(2I10/4F10.2/(3F10.2))                                       AAA 1743
      IF(FLOAT(NCOL*NROW)*XWIDE*YHIGH*ZLONG.GT.0.0)GO TO 21              AAA 1744
      KERR=1                                                             AAA 1745
      WRITE(K2,18) NCOL,NROW,XWIDE,YHIGH,ZLONG                           AAA 1746
18    FORMAT(27H FURNACE GEOMETRY INCORRECT/10X,5HNCOL =I5,10X,5HNROW =I5 AAA 1747
     1/10X,3HX =F10.4,10X,3HY =F10.4,10X,3H Z=F10.4)                     AAA 1748
      GO TO 30                                                           AAA 1749
21    XD=XWIDE/FLOAT(NCOL)                                               AAA 1750
      YD=YHIGH/FLOAT(NROW)                                               AAA 1751
      NVOL=NCOL*NROW                                                     AAA 1752
      NXSXN=0                                                            AAA 1753
      DO 22 J=1,9                                                        AAA 1754
      IF(XSURFX(J).EQ.0.0)GO TO 24                                       AAA 1755
      NXSXN=NXSXN+1                                                      AAA 1756
      XSURFX(J)=(AINT(XSURFX(J)/XD+.5))*XD                               AAA 1757
22    CONTINUE                                                           AAA 1758
24    NSURF=2*(NCOL+NROW)+NXSXN*NROW                                     AAA 1759
      NCR=2*(NCOL+NROW)                                                  AAA 1760
      NSSBLK=NSURF/15                                                    AAA 1761
      IF(NSSBLK*15-NSURF.EQ.0)GO TO 25                                   AAA 1762
      NSSBLK=NSSBLK+1                                                    AAA 1763
25    NGGBLK=NVOL/15                                                     AAA 1764
      IF(NGGBLK*15-NVOL.EQ.0) GO TO 26                                   AAA 1765
      NGGBLK=NGGBLK+1                                                    AAA 1766
26    NGSBLK=NSSBLK                                                      AAA 1767
      NSGBLK=NGGBLK                                                      AAA 1768
      IF(NVOL.LE. 60.AND.NSURF.LE. 60)GO TO 28                           AAA 1769
      KERR=1                                                             AAA 1770
      WRITE(K2,27) NVOL,NSURF                                            AAA 1771
27    FORMAT(' NUMBER OF GAS VOLUMES AND/OR SURFACE AREAS EXCEEDED 60',  AAA 1772
     1/,10X,' GAS VOLUMES =',I5,10X,' SURFACE AREAS=',I5)                AAA 1773
      GO TO 30                                                           AAA 1774
28    WRITE(K2,8000)XWIDE,YHIGH,ZLONG,(J,XSURFX(J),J=1,9),NCOL,          AAA 1775
```

```
      1NROW,XO,YO,NVOL,NSURF                                                AAA 1776
8000  FORMAT(1H1,14X,' FURNACE GEOMETRY',/,15X,'---------------------'AAA 1777
     1,///,20X,15HSIZE OF FURNACE  ,//,25X,11HWIDTH, FEET,     F33.2,/,25AAA 1778
     2X, 12HHEIGHT, FEET, F32.2,//,25X,12HLENGTH, FEET, F32.2//,25X,      AAA 1779
     336HINTERMEDIATE TUBE ROW LOCATION, FEET9(/,53X,I5,F10.2)///,20X,     AAA 1780
     4'SUBDIVISION OF FURNACE',//,25X,'NO. OF COLUMNS',I29/,25X,           AAA 1781
     5'NO. OF ROWS',I32//,25X,'COLUME WIDTH , FEET',F25.2/,25X,            AAA 1782
     6'ROW HEIGHT, FEET',F28.2//,25X,'NO. OF GAS VOLUMES',I25,/,25X,       AAA 1783
     7 ' NO OF SURFACE AREAS',I23)                                         AAA 1784
C    DUTY(MM BTU/HR),HEAT AVAILABILITY(BTU/LB FUEL)                        AAA 1785
30    READ(K1,31)HDUTY,HTVAL                                               AAA 1786
31    FORMAT(2F10.2)                                                       AAA 1787
      IF(HDUTY*HTVAL.NE.0.0)GO TO 33                                       AAA 1788
      KERR=1                                                               AAA 1789
      WRITE(K2,32)HDUTY,HTVAL                                              AAA 1790
32    FORMAT(' FURNACE FIRING RATE AND OR FUEL HEATING VALUES ARE NOT      AAA 1791
     1COMPLETE'/10X,' FIRING RATE (MM BTU/HR) =',F20.5   ,10X,'FUEL HEATAAA 1792
     2ING VALUE (BTU/LB) =',F10.0)                                         AAA 1793
      GO TO 34                                                             AAA 1794
C     FRATE= LB FUEL/FT OF FURNACE LENGTH                                  AAA 1795
33    FRATE=HDUTY/HTVAL*1.E6/ZLONG                                         AAA 1796
C     HEAT RELEASE PATTERN EXPRESSED AS BTU/HR/FT OF FURNACE               AAA 1797
C    READ DATA IN AS A PERCENTAGE OR FRACTION OF TOTAL HEAT RELEASED       AAA 1798
34    CALL PZERO(Z(1),120)                                                 AAA 1799
      READ(K1,35)(Z1(N),N=1,NVOL)                                          AAA 1800
      READ(K1,35)(Z2(N),N=1,NSURF)                                         AAA 1801
35    FORMAT(7F10.0)                                                       AAA 1802
      SUM=0.0                                                              AAA 1803
      DO 36 N=1,120                                                        AAA 1804
      SUM=SUM+Z(N)                                                         AAA 1805
36    CONTINUE                                                             AAA 1806
      IF(HDUTY*ZLONG*SUM.EQ.0.0)GO TO 40                                   AAA 1807
      FAC=HDUTY/ZLONG*1.E6/SUM                                             AAA 1808
      DO 37 N=1,120                                                        AAA 1809
      Z(N)=Z(N)*FAC                                                        AAA 1810
37    CONTINUE                                                             AAA 1811
      CALL WRITE(2,'HGAS',Z1(1), 60)                                       AAA 1812
      CALL WRITE(2,'HSUF',Z2(1), 60)                                       AAA 1813
      WRITE(K2,8010)HDUTY,HTVAL                                            AAA 1814
8010  FORMAT(1H1,14X,'FURNACE HEAT DUTY AND HEAT RELEASE PATTERN'/         AAA 1815
     115X,'----- ----------------------------------'///20X,'HEAT DUTY AAA 1816
     2,MM BTU/HR  ',F16.5/23X,'HEAT AVAILIBILITY'/25X,'BTU/LB OF FUEL',FAAA 1817
     316.0)                                                                AAA 1818
      WRITE(K2,8020)(Z1(N),N=1,NVOL)                                       AAA 1819
8020  FORMAT(//20X,'HEAT RELEASE PATTERN --- BTU/HR/FOOT OF FURNACE'//25AAA 1820
     1X,'GAS VOLUMES'//(25X,6F15.0))                                       AAA 1821
      WRITE(K2,8030)(Z2(N),N=1,NSURF)                                      AAA 1822
8030  FORMAT(/25X,' SURFACE AREAS'//(25X,6F15.0))                          AAA 1823
      IF(KERR.NE.0)KAPUT=KERR                                              AAA 1824
40    CONTINUE                                                             AAA 1825
```

```
101         RETURN                                                    AAA 1826
102         END                                                       AAA 1827
```

```
      SUBROUTINE BBB(KAPUT)                                              BBB 1828
C     COMPUTE FUEL GAS SPECIFIC HEAT+ENTHALPY                            BBB 1829
C     (SPECIFIC HEAT AND ENTHALPY DATA TO BE STORED IN POLYNOMINAL FORM) BBB 1830
C                                                                        BBB 1831
      COMMON // DUMMY(3),KK, ICODE, HCODE,                               BBB 1832
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                     BBB 1833
     A TERIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                        BBB 1834
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, ETEMP,                     BBB 1835
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                      BBB 1836
     A XSUREX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                      BBB 1837
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                               BBB 1838
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                            BBB 1839
C                                                                        BBB 1840
      INTEGER SCODE, TCODE, RSTART, HCODE                                BBB 1841
      COMMON/ED/ A(10,5),Z(12,7),C(11,7),CMW(7)                          BBB 1842
      COMMON/CPHV/ CP(11),HV(12)                                         BBB 1843
      REAL CMP(25),CMWGAS(25),FWT(5)                                     BBB 1844
      DATA CMWGAS /16.,30.1,44.1,2*58.1,2*72.1,86.2,100.2,114.2,28.0,42.BBB 1845
     11,4*56.1,26.1,40.1,54.1,28.0,44.0,2.0,34.1,18.0,28.0/              BBB 1846
      KERR=0                                                             BBB 1847
      IF(RSTART.EQ.2)GO TO 80                                            BBB 1848
      FLUET=1.                                                           BBB 1849
      XMWX=1.                                                            BBB 1850
      IF(KFUEL.NE.0)GO TO 60                                             BBB 1851
C     COMPUTE FUEL GAS ANALYSIS ON A PER FOOT OF FURNACE BASIS           BBB 1852
C     FLUE(1)       CO2                                                  BBB 1853
C     FLUE(2)       H2O                                                  BBB 1854
C     FLUE(3)       SO2                                                  BBB 1855
C     FLUE(4)       O2                                                   BBB 1856
C     FLUE(5)       N2                                                   BBB 1857
C     FUEL DATA -- OIL FIRING                                            BBB 1858
C     HCRATO= H/C ON WT BASIS                                            BBB 1859
C     FSULF = WT % SULFUR IN FUEL OIL                                    BBB 1860
C     STEAM = LB STEAM/ LB FUEL OIL                                      BBB 1861
      READ(K1,35)FMW,FAPI,FBP,FWATK,HCRATO,FSULF,STEAM                   BBB 1862
35    FORMAT(7F10.0)                                                     BBB 1863
      IF(STEAM.LT.0.0.OR.STEAM.GT.1.0)STEAM=0.5                          BBB 1864
      SRATE=FRATE*STEAM                                                  BBB 1865
C     PRIORITY OF MOL WT DETERMINATION                                   BBB 1866
C       1   MOL WT KNOW                                                  BBB 1867
C       2   API+BP                                                       BBB 1868
C       3   BP+WATK                                                      BBB 1869
C       4   API+WATK                                                    BBB 1870
C       5   BP                                                           BBB 1871
      KJ=0                                                               BBB 1872
      IF(FMW.GT.0.)GO TO 57                                              BBB 1873
      IF(FBP.NE.0.0)KJ=4                                                 BBB 1874
      IF(FAPI*FWATK.NE.0.0)KJ=3                                          BBB 1875
      IF(FBP*FWATK.NE.0.0)KJ=2                                           BBB 1876
      IF(FAPI*FBP.NE.0.0)KJ=1                                            BBB 1877
```

```
      IF(KJ.EQ.0)GO TO 53                                              BBB 1878
      GO TO (42,45,46,52),KJ                                           BBB 1879
C     KJ=1  BB CHART 3-25                                              BBB 1880
42    FBP=AMIN1(FBP,1200.)                                             BBB 1881
      FBP=AMAX1(FBP,100.)                                              BBB 1882
      B=(FBP+460.)/1000.                                               BBB 1883
      IF(FBP.LE.750.)GO TO 43                                          BBB 1884
      FAPI=AMIN1(FAPI,40.)                                             BBB 1885
      FAPI=AMAX1(FAPI,-30.)                                            BBB 1886
      S=141.5/(FAPI+131.5)                                             BBB 1887
      GO TO 44                                                         BBB 1888
43    FAPI=AMAX1(FAPI,0.)                                              BBB 1889
      S=141.5/(FAPI+131.5)                                             BBB 1890
      SMIN=((0.6256337E-2*B**3-0.40441530)*B**2+                       BBB 1891
     1      0.10806022E01)*B+0.74099427E-1                             BBB 1892
      S=AMAX1(S,SMIN)                                                  BBB 1893
44    FMW=-458.6322+56.096181*S**4-314.00029*S**3+16.97091*(S*P)**3    BBB 1894
     1  +401.54661*B**2-3.8014649*B**6+24.871805/(S**2*P)-10.016105/(S*BBB 1895
     2**3)+94.033174*S**4/B+457.37528*S/B-77.255634*(S/B)**3+3.4481747*(BBB 1896
     3S/B)**6-39.325111*S**4*B**3+32.007505*(B/S)**3-.82716166*(B/S)**6 BBB 1897
      GO TO 57                                                         BBB 1898
C     KJ=2   BB CHART 2-20 TO OBTAIN API THEN DO KJ=1                  BBB 1899
45    FBP=AMIN1(FBP,1000.)                                             BBB 1900
      FBP=AMAX1(FBP,100.)                                              BBB 1901
      FWATK=AMIN1(FWATK,14.)                                           BBB 1902
      FWATK=AMAX1(FWATK,9.)                                            BBB 1903
      B=(FBP+460.)/1000.                                               BBB 1904
      AK=FWATK/10.                                                     BBB 1905
      FAPI=-102.40915+139.36071*AK-7.90343*AK**2-28.81656*B+0.06136*B**5BBB 1906
     1+9.84756*AK/B-0.16243*(AK/B)**5                                  BBB 1907
      GO TO 42                                                         BBB 1908
C     KJ=3 BB CHART 2-20 TO OBTAIN BP THAN DO KJ=1                     BBB 1909
46    FWATK=AMIN1(FWATK,14.)                                           BBB 1910
      FWATK=AMAX1(FWATK,9.)                                            BBB 1911
      FAPI=AMIN1(FAPI,105.)                                            BBB 1912
      FAPI=AMAX1(FAPI,-20.)                                            BBB 1913
47    S=141.5/ (FAPI+131.5)                                            BBB 1914
      AK=FWATK/10.                                                     BBB 1915
      X1=S/AK                                                          BBB 1916
      X2=AK/S                                                          BBB 1917
      B=-0.46639378+(-0.094640507*S**4+0.39503379)*S-0.01592527*AK**5  BBB 1918
     1+((-0.1002351*X1+0.19565272)*X1**2-0.6665293E-1) *X1**2+(-0.31778BBB 1919
     282E-3*X2**4+0.14858729)*X2+0.10089545E+1*(S*AK)**3               BBB 1920
      FBP=B*1000.-460.                                                 BBB 1921
      IF(FBP.GE.100.)GO TO 51                                          BBB 1922
      FAPI=AMAX1(FAPI,24.)                                             BBB 1923
      GO TO 47                                                         BBB 1924
51    IF(FBP.LE.1000.) GO TO 42                                        BBB 1925
      FAPI=AMIN1(FAPI,42.5)                                            BBB 1926
      GO TO 47                                                         BBB 1927
```

```
      C   KJ=4   BB CHART 3-20                                                BBB 1926
   52     B=(FBP+460.)/1000.                                                  BBB 1929
          FMW=-1.446891+81.95931*P+152.39287*B**3-9.97706*B**5                BBB 1930
          GO TO 57                                                            BBB 1931
   53     KERR=1                                                              BBB 1932
          WRITE(K2,55)                                                        BBB 1933
   55     FORMAT(' INSUFFICIENT DATA TO COMPUTE MOL WT OF FUEL OIL ')          BBB 1934
          GO TO 80                                                            BBB 1935
      C   HC COMPOSITION   X=ATOMS OF CARBON   Y = ATOMS OF HYDROGEN         BBB 1936
   57     IF(HCRATO.NE.0.0)GO TO 59                                           BBB 1937
          KERR=1                                                              BBB 1938
          WRITE(K2,58)                                                        BBB 1939
   58     FORMAT(' HYDROGEN CARBON RATO MUST BE GIVEN TO FUEL GAS COMPOSITIOBBB 1940
         1N!)                                                                 BBB 1941
          GO TO 80                                                            BBB 1942
   59     HCFAC=12.*HCRATO                                                    BBB 1943
          X=FMW/(12.+HCFAC)                                                   BBB 1944
          Y=HCFAC*X                                                           BBB 1945
          FMOL=FRATE/FMW                                                      BBB 1946
      C   SULFUR RATE IN LB/HR/FT                                            BBB 1947
          SLBHR=FRATE*FSULF/100.                                              BBB 1948
          WRITE(K2,8030) FMW,FAPI,FBP,FWATK,HCRATO,FSULF,STEAM                BBB 1949
 8030     FORMAT(//20X,'OIL FIRING'//25X,'MOLECULAR WEIGHT',F27.2/25X,'API',BBB 1950
         1F40.2/25X,'BUILING POINT (MEAN)',F23.2/25X,'WATSON K',F35.2//25X,'BBB 1951
         2H/C RATIO, WT.BASIS',F24.4//25X,'WT. % SULFUR',F31.4//25X,'ATOMIZABBB 1952
         3TION STEAM'/30X,'LBS. STEAM/ LB. FUEL OIL',F13.4)                   BBB 1953
          FLUE(1)=X*FMOL                                                      BBB 1954
          FLUE(2)=Y/2.*FMOL+SRATE/18.                                         BBB 1955
          FLUE(3)=SLBHR/32.                                                   BBB 1956
          REQO2=((X+Y/4.)*FMOL)+SLBHR/32.                                     BBB 1957
          FLUE(4)=REQO2*XAIR/100.                                             BBB 1958
          FLUE(5)=79./21.*REQO2*(1.+XAIR/100.)                                BBB 1959
          GO TO 67                                                            BBB 1960
      C   FUEL DATA --- GAS FIRING                                           BBB 1961
   60     READ(K1,35)(COMP(J),J=1,25)                                         BBB 1962
          SUM=0.                                                              BBB 1963
          DO 62 N=1,25                                                        BBB 1964
          SUM=SUM+COMP(N)                                                     BBB 1965
   62     CONTINUE                                                            BBB 1966
          IF(SUM.NE.0.0)GO TO 64                                              BBB 1967
          KERR=1                                                              BBB 1968
          WRITE(K2,63)                                                        BBB 1969
   63     FORMAT(' FUEL COMPOSITION REQUIRED!')                               BBB 1970
          GO TO 80                                                            BBB 1971
   64     FMW=0.                                                              BBB 1972
          DO 65 N=1,25                                                        BBB 1973
          COMP(N)=COMP(N)/SUM                                                 BBB 1974
          FMW=FMW+COMP(N)*CMWGAS(N)                                           BBB 1975
   65     CONTINUE                                                            BBB 1976
          WRITE(K2,8040)FMW,(COMP(J),J=1,25)                                  BBB 1977
```

```
      FMOL=FRATE/FMW                                                    BBB 1978
 8040 FORMAT(//20X,'GAS FIRING'//25X,'MOLECULAR WEIGHT',15X,F12.2//25X,'BBB 1979
     1FUEL COMPOSITION MOLE FRACTION'//30X,'METHANE',F28.6/30X,'ETHAN',FBBB 1980
     229.6/30X,'PROPANE',F29.6/30X,'ISOBUTANE',F26.6/30X,'BUTANE',F29.6/BBB 1981
     330X ,'ISOPENTANE',F25.6/30X,'PENTANE',F28.6/30X,'HEXANE',F29.6/30XBBB 1982
     4,'HEPTANE',F28.6/30X,'OCTANE',F29.6//30X,'ETHYLENE',F27.6/30X,'PROBBB 1983
     5OPYLENE',F26.6/30X,'BUTENE-1',F27.6/30X,'C-BUTENE-2,',F25.6/30X,'TBBB 1984
     6-BUTENE-2,',F25.6/30X,'ISOBUTENE',F26.6//30X,'ACETYLENE',F26.6/30XBBB 1985
     7 ,'PROPYNE',F28.6/30X,'BUTYNE-1',F27.6//30X,'CARBON MONOXIDE',F20.BBB 1986
     86 /30X,'CARBON DIOXIDE',F21.6 /30X,'HYDROGEN',F27.6/30X,'HYDROGEN BBB 1987
     9SULFIDE',F19.6/30X,'WATER',F30.6/30X,'NITROGEN',F27.6)            BBB 1988
      DO 66 N=1,25                                                      BBB 1989
      COMP(N)=COMP(N)*FMOL                                              BBB 1990
 66   CONTINUE                                                          BBB 1991
      FLUE(1)=COMP(1)+2.*COMP(2)+3.*COMP(3)+4.*(COMP(4)+COMP(5))+5.*(COMBBB 1992
     1P(7))+6.*COMP(8)+7.*COMP(9)+8.*COMP(10)+2.*COMP(11)+3.*COMP(12)+4.BBB 1993
     2*(COMP(13)+COMP(14)+COMP(15)+COMP(16))+2.*COMP(17)+3.*COMP(18)+4.*BBB 1994
     3COMP(19)+COMP(20)+COMP(21)                                        BBB 1995
      FLUE(2)=2.*COMP(1)+3.*COMP(2)+4.*COMP(3)+5.*(COMP(4)+COMP(5)+COMP(BBB 1996
     16)+COMP(7))+7.*COMP(8)+8.*COMP(9)+9.*COMP(10)+2.*COMP(11)+3.*COMP(BBB 1997
     212)+4.*COMP(13)+4.*(COMP(15)+COMP(16)+COMP(14))+COMP(17)+2.*COMP(1BBB 1998
     38)+3.*COMP(19)+COMP(22)+COMP(23)+COMP(24)                         BBB 1999
      FLUE(3)=COMP(23)                                                  BBB 2000
      RECO2=2.*COMP(1)+3.5*COMP(2)+5.*COMP(3)+6.5*(COMP(4)+COMP(5))+8.*(BBB 2001
     1COMP(6)+COMP(7))+9.5*COMP(8)+11.*COMP(9)+12.5*COMP(10)+6.*(COMP(13BBB 2002
     2)+COMP(14)+COMP(15)+COMP(16))+2.5*COMP(17)+4.*COMP(18)+5.5*COMP(19BBB 2003
     39)+.5*COMP(20)+.5*COMP(22)+1.5*COMP(23)                           BBB 2004
      FLUE(4)=RECO2*XAIR/100.                                           BBB 2005
      FLUE(5)=79./21.*RECO2*(1.+XAIR/100.)+COMP(25)                     BBB 2006
C     NORMALIZE FLUE GAS COMPOSITION AND COMPUTIES TOTAL MOLES OF FLUE  BBB 2007
C           GAS PER FOOT OF FURNACE                                     BBB 2008
 67   FLUET=0.                                                          BBB 2009
      DUMMY(3)=FRATE                                                    BBB 2010
      DO 68 N=1,5                                                       BBB 2011
      FLUET=FLUET+FLUE(N)                                               BBB 2012
 68   CONTINUE                                                          BBB 2013
      DO 69 N=1,5                                                       BBB 2014
      FLUE(N)=FLUE(N)/FLUET                                             BBB 2015
 69   CONTINUE                                                          BBB 2016
C     SPECIFIC HEAT AND ENTHALPY DATA ARE TO BE IN TERMS OF DEG R       BBB 2017
      XMWX=0.                                                           BBB 2018
      DO 71 J=1,5                                                       BBB 2019
      XMWX=XMWX+FLUE(J)*CMW(J)                                          BBB 2020
 71   CONTINUE                                                          BBB 2021
      WRITE(K2,8050)FLUET,XMWX,(FLUE(J),J=1,5)                          BBB 2022
 8050 FORMAT(//20X,'FLUE GAS'//25X,'RATE MOLES/HR PER'/30X,'FOOT OF FURNBBB 2023
     1ACE',F23.2/25X,'MOLECULAR WEIGHT',15X,F12.2//25X,'FLUE GAS COMPOSIBBB 2024
     2TION, MOLE FRACTION'/51X,'CO2' ,F14.6/51X,'H2O',F14.6/51X,'SO2' ,FBBB 2025
     314.6/51X,'O2' ,F15.6/51X,'N2' ,F15.6)                             BBB 2026
      DO 72 J=1,5                                                       BBB 2027
```

```
      FWT(J)=FLUE(J)*CMW(J)/XMWX                                        BBB 2028
72    CONTINUE                                                          BBB 2029
      HV(1)=10.                                                         BBB 2030
      HV(2)=0.                                                          BBB 2031
      DO 75 K=1,10                                                      BBB 2032
      HV(K+2)=0.                                                        BBB 2033
      DO 74 J=1,5                                                       BBB 2034
      HV(K+2)=HV(K+2)+A(K,J)*FWT(J)                                     BBB 2035
74    CONTINUE                                                          BBB 2036
75    CONTINUE                                                          BBB 2037
      CP(1)=9.                                                          BBB 2038
      DO 77 K=3,12                                                      BBB 2039
      CP(K-1)=FLOAT(K-2)*HV(K)/1000.                                    BBB 2040
77    CONTINUE                                                          BBB 2041
      CALL WRITE(2,'HV  ',HV(1),12)                                     BBB 2042
      CALL WRITE(2,'CP  ',CP(1),11)                                     BBB 2043
      GO TO 82                                                          BBB 2044
C     BULK FLOW PATTERN                                                 BBB 2045
80    FLUET=FLUET/DUMMY(3)*FRATE                                        BBB 2046
      DUMMY(3)=FRATE                                                    BBB 2047
82    CALL FLOW(FLUET*XMWX,KERR)                                        BBB 2048
      IF(KERR.NE.0)KAPUT=KERR                                           BBB 2049
      RETURN                                                            BBB 2050
      END                                                               BBB 2051
```

```
      SUBROUTINE FLOW (FAC,KAPUT)                                       FLOW2052
C   FAC= TOTAL FLUE GAS FLOW RATE PER FOOT OF FURNACE -- LB/HR          FLOW2053
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              FLOW2054
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(3,3),                    FLOW2055
     A TBRIDG, PPES, FLUET, FLUE(5), XMWX, TSINK,                       FLOW2056
     A NCP, HDUTY, HTVAL, FRATE, KFUEL, YAIR, FTEMP,                    FLOW2057
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     FLOW2058
     A XSUREX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     FLOW2059
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              FLOW2060
     A K1, K2, RORD(10), TDEP(100), PERM(200)                           FLOW2061
      INTEGER SCODE,TCODE,RSTART,HCODE                                  FLOW2062
      DIMENSION Z(240),NI(120),GMX(120),GMY(120)                        FLOW2063
      EQUIVALENCE (GMX(1),Z(1)),(GMY(1),Z(121))                         FLOW2064
      KERR=0                                                            FLOW2065
C   READ IN THE BULK FLOW PATTERN -- BASIS IS 1.0 LB/HR/FOOT OF FURNACE FLOW2066
C   X = DIRECTION    (NCOL+1)*NROW                                      FLOW2067
C    Y= DIRECTION    (NROW+1)*NCOL                                      FLOW2068
      CALL PZERO(Z(1),240)                                              FLOW2069
      NX=(NCOL+1)*NROW                                                  FLOW2070
      READ(K1,35)(GMX(N),N=1,NX)                                        FLOW2071
35    FORMAT(7F10.0)                                                    FLOW2072
      NY=(NROW+1)*NCOL                                                  FLOW2073
      READ(K1,35)(GMY(N),N=1,NY)                                        FLOW2074
C   ADJUSTES FLOW PATTERN BASED ON ACTUAL TOTAL FLUE GAS FLOW RATE      FLOW2075
C                PER FOOT OF FURNACE                                    FLOW2076
36    FFAC=FAC                                                          FLOW2077
      DO 37 N=1,240                                                     FLOW2078
      Z(N)=Z(N)*FFAC                                                    FLOW2079
37    CONTINUE                                                          FLOW2080
      CALL WRITE(2,'GMX ',GMX(1), NX)                                   FLOW2081
      CALL WRITE(2,'GMY ',GMY(1), NY)                                   FLOW2082
      WRITE(K2,8099)                                                    FLOW2083
8099  FORMAT('1',15X,'FLUE GAS FLOW PATTERN,LB/HR/FOOT OF FURNACE'/15X,FLOW2084
     1'3('-'))                                                          FLOW2085
      WRITE(K2,8110)(GMX(N),N=1,NX)                                     FLOW2086
8110  FORMAT(//23X,'X = DIRECTION'//(25X,6F15.0))                       FLOW2087
      WRITE(K2,8120)(GMY(N),N=1,NY)                                     FLOW2088
8120  FORMAT(///,20X,'Y = DIRECTION',//(25X,6F15.0))                    FLOW2089
C   CHECK EACH GAS VOLUME FOR FLOW BALANCE (IN = OUT)                   FLOW2090
C   MATERAL BALANCE CHECK ON GAS VOL      JR=ROW NO   JC=COL NO         FLOW2091
C      X -  DIRECTION                                                   FLOW2092
C         IN      JX1=(JR-1)*(NCOL+1)+(JC)                            FLOW2093
C         OUT     JX2= (JR-1)*(NCOL+1)+(JC+1)                         FLOW2094
C      Y - DIRECTION                                                    FLOW2095
C         IN      JY1=(J)                                             FLOW2096
C         OUT     JY2 = (J+NCOL)                                      FLOW2097
38    K=0                                                               FLOW2098
      CALL NZERO(NI(1),150)                                             FLOW2099
      DO 43 J=1,NVOL                                                    FLOW2100
      JR=0                                                              FLOW2101
```

```
      JC=J                                                              FLOW2102
   40 JR=JR+1                                                           FLOW2103
      IF(JC.LE.NCOL)GO TO 41                                            FLOW2104
      JC=JC-NCOL                                                        FLOW2105
      GO TO 40                                                          FLOW2106
   41 JX1=(JR-1)*(NCOL+1)+JC                                            FLOW2107
      JX2=JX1+1                                                         FLOW2108
      JY1=J                                                             FLOW2109
      JY2=J+NCOL                                                        FLOW2110
      TEST=GMX(JX1)+GMY(JY1)-GMX(JX2)-GMY(JY2)                          FLOW2111
      TMAX=(ABS(GMX(JX1))+ABS(GMY(JY1))+ABS(GMX(JX2))+ABS(GMY(JY2)))/2.0FLOW2112
      IF(ABS(TEST).LE.0.00001*TMAX)GO TO 43                             FLOW2113
      K=K+1                                                             FLOW2114
      NI(K)=J                                                           FLOW2115
   43 CONTINUE                                                          FLOW2116
      IF(K.EQ.0)GO TO 46                                                FLOW2117
      KERR=1                                                            FLOW2118
      WRITE(K2,44)(NI(KJ),KJ=1,K)                                       FLOW2119
C     CHECK EACH GAS VOLUME FOR FLOW BALANCE (IN = OUT)                 FLOW2120
   44 FORMAT(' GAS VOL DO NOT MATERAL BALANCE'/(1X,1015))               FLOW2121
C     MATTERAL BALANCE CHECK ON GAS VOL        JR=ROW NO   JC=COL NO    FLOW2122
C       Y - DIRECTION                                                   FLOW2123
C          IN      JY1=L          L=1,2,3,....,NCOL      TOP           FLOW2124
C          OUT     JY2=NCOL*NROW+L=1,2,3,....,NCOL      BUTTON        FLOW2125
C       X - DIRECTION                                                   FLOW2126
C          IN      JX1=L*(NCOL+1)+1  L=0,1,2,3,...,NROW-1     LEFT     FLOW2127
C          OUT     JX2=L*(NCOL+1)    L=1,2,3,...,NROW         RIGHT    FLOW2128
   46 TEST=0.0                                                          FLOW2129
      TMAX=0.0                                                          FLOW2130
      NN=NCOL*NROW                                                      FLOW2131
      DO 47 L=1,NCOL                                                    FLOW2132
      JY1=L                                                             FLOW2133
      JY2=NN+L                                                          FLOW2134
      TEST=TEST+GMY(JY1)-GMY(JY2)                                       FLOW2135
      TMAX=TMAX+ABS(GMY(JY1))+ABS(GMY(JY2))                             FLOW2136
   47 CONTINUE                                                          FLOW2137
      NN=NCOL+1                                                         FLOW2138
      DO 48 L=1,NROW                                                    FLOW2139
      JX1=(L-1)*NN+1                                                    FLOW2140
      JX2=L*NN                                                          FLOW2141
      TEST=TEST+GMX(JX1)-GMX(JX2)                                       FLOW2142
      TMAX=TMAX+ABS(GMX(JX1))+ABS(GMX(JX2))                             FLOW2143
   48 CONTINUE                                                          FLOW2144
      IF(ABS(TEST).LE.0.00001*TMAX/2.)GO TO 50                          FLOW2145
      KERR=1                                                            FLOW2146
      WRITE(K2,49)                                                      FLOW2147
   49 FORMAT(' FURNACE BOX DOES NOT OVER ALL MATTERAL BALANCE ')        FLOW2148
   50 IF(KERR.NE.0)KAPUT=KERR                                           FLOW2149
      RETURN                                                            FLOW2150
      END                                                               FLOW2151
```

```
      SUBROUTINE CCC                                                    CCC 2152
C                                                                       CCC 2153
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CCC 2154
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    CCC 2155
     A TBRIDG, PRES, FLUET, FLUE(5), XMMX, TSINK,                       CCC 2156
     A NCR, HDUTY, HTVAL, ERATE, KEVEL, XAIR, FTEMP,                    CCC 2157
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CCC 2158
     A XSUREX(9), XO, YO, ZLCNC, NCCL, NCDV, NXSXN,                     CCC 2159
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              CCC 2160
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           CCC 2161
C                                                                       CCC 2162
      INTEGER SCODE, TCODE, RSTART, HCODE                               CCC 2163
      DIMENSION Z(120),Z1( 60),Z2( 60),NM( 60),NN( 60)                  CCC 2164
      EQUIVALENCE (Z1(1),NM(1),Z(1)),(Z2(1),NN(1),Z( 61))               CCC 2165
      WRITE(K2,8200)                                                    CCC 2166
8200  FORMAT('1',15X,'TEMPERTURE DATA'//15X,16('-'))                    CCC 2167
C   GAS VOLUME AND SURFACE AREA TEMPERATURES                            CCC 2168
80    CALL PZERO(Z(1),120)                                              CCC 2169
      IF(TCODE.GT.0) GO TO 81                                           CCC 2170
      READ(K1,35)(Z1(N),N=1,NVOL)                                       CCC 2171
35    FORMAT(7F10.0)                                                    CCC 2172
      READ(K1,35)(Z2(N),N=1,NSURF)                                      CCC 2173
      GO TO 87                                                          CCC 2174
81    GO TO (82,86),TCODE                                               CCC 2175
82    READ(K1,35)TMIN,TMAX                                              CCC 2176
83    DO 84 N=1,NVOL                                                    CCC 2177
      Z1(N)=TMAX                                                        CCC 2178
84    CONTINUE                                                          CCC 2179
      DO 85 N=1,NSURF                                                   CCC 2180
      Z2(N)=TMIN                                                        CCC 2181
85    CONTINUE                                                          CCC 2182
      GO TO 87                                                          CCC 2183
86    CALL AFLAME (TMIN,TMAX)                                           CCC 2184
      GO TO 83                                                          CCC 2185
87    WRITE(K2,8210)(Z1(N),N=1,NVOL)                                    CCC 2186
8210  FORMAT(//20X,'GAS VOLUME TEMPERTURE,DEG F.'//(25X,6F15.0))        CCC 2187
      WRITE(K2,8220)(Z2(N),N=1,NSURF)                                   CCC 2188
8220  FORMAT(//20X,'SURFACE AREA TEMPERTURES,DEG.F. '//(25X,6F15.0))    CCC 2189
      DO 89 N=1,120                                                     CCC 2190
      IF(Z(N).EQ.0.0)GO TO 89                                           CCC 2191
      Z(N)=Z(N)+460.                                                    CCC 2192
89    CONTINUE                                                          CCC 2193
      CALL WRITE(2,'TEMG',Z1(1), 60)                                    CCC 2194
      CALL WRITE(2,'TEMS',Z2(1), 60)                                    CCC 2195
C   IF ANY VOLUME AND OR SURFACE TEMP ARE TO BE HELD CONSTANT           CCC 2196
C        THEN READ IN VOLUME AND OR SURFACE NUMBER                      CCC 2197
      CALL PZERO(Z(1),120)                                              CCC 2198
      IF(SCODE.EQ.0)GOTO903                                             CCC 2199
      GO TO(900,903,900),SCODE                                          CCC 2200
900   READ(K1,901)NN,(NM(N),N=1,NN)                                     CCC 2201
```

```
      901   FORMAT(I10/(7I10))                                              CCC 2202
            WRITE(K2,8230)(NN(N),N=1,NM)                                    CCC 2203
      8230  FORMAT(//20X,'GAS VOLUME NUMBERS WHICH HAVE KNOWED TEMPERATURES ARCCC 2204
     1E AS FOLLOWS'//(25X,6I15))                                            CCC 2205
            DO 902 N=1,NM                                                   CCC 2206
            K=NN(N)                                                         CCC 2207
            MM(K)=1                                                         CCC 2208
      902   CONTINUE                                                        CCC 2209
      903   CALL WRITE(2,'CONV',MM(1), 60)                                  CCC 2210
            CALL PZERO(MM(1), 60)                                           CCC 2211
            IF(SCODE.EQ.0)GO TO 913                                         CCC 2212
            GO TO(   913,911,910),SCODE                                     CCC 2213
      910   READ(K1,901)NM,(NN(N),N=1,NM)                                   CCC 2214
            WRITE(K2,8231)(NN(N),N=1,NM)                                    CCC 2215
      8231  FORMAT(//20X,'SURFACE AREA NUMBERS WHICH HAVE KNOWN TEMPERTURES ARCCC 2216
     1E AS FOLLOWS'//(25X,6I15))                                            CCC 2217
            DO 912 N=1,NM                                                   CCC 2218
            K=NN(N)                                                         CCC 2219
            MM(K)=1                                                         CCC 2220
      912   CONTINUE                                                        CCC 2221
      913   CALL WRITE(2,'CONS',MM(1), 60)                                  CCC 2222
      C     READ IN PROCESS TEMPERATURES ASSOCIATED WITH EACH SURFACE       CCC 2223
            CALL PZERO(Z(1),120)                                            CCC 2224
            READ(K1,35)(Z(N),N=1,NSURF)                                     CCC 2225
            WRITE(K2,8240)(Z(N),N=1,NSURF)                                  CCC 2226
      8240  FORMAT(//20X,'PROCESS TEMPERTURE ASSOCIATED WITH EACH SURFACE,DEG.CCC 2227
     1F.'//(25X,6F15.0))                                                    CCC 2228
            DO 93 N=1,NSURF                                                 CCC 2229
            IF(Z(N).EQ.0.0)GO TO   93                                       CCC 2230
            Z(N)=Z(N)+460.                                                  CCC 2231
      93    CONTINUE                                                        CCC 2232
            CALL WRITE(2,'TEMP',Z(1), 60)                                   CCC 2233
      C     READ IN AMBIENT TEMPERTURES                                     CCC 2234
            READ(K1,35)TSINK                                                CCC 2235
            WRITE(K2,8250) TSINK                                            CCC 2236
      8250  FORMAT(//20X,'AMBIENT TEMPERTURE,DEG.F.',F22.0)                 CCC 2237
            TSINK=TSINK+460.                                                CCC 2238
      99    RETURN                                                          CCC 2239
            END                                                             CCC 2240
```

```
      FUNCTION H(TT,JJ)                                                 H 2241
      COMMON /ED/ A(10,5),B(12,7),D(11,7),CMW(7)                        H 2242
      H=EQUA(TT/1000.,B(1,JJ))                                          H 2243
      RETURN                                                            H 2244
      END                                                               H 2245
```

```
      SUBROUTINE DDD(JUNK,KAPUT)                                        DDD 2246
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              DDD 2247
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    DDD 2248
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       DDD 2249
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    DDD 2250
     A NGSBLK, NCSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     DDD 2251
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     DDD 2252
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              DDD 2253
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           DDD 2254
C                                                                       DDD 2255
      INTEGER SCODE,TCODE,RSTART,HCODE                                  DDD 2256
      DIMENSION Z(120),Z1(60),Z2(60),NI(60)                             DDD 2257
      DIMENSION ALPHA(60)                                               DDD 2258
      EQUIVALENCE (Z1(1),Z(1)),(Z2(1),Z(61))                            DDD 2259
      KERR=0                                                            DDD 2260
      IF(JUNK.EQ.0)GO TO 80                                             DDD 2261
      GO TO(111,90),JUNK                                                DDD 2262
   80 WRITE(K2,8300)                                                    DDD 2263
 8300 FORMAT(1H1,14X,'SURFACE AREA GAS VOLUME DATA'/15X,30('-'))        DDD 2264
C     READ IN SURFACE DATA                                              DDD 2265
      CALL PZERO(Z(1),120)                                              DDD 2266
C           EMISSIVITY                                                  DDD 2267
      READ(K1,35)(Z1(N),N=1,NSURF)                                      DDD 2268
      DO 81 J=1,NSURF                                                   DDD 2269
      IF(Z1(J).LT..0001)Z1(J)=.0001                                     DDD 2270
      IF(Z1(J).GT..9999)Z1(J)=.9999                                     DDD 2271
   81 CONTINUE                                                          DDD 2272
      CALL WRITE(1,'ESUR',Z(1), 60)                                     DDD 2273
      WRITE(K2,8310)(Z1(J),J=1,NSURF)                                   DDD 2274
 8310 FORMAT(//20X,'SURFACE EMISSIVITY  DIMENSIONLESS'//(25X,6F15.4))   DDD 2275
C     TRANSMISSIVITY( OUTSIDE SURFACES HAVE A VALUE OF ZERO             DDD 2276
      IF(NSURF.EQ.NCR)GO TO 82                                          DDD 2277
      READ(K1,35)(TAU(J),J=1,9)                                         DDD 2278
   35 FORMAT(7F10.0)                                                    DDD 2279
   82 CALL NETTAU                                                       DDD 2280
C     TEST TO SEE THAT NO SURFACE HAS ZERO OR NEGITIVE REFLECTIVITY     DDD 2281
C        1.0=EMISSIVITY+TRANSMISSIVITY+REFLECTIVITY                     DDD 2282
      CALL PZERO(NI(1), 60)                                             DDD 2283
      CALL READ(1,'TSUR',Z2(1), 60)                                     DDD 2284
      WRITE(K2,8229)(Z2(J),J=1,NSURF)                                   DDD 2285
 8229 FORMAT(//20X,'SURFACE TRANSMISSIVITY DIMENSIONLESS'//(25X,6F15.4))DDD 2286
      NN=NCR+1                                                          DDD 2287
      IF(NSURF.EQ.NCR)GO TO 832                                         DDD 2288
      DO 831 J=NN,NSURF                                                 DDD 2289
  831    ALPHA(J)=1.-Z2(J)                                              DDD 2290
  832 CONTINUE                                                          DDD 2291
      CALL WRITE(1,'ALP ',ALPHA(1), 60)                                 DDD 2292
      IF(NN.EQ.NCR+1) GO TO 850                                         DDD 2293
   830 N=0                                                              DDD 2294
      DO 83 J=1,NSURF                                                   DDD 2295
```

```
      IF(1.0-Z1(J)-Z2(J).GT.0.0)GO TO 83                                DDD 2296
      N=N+1                                                             DDD 2297
      NI(N)=J                                                           DDD 2298
   83 CONTINUE                                                          DDD 2299
      IF(N.EQ.0)GO TO 850                                               DDD 2300
      KERR=1                                                            DDD 2301
      WRITE(K2,84)(NI(J),J=1,N)                                         DDD 2302
   84 FORMAT(' SURF HAVE ZERO OR NEGITIVITY REFLECTIVITY'//(10I5))      DDD 2303
C      AREA                                                            DDD 2304
  850 CALL PZERO(Z1(1), 60)                                             DDD 2305
      NM=2*NCOL                                                         DDD 2306
      DO 85 N=1,NM                                                      DDD 2307
      Z(N)=XO                                                           DDD 2308
   85 CONTINUE                                                          DDD 2309
      NM=NM+1                                                           DDD 2310
      DO 86 N=NM,NCR                                                    DDD 2311
      Z(N)=YO                                                           DDD 2312
   86 CONTINUE                                                          DDD 2313
      IF(NXSXN.EQ.0)GO TO 88                                            DDD 2314
      YAREA=YO*2.                                                       DDD 2315
      NM=NCR+1                                                          DDD 2316
      DO 87 N=NM,NSURF                                                  DDD 2317
      Z(N)=YAREA*ALPHA(N)                                               DDD 2318
   87 CONTINUE                                                          DDD 2319
   88 CALL WRITE(1,'ASUR',Z(1), 60)                                     DDD 2320
      WRITE(K2,8330)(Z(J),J=1,NSURF)                                    DDD 2321
 8330 FORMAT(//20X,'SURFACE AREA PER FOOT OF FURNACE SQUARE FEET'//(25X,DDD 2322
     1,6F15.4))                                                         DDD 2323
C      READ IN VOLUME DATA                                             DDD 2324
   90 CALL PZERO(Z(1), 60)                                              DDD 2325
C      LUMINOSITY ( GAS VOLUME CORECTION FACTOR )                      DDD 2326
      READ(K1,35)(Z(N),N=1,NVOL)                                        DDD 2327
      CALL WRITE(1,'XLUM',Z(1), 60)                                     DDD 2328
      WRITE(K2,8340)(Z(J),J=1,LVOL)                                     DDD 2329
 8340 FORMAT(//20X,'GAS VOLUME CORRECTION FACTOR DIMENSIONLESS'//(25X,6FDDD 2330
     115.4))                                                            DDD 2331
C   HEAT TRANSFER COEFFICIENTS                                          DDD 2332
C      HC         SURFACE TO GAS                                       DDD 2333
C      HCP        SURFACE TO PROCESS FLUID                             DDD 2334
C      HCPP       SURFACE TO AMBIENT SINK                              DDD 2335
C   NOTE --- CORRECT BOTH HC AND HCP FOR TUBE-T/ -PLAIN AREA            DDD 2336
      WRITE(K2,8400)                                                    DDD 2337
 8400 FORMAT(1H1,14X,'SURFACE HEAT TRANSFER COEFFICIENTS'/15X,34('-'))  DDD 2338
      HAREA=0.0                                                         DDD 2339
      VAREA=0.0                                                         DDD 2340
C      READ IN WALL ARRANGEMENT                                        DDD 2341
      READ(K1,35)HDIA,HCLCL,HNROW                                       DDD 2342
      IF(HCLCL.EQ.0.0)GO TO 91                                          DDD 2343
      HAREA=HNROW*3.1415927*HDIA/HCLCL                                  DDD 2344
C   READ IN INTERMEDIATE WALL TUBE ARRANGEMENT                          DDD 2345
```

```
101 91    READ(K1,35)VDIA,VCLCL,VNROW                                    DDD 2346
102       IF(VCLCL.EQ.0.0)GO TO 92                                       DDD 2347
103       VAREA=VNROW*3.141592?*VDIA/VCLCL                               DDD 2348
104 92    WRITE(K2,8410)HDIA,VDIA,HCLCL,VCLCL,HNROW,VNROW,HAREA,VAREA    DDD 2349
105 8410  FORMAT(//20X,'TUBE ARRANGEMENT'/65X,'WALL1',6X,'INTERMEDIATE'/25X, DDD 2350
106      1'DIAMETER,INCHES  ',F28.4,F15.4/25X,'CL-CL DISTANCE,INCHES',F24.4,DDD 2351
107      2 F15.4/25X,'NUMBER OF ROWS',F31.4,F15.4/25X,'TUBE PLAIN AREA RATIODDD 2352
108      3',F24.4,F13.4)                                                DDD 2353
109       CALL PZERO(Z(1),120)                                           DDD 2354
110       READ(K1,35)(Z1(N),N=1,NSURF)                                   DDD 2355
111       READ(K1,35)(Z2(N),N=1,NSURF)                                   DDD 2356
112       WRITE(K2,8415)                                                 DDD 2357
113 8415  FORMAT(//20X,'SURFACE HEAT TRANSFER COEFICIENTS HAVE THE FOLLOWINGDDD 2358
114      1 UNITS --- BTU PER HOUR PER'/20X,'SQUARE FOOT OF PLAIN AREA')  DDD 2359
115 C   CONVERT WALL HEAT TRANSFER COEFFICIENTS                          DDD 2360
116       IF(HAREA.EQ.0.0) GO TO 95                                      DDD 2361
117       DO 94 N=1,NCR                                                  DDD 2362
118       Z1(N)=Z1(N)*HAREA                                              DDD 2363
119       Z2(N)=Z2(N)*HAREA                                              DDD 2364
120 94    CONTINUE                                                       DDD 2365
121 C   READ IN SURFACE DATA                                            DDD 2366
122 95    IF(NXSXH.EQ.0)GO TO 99                                         DDD 2367
123       NN=NCR+1                                                       DDD 2368
124       DO 98 N=NN,NSURF                                               DDD 2369
125       Z1(N)=Z1(N)*VAREA                                              DDD 2370
126       Z2(N)=Z2(N)*VAREA                                              DDD 2371
127 98    CONTINUE                                                       DDD 2372
128 99    CALL WRITE(2,'HC  ',Z1(1), 60)                                 DDD 2373
129       CALL WRITE(2,'HCP ',Z2(1), 60)                                 DDD 2374
130       WRITE(K2,8420)(Z1(N),N=1,NSURF)                                DDD 2375
131       WRITE(K2,8430)(Z2(N),N=1,NSURF)                                DDD 2376
132 8420  FORMAT(//20X,' CORECTED COEFFICIENTS SURFACE TO GAS'//(25X,6F15.4)DDD 2377
133      1)                                                              DDD 2378
134 8430  FORMAT(//20X,'CORRECTED COEFFICIENT,SURFACE TO PROCESS FLUID'//(25DDD 2379
135      1X,6F15.4))                                                     DDD 2380
136 100   CALL PZERO(Z(1),120)                                           DDD 2381
137       READ(K1,35)(Z(N),N=1,NCR)                                      DDD 2382
138       CALL WRITE(2,'HCPP',Z1(1), 60)                                 DDD 2383
139       WRITE(K2,8440)(Z(N),N=1,NCR)                                   DDD 2384
140 8440  FORMAT(//23X,'COEFFICIENT SURFACE TO ABIENT'//(25X,6F15.4))    DDD 2385
141 110   IF(KERR.NE.0)KAPUT=KERR                                        DDD 2386
142 111   RETURN                                                         DDD 2387
143       END                                                            DDD 2388
```

```
      SUBROUTINE EEE                                                    EEE 2389
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              EEE 2390
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    EEE 2391
     A TBRIDG, PRES, FLUET, FLUE(5), XXXX, TSINK,                       EEE 2392
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    EEE 2393
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     EEE 2394
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     EEE 2395
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              EEE 2396
     A K1, K2, RCRB(10), TDEP(100), PEAK(200)                           EEE 2397
      INTEGER SCODE,TCODE,ESTART,HCODE                                  EEE 2398
      REAL T(10),A(10),TT(10)                                           EEE 2399
      REAL*4 LOG                                                        EEE 2400
      DATA T/500.,1000.,1500.,2000.,2500.,3000.,3500.,4000.,4500.,5000./EEE 2401
      PCO2=FLUE(1)*PRES                                                 EEE 2402
      PH2O=FLUE(2)*PRES                                                 EEE 2403
      PSO2=FLUE(3)*PRES                                                 EEE 2404
C     CHARACTERIZED REAL GAS BY                                         EEE 2405
C          1 == CLEAR GAS                                               EEE 2406
C          3 -- GRAY GAS MAXIUM (PRESENT LOGIC VALID FOR 1 GRAY GAS)    EEE 2407
C     COMPUTE ABSORPTION COEFFICIENT FOR THE SINGLE GRAY GAS            EEE 2408
      EE1=EMIS(PCO2,PH2O,PSO2,PRES,TBRIDG,XLX)                          EEE 2409
      EE2=EMIS(PCO2,PH2O,PSO2,PRES,TBRIDG,2.*XLX)                       EEE 2410
      XK(1)=LOG(ABS(EE1/(EE2-EE1)))/XLX                                 EEE 2411
    6 DO 10 J=1,10                                                      EEE 2412
      E1=EMIS(PCO2,PH2O,PSO2,PRES,T(J),XLX)                             EEE 2413
      E2=EMIS(PCO2,PH2O,PSO2,PRES,T(J),2.*XLX)                          EEE 2414
    9 A(J)=E1**2/(2.*E1-E2)                                             EEE 2415
   10 CONTINUE                                                          EEE 2416
      DO 15 J=1,10                                                      EEE 2417
      TT(J)=T(J)/1000.                                                  EEE 2418
   15 CONTINUE                                                          EEE 2419
      SEA=FITIT(TT,A,10,6,ACOEF(1,1),2,1.)                              EEE 2420
      TBR=TBRIDG-460.0                                                  EEE 2421
      WRITE(K2,8600)NGRAY,XLX,(J,XK(J),J=1,3),PRES,TBR,(J,A(J),T(J),J=1,EEE 2422
     110)                                                               EEE 2423
 8600 FORMAT(1H1,14X,'CHARACTERIZATION OF FLUE GAS'//15X,28(1H-)///20X,'EEE 2424
     1NUMBER OF GRAY GASES',I20/20X,'MEAN BEAN LENGTH ,FEET',F26.2//20X,EEE 2425
     2 'ABSORPTIVITY OF GRAY GAS,RECIPROCAL FEET',3(/I53,F15.7)///20X,'PREEEE 2426
     3SSURE ATM.',F32.4//20X,'BRIDGE WALL TEMPERATURE,DEG F',F17.2//20XEEE 2427
     4,'DATA TO CORRELATE ABSORPTIVITY WITH TEMPERATURE'/ 46X,'EACTOR,',EEE 2428
     59X,'DEG. R.',10(/I38,F15.7,F15.1))                                EEE 2429
   20 RETURN                                                            EEE 2430
      END                                                               EEE 2431
```

```
      FUNCTION CP ( TT )                                                CP  2432
C                                                                       CP  2433
C     FUNCTION COMPUTES SPECIFIC HEAT OF FLUE GAS                       CP  2434
      COMMON /CPUV/ CPCP(11), UVHV(12)                                  CP  2435
C                                                                       CP  2436
      CP = EQUA ( TT/1000.0, CPCP )                                     CP  2437
C                                                                       CP  2438
      RETURN                                                            CP  2439
      END                                                               CP  2440
```

```
      1         FUNCTION CZZ(TT,JJ)                                          CZZ 2441
      2         COMMON /ED/ A(10,5),B(12,7), D(11,7),CHW(7)                  CZZ 2442
      3         DATA NTIME /0/                                               CZZ 2443
      4         IF(NTIME.NE.0)GO TO 20                                       CZZ 2444
      5         DO 9 J=1,7                                                   CZZ 2445
      6         D(1,J)=3.                                                    CZZ 2446
      7         DO 8 K=3,12                                                  CZZ 2447
      8         D(K-1,J)=FLOAT(K-2)*B(K,J)/1000.                             CZZ 2448
      9 8       CONTINUE                                                     CZZ 2449
     10 9       CONTINUE                                                     CZZ 2450
     11         NTIME=1                                                      CZZ 2451
     12 20      CZZ=EQUA(TT/1000.,D(1,JJ))                                   CZZ 2452
     13 99      RETURN                                                       CZZ 2453
     14         END                                                          CZZ 2454
```

```
      SUBROUTINE AFLAME(TMIN,TMAX)                                      AFLA2455
C                                                                       AFLA2456
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              AFLA2457
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    AFLA2458
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       AFLA2459
     A HCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    AFLA2460
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     AFLA2461
     A XSURFX(9), XO, YO, ZLENG, NCOL, NROW, NXSXN,                     AFLA2462
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              AFLA2463
     A K1, K2, RCRD(10), TDEP(100), PDEN(200)                           AFLA2464
C                                                                       AFLA2465
      INTEGER SCODE, TCODE, RSTART, HCODE                               AFLA2466
      COMMON /ED/ A(10, 5),B(12,7),D(11,7),CMW(7)                       AFLA2467
      REAL F(7),AM(6,6),AV(6),AA(6,7)                                   AFLA2468
      REAL*4 LOG                                                        AFLA2469
      EQUIVALENCE (AM(1,1),AA(1,1)),(AV(1),AA(1,7))                     AFLA2470
C     CONSTANTS NEEDED FOR DERIVATIES                                   AFLA2471
      ZKP1(T)=EXP(A1/T+B1)                                              AFLA2472
      PKP1(T)=-ZKP1(T)*A1/T**2                                          AFLA2473
C     EQUILIBRIUM CONSTANT AND PARTIAL DERIVATIVE FOR CO2,H2O,CO, AND O2 AFLA2474
C     FOR H2O,H2,AND O2                                                 AFLA2475
      ZKP2(T)=EXP(A2/T+B2)                                              AFLA2476
      PKP2(T)=-ZKP2(T)*A2/T**2                                          AFLA2477
      DEN=1./2500.-1./5500.                                             AFLA2478
      A1=(LOG(2.77E6)-LOG(17.8))/DEN                                    AFLA2479
      B1=LOG(2.77E6)-A1/2500.                                           AFLA2480
      A2=(LOG(1.26E6)-LOG(2.32))/DEN                                    AFLA2481
      B2=LOG(1.26E6)-A2/2500.                                           AFLA2482
C     MOLES OF FLUE GAS                                                 AFLA2483
C       F(1)   CO2                                                      AFLA2484
C       F(2)=  H2O                                                      AFLA2485
C       F(3)   SO2 = CONSTANT                                           AFLA2486
C       F(4)   N2                                                       AFLA2487
C       F(5)   O2 = CONSTANT                                            AFLA2488
C       F(6)   CO                                                       AFLA2489
C       F(7)   H2                                                       AFLA2490
      DO 13 J=1,5                                                       AFLA2491
      F(J)= FLUE(J)*FLUET                                               AFLA2492
   13 CONTINUE                                                          AFLA2493
      F(6)=0.0                                                          AFLA2494
      F(7)=0.0                                                          AFLA2495
C       CONSTANT                                                        AFLA2496
C       1. TOTAL MASS                                                   AFLA2497
C       2. CARBON ATOMS                                                 AFLA2498
C       3. HYDROGEN ATOMS                                               AFLA2499
      CONWT=0.0                                                         AFLA2500
      DO 14 J=1,7                                                       AFLA2501
      CONWT=CONWT+F(J)*CMW(J)                                           AFLA2502
   14 CONTINUE                                                          AFLA2503
      CARBON=F(1)+F(7)                                                  AFLA2504
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      HYDRO=F(2)+F(7)                                                    AFLA2505
      Q=HDUTY*1.E6/ZLOWC                                                 AFLA2506
C      INITIAL GUESSES OF GAS AND TEMPERATURE                            AFLA2507
      NTRY=0                                                             AFLA2508
      CO2=0.25*F(1)                                                      AFLA2509
      H2O=0.05*F(2)                                                      AFLA2510
      F(1)=F(1)-CO2                                                      AFLA2511
      F(2)=F(2)-H2O                                                      AFLA2512
      F(4)=F(4)+.5*(CO2+H2O)                                             AFLA2513
      F(6)=CO2                                                           AFLA2514
      F(7)=H2O                                                           AFLA2515
      T=5500.                                                            AFLA2516
C  CALCULATE FROM LAST ITERATION TOTAL NUMBER OF MOLES PRESENT            AFLA2517
20    TOTAL=0.0                                                          AFLA2518
      DO 22 J=1,7                                                        AFLA2519
      TOTAL=TOTAL+F(J)                                                   AFLA2520
22    CONTINUE                                                           AFLA2521
C     CALCULATE MOLES OF H2 AND CO KNOWING H2O,CO2,AND O2                AFLA2522
C      PLUS THE APPROPATE EQUILIBRIUM CONSTANTS                          AFLA2523
      F(7)=F(2)/(ZKP1(T)*SQRT(F(4)/TOTAL))                               AFLA2524
      F(6)=F(1)/(ZKP2(T)*SQRT(F(4)/TOTAL))                               AFLA2525
      CALL PZERO(AA(1,1),42)                                             AFLA2526
C  SET UP MATRIX                                                         AFLA2527
C      ROW 1                                                             AFLA2528
      AM(1,1)=CMW(1)                                                     AFLA2529
      AM(1,2)=CMW(2)                                                     AFLA2530
      AM(1,3)=CMW(4)                                                     AFLA2531
      AM(1,4)=CMW(6)                                                     AFLA2532
      AM(1,7)=CMW(7)                                                     AFLA2533
C      ROW 2                                                             AFLA2534
      SQT=SQRT(TOTAL)                                                    AFLA2535
      CON=F(1)/(2.*SQT)                                                  AFLA2536
      AM(2,1)=-SQT-CON                                                   AFLA2537
      AM(2,2)=-CON                                                       AFLA2538
      AM(2,3)=F(6)/2.*ZKP1(T)/SQRT(F(4))-CON                             AFLA2539
      AM(2,4)=SQRT(F(4))*ZKP1(T)-CON                                     AFLA2540
      AM(2,5)=-CON                                                       AFLA2541
      AM(2,6)=F(6)*SQRT(F(4))*DKP1(T)                                    AFLA2542
C      ROW 3                                                             AFLA2543
      CON=F(2)/(2.*SQT)                                                  AFLA2544
      AM(3,1)=-CON                                                       AFLA2545
      AM(3,2)=-SQT-CON                                                   AFLA2546
      AM(3,3)=F(7)/2.*ZKP2(T)/SQRT(F(4))-CON                             AFLA2547
      AM(3,4)=-CON                                                       AFLA2548
      AM(3,5)=SQRT(F(4))*ZKP2(T)-CON                                     AFLA2549
      AM(3,6)=F(7)*SQRT(F(4))*DKP2(T)                                    AFLA2550
C      ROW 4                                                             AFLA2551
      AM(4,1)=H(T,1)-H(FTEMP,1)                                          AFLA2552
      AM(4,2)=H(T,2)-H(FTEMP,2)                                          AFLA2553
      AM(4,3)=H(T,4)-H(FTEMP,4)                                          AFLA2554
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      AM(4,4)=H(T,6)-H(FTEMP,6)                                          AFLA2555
      AM(4,5)=H(T,7)-H(FTEMP,7)                                          AFLA2556
      DO 26 J=1,7                                                        AFLA2557
      AM(4,6)=AM(4,6)+F(J)*CZZ(T,J)                                      AFLA2558
   26 CONTINUE                                                           AFLA2559
C      ROW 5                                                            AFLA2560
      AM(5,1)=1.                                                         AFLA2561
      AM(5,4)=1.                                                         AFLA2562
C      ROW 6                                                            AFLA2563
      AM(6,2)=1.                                                         AFLA2564
      AM(6,4)=1.                                                         AFLA2565
C      SET UP VECTORS                                                   AFLA2566
      AV(1)=CONWT-F(1)*CMW(1)-F(2)*CMW(2)-F(4)*CMW(4)-F(6)*CMW(6)-F(7)*CAFLA2567
     1MW(7)                                                              AFLA2568
      AV(2)=-F(6)*SQRT(F(4))*ZKP1(T)+F(1)*SQT                            AFLA2569
      AV(3)=-F(7)*SQRT(F(4))*ZKP2(T)+F(2)*SQT                            AFLA2570
      AV(4)=0                                                            AFLA2571
      DO 29 J=1,7                                                        AFLA2572
      AV(4)=AV(4)+F(J)*(H(FTEMP,J)-H(T,J))                               AFLA2573
   29 CONTINUE                                                           AFLA2574
      AV(5)=-F(1)-F(6)+CARBON                                            AFLA2575
      AV(6)=-F(2)-F(6)+HYDRO                                             AFLA2576
C      SOLVE LINEARIZED SYSTEM                                          AFLA2577
      DO 34 J=1,6                                                        AFLA2578
      SUM=0.                                                             AFLA2579
      DO 32 K=1,6                                                        AFLA2580
      SUM=SUM+AM(J,K)                                                    AFLA2581
   32 CONTINUE                                                           AFLA2582
      DO 33 K=1,6                                                        AFLA2583
      AM(J,K)=AM(J,K)/SUM                                                AFLA2584
   33 CONTINUE                                                           AFLA2585
      AV(J)=AV(J)/SUM                                                    AFLA2586
   34 CONTINUE                                                           AFLA2587
      CALL ISIME3(AA,6,7,6)                                              AFLA2588
   35 DF1=AV(1)                                                          AFLA2589
      DF2=AV(2)                                                          AFLA2590
      DF3=AV(3)                                                          AFLA2591
      DF4=AV(4)                                                          AFLA2592
      DF5=AV(5)                                                          AFLA2593
      DT=AV(6)                                                           AFLA2594
C      TEST FOR CONVERGENCE                                             AFLA2595
      CON=.001                                                           AFLA2596
      IF(ABS(DF1).LT.CON*F(1).AND.ABS(DF2).LT.CON*F(2).AND.              AFLA2597
     1   ABS(DF4).LT.CON*F(4).AND.ABS(DF6).LT.CON*F(6).AND.              AFLA2598
     2   ABS(DF7).LT.CON*F(7).AND.ABS(DT).LT.1.)GO TO 50                 AFLA2599
C      TEST FOR NEGITIVE OR ZERO NOTIES                                 AFLA2600
   40 IF(F(1)+DF1.GT. 0..AND.F(2)+DF2.GT.0. .AND.F4+DF4.GT. 0. .AND.F(6)AFLA2601
     1+DF6.GT.0.0.AND.F(7)+DF7.GT.0.0)GO TO 50                           AFLA2602
      DF1=DF1/2.                                                         AFLA2603
      DF2=DF2/2.                                                         AFLA2604
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      DF4=DF4/2.                                                        AFLA2605
      DF6=DF6/2.                                                        AFLA2606
      DF7=DF4                                                           AFLA2607
      GO TO 40                                                          AFLA2608
C      LIMIT MAXIMUN CORRECTION TO 10 PERCENT OF RATE                   AFLA2609
C          AND 100 DEGER FOR TEMPERTURE                                 AFLA2610
50    DF1=SIGN(AMIN1(ABS(DF1),0.1*F(1)),DF1)                            AFLA2611
      DF2=SIGN(AMIN1(ABS(DF2),0.1*F(2)),DF2)                            AFLA2612
      DF4=SIGN(AMIN1(ABS(DF4),0.1*F(4)),DF4)                            AFLA2613
      DF6=SIGN(AMIN1(ABS(DF6),0.1*F(6)),DF6)                            AFLA2614
      DF7=SIGN(AMIN1(ABS(DF7),0.1*F(7)),DF7)                            AFLA2615
      DT=SIGN(AMIN1(ABS(DT),100.),DT)                                   AFLA2616
      NTRY=NTRY+1                                                       AFLA2617
      F(1)=F(1)+DF1                                                     AFLA2618
      F(2)=F(2)+DF2                                                     AFLA2619
      F(4)=F(4)+DF4                                                     AFLA2620
      F(6)=F(6)+DF6                                                     AFLA2621
      F(7)=F(7)+DF7                                                     AFLA2622
      T=T+DT                                                            AFLA2623
      IF(NTRY.LT.100)GO TO 20                                           AFLA2624
60    TMIN=0.75*T-460.                                                  AFLA2625
      RETURN                                                            AFLA2626
      END                                                               AFLA2627
```

```
      FUNCTION EMIS(PPCO2,PPH2O,PPSO2,PPRES,TEMP,XXLXX)                 EMIS2628
      DIMENSION PC(7),TC(7),PH(15),PS(4),TS(4),EZ(3),TO(3),CCOF(6),HCOF(EMIS2629
     18),SCOF(8),DCOF(8),TH(15)                                         EMIS2630
      REAL*4 LOG                                                        EMIS2631
      DATA PC/.001,.002,.003,.004,.005,.006,.0063/,TC/2350.,3400.,3950.,EMIS2632
     14300.,4600.,4875.,5000./,PH/.005,.007,.010,.012,.015,.020,.025,.03EMIS2633
     20,.035,.040,.050,.060,.070,.08,.085/,TH/1480.,1795.,2150.,2330.,25EMIS2634
     340.,2840.,2160.,3400.,3590.,3760.,4100.,4375.,4625.,4830.,5000./, EMIS2635
     4PS/.002,.004,.006,.0075/,TS/1450.,2400.,3050.,3500./,TO/720.,1460.EMIS2636
     5,2160./,LTIME/0/                                                  EMIS2637
      IF(NTIME.NE.0)GO TO 10                                            EMIS2638
      DO 1 J=1,7                                                        EMIS2639
      TC(J)=TC(J)/1000.                                                 EMIS2640
    1 CONTINUE                                                          EMIS2641
      S1=FITIT(TC,PC,7,6,CCOF,2,1.0)                                    EMIS2642
      DO 2 J=1,15                                                       EMIS2643
      TH(J)=TH(J)/1000.                                                 EMIS2644
    2 CONTINUE                                                          EMIS2645
      S2=FITIT(TH,PH,15,6,HCOF,2,1.)                                    EMIS2646
      DO 3 J=1,4                                                        EMIS2647
      TS(J)=TS(J)/1000.                                                 EMIS2648
    3 CONTINUE                                                          EMIS2649
      S3=FITIT(TS,PS,4,3,SCOF,2,1.)                                     EMIS2650
      DO 8 J=1,3                                                        EMIS2651
      TO(J)=TO(J)/1000.                                                 EMIS2652
    8 CONTINUE                                                          EMIS2653
      NTIME=1                                                           EMIS2654
C                                                                       EMIS2655
   10 PCO2=PPCO2                                                        EMIS2656
      PH2O=PPH2O                                                        EMIS2657
      PSO2=PPSO2                                                        EMIS2658
      PRES=PPRES                                                        EMIS2659
      TT=TEMP                                                           EMIS2660
      XX=XXLXX                                                          EMIS2661
C   CO2 EMMISSIVITY                                                     EMIS2662
   20 T=AMAX1(500.,TT)                                                  EMIS2663
      T=AMIN1(5000.,T )                                                 EMIS2664
      IF(T.GE.2350.)GO TO 21                                            EMIS2665
      PMIN=.001                                                         EMIS2666
      GO TO 22                                                          EMIS2667
   21 PMIN=EXP(EQUA(T/1000.,CCOF))                                      EMIS2668
   22 PCL=AMAX1(PCO2*XX,PMIN)                                           EMIS2669
      PCL=AMIN1(PCL,5.0)                                                EMIS2670
      A=T/1000.                                                         EMIS2671
      B=PCL                                                             EMIS2672
      C=LOG(PCL)                                                        EMIS2673
      D=A*B                                                             EMIS2674
      E=A*C                                                             EMIS2675
      F=A/B                                                             EMIS2676
      G=B/A                                                             EMIS2677
```

```
      IF(T.GT.2000.)GO TO 23                                            EMIS2678
      ECO2=-.1321461E+01+((-0.19470896*A+0.56891554)*A**2-.1112367E1)*AEMIS2679
     1+(.02086496*B+0.36506376)*B+((.68352178E-4*C**3-.018511476)*C+.26EMIS2680
     2049826 )*C+((.0012690888*D-.02881621)*D+.31656996)*D+((-.5545739E-EMIS2681
     35*E-.10411429E-3)*E**3-.05242469)*E+((.27741309E-13*F**2-.20726362EMIS2682
     4E-6)*F+.49935057E-3)*F+(-.22536606E-2*G+.076587927)*G              EMIS2683
      GO TO 24                                                          EMIS2684
   23 ECO2=-.1587369E1+((.1482632EE-3*A**2-.67238054E-2)*A-.032329011)*AEMIS2685
     1**2+(-.96049276E-3*B**2+.2629715C)*B+(.39288750E-2*C**2+.13660492)EMIS2686
     2*C+(.3639625E-3*D-.77139670E-1)*D+((.35397314E-7*E**2-.49179432E-EMIS2687
     34)*E**2+.74160975E-1)*E+((-.25856067E-16*F+.73653414E-13)*F**3    EMIS2688
     5-.45602351E-3)*F+(.22187283E-3*G**4-.28814881)*G                  EMIS2689
   24 ECO2=EXP(ECO2)                                                    EMIS2690
C  CO2 EMISSIVITY CORRECTION FACTOR                                     EMIS2691
   30 PT=AMAX1(.05,PRES)                                               EMIS2692
      PT=AMIN1(5.,PT)                                                   EMIS2693
      PCL=AMAX1(PCO2*XX,.02)                                            EMIS2694
      PCL=AMIN1(PCL,2.5)                                                EMIS2695
      A=ALOG(PT)                                                        EMIS2696
      B=A*ALOG(PCL)                                                     EMIS2697
      CCO2=(((-.86747709E-3*A-.45999058E-2)*A-.56062809E-2)*A-.6220262EEMIS2698
     1=2)*A+.1541251)*A+(((.36989449E-6*B+.64106038E-5)*B-.1301235E-3EMIS2699
     2)*B-.27531686E-3)*B-.53974179E-1)*B                               EMIS2700
      CCO2=EXP(CCO2)                                                    EMIS2701
C   H2O EMISSIVITY                                                      EMIS2702
   40 T=AMAX1(500.,TT)                                                  EMIS2703
      T=AMIN1(5000.,T)                                                  EMIS2704
      IF(T.GE.1430.)GO TO 41                                            EMIS2705
      PMIN=.005                                                         EMIS2706
      GO TO 42                                                          EMIS2707
   41 PMIN=EXP(EQUA(T/1000.,HCOF))                                      EMIS2708
   42 PWL=AMAX1(EH2O*XX,PMIN)                                           EMIS2709
      PWL=AMIN1(PWL,20.)                                                EMIS2710
      A=T/1000.                                                         EMIS2711
      B=PWL                                                             EMIS2712
      C=ALOG(B)                                                         EMIS2713
      D=A*B                                                             EMIS2714
      E=A*C                                                             EMIS2715
      F=A/B                                                             EMIS2716
      G=E/A                                                             EMIS2717
      EH2O=-.92160574+((.36785012E-4*A**3-0.16945229E-1)*A-.2830788)*A- EMIS2718
     1.1787129E-3*B**2+(((.1426699E-3*C+.1324707E-2)*C+.6148015E-3)*CEMIS2719
     2-.36606564E-1)*C+.31305419)*C+(.46970019E-8*D**2-.9862886IE-3)*D+ EMIS2720
     3((.40-22711E-5*E**2-.24520978E-2)*E+.6456909E-1)*E+(((.49852337E-1EMIS2721
     42*F**2-.14865877E-6)*F+.49533045E-4)*F-.7292208E-2)*F+(.12739632E-EMIS2722
     58*G**4-.57217605E-2)*G                                            EMIS2723
      EH2O=EXP(EH2O)                                                    EMIS2724
C      H2O CORRECTION FACTOR                                            EMIS2725
   50 PP=AMAX1((PH2O+PRES)/2.,0.0)                                      EMIS2726
      PP=AMIN1(PP,1.2)                                                  EMIS2727
```

```
      PWL=AMAX1(PH2O*XX,.05)                                            EMIS2728
      PWL=AMIN1(PWL,10.)                                                EMIS2729
      A=PP-.5                                                           EMIS2730
      B=PP*LOG(PWL)                                                     EMIS2731
      CH2O=((((-.2029815E-1*A+.25004224)*A-.12401985)*A-.5385303)*A+1.06EMIS2732
     1228883)*A+(((((-.72108284E-2*B-.87216391E-2)*B+.39616676E-1)*B+.84532EMIS2733
     2464E-2)*B-.19942644)*B+1.0                                        EMIS2734
C     CO2 AND H2O CORRECTION FACTOR                                     EMIS2735
   60 EZ(1)=0.0                                                         EMIS2736
      EZ(2)=0.0                                                         EMIS2737
      EZ(3)=0.0                                                         EMIS2738
      PP=AMAX1(PH2O/(PCO2+PH2O),0.0)                                    EMIS2739
      PP=AMIN1(PP,1.0)                                                  EMIS2740
      PL=AMAX1((PCO2+PH2O)*XX,.2)                                       EMIS2741
      PL=AMIN1(PL,5.0)                                                  EMIS2742
      KODE=0                                                            EMIS2743
      IF(TT.LE.720.)KODE=1                                              EMIS2744
      IF(TT.GE.2160.)KODE=3                                             EMIS2745
      IF(TT.EQ.1460.0)KODE=4                                            EMIS2746
      IF(KODE.EQ.0)KODE=2                                               EMIS2747
      A=PP                                                              EMIS2748
      B=LOG(PL)                                                         EMIS2749
      C=A*B                                                             EMIS2750
      GO TO (61,61,63,62),KODE                                          EMIS2751
   61 EZ(1)=-.67495633E-2+((-.91419565E-1*A+.60735416E-1)*A**3+.0324484BEMIS2752
     2)*A+((((.7953495E-3*B+.33302833E-3)*B-.7928822E-4)*B-.3966270E-2)*AEMIS2753
     3B+.011549225)*B+((((-.38471551E-2*C-.44283372E-2)*C+.59025659E-2)*AEMIS2754
     4C+.01778374)*C-.37869872E-2)*C                                    EMIS2755
      EZ(1)=AMAX1(EZ(1),0.0)                                            EMIS2756
      GO TO (65,62),KODE                                                EMIS2757
   62 EZ(2)=-.51425029E-3+((-0.30954913E-1*A**3-.27576063E-1)*A         EMIS2758
     1+.52277457E-1)*A+((((.82787757E-3*B-.80104563E-4)*B-.26232567E-2)*AEMIS2759
     28+.72816575E-3)*B+.63547973E-2)*B+((((-.69847306E-3*C+.16586398E-2EMIS2760
     3)*C-.41582562E-2)*C-.20869105E-2)*C+.13114829E-1)*C               EMIS2761
      EZ(2)=AMAX1(EZ(2),0.0)                                            EMIS2762
      IF(KODE.EQ.4)GO TO 67                                             EMIS2763
   63 EZ(3)=-.38985195E-2+((-.25438321E-6*A**3-.131836E-2)*A+.15184442E-EMIS2764
     1)*A+((((.3039264E-3*B-.13022385E-3)*B-.23495424E-2)*B-.1333573E-EMIS2765
     22)*B+.18003497E-1)*B+((((-.64092173E-8*C+.11118057E-5)*C-.69767036EMIS2766
     3E-5)*C-.1335407E-3)*C+.12768373E-2)*C                             EMIS2767
      EZ(3)=AMAX1(EZ(3),0.0)                                            EMIS2768
      IF(KODE.EQ.2)GO TO 66                                             EMIS2769
   65 DELE=EZ(KODE)                                                     EMIS2770
      GO TO 70                                                          EMIS2771
   66 S4=FITIT(TT,EZ,3,2,DCOF,1,1,0)                                    EMIS2772
      DELE=EQUA(TT/1000.,DCOF)                                          EMIS2773
      GO TO 70                                                          EMIS2774
   67 DELE=EZ(2)                                                        EMIS2775
C     SO2 EMISSIVITY                                                    EMIS2776
   70 IF(PSO2.EQ.0.0) GO TO 75                                          EMIS2777
```

```
      T=AMAX1(TT,700.)                                                  EMIS2778
      T=AMIN1(T,3500.)                                                  EMIS2779
      IF(T.GE.1450.)GO TO 71                                            EMIS2780
      PMIN=.002                                                         EMIS2781
      GO TO 72                                                          EMIS2782
   71 PMIN=EXP(EQUA(T/1000.,SCOE))                                      EMIS2783
   72 PSL=AMAX1(PSO2*XX,PMIN)                                           EMIS2784
      PSL=AMIN1(PSL,2.0)                                                EMIS2785
      A=T/1000.                                                         EMIS2786
      B=PSL                                                             EMIS2787
      C=LOG(PSL)                                                        EMIS2788
      D=A*B                                                             EMIS2789
      E=A/B                                                             EMIS2790
      G=B/A                                                             EMIS2791
      ESO2=-.2772374E1+((.202776E-2*A**3-.3155203)*A+.10762355E+1)*A+   EMIS2792
     1(-.20794123*B+.545024E2)*B**3+((-.95999255E-4*C*#3-.17241112)*C-.5EMIS2793
     25857489)*C-.23427193*D+((.32929102E-5*E+.75033122E-4)*E**3+.281592EMIS2794
     316)*E+((.46510705E-13*E-.33743806E-10)*E**3+.19603745E-2)*E+      EMIS2795
     4(((-.16889012E-1*G**2+.51539196)*G-.16932033E1)*G+.20649587E1)*G  EMIS2796
      ESO2=EXP(ESO2)                                                    EMIS2797
      GO TO 80                                                          EMIS2798
   75 ESO2=0.0                                                          EMIS2799
   80 EMIS=ECO2*CCO2+EH2O*CH2O+ELE+ESO2                                 EMIS2800
      RETURN                                                            EMIS2801
      END                                                               EMIS2802
```

```
      SUBROUTINE NETTAU                                                 NETT2803
C     ZTAUZ == 0  NO INTERMEDIATE SURFACES EXIST     ** NET TAU =1,     NETT2804
C              1  INTERMEDIATE SURFACES EXIST  **  COMPUTE NET TAU      NETT2805
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              NETT2806
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    NETT2807
     A TBRIDG, PRES, FLUET, FLUE(5), XMMX, TSINK,                       NETT2808
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    NETT2809
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     NETT2810
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     NETT2811
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              NETT2812
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           NETT2813
C                                                                       NETT2814
      INTEGER SCODE,TCODE,RSTART,HCODE                                  NETT2815
      DIMENSION ZSS(8),ZGS(8),ZSG(8),ZGG(8),Z( 60),AA( 60, 60)          NETT2816
      INTEGER ZTAUZ                                                     NETT2817
C     NET TRANSMISSIVITY SURFACE TO SURFACE                             NETT2818
      DATA ZSS/'ZSS1','ZSS2','ZSS3','ZSS4','ZSS5','ZSS6','ZSS7','ZSS8'/ NETT2819
C     NET TRANSMISSIVITY  SURFACE TO GAS                                NETT2820
      DATA ZSG/'ZSG1','ZSG2','ZSG3','ZSG4','ZSG5','ZSG6','ZSG7','ZSG8'/ NETT2821
C     NET TRANSMISSIVITY GAS TO SURFACE                                 NETT2822
      DATA ZGS/'ZGS1','ZGS2','ZGS3','ZGS4','ZGS5','ZGS6','ZGS7','ZGS8'/ NETT2823
C     NET TRANSMISSIVITY GAS TO GAS                                     NETT2824
      DATA ZGG/'ZGG1','ZGG2','ZGG3','ZGG4','ZGG5','ZGG6','ZGG7','ZGG8'/ NETT2825
      NN=2*NCOL                                                         NETT2826
      XTEST=0.001*XO                                                    NETT2827
      HALFXO=XO/2.                                                      NETT2828
      ZTAUZ=0                                                           NETT2829
      IF(NXSXN.NE.0)ZTAUZ=1                                             NETT2830
C     COMPUTE SURFACE TRANSMISSIVITY AND STORE                          NETT2831
      IF(NXSXN.NE.0)GO TO 9                                             NETT2832
      CALL PZERO(Z(1),60)                                               NETT2833
      DO 5 J=1,NXSXN                                                    NETT2834
      MM=NCR+(J-1)*NROW                                                 NETT2835
      DO 4 K=1,NROW                                                     NETT2836
      M=MM+K                                                            NETT2837
      Z(M)=TAU(J)                                                       NETT2838
4     CONTINUE                                                          NETT2839
5     CONTINUE                                                          NETT2840
9     CALL WRITE(1,'TSUR',Z(1), 60)                                     NETT2841
C     NET TAU FOR SURFACE TO SURFACE INTERCHANGE AREA                   NETT2842
10    CALL PZERO(AA(1,1), 3600)                                         NETT2843
      IF(ZTAUZ.NE.0)GO TO 15                                            NETT2844
      DO 14 K=1,NSURF                                                   NETT2845
      DO 13 J=1,NSURF                                                   NETT2846
      AA(J,K)=1.0                                                       NETT2847
13    CONTINUE                                                          NETT2848
14    CONTINUE                                                          NETT2849
      GO TO 47                                                          NETT2850
C     COMPUTE NET TRANSMISSIVITY                                        NETT2851
C     CALULATE LOWER LEFT HALF OF MATRIX                                NETT2852
```

```
 51 15     DO 43 K=1,NSURF                                          NETT2853
 52        CALL ZONE (0,K,XE,YE)                                    NETT2854
 53        DO 42 J=K,NSURF                                          NETT2855
 54        IF(J.EQ.K)GO TO 26                                       NETT2856
 55        XXE=XE                                                   NETT2857
 56        IF(K.LE.NN)XXE=XXE+HALFXD                                NETT2858
 57        CALL ZONE(0,J,XR,YR)                                     NETT2859
 58        IF(ABS(XE-XR).LT.XTEST)GO TO 26                          NETT2860
 59        XXR=XR                                                   NETT2861
 60        IF(J.LE.NN)XXR=XXR+HALFXD                                NETT2862
 61 C   K AND J ARE BOUNDARY SURFACES                               NETT2863
 62        IF(K.LE.NCR.AND.J.LE.NCR)GO TO 25                        NETT2864
 63 C   K IS THE BOUNDARY SURFACE                                   NETT2865
 64 C   J IS AN INTERMEDIATE SURFACE                               NETT2866
 65        IF(K.GT.NCR)GO TO 18                                     NETT2867
 66        IF(XXE-XXR)17,16,16                                      NETT2868
 67 16     XXR=XXR+HALFXD                                           NETT2869
 68        GO TO 25                                                 NETT2870
 69 17     XXR=XXR-HALFXD                                           NETT2871
 70        GO TO 25                                                 NETT2872
 71 C   K IS AN INTERMEDIATE SURFACE                                NETT2873
 72 C   J IS A BOUNDARY SURFACE                                     NETT2874
 73 18     IF(J.GT.NCR)GO TO 21                                     NETT2875
 74        IF(XXR-XXE)20,19,19                                      NETT2876
 75 19     XXE=XXE+HALFXD                                           NETT2877
 76        GO TO 25                                                 NETT2878
 77 20     XXE=XXE-HALFXD                                           NETT2879
 78        GO TO 25                                                 NETT2880
 79 C   K AND J ARE INTERMEDIATE SURFACES                           NETT2881
 80 21     IF(XXR-XXE)23,22,22                                      NETT2882
 81 22     XXR=XXR-HALFXD                                           NETT2883
 82        XXE=XXE+HALFXD                                           NETT2884
 83        GO TO 25                                                 NETT2885
 84 23     XXR=XXR+HALFXD                                           NETT2886
 85        XXE=XXE-HALFXD                                           NETT2887
 86 25     T=TCALC(XXE,XXR)                                         NETT2888
 87        GO TO 40                                                 NETT2889
 88 26     T=1.                                                     NETT2890
 89 40     AA(J,K)=T                                                NETT2891
 90 42     CONTINUE                                                 NETT2892
 91 43     CONTINUE                                                 NETT2893
 92 C   GENERATE UPPER RIGTH OF MATRIX FROM LOWER LEFT              NETT2894
 93        JJ=NSURF-1                                               NETT2895
 94        DO 46 J=1,JJ                                             NETT2896
 95        KJ=J+1                                                   NETT2897
 96        DO 45 K=KJ,NSURF                                         NETT2898
 97        AA(J,K)=AA(K,J)                                          NETT2899
 98 45     CONTINUE                                                 NETT2900
 99 46     CONTINUE                                                 NETT2901
100 C   STORE RESULTS ON DISK                                       NETT2902
```

```
101 47    DO 48 J=1,NSSBLK                                          NETT2903
102       CALL WRITE(1,ZSS(J),AA(1,15*J-14), 900)                   NETT2904
103 48    CONTINUE                                                  NETT2905
104 C   NET TAU FOR SURFACE TO GAS INTERCHANE  AREA                  NETT2906
105 50    CALL PZERO(AA(1,1), 3600)                                 NETT2907
106       IF(ZTAUZ.NE.0)GO TO 55                                    NETT2908
107       DO 53 K=1,NSURF                                           NETT2909
108       DO 52 J=1,NVOL                                            NETT2910
109       AA(J,K)=1.                                                NETT2911
110 52    CONTINUE                                                  NETT2912
111 53    CONTINUE                                                  NETT2913
112       GO TO 77                                                  NETT2914
113 C   CALULATES NET TRANSMISSIVITY                                NETT2915
114 55    DO 76 K=1,NSURF                                           NETT2916
115       CALL ZONE(0,K,XE,YE)                                      NETT2917
116       DO 75 J=1,NVOL                                            NETT2918
117       XXE=XE                                                    NETT2919
118       IF(K.LE.NN)XXE=XXE+HALFXD                                 NETT2920
119       CALL ZONE(1,J,XR,YR)                                      NETT2921
120       IF(ABS(XE-XR).LT.XTEST)GO TO 63                           NETT2922
121       XXR=XR+HALFXD                                             NETT2923
122       IF(K.LE.NGR)GO TO 62                                      NETT2924
123       IF(XXR-XXE)56,57,57                                       NETT2925
124 57    XXE=XXE+HALFXD                                            NETT2926
125       GO TO 62                                                  NETT2927
126 58     XXE=XXE-HALFXD                                           NETT2928
127 62    T=TCALC(XXE,XXR)                                          NETT2929
128       GO TO 74                                                  NETT2930
129 63    T=1.0                                                     NETT2931
130 74    AA(J,K)=T                                                 NETT2932
131 75    CONTINUE                                                  NETT2933
132 76    CONTINUE                                                  NETT2934
133 C   STORE RESULTS                                               NETT2935
134 77    DO 78 J=1,NSGBLK                                          NETT2936
135       CALL WRITE(1,ZGS(J),AA(1,15*J-14), 900)                   NETT2937
136 78    CONTINUE                                                  NETT2938
137 C   NET TAU FOR GAS TO SURFACE INTERCHANGE AREA                  NETT2939
138 C   SINCE G-S = S-G ALL THAT REMAINS TO BE DONE IS TRANSPOSE MATRIX AA  NETT2940
139 60    NL=MIN0(NSURF,NVOL)                                       NETT2941
140       NN=NL-1                                                   NETT2942
141       DO 82 N=1,NN                                              NETT2943
142       LL=N+1                                                    NETT2944
143       DO 81 L=LL,NL                                             NETT2945
144       SAVE=AA(N,L)                                              NETT2946
145         AA(N,L)=AA(L,N)                                         NETT2947
146       AA(L,N)=SAVE                                              NETT2948
147 81    CONTINUE                                                  NETT2949
148 82    CONTINUE                                                  NETT2950
149       NL=NL+1                                                   NETT2951
150       IF(NSURF-NVOL)83,88,84                                    NETT2952
```

```
      C   NVOL.GT.NSURF                                                  NETT2953
   83     NSTART=NL                                                      NETT2954
          LSTART=1                                                       NETT2955
          GO TO 85                                                       NETT2956
      C   NSURF.GT.NVOL                                                  NETT2957
   84     NSTART=1                                                       NETT2958
          LSTART=NL                                                      NETT2959
   85     DO 87 N=NSTART,NVOL                                            NETT2960
          DO 86 L=LSTART,NSURF                                           NETT2961
          AA(L,N)=AA(N,L)                                                NETT2962
          AA(N,L)=0.0                                                    NETT2963
   86     CONTINUE                                                       NETT2964
   87     CONTINUE                                                       NETT2965
      C   STORE RESULTES                                                 NETT2966
   88     DO 89 J=1,NSGBLK                                               NETT2967
          CALL WRITE(1,ZSG(1,J),AA(1,15*J-14), 900)                      NETT2968
   89     CONTINUE                                                       NETT2969
      C   NET TAU FOR GAS TO GAS INTERCHANGE AREA                        NETT2970
          CALL PZERO(AA(1,1), 3600)                                      NETT2971
          IF(ZTAUZ.NE.0)GO TO 92                                         NETT2972
          DO 91 K=1,NVOL                                                 NETT2973
          DO 90 J=1,NVOL                                                 NETT2974
          AA(J,K)=1.                                                     NETT2975
   90     CONTINUE                                                       NETT2976
   91     CONTINUE                                                       NETT2977
          GO TO 113                                                      NETT2978
      C   CALCULATE NET TRANSMISSIVITY                                   NETT2979
      C       CALULATE LOWER LEFT HALF OF MATRIX                         NETT2980
   92     DO 109 K=1,NVOL                                                NETT2981
          CALL ZONE(1,K,XE,YE)                                           NETT2982
          XXE=XE+HALFX                                                   NETT2983
          DO 108 J=K,NVOL                                                NETT2984
          IF(J.EQ.K)GO TO 97                                             NETT2985
          CALL ZONE(1,J,XR,YR)                                           NETT2986
          IF(ABS(XE-XR).LT.XTEST)GO TO 97                                NETT2987
          XXR=XR+HALFX                                                   NETT2988
          T=TCALC(XXE,XXR)                                               NETT2989
          GO TO 105                                                      NETT2990
   97     T=1.                                                           NETT2991
  105     AA(J,K)=T                                                      NETT2992
  108     CONTINUE                                                       NETT2993
  109     CONTINUE                                                       NETT2994
      C   GENERATE UPPER RIGTH OF MATRIX FROM LOWER LEFT                 NETT2995
          JJ=NVOL-1                                                      NETT2996
          DO 112 J=1,JJ                                                  NETT2997
          KJ=J+1                                                         NETT2998
          DO 111 K=KJ,NVOL                                               NETT2999
          AA(J,K)=AA(K,J)                                                NETT3000
  111     CONTINUE                                                       NETT3001
  112     CONTINUE                                                       NETT3002
```

```
      C     STORE RESULTS                                              NETT3003
      DO 114 J=1,NGCBLK                                                NETT3004
      CALL WRITE(1,ZGG(J),AA(1,15*J-14), 900)                          NETT3005
  114 CONTINUE                                                         NETT3006
      RETURN                                                           NETT3007
      END                                                              NETT3008
```

```
      FUNCTION TCALC(XXE,XXR)                                          TCAL3009
      COMMON // DUMMY(3),KK, ICODE, HCODE,                             TCAL3010
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                   TCAL3011
     A TBRIDG, PRES, FLUET, FLUE(5), XNWX, TSINK,                      TCAL3012
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                   TCAL3013
     A NSSBLK, NCSBLK, NSGBLK, NCGBLK, NSURF, NVOL,                    TCAL3014
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                    TCAL3015
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                             TCAL3016
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                          TCAL3017
C                                                                      TCAL3018
      INTEGER SCODE,TCODE,RSTART,HCODE                                 TCAL3019
      REAL XDOWN(9)                                                    TCAL3020
      DATA NTIME/0/                                                    TCAL3021
      IF(NTIME.NE.0)GO TO 10                                           TCAL3022
      DO 2 L=1,NXSXN                                                   TCAL3023
      LL=NXSXN+1-L                                                     TCAL3024
      XDOWN(L)=XSURFX(LL)                                              TCAL3025
2     CONTINUE                                                         TCAL3026
      XTEST=.001*XO                                                    TCAL3027
      NTIME=1                                                          TCAL3028
10    XLT=AMIN1(XXE,XXR)                                               TCAL3029
      XRT=AMAX1(XXE,XXR)                                               TCAL3030
      IF(ABS(XXE-XXR).LT.XTEST)GO TO 40                                TCAL3031
      M1=0                                                             TCAL3032
      M2=0                                                             TCAL3033
C     COMPUTE M1                                                       TCAL3034
      DO 12 L=1,NXSXN                                                  TCAL3035
      IF(XSURFX(L).GT.XLT)GO TO 14                                     TCAL3036
12    CONTINUE                                                         TCAL3037
      GO TO 40                                                         TCAL3038
14    M1=L                                                             TCAL3039
      DO 22 L=1,NXSXN                                                  TCAL3040
      IF(XDOWN(L).LT.XRT)GO TO 24                                      TCAL3041
22    CONTINUE                                                         TCAL3042
      GO TO 40                                                         TCAL3043
24    M2 =NXSXN-L+1                                                    TCAL3044
C     COMPUTE TCALC                                                    TCAL3045
      IF(M1.GT.M2)GO TO 40                                             TCAL3046
      TCALC=1.                                                         TCAL3047
      DO 32 M=M1,M2                                                    TCAL3048
      TCALC=TCALC*TAU(M)                                               TCAL3049
32    CONTINUE                                                         TCAL3050
      GO TO 50                                                         TCAL3051
C   ALL INTERMEDIATE SURFACES ARE                                      TCAL3052
C     (1) TO LEFT OF XLT                                               TCAL3053
C     (2) TO THE RIGTH OF XRT                                          TCAL3054
40    TCALC=1.                                                         TCAL3055
50    RETURN                                                           TCAL3056
      END                                                              TCAL3057
```

```
      SUBROUTINE ZONE ( KODE, ND, XX, YY )                              ZONE3058
C                                                                       ZONE3059
C     KODE SURFACE AREA / GAS VOLUME ( 0=AREA, 1=VOLUME )               ZONE3060
C     ND NUMBER OF SURFACE OR VOLUME                                    ZONE3061
C     XX/YY COORDINATES REFERENCED TO UPPER LEFT CORNER                 ZONE3062
C                                                                       ZONE3063
C                                                                       ZONE3064
      COMMON // DUMMY(3), KK, ICODE, HCODE,                             ZONE3065
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    ZONE3066
     A TBRIDG, PRES, FLUET, FLUE(5), XNWX, TSINK,                       ZONE3067
     A NCR, HOUTV, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    ZONE3068
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     ZONE3069
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     ZONE3070
     A RSTART, ICODE, SCODE, NGRAY, JHCHC,                              ZONE3071
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           ZONE3072
C                                                                       ZONE3073
      INTEGER SCODE, TCODE, RSTART, HCODE                               ZONE3074
C                                                                       ZONE3075
C                                                                       ZONE3076
      K = 0                                                             ZONE3077
      L = ND                                                            ZONE3078
      IF ( KODE .NE. 0 ) GO TO 80                                       ZONE3079
C                                                                       ZONE3080
C     SURFACE AREA                                                      ZONE3081
      IF ( L .GT. NCOL ) GO TO 12                                       ZONE3082
C     TOP SURFACE                                                       ZONE3083
      X = XO * FLOAT ( L - 1 )                                          ZONE3084
      Y = 0.0                                                           ZONE3085
      GO TO 99                                                          ZONE3086
   12 L = L - NCOL                                                      ZONE3087
      IF ( L .GT. NCOL ) GO TO 14                                       ZONE3088
C     BOTTOM SURFACE                                                    ZONE3089
      X = XO * FLOAT ( L - 1 )                                          ZONE3090
      Y = YO * FLOAT ( NROW )                                           ZONE3091
      GO TO 99                                                          ZONE3092
   14 L = L - NCOL                                                      ZONE3093
      IF ( L .GT. NROW ) GO TO 16                                       ZONE3094
C     LEFT SIDE                                                         ZONE3095
      X = 0.0                                                           ZONE3096
      Y = YO * FLOAT ( L - 1 )                                          ZONE3097
      GO TO 99                                                          ZONE3098
   16 L = L - NROW                                                      ZONE3099
      IF ( L .GT. NROW ) GO TO 20                                       ZONE3100
C     RIGHT SIDE                                                        ZONE3101
      X = XO * FLOAT ( NCOL )                                           ZONE3102
      Y = YO * FLOAT ( L - 1 )                                          ZONE3103
      GO TO 99                                                          ZONE3104
   20 K = K + 1                                                         ZONE3105
      L = L - NROW                                                      ZONE3106
      IF ( L .GT. NROW ) GO TO 20                                       ZONE3107
```

```
      C     INTERMEDIATE SURFACES                                      ZONE3108
            X = XSURFX(K)                                              ZONE3109
            Y = YO * FLOAT ( L - 1 )                                   ZONE3110
            GO TO 99                                                   ZONE3111
      C     GAS VOLUME                                                 ZONE3112
        80  K = K + 1                                                  ZONE3113
            IF ( L .LE. NCOL ) GO TO 81                                ZONE3114
            L = L - NCOL                                               ZONE3115
            GO TO 80                                                   ZONE3116
        81  X = XO * FLOAT ( L - 1 )                                   ZONE3117
            Y = YO * FLOAT ( K - 1 )                                   ZONE3118
      C                                                                ZONE3119
        99  XX = X                                                     ZONE3120
            YY = Y                                                     ZONE3121
            RETURN                                                     ZONE3122
            END                                                        ZONE3123
```

```
      FUNCTION HV ( TT )                                              HV  3124
C                                                                     HV  3125
C     FUNCTION COMPUTES ENTHALPY OF FLUE GAS                          HV  3126
C                                                                     HV  3127
      COMMON /CPHV/ CPCP(11), HVHV(12)                                HV  3128
C                                                                     HV  3129
      HV = EQUA ( TT/1000.0, HVHV )                                   HV  3130
C                                                                     HV  3131
      RETURN                                                          HV  3132
      END                                                             HV  3133
```

```
      SUBROUTINE CL2                                                    CL2 3134
C   CORE LOAD 2                                                         CL2 3135
C                                                                       CL2 3136
C                                                                       CL2 3137
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CL2 3138
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    CL2 3139
     A TBRIDG, PFES, FLUET, FLUE(5), XMWX, TSINK,                       CL2 3140
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    CL2 3141
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CL2 3142
     A XSUREX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     CL2 3143
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              CL2 3144
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           CL2 3145
C                                                                       CL2 3146
      INTEGER SCODE, TCODE, RSTART, HCODE                               CL2 3147
      COMMON/JAZZ2/ SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),            CL2 3148
     1 ZSS(8),ZGS(8),ZSG(8),ZGG(8)                                      CL2 3149
      COMMON/SPCE2/ AA( 60, 60),BB( 60,15),CC( 60,15),ALPHA( 60)        CL2 3150
      COMMON/GAUSS/ WT(9),XY(9),ARG(9,9),NPT                            CL2 3151
      WRITE(K2,2001)                                                    CL2 3152
2001  FORMAT(//T10,'CL2 A')                                             CL2 3153
      CALL SSCALC                                                       CL2 3154
      WRITE(K2,2002)                                                    CL2 3155
2002  FORMAT(T10,'CL2 B')                                               CL2 3156
60    CALL GSCALC                                                       CL2 3157
      WRITE(K2,2003)                                                    CL2 3158
2003  FORMAT(T10,'CL2 C')                                               CL2 3159
      CALL GGCALC                                                       CL2 3160
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * CL2 3161
C   TEST OF COMPUTION OF TOTAL INERTCCANGE AREAS                        CL2 3162
C      (1)   SURFACE AS THE EMITTER                                     CL2 3163
C      (2)   VOLUMN AS THE EMITTER                                      CL2 3164
      WRITE(K2,2004)                                                    CL2 3165
2004  FORMAT(T10,'CL2 D')                                               CL2 3166
61    CALL PZERO(BB(1,1),1320)                                          CL2 3167
62    CALL READ(1,'ASUR',BB(1,5), 60)                                   CL2 3168
C   SURFACE AS THE EMITTER                                              CL2 3169
C      NSSBLK=NUMBER OF SURFACE TO SURFACE BLOCKS                       CL2 3170
C      NGSBLK=NUMBER OF SURFACE TO GAS BLOCKS                           CL2 3171
      KMAX=NGRAY+1                                                      CL2 3172
      DO 69 K=1,KMAX                                                    CL2 3173
      IF(K.EQ.KMAX)GO TO 63                                             CL2 3174
      KK=K                                                              CL2 3175
      GO TO 64                                                          CL2 3176
63    KK=4                                                              CL2 3177
64    DO 65 J=1,NSSBLK                                                  CL2 3178
      CALL READ(1,SSNM(J,KK),AA(1,15*J-14), 900)                        CL2 3179
65    CONTINUE                                                          CL2 3180
      DO 67 L=1,NSURF                                                   CL2 3181
      DO 66 N=1,NSURF                                                   CL2 3182
      BB(L,KK)=BB(L,KK)+AA(N,L)                                         CL2 3183
```

```
 51 66    CONTINUE                                                        CL2 3184
 52 67    CONTINUE                                                        CL2 3185
 53       IF(K.EQ.KMAX)GO TO 90                                           CL2 3186
 54       DO 72 J=1,NGSBLK                                                CL2 3187
 55       CALL READ(1,GSNM(J,KK),AA(1,15*J-14), 900)                      CL2 3188
 56 72    CONTINUE                                                        CL2 3189
 57       DO 74 L=1,NSURF                                                 CL2 3190
 58       DO 73 N=1,NVOL                                                  CL2 3191
 59       BB(L,KK)=BB(L,KK)+AA(N,L)                                       CL2 3192
 60 73    CONTINUE                                                        CL2 3193
 61 74    CONTINUE                                                        CL2 3194
 62 C      GAS AS THE EMITTER                                             CL2 3195
 63 C      NGGBLK=NUMBER OF GAS TO GAS BLOCKS                             CL2 3196
 64 C      NSGBLK=NUMBER OF GAS TO SURFACE BLOCKS                         CL2 3197
 65       KO=6+2*(KK-1)                                                   CL2 3198
 66       DO 76 J=1,NGGBLK                                                CL2 3199
 67       CALL READ(1,GGNM(J,KK),AA(1,15*J-14), 900)                      CL2 3200
 68 76    CONTINUE                                                        CL2 3201
 69       DO 79 L=1,NVOL                                                  CL2 3202
 70       DO 78 N=1,NVOL                                                  CL2 3203
 71       BB(L,KO)=BB(L,KO)+AA(N,L)                                       CL2 3204
 72 78    CONTINUE                                                        CL2 3205
 73 79    CONTINUE                                                        CL2 3206
 74       DO 81 J=1,NSGBLK                                                CL2 3207
 75       CALL READ(1,SGNM(J,KK),AA(1,15*J-14), 900)                      CL2 3208
 76 81    CONTINUE                                                        CL2 3209
 77       DO 83 L=1,NVOL                                                  CL2 3210
 78       DO 82 N=1,NSURF                                                 CL2 3211
 79       BB(L,KO)=BB(L,KO)+AA(N,L)                                       CL2 3212
 80 82    CONTINUE                                                        CL2 3213
 81 83    CONTINUE                                                        CL2 3214
 82       CON=4.*XX(KK)*XO*YO                                             CL2 3215
 83       DO 84 L=1,NVOL                                                  CL2 3216
 84       BB(L,KO+1)=CON                                                  CL2 3217
 85 84    CONTINUE                                                        CL2 3218
 86 89    CONTINUE                                                        CL2 3219
 87 90    WRITE(K2,91)                                                    CL2 3220
 88 91    FORMAT(1H1,8X,'FOR EACH CHARACTERISTIC GAS THE SUM OF ALL DIRECT INTERRCHCL2 3221
 89      1ANGE AREAS WITH THE SURFACE AREA AS THE THE EMITTER MUST EQUAL THECL2 3222
 90      2 AREA'//10X,'GRAY GAS 1',5X,'GRAY GAS 2',5X,'GRAY GAS 3',11X,'CLCL2 3223
 91      2EAR GAS',16X,'AREA')                                           CL2 3224
 92       WRITE(K2,92)(I,(BB(I,N),N=1,5),I=1,NSURF)                      CL2 3225
 93 92    FORMAT(//(I5,3F15.5,2F20.5))                                    CL2 3226
 94       WRITE(K2,93)                                                    CL2 3227
 95 93    FORMAT('1',8X,'FOR EACH CHARACTERISTIC GAS THE SUM OF ALL DIRECT INTERCHCL2 3228
 96      1ANGE AREAS WITH A GAS VOLUME AS THE EMITTER MUST EQUAL THE' /' PRODCL2 3229
 97      2UCT OF THE GAS ABSORPTION COEFFICIENT AND THE VOLUME MULTIPLIED BYCL2 3230
 98      2 A CONSTANT OF 4.C'//23X,'GRAY GAS 1',25X,'GRAY GAS 2',25X,'GRAY CL2 3231
 99      4 GAS 3,'/15X,' INTER-AREA',6X,'ABS*VOL',10X,'INTER-AREA',6X,'ABS*VCL2 3232
100      0L',10X,'INTER-AREA',6X,'ABS*VOL'//)                            CL2 3233
```

```
      WRITE(K2,94)(I,(BB(I,M),M=6,11),I=1,NVOL)                    CL2 3234
   94 FORMAT(/(I5,3(3X,2E15.5)))                                   CL2 3235
      CALL WRITE(4,'STAR',WT(1),1)                                 CL2 3236
      RETURN                                                       CL2 3237
      END                                                          CL2 3238
```

```
      FUNCTION SS(XXE,YYE,XXR,YYR,NNN,MMM)                              SS 3239
      COMMON // DUMMY(2),KK, ICODE, HCODE,                              SS 3240
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    SS 3241
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       SS 3242
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    SS 3243
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     SS 3244
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     SS 3245
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              SS 3246
     A K1, K2, RCRD(10), TOEP(100), PERM(200)                           SS 3247
C                                                                       SS 3248
      INTEGER SCODE,TCODE,RSTART,HCODE                                  SS 3249
      COMMON/GAUSS/ WT(9),XY(9),ARG(9,9),NPT                            SS 3250
      DIMENSION W(9),Z(9)                                               SS 3251
      EQUIVALENCE (XY(1),W(1),Z(1))                                     SS 3252
C      NN=1 SURFACE IS HORIZONTAL                                       SS 3253
C      NN=2  SURFACE IS VERTICAL                                        SS 3254
C      RECEIVER ORIENTATION                                             SS 3255
C      MM=1  HORIZONTAL                                                 SS 3256
C      MM=2  SURFACE IS VERTICAL                                        SS 3257
      XE=XXE                                                            SS 3258
      YE=YYE                                                            SS 3259
      XR=XXR                                                            SS 3260
      YR=YYR                                                            SS 3261
      NN=NNN                                                            SS 3262
      MM=MMM                                                            SS 3263
      IF(KK.EQ.4)GO TO 23                                               SS 3264
      ZZ=XK(KK)                                                         SS 3265
      GO TO 30                                                          SS 3266
   23 ZZ=0.0                                                            SS 3267
C      J=VARIATION ACROSS EMITTING SURFACE                              SS 3268
C      I=VARIATION ACCROSS RECEIVING SURFACE                            SS 3269
   30 CALL PZERO(ARG(1,1),81)                                           SS 3270
      XX=ABS(XR-XE)                                                     SS 3271
      YY=ABS(YR-YE)                                                     SS 3272
      GO TO(31,32),NN                                                   SS 3273
   31 GO TO (61,41),MM                                                  SS 3274
   32 GO TO(51,71),MM                                                   SS 3275
C  CASE 1 NN=1  MM=2                                                    SS 3276
C      EMITTER IS HORIZONTAL   Y CONSTANT                               SS 3277
C      RECEIVER IS VERTICAL    X CONSTANT                               SS 3278
   41 IF(XR.GT.XE)GO TO 42                                              SS 3279
      X1=XX                                                             SS 3280
      X2=XX+XO                                                          SS 3281
      GO TO 43                                                          SS 3282
   42 X1=XX-XO                                                          SS 3283
      X2=XX                                                             SS 3284
   43 IF(YR.LT.YE) GO TO 44                                             SS 3285
      Y1=YY                                                             SS 3286
      Y2=YY+YO                                                          SS 3287
      GO TO 45                                                          SS 3288
```

```
 51 44     Y1=YY-YO                                                    SS 3289
 52        Y2=YY                                                       SS 3290
 53 45     DO 47 J=1,NPT                                               SS 3291
 54        X=(X2*(1.+W(J))+X1*(1.-W(J)))/2.                            SS 3292
 55        DO 46 I=1,NPT                                               SS 3293
 56        Y=(Y2*(1.+Z(I))+Y1*(1.-Z(I)))/2.                            SS 3294
 57        U= SQRT(X**2+Y**2)                                          SS 3295
 58        ARG(I,J)=F(ZZ*U)/U**3*X*Y*(X2-X1)/2.*(Y2-Y1)/2.             SS 3296
 59 46     CONTINUE                                                    SS 3297
 60 47     CONTINUE                                                    SS 3298
 61        GO TO 85                                                    SS 3299
 62 C   CASE 2 NN=2  MM=1                                             SS 3300
 63 C      EMITTER IS VERTICAL       X CONSTANT                        SS 3301
 64 C      RECEIVER IS HORIZONTAL    Y CONSTANT                        SS 3302
 65 51     IF(XR.LT.XE)GO TO 52                                        SS 3303
 66        X1=XX                                                       SS 3304
 67        X2=XX+XO                                                    SS 3305
 68        GO TO 53                                                    SS 3306
 69 52     X1=XX-XO                                                    SS 3307
 70        X2=XX                                                       SS 3308
 71 53     IF(YR.GT.YE)GO TO 54                                        SS 3309
 72        Y1=YY                                                       SS 3310
 73        Y2=YY+YO                                                    SS 3311
 74        GO TO 55                                                    SS 3312
 75 54     Y1=YY-YO                                                    SS 3313
 76        Y2=YY                                                       SS 3314
 77 55     DO 57 J=1,NPT                                               SS 3315
 78        Y=(Y2*(1.+W(J))+Y1*(1.-W(J)))/2.                            SS 3316
 79        DO 56 I=1,NPT                                               SS 3317
 80        X=(X2*(1.+Z(I))+X1*(1.-Z(I)))/2.                            SS 3318
 81        U=SQRT(X**2+Y**2)                                           SS 3319
 82        ARG(I,J)=F(ZZ*U)/U**3*X*Y*(Y2-Y1)/2.*(X2-X1)/2.             SS 3320
 83 56     CONTINUE                                                    SS 3321
 84 57     CONTINUE                                                    SS 3322
 85        GO TO 85                                                    SS 3323
 86 C   CASE 3  NN=1  MM=1                                            SS 3324
 87 C      EMITTER IS HORIZONTAL     Y CONSTANT                        SS 3325
 88 C      RECEIVER IS HORIZONTAL    Y CONSTANT                        SS 3326
 89 61     IF(YY.EQ.0.0)GO TO 84                                       SS 3327
 90        Y=YY                                                        SS 3328
 91        X1BAR=0.0                                                   SS 3329
 92        X2BAR=XO                                                    SS 3330
 93        DO 65 J=1,NPT                                               SS 3331
 94        XBAR=(X2BAR*(1.+W(J))+X1BAR*(1.-W(J)))/2.                   SS 3332
 95        IF(XR.EQ.XE)GO TO 62                                        SS 3333
 96        X1=XX-XO+XBAR                                               SS 3334
 97        X2=X1+XO                                                    SS 3335
 98        GO TO 63                                                    SS 3336
 99 62     X1=-XBAR                                                    SS 3337
100        X2=X1+XO                                                    SS 3338
```

```
101 63    DO 64 I=1,NPT                                                  SS  3339
102       X=(X2*(1.+Z(I))+X1*(1.-Z(I)))/2.                              SS  3340
103       U=SQRT(X**2+Y**2)                                              SS  3341
104       ARG(I,J) =F(ZZ*U)/U**3*Y**2*(X2BAR-X1BAR)/2.*(X2-X1)/2.        SS  3342
105 64    CONTINUE                                                       SS  3343
106 65    CONTINUE                                                       SS  3344
107       GO TO 85                                                       SS  3345
108 C   CASE 4 NN=2  MM=2                                               SS  3346
109 C      EMITTER IS VERTICAL    X CONSTANT                            SS  3347
110 C      RECEIVER IS VERTICAL   X CONSTANT                            SS  3348
111 71    IF(XX.EQ.0.0)GO TO 84                                          SS  3349
112       X=XX                                                           SS  3350
113       Y1BAR=0.                                                       SS  3351
114       Y2BAR=YO                                                       SS  3352
115       DO 75 J=1,NPT                                                  SS  3353
116       YBAR=(Y2BAR*(1.+W(J))+Y1BAR*(1.-W(J)))/2.                      SS  3354
117       IF(YR.EQ.YE)GO TO 72                                           SS  3355
118       Y1=YY-YO+YBAR                                                  SS  3356
119       Y2=Y1+YO                                                       SS  3357
120       GO TO 73                                                       SS  3358
121 72    Y1=-YBAR                                                       SS  3359
122       Y2=Y1+YO                                                       SS  3360
123 73    DO 74 I=1,NPT                                                  SS  3361
124       Y=(Y2*(1.+Z(I))+Y1*(1.-Z(I)))/2.                               SS  3362
125       U=SQRT(X**2+Y**2)                                              SS  3363
126       ARG(I,J)=F(ZZ*U)/U**3*X**2*(Y2BAR-Y1BAR)/2.*(Y2-Y1)/2.         SS  3364
127 74    CONTINUE                                                       SS  3365
128 75    CONTINUE                                                       SS  3366
129       GO TO 85                                                       SS  3367
130 C   SURFACES ARE IN THE SAME PLANE BUT NOT ADJACENT                  SS  3368
131 84    SS=0.0                                                         SS  3369
132       GO TO 88                                                       SS  3370
133 85    SS=0.                                                          SS  3371
134       DO 87 J=1,NPT                                                  SS  3372
135       FAC=0.0                                                        SS  3373
136       DO 86 I=1,NPT                                                  SS  3374
137       FAC=FAC+WT(I)*ARG(I,J)                                         SS  3375
138 86    CONTINUE                                                       SS  3376
139       SS=SS+WT(J)*FAC                                                SS  3377
140 87    CONTINUE                                                       SS  3378
141       SS=SS/3.1415927                                                SS  3379
142 88    RETURN                                                         SS  3380
143       END                                                            SS  3381
```

```
A FORTRAN IV (VER L43) SOURCE LISTING:  F        FUNCTION        03/05/74      PAGE  0083

      1         FUNCTION F(W)                                                  F  3382
      2 C     W=ABSORTIVITY*SQRT(X*X+Y*Y)                                      F  3383
      3         WW=W                                                           F  3384
      4         IF(WW.GT.0.0) GO TO 5                                          F  3385
      5         F=1.5707928                                                    F  3386
      6         GO TO 99                                                       F  3387
      7 5       IF(WW.LE.3.9) GO TO 10                                         F  3388
      8         IF(WW.LE.7.9) GO TO 20                                         F  3389
      9         IF(WW.LE.11.9)GO TO 30                                         F  3390
     10         IF(WW.LE.15.9)GO TO 40                                         F  3391
     11         IF(WW.LE.19.9)GO TO 50                                         F  3392
     12         F=0.0                                                          F  3393
     13         GO TO 99                                                       F  3394
     14 10      V=EXP(-WW)                                                     F  3395
     15         F=((((-.55633800E-1*V**3+.24494718E+00)*V**2-.52658248)*V+.85870888F  3396
     16        1*V+.10520692E+1)*V-.2878833E-02                                F  3397
     17         GO TO 99                                                       F  3398
     18 20      V=EXP(-WW/2.0)                                                 F  3399
     19         F=(((((.1056065E+07*V**5-.61555166E+03)*V**2+.11892488E3)*V    F  3400
     20        1+.82146 1E+02)*V-.26387279E 0)*V+.10988744E-2)*1.0E-2          F  3401
     21         GO TO 99                                                       F  3402
     22 30      V=EXP(-WW/3.)                                                  F  3403
     23         F=(((.13272233E+05*V+.66956509E4)*V**2-.47270165)*V+.59591527E-2)*F  3404
     24        11.0E-4                                                         F  3405
     25         GO TO 99                                                       F  3406
     26 40      V=EXP(-WW/4.)                                                  F  3407
     27         F=((((-.86991805E+9*V**3+.20670843E+7)*V+.54843329E+6)*V**3     F  3408
     28        1-.17417612E 0)*V+.16454718E-2)*1.E-6                           F  3409
     29         GO TO 99                                                       F  3410
     30 50      V=EXP(-WW/5.)                                                  F  3411
     31         F=(((+.16617530E+9*V+.30842624E+8)*V**3                        F  3412
     32        1-.2399666E+2)*V**2+.46168566E-2)*1.E-8                         F  3413
     33 99      RETURN                                                         F  3414
     34         END                                                            F  3415
```

```
      SUBROUTINE SSCALC                                                 SSCA3416
C     COMPUTATION OF SURFACE TO SURFACE DIRECT INTERCHANGE AREA         SSCA3417
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              SSCA3418
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    SSCA3419
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       SSCA3420
     A NGR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    SSCA3421
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     SSCA3422
     A XSUREX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     SSCA3423
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              SSCA3424
     A K1, K2, RCRD(10), TDEP(100), PERM(200),NPRNT                     SSCA3425
C                                                                       SSCA3426
      INTEGER SCODE,TCODE,RSTART,HCODE                                  SSCA3427
C                                                                       SSCA3428
      COMMON/JAZZ2/ SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),            SSCA3429
     1 ZSS(8),ZGS(8),ZSG(8),ZGG(8)                                      SSCA3430
      COMMON/SPCE2/AA( 60, 60),BB( 60,15),CC( 60,15),ALPHA( 60)         SSCA3431
      CALL READ(1,'ALP ',ALPHA(1), 60)                                  SSCA3432
C   KK= GAS NUMBER                                                      SSCA3433
      CALL PZERO(BB(1,1),600)                                           SSCA3434
      KMAX=NGRAY+1                                                      SSCA3435
      DO 99 K=1,KMAX                                                    SSCA3436
      CALL PZERO(AA(1,1), 3600)                                         SSCA3437
      IF(K.EQ.KMAX)GO TO 12                                             SSCA3438
      KK=K                                                              SSCA3439
      ZZ=XK(KK)                                                         SSCA3440
      GO TO 21                                                          SSCA3441
12    KK=4                                                              SSCA3442
      ZZ=0.0                                                            SSCA3443
C   GENERATE ONLY LOWER LEFT OF SURFACE TO SURFACE MATRIX               SSCA3444
C   ORTAIN REMAINDER USEING SYMMETRY OF MATRIX                          SSCA3445
C      N=NUMBER OF EMITTING SURFACES                                    SSCA3446
C      M=NUMBER OF RECEIVING SURFACES                                   SSCA3447
21    DO 89 N=1,NSURF                                                   SSCA3448
      CALL ZONE(0,N,XE,YE)                                              SSCA3449
      NN=1                                                              SSCA3450
      IF(N.GT.2*NCOL)NN=2                                               SSCA3451
      DO 88 M=1,NSURF                                                   SSCA3452
      CALL ZONE(0,M,XR,YR)                                              SSCA3453
      MM=1                                                              SSCA3454
      IF(M.GT.2*NCOL)MM=2                                               SSCA3455
      XX=ABS(XR-XE)                                                     SSCA3456
      YY=ABS(YR-YE)                                                     SSCA3457
      GO TO (31,32),NN                                                  SSCA3458
31    GO TO (61,85),MM                                                  SSCA3459
32    GO TO(85,61),MM                                                   SSCA3460
61    IF(XX+YY.EQ.0.0)GO TO 81                                          SSCA3461
      GO TO 85                                                          SSCA3462
C   A SURFACE CANNOT VIEW ITSELF                                        SSCA3463
81    AA(M,N)=0.0                                                       SSCA3464
      GO TO 88                                                          SSCA3465
```

```
 51 85    AA(M,N)=SS(XE,YE,XR,YR,NN,MM)                                  SSCA3466
 52       IF(M.GT.NCR) AA(M,N)=AA(M,N)*ALPHA(M)                          SSCA3467
 53       IF(N.GT.NCR)AA(M,N)=AA(M,N)*ALPHA(N)                           SSCA3468
 54 88    CONTINUE                                                       SSCA3469
 55 89    CONTINUE                                                       SSCA3470
 56 C   COMPLETE UPPER RIGHT OF MATRIX                                   SSCA3471
 57 C      N ROW    L COL                                                SSCA3472
 58 90    NN=NSURF-1                                                     SSCA3473
 59       DO 94 N=1,NN                                                   SSCA3474
 60       LL=N+1                                                         SSCA3475
 61       DO 93 L=LL,NSURF                                               SSCA3476
 62       AA(N,L)=AA(L,N)                                                SSCA3477
 63 93    CONTINUE                                                       SSCA3478
 64 94    CONTINUE                                                       SSCA3479
 65       DO 945  J=1,NSSBLK                                             SSCA3480
 66       CALL READ(1,ZSS(J),CC(1,1), 900)                               SSCA3481
 67       JJ=(J-1)*15                                                    SSCA3482
 68       NLAST=15                                                       SSCA3483
 69       IF(J.EQ.NSSBLK)NLAST=NSURF-JJ                                  SSCA3484
 70       DO 943 N=1,NLAST                                               SSCA3485
 71       DO 941 N=1,NSURF                                               SSCA3486
 72       MM=JJ+N                                                        SSCA3487
 73       AA(N,MM)=AA(N,MM)*CC(N,M)                                      SSCA3488
 74       IF(AA(N,MM).LT.0.)CALL ERROR(1SSCC1,N,MM)                      SSCA3489
 75 941   CONTINUE                                                       SSCA3490
 76 943   CONTINUE                                                       SSCA3491
 77 945   CONTINUE                                                       SSCA3492
 78 C   NORMALIZED CLEAR GAS SURFACE TO SURFACE INTERCHANGE AREA         SSCA3493
 79 C   SO THAT THEY SUM TO THE AREA OF THE EMITTER                      SSCA3494
 80       IF(K.NE.KMAX)GO TO 301                                         SSCA3495
 81 95    NN=2*NCOL                                                      SSCA3496
 82       DO 209 N=1,NSURF                                               SSCA3497
 83       IF(N.GT.NN)GO TO 201                                           SSCA3498
 84       AREA=XO                                                        SSCA3499
 85       GO TO 203                                                      SSCA3500
 86 201   IF(N.GT.NCR)GO TO 202                                          SSCA3501
 87       AREA=YO                                                        SSCA3502
 88       GO TO 203                                                      SSCA3503
 89 202   AREA=YO*2.*ALPHA(N)                                            SSCA3504
 90 203   ZZ=0.0                                                         SSCA3505
 91       DO 205 M=1,NSURF                                               SSCA3506
 92       ZZ=ZZ+AA(M,N)                                                  SSCA3507
 93 205   CONTINUE                                                       SSCA3508
 94 206   ZZ=AREA/ZZ                                                     SSCA3509
 95       DO 207 M=1,NSURF                                               SSCA3510
 96       AA(M,N)=AA(M,N)*ZZ                                             SSCA3511
 97       IF(AA(M,N).LT.0.)CALL ERROR(1SSZZ1,M,N)                        SSCA3512
 98 207   CONTINUE                                                       SSCA3513
 99 209   CONTINUE                                                       SSCA3514
100       GO TO 96                                                       SSCA3515
```

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      C   COMPUTE SUM OF SURFACE TO SURFACE INTERCHANGE AREAS                SSCA3516
      C   SO THAT THEY CAN BE LATER NORMALIZED TO THE AREA OF THE EMITTER     SSCA3517
  301     DO 303 N=1,NSURF                                                   SSCA3518
          DO 302 M=1,NSURF                                                   SSCA3519
          BB(N,KK)=BB(N,KK)+AA(M,N)                                          SSCA3520
  302     CONTINUE                                                           SSCA3521
  303     CONTINUE                                                           SSCA3522
      C   WRITE DATA OUT ON DISK                                             SSCA3523
   96     DO 97 J=1,NSSBLK                                                   SSCA3524
          CALL WRITE(1,SSNM(J,KK),AA(1,15*J-14),900)                         SSCA3525
   97     CONTINUE                                                           SSCA3526
          IF(K.NE.KMAX)GO TO 99                                              SSCA3527
          IF(NPRNT.EQ.1)GO TO 99                                             SSCA3528
  400     WRITE(K2,401)KK                                                    SSCA3529
  401     FORMAT('1',19X,'SURFACE TO SURFACE DIRECT INTERCHANGE AREAS',10X,'SSCA3530
     1 K= ',I5)                                                              SSCA3531
          CALL PRINT(AA,NSURF,NSURF)                                         SSCA3532
   99     CONTINUE                                                           SSCA3533
  101     RETURN                                                             SSCA3534
          END                                                                SSCA3535
```

```
      SUBROUTINE GSCALC                                                 GSCA3536
C   COMPUTATION OF SURFACE TO VOLUME DIRECT INTERCHANGE AREA            GSCA3537
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              GSCA3538
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    GSCA3539
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       GSCA3540
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    GSCA3541
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     GSCA3542
     A XSUREX(9), XO, YO, ZLONG, NCOL, IROW, NXSXN,                     GSCA3543
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              GSCA3544
     A K1, K2, RCRD(10), TDEP(100), PERM(200),NPRNT                     GSCA3545
C                                                                       GSCA3546
      INTEGER SCODE,TCODE,RSTART,HCODE                                  GSCA3547
      COMMON/JAZZ2/ SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),            GSCA3548
     1ZSS(8),ZGS(8),ZSG(8),ZGG(8)                                       GSCA3549
      COMMON/SPCE2/ AA( 60, 60),BB( 60,15),CC( 60,15),ALPHA( 60)        GSCA3550
      XOYO=AMIN1(XO,YO)                                                 GSCA3551
      CALL READ(1,'ASUR',BB(1,5), 60)                                   GSCA3552
C   KK=GAS NUMBER                                                       GSCA3553
10    DO 1900 KK=1,NGRAY                                                GSCA3554
      CALL PZERO(AA(1,1), 3600)                                         GSCA3555
C      N=NUMBER OF EMITTING SURFACE                                     GSCA3556
C      M=NUMBER OF RECEIVING VOLUME                                     GSCA3557
      DO 1850 N=1,NSURF                                                 GSCA3558
      CALL ZONE(0,N,XE,YE)                                              GSCA3559
      DO 1840 M=1,NVOL                                                  GSCA3560
      CALL ZONE(1,M,XR,YR)                                              GSCA3561
C     WRITE(K2,16)N,XE,YE,M,XR,YR                                       GSCA3562
C16   FORMAT(//I5,2F15.5)                                               GSCA3563
      XRA=XR                                                            GSCA3564
      YRA=YR                                                            GSCA3565
      XRB=XR+XO                                                         GSCA3566
      YRB=YR                                                            GSCA3567
      XRC=XR                                                            GSCA3568
      YRC=YR+YO                                                         GSCA3569
      XRD=XR                                                            GSCA3570
      YRD=YR                                                            GSCA3571
C     WRITE(K2,25)XRA,TRA,XRB,YRB,XRC,YRC,XRD,YRD                       GSCA3572
C25   FORMAT(1X,2F15.5)                                                 GSCA3573
      IF(N.GT.2*NCOL)GO TO 37                                           GSCA3574
C   HORIZONTAL SURFACES                                                 GSCA3575
      NN=1                                                              GSCA3576
      IF(YE.GT.YR)GO TO 30                                              GSCA3577
      IF(XE-XR)100,200,300                                              GSCA3578
30    IF(XE-XR)1000,1100,1200                                           GSCA3579
C     VERTICAL SURFACES                                                 GSCA3580
37    NN=2                                                              GSCA3581
      IF(XE.GT.XR)GO TO 50                                              GSCA3582
      IF(YE-YR)400,600,800                                              GSCA3583
50    IF(YE-YR)500,700,900                                              GSCA3584
C      SURFACE AREA TO GAS VOLUME                                       GSCA3585
```

```
      C   ORIENTATION 1                                                  GSCA3586
  100     S1=1.                                                          GSCA3587
          S2=-1.                                                         GSCA3588
          S3=-1.                                                         GSCA3589
          S4=1.                                                          GSCA3590
          GO TO 1500                                                     GSCA3591
      C   ORIENTATION 2                                                  GSCA3592
  200     IF(ABS(YR-YE).EQ.0.0)GO TO 210                                 GSCA3593
          S1=1.                                                          GSCA3594
          S2=-1.                                                         GSCA3595
          S3=-1.                                                         GSCA3596
          S4=-1.                                                         GSCA3597
          GO TO 1500                                                     GSCA3598
  210     FAC=XO-SS(XE,YE,XRB,YRB,NN,2)-SS(XE,YE,XRC,YRC,NN,1)-SS(XE,YE,XRD,GSCA3599
         1YRD,NN,2)                                                      GSCA3600
          GO TO 1700                                                     GSCA3601
      C   ORIENTATION 3                                                  GSCA3602
  300     S1=1.                                                          GSCA3603
          S2=1.                                                          GSCA3604
          S3=-1.                                                         GSCA3605
          S4=-1.                                                         GSCA3606
          GO TO 1500                                                     GSCA3607
      C   ORIENTATION 4                                                  GSCA3608
  400     S1=1.                                                          GSCA3609
          S2=-1.                                                         GSCA3610
          S3=-1.                                                         GSCA3611
          S4=1.                                                          GSCA3612
          GO TO 1500                                                     GSCA3613
      C   ORIENTATION 5                                                  GSCA3614
  500     S1=1.                                                          GSCA3615
          S2=1.                                                          GSCA3616
          S3=-1.                                                         GSCA3617
          S4=-1.                                                         GSCA3618
          GO TO 1500                                                     GSCA3619
      C   ORIENTATION 6                                                  GSCA3620
  600     IF(ABS(XR-XE).EQ.0.0)GO TO 610                                 GSCA3621
          S1=-1.                                                         GSCA3622
          S2=-1.                                                         GSCA3623
          S3=-1.                                                         GSCA3624
          S4=1.                                                          GSCA3625
          GO TO 1500                                                     GSCA3626
  610     FAC=YO-SS(XE,YE,XRA,YRA,NN,1)-SS(XE,YE,XRB,YRB,NN,2)           GSCA3627
         1-SS(XE,YE,XRC,YRC,NN,1)                                        GSCA3628
          GO TO 1700                                                     GSCA3629
      C   ORIENTATION 7                                                  GSCA3630
  700     IF(ABS(ABS(XR-XE)-XO).LT.XOYO)GO TO 710                        GSCA3631
          S1=-1.                                                         GSCA3632
          S2=1.                                                          GSCA3633
          S3=-1.                                                         GSCA3634
          S4=-1.                                                         GSCA3635
```

```
      GO TO 1500                                                        GSCA3636
710   FAC=YO=SS(XE,YE,XRA,YRA,NN,1)=SS(XE,YE,XRC,YRC,NN,1)             GSCA3637
     1=SS(XE,YE,XRD,YRD,NN,2)                                           GSCA3638
      GO TO 1700                                                        GSCA3639
C     ORIENTATION 8                                                     GSCA3640
800   S1=-1.                                                            GSCA3641
      S2=-1.                                                            GSCA3642
      S3=1.                                                             GSCA3643
      S4=1.                                                             GSCA3644
      GO TO 1500                                                        GSCA3645
C     ORIENTATION 9                                                     GSCA3646
900   S1=-1.                                                            GSCA3647
      S2=1.                                                             GSCA3648
      S3=1.                                                             GSCA3649
      S4=-1.                                                            GSCA3650
      GO TO 1500                                                        GSCA3651
C     ORIENTATION 10                                                    GSCA3652
1000  S1=-1.                                                            GSCA3653
      S2=-1.                                                            GSCA3654
      S3=1.                                                             GSCA3655
      S4=1.                                                             GSCA3656
      GO TO 1500                                                        GSCA3657
C     ORIENTATION 11                                                    GSCA3658
1100  IF(ABS(ABS(YR-YE)-YO),LT,XOYO)GO TO 1110                          GSCA3659
      S1=1.                                                             GSCA3660
      S2=-1.                                                            GSCA3661
      S3=1.                                                             GSCA3662
      S4=-1.                                                            GSCA3663
      GO TO 1500                                                        GSCA3664
1110  FAC=XO=SS(XE,YE,XRA,YRA,NN,1)=SS(XE,YE,XRB,YRB,NN,2)             GSCA3665
     1=SS(XE,YE,XRD,YRD,NN,2)                                           GSCA3666
      GO TO 1700                                                        GSCA3667
C     ORIENTATION 12                                                    GSCA3668
1200  S1=-1.                                                            GSCA3669
      S2=1.                                                             GSCA3670
      S3=1.                                                             GSCA3671
      S4=-1.                                                            GSCA3672
1500  FAC=SS(XE,YE,XRA,YRA,NN,1)*S1+SS(XE,YE,XRB,YRB,NN,2)*S2          GSCA3673
     1+SS(XE,YE,XRC,YRC,NN,1)*S3+SS(XE,YE,XRD,YRD,NN,2)*S4              GSCA3674
1700  AA(N,N)=FAC                                                       GSCA3675
      IF(N.GT.NCR)AA(M,N)=FAC*ALPHA(N)                                  GSCA3676
1840  CONTINUE                                                          GSCA3677
1850  CONTINUE                                                          GSCA3678
      DO 1851 J=1,NGSBLK                                                GSCA3679
      CALL READ(1,ZGS(J),CC(1,1), 900)                                  GSCA3680
      JJ=(J-1)*15                                                       GSCA3681
      NLAST=15                                                          GSCA3682
      IF(J.EQ.NGSBLK)NLAST=NVOL-JJ                                      GSCA3683
      DO 1852 M=1,NLAST                                                 GSCA3684
      DO 1853 N=1,NVOL                                                  GSCA3685
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```
      MM=JJ+M                                                          GSCA3686
      AA(N,MM)=AA(N,MM)*CC(N,M)                                        GSCA3687
 1853 CONTINUE                                                         GSCA3688
 1852 CONTINUE                                                         GSCA3689
 1851 CONTINUE                                                         GSCA3690
C     WRITE SURFACE TO VOLUME INTERCHANGE AREA ON DISK                 GSCA3691
 1860 DO 1862  J=1,NGSBLK                                              GSCA3692
      CALL WRITE(1,GSNM(J,KK),AA(1,15*J-14), 900)                      GSCA3693
 1862 CONTINUE                                                         GSCA3694
C     COMPLATE SUM OF INTERCHANGE AREA WITH SURFACE AS EMITTER         GSCA3695
      DO 2002 I=1,NSURF                                                GSCA3696
      DO 2001 M=1,NVOL                                                 GSCA3697
      BB(N,KK)=BB(N,KK)+AA(M,N)                                        GSCA3698
 2001 CONTINUE                                                         GSCA3699
 2002 CONTINUE                                                         GSCA3700
C     NORMALIZE SURFACE TO SURFACE INTERCHANGE AREA                    GSCA3701
      DO 2011 J=1,NSSBLK                                               GSCA3702
      CALL READ(1,SSNM(J,KK),AA(1,15*J-14), 900)                       GSCA3703
 2011 CONTINUE                                                         GSCA3704
      DO 2022 N=1,NSURF                                                GSCA3705
      FAC=BB(N,5)/BB(N,KK)                                             GSCA3706
      DO 2021 M=1,NSURF                                                GSCA3707
      AA(M,N)=AA(M,N)*FAC                                              GSCA3708
 2021 CONTINUE                                                         GSCA3709
 2022 CONTINUE                                                         GSCA3710
      DO 2031 J=1,NSSBLK                                               GSCA3711
      CALL WRITE(1,SSNM(J,KK),AA(1,15*J-14), 900)                      GSCA3712
 2031 CONTINUE                                                         GSCA3713
      IF(NPRNT.EQ.1)GO TO 2040                                         GSCA3714
 4000 WRITE(K2,4001)KK                                                 GSCA3715
 4001 FORMAT(1H1,19X,'SURFACE TO SURFACE DIRECT INTERCHANGE AREA',10X,' GSCA3716
     1= ',I5)                                                          GSCA3717
      CALL PRINT(AA,NSURF,NSURF)                                       GSCA3718
C     NORMALIZE SURFACE TO VOLUME INTERCHANGE AREAS                    GSCA3719
 2040 DO 2041 J=1,NGSBLK                                               GSCA3720
      CALL READ(1,GSNM(J,KK),AA(1,15*J-14), 900)                       GSCA3721
 2041 CONTINUE                                                         GSCA3722
      DO 2052 N=1,NSURF                                                GSCA3723
      FAC=BB(N,5)/BB(N,KK)                                             GSCA3724
      DO 2051 M=1,NVOL                                                 GSCA3725
      AA(M,N)=AA(M,N)*FAC                                              GSCA3726
 2051 CONTINUE                                                         GSCA3727
 2052 CONTINUE                                                         GSCA3728
      DO 2061 J=1,NGSBLK                                               GSCA3729
      CALL WRITE(1,GSNM(J,KK),AA(1,15*J-14), 900)                      GSCA3730
 2061 CONTINUE                                                         GSCA3731
      IF(NPRNT.EQ.1)GO TO 1870                                         GSCA3732
 5000 WRITE(K2,5001)KK                                                 GSCA3733
 5001 FORMAT(1H1,19X,'SURFACE TO VOLUME DIRECT INTERCHANGE AREAS',10X,'KGSCA3734
     1= ',I5)                                                          GSCA3735
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```
      CALL PRINT(AA,NVOL,NSURF)                                          GSCA3736
C     OBTAIN VOLUME TO SURFACE DIRECT INTERCHANGE AREA                   GSCA3737
C     BY TRANSPOSING MATRIX AA(NVOL,NSURF)                               GSCA3738
C        N -- ROW DESIGNATION                                            GSCA3739
C        L -- COLUMN DESIGNATION                                         GSCA3740
C     TRANSPOSE SQUARE PART OF MATRIX                                    GSCA3741
1870  NL=MINO(NSURF,NVOL)                                                GSCA3742
      DO 1872 N=2,NL                                                     GSCA3743
      LZ=N-1                                                             GSCA3744
      DO 1871 L=1,LZ                                                     GSCA3745
      SAVE=AA(N,L)                                                       GSCA3746
      AA(N,L)=AA(L,N)                                                    GSCA3747
      AA(L,N)=SAVE                                                       GSCA3748
1871  CONTINUE                                                           GSCA3749
1872  CONTINUE                                                           GSCA3750
      NZ=NL+1                                                            GSCA3751
      IF(NVOL-NSURF)1873,1878,1874                                       GSCA3752
C     NSURF.GT.NVOL        COLUMNS.GT.ROWS                               GSCA3753
1873  NSTART=1                                                           GSCA3754
      LSTART=NZ                                                          GSCA3755
      GO TO 1875                                                         GSCA3756
C     NVOL.GT.NSURF.       ROWS.GT.COLUMNS                               GSCA3757
1874  NSTART=NZ                                                          GSCA3758
      LSTART=1                                                           GSCA3759
1875  DO 1877 N=NSTART,NVOL                                              GSCA3760
      DO 1876 L=LSTART,NSURF                                             GSCA3761
      AA(L,N)=AA(N,L)                                                    GSCA3762
      AA(N,L)=0.                                                         GSCA3763
1876  CONTINUE                                                           GSCA3764
1877  CONTINUE                                                           GSCA3765
C     WRITE VOLUME TO SURFACE INTERCHANGE AREAS ON DISK                  GSCA3766
1878  DO 1879 J=1,NSGBLK                                                 GSCA3767
      CALL WRITE(1,SGNH(J,KK),AA(1,15*J-14), 900)                        GSCA3768
1879  CONTINUE                                                           GSCA3769
      IF(NPRNT.EQ.1)GO TO 1900                                           GSCA3770
6000  WRITE(K2,6001)KK                                                   GSCA3771
6001  FORMAT(1H1,19X,'VOLUME TO SURFACE DIRECT INTERCHANGE AREA',10X,'K=GSCA3772
     1',I5)                                                              GSCA3773
      CALL PRINT(AA,NSURF,NVOL)                                          GSCA3774
1900  CONTINUE                                                           GSCA3775
      RETURN                                                             GSCA3776
      END                                                                GSCA3777
```

```
      SUBROUTINE GGCALC                                                 GGCA3778
C     COMPUTE DE VOLUME TO VOLUME DIRECT INTER CHANGE AREAS             GGCA3779
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              GGCA3780
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    GGCA3781
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       GGCA3782
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    GGCA3783
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     GGCA3784
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     GGCA3785
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              GGCA3786
     A K1, K2, RCRD(10), TDEP(100), PERM(200),NPRNT                     GGCA3787
C                                                                       GGCA3788
      INTEGER SCODE,TCODE,RSTART,HCODE                                  GGCA3789
      COMMON/JAZZ2/ SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),            GGCA3790
     1ZSS(8),ZGS(8),ZSG(8),ZGG(8)                                       GGCA3791
      COMMON/SPCE2/ AA( 60, 60),BB( 60,15),CC( 60,15),ALPHA( 60)        GGCA3792
C     KK=GAS NUMBER                                                     GGCA3793
      DO 1900 KK=1,NGRAY                                                GGCA3794
      CALL PZERO(AA(1,1), 3600)                                         GGCA3795
C     GENERATE ONLY LOWER LEFT OF VOLUME TO VOLUME MATRIX               GGCA3796
C     OBTAIN THE REST USING THE SYMMETRY FEATURE OF MATRIX              GGCA3797
C       N=NUMBER OF EMITTING VOLUMES                                    GGCA3798
C       M=NUMBER OF RECEIVING VOLUMES                                   GGCA3799
      DO 1850 N=1,NVOL                                                  GGCA3800
      CALL ZONE(1,N,XE,YE)                                              GGCA3801
      DO 1840 M=N,NVOL                                                  GGCA3802
      CALL ZONE(1,M,XR,YR)                                              GGCA3803
C     WRITE(K2,5)N,XE,YE,M,XR,YR                                        GGCA3804
C5    FORMAT(//I5,2F15.5)                                               GGCA3805
C     COORDINATES OF SURFACES MAKING UP RECEIVING VOLUME                GGCA3806
      XRA=XR                                                            GGCA3807
      YRA=YR                                                            GGCA3808
      XRB=XR+XO                                                         GGCA3809
      YRB=YR                                                            GGCA3810
      XRC=XR                                                            GGCA3811
      YRC=YR+YO                                                         GGCA3812
      XRD=XR                                                            GGCA3813
      YRD=YR                                                            GGCA3814
C     WRITE(K2,8)XRA,YRA,XRB,YRB,XRC,YRC,XRD,YRD                        GGCA3815
C8    FORMAT(1OX,2F15.5)                                                GGCA3816
      IF(YE-YR)10,20,30                                                 GGCA3817
10    IF(XE-XR)45,50,55                                                 GGCA3818
20    IF(XE-XR)80,1800,60                                               GGCA3819
30    IF(XE-XR)75,70,65                                                 GGCA3820
C     ORIENTATION 1                                                     GGCA3821
C     GAS VOLUME TO GAS VOLUME                                          GGCA3822
45    S1=1.                                                             GGCA3823
      S2=-1.                                                            GGCA3824
      S3=-1.                                                            GGCA3825
      S4=1.                                                             GGCA3826
      GO TO 1700                                                        GGCA3827
```

```
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3828
      C   ORIENTATION 2                                                   GGCA3829
   50      S1=1.                                                          GGCA3830
           S2=-1.                                                         GGCA3831
           S3=-1.                                                         GGCA3832
           S4=-1.                                                         GGCA3833
           GO TO 1700                                                     GGCA3834
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3835
      C   ORIENTATION 3                                                   GGCA3836
   55      S1=1.                                                          GGCA3837
           S2=1.                                                          GGCA3838
           S3=-1.                                                         GGCA3839
           S4=-1.                                                         GGCA3840
           GO TO 1700                                                     GGCA3841
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3842
      C   ORIENTATION 4                                                   GGCA3843
   60      S1=-1.                                                         GGCA3844
           S2=1.                                                          GGCA3845
           S3=-1.                                                         GGCA3846
           S4=-1.                                                         GGCA3847
           GO TO 1700                                                     GGCA3848
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3849
      C   ORIENTATION 5                                                   GGCA3850
   65      S1=-1.                                                         GGCA3851
           S2=1.                                                          GGCA3852
           S3=1.                                                          GGCA3853
           S4=-1.                                                         GGCA3854
           GO TO 1700                                                     GGCA3855
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3856
      C   ORIENTATION 6                                                   GGCA3857
   70      S1=-1.                                                         GGCA3858
           S2=-1.                                                         GGCA3859
           S3=+1.                                                         GGCA3860
           S4=-1.                                                         GGCA3861
           GO TO 1700                                                     GGCA3862
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3863
      C   ORIENTATION 7                                                   GGCA3864
   75      S1=-1.                                                         GGCA3865
           S2=-1.                                                         GGCA3866
           S3=1.                                                          GGCA3867
           S4=1.                                                          GGCA3868
           GO TO 1700                                                     GGCA3869
      C   GAS VOLUME TO GAS VOLUME                                        GGCA3870
      C   ORIENTATION 8                                                   GGCA3871
   80      S1=-1.                                                         GGCA3872
           S2=-1.                                                         GGCA3873
           S3=-1.                                                         GGCA3874
           S4=1.                                                          GGCA3875
 1700      AA(M,N)=SG(XE,YE,XRA,YRA,1)*S1+SG(XE,YE,XRB,YRB,2)*S2          GGCA3876
     1+SG(XE,YE,XRC,YRC,1)*S3+SG(XE,YE,XRD,YRD,2)*S4                      GGCA3877
```

```
      GO TO 1840                                                        GGCA3878
C     A VOLUME CAN SEE ITSELF , BUT WE WILL COMPUTE ITS VALUE LATER     GGCA3879
1800  AA(M,N)=0.0                                                       GGCA3880
1840  CONTINUE                                                          GGCA3881
1850  CONTINUE                                                          GGCA3882
C     COMPLETE UPPER RIGTH OF MATRIX                                    GGCA3883
C        N -- ROW    L -- COL                                          GGCA3884
1860  N1=NVOL-1                                                         GGCA3885
      DO 1880 N=1,N1                                                    GGCA3886
      L1=N+1                                                            GGCA3887
      DO 1870  L=L1,NVOL                                                GGCA3888
      AA(N,L)=AA(L,N)                                                   GGCA3889
1870  CONTINUE                                                          GGCA3890
1880  CONTINUE                                                          GGCA3891
      DO 5881 J=1,NGGBLK                                                GGCA3892
      CALL READ(1,ZGG(J),CC(1,1), 900)                                  GGCA3893
      JJ=(J-1)*15                                                       GGCA3894
      MLAST=15                                                          GGCA3895
      IF(J.EQ.NGGBLK)MLAST=NVOL-JJ                                      GGCA3896
      DO 5882 M=1,MLAST                                                 GGCA3897
      DO 5883 N=1,NVOL                                                  GGCA3898
      MM=JJ+M                                                           GGCA3899
      AA(N,MM)=AA(N,MM)*CC(N,M)                                         GGCA3900
5883  CONTINUE                                                          GGCA3901
5882  CONTINUE                                                          GGCA3902
5881  CONTINUE                                                          GGCA3903
C     COMPUTE GAS TO GAS INTERCHANGE AREA FOR VOLUME VIEWING ITSELF     GGCA3904
      MN=MAXO(NSURF,NVOL)                                               GGCA3905
      CON=4.*XK(KK)*XO*YO                                               GGCA3906
      DO 1885 J=1,NSGBLK                                                GGCA3907
      CALL READ(1,SGNN(J,KK),BB(1,1), 900)                              GGCA3908
      IF(J.EQ.NSGBLK)GO TO 1881                                         GGCA3909
      NN=15                                                             GGCA3910
      GO TO 1882                                                        GGCA3911
1881  NN=NVOL-(NSGBLK-1)*15                                             GGCA3912
1882  DO 1884 N=1,NN                                                    GGCA3913
      ZZ=0.                                                             GGCA3914
      NM=N+(J-1)*15                                                     GGCA3915
      DO 1883 M=1,MN                                                    GGCA3916
      ZZ=ZZ+AA(M,NM)*BB(M,N)                                            GGCA3917
1883  CONTINUE                                                          GGCA3918
      AA(NM,NM)=CON-ZZ                                                  GGCA3919
1884  CONTINUE                                                          GGCA3920
1885  CONTINUE                                                          GGCA3921
C     WRITE VOLUME TO VOLUME INTERCHANGE AREA ON DISK                   GGCA3922
1890  DO 1892 J=1,NGGBLK                                                GGCA3923
      CALL WRITE(1,GGNN(J,KK),AA(1,15*J-14), 900)                       GGCA3924
1892  CONTINUE                                                          GGCA3925
      IF(NPRNT.EQ.1)GO TO 1900                                          GGCA3926
5000  WRITE(K2,5001)KK                                                  GGCA3927
```

```
      5001  FORMAT(1H1,19X,'VOLUME TO VOLUME DIRECT INTERCHANGE AREA',10X,'K='GGCA3928
     1,I5)                                                              GGCA3929
            CALL PRINT(AA,NVOL,NVOL)                                    GGCA3930
      1900  CONTINUE                                                    GGCA3931
            RETURN                                                      GGCA3932
            END                                                         GGCA3933
```

```
      FUNCTION SG(XXE,YYE,XXR,YYR,NM)                                   SG 3934
C     THIS FUCTION IS USED TO CALULATE SURFACE TO VOLUME INTERCHANGE AREA SG 3935
C     THE EVALUATION IS MADE UP BY CONSIDERING THE RECEIVING (VOLUNE)TO BESG 3936
C     MADE UP OF FOUR SURFACES                                          SG 3937
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              SG 3938
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    SG 3939
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       SG 3940
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    SG 3941
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     SG 3942
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     SG 3943
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              SG 3944
C                                                                       SG 3945
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           SG 3946
      INTEGER SCODE,TCODE,RSTART,HCODE                                  SG 3947
C     INTERCHANGE ROLL OF SURFACE TO VOLUME AND USE FUCTION SS          SG 3948
C       TO OBTAIN SURFACE - VOLUME INTERCHANGE AREA CONTRIBUTION        SG 3949
      XOYO=AMIN1(XO,YO)                                                 SG 3950
      XE=XXR                                                            SG 3951
      YE=YYR                                                            SG 3952
      XR=XXE                                                            SG 3953
      YR=YYE                                                            SG 3954
      XRA=XR                                                            SG 3955
      YRA=YR                                                            SG 3956
      XRB=XR+XO                                                         SG 3957
      YRB=YR                                                            SG 3958
      XRC=XR                                                            SG 3959
      YRC=YR+YO                                                         SG 3960
      XRD=XR                                                            SG 3961
      YRD=YR                                                            SG 3962
C     SURFACE ORIENTATION                                               SG 3963
C       NM=1 HORIZONTAL SURFACE                                         SG 3964
C       NM=2   VERTICAL SURFACE                                         SG 3965
      GO TO(20,37),NM                                                   SG 3966
C     HORIZONTAL SURFACES                                               SG 3967
20    NN=1                                                              SG 3968
      IF(YE.GT.YR)GO TO 30                                              SG 3969
      IF(XE-XR)100,200,300                                              SG 3970
30    IF(XE-XR)1000,1100,1200                                           SG 3971
C     VERTICAL SURFACES                                                 SG 3972
37    NN=2                                                              SG 3973
      IF(XE.GT.XR)GO TO 50                                              SG 3974
      IF(YE-YR)400,600,800                                              SG 3975
50    IF(YE-YR)500,700,900                                              SG 3976
C                                                                       SG 3977
C     ORIENTATION 1                                                     SG 3978
100   S1=1.                                                             SG 3979
      S2=-1.                                                            SG 3980
      S3=-1.                                                            SG 3981
      S4=1.                                                             SG 3982
      GO TO 1500                                                        SG 3983
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      C   ORIENTATION 2                                                  SG  3984
  200 IF(ABS(YR-YE),EQ,0,0)GO TO 210                                     SG  3985
      S1=1.                                                              SG  3986
      S2=-1.                                                             SG  3987
      S3=-1.                                                             SG  3988
      S4=-1.                                                             SG  3989
      GO TO 1500                                                         SG  3990
  210 FAC=XO-SS(XE,YE,XRB,YRB,NN,2)-SS(XE,YE,XRC,YRC,NN,1)-SS(XE,YE,XRD,SG  3991
     1YRD,NN,2)                                                          SG  3992
      GO TO 1700                                                         SG  3993
      C   ORIENTATION 3                                                  SG  3994
  300 S1=1.                                                              SG  3995
      S2=1.                                                              SG  3996
      S3=-1.                                                             SG  3997
      S4=-1.                                                             SG  3998
      GO TO 1500                                                         SG  3999
      C   ORIENTATION 4                                                  SG  4000
  400 S1=1.                                                              SG  4001
      S2=-1.                                                             SG  4002
      S3=-1.                                                             SG  4003
      S4=1.                                                              SG  4004
      GO TO 1500                                                         SG  4005
      C   ORIENTATION 5                                                  SG  4006
  500 S1=1.                                                              SG  4007
      S2=1.                                                              SG  4008
      S3=-1.                                                             SG  4009
      S4=-1.                                                             SG  4010
      GO TO 1500                                                         SG  4011
      C   ORIENTATION 6                                                  SG  4012
  600 IF(ABS(XR-XE),EQ,0,0)GO TO 610                                     SG  4013
      S1=-1.                                                             SG  4014
      S2=-1.                                                             SG  4015
      S3=-1.                                                             SG  4016
      S4=1.                                                              SG  4017
      GO TO 1500                                                         SG  4018
  610 FAC=YO-SS(XE,YE,XRA,YRA,NN,1)-SS(XE,YE,XRB,YRB,NN,2)               SG  4019
     1-SS(XE,YE,XRC,YRC,NN,1)                                            SG  4020
      GO TO 1700                                                         SG  4021
      C   ORIENTATION 7                                                  SG  4022
  700 IF(ABS(ABS(XR-XE)-XO),LT,XDYO)GO TO 710                            SG  4023
      S1=-1.                                                             SG  4024
      S2=1.                                                              SG  4025
      S3=-1.                                                             SG  4026
      S4=-1.                                                             SG  4027
      GO TO 1500                                                         SG  4028
  710 FAC=YO-SS(XE,YE,XRA,YRA,NN,1)-SS(XE,YE,XRC,YRC,NN,1)               SG  4029
     1-SS(XE,YE,XRD,YRD,NN,2)                                            SG  4030
      GO TO 1700                                                         SG  4031
      C   ORIENTATION 8                                                  SG  4032
  800 S1=-1.                                                             SG  4033
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      S2=-1.                                                            SG  4034
      S3=1.                                                             SG  4035
      S4=1.                                                             SG  4036
      GO TO 1500                                                        SG  4037
C     ORIENTATION 9                                                     SG  4038
900   S1=-1.                                                            SG  4039
      S2=1.                                                             SG  4040
      S3=1.                                                             SG  4041
      S4=-1.                                                            SG  4042
      GO TO 1500                                                        SG  4043
C     ORIENTATION 10                                                    SG  4044
1000  S1=-1.                                                            SG  4045
      S2=-1.                                                            SG  4046
      S3=1.                                                             SG  4047
      S4=1.                                                             SG  4048
      GO TO 1500                                                        SG  4049
C     ORIENTATION 11                                                    SG  4050
1100  IF(ABS(ABS(YR-YE)-YD),LT.XDYD)GO TO 1110                          SG  4051
      S1=-1.                                                            SG  4052
      S2=-1.                                                            SG  4053
      S3=1.                                                             SG  4054
      S4=-1.                                                            SG  4055
      GO TO 1500                                                        SG  4056
1110  FAC=XU-SS(XE,YE,XRA,YRA,NN,1)-SS(XE,YE,XRB,YRB,NN,2)              SG  4057
     1-SS(XE,YE,XRD,YRD,NN,2)                                           SG  4058
      GO TO 1700                                                        SG  4059
C     ORIENTATION 12                                                    SG  4060
1200  S1=-1.                                                            SG  4061
      S2=1.                                                             SG  4062
      S3=1.                                                             SG  4063
      S4=-1.                                                            SG  4064
1500  FAC=SS(XE,YE,XRA,YRA,NN,1)*S1+SS(XE,YE,XRB,YRB,NN,2)*S2          SG  4065
     1+SS(XE,YE,XRC,YRC,NN,1)*S3+SS(XE,YE,XRD,YRD,NN,2)*S4              SG  4066
1700  SG=FAC                                                            SG  4067
      RETURN                                                            SG  4068
      END                                                               SG  4069
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      SUBROUTINE CL3                                                    CL3 4070
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CL3 4071
     A TAU(9), VAREA, HAREA, XLX, XX(3), ACOEF(8,3),                    CL3 4072
     A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       CL3 4073
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    CL3 4074
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CL3 4075
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     CL3 4076
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              CL3 4077
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           CL3 4078
C                                                                       CL3 4079
      INTEGER SCODE,TCODE,RSTART,HCODE                                  CL3 4080
      COMMON/JAZZ3/SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),SRSNM(8,4),  CL3 4081
     1SRGNM(8,3),TSSNM(8,4),TGSNM(8,3),TSGNM(8,3),TGGNM(8,3)            CL3 4082
      COMMON/BLOCK/ ESURF( 60),TSURF( 60),ASURF( 60),AEP( 60)           CL3 4083
      COMMON/SPCE3/AA( 60, 60),BB( 60,15),CC( 60,15)                    CL3 4084
      CALL READ(1,'ESURI,ESURF(1), 60)                                  CL3 4085
      CALL READ(1,'ASURI,ASURF(1), 60)                                  CL3 4086
      CALL READ(1,'TSURI,TSURF(1), 60)                                  CL3 4087
      CALL RRRR                                                         CL3 4088
      CALL TTTT                                                         CL3 4089
C   TEST OF COMPUTION OF TOTAL INTERCHANGE AREA                         CL3 4090
C     (1)   SURFACE AS EMITTER                                          CL3 4091
C     (2)   VOLUME AS EMITTER                                           CL3 4092
61    CALL PZERO(BB(1,1), 660)                                          CL3 4093
      DO 62 L=1,NSURF                                                   CL3 4094
      BB(L,5)=ESURF(L)*ASURF(L)                                         CL3 4095
62    CONTINUE                                                          CL3 4096
C   SURFACE AS EMITTER                                                  CL3 4097
C     NSSBLK=NUMBER OF SURFACE TO SURFACE BLOCKS                        CL3 4098
C     NGSBLK=NUMBER OF SURFACE TO GAS BLOCKS                            CL3 4099
      KMAX=NGRAY+1                                                      CL3 4100
      DO 69 K=1,KMAX                                                    CL3 4101
      IF(K.EQ.KMAX)GO TO 63                                             CL3 4102
      KK=K                                                              CL3 4103
      GO TO 64                                                          CL3 4104
63    KK=4                                                              CL3 4105
64    DO 65 J=1,NSSBLK                                                  CL3 4106
      CALL READ(1,TSSNM(J,KK),AA(1,15*J-14), 900)                       CL3 4107
65    CONTINUE                                                          CL3 4108
      DO 67 L=1,NSURF                                                   CL3 4109
      DO 66 N=1,NSURF                                                   CL3 4110
                                                                        CL3 4111
      BB(L,KK)=BB(L,KK)+AA(N,L)                                         CL3 4112
66    CONTINUE                                                          CL3 4113
67    CONTINUE                                                          CL3 4114
      IF(K.EQ.KMAX)GO TO 90                                             CL3 4115
      DO 72 J=1,NGSBLK                                                  CL3 4116
      CALL READ(1,TGSNM(J,KK),AA(1,15*J-14), 900)                       CL3 4117
72    CONTINUE                                                          CL3 4118
      DO 74 L=1,NSURF                                                   CL3 4119
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      DO 73 N=1,NVOL                                                    CL3 4120
      BB(L,KK)=BB(L,KK)+AA(N,L)                                         CL3 4121
   73 CONTINUE                                                          CL3 4122
   74 CONTINUE                                                          CL3 4123
C     GAS AS EMITTER                                                    CL3 4124
C       NGGBLK=NUMBER OF GAS TO GAS BLOCKS                              CL3 4125
C       NSGBLK=NUMBER OFGAS TO SURFACE BLOCKS                           CL3 4126
      KO=6+2*(KK-1)                                                     CL3 4127
      DO 76 J=1,NGGBLK                                                  CL3 4128
      CALL READ(1,TGGNM(J,KK),AA(1,15*J-14), 900)                       CL3 4129
   76 CONTINUE                                                          CL3 4130
      DO 79 L=1,NVOL                                                    CL3 4131
      DO 78 N=1,NVOL                                                    CL3 4132
      BB(L,KO)=BB(L,KO)+AA(N,L)                                         CL3 4133
   78 CONTINUE                                                          CL3 4134
   79 CONTINUE                                                          CL3 4135
      DO 81 J=1,NSGBLK                                                  CL3 4136
      CALL READ(1,TSGNM(J,KK),AA(1,15*J-14), 900)                       CL3 4137
   81 CONTINUE                                                          CL3 4138
      DO 86 L=1,NVOL                                                    CL3 4139
      DO 85 N=1,NSURF                                                   CL3 4140
      BB(L,KO)=BB(L,KO)+AA(N,L)                                         CL3 4141
   85 CONTINUE                                                          CL3 4142
   86 CONTINUE                                                          CL3 4143
      CON=4.*XK(KK)*XO*YO                                               CL3 4144
      DO 87 L=1,NVOL                                                    CL3 4145
      BB(L,KO+1)=CON                                                    CL3 4146
   87 CONTINUE                                                          CL3 4147
   89 CONTINUE                                                          CL3 4148
   90 WRITE(K2,91)                                                      CL3 4149
   91 FORMAT('1FOR EACH CHARACTERIST GAS THE SUN OF ALL TOTAL INTERCHANGCL3 4150
     1E AREA WITH THE GAS VOLUME AS THE EMITTER MUST EQUAL THE'/' PRODUCCL3 4151
     2 OF THE EMISSIVITY AND THE AREA'//10X,'GRAY GAS 1',5X,'GRAY GAS 2',CL3 4152
     3',5X,'GRAY GAS 3',',11X,'CLEAR GAS',8X,'EMISS*AREA'//)            CL3 4153
      WRITE(K2,92)(I,(BB(I,M),M=1,5),I=1,NSURF)                         CL3 4154
   92 FORMAT(I5,3E15.5,2E20.5)                                          CL3 4155
      WRITE(K2,93)                                                      CL3 4156
   93 FORMAT('1FOR EACH CHARACTERIST GAS THE SUM OF THE TOTAL INTERCHANGCL3 4157
     1E AREAS WITH A GAS VOLUME AS THE EMITTER MUST EQUAL THE'/' PRODUCTCL3 4158
     2 OF THE GAS ABSORPTION COEFFICIENT AND THE VOLUME MULTIPLIED BY A CL3 4159
     1 CONSTANT OF 4.'//23X,'GRAY GAS 1',25X,'GRAY GAS 2',',25X,'GRAY GASCL3 4160
     23',',15X,'INTER-AREA',6X,'ABS * VOL',',10X,'INTER-AREA',6X,'ABS * VOLCL3 4161
     3',10X,'INTER AREA',6X,'ABS * VOL'//)                              CL3 4162
      WRITE(K2,94)(I,(BB(I,M),M=6,11),I=1,NVOL)                         CL3 4163
   94 FORMAT(/(I5,3(5X,2F15.5)))                                        CL3 4164
      RETURN                                                            CL3 4165
      END                                                               CL3 4166
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```
      1        SUBROUTINE RRRR                                                  RRRR4167
      2 C    COMPUTES SURFACE REFLECTIVITES AND STORE ON DISK 1                 RRRR4168
      3 C        (1) = SURFACE  AREA AS EMITTER                                 RRRR4169
      4 C        (2) = GAS VOLUME AS EMITTER                                    RRRR4170
      5         COMMON // DUMMY(3),KK, ICODE, HCODE,                           RRRR4171
      6        A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                 RRRR4172
      7        A TBRIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                    RRRR4173
      8        A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                 RRRR4174
      9        A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                  RRRR4175
     10        A XSUREX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                  RRRR4176
     11        A RSTART, TCODE, SCODE, NGRAY, JHCHC,                           RRRR4177
     12        A K1, K2, RGRD(10), TDEP(100), PERM(200)                        RRRR4178
     13 C                                                                      RRRR4179
     14         INTEGER SCODE,TCODE,RSTART,HCODE                               RRRR4180
     15         COMMON/JAZZ3/SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),SRSNM(8,4),RRRR4181
     16        1SRGNM(8,3),TSSNM(8,4),TGSNM(8,3),TSGNM(8,3),TGGNM(8,3)         RRRR4182
     17         COMMON/BLOCK/ ESURF( 60),TSURF( 60),ASURF( 60),AEP( 60)         RRRR4183
     18         COMMON/SPCE3/AA( 60, 60),BB( 60,15),CC( 60,15)                  RRRR4184
     19         DIMENSION RHO( 60),FACTR( 60)                                   RRRR4185
     20 C    GENERATE REQUIRED SURFACE PARAMETERS                              RRRR4186
     21 C        REFLECTIVITY                    RHO                           RRRR4187
     22 C        AREA / REFLECTIVITY             FACTR                         RRRR4188
     23 C        AREA * EMISSIBITY/REFLECTIVITY  AEP                           RRRR4189
     24         DO 10 JJ=1,NSURF                                               RRRR4190
     25         RHO(JJ)=1.-ESURF(JJ)                                           RRRR4191
     26         FACTR(JJ)=ASURF(JJ)/RHO(JJ)                                    RRRR4192
     27         AEP(JJ)=FACTR(JJ)*ESURF(JJ)                                    RRRR4193
     28 10      CONTINUE                                                       RRRR4194
     29 C    KK=GAS NUMBER                                                     RRRR4195
     30 12      KMAX=1+NGRAY                                                   RRRR4196
     31         DO 80 K=1,KMAX                                                 RRRR4197
     32         CALL PZERO(AA(1,1), 3600)                                      RRRR4198
     33         IF(K.EQ.KMAX)GO TO 16                                          RRRR4199
     34         KK=K                                                           RRRR4200
     35         GO TO 18                                                       RRRR4201
     36 16      KK=4                                                           RRRR4202
     37 C    SET UP MATRIX AND INVERT FOR EACH CHARACTEISTIC GAS               RRRR4203
     38 C    MATRI EQUALS S=S DIRECT INTERCHANGE AREA WITH                     RRRR4204
     39 C    DIAGONAL TERMS ADJUSTED FOR AREA/REFLECTIVITY TERM                RRRR4205
     40 C        NSSBLK = NUMBER OF SURFACE TO SURFACE BLOCKS                  RRRR4206
     41 18      DO 20 J=1,NSSBLK                                               RRRR4207
     42         CALL READ(1,SSNM(J,KK),AA(1,15*J-14), 900)                     RRRR4208
     43 20      CONTINUE                                                       RRRR4209
     44         DO 21 JJ=1,NSURF                                               RRRR4210
     45         AA(JJ,JJ)=AA(JJ,JJ)-FACTR(JJ)                                  RRRR4211
     46 21      CONTINUE                                                       RRRR4212
     47 C    OBTAIN INVERSE OF OUTGOING FLUX DENSITY FOR EACH                  RRRR4213
     48 C    CHARACTERISTIC GAS -- SAVE SINCE IT CAN BE USED                   RRRR4214
     49 C    FOR BOTH EMITTERS( SURFACE AREA AND GAS VOLUME )                  RRRR4215
     50 23      KODE=0                                                         RRRR4216
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      CALL INVERT(NSURF, 60,AA,CC,KODE)                                  RRRR4217
   26 IF(KODE.NE.10)GO TO 31                                             RRRR4218
      WRITE(K2,29)                                                       RRRR4219
   29 FORMAT(1H1,TROUBLE IN INVERT)!)                                    RRRR4220
      STOP                                                               RRRR4221
C  REFLECTIVITES WITH SURFACE AS EMITTER                                 RRRR4222
C  OBTAINED BY MATRIX -- VECTOR  MULTIPLICATION                          RRRR4223
C  MATRIX PREVIOUSLY OBTAINED INVERSE                                    RRRR4224
C  VECTOR NEGATIVIVE OS S-S DIRECT INTERCHANGE                           RRRR4225
C     AREA * EMISSIVITY OF EMITTER                                       RRRR4226
C     NSSBLK = NUMBER OF SURFACE TO SURFACE BLOCKS                       RRRR4227
   31 DO 49 J =1,NSSBLK                                                  RRRR4228
      CALL READ(1,SSNM(J,KK),BB(1,1), 900)                               RRRR4229
      J1=15*(J-1)                                                        RRRR4230
      IF(J.EQ.NSSBLK)GO TO 33                                            RRRR4231
      JJMAX=15                                                           RRRR4232
      GO TO 34                                                           RRRR4233
   33 JJMAX=NSURF-(NSSBLK-1)*15                                          RRRR4234
   34 DO 38 JJ=1,JJMAX                                                   RRRR4235
      DO 36 N=1,NSURF                                                    RRRR4236
      J2=J1+JJ                                                           RRRR4237
      BB(N,JJ)=BB(N,JJ)*ESURF(J2)                                        RRRR4238
   36 CONTINUE                                                           RRRR4239
   38 CONTINUE                                                           RRRR4240
      CALL PZERO(CC(1,1), 900)                                           RRRR4241
      DO 46 JJ=1,JJMAX                                                   RRRR4242
      DO 44 N=1,NSURF                                                    RRRR4243
      DO 42 L=1,NSURF                                                    RRRR4244
      CC(N,JJ)=CC(N,JJ)-AA(N,L)*BB(L,JJ)                                 RRRR4245
   42 CONTINUE                                                           RRRR4246
   44 CONTINUE                                                           RRRR4247
   46 CONTINUE                                                           RRRR4248
      CALL WRITE(1,SRSNM(J,KK),CC(1,1), 900)                             RRRR4249
   49 CONTINUE                                                           RRRR4250
C  TEST TO SEE IF WE HAVE FINISHED THE CLEAR GAS                         RRRR4251
C     THAN COMPUTION IS FINISHED                                         RRRR4252
      IF(K.EQ.KMAX)GO TO 90                                              RRRR4253
C  REFLECTIVITY AS GAS AS  EMITTER  (GAS TO SURFACE)                     RRRR4254
C  OBTAINED BY MATRIX VECTOR MULIPLICATION                               RRRR4255
C  MATRIX PREVIOUSLY OBTAINED INVERSE                                    RRRR4256
C  VECTOR NEGATIVE OF G-S DIRECT INTERCHANGE AREA                        RRRR4257
C     NSGBLK = NUMBER OF GAS TO SURFACE BLOCKS                           RRRR4258
      DO 69 J=1,NSGBLK                                                   RRRR4259
      CALL READ(1,SGNM(J,KK),BB(1,1), 900)                               RRRR4260
      IF(J.EQ.NSGBLK)GO TO 52                                            RRRR4261
      JJMAX=15                                                           RRRR4262
      GO TO 54                                                           RRRR4263
   52 JJMAX=NVUL-(NSGBLK-1)*15                                           RRRR4264
   54 CALL PZERO(CC(1,1), 900)                                           RRRR4265
      DO 66 JJ=1,JJMAX                                                   RRRR4266
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      DO 64 N=1,NSURF                                                   RRRR4267
      DO 62 L=1,NSURF                                                   RRRR4268
      CC(N,JJ)=CC(N,JJ)-AA(N,L)*BB(L,JJ)                                RRRR4269
62    CONTINUE                                                          RRRR4270
64    CONTINUE                                                          RRRR4271
66    CONTINUE                                                          RRRR4272
      CALL WRITE(1,SRGNM(J,KK),CC(1,1), 900)                            RRRR4273
69    CONTINUE                                                          RRRR4274
60    CONTINUE                                                          RRRR4275
90    RETURN                                                            RRRR4276
      END                                                               RRRR4277
```

```
      SUBROUTINE INVERT (NEG,MAX,A,E,KERR)                              INVE4278
      REAL A(MAX,1),E(1)                                                INVE4279
      KERR=0                                                            INVE4280
      NN=NEG                                                            INVE4281
10    DO 16 I=1,NN                                                      INVE4282
      Q=A(I,I)                                                          INVE4283
      IF(Q.NE.0.0)GO TO 12                                              INVE4284
      KK=10                                                             INVE4285
      GO TO 30                                                          INVE4286
12    DO 13 J=1,NN                                                      INVE4287
      A(I,J)=A(I,J)/Q                                                   INVE4288
13    CONTINUE                                                          INVE4289
      A(I,I)=1./Q                                                       INVE4290
      IF(I.EQ.NN)GO TO 20                                               INVE4291
      L=I+1                                                             INVE4292
      DO 15 K=L,NN                                                      INVE4293
      R=A(K,I)                                                          INVE4294
      IF(R.EQ.0.0)GO TO 15                                              INVE4295
      DO 14 J=1,NN                                                      INVE4296
      A(K,J)=A(K,J)-R*A(I,J)                                            INVE4297
14    CONTINUE                                                          INVE4298
      A(K,I)=-R/Q                                                       INVE4299
15    CONTINUE                                                          INVE4300
16    CONTINUE                                                          INVE4301
20    DO 24 L=2,NN                                                      INVE4302
      I=NN-L+1                                                          INVE4303
      K=I+1                                                             INVE4304
      DO 21 J=K,NN                                                      INVE4305
      E(J)=A(I,J)                                                       INVE4306
      A(I,J)=0.0                                                        INVE4307
21    CONTINUE                                                          INVE4308
      DO 23 J=1,NN                                                      INVE4309
      DO 22 M=K,NN                                                      INVE4310
      A(I,J)=A(I,J)-E(M)*A(M,J)                                         INVE4311
22    CONTINUE                                                          INVE4312
23    CONTINUE                                                          INVE4313
24    CONTINUE                                                          INVE4314
30    RETURN                                                            INVE4315
      END                                                               INVE4316
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      SUBROUTINE TTTT                                                    TTTT4317
C     COMPUTE TOTAL INTERCHANGE AREA -- FOR EACH CHARACTERISTIC GAS      TTTT4318
      COMMON // DUMMY(3),KK, ICODE, HCODE,                               TTTT4319
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                     TTTT4320
     A TBRIDG, PRES, FLUET, FLUE(5), XHWX, TSINK,                        TTTT4321
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                     TTTT4322
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                      TTTT4323
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                      TTTT4324
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                               TTTT4325
     A K1, K2, RCRD(10), TOEP(100), PERM(200),NPRNT                      TTTT4326
C                                                                        TTTT4327
      INTEGER SCODE,TCODE,RSTART,HCODE                                   TTTT4328
      COMMON/JAZZ3/SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),SRSNM(8,4),   TTTT4329
     1SRGNM(8,3),TSSNM(8,4),TGSNM(8,3),TSGNM(8,3),TGGNM(8,3)             TTTT4330
      COMMON/BLOCK/ ESURF( 60),TSURF( 60),ASURF( 60),AEP( 60)            TTTT4331
      COMMON/SPCE3/AA( 60, 60),EB( 60,15),CC( 60,15)                     TTTT4332
      COMMON/FIX/ FIXS( 60,4),Z( 60)                                     TTTT4333
C     KK= GAS NUMBER                                                     TTTT4334
      CALL PZERO(FIXS(1,1),240)                                          TTTT4335
      KMAX=1+NGRAY                                                       TTTT4336
      DO 60 K=1,KMAX                                                     TTTT4337
      IF(K.EQ.KMAX)GO TO 8                                               TTTT4338
      KK=K                                                               TTTT4339
      GO TO 11                                                           TTTT4340
    8 KK=4                                                               TTTT4341
C     SURFACE-TO-SURFACE TOTAL INTERCHANGE AREA                          TTTT4342
C     OBTAIN BY MULTIPLYING S-S REFLECTIVIY BY AEP OF THE RECEIVER       TTTT4343
C       AEP=AEP*EMISSIVITY/REFLECTIVITY                                  TTTT4344
C          NSSBLK=NUMBER OF SURFACE TO SURFACE BLOCKS                    TTTT4345
   11 CALL PZERO(AA(1,1), 3600)                                          TTTT4346
      DO 12 J=1,NSSBLK                                                   TTTT4347
      CALL READ(1,SRSNM(J,KK),AA(1,15*J-14), 900)                        TTTT4348
   12 CONTINUE                                                           TTTT4349
      DO 17 N=1,NSURF                                                    TTTT4350
      DO 16 L=1,NSURF                                                    TTTT4351
      AA(L,N)=AA(L,N)*AEP(L)                                             TTTT4352
      FIXS(N,KK)=FIXS(N,KK)+AA(L,N)                                      TTTT4353
   16 CONTINUE                                                           TTTT4354
   17 CONTINUE                                                           TTTT4355
      DO 19 J=1,NSSBLK                                                   TTTT4356
      CALL WRITE(1,TSSNM(J,KK),AA(1,15*J-14), 900)                       TTTT4357
   19 CONTINUE                                                           TTTT4358
C     TEST TO SEE IF WE HAVE FINISHED THE CLEAR GAS                      TTTT4359
C       THEN COMPUTION IS FINISHED                                       TTTT4360
   21 IF(K.EQ.KMAX)GO TO 63                                              TTTT4361
C     GAS TO SURFACE TOTAL INTERCHANGE AREA                              TTTT4362
C     OBTAIN BY MULTIPLYING G-S REFLECTIVITY BY AEP OF THE RECEIVER      TTTT4363
C     AEP V AREA*EMISSIVITY/REFLECTIVITY                                 TTTT4364
C       NSGBLK=NUMBER OF GAS TO SURFACE BLOCKS                           TTTT4365
      CALL PZERO(AA(1,1), 3600)                                          TTTT4366
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      DO 22 J=1,NSGBLK                                                  TTTT4367
      CALL READ(1,SRGNM(J,KK),AA(1,15*J-14), 900)                       TTTT4368
22    CONTINUE                                                          TTTT4369
      DO 25 N=1,NVOL                                                    TTTT4370
      DO 24 L=1,NSURF                                                   TTTT4371
      AA(L,N)=AA(L,N)*AEP(L)                                            TTTT4372
24    CONTINUE                                                          TTTT4373
25    CONTINUE                                                          TTTT4374
      DO 27 J=1,NSGBLK                                                  TTTT4375
      CALL WRITE(1,TSGNM(J,KK),AA(1,15*J-14), 900)                      TTTT4376
27    CONTINUE                                                          TTTT4377
C     SURFACE-TO-GAS TOTAL INTERCHANGE AREA                             TTTT4378
C     SINCE G-S=S-G ALL THAT NEEDS TO BE DONE IS                        TTTT4379
C       TRANSPOSE SURFACE TO GAS MATRIX                                 TTTT4380
C        NGSBLK=NUMBER OF SURFACE TO GAS BLOCKS                         TTTT4381
30    NL=MIN0(NVOL,NSURF)                                               TTTT4382
      DO 32 N=2,NL                                                      TTTT4383
      LZ=N-1                                                            TTTT4384
      DO 31 L=1,LZ                                                      TTTT4385
      SAVE=AA(N,L)                                                      TTTT4386
      AA(N,L)=AA(L,N)                                                   TTTT4387
      AA(L,N)=SAVE                                                      TTTT4388
31    CONTINUE                                                          TTTT4389
32    CONTINUE                                                          TTTT4390
      NZ=NL+1                                                           TTTT4391
      IF(NSURF-NVOL)33,38,34                                            TTTT4392
C     NVOL.GT.NSURF                                                     TTTT4393
33    NSTART=1                                                          TTTT4394
      LSTART=NZ                                                         TTTT4395
      GO TO 35                                                          TTTT4396
C     NSURF.GT.NVOL                                                     TTTT4397
34    NSTART=NZ                                                         TTTT4398
      LSTART=1                                                          TTTT4399
35    DO 37 N=NSTART,NSURF                                              TTTT4400
      DO 36 L=LSTART,NVOL                                               TTTT4401
      AA(L,N)=AA(N,L)                                                   TTTT4402
      AA(N,L)=0.0                                                       TTTT4403
36    CONTINUE                                                          TTTT4404
37    CONTINUE                                                          TTTT4405
38    DO 372 N=1,NSURF                                                  TTTT4406
      DO 371 L=1,NVOL                                                   TTTT4407
      FIXS(N,KK)=FIXS(N,KK)+AA(L,N)                                     TTTT4408
371   CONTINUE                                                          TTTT4409
372   CONTINUE                                                          TTTT4410
      DO 39 J=1,NGSBLK                                                  TTTT4411
      CALL WRITE(1,TGSNM(J,KK),AA(1,15*J-14), 900)                      TTTT4412
39    CONTINUE                                                          TTTT4413
C     GAS TO GAS TOTAL INTERCHANGE AREA                                 TTTT4414
C     THIS INTERCHANGE AREA HAS TO COMBINATIONS                         TTTT4415
C       (1) G-G VIA REFLECTION FROM SURFACES                            TTTT4416
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      (2) G=G VIA DIRECT INTERCHANGE                                    TTTT4417
C  COMPUTE (1) FIRST BY MATRIX MULTIPLICATION                           TTTT4418
C     MATRIX SURFACE TO GAS REFLECTIVITY                                TTTT4419
C     VECTOR SURFACE TO GAS DIRECT INTERCHANGE AREA                     TTTT4420
C  ADD (2) TO (1) TO GET TOTAL INTERCHANGE AREA                         TTTT4421
C     NGGBLK = NUMBER OF GAS TO GAS BLOCKS                              TTTT4422
C     NGSBLK = NUMBER OF SURFACE TO GAS BLOCKS                          TTTT4423
41    CALL PZERO(AA(1,1), 3600)                                         TTTT4424
      DO 42 J=1,NGSBLK                                                  TTTT4425
      CALL READ(1,GSNM(J,KK),AA(1,15*J-14), 900)                        TTTT4426
42    CONTINUE                                                          TTTT4427
      DO 49 J=1,NSGBLK                                                  TTTT4428
      CALL PZERO(CC(1,1), 900)                                          TTTT4429
      CALL READ(1,SGNM(J,KK),BB(1,1), 900)                              TTTT4430
      IF(J.EQ.NSGBLK)GO TO 43                                           TTTT4431
      NMAX=15                                                           TTTT4432
      GO TO 44                                                          TTTT4433
43    NMAX=NVOL-(NSGBLK-1)*15                                           TTTT4434
44    DO 47 N=1,NMAX                                                    TTTT4435
      DO 46 L=1,NVOL                                                    TTTT4436
      DO 45 M=1,NSURF                                                   TTTT4437
      CC(L,N)=CC(L,N)+BB(M,N)*AA(L,M)                                   TTTT4438
45    CONTINUE                                                          TTTT4439
46    CONTINUE                                                          TTTT4440
47    CONTINUE                                                          TTTT4441
      CALL WRITE(1,TGGNM(J,KK),CC(1,1), 900)                            TTTT4442
49    CONTINUE                                                          TTTT4443
      DO 59 J=1,NGGBLK                                                  TTTT4444
      CALL PZERO(AA(1,1), 900)                                          TTTT4445
      CALL READ(1,GGNM(J,KK),BB(1,1), 900)                              TTTT4446
      CALL READ(1,TGGNM(J,KK),CC(1,1), 900)                             TTTT4447
      IF(J.EQ.NGGBLK)GO TO 51                                           TTTT4448
      NMAX=15                                                           TTTT4449
      GO TO 52                                                          TTTT4450
51    NMAX=NVOL-(NGGBLK-1)*15                                           TTTT4451
52    DO 56 N=1,NMAX                                                    TTTT4452
      DO 55 L=1,NVOL                                                    TTTT4453
      AA(L,N)=BB(L,N)+CC(L,N)                                           TTTT4454
55    CONTINUE                                                          TTTT4455
56    CONTINUE                                                          TTTT4456
      CALL WRITE(1,TGGNM(J,KK),AA(1,1),900)                             TTTT4457
59    CONTINUE                                                          TTTT4458
60    CONTINUE                                                          TTTT4459
C  NORMALIZE INTERCHANGE AREAS                                          TTTT4460
63    DO 96 K=1,KMAX                                                    TTTT4461
      IF(K.EQ.KMAX)GO TO 65                                             TTTT4462
      KK=K                                                              TTTT4463
      GO TO 66                                                          TTTT4464
65    KK=4                                                              TTTT4465
66    DO 67 N=1,NSURF                                                   TTTT4466
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      FIXS(N,KK)=ESURF(N)*ASURF(N)/FIXS(N,KK)                          TTTT4467
   67 CONTINUE                                                         TTTT4468
      CALL PZERO(AA(1,1), 3600)                                        TTTT4469
      DO 68 J=1,NSSBLK                                                 TTTT4470
      CALL READ(1,TSSNM(J,KK),AA(1,15*J-14), 900)                      TTTT4471
   68 CONTINUE                                                         TTTT4472
      DO 72 N=1,NSURF                                                  TTTT4473
      DO 71 L=1,NSURF                                                  TTTT4474
      AA(L,N)=AA(L,N)*FIXS(N,KK)                                       TTTT4475
   71 CONTINUE                                                         TTTT4476
   72 CONTINUE                                                         TTTT4477
      DO 73 J=1,NSSBLK                                                 TTTT4478
      CALL WRITE(1,TSSNM(J,KK),AA(1,J*15-14), 900)                     TTTT4479
   73 CONTINUE                                                         TTTT4480
      IF(NPRNT.EQ.1)GO TO 74                                           TTTT4481
 4000 WRITE(K2,4001)KK                                                 TTTT4482
 4001 FORMAT(1H1,19X,'SURFACE TO SURFACE TOTAL INTERCHANGE AREA',10X,'K TTTT4483
     1=',I5)                                                           TTTT4484
      CALL PRINT(AA,NSURF,NSURF)                                       TTTT4485
      CALL PRINT(FIXS(1,KK),NSURF,1)                                   TTTT4486
   74 IF(K.EQ.KMAX)GO TO 99                                            TTTT4487
      CALL PZERO(AA(1,1), 3600)                                        TTTT4488
      DO 76 J=1,NGSBLK                                                 TTTT4489
      CALL READ(1,TGSNM(J,KK),AA(1,15*J-14), 900)                      TTTT4490
   76 CONTINUE                                                         TTTT4491
      DO 78 N=1,NSURF                                                  TTTT4492
      DO 77 L=1,NVOL                                                   TTTT4493
      AA(L,N)=AA(L,N)*FIXS(N,KK)                                       TTTT4494
   77 CONTINUE                                                         TTTT4495
   78 CONTINUE                                                         TTTT4496
      DO 79 J=1,NGSBLK                                                 TTTT4497
      CALL WRITE(1,TGSUM(J,KK),AA(1,15*J-14), 900)                     TTTT4498
   79 CONTINUE                                                         TTTT4499
      IF(NPRNT.EQ.1)GO TO 80                                           TTTT4500
 4010 WRITE(K2,4011)KK                                                 TTTT4501
 4011 FORMAT(1H1,19X,'SURFACE TO VOLUME TOTAL INTERCHANGE AREA',10X,'K='TTTT4502
     1,I5)                                                             TTTT4503
      CALL PRINT(AA,NVOL,NSURF)                                        TTTT4504
   80 NL=MINO(NSURF,NVOL)                                              TTTT4505
      DO 82 N=2,NL                                                     TTTT4506
      LZ=N-1                                                           TTTT4507
      DO 81 L=1,LZ                                                     TTTT4508
      SAVE=AA(N,L)                                                     TTTT4509
      AA(N,L)=AA(L,N)                                                  TTTT4510
      AA(L,N)=SAVE                                                     TTTT4511
   81 CONTINUE                                                         TTTT4512
   82 CONTINUE                                                         TTTT4513
      NZ=NL+1                                                          TTTT4514
      IF(NVOL-NSURF)83,870,84                                          TTTT4515
C   NSURF.GT.NVOL                                                      TTTT4516
```

```
      NSTART=1                                                          TTTT4517
      LSTART=NZ                                                         TTTT4518
      GO TO 85                                                          TTTT4519
C     NVOL.GT.NSURF                                                     TTTT4520
84    NSTART=NZ                                                         TTTT4521
      LSTART=1                                                          TTTT4522
85    DO 87 N=NSTART,NVOL                                               TTTT4523
      DO 86 L=LSTART,NSURF                                              TTTT4524
      AA(L,N)=AA(N,L)                                                   TTTT4525
      AA(N,L)=0.0                                                       TTTT4526
86    CONTINUE                                                          TTTT4527
87    CONTINUE                                                          TTTT4528
870   DO 89 N=1,NVOL                                                    TTTT4529
      Z(N)=0.0                                                          TTTT4530
      DO 88 L=1,NSURF                                                   TTTT4531
      Z(N)=Z(N)+AA(L,N)                                                 TTTT4532
88    CONTINUE                                                          TTTT4533
89    CONTINUE                                                          TTTT4534
      DO 90 J=1,NSGBLK                                                  TTTT4535
      CALL WRITE(1,TSGNM(J,KK),AA(1,15*J-14), 900)                      TTTT4536
90    CONTINUE                                                          TTTT4537
      IF(NPRNT.EQ.1)GO TO 900                                           TTTT4538
4020  WRITE(K2,4021)KK                                                  TTTT4539
4021  FORMAT(1H1,19X,'VOLUME TO SURFACE TOTAL INTERCHANGE AREA',10X,'K=' TTTT4540
     1,I5)                                                              TTTT4541
      CALL PRINT(AA,NSURF,NVOL)                                         TTTT4542
      CALL PRINT(Z,NVOL,1)                                              TTTT4543
900   CON=4.0*XO*YO*XK(KK)                                              TTTT4544
      CALL PZERO(AA(1,1), 3600)                                         TTTT4545
      DO 91 J=1,NGGBLK                                                  TTTT4546
      CALL READ(1,TGGNM(J,KK),AA(1,15*J-14), 900)                       TTTT4547
91    CONTINUE                                                          TTTT4548
      DO 94 N=1,NVOL                                                    TTTT4549
      ZZ=0.0                                                            TTTT4550
      DO 92 L=1,NVOL                                                    TTTT4551
      ZZ=ZZ+AA(L,N)                                                     TTTT4552
92    CONTINUE                                                          TTTT4553
      ZZ=(CON-Z(N))/ZZ                                                  TTTT4554
      DO 93 L=1,NVOL                                                    TTTT4555
      AA(L,N)=AA(L,N)*ZZ                                                TTTT4556
93    CONTINUE                                                          TTTT4557
94    CONTINUE                                                          TTTT4558
      DO 95 J=1,NGGBLK                                                  TTTT4559
      CALL WRITE(1,TGGNM(J,KK),AA(1,15*J-14), 900)                      TTTT4560
95    CONTINUE                                                          TTTT4561
      IF(NPRNT.EQ.1)GO TO 96                                            TTTT4562
4030  WRITE(K2,4031)KK                                                  TTTT4563
4031  FORMAT(1H1,19X,'VOLUME TO VOLUME TOTAL INTERCHANGE AREA',10X,'K=',TTTT4564
     1I5)                                                               TTTT4565
      CALL PRINT(AA, NVOL,NVOL)                                         TTTT4566
```

```
  251 96    CONTINUE                                                TTTT4567
  252 99    RETURN                                                  TTTT4568
  253       END                                                     TTTT4569
```

```
      FUNCTION LOC(KIK)                                                 LOC 4570
C     L  LOC   CODE FOR GAS VOLUME ORIENTATION                          LOC 4571
C     K  KK    GAS VOLUME NUMBER                                        LOC 4572
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              LOC 4573
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    LOC 4574
     A TORIDG, PRES, FLUET, FLUE(5), XMWX, TSINK,                       LOC 4575
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    LOC 4576
     A NSSBLK, NCSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     LOC 4577
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     LOC 4578
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              LOC 4579
     A K1, K2, KCRD(10), TDEP(100), PERM(200)                           LOC 4580
C                                                                       LOC 4581
      INTEGER SCODE,TCODE,RSTART,HCODE                                  LOC 4582
      COMMON/GAS/ NX1,NX2,NY1,NY2,HT,HTT,XTEST,ALFA(3),BETA(3),GAMA(3), LOC 4583
     1DELT(3),GMX(120),GMY(120),HC( 60),JX1,JX2,JY1,JY2                 LOC 4584
      COMMON/TTT/ TV(120,2),TS(120,2)                                   LOC 4585
10    K=KIK                                                             LOC 4586
      CALL PZERO(ALFA(1) ,3)                                            LOC 4587
      CALL PZERO(BETA(1) ,3)                                            LOC 4588
      CALL PZERO(GAMA(1) ,3)                                            LOC 4589
      CALL PZERO(DELT(1),3)                                             LOC 4590
C   FOR GAS VOLUME OBTAIN                                               LOC 4591
C     JR   ROW NUMBER                                                   LOC 4592
C     JC   COLUMN NUMBER                                                LOC 4593
      JR=0                                                              LOC 4594
      JC=K                                                              LOC 4595
12    JR=JR+1                                                           LOC 4596
      IF(JC.LE.NCOL)GO TO 14                                            LOC 4597
      JC=JC-NCOL                                                        LOC 4598
      GO TO 12                                                          LOC 4599
C   BULK FLOW INDICIES                                                  LOC 4600
C     JX1   X DIRECTION IN                                              LOC 4601
C     JX2                 OUT                                           LOC 4602
C     JY1   Y DIRECTION IN                                              LOC 4603
C     JY2                 OUT                                           LOC 4604
14    JX1=(JR-1)*(NCOL+1)+JC                                            LOC 4605
      JX2=JX1+1                                                         LOC 4606
      JY1=K                                                             LOC 4607
      JY2=K+NCOL                                                        LOC 4608
C   COMPUTE VALUE OF L AND NX1,NX2,,NY1,NY2                             LOC 4609
16    IF(JR.NE.1)GO TO 21                                               LOC 4610
      IF(JC.NE.1)GO TO 17                                               LOC 4611
C   SURF VOL   SURF VOL                                                 LOC 4612
      L=1                                                               LOC 4613
      NX1=2*NCOL+1                                                      LOC 4614
      NX2=K+1                                                           LOC 4615
      NY1=1                                                             LOC 4616
      NY2=K+NCOL                                                        LOC 4617
      GO TO 61                                                          LOC 4618
17    IF(JC.EQ.NCOL)GO TO 19                                            LOC 4619
```

```
      IF(NXSXN.NE.0)GO TO 31                                    LOC 4620
C   VOL   VOL   SURF   VOL                                      LOC 4621
18    L=2                                                       LOC 4622
      NX1=K-1                                                   LOC 4623
      NX2=K+1                                                   LOC 4624
      NY1=K                                                     LOC 4625
      NY2=K+NCOL                                                LOC 4626
      GO TO 81                                                  LOC 4627
19    L=3                                                       LOC 4628
C   VOL   SURF   SURF   VOL                                     LOC 4629
      NX1=K-1                                                   LOC 4630
      NX2=2*NCOL+NROW+1                                         LOC 4631
      NY1=K                                                     LOC 4632
      NY2=K+NCOL                                                LOC 4633
      GO TO 101                                                 LOC 4634
21    IF(JR.NE.NR(W)GO TO 25                                    LOC 4635
      IF(JC.NE.1)GO TO 22                                       LOC 4636
      L=7                                                       LOC 4637
C   SURR  VOL   VOL   SURF                                      LOC 4638
      NX1=2*NCOL+NROW                                           LOC 4639
      NX2=K+1                                                   LOC 4640
      NY1=K-NCOL                                                LOC 4641
      NY2=NCOL+1                                                LOC 4642
      GO TO 181                                                 LOC 4643
22    IF(JC.EQ.NCOL)GO TO 24                                    LOC 4644
      IF(NXSXN.NE.0)GO TO 31                                    LOC 4645
23    L=8                                                       LOC 4646
C   VOL   VOL   VOL   SURF                                      LOC 4647
      NX1=K-1                                                   LOC 4648
      NX2=K+1                                                   LOC 4649
      NY1=K-NCOL                                                LOC 4650
      NY2=NCOL+JC                                               LOC 4651
      GO TO 201                                                 LOC 4652
24    L=9                                                       LOC 4653
C   VOL   SURF   VOL   SURF                                     LOC 4654
      NX1=K-1                                                   LOC 4655
      NX2=NCR                                                   LOC 4656
      NY1=K-NCOL                                                LOC 4657
      NY2=2*NCOL                                                LOC 4658
      GO TO 221                                                 LOC 4659
25    IF(JC.NE.1)GO TO 26                                       LOC 4660
      L=4                                                       LOC 4661
C   SURF   VOL   VOL   VOL                                      LOC 4662
      NX1=2*NCOL+JR                                             LOC 4663
      NX2=K+1                                                   LOC 4664
      NY1=K-NCOL                                                LOC 4665
      NY2=K+NCOL                                                LOC 4666
      GO TO 121                                                 LOC 4667
26    IF(JC.NE.NCOL)GO TO 27                                    LOC 4668
      L=6                                                       LOC 4669
```

```
      C   VOL SURF   VOL   VOL                                          LOC 4670
           NX1=K-1                                                      LOC 4671
           NX2=2*NCOL+NROW+JR                                           LOC 4672
           NY1=K-NCOL                                                   LOC 4673
           NY2=K+NCOL                                                   LOC 4674
           GO TO 161                                                    LOC 4675
   27      IF(NXSXN.NE.0)GO TO 31                                       LOC 4676
   28      L=5                                                          LOC 4677
      C   VOL   VOL   VOL VOL                                          LOC 4678
           NX1=K-1                                                      LOC 4679
           NX2=K+1                                                      LOC 4680
           NY1=K-NCOL                                                   LOC 4681
           NY2=K+NCOL                                                   LOC 4682
           GO TO 141                                                    LOC 4683
      C   INTERMEDIATE SURFACE PRESENT                                 LOC 4684
      C   SURFACE ON LEFT SIDE OF GAS VOLUME                           LOC 4685
      C   L=11,OR,13,OR,15                                             LOC 4686
   31      XX=XO*FLOAT(JC-1)                                           LOC 4687
           DO 32 J=1,NXSXN                                             LOC 4688
           IF(ABS(XX-XSURFX(J)).GT.XTEST)GO TO 32                      LOC 4689
           NSN=J                                                       LOC 4690
           GO TO 33                                                    LOC 4691
   32      CONTINUE                                                    LOC 4692
           GO TO 41                                                    LOC 4693
   33      IF(JR.NE.1)GO TO 34                                         LOC 4694
           L=11                                                        LOC 4695
      C   SURF   VOL   SURF   VOL                                      LOC 4696
           NX1=NCR+(NSN-1)*NROW+1                                      LOC 4697
           NX2=K+1                                                     LOC 4698
           NY1=K                                                       LOC 4699
           NY2=K+NCOL                                                  LOC 4700
           GO TO 261                                                   LOC 4701
   34      IF(JR.NE.NROW)GO TO 35                                      LOC 4702
           L=13                                                        LOC 4703
      C   (7)    VOL VOL   VOL                                        LOC 4704
           NX1=NCR+(NSN-1)*NROW+JR                                     LOC 4705
           NX2=K+1                                                     LOC 4706
           NY1=K-NCOL                                                  LOC 4707
           NY2=K+NCOL                                                  LOC 4708
           GO TO 301                                                   LOC 4709
   35      L=15                                                        LOC 4710
      C   SUR   VOL   VOL   SURF                                       LOC 4711
           NX1=NCR+NSN*NROW                                            LOC 4712
           NX2=K+1                                                     LOC 4713
           NY1=K-NCOL                                                  LOC 4714
           NY2=NCOL+JC                                                 LOC 4715
           GO TO 341                                                   LOC 4716
      C   SURFACE ON RIGTH SIDE OF GAS VOLUME                         LOC 4717
      C     L=10,OR,12,OR,14                                          LOC 4718
   41      XX=XX+XO                                                    LOC 4719
```

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      DO 42 J=1,NXSXN                                                   LOC 4720
      IF(ABS(XX-XSURFX(J)).GT.XTEST)GO TO 42                            LOC 4721
      NSN=J                                                             LOC 4722
      GO TO 43                                                          LOC 4723
42    CONTINUE                                                          LOC 4724
      IF(JR.EQ.1)GO TO 18                                               LOC 4725
      IF(JR.EQ.NROW)GO TO 23                                            LOC 4726
      GO TO 28                                                          LOC 4727
43    IF(JR.NE.1)GO TO 44                                               LOC 4728
      L=10                                                              LOC 4729
C     VOL   SURF   SURF   VOL                                           LOC 4730
      NX1=K=1                                                           LOC 4731
      NX2=NCR+(NSN-1)*NROW+1                                            LOC 4732
      NY1=K                                                             LOC 4733
      NY2=K+NCOL                                                        LOC 4734
      GO TO 241                                                         LOC 4735
44    IF(JR.EQ.NROW)GO TO 45                                            LOC 4736
      L=12                                                              LOC 4737
C     VOL   SURF   VOL   VOL                                            LOC 4738
      NX1=K=1                                                           LOC 4739
      NX2=NCR+(NSN-1)*NROW+JR                                           LOC 4740
      NY1=K=NCOL                                                        LOC 4741
      NY2=K+NCOL                                                        LOC 4742
      GO TO 281                                                         LOC 4743
45    L=14                                                              LOC 4744
C     VOL   SURF   VOL   SURF                                           LOC 4745
      NX1=K=1                                                           LOC 4746
      NX2=NCR+NSN*NROW                                                  LOC 4747
      NY1=K=NCOL                                                        LOC 4748
      NY2=NCOL+JC                                                       LOC 4749
      GO TO 321                                                         LOC 4750
C     COMPUTE HEAT TRANSFER AND BULK FLOW TERMS                         LOC 4751
C     L=1                                                               LOC 4752
61    HX=HC(NX1)*YO                                                     LOC 4753
      HY=HC(NY1)*XO                                                     LOC 4754
      HT=-HX-HY                                                         LOC 4755
      HTT=-HX*TS(NX1,1)-HY*TS(NY1,1)                                    LOC 4756
      IF(GMX(JX1))62,64,63                                              LOC 4757
62    GX=GMX(JX1)*CP(TV(K,1))                                           LOC 4758
      ALFA(2)=GX                                                        LOC 4759
      ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                          LOC 4760
      GO TO 64                                                          LOC 4761
63    ALFA(3)=-GMX(JX1)*HV(FTEMP)                                       LOC 4762
64    IF(GMX(JX2))65,67,66                                              LOC 4763
65    GX=GMX(JX2)*CP(TV(NX2,1))                                         LOC 4764
      GAMA(2)=-GX                                                       LOC 4765
      GAMA(3)=GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                       LOC 4766
      GO TO 67                                                          LOC 4767
66    GX=GMX(JX2)*CP(TV(K,1))                                           LOC 4768
      GAMA(1)=-GX                                                       LOC 4769
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      GAMA(3)=GMX(JX2)*HV(TV(K,1))-GX*TV(K,1)                          LOC 4770
67    IF(GMY(JY1))68,70,69                                             LOC 4771
68    GY=GMY(JY1)*CP(TV(K,1))                                          LOC 4772
      BETA(2)=GY                                                       LOC 4773
      BETA(3)=-GMY(JY1)*HV(TV(K,1))+GY*TV(K,1)                         LOC 4774
      GO TO 70                                                         LOC 4775
69    BETA(3)=-GMY(JY1)*HV(FTEMP)                                      LOC 4776
70    IF(GMY(JY2))71,999,72                                            LOC 4777
71    GY=GMY(JY2)*CP(TV(NY2,1))                                        LOC 4778
      DELT(2)=-GY                                                      LOC 4779
      DELT(3)=GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                      LOC 4780
      GO TO 999                                                        LOC 4781
72    GY=GMY(JY2)*CP(TV(K,1))                                          LOC 4782
      DELT(1)=-GY                                                      LOC 4783
      DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                         LOC 4784
      GO TO 999                                                        LOC 4785
C     L=2                                                              LOC 4786
81    HT=-HC(NY1)*XO                                                   LOC 4787
      HTT=HT*TS(NY1,1)                                                 LOC 4788
      IF(GMX(JX1))82,84,83                                             LOC 4789
82    GX=GMX(JX1)*CP(TV(K,1))                                          LOC 4790
      ALFA(2)=GX                                                       LOC 4791
      ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                         LOC 4792
      GO TO 84                                                         LOC 4793
83    GX=GMX(JX1)*CP(TV(NX1,1))                                        LOC 4794
      ALFA(1)=+GX                                                      LOC 4795
      ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)                     LOC 4796
84    IF(GMX(JX2))85,87,86                                             LOC 4797
85    GX=GMX(JX2)*CP(TV(NX2,1))                                        LOC 4798
      GAMA(2)=-GX                                                      LOC 4799
      GAMA(3)=GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                      LOC 4800
      GO TO 87                                                         LOC 4801
86    GX=GMX(JX2)*CP(TV(K,1))                                          LOC 4802
      GAMA(1)=-GX                                                      LOC 4803
      GAMA(3)=GMX(JX2)*HV(TV(K,1))-GX*TV(K,1)                          LOC 4804
87    IF(GMY(JY1))88,90,89                                             LOC 4805
88    GY=GMY(JY1)*CP(TV(K,1))                                          LOC 4806
      BETA(2)=GY                                                       LOC 4807
      BETA(3)=-GMY(JY1)*HV(TV(K,1))+GY*TV(K,1)                         LOC 4808
      GO TO 90                                                         LOC 4809
89    BETA(3)=-GMY(JY1)*HV(FTEMP)                                      LOC 4810
90    IF(GMY(JY2))91,999,92                                            LOC 4811
91    GY=GMY(JY2)*CP(TV(NY2,1))                                        LOC 4812
      DELT(2)=-GY                                                      LOC 4813
      DELT(3)=GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                      LOC 4814
      GO TO 999                                                        LOC 4815
92    GY=GMY(JY2)*CP(TV(K,1))                                          LOC 4816
      DELT(1)=-GY                                                      LOC 4817
      DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                         LOC 4818
      GO TO 999                                                        LOC 4819
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  251 C   L=3                                                          LOC 4820
  252 101   HX=HC(NX2)*YD                                             LOC 4821
  253       HY=HC(NY1)*XD                                             LOC 4822
  254       HT=-HX-HY                                                 LOC 4823
  255       HTT=-HX*TS(NX2,1)-HY*TS(NY1,1)                            LOC 4824
  256       IF(GMX(JX1))102,104,103                                   LOC 4825
  257 102   GX=GMX(JX1)*CP(TV(K,1))                                   LOC 4826
  258       ALFA(2)=GX                                                LOC 4827
  259       ALFA(3)=-GMX(JX1)*HV(TV(K,1))*GX*TV(K,1)                  LOC 4828
  260       GO TO 104                                                 LOC 4829
  261 103   GX=GMX(JX1)*CP(TV(NX1,1))                                 LOC 4830
  262       ALFA(1)=-GX                                               LOC 4831
  263       ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)              LOC 4832
  264 104   IF(GMX(JX2))105,107,106                                   LOC 4833
  265 105   GAMA(3)=GMX(JX2)*HV(FTEMP)                                LOC 4834
  266       GO TO 107                                                 LOC 4835
  267 106   GX=GMX(JX2)*CP(TV(K,1))                                   LOC 4836
  268       GAMA(1)=-GX                                               LOC 4837
  269       GAMA(3)=GMX(JX2)*HV(TV(K,1))-GX*TV(K,1)                   LOC 4838
  270 107   IF(GMY(JY1))108,110,109                                   LOC 4839
  271 108   GY=GMY(JY1)*CP(TV(K,1))                                   LOC 4840
  272       BETA(2)=GY                                                LOC 4841
  273       BETA(3)=-GMY(JY1)*HV(TV(K,1))+GY*TV(K,1)                  LOC 4842
  274       GO TO 110                                                 LOC 4843
  275 109   BETA(3)=-GMY(JY1)*HV(FTEMP)                               LOC 4844
  276 110   IF(GMY(JY2))111,299,112                                   LOC 4845
  277 111   GY=GMY(JY2)*CP(TV(NY2,1))                                 LOC 4846
  278       DELT(2)=GY                                                LOC 4847
  279       DELT(3)=GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)               LOC 4848
  280       GO TO 999                                                 LOC 4849
  281 112   GY=GMY(JY2)*CP(TV(K,1))                                   LOC 4850
  282       DELT(1)=-GY                                               LOC 4851
  283       DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                  LOC 4852
  284       GO TO 999                                                 LOC 4853
  285 C   L=4                                                         LOC 4854
  286 121   HT= -HC(NX1)*YD                                           LOC 4855
  287       HTT=HT*TS(NX1,1)                                          LOC 4856
  288       IF(GMX(JX1))122,124,123                                   LOC 4857
  289 122   GX=GMX(JX1)*CP(TV(K,1))                                   LOC 4858
  290       ALFA(2)=GX                                                LOC 4859
  291       ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                  LOC 4860
  292       GO TO 124                                                 LOC 4861
  293 123   ALFA(3)=-GMX(JX1)*HV(FTEMP)                               LOC 4862
  294 124   IF(GMX(JX2))125,127,126                                   LOC 4863
  295 125   GX=GMX(JX2)*CP(TV(NX2,1))                                 LOC 4864
  296       GAMA(2)=-GX                                               LOC 4865
  297       GAMA(3)=GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)               LOC 4866
  298       GO TO 127                                                 LOC 4867
  299 126   GX=GMX(JX2)*CP(TV(K,1))                                   LOC 4868
  300       GAMA(1)=-GX                                               LOC 4869
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      GAMA(3)=GMX(JX2)*HV(TV(K,1))-GX*TV(K,1)                          LOC 4870
  127 IF(GMY(JY1))128,130,129                                          LOC 4871
  128 GY=GMY(JY1)*CP(TV(K,1))                                          LOC 4872
      BETA(2)=+GY                                                      LOC 4873
      BETA(3)=-GMY(JY1)*HV(TV(K,1))+GY*TV(K,1)                         LOC 4874
      GO TO 130                                                        LOC 4875
  129 GY=GMY(JY1)*CP(TV(NY1,1))                                        LOC 4876
      BETA(1)= GY                                                      LOC 4877
      BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                     LOC 4878
  130 IF(GMY(JY2))131,999,132                                          LOC 4879
  131 GY=GMY(JY2)*CP(TV(NY2,1))                                        LOC 4880
      DELT(2)=-GY                                                      LOC 4881
      DELT(3)=GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                      LOC 4882
      GO TO 999                                                        LOC 4883
  132 GY=GMY(JY2)*CP(TV(K,1))                                          LOC 4884
      DELT(1)=-GY                                                      LOC 4885
      DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                         LOC 4886
      GO TO 999                                                        LOC 4887
C     L=5                                                              LOC 4888
  141 HT=0.0                                                           LOC 4889
      HTT=0.0                                                          LOC 4890
      IF(GMX(JX1))142,144,143                                          LOC 4891
  142 GX=GMX(JX1)*CP(TV(K,1))                                          LOC 4892
      ALFA(2)=GX                                                       LOC 4893
      ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                         LOC 4894
      GO TO 144                                                        LOC 4895
  143 GX=GMX(JX1)*CP(TV(NX1,1))                                        LOC 4896
      ALFA(1)= GX                                                      LOC 4897
      ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)                     LOC 4898
  144 IF(GMX(JX2))145,147,146                                          LOC 4899
  145 GX=GMX(JX2)*CP(TV(NX2,1))                                        LOC 4900
      GAMA(2)=-GX                                                      LOC 4901
      GAMA(3)=GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                      LOC 4902
      GO TO 147                                                        LOC 4903
  146 GX=GMX(JX2)*CP(TV(K,1))                                          LOC 4904
      GAMA(1)=-GX                                                      LOC 4905
      GAMA(3)=GMX(JX2)*HV(TV(K,1))-GX*TV(K,1)                          LOC 4906
  147 IF(GMY(JY1))148,150,149                                          LOC 4907
  148 GY=GMY(JY1)*CP(TV(K,1))                                          LOC 4908
      BETA(2)=GY                                                       LOC 4909
      BETA(3)=-GMY(JY1)*HV(TV(K,1))+GY*TV(K,1)                         LOC 4910
      GO TO 150                                                        LOC 4911
  149 GY=GMY(JY1)*CP(TV(NY1,1))                                        LOC 4912
      BETA(1)=GY                                                       LOC 4913
      BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                     LOC 4914
  150 IF(GMY(JY2))151,999,152                                          LOC 4915
  151 GY=GMY(JY2)*CP(TV(NY2,1))                                        LOC 4916
      DELT(2)=-GY                                                      LOC 4917
      DELT(3)=GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                      LOC 4918
      GO TO 999                                                        LOC 4919
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                GY=GMY(JY2)*CP(TV(K,1))                                 LOC 4920
                DELT(1)=-GY                                             LOC 4921
                DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                LOC 4922
                GO TO 999                                               LOC 4923
C     L=6                                                               LOC 4924
161             HT=-HC(NX2)*YD                                          LOC 4925
                HTT=HT*TS(NX2,1)                                        LOC 4926
                IF(GMX(JX1))162,164,163                                 LOC 4927
162             GX=GMX(JX1)*CP(TV(K,1))                                 LOC 4928
                ALFA(2)=GX                                              LOC 4929
                ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                LOC 4930
                GO TO 164                                               LOC 4931
163             GX=GMX(JX1)*CP(TV(NX1,1))                               LOC 4932
                ALFA(1)= GX                                             LOC 4933
                ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)            LOC 4934
164             IF(GMX(JX2))165,167,166                                 LOC 4935
165             GAMA(3)= GMX(JX2)*HV(FTEMP)                             LOC 4936
                GO TO 167                                               LOC 4937
166             GX=GMX(JX2)*CP(TV(K,1))                                 LOC 4938
                GAMA(1)=-GX                                             LOC 4939
                GAMA(3)=GMX(JX2)*HV(TV(K,1))-GX*TV(K,1)                 LOC 4940
167             IF(GMY(JY1))168,170,169                                 LOC 4941
168             GY=GMY(JY1)*CP(TV(K,1))                                 LOC 4942
                BETA(2)=GY                                              LOC 4943
                BETA(3)=-GMY(JY1)*HV(TV(K,1))+GY*TV(K,1)                LOC 4944
                GO TO 170                                               LOC 4945
169             GY=GMY(JY1)*CP(TV(NY1,1))                               LOC 4946
                BETA(1)=GY                                              LOC 4947
                BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)            LOC 4948
170             IF(GMY(JY2))171,999,172                                 LOC 4949
171             GY=GMY(JY2)*CP(TV(NY2,1))                               LOC 4950
                DELT(2)=-GY                                             LOC 4951
                DELT(3)=GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)             LOC 4952
                GO TO 999                                               LOC 4953
172             GY=GMY(JY2)*CP(TV(K,1))                                 LOC 4954
                DELT(1)=-GY                                             LOC 4955
                DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                LOC 4956
                GO TO 999                                               LOC 4957
C     L=7                                                               LOC 4958
181             HX=HC(NX1)*YD                                           LOC 4959
                HY=HC(NY2)*XD                                           LOC 4960
                HT=-HX-HY                                               LOC 4961
                HTT=-HX*TS(NX1,1)-HY*TS(NY2,1)                          LOC 4962
                IF(GMX(JX1))182,184,183                                 LOC 4963
182             GX=GMX(JX1)*CP(TV(K,1))                                 LOC 4964
                ALFA(2)= GX                                             LOC 4965
                ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                LOC 4966
                GO TO 184                                               LOC 4967
183             ALFA(3)=-GMX(JX1)*HV(FTEMP)                             LOC 4968
184             IF(GMX(JX2))185,187,186                                 LOC 4969
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401 185   GX=GMX(JX2)*CP(TV(NX2,1))                                    LOC 4970
402       GAMA(2)=-GX                                                   LOC 4971
403       GAMA(3)=+GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                  LOC 4972
404       GO TO 187                                                     LOC 4973
405 186   GX=GMX(JX2)*CP(TV(K,1))                                       LOC 4974
406       GAMA(1)=-GX                                                   LOC 4975
407       GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                  LOC 4976
408 187   IF(GMY(JY1))188,190,189                                       LOC 4977
409 188   GY=GMY(JY1)*CP(TV(K  ,1))                                     LOC 4978
410       BETA(2)=+GY                                                   LOC 4979
411       BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                  LOC 4980
412       GO TO 190                                                     LOC 4981
413 189   GY=GMY(JY1)*CP(TV(NY1,1))                                     LOC 4982
414       BETA(1)=+GY                                                   LOC 4983
415       BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                  LOC 4984
416 190   IF(GMY(JY2))191,999,192                                       LOC 4985
417 191   DELT(3)=+GMY(JY2)*HV(PTEMP)                                   LOC 4986
418       GO TO 999                                                     LOC 4987
419 192   GY=GMY(JY2)*CP(TV(K  ,1))                                     LOC 4988
420       DELT(1)=-GY                                                   LOC 4989
421       DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                      LOC 4990
422       GO TO 999                                                     LOC 4991
423 C   L=8                                                             LOC 4992
424 201   HT=-HC(NY2)*XQ                                                LOC 4993
425       HTT= HT*TS(NY2,1)                                             LOC 4994
426       IF(GMX(JX1))202,204,203                                       LOC 4995
427 202   GX=GMX(JX1)*CP(TV(K,1))                                       LOC 4996
428       ALFA(2)= GX                                                   LOC 4997
429       ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                      LOC 4998
430       GO TO 204                                                     LOC 4999
431 203   GX=GMX(JX1)*CP(TV(NX1,1))                                     LOC 5000
432       ALFA(1)=GX                                                    LOC 5001
433       ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)                  LOC 5002
434 204   IF(GMX(JX2))205,207,206                                       LOC 5003
435 205   GX=GMX(JX2)*CP(TV(NX2,1))                                     LOC 5004
436       GAMA(2)=-GX                                                   LOC 5005
437       GAMA(3)=+GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                  LOC 5006
438       GO TO 207                                                     LOC 5007
439 206   GX=GMX(JX2)*CP(TV(K,1))                                       LOC 5008
440       GAMA(1)=-GX                                                   LOC 5009
441       GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                  LOC 5010
442 207   IF(GMY(JY1))208,210,209                                       LOC 5011
443 208   GY=GMY(JY1)*CP(TV(K  ,1))                                     LOC 5012
444       BETA(2)=+GY                                                   LOC 5013
445       BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                  LOC 5014
446       GO TO 210                                                     LOC 5015
447 209   GY=GMY(JY1)*CP(TV(NY1,1))                                     LOC 5016
448       BETA(1)=+GY                                                   LOC 5017
449       BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                  LOC 5018
450 210   IF(GMY(JY2))211,999,212                                       LOC 5019
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451 211    DELT(3)=+GMY(JY2)*HV(FTEMP)                                    LOC 5020
452        GO TO 999                                                      LOC 5021
453 212    GY=GMY(JY2)*CP(TV(K  ,1))                                      LOC 5022
454        DELT(1)=-GY                                                    LOC 5023
455        DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                       LOC 5024
456        GO TO 999                                                      LOC 5025
457 C   L=9                                                               LOC 5026
458 221    HX=HC(NX2)*YO                                                  LOC 5027
459        HY=HC(NY2)*XO                                                  LOC 5028
460        HT=-HX-HY                                                      LOC 5029
461        HTT=-HX*TS(NX2,1)-HY*TS(NY2,1)                                 LOC 5030
462        IF(GMX(JX1))222,224,223                                        LOC 5031
463 222    GX=GMX(JX1)*CP(TV(K,1))                                        LOC 5032
464        ALFA(2)= GX                                                    LOC 5033
465        ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                       LOC 5034
466        GO TO 224                                                      LOC 5035
467 223    GX=GMX(JX1)*CP(TV(NX1,1))                                      LOC 5036
468        ALFA(1)=GX                                                     LOC 5037
469        ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)                   LOC 5038
470 224    IF(GMX(JX2))225,227,226                                        LOC 5039
471 225    GAMA(3)=+GMX(JX2)*HV(FTEMP)                                    LOC 5040
472        GO TO 227                                                      LOC 5041
473 226    GX=GMX(JX2)*CP(TV(K,1))                                        LOC 5042
474        GAMA(1)=-GX                                                    LOC 5043
475        GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                   LOC 5044
476 227    IF(GMY(JY1))228,230,229                                        LOC 5045
477 228    GY=GMY(JY1)*CP(TV(K  ,1))                                      LOC 5046
478        BETA(2)=+GY                                                    LOC 5047
479        BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                   LOC 5048
480        GO TO 230                                                      LOC 5049
481 229    GY=GMY(JY1)*CP(TV(NY1,1))                                      LOC 5050
482        BETA(1)=+GY                                                    LOC 5051
483        BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                   LOC 5052
484 230    IF(GMY(JY2))231,999,232                                        LOC 5053
485 231    DELT(3)=+GMY(JY2)*HV(FTEMP)                                    LOC 5054
486        GO TO 999                                                      LOC 5055
487 232    GY=GMY(JY2)*CP(TV(K  ,1))                                      LOC 5056
488        DELT(1)=-GY                                                    LOC 5057
489        DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                       LOC 5058
490        GO TO 999                                                      LOC 5059
491 C   L=10                                                              LOC 5060
492 241    HX=HC(NX2)*YO/2.                                               LOC 5061
493        HY=HC(NY1)*XO                                                  LOC 5062
494        HT=-HX-HY                                                      LOC 5063
495        HTT=-HX*TS(NX2,1)-HY*TS(NY1,1)                                 LOC 5064
496        IF(GMX(JX1))242,244,243                                        LOC 5065
497 242    GX=GMX(JX1)*CP(TV(K,1))                                        LOC 5066
498        ALFA(2)= GX                                                    LOC 5067
499        ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                       LOC 5068
500        GO TO 244                                                      LOC 5069
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501 243    GX=GMX(JX1)*CP(TV(NX1,1))                                    LOC 5070
502        ALFA(1)=GX                                                   LOC 5071
503        ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)                 LOC 5072
504 244    IF(GMX(JX2))245,247,246                                      LOC 5073
505 245    GX=GMX(JX2)*CP(TV(K+1,1))                                    LOC 5074
506        GAMA(2)=-GX                                                  LOC 5075
507        GAMA(3)=+GMX(JX2)*HV(TV(K+1,1))-GX*TV(K+1,1)                 LOC 5076
508        GO TO 247                                                    LOC 5077
509 246    GX=GMX(JX2)*CP(TV(K  ,1))                                    LOC 5078
510        GAMA(1)=-GX                                                  LOC 5079
511        GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                 LOC 5080
512 247    IF(GMY(JY1))248,250,249                                      LOC 5081
513 248    GY=GMY(JY1)*CP(TV(K  ,1))                                    LOC 5082
514        BETA(2)=+GY                                                  LOC 5083
515        BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                 LOC 5084
516        GO TO 250                                                    LOC 5085
517 249    BETA(3)=-GMY(JY1)*HV(FTEMP)                                  LOC 5086
518 250    IF(GMY(JY2))251,999,252                                      LOC 5087
519 251    GY=GMY(JY2)*CP(TV(NY2,1))                                    LOC 5088
520        DELT(2)=-GY                                                  LOC 5089
521        DELT(3)=+GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                 LOC 5090
522        GO TO 999                                                    LOC 5091
523 252    GY=GMY(JY2)*CP(TV(K  ,1))                                    LOC 5092
524        DELT(1)=-GY                                                  LOC 5093
525        DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                     LOC 5094
526        GO TO 999                                                    LOC 5095
527 C   L=11                                                            LOC 5096
528 261    HX=HC(NX1)*YD/2.                                             LOC 5097
529        HY=HC(NY1)*XD                                                LOC 5098
530        HT=-HX-HY                                                    LOC 5099
531        HTT=-HX*TS(NX1,1)-HY*TS(NY1,1)                               LOC 5100
532        IF(GMX(JX1))262,264,263                                      LOC 5101
533 262    GX=GMX(JX1)*CP(TV(K,1))                                      LOC 5102
534        ALFA(2)= GX                                                  LOC 5103
535        ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                     LOC 5104
536        GO TO 264                                                    LOC 5105
537 263    GX=GMX(JX1)*CP(TV(K-1,1))                                    LOC 5106
538        ALFA(1)=GX                                                   LOC 5107
539        ALFA(3)=-GMX(JX1)*HV(TV(K-1,1))+GX*TV(K-1,1)                 LOC 5108
540 264    IF(GMX(JX2))265,267,266                                      LOC 5109
541 265    GX=GMX(JX2)*CP(TV(NX2,1))                                    LOC 5110
542        GAMA(2)=-GX                                                  LOC 5111
543        GAMA(3)=+GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                 LOC 5112
544        GO TO 267                                                    LOC 5113
545 266    GX=GMX(JX2)*CP(TV(K  ,1))                                    LOC 5114
546        GAMA(1)=-GX                                                  LOC 5115
547        GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                 LOC 5116
548 267    IF(GMY(JY1))268,270,269                                      LOC 5117
549 268    GY=GMY(JY1)*CP(TV(K  ,1))                                    LOC 5118
550        BETA(2)=+GY                                                  LOC 5119
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      BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                    LOC 5120
      GO TO 270                                                       LOC 5121
  269 BETA(3)=-GMY(JY1)*HV(FTEMP)                                     LOC 5122
  270 IF(GMY(JY2))271,999,272                                         LOC 5123
  271 GY=GMY(JY2)*CP(TV(NY2,1))                                       LOC 5124
      DELT(2)=-GY                                                     LOC 5125
      DELT(3)=+GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                    LOC 5126
      GO TO 999                                                       LOC 5127
  272 GY=GMY(JY2)*CP(TV(K  ,1))                                       LOC 5128
      DELT(1)=-GY                                                     LOC 5129
      DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                        LOC 5130
      GO TO 999                                                       LOC 5131
C     L=12                                                            LOC 5132
  281 HT=-HC(NX2)*YO/2.                                               LOC 5133
      HTT= HT*TS(NX2,1)                                               LOC 5134
      IF(GMX(JX1))282,284,283                                         LOC 5135
  282 GX=GMX(JX1)*CP(TV(K,1))                                         LOC 5136
      ALFA(2)= GX                                                     LOC 5137
      ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                        LOC 5138
      GO TO 284                                                       LOC 5139
  283 GX=GMX(JX1)*CP(TV(NX1,1))                                       LOC 5140
      ALFA(1)=GX                                                      LOC 5141
      ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)                    LOC 5142
  284 IF(GMX(JX2))285,287,286                                         LOC 5143
  285 GX=GMX(JX2)*CP(TV(K+1,1))                                       LOC 5144
      GAMA(2)=-GX                                                     LOC 5145
      GAMA(3)=+GMX(JX2)*HV(TV(K+1,1))-GX*TV(K+1,1)                    LOC 5146
      GO TO 287                                                       LOC 5147
  286 GX=GMX(JX2)*CP(TV(K  ,1))                                       LOC 5148
      GAMA(1)=-GX                                                     LOC 5149
      GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                    LOC 5150
  287 IF(GMY(JY1))288,290,289                                         LOC 5151
  288 GY=GMY(JY1)*CP(TV(K  ,1))                                       LOC 5152
      BETA(2)=+GY                                                     LOC 5153
      BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                    LOC 5154
      GO TO 290                                                       LOC 5155
  289 GY=GMY(JY1)*CP(TV(NY1,1))                                       LOC 5156
      BETA(1)=+GY                                                     LOC 5157
      BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                    LOC 5158
  290 IF(GMY(JY2))291,999,292                                         LOC 5159
  291 GY=GMY(JY2)*CP(TV(NY2,1))                                       LOC 5160
      DELT(2)=-GY                                                     LOC 5161
      DELT(3)=+GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)                    LOC 5162
      GO TO 999                                                       LOC 5163
  292 GY=GMY(JY2)*CP(TV(K  ,1))                                       LOC 5164
      DELT(1)=-GY                                                     LOC 5165
      DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                        LOC 5166
      GO TO 999                                                       LOC 5167
C     L=13                                                            LOC 5168
  301 HT=-HC(NX1)*YO/2.                                               LOC 5169
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  601          HTT= HT*TS(NX1,1)                                          LOC 5170
  602          IF(GMX(JX1))302,304,303                                    LOC 5171
  603 302      GX=GMX(JX1)*CP(TV(K,1))                                    LOC 5172
  604          ALFA(2)= GX                                                LOC 5173
  605          ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                   LOC 5174
  606          GO TO 304                                                  LOC 5175
  607 303      GX=GMX(JX1)*CP(TV(K-1,1))                                  LOC 5176
  608          ALFA(1)=GX                                                 LOC 5177
  609          ALFA(3)=-GMX(JX1)*HV(TV(K-1,1))+GX*TV(K-1,1)               LOC 5178
  610 304      IF(GMX(JX2))305,307,306                                    LOC 5179
  611 305      GX=GMX(JX2)*CP(TV(NX2,1))                                  LOC 5180
  612          GAMA(2)=-GX                                                LOC 5181
  613          GAMA(3)=+GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)               LOC 5182
  614          GO TO 307                                                  LOC 5183
  615 306      GX=GMX(JX2)*CP(TV(K  ,1))                                  LOC 5184
  616          GAMA(1)=-GX                                                LOC 5185
  617          GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)               LOC 5186
  618 307      IF(GMY(JY1))308,310,309                                    LOC 5187
  619 308      GY=GMY(JY1)*CP(TV(K  ,1))                                  LOC 5188
  620          BETA(2)=+GY                                                LOC 5189
  621          BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)               LOC 5190
  622          GO TO 310                                                  LOC 5191
  623 309      GY=GMY(JY1)*CP(TV(NY1,1))                                  LOC 5192
  624          BETA(1)=+GY                                                LOC 5193
  625          BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)               LOC 5194
  626 310      IF(GMY(JY2))311,999,312                                    LOC 5195
  627 311      GY=GMY(JY2)*CP(TV(NY2,1))                                  LOC 5196
  628          DELT(2)=-GY                                                LOC 5197
  629          DELT(3)=+GMY(JY2)*HV(TV(NY2,1))-GY*TV(NY2,1)               LOC 5198
  630          GO TO 999                                                  LOC 5199
  631 312      GY=GMY(JY2)*CP(TV(K  ,1))                                  LOC 5200
  632          DELT(1)=-GY                                                LOC 5201
  633          DELT(3)=+GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                   LOC 5202
  634          GO TO 999                                                  LOC 5203
  635 C    L=14                                                           LOC 5204
  636 321      HX=HC(NX2)*YO/2.                                           LOC 5205
  637          HY=HC(NY2)*XO                                              LOC 5206
  638          HT=-HX-HY                                                  LOC 5207
  639          HTT=-HX*TS(NX2,1)-HY*TS(NY2,1)                             LOC 5208
  640          IF(GMX(JX1))322,324,323                                    LOC 5209
  641 322      GX=GMX(JX1)*CP(TV(K,1))                                    LOC 5210
  642          ALFA(2)= GX                                                LOC 5211
  643          ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                   LOC 5212
  644          GO TO 324                                                  LOC 5213
  645 323      GX=GMX(JX1)*CP(TV(NX1,1))                                  LOC 5214
  646          ALFA(1)=GX                                                 LOC 5215
  647          ALFA(3)=-GMX(JX1)*HV(TV(NX1,1))+GX*TV(NX1,1)               LOC 5216
  648 324      IF(GMX(JX2))325,327,326                                    LOC 5217
  649 325      GX=GMX(JX2)*CP(TV(K+1,1))                                  LOC 5218
  650          GAMA(2)=-GX                                                LOC 5219
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      GAMA(3)=+GMX(JX2)*HV(TV(K+1,1))-GX*TV(K+1,1)                    LOC 5220
      GO TO 327                                                       LOC 5221
  326 GX=GMX(JX2)*CP(TV(K  ,1))                                       LOC 5222
      GAMA(1)=-GX                                                     LOC 5223
      GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                    LOC 5224
  327 IF(GMY(JY1))328,330,329                                         LOC 5225
  328 GY=GMY(JY1)*CP(TV(K  ,1))                                       LOC 5226
      BETA(2)=+GY                                                     LOC 5227
      BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                    LOC 5228
      GO TO 330                                                       LOC 5229
  329 GY=GMY(JY1)*CP(TV(NY1,1))                                       LOC 5230
      BETA(1)=+GY                                                     LOC 5231
      BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                    LOC 5232
  330 IF(GMY(JY2))331,999,332                                         LOC 5233
  331 DELT(3)=+GMY(JY2)*HV(FTEMP)                                     LOC 5234
      GO TO 999                                                       LOC 5235
  332 GY=GMY(JY2)*CP(TV(K  ,1))                                       LOC 5236
      DELT(1)=-GY                                                     LOC 5237
      DELT(3)=GMY(JY2)*HV(TV(K,1))-GY*TV(K,1)                         LOC 5238
      GO TO 999                                                       LOC 5239
C   L=15                                                              LOC 5240
  341 HX=HC(NX1)*XO/2.                                                LOC 5241
      HY=HC(NY2)*XO                                                   LOC 5242
      HT=-HX-HY                                                       LOC 5243
      HTT=-HX*TS(NX1,1)-HY*TS(NY2,1)                                  LOC 5244
      IF(GMX(JX1))342,344,343                                         LOC 5245
  342 GX=GMX(JX1)*CP(TV(K,1))                                         LOC 5246
      ALFA(2)= GX                                                     LOC 5247
      ALFA(3)=-GMX(JX1)*HV(TV(K,1))+GX*TV(K,1)                        LOC 5248
      GO TO 344                                                       LOC 5249
  343 GX=GMX(JX1)*CP(TV(K-1,1))                                       LOC 5250
      ALFA(1)= GX                                                     LOC 5251
      ALFA(3)=-GMX(JX1)*HV(TV(K-1,1))+GX*TV(K-1,1)                    LOC 5252
  344 IF(GMX(JX2))345,347,346                                         LOC 5253
  345 GX=GMX(JX2)*CP(TV(NX2,1))                                       LOC 5254
      GAMA(2)=-GX                                                     LOC 5255
      GAMA(3)=+GMX(JX2)*HV(TV(NX2,1))-GX*TV(NX2,1)                    LOC 5256
      GO TO 347                                                       LOC 5257
  346 GX=GMX(JX2)*CP(TV(K  ,1))                                       LOC 5258
      GAMA(1)=-GX                                                     LOC 5259
      GAMA(3)=+GMX(JX2)*HV(TV(K  ,1))-GX*TV(K  ,1)                    LOC 5260
  347 IF(GMY(JY1))348,350,349                                         LOC 5261
  348 GY=GMY(JY1)*CP(TV(K  ,1))                                       LOC 5262
      BETA(2)=GY                                                      LOC 5263
      BETA(3)=-GMY(JY1)*HV(TV(K  ,1))+GY*TV(K  ,1)                    LOC 5264
      GO TO 350                                                       LOC 5265
  349 GY=GMY(JY1)*CP(TV(NY1,1))                                       LOC 5266
      BETA(1)=GY                                                      LOC 5267
      BETA(3)=-GMY(JY1)*HV(TV(NY1,1))+GY*TV(NY1,1)                    LOC 5268
  350 IF(GMY(JY2))351,999,352                                         LOC 5269
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  701 351   DELT(3)=GMY(JY2)*HV(PTEMP)                                  LOC 5270
  702       GO TO 999                                                    LOC 5271
  703 352   GY=GMY(JY2)*CP(TV(K  ,1))                                    LOC 5272
  704       DELT(1)=GY                                                   LOC 5273
  705       DELT(3)=GMY(JY2) *HV(TV(K,1))-GY*TV(K,1)                     LOC 5274
  706 999   LOC=L                                                        LOC 5275
  707       RETURN                                                       LOC 5276
  708       END                                                          LOC 5277
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```
      SUBROUTINE CL4                                                    CL4 5278
C   COMPUTION OF TOTAL INTERCHANGE AREA === REAL GAS                    CL4 5279
C   COMPUTION HAS TWO PARTS                                             CL4 5280
C      HCODE=0    INITAL CALULATION OF GAS VOLUME INTERCHANGE AREAS     CL4 5281
C           =10   UPDATE INTERCHANGE AREAS WITH NEW TEMPERTURES         CL4 5282
C      ICODE=0    INITAL CALULATION OF SURFACE AREA INTERCHANGE AREAS   CL4 5283
C           =10   UPDATE INTERCHANGE AREA WITH NEW TEMPERTURES          CL4 5284
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CL4 5285
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    CL4 5286
     A TBRIDG, PRES, FLUET, FLUE(5), XNWX, TSINK,                       CL4 5287
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    CL4 5288
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CL4 5289
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     CL4 5290
     A KSTART, TCODE, SCODE, NGRAY, JHCHC,                              CL4 5291
     A K1, K2, RCRD(10), TDEP(100), PERM(200),NPRNT                     CL4 5292
C                                                                       CL4 5293
      INTEGER SCODE,TCODE,RSTART,HCODE                                  CL4 5294
      COMMON/SPCE4/AA( 60, 60),BB( 60,15)                               CL4 5295
      COMMON/JAZZ4/TSSNM(8,4), TGSNM(8,3),TSGNM(8,3),TGGNM(8,3),        CL4 5296
     1SS(8),GS(8),SG(8),GG(8)                                           CL4 5297
      DIMENSION T( 60),Z( 60)                                           CL4 5298
      CALL READ(1,'XLUM',Z(1), 60)                                      CL4 5299
      IJK=HCODE+ICODE                                                   CL4 5300
      IF(IJK.EQ.0)GO TO 11                                              CL4 5301
      IF(HCODE.EQ.10)GO TO 11                                           CL4 5302
      IF(ICODE.EQ.10)GO TO 31                                           CL4 5303
   11 CONTINUE                                                          CL4 5304
      CALL READ(2,'TEMG',T(1), 60)                                      CL4 5305
      CALL WRITE(3,'TEMG',T(1), 60)                                     CL4 5306
C   KK=GAS NUMBER                                                       CL4 5307
C  GAS TO SURFACE INTERCHANGE AREA                                      CL4 5308
      CALL PZERO(AA(1,1), 3600)                                         CL4 5309
      DO 18 KK=1,NGRAY                                                  CL4 5310
      DO 17 J=1,NSGBLK                                                  CL4 5311
      MM=15*(J-1)                                                       CL4 5312
      CALL READ(1,TSGNM(J,KK),BB(1,1), 900)                             CL4 5313
      IF(J.EQ.NSGBLK)GO TO 13                                           CL4 5314
      NMAX=15                                                           CL4 5315
      GO TO 14                                                          CL4 5316
   13 NMAX=NVOL-(NSGBLK-1)*15                                           CL4 5317
   14 DO 16 N=1,NMAX                                                    CL4 5318
      M=MM+N                                                            CL4 5319
      ZZ=EXP(EQUA(T(M)/1000.,ACOEF(1,KK)))*Z(M)                         CL4 5320
      DO 15 L=1,NSURF                                                   CL4 5321
      AA(L,M)=AA(L,M)+BB(L,N)*ZZ                                        CL4 5322
   15 CONTINUE                                                          CL4 5323
   16 CONTINUE                                                          CL4 5324
   17 CONTINUE                                                          CL4 5325
   18 CONTINUE                                                          CL4 5326
      DO 19 J=1,NSGBLK                                                  CL4 5327
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      CALL WRITE(2,SG(J),AA(1,15*J-14), 900)                            CL4 5328
19    CONTINUE                                                          CL4 5329
6000  IF(NPRNT.EQ.1)GO TO 22                                            CL4 5330
      WRITE(K2,5001)(T(N),N=1,NVOL)                                     CL4 5331
5001  FORMAT(1H1,19X,'GAS VOLUME TEMPERATURES USED IN EVALUATION OF GAS CL4 5332
     1VOLUMES'/20X,'TEMPERATURE DEPENDENT INTERCHANGE AREA,DEG. R'//(25X,CL4 5333
     26F15.3))                                                          CL4 5334
      WRITE(K2,6001)                                                    CL4 5335
6001  FORMAT(/'1 ',20X,'VOLUME TO SURFACE INTERCHANGE AREA')            CL4 5336
      CALL PRINT(AA,NSURF,NVOL)                                         CL4 5337
C      GAS TO GAS INTERCHANGE AREA                                      CL4 5338
22    CALL PZERO(AA(1,1), 3600)                                         CL4 5339
      DO 28 KK=1,NGRAY                                                  CL4 5340
      DO 27 J=1,NGGBLK                                                  CL4 5341
      MM=15*(J-1)                                                       CL4 5342
      CALL READ(1,TGGNM(J,KK),BB(1,1), 900)                             CL4 5343
      IF(J.EQ.NGGBLK)GO TO 23                                           CL4 5344
      NMAX=15                                                           CL4 5345
      GO TO 24                                                          CL4 5346
23    NMAX=NVOL-(NGGBLK-1)*15                                           CL4 5347
24    DO 26 N=1,NMAX                                                    CL4 5348
      M=MM+N                                                            CL4 5349
      ZZ=EXP(EQUA(T(M)/5000.,ACOEF(1,KK)))*Z(M)                         CL4 5350
      DO 25 L=1,NVOL                                                    CL4 5351
      AA(L,M)=AA(L,M)+BB(L,N)*ZZ*Z(L)                                   CL4 5352
25    CONTINUE                                                          CL4 5353
26    CONTINUE                                                          CL4 5354
27    CONTINUE                                                          CL4 5355
28    CONTINUE                                                          CL4 5356
         DO 29 J=1,NGGBLK                                               CL4 5357
      CALL WRITE(2,GG(J),AA(1,15*J-14), 900)                            CL4 5358
29    CONTINUE                                                          CL4 5359
      IF(NPRNT.EQ.1)GO TO 30                                            CL4 5360
6010  WRITE(K2,6002)                                                    CL4 5361
6002  FORMAT(/'1 ',20X,'VOLUME TO VOLUME INTERCHANGE AREA')             CL4 5362
      CALL PRINT(AA,NVOL,NVOL)                                          CL4 5363
30    CONTINUE                                                          CL4 5364
      IF(IJK.EQ.0)GO TO 31                                              CL4 5365
      GO TO 67                                                          CL4 5366
C   PART 2   SURFACE AREA TEMPERTATURE DEPENDENT                        CL4 5367
31    CALL READ(2,'TEMS',T(1), 60)                                      CL4 5368
      CALL WRITE(3,'TEMS',T(1), 60)                                     CL4 5369
C   SURFACE TO SURFACE INTERCHANGE AREA                                 CL4 5370
C   KK=GAS NUMBER                                                       CL4 5371
      CALL PZERO(AA(1,1), 3600)                                         CL4 5372
      KMAX=1+NGRAY                                                      CL4 5373
      DO 45 K=1,KMAX                                                    CL4 5374
      IF(K.EQ.KMAX)GO TO 33                                             CL4 5375
      KK=K                                                              CL4 5376
      GO TO 34                                                          CL4 5377
```

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101 33     KK=4                                                          CL4 5378
102 34     DO 44 J=1,NSSBLK                                              CL4 5379
103        MM=15*(J-1)                                                   CL4 5380
104        CALL READ(1,TSSNM(J,KK),BB(1,1), 900)                         CL4 5381
105        IF(J.EQ.NSSBLK)GO TO 36                                       CL4 5382
106        NMAX=15                                                       CL4 5383
107        GO TO 37                                                      CL4 5384
108 36     NMAX=NSURF-(NSSBLK-1)*15                                      CL4 5385
109 37     DO 43 N=1,NMAX                                                CL4 5386
110        M=MM+N                                                        CL4 5387
111        IF(KK.EQ.4)GO TO 38                                           CL4 5388
112        ZZ=EXP(EQUA(T(M)/1000.,ACOEF(1,KK)))                          CL4 5389
113        GO TO 41                                                      CL4 5390
114 38     ZZ=1.                                                         CL4 5391
115        DO 40 I=1,NGRAY                                               CL4 5392
116        ZZ=ZZ-EXP(EQUA(T(M)/1000.,ACOEF(1,I)))                        CL4 5393
117 40     CONTINUE                                                      CL4 5394
118 41     DO 42 L=1,NSURF                                               CL4 5395
119        AA(L,N)=AA(L,M)+BB(L,N)*ZZ                                    CL4 5396
120 42     CONTINUE                                                      CL4 5397
121 43     CONTINUE                                                      CL4 5398
122 44     CONTINUE                                                      CL4 5399
123 45     CONTINUE                                                      CL4 5400
124        DO 47 J=1,NSSBLK                                              CL4 5401
125        CALL WRITE(2,SS(J),AA(1,15*J-14), 900)                        CL4 5402
126 47     CONTINUE                                                      CL4 5403
127 7000   IF(NPRNT.EQ.1)GO TO 52                                        CL4 5404
128        WRITE(K2,5002)(T(N),N=1,NSURF)                                CL4 5405
129 5002   FORMAT(1H1,19X,'SURFACE AREA TEMPERTURE USED IN EVALUATING SURFACE CL4 5406
130       1AREA'/20X,'TEMPERTURE DEPENDENT INTERCHANGE AREA,DEG R'//(25X,6F15CL4 5407
131       2.3))                                                         CL4 5408
132        WRITE(K2,7001)                                                CL4 5409
133 7001   FORMAT(//1 ',20X,'SURFACE TO SURFACE INTERCHANGE AREA')        CL4 5410
134        CALL PRINT(AA,NSURF,NSURF)                                    CL4 5411
135 C    SURFACE TO SURFACE INTERCHANGE AREA                             CL4 5412
136 C    KK=GAS NUMBER                                                   CL4 5413
137 52     CALL PZERO(AA(1,1), 3600)                                     CL4 5414
138        DO 58 KK=1,NGRAY                                              CL4 5415
139        DO 57 J=1,NGSBLK                                              CL4 5416
140        MM=(J-1)*15                                                   CL4 5417
141        CALL READ(1,TGSNM(J,KK),BB(1,1), 900)                         CL4 5418
142        IF(J.EQ.NGSBLK)GO TO 53                                       CL4 5419
143        NMAX=15                                                       CL4 5420
144        GO TO 54                                                      CL4 5421
145 53     NMAX=NSURF-(NGSBLK-1)*15                                      CL4 5422
146 54     DO 56 N=1,NMAX                                                CL4 5423
147        M=MM+N                                                        CL4 5424
148        ZZ=EXP(EQUA(T(M)/1000.,ACOEF(1,KK)))                          CL4 5425
149        DO 55 L=1,NVUL                                                CL4 5426
150        AA(L,M)=AA(L,M)+BB(L,N)*ZZ*Z(L)                               CL4 5427
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      CONTINUE                                                          CL4 5428
      CONTINUE                                                          CL4 5429
   57 CONTINUE                                                          CL4 5430
   58 CONTINUE                                                          CL4 5431
      DO 59 J=1,NGSBLK                                                  CL4 5432
      CALL WRITE(2,GS(J),AA(1,15*J-14), 900)                            CL4 5433
   59 CONTINUE                                                          CL4 5434
      IF(NPRNT.EQ.1)GO TO 67                                            CL4 5435
 7010 WRITE(K2,7011)                                                    CL4 5436
 7011 FORMAT(/11 1,20X,'SURFACE TO VOLUME INTERCHANGE AREA!')           CL4 5437
      CALL PRINT(AA,NVOL,NSURF)                                         CL4 5438
   67 RETURN                                                            CL4 5439
      END                                                               CL4 5440
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```
      SUBROUTINE CL5                                                    CL5 5441
C   GAS VOLUME HEAT BALANCE                                             CL5 5442
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CL5 5443
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    CL5 5444
     A TBRIDG, PRES, FLUET, FLUE(5), XHWX, TSINK,                       CL5 5445
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    CL5 5446
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CL5 5447
     A XSUREX(2), XO, YO, ZLCNC, NCOL, NROW, NXSXN,                     CL5 5448
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              CL5 5449
     A K1, K2, RCRD(10), TDEP(100), PERM(200),NPRNT                     CL5 5450
C                                                                       CL5 5451
      INTEGER SCODE,TCODE,RSTART,HCODE                                  CL5 5452
      EQUIVALENCE (DUMMY(1),NFMAX),(PERM(199),DHTCL5)                   CL5 5453
      COMMON/GAS/ NX1,NX2,NY1,NY2,HT,HTT,XTEST,ALFA(3),BETA(3),GAMA(3), CL5 5454
     1DELT(3),GMX(120),GMY(120),HC( 60),JX1,JX2,JY1,JY2                 CL5 5455
      COMMON/TTT/TV(120,2),TS(120,2)                                    CL5 5456
      COMMON/JAZZ5/ GS(8),SG(8),GG(8)                                   CL5 5457
      COMMON/CPHV/CPCP(11),HVHV(12)                                     CL5 5458
      DIMENSION AA( 60, 60),RHS( 60),AAA( 60, 61),ET( 60),ZZ( 60),MM( 60CL5 5459
     1)                                                                 CL5 5460
      EQUIVALENCE (AA(1,1),AAA(1,1)),(RHS(1),AAA(1, 61)),(ZZ(1),MM(1))  CL5 5461
      DATA SIG /0.1713E-8/                                              CL5 5462
      HCODE=1                                                           CL5 5463
      NFIX=0                                                            CL5 5464
      XTEST=.10*XO                                                      CL5 5465
C   RETRIEVE DATA                                                       CL5 5466
C     SURFACE AND VOLUME TEMPERATURES                                   CL5 5467
C     HEAT RELEASE PATTERN                                              CL5 5468
C   BULK FLOW PATTERN                                                   CL5 5469
C   GAS --- SURFACE HEAT TRANSFER COEFFICIENT                           CL5 5470
      CALL READ(2,'TEMG',TV(1,1), 60)                                   CL5 5471
      CALL READ(2,'TEMS',TS(1,1), 60)                                   CL5 5472
      CALL READ(2,'HGAS',ET(1), 60)                                     CL5 5473
      NX=(NCOL+1)*NROW                                                  CL5 5474
      NY=(NROW+1)*NCOL                                                  CL5 5475
      CALL READ(2,'GMY ',GMY(1),  NY)                                   CL5 5476
      CALL READ(2,'GMX ',GMX(1),  NX)                                   CL5 5477
      CALL READ(2,'HC  ',HC(1), 60)                                     CL5 5478
      CALL READ(2,'CP  ',CPCP(1),11)                                    CL5 5479
      CALL READ(2,'HV  ',HVHV(1),12)                                    CL5 5480
C   COMPUTE TEMPERATURE FACTORS (T**3 ANDT**4)                          CL5 5481
      DO 4 J=1,NSURF                                                    CL5 5482
      TS(J,2)=TS(J,1)                                                   CL5 5483
4     CONTINUE                                                          CL5 5484
10    DO 11 J=1,NVOL                                                    CL5 5485
      TV(J,2)=TV(J,1)**3                                                CL5 5486
11    CONTINUE                                                          CL5 5487
C   PUT SURFACE TO GAS INTERCHANGE AREA IN AA                           CL5 5488
      CALL PZERO(AA(1,1), 3600)                                         CL5 5489
      DO 15 J=1,NGSBLK                                                  CL5 5490
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      CALL READ(2,GS(J),AA(1,15*J-14), 900)                              CL5 5491
15    CONTINUE                                                           CL5 5492
C   COMPUTE S-G CONTRIBUTION TO RHS --- SUM OVER SURFACE EMITTER FOR     CL5 5493
C   EACH GAS RECEIVER ACCOUNTING FOR TEMPERATURE OF EMITTER             CL5 5494
      DO 17 I=1,NVOL                                                     CL5 5495
      RHS(I)=0.0                                                         CL5 5496
      DO 16 J=1,NSURF                                                    CL5 5497
      RHS(I)=RHS(I)+AA(I,J)*TS(J,2)                                      CL5 5498
16    CONTINUE                                                           CL5 5499
      RHS(I)=RHS(I)*(-SIG)                                               CL5 5500
17    CONTINUE                                                           CL5 5501
C   PUT GAS TO SURFACE AREA IN AA                                        CL5 5502
      CALL PZERO(AA(1,1), 3600)                                          CL5 5503
      DO 23 J=1,NSGBLK                                                   CL5 5504
      CALL READ(2,SG(J),AA(1,15*J-14), 900)                              CL5 5505
23    CONTINUE                                                           CL5 5506
C   COMPUTE G-S CONTRIBUTION TO DIAGONAL OF MATRIX AA AND SAVE IN        CL5 5507
C   TEMPERARY STORAGE -- SUM OVER SURFACE RECEIVER FOR EACH GAS          CL5 5508
C   EMITTER AND STORE IN ZZ                                              CL5 5509
      DO 25 J=1,NVOL                                                     CL5 5510
      ZZ(J)=0.0                                                          CL5 5511
      DO 24 I=1,NSURF                                                    CL5 5512
      ZZ(J)=ZZ(J)+AA(I,J)                                                CL5 5513
24    CONTINUE                                                           CL5 5514
25    CONTINUE                                                           CL5 5515
C   PUT G-G TOTAL INTERCHANGE AREA IN AA                                 CL5 5516
      CALL PZERO(AA(1,1), 3600)                                          CL5 5517
      DO 27 J=1,NGGBLK                                                   CL5 5518
      CALL READ(2,GG(J),AA(1,15*J-14), 900)                              CL5 5519
27    CONTINUE                                                           CL5 5520
C   COMPUTE G-G CONTRIBUTION TO DIAGONAL OF MATRIX AA AND SAVE IN        CL5 5521
C   TEMPERARY STORAGE ALONG WITH G-S CONTRIBUTIONS -- SUM OVER GAS       CL5 5522
C   RECEIVER FOR EACH GAS EMITTER AND ADD IN TEMPORARY STORAGE  ZZ       CL5 5523
C   WHEN FINISHED MULTIPLY BY MINUS SIGMA                                CL5 5524
      DO 29 J=1,NVOL                                                     CL5 5525
      DO 28 I=1,NVOL                                                     CL5 5526
      ZZ(J)=ZZ(J)+AA(I,J)                                                CL5 5527
28    CONTINUE                                                           CL5 5528
      ZZ(J)=ZZ(J)*(-SIG)                                                 CL5 5529
29    CONTINUE                                                           CL5 5530
C   MULTIPLY AA BY SIMGA                                                 CL5 5531
      DO 32 J=1,NVOL                                                     CL5 5532
      DO 31 I=1,NVOL                                                     CL5 5533
      AA(I,J)=AA(I,J)*SIG                                                CL5 5534
31    CONTINUE                                                           CL5 5535
32    CONTINUE                                                           CL5 5536
C   EACH GAS VOLUME MUST BE ANALYED INDIVDUALLY TO DERTERMINE            CL5 5537
C   CONVECTIVE HEAT TRANSFER TERMS                                       CL5 5538
C     1 -- BULK FLOW ADJACENT SURFACE AND VOLUMES                        CL5 5539
C     2 -- SURFACE HEAT TRANSFER INTO GAS VOLUME                         CL5 5540
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```
      I=1                                                                CL5 5541
50    LL=LOC(I)                                                          CL5 5542
      AA(I,I)=AA(I,I)+(HT+ALFA(2)+BETA(2)+GAMA(1)+DELT(1))/TV(I,2)+ZZ(I) CL5 5543
      RHS(I)=RHS(I)+(HTT+ALFA(3)+BETA(3)+GAMA(3)+DELT(3))*ET(I)          CL5 5544
      GO TO(51,52,53,54,55,56,57,58,59,510,511,512,513,514,515),LL       CL5 5545
C     LL=1                                                               CL5 5546
51    AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5547
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5548
      GO TO 60                                                           CL5 5549
C     LL=2                                                               CL5 5550
52    AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5551
      AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5552
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5553
      GO TO 60                                                           CL5 5554
C     LL=3                                                               CL5 5555
53    AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5556
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5557
      GO TO 60                                                           CL5 5558
C     LL=4                                                               CL5 5559
54    AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5560
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5561
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5562
      GO TO 60                                                           CL5 5563
C     LL=5                                                               CL5 5564
55    AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5565
      AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5566
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5567
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5568
      GO TO 60                                                           CL5 5569
C     LL=6                                                               CL5 5570
56    AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5571
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5572
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5573
      GO TO 60                                                           CL5 5574
C     LL=7                                                               CL5 5575
57    AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5576
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5577
      GO TO 60                                                           CL5 5578
C     LL=8                                                               CL5 5579
58    AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5580
      AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5581
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5582
      GO TO 60                                                           CL5 5583
C     LL=9                                                               CL5 5584
59    AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5585
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5586
      GO TO 60                                                           CL5 5587
C     LL=10                                                              CL5 5588
510   AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5589
      AA(I,I+1)=AA(I,I+1)+GAMA(2)/TV(I+1,2)                              CL5 5590
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```
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5591
      GO TO 60                                                           CL5 5592
C   LL=11                                                                CL5 5593
511   AA(I,I-1)=AA(I,I-1)+ALFA(1)/TV(I-1,2)                              CL5 5594
      AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5595
      AA(I,NY2)=AA(I,NY2)+DELT(2)/TV(NY2,2)                              CL5 5596
      GO TO 60                                                           CL5 5597
C   LL=12                                                                CL5 5598
512   AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5599
      AA(I,I+1)=AA(I,I+1)+GAMA(2)/TV(I+1,2)                              CL5 5600
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5601
      AA(I,Ny2)=AA(I,Ny2)+DELT(2)/TV(Ny2,2)                              CL5 5602
      GO TO 60                                                           CL5 5603
C   LL=13                                                                CL5 5604
513   AA(I,I-1)=AA(I,I-1)+ALFA(1)/TV(I-1,2)                              CL5 5605
      AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NY2,2)                              CL5 5606
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5607
      AA(I,Ny2)=AA(I,Ny2)+DELT(2)/TV(Ny2,2)                              CL5 5608
      GO TO 60                                                           CL5 5609
C   LL=14                                                                CL5 5610
514   AA(I,NX1)=AA(I,NX1)+ALFA(1)/TV(NX1,2)                              CL5 5611
      AA(I,I+1)=AA(I,I+1)+GAMA(2)/TV(I+1,2)                              CL5 5612
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5613
      GO TO 60                                                           CL5 5614
C   LL=15                                                                CL5 5615
515   AA(I,I-1)=AA(I,I-1)+ALFA(1)/TV(I-1,2)                              CL5 5616
      AA(I,NX2)=AA(I,NX2)+GAMA(2)/TV(NX2,2)                              CL5 5617
      AA(I,NY1)=AA(I,NY1)+BETA(1)/TV(NY1,2)                              CL5 5618
60    IF(I.EQ.NVOL)GO TO 61                                              CL5 5619
      I=I+1                                                              CL5 5620
      GO TO 50                                                           CL5 5621
C   FOR VOLUMES WITH KNOWED TEMPERATURE SET DIAGONAL OF AA EQUAL TO      CL5 5622
C   1.0 AND RHS=T**4                                                     CL5 5623
61    CALL READ(2,'CONV1,MM(1), 60)                                      CL5 5624
      DO 63 I=1,NVOL                                                     CL5 5625
      IF(MM(I).EQ.0)GO TO 63                                             CL5 5626
      DO 62 J=1,NVOL                                                     CL5 5627
      AA(I,J)=0.0                                                        CL5 5628
62    CONTINUE                                                           CL5 5629
      AA(I,I)=1.                                                         CL5 5630
      RHS(I)=TV(I,1)**4                                                  CL5 5631
63    CONTINUE                                                           CL5 5632
C   SOLVE FOR TEMPERATURE OF GAS VOLUME RAISED TO THE FORTH POWER AND    CL5 5633
C   THAN EXTRACT THE FOURTH ROOT                                         CL5 5634
      N=NVOL+1                                                           CL5 5635
      DO 67 I=1,NVOL                                                     CL5 5636
      AAA(I,N)=RHS(I)                                                    CL5 5637
67    CONTINUE                                                           CL5 5638
      IF(NPRNT.EQ.1)GO TO 681                                            CL5 5639
671   WRITE(K2,6000)                                                     CL5 5640
```

```
      6000  FORMAT(1H1,19X,'GAS VOLUME ENERGY   BALANCE')                    CL5 5641
            CALL PRINT(AAA,NVOL,N)                                           CL5 5642
      681   CALL ISIMEQ(AAA, 60, 61,NVOL)                                    CL5 5643
            DT=0.0                                                           CL5 5644
            DO 69 I=1,NVOL                                                   CL5 5645
            RHS(I)=SQRT(SQRT(AAA(I,N)))                                      CL5 5646
            DT=AMAX1(ABS(RHS(I)-TV(I,1)),DT)                                 CL5 5647
            DEL=RHS(I)-TV(I,1)                                               CL5 5648
            TV(I,1)=TV(I,1)+SIGN(AMIN1(ABS(DEL),250.0),DEL)                  CL5 5649
      69    CONTINUE                                                         CL5 5650
      71    NFIX=NFIX+1                                                      CL5 5651
            IF(DT.LT.5.*DHTCL5.OR.NFIX.EQ.NFMAX)GO TO 81                     CL5 5652
            IF(DT.LT.250.)GO TO 10                                           CL5 5653
            GO TO 85                                                         CL5 5654
C     COMPARE TEMPERATURES OBTAINED FROM GAS VOLUME HEAT BALANCE WITH        CL5 5655
C     THOSE USED IN OBTAINING GAS VOLUME TEMPERATURE DEPENDENT               CL5 5656
C     INTERCHANGE AREA (G-G AND G-S                                          CL5 5657
      81    CALL READ(3,'TEMG',ZZ(1), 60)                                    CL5 5658
            DT=0.0                                                           CL5 5659
            DO 82 I=1,NVOL                                                   CL5 5660
            DT=AMAX1(ABS(ZZ(I)-TV(I,1)) ,DT)                                CL5 5661
      82    CONTINUE                                                         CL5 5662
            IF(DT.LT.DHTCL5)NCODE=2                                          CL5 5663
      85    CALL WRITE(2,'TEMG',TV(1,1), 60)                                 CL5 5664
            WRITE(6,3003)DT                                                  CL5 5665
            IF(NPRNT.EQ.1)GO TO 86                                           CL5 5666
            WRITE(K2,3002) (TV(N,1),N=1,NVOL)                                CL5 5667
      3002  FORMAT(///20X,'COMPUTED GAS VOLUME TEMPERATURES,DEG.R'///(25X,6F15.3CL5 5668
           1))                                                               CL5 5669
      3003  FORMAT(20X,'MAX TEMPERATURE DIFFERENCE FOUND IN COMPUTING GAS VOLUCL5 5670
           1ME',F10.3)                                                       CL5 5671
      86    RETURN                                                           CL5 5672
            END                                                              CL5 5673
```

```
      SUBROUTINE CL6                                                    CL6 5674
C  SURFACE AREA HEAT BALANCE                                           CL6 5675
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CL6 5676
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    CL6 5677
     A TBRIDG, PRES, FLUET, FLUE(5), XNWX, TSINK,                       CL6 5678
     A NCR, HOUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    CL6 5679
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CL6 5680
     A XSUREX(3), XD, YD, ZLONG, NCOL, NROW, NXSXN,                     CL6 5681
     A RSTART, TCODE, SCODE, NGRAY, JHCHC,                              CL6 5682
     A K1, K2, RCED(10), TOEP(100), PERM(200),NPRNT                     CL6 5683
C                                                                       CL6 5684
      INTEGER SCODE,TCODE,RSTART,HCODE                                  CL6 5685
      EQUIVALENCE (DUMMY(2),NFMAX),(PERM(200),DHTCL6)                   CL6 5686
      COMMON/JAZZ6/ SG(8),GS(8),SS(8)                                   CL6 5687
      DIMENSION AA( 60, 60),RHS( 60),AAA( 60, 61),ET( 60),ZZ( 60),MM( 60CL6 5688
     1),TV( 60,2),TS( 60,2),TP( 60),HC( 60,3)                           CL6 5689
      EQUIVALENCE (AA(1,1),AAA(1,1)),(RHS(1),AAA(1, 61)),(ZZ(1),MM(1))  CL6 5690
      DATA SIG /0.1713E-8/                                              CL6 5691
      ICODE=1                                                           CL6 5692
      NFIX=0                                                            CL6 5693
C  RETRIEVE DATA                                                        CL6 5694
C  SURFACE VOLUME AND PROCESS TEMPERATURES                              CL6 5695
C     HEAT RELEASE PATTERN                                              CL6 5696
C     ALL THREE HEAT TRANSFER COEFFICIENTS                              CL6 5697
      CALL READ(2,'TEMG',TV(1,1), 60)                                   CL6 5698
      CALL READ(2,'TEMS',TS(1,1), 60)                                   CL6 5699
      CALL READ(2,'TEMP',TP(1), 60)                                     CL6 5700
      CALL READ(2,'HSUF',ET(1), 60)                                     CL6 5701
      CALL READ(2,'HC  ',HC(1,1), 60)                                   CL6 5702
      CALL READ(2,'HCP ',HC(1,2), 60)                                   CL6 5703
      CALL READ(2,'HCPP',HC(1,3), 60)                                   CL6 5704
C  COMPUTE TEMPERATURE FACTORS (T**3 AND T**4)                          CL6 5705
      DO 8 J=1,NVOL                                                     CL6 5706
      TV(J,2)=TV(J,1)**4                                                CL6 5707
    8 CONTINUE                                                          CL6 5708
   10 DO 11 J=1,NSURF                                                   CL6 5709
      TS(J,2)=TS(J,1)**3                                                CL6 5710
   11 CONTINUE                                                          CL6 5711
C  PUT GAS TO SURFACE INTERCHANGE AREA IN AA                            CL6 5712
      CALL  PZERO(AA(1,1), 3600)                                        CL6 5713
      DO 13 J=1,NSGBLK                                                  CL6 5714
      CALL READ(2,SG(J),AA(1,15*J-14), 900)                             CL6 5715
   13 CONTINUE                                                          CL6 5716
C  COMPUTE G-S CONTRIBUTION TO RHS -- SUM OVER GAS EMITTER FOR EACH     CL6 5717
C  SURFACE RECEIVER ACCOUNTING FOR TEMPERATURE OF EMITTER               CL6 5718
      DO 16 I=1,NSURF                                                   CL6 5719
      RHS(I)=0.0                                                        CL6 5720
      DO 15 J=1,NVOL                                                    CL6 5721
      RHS(I)=RHS(I)+AA(I,J)*TV(J,2)                                     CL6 5722
   15 CONTINUE                                                          CL6 5723
```

```
      RHS(I)=RHS(I)*(-SIG)                                              CL6 5724
16    CONTINUE                                                          CL6 5725
C   PUT SURFACE TO GAS INTERCHANGE AREA IN AA                           CL6 5726
      CALL PZERO(AA(1,1), 3600)                                         CL6 5727
      DO 21 J=1,NGSBLK                                                  CL6 5728
      CALL READ(2,GS(J),AA(1,15*J-14), 900)                             CL6 5729
21    CONTINUE                                                          CL6 5730
C   COMPUTE S-G CONTRIBUTIONS TO DIAGONAL OF MATRIX AA AND SAVE IN      CL6 5731
C   TEMPORARY STORAGE -- SUM OVER GAS RECEIVER FOR EACH SURFACE EMITTER CL6 5732
C   AND STORE IN ZZ                                                   CL6 5733
      DO 23 J=1,NSURF                                                   CL6 5734
      ZZ(J)=0.0                                                         CL6 5735
      DO 22 I=1,NVOL                                                    CL6 5736
      ZZ(J)=ZZ(J)+AA(I,J)                                               CL6 5737
22    CONTINUE                                                          CL6 5738
23    CONTINUE                                                          CL6 5739
C   PUT SURFACE TO SURFACE INTERCHANGE AREA IN AA                       CL6 5740
      CALL PZERO(AA(1,1), 3600)                                         CL6 5741
      DO 27 J=1,NSSBLK                                                  CL6 5742
      CALL READ(2,SS(J),AA(1,15*J-14), 900)                             CL6 5743
27    CONTINUE                                                          CL6 5744
C   COMPUTE S-S CONTRIBUTION TO DIAGONAL OF MATRIX AA AND SAVE IN       CL6 5745
C   TEMPORARY STORAGE ALONG WITH S-G CONTRIBUTION -- SUM OVER SURFACE   CL6 5746
C   RECEIVER FOR EACH SURFACE EMITTER AND STORE IN ZZ , WHEN           CL6 5747
C   FINISHED MULTIPLY BY MINUS SIGMA                                  CL6 5748
      DO 29 J=1,NSURF                                                   CL6 5749
      DO 28 I=1,NSURF                                                   CL6 5750
      ZZ(J)=ZZ(J)+AA(I,J)                                               CL6 5751
28    CONTINUE                                                          CL6 5752
      ZZ(J)=ZZ(J)*(-SIG)                                                CL6 5753
29    CONTINUE                                                          CL6 5754
C   MULTIPLY AA THROUGH BY SIGMA                                        CL6 5755
      DO 37 J=1,NSURF                                                   CL6 5756
      DO 36 I=1,NSURF                                                   CL6 5757
      AA(I,J)=AA(I,J)*SIG                                               CL6 5758
36    CONTINUE                                                          CL6 5759
37    CONTINUE                                                          CL6 5760
C   COMPLETE MATRIX AND RHS IN TWO STEPS                                CL6 5761
C     1 -- RADIANT AND SOURCE TERMS                                     CL6 5762
C     2 -- CONVECTIVE TERMS                                             CL6 5763
      DO 38 I=1,NSURF                                                   CL6 5764
      AA(I,I)=AA(I,I)+ZZ(I)                                             CL6 5765
      RHS(I)=RHS(I)-ET(I)                                               CL6 5766
38    CONTINUE                                                          CL6 5767
      DO49 I=1,NSURF                                                    CL6 5768
      CALL IGAS(I,K,I1,I2)                                              CL6 5769
      IF(I.GT.2*NCOL)GO TO 39                                           CL6 5770
      XY=XO                                                             CL6 5771
      GO TO 46.                                                         CL6 5772
39    XY=YO                                                             CL6 5773
```

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101 46    GO TO (47,48),K                                                CL6 5774
102 C   K=1 ===== OUTTER SURFACE                                         CL6 5775
103 47    AA(I,I)=AA(I,I)-(HC(I,1)+HC(I,2)+HC(I,3))*XY/TS(I,2)           CL6 5776
104       RHS(I)=RHS(I)-(HC(I,1)*TV(I1,1)+HC(I,2)*TP(I)+HC(I,3)*TSINK)*XY CL6 5777
105       GO TO 49                                                       CL6 5778
106 C   K=2 ====== INNER SURFACE                                         CL6 5779
107 48    AA(I,I)=AA(I,I)-(HC(I,1)+HC(I,2))*XY/TS(I,2)                   CL6 5780
108       RHS(I)=RHS(I)-(HC(I,1)*(TV(I1,1)+TV(I2,1))/2.+HC(I,2)*TP(I))*XY CL6 5781
109 49    CONTINUE                                                       CL6 5782
110 C   FOR SURFACES WITH KNOWNE TEMPERATURE SET DIAGONAL OF AA EQUAL TO  CL6 5783
111 C   1.0 AND RHS EQUAL TO TS**4                                       CL6 5784
112       CALL READ(2,'CONS',MM(1), 60)                                  CL6 5785
113       DO 54 I=1,NSURF                                                CL6 5786
114       IF(MM(I).EQ.0)GO TO 54                                         CL6 5787
115       DO 53 J=1,NSURF                                                CL6 5788
116       AA(I,J)=0.0                                                    CL6 5789
117 53    CONTINUE                                                       CL6 5790
118       AA(I,I)=1.                                                     CL6 5791
119       RHS(I)=TS(I,1)**4                                              CL6 5792
120 54    CONTINUE                                                       CL6 5793
121 C   SOLVE FOR TEMPERATURE OF SURFACES ARE RAISED TO THE FOURTH POWER ANDCL6 5794
122 C   THEN EXTRACT THE FOURTH ROOT                                     CL6 5795
123       N=NSURF+1                                                      CL6 5796
124       DO 56 I=1,NSURF                                                CL6 5797
125       AAA(I,N)=RHS(I)                                                CL6 5798
126 56    CONTINUE                                                       CL6 5799
127       IF(NPRNT.EQ.1)GO TO 581                                        CL6 5800
128 571   WRITE(K2,6000)                                                 CL6 5801
129 6000  FORMAT('1',19X,'SURFACE AREA ENERGY BALANCE')                   CL6 5802
130       CALL PRINT(AAA,NSURF,N)                                        CL6 5803
131 581   CALL ISNEQ(AAA, 60,61,NSURF)                                   CL6 5804
132       DT=0.0                                                         CL6 5805
133       DO 62 I=1,NSURF                                                CL6 5806
134       RHS(I)=SQRT(SQRT(AAA(I,N)))                                    CL6 5807
135       DT=AMAX1(ABS(RHS(I)-TS(I,1)),DT)                               CL6 5808
136       DEL=RHS(I)-TS(I,1)                                             CL6 5809
137       TS(I,1)=TS(I,1)+SIGN(AMIN1(ABS(DEL),250.0),DEL)                CL6 5810
138 62    CONTINUE                                                       CL6 5811
139 71    NFIX=NFIX+1                                                    CL6 5812
140       IF(DT.LT.5.0*DHTCL6.OR.NFIX.EQ.NEMAX)GO TO 81                  CL6 5813
141       IF(DT.LT.250.)GO TO 10                                         CL6 5814
142       GO TO 85                                                       CL6 5815
143 C   COMPARE AREA                                                     CL6 5816
144 C   COMPARE TEMPERATURES OBTAINED FROM SURFACE AREA HEAT BALANCE WITH CL6 5817
145 C   THOSE USED IN OBTAINING SURFACE AREA TEMPERATURE DEPENDENT       CL6 5818
146 C   INTERCHANGE AREAS(S=S AND S=G)                                   CL6 5819
147 81    CALL READ(3,'TEMS',ZZ(1), 60)                                  CL6 5820
148       DT=0.                                                          CL6 5821
149       DO 82 I=1,NSURF                                                CL6 5822
150       DT=AMAX1(ABS( ZZ(I)-TS(I,1)),DT)                               CL6 5823
```

```
151 82    CONTINUE                                                        CL6 5824
152 85    CALL WRITE(2,ITEMS',TS(1,1), 60)                                CL6 5825
153       IF(DT.LE.DHTCL6)ICODE=2                                         CL6 5826
154       WRITE(K2,3002)DT                                                CL6 5827
155       IF(NPRNT.EQ.1)GO TO 86                                          CL6 5828
156       WRITE(K2,3001) (TS(N,1),N=1,NSURF)                              CL6 5829
157 3001   FORMAT(//20X'COMPUTED SURFACE AREA TEMPERATURES,DEG,R'//(25X,6F15CL6 5830
158      1.3))                                                            CL6 5831
159 3002  FORMAT(20X,'MAX TEMPERATURE DIFFERENCE IN SURFACE ARAE CALULATION CL6 5832
160     1',F12.3)                                                         CL6 5833
161 86    RETURN                                                          CL6 5834
162       END                                                             CL6 5835
```

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      SUBROUTINE IGAS(II,KKK,IG1,IG2)                                   IGAS5836
C     SUBROUTIN COMPUTES THE INDEX OF GAS VOLUMES ADJACENT TO SURFACE AR IGAS5837
C      I1          SURFACE AREA INDEX                                   IGAS5838
C      KKK         NUMBER OF AJACENT GAS VOLUMES                        IGAS5839
C      IG1,2       INDEX OF AJACENT GAS VOLUMES                         IGAS5840
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              IGAS5841
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    IGAS5842
     A TBRIDG, PRES, FLUET, FLUE(5), XMNX, TSINK,                       IGAS5843
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    IGAS5844
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     IGAS5845
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     IGAS5846
     A RSTART, TCODE, SCODE, NGRAY, JHGHG,                              IGAS5847
     A K1, K2, RCRD(10), TDEP(100), PERM(200)                           IGAS5848
C                                                                       IGAS5849
      INTEGER SCODE,TCODE,RSTART,HCODE                                  IGAS5850
      I=II                                                              IGAS5851
      I1=0                                                              IGAS5852
      I2=0                                                              IGAS5853
      K=1                                                               IGAS5854
      IF(I.GT.NCOL)GO TO 11                                             IGAS5855
C   TOP OF FURNACE                                                      IGAS5856
      I1=I                                                              IGAS5857
      GO TO 19                                                          IGAS5858
11    IF(I.GT.2*NCOL)GO TO 12                                           IGAS5859
C   BOTTOM OF FURNACE                                                   IGAS5860
      I1=NCOL*(NROW-1)+(I-NCOL)                                         IGAS5861
      GO TO 19                                                          IGAS5862
12    IF(I.GT.2*NCOL+NROW)GO TO 13                                      IGAS5863
C   LEFT SIDE OF FURNACE                                                IGAS5864
      I1=NCOL*(I-2*NCOL-1)+1                                            IGAS5865
      GO TO 19                                                          IGAS5866
13    IF(I.GT.NCR)GO TO 14                                              IGAS5867
C   RIGTH SIDE OF FURNACE                                               IGAS5868
      I1=(I-2*NCOL-NROW)*NCOL                                           IGAS5869
      GO TO 19                                                          IGAS5870
14    K=2                                                               IGAS5871
      I=I-NCR                                                           IGAS5872
C   INTER-SURFACE HENCE TWO GAS VOLUMES                                 IGAS5873
      DO 17 J=1,9                                                       IGAS5874
      IF(I.GT.NROW)GO TO 15                                             IGAS5875
      I1=(I-1)*NCOL+INT(XSURFX(J)/XO+.1)                                IGAS5876
      I2=I1+1                                                           IGAS5877
      GO TO 19                                                          IGAS5878
15    I=I-NROW                                                          IGAS5879
17    CONTINUE                                                          IGAS5880
19    KKK=K                                                             IGAS5881
      IG1=I1                                                            IGAS5882
      IG2=I2                                                            IGAS5883
      RETURN                                                            IGAS5884
      END                                                               IGAS5885
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      SUBROUTINE CL7                                                    CL7 5886
C     FINALE OUTPUT                                                     CL7 5887
      COMMON // DUMMY(3),KK, ICODE, HCODE,                              CL7 5888
     A TAU(9), VAREA, HAREA, XLX, XK(3), ACOEF(8,3),                    CL7 5889
     A TBRIDG, PRES, FLUET, FLUE(5), XMAX, TSINK,                       CL7 5890
     A NCR, HDUTY, HTVAL, FRATE, KFUEL, XAIR, FTEMP,                    CL7 5891
     A NSSBLK, NGSBLK, NSGBLK, NGGBLK, NSURF, NVOL,                     CL7 5892
     A XSURFX(9), XO, YO, ZLONG, NCOL, NROW, NXSXN,                     CL7 5893
     A KSTART, TCODE, SCODE, NGRAY, JHCHC,                              CL7 5894
     A K1, K2, RGRD(10), TDEP(100), REMN(200)                           CL7 5895
      COMMON/TUBE2/IND,TX(100),QT(4),QFF                                CL7 5896
C                                                                       CL7 5897
      INTEGER SCODE,TCODE,KSTART,HCODE                                  CL7 5898
      REAL T( 60),V( 60),Z( 50),HTDEN( 60),GMY(120)                     CL7 5899
      DATA IN3/1/                                                       CL7 5900
      NDONE=KK                                                          CL7 5901
      IF(NDONE.EQ.0)GO TO 65                                            CL7 5902
      WRITE(K2,63)                                                      CL7 5903
63    FORMAT('1',14X,'CASE CONVERGED'/15X    ,14('-'))                  CL7 5904
      GO TO 70                                                          CL7 5905
65    WRITE(   K2,66)                                                   CL7 5906
66    FORMAT('1',14X,'CASE NOT CONVERGED'/15X,18('-'))                  CL7 5907
70    CALL READ(2,'TEMG',T(1), 60)                                      CL7 5908
      DO 71 N=1,NVOL                                                    CL7 5909
      IF(T(N).EQ.0.0)GO TO 71                                           CL7 5910
      T(N)=T(N)-460.                                                    CL7 5911
71    CONTINUE                                                          CL7 5912
      JJ=0                                                              CL7 5913
      TBR=0.0                                                           CL7 5914
      NY=(NROW+1)*NCOL                                                  CL7 5915
      CALL READ(2,'GMY ',GMY(1), NY)                                    CL7 5916
      DO 710 J=1,NCOL                                                   CL7 5917
      IF(GMY(J).GE.0.0)GO TO 710                                        CL7 5918
      JJ=JJ+1                                                           CL7 5919
      TBR=TBR+T(J)                                                      CL7 5920
710   CONTINUE                                                          CL7 5921
      TBR=TBR/FLOAT(JJ)                                                 CL7 5922
      WRITE(K2,72)(T(N),N=1,NVOL)                                       CL7 5923
72    FORMAT('//20X,'FINALE GAS VOLUME TEMPERATURE,DEG. F.             CL7 5924
     1'//(25X,6F15.1))                                                  CL7 5925
      CALL READ(2,'TEMS',T(1), 60)                                      CL7 5926
      DO 78 N=1,NSURF                                                   CL7 5927
      IF(T(N).EQ.0.0)GO TO 78                                           CL7 5928
      T(N)=T(N) -460.                                                   CL7 5929
78    CONTINUE                                                          CL7 5930
      WRITE(K2,79)(T(N),N=1,NSURF)                                      CL7 5931
79    FORMAT('//20X,'FINAL  SURFACE AREA TEMPERATURES, DEGREES F.'//(25X,CL7 5932
     16F15.1))                                                          CL7 5933
80    CALL READ(2,'TEMP',V(1), 60)                                      CL7 5934
      DO 82 N=1,NSURF                                                   CL7 5935
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      IF(V(N).EQ.0.0)GO TO 82                                          CL7 5936
      V(N)=V(N)+460.                                                   CL7 5937
   82 CONTINUE                                                         CL7 5938
      CALL READ(2,'HCP ',Z(1), 60)                                     CL7 5939
      DO 85 N=1,NSURF                                                  CL7 5940
      HTDEN(N)=Z(N)*(T(N)-V(N))                                        CL7 5941
   85 CONTINUE                                                         CL7 5942
      IF(HAREA.EQ.0.0)GO TO 860                                        CL7 5943
      DO 86 N=1,NCR                                                    CL7 5944
      HTDEN(N)=HTDEN(N)/HAREA                                          CL7 5945
   86 CONTINUE                                                         CL7 5946
  860 IF(NXSX4.EQ.0)GO TO 88                                           CL7 5947
      NN=NCR+1                                                         CL7 5948
      DO 87 N=NN,NSURF                                                 CL7 5949
      HTDEN(N)=HTDEN(N)/VAREA                                          CL7 5950
   87 CONTINUE                                                         CL7 5951
   88 WRITE(K2,89)(HTDEN(N),N=1,NSURF)                                 CL7 5952
  102 FORMAT(1 SURFACE TO AREA COEEFICIENT!/(27X,6F15.1))              CL7 5953
   89 FORMAT(//20X,'COMPUTED HEAT DENSITIES,BTU/HR/SQUARE FOOT OF TUBE SCL7 5954
     1URFACE'//(25X,6F15.1))                                           CL7 5955
      HCOMB=HOUTY*1.E6/ZLONG                                           CL7 5956
      HFIN=FLUET*XMWX*HV(FTEMP)                                        CL7 5957
      CALL READ(2,'HCPP',Z(1), 60)                                     CL7 5958
      TSINKF=TSINK -460.                                               CL7 5959
      HAMB=0.0                                                         CL7 5960
      DO 91 N=1,NCR                                                    CL7 5961
      HAMB=HAMB+Z(N)*(T(N)-TSINKF)                                     CL7 5962
   91 CONTINUE                                                         CL7 5963
      HPROC=0.0                                                        CL7 5964
      NN=2*NCUL                                                        CL7 5965
      DO 92 N=1,NN                                                     CL7 5966
      HPROC=HPROC+HTDEN(N)*XC*HAREA                                    CL7 5967
   92 CONTINUE                                                         CL7 5968
      NN=NN+1                                                          CL7 5969
      DO 93 N=NN,NCR                                                   CL7 5970
      HPROC=HPROC+ HTDEN(N)*YO*HAREA                                   CL7 5971
   93 CONTINUE                                                         CL7 5972
      IF( NXSX5.EQ.0)GO TO 95                                          CL7 5973
      DO 94 N=NN,NCR                                                   CL7 5974
      HPROC=HPROC+HTDEN(N)*YC*VAREA                                    CL7 5975
   94 CONTINUE                                                         CL7 5976
   95 HFOUT=FLUET*XMWX*HV(TAR+460.)                                    CL7 5977
      HNET=HCOMB+HFIN-HAMB-HPROC-HFOUT                                 CL7 5978
      WRITE(K2,96)HCOMB,HFIN,HAMB,HPROC,HFOUT,HNET                     CL7 5979
      QFF=HPROC                                                        CL7 5980
   96 FORMAT(1!!,14X,'FURNACE OVERALL HEAT BALANCE,BTU/HR/FOOT OF FURNACCL7 5981
     1E!/15X,56('-')///20X,'HEAT IN!//25X,'COMBUSTION!',F21.0/25X,'FLUE GCL7 5982
     2AS!,F23.0//20X,'HEAT OUT!//25X,'AMBIET!,F24.0/25X,'PROCESS FLUID!,CL7 5983
     3F18.0/25X,'FLUE GAS',F23.0//20X,'NET HEAT BALANCE(HEAT IN-HEAT OUTCL7 5984
     4)!,F20.0)                                                        CL7 5985
```

```
      IF(HPROC.LE.0.0)WRITE(K2,103)HPROC,XO,YO,HAREA,VAREA                  CL7 5986
  103 FORMAT(' HPROC= ',F8.3,' XO= ',F8.3,' YO= ',F8.3,' HAREA= ',F8.3,     CL7 5987
     1' VAREA= ',F8.3)                                                      CL7 5988
      WRITE(K2,97)                                                          CL7 5989
   97 FORMAT('1')                                                           CL7 5990
      HEAT=HCOMB+HFIN-HAMB-HPROC                                            CL7 5991
      ENTH=HEAT/FLUET/XMWX                                                  CL7 5992
      TSTOP=9000.-460.                                                      CL7 5993
      TT=600.-460.                                                          CL7 5994
      TOL=.01                                                               CL7 5995
   99 IF(WAYA(HV(TT+460.),ENTH,TOL,TT,TSTOP,1))99,105,100                   CL7 5996
  100 WRITE(K2,101)ENTH,TT                                                  CL7 5997
  101 FORMAT(15X,'BRIDGE WALL TEMPERATURE CANNOT BE COMPUTED'/15X42('-')CL7 5998
     1//20X,'REQUIRED ENTHALPY,BTU/LB',F20.3/20X,'LAST VALUE OF BRIDGE      CL7 5999
     2 WALL TEMPERATURE,DEG F',F20.3)                                       CL7 6000
      GO TO 110                                                             CL7 6001
  105 WRITE(K2,106)ENTH,TT                                                  CL7 6002
  106 FORMAT(15X,'BRIDGE WALL TEMPERATURE COMPUTION'/15X 35('-')//20X 'RCL7 6003
     1EQUIRED ENTHALPY,BTU/LB',F20.3/20X,'BRIDGE WALL TEMPERATURE,DEG F'CL7 6004
     2 ,F15.3)                                                              CL7 6005
  110 TT=0.0                                                                CL7 6006
      IF(IN3.GT.1)GO TO 999                                                 CL7 6007
      IN3=IN3+1                                                             CL7 6008
      N=1                                                                   CL7 6009
  120 T(N)=TT                                                               CL7 6010
      V(N)=HV(TT+460.)                                                      CL7 6011
      Z(N)= CP(TT+460.)                                                     CL7 6012
      IF(TT.GE.4000.)GO TO 130                                              CL7 6013
      N=N+1                                                                 CL7 6014
      TT=TT+100.                                                            CL7 6015
      GO TO 120                                                             CL7 6016
  130 NN=N                                                                  CL7 6017
      WRITE(K2,131)(T(N),V(N),Z(N),N=1,NN)                                  CL7 6018
  131 FORMAT('1',14X,'FLUE GAS ENTHALPY AND SPECIFIC HEAT DATA'/15X40('-'CL7 6019
     1)///20X,'TEMP,DEG F ',5X,'ENTHALPY,BTU/LB',5X,'SPECFIC HEAT,BTU/LCL7 6020
     2B/LB/DEG'//(F30.1,F21.3,F25.6))                                       CL7 6021
  999 RETURN                                                                CL7 6022
      END                                                                   CL7 6023
```

```
      FUNCTION WAYA(A,ANS,TOL,START,STOP,LEVEL)                          WAYA6024
C  ROUTINE TO CONVERGE ON SINGLE VALUED FUNCTION                         WAYA6025
C  A       =CURRENT VALUE OF DEPENDENT VARIABLE                          WAYA6026
C  ANS     =DESIRED VALUE OF DEPENDENT VARIABLE                          WAYA6027
C  TOL     =TOLERANCE                                                    WAYA6028
C  START   =CURRENT VALUE OF INDEPENDENT VARIABLE,A BETTER VALUE RETURNDWAYA6029
C  STOP    =LIMIT OF INDEPENDENT VARIABLE ANSWER BETWEEN START AND STOP  WAYA6030
C  LEVEL   =1,2,3 AS A INDEX FOR MULTILEVEL USE                          WAYA6031
C  WAYA WILL VARY START BETWEEN ITS INITIAL VALUE AND STOP UNTIL         WAYA6032
C     ABS(ANS-A).LE.TOL OR 30 TRIALS TAKEN                               WAYA6033
C  ON EXIT WAYA IS                                                       WAYA6034
C     = FOR NOT CONVERGED,REPEAT CALULATIONS WITH A NEW VALUE IN START   WAYA6035
C     0 CONVERGED IN LIMITS OR 30 TRIALS TAKEN                           WAYA6036
C     * FOR CANNOT CONVERAGE START OR STOP WILL BE INITIAL VALUE         WAYA6037
C     WHICHEVER GIVES LESSER ERROR,OR ITS INITIAL VALUE IF LEVEL IS      WAYA6038
C     NEGATIVE                                                           WAYA6039
      DIMENSION X1(10),X2(10),Y1(10),Y2(10),KOUNT(10)                    WAYA6040
      DATA KOUNT/10*0/                                                   WAYA6041
C  SET X ,Y , AND LEVEL                                                  WAYA6042
      X=START                                                            WAYA6043
      Y=ANS-A                                                            WAYA6044
      L=IABS(LEVEL)                                                      WAYA6045
      WAYA=1.0                                                           WAYA6046
C     SEE IF CONVERGED                                                   WAYA6047
      IF(ABS(Y).LE.TOL)GO TO 70                                          WAYA6048
C  NOT CONVERGED SEE WHICH CALL                                          WAYA6049
      IF(KOUNT(L))40,30,10                                               WAYA6050
C     SECOND OR HIHGER CALL SEE IF Y AND Y1(L) BRACKET ANSWER            WAYA6051
10    IF(Y*Y1(L).LT.0.0)GO TO 20                                         WAYA6052
C  NO Y=Y1 BRACKET SEE IF SECOND OR HIGHER CALL                          WAYA6053
      IF(KOUNT(L).GT.1)GO TO 30                                          WAYA6054
C  NO BRACKET AT ALL REDO AT START IF THAT LIMIT IS CLOSER OR IF LEVEL   WAYA6055
C                        MINUS                                           WAYA6056
      IF(ABS(Y).LE.ABS(Y1(L)).AND.LEVEL.GT.0)GO TO 80                    WAYA6057
      X=X1(L)                                                            WAYA6058
      KOUNT(L)=-1                                                        WAYA6059
      GO TO 60                                                           WAYA6060
C  Y =Y1 BRACKET STORE X AND Y IN X2(L) AND Y2(L)                        WAYA6061
20    X2(L)=X                                                            WAYA6062
      Y2(L)=Y                                                            WAYA6063
      GO TO 40                                                           WAYA6064
C  FIRST CALL OR CONVERGING Y =Y1 BRACKET CALL                           WAYA6065
C        STORE RESULT IN X AND Y IN XU AND Y1                            WAYA6066
30    X1(L)=X                                                            WAYA6067
      Y1(L)=Y                                                            WAYA6068
      X=STOP                                                             WAYA6069
      IF(KOUNT(L).EQ.0)GO TO 50                                          WAYA6070
C  INTERPOLATE NEW X AND CONTINUE OR QUIT DEPENDING ON KOUNT(L)          WAYA6071
40    X=(X1(L)*(3.*Y2(L)-Y1(L))+X2(L)*(Y2(L)-3.*Y1(L)))/(4.*(Y2(L)-Y1(L)WAYA6072
     1))                                                                 WAYA6073
```

```
      IF(KOUNT(L).GE.30)GO TO 70                                        WAYA6074
50    KOUNT(L)=KOUNT(L)+1                                               WAYA6075
60    WAYA=-1.                                                          WAYA6076
      GO TO 90                                                          WAYA6077
C   CONVERGED OR TOO MANY TRAILS                                        WAYA6078
70    WAYA=0.0                                                          WAYA6079
80    KOUNT(L)=0                                                        WAYA6080
C   SET NEW VALUE OF INDEPENDENT VARIABLE                             WAYA6081
90    START=X                                                           WAYA6082
      RETURN                                                            WAYA6083
      END                                                               WAYA6084
```

```
      1         SUBROUTINE PZERO(A,N)                                  PZER6085
      2         DIMENSION A(1),HH(1)                                   PZER6086
      3         DO 1 K=1,N                                             PZER6087
      4  1      A(K)=0.0                                               PZER6088
      5         RETURN                                                 PZER6089
      6         ENTRY NZERO(HH,N)                                      PZER6090
      7         DO 2 K=1,N                                             PZER6091
      8  2      HH(K)=0                                                PZER6092
      9         RETURN                                                 PZER6093
     10         END                                                    PZER6094
```

```
      FUNCTION FITIT ( X, Y, NO, MAX, C, LN, A )                        FIT 6095
C                                                                       FIT 6096
C     WILL FIT POLYNOMIAL OF ORDER MAX ( MAX .LT. 7 ) TO NO Y VS. X DATAFIT 6097
C     POINTS SUPPLIED IN ARRAYS Y AND X. COEFFICIENTS RETURNED IN ARRAY FIT 6098
C     C IN FORM NEEDED BY FUNCTION EQUA. STANDARD DEVIATION OF Y RETURNEFIT 6099
C     D AS FITIT.                                                       FIT 6100
C                                                                       FIT 6101
C     LN = LOG TRANSFORMATION CODE 1 = Y VS. X                          FIT 6102
C                                  2 = LN Y VS. X                       FIT 6103
C                                  3 = Y VS. LN X                       FIT 6104
C                                  4 = LN Y VS. LN X                    FIT 6105
C                                                                       FIT 6106
C     A = INTERCEPT CODE ZERO = INTERCEPT = 0.0                         FIT 6107
C     NONZERO = INTERCEPT CALCULATED                                    FIT 6108
C                                                                       FIT 6109
      DOUBLE PRECISION D,S,XY,O                                         FIT 6110
      DIMENSION X(1), Y(1), C(1), D(7), S(7), XY(7,7)                   FIT 6111
      REAL*4 LOG                                                        FIT 6112
C                                                                       FIT 6113
C     SET CONTROLS AND ZEROS AND XY.                                    FIT 6114
C                                                                       FIT 6115
      N = NO                                                            FIT 6116
      M = MINO ( MAX + 1, N, 7)                                         FIT 6117
      L = MINO ( 4, MAXO ( 1, LN ) )                                    FIT 6118
      Z = N                                                             FIT 6119
      DO 10 I = 1, M                                                    FIT 6120
      S(I) = 0.0                                                        FIT 6121
      DO 10 J = I, M                                                    FIT 6122
   10 XY(I, J) = 0.0                                                    FIT 6123
C                                                                       FIT 6124
C     FOR EACH DATUM, MOVE Y AND X TO D(1) AND D(2), GET LOGS IF NEEDED FIT 6125
C     AND POWERS OF X, AND ACCUMULATE SUMS, SQUARES, AND CROSS PRODUCTS FIT 6126
C     IN S AND XY.                                                      FIT 6127
C                                                                       FIT 6128
      DO 80 K =1, N                                                     FIT 6129
      D(1) = Y(K)                                                       FIT 6130
      D(2) = X(K)                                                       FIT 6131
      GO TO ( 50, 20, 40, 30 ), L                                       FIT 6132
   20 D(1) =  LOG ( D(1) )                                              FIT 6133
      GO TO 50                                                          FIT 6134
   30 D(1) =  LOG ( D(1) )                                              FIT 6135
   40 D(2) =  LOG ( D(2) )                                              FIT 6136
   50 DO 60 I =3, M                                                     FIT 6137
   60 D(I) = D(2) * D(I - 1)                                            FIT 6138
      DO 70 I = 1, M                                                    FIT 6139
      S(I) = S(I) + D(I)                                                FIT 6140
      DO 70 J = I, M                                                    FIT 6141
   70 XY(I, J) = XY(I, J) + D(I) * D(J)                                 FIT 6142
   80 CONTINUE                                                          FIT 6143
C                                                                       FIT 6144
```

```
      C     GET REDUCED SQUARES AND CROSS PRODUCTS IF A NONZERO AND FOLD XY    FIT 6145
      C     OVER.                                                              FIT 6146
      C                                                                        FIT 6147
            IF ( A .EQ. 0.0 ) GO TO 110                                        FIT 6148
            DO 100 I = 1, M                                                    FIT 6149
            Q = S(I) / Z                                                       FIT 6150
            DO 90 J = I, M                                                     FIT 6151
         90 XY(I, J) = XY(I, J) - Q * S(J)                                     FIT 6152
        100 S(I) = Q                                                           FIT 6153
        110 DO 120 J = 1, M                                                    FIT 6154
            DO 120 I = J, M                                                    FIT 6155
        120 XY(I, J) = XY(J, I)                                                FIT 6156
      C                                                                        FIT 6157
      C     SOLVE REGRESSION MATRIX AND GET STANDARD DEVIATION OF Y.           FIT 6158
      C                                                                        FIT 6159
            DO 160 I = 2, M                                                    FIT 6160
            Q = XY(I, I)                                                       FIT 6161
            XY(I, I) = 1.0                                                     FIT 6162
            DO 130 J = 1, M                                                    FIT 6163
        130 XY(I, J) = XY(I, J) / Q                                            FIT 6164
            DO 150 K = 1, M                                                    FIT 6165
            IF ( K .EQ. I ) GO TO 150                                          FIT 6166
            Q = XY(K, I)                                                       FIT 6167
            XY(K, I) = 0.0                                                     FIT 6168
            DO 140 J = 1, M                                                    FIT 6169
        140 XY(K, J) = XY(K, J) - XY(I, J) * Q                                 FIT 6170
        150 CONTINUE                                                           FIT 6171
        160 CONTINUE                                                           FIT 6172
            Q=       (MAXO(N-M,1))                                             FIT 6173
            FITIT=0.0                                                          FIT 6174
            IF(XY(1,1).GT.0.)FITIT=DSQRT(XY(1,1)/Q)                            FIT 6175
      C                                                                        FIT 6176
      C     STORE COEFFICIENTS IN C ARRAY.                                     FIT 6177
      C                                                                        FIT 6178
            C(1) = M - 1                                                       FIT 6179
            C(2) = 0.0                                                         FIT 6180
            DO 170 I = 2, M                                                    FIT 6181
            S(1) = S(1) - S(I) * XY(I, 1)                                      FIT 6182
        170 C(I + 1) = XY(I, 1)                                                FIT 6183
            IF ( A .NE. 0.0 ) C(2) = S(1)                                      FIT 6184
            RETURN                                                             FIT 6185
      C                                                                        FIT 6186
            END                                                                FIT 6187
```

```
      FUNCTION      EQUA  ( X, C )                                        EQUA6188
C                                                                        EQUA6189
C     THIS FUNCTION EVALUATES A SET OF POLYNOMINAL COEFFICIENTS BY       EQUA6190
C     NESTED EXPANSION ---- AS GENERATED BY FUNCTION FITIT.              EQUA6191
C                                                                        EQUA6192
C        Y = A0 + A1*X + A2*X**2 + ..... + AM*X**M                       EQUA6193
C                                                                        EQUA6194
C              M = C(1)                                                  EQUA6195
C                                                                        EQUA6196
C              A0 = C(2)                                                 EQUA6197
C              A1 = C(3)                                                 EQUA6198
C              A2 = C(4)                                                 EQUA6199
C              .. . ....                                                 EQUA6200
C              .. . ....                                                 EQUA6201
C              AM = C(M+2)                                               EQUA6202
C                                                                        EQUA6203
      REAL      C(1)                                                     EQUA6204
C                                                                        EQUA6205
      M = C(1)                                                           EQUA6206
      Y = C(M+2)                                                         EQUA6207
      MM = M+2                                                           EQUA6208
      DO  1  J=1,M                                                       EQUA6209
      K=MM-J                                                             EQUA6210
      Y=Y*X+C(K)                                                         EQUA6211
    1 CONTINUE                                                           EQUA6212
      EQUA = Y                                                           EQUA6213
      RETURN                                                             EQUA6214
      END                                                                EQUA6215
```

```
      SUBROUTINE READ(IJ,NAME,X,N)                                      READ6216
      COMMON//SLURP(66),NVOL,NSURF,SLURP2(32),NPRNT                     READ6217
      COMMON/ZREAD/ID                                                   READ6218
      DIMENSION X(1),XX(60),K(3),KN(150,3),NAMES(150,3)                 READ6219
      DATA K/3*0/,KN/1,149*0,1,149*0,1,149*0/,NAMES/450*1     !/        READ6220
      DATA STAR/!STAR!/                                                 READ6221
      J=IJ                                                              READ6222
      IF(NAME.EQ.STAR.OR.IJ.EQ.4)GO TO 50                               READ6223
      IF(K(J).EQ.0)GO TO 100                                            READ6224
      KK=K(J)                                                           READ6225
      DO 1 I=1,KK                                                       READ6226
      IF(NAME.EQ.NAMES(I,J))GO TO 10                                    READ6227
    1 CONTINUE                                                          READ6228
C     ERROR HAS OCCURED                                                 READ6229
  100 CALL ERROR(NAME,KK,J)                                             READ6230
   10 ID=KN(I,J)                                                        READ6231
      J=J+19                                                            READ6232
      IF(FLOAT(N/ 60).EQ.FLOAT(N)/ 60.)GO TO 20                         READ6233
      READ(J!ID)(X(NN),NN=1,N)                                          READ6234
      FIND(J!ID)                                                        READ6235
      J=J-19                                                            READ6236
      RETURN                                                            READ6237
   20 INUM=N/ 60                                                        READ6238
      DO 21 NN1=1,INUM                                                  READ6239
      NNX=(NN1-1)* 60+1                                                 READ6240
      NNY=NNX+NMAX-1                                                    READ6241
      READ(J!ID)(X(NN),NN=NNX,NNY)                                      READ6242
      FIND(J!ID)                                                        READ6243
   21 CONTINUE                                                          READ6244
      RETURN                                                            READ6245
   50 ID=1                                                              READ6246
      READ(23!ID)K,KN,NAMES,NMAX                                        READ6247
      READ(23!ID)SLURP,NVOL,NSURF,SLURP2,NPRNT                          READ6248
      WRITE(6,601)K,KN,NAMES,NMAX                                       READ6249
      K(3)=0                                                            READ6250
      RETURN                                                            READ6251
  743 CONTINUE                                                          READ6252
      J1=K(1)+1                                                         READ6253
      J1=KN(J1,1)-1                                                     READ6254
      DO 51  I=1,J1                                                     READ6255
      READ(24!I)(XX(NN),NN=1,NMAX)                                      READ6256
      WRITE(20!I)(XX(NN),NN=1,NMAX)                                     READ6257
   51 CONTINUE                                                          READ6258
      K(2)=13                                                           READ6259
      DO 53 J2=1,14                                                     READ6260
   53 KN(J2,2)=J2                                                       READ6261
      J2=K(2)+1                                                         READ6262
      J2=KN(J2,2)=1                                                     READ6263
      M=0                                                               READ6264
      DO 52 I=1,13                                                      READ6265
```

```
      L=I                                                                READ6266
      M=M+1                                                              READ6267
      NMAX1=NMAX                                                         READ6268
      IF(I.EQ.3)NMAX1=12                                                 READ6269
      IF(I.EQ.4)NMAX1=11                                                 READ6270
      IF(I.EQ.6.OR.I.EQ.7)M=M+2                                          READ6271
      READ(25!M,ERR=59)(XX(NN),NN=1,NMAX1)                               READ6272
      WRITE(2!L)(XX(NN),NN=1,NMAX1)                                      READ6273
   52 CONTINUE                                                           READ6274
      RETURN                                                             READ6275
   59 WRITE(2,902)I,K                                                    READ6276
  902 FORMAT(! ERROR IN READ DATA SET=25 RECORD=!,I3,!  NMAX=!,I3/! TYPEREAD6277
     1E TO CONTINUE PROGRAM TYPE 2 TO STOP!)                             READ6278
      RETURN                                                             READ6279
      ENTRY WRITE(IJ,NAME,X,N)                                           READ6280
      IF(NAME.EQ.STAR.OR.IJ.EQ.4)GO TO 150                               READ6281
      J=IJ                                                               READ6282
      IF(K(J).EQ.0)GO TO 115                                             READ6283
      KK=K(J)                                                            READ6284
      DO 2 I=1,KK                                                        READ6285
      IF(NAME.EQ.NAMES(I,J))GO TO 120                                    READ6286
    2  CONTINUE                                                          READ6287
  115 K(J)=K(J)+1                                                        READ6288
      KK=K(J)                                                            READ6289
      NMAX=MAXO(NVOL,NSURF)                                              READ6290
      GO TO 200                                                          READ6291
  120  KK=I                                                              READ6292
  200 NAMES(KK,J)=NAME                                                   READ6293
      ID=KN(KK,J)                                                        READ6294
      J=J+19                                                             READ6295
      IF(FLOAT(N/ 60).EQ.FLOAT(N)/ 60.)GO TO 30                          READ6296
      WRITE(J!ID)(X(NN),NN=1,N)                                          READ6297
      J=J-19                                                             READ6298
      KN(KK+1,J)=ID                                                      READ6299
      RETURN                                                             READ6300
   30 INUM=N/ 60                                                         READ6301
      DO 31 NN1=1,INUM                                                   READ6302
      NNX=(NN1-1)* 60+1                                                  READ6303
      NNY=NNX+NMAX-1                                                     READ6304
   31 WRITE(J!ID)(X(NN),NN=NNX,NNY)                                      READ6305
      J=J-19                                                             READ6306
      KN(KK+1,J)=ID                                                      READ6307
      RETURN                                                             READ6308
  150 ID=1                                                               READ6309
      WRITE(6,901)K,KN,NAMES,NMAX                                        READ6310
  901 FORMAT(!1!,20X,!K(1)=!,I3,3X,!K(2)=!,I3,3X,!K(3)=!,I3,3X/! !,20X,!READ6311
     1KN VALS!//3(6(25I5/)//)/!1!,40X !NAMES!//18(25(1X,A4)/)/!0NMAX=!,IREAD6312
     23)                                                                 READ6313
      WRITE(23!ID)K,KN,NAMES,NMAX                                        READ6314
      WRITE(23!ID)SLURP,NVOL,NSURF,SLURP2,NPRNT                          READ6315
```

```
101         RETURN                                                    READ6316
102         END                                                       READ6317
```

```
      SUBROUTINE PRINT(AA,N1,N2)                                        PRNT6318
      REAL AA(1)                                                        PRNT6319
      COMMON//SLURP(89),K2,SLURP2(310),K3                               PRNT6320
      IF(K3.EQ.1)RETURN                                                 PRNT6321
      IF(N2.EQ.1)GO TO 20                                               PRNT6322
      NJ=N2/6                                                           PRNT6323
      NR=N2-NJ*6                                                        PRNT6324
      IF(NR.NE.0)NJ=NJ+1                                                PRNT6325
      NC=0                                                              PRNT6326
      KK=-5                                                             PRNT6327
      DO 1 J=1,NJ                                                       PRNT6328
      KK=KK+6                                                           PRNT6329
      KL=KK+5                                                           PRNT6330
      IF(J+6.GT.N2)KL=KK+NR-1                                           PRNT6331
      NC=NC+N1+2                                                        PRNT6332
      IF(N1.GT.61)GO TO 4                                               PRNT6333
      IF(NC.GT.61)NC=N1+2                                               PRNT6334
      NC=0                                                              PRNT6335
    3 FORMAT('1')                                                       PRNT6336
    4 WRITE(K2,2)(I,I=KK,KL)                                            PRNT6337
    2 FORMAT(/27X,6(6X,I3,5X))                                          PRNT6338
      DO 1 NX=1,N1                                                      PRNT6339
      NF=NX+(KK-1)* 60                                                  PRNT6340
      NL=NF+5* 60                                                       PRNT6341
      IF(J*6.GT.N2)NL=NF+(NR-1)* 60                                     PRNT6342
    1 WRITE(K2,10)NX,(AA(NY),NY=NF,NL, 60)                              PRNT6343
   10 FORMAT(2(X,I3,4X,6(1PE14.6))                                      PRNT6344
      RETURN                                                            PRNT6345
   20 WRITE(K2,11)(AA(NY),NY=1,N1)                                      PRNT6346
   11 FORMAT(27X,1PE14.6,5E14.6)                                        PRNT6347
      RETURN                                                            PRNT6348
      END                                                               PRNT6349
```

```
      1     FUNCTION LOG(X)                                          LOG 6350
      2     REAL*4 LOG                                               LOG 6351
      3     LOG=ALOG(X)                                              LOG 6352
      4     RETURN                                                   LOG 6353
      5     END                                                      LOG 6354
```

```
      SUBROUTINE ERROR(NAME,N1,N2)                                      ERR 6355
C     ALL UNRECOVERABLE ERRORS COME HERE                                ERR 6356
      COMMON//SLURP(89),K2                                              ERR 6357
      WRITE( 2,10)NAME,N1,N2                                            ERR 6358
10    FORMAT(' ',20X,'AN ERROR HAS OCCURED IN SUBROUTINE',2X,A4,2I10)   ERR 6359
      CALL WRITE(4,'STAR',X,NN)                                         ERR 6360
      STOP                                                              ERR 6361
      END                                                               ERR 6362
```

```
      SUBROUTINE ISIMEQ(C,NMAX,NNMAX,NN)                                SMEQ6363
      REAL C(NMAX,NNMAX)                                                SMEQ6364
C   CONVERT LOWER LEFT TO ZERO AND DIAGONAL TO 1.0                      SMEQ6365
C   N=ROW   M=COLUMN                                                    SMEQ6366
      DO 73 N=1,NN                                                      SMEQ6367
       IF(N-1)60,30,30                                                  SMEQ6368
C   SET ZERO VALUES                                                     SMEQ6369
30    NM1=N-1                                                           SMEQ6370
      DO 50 M=1,NM1                                                     SMEQ6371
      HOLD=C(N,M)                                                       SMEQ6372
      IF (HOLD)32,50,32                                                 SMEQ6373
32    CONTINUE                                                          SMEQ6374
C32   C(N,M)=0                                                          SMEQ6375
      MP1=M+1                                                           SMEQ6376
      DO 40 K=MP1,NN                                                    SMEQ6377
40    C(N,K)=C(N,K)-HOLD*C(M,K)                                         SMEQ6378
      C(N,NN+1)=C(N,NN+1)-HOLD*C(M,NN+1)                                SMEQ6379
50    CONTINUE                                                          SMEQ6380
C   SET DIAGONAL EQUAL TO 1.0                                           SMEQ6381
60    HOLD=C(N,N)                                                       SMEQ6382
      IF(HOLD)63,200,63                                                 SMEQ6383
63    CONTINUE                                                          SMEQ6384
C63   C(N,N)=1.0                                                        SMEQ6385
      IF(N.EQ.1)GO TO 72                                                SMEQ6386
68    NP1=N+1                                                           SMEQ6387
      DO 70 M=NP1,NN                                                    SMEQ6388
70    C(N,M)=C(N,M)/HOLD                                                SMEQ6389
72    C(N,NN+1)=C(N,NN+1)/HOLD                                          SMEQ6390
73    CONTINUE                                                          SMEQ6391
C   CLEAR UPPER RIGHT BY BACK SUBSTITUTION                              SMEQ6392
C   STARTING WITH ROW NN-1                                              SMEQ6393
74    DO 90 J=2,NN                                                      SMEQ6394
      N=NN+1-J                                                          SMEQ6395
      JM1=J-1                                                           SMEQ6396
      DO 87 K=1,JM1                                                     SMEQ6397
      M=NN+1-K                                                          SMEQ6398
      HOLD=C(N,M)                                                       SMEQ6399
      IF(HOLD)75,87,75                                                  SMEQ6400
75    CONTINUE                                                          SMEQ6401
C75   C(N,M)=0.0                                                        SMEQ6402
      C(N,NN+1)=C(N,NN+1)-HOLD*C(M,NN+1)                                SMEQ6403
87    CONTINUE                                                          SMEQ6404
90    CONTINUE                                                          SMEQ6405
      RETURN                                                            SMEQ6406
200   CALL ERROR('ISIQ',N,M)                                            SMEQ6407
      RETURN                                                            SMEQ6408
      END                                                               SMEQ6409
```

```
      BLOCK DATA                                                        DATA6410
      COMMON/JAZZ2/SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),ZSS(8),      DATA6411
     1ZGS(8),ZSG(8),ZGG(8)                                              DATA6412
C     SURFACE TO SURFACE DIRECT INTERCHANGE AREAS                        DATA6413
      DATA SSNM/'DSSA','DSSB','DSSC','DSSD','DSSE','DSSF','DSSG',      DATA6414
     1    'DSSH','DSSI','DSSJ','DSSK','DSSL','DSSM','DSSN'             DATA6415
     2,'DSSO','DSSP','DSSQ','DSSR','DSSS','DSST','DSSU','DSSV','DSSW', DATA6416
     3'DSSX','DSSY','DSSZ','DSS1','DSS2','DSS3','DSS4','DSS5','DSS6'/  DATA6417
C     SURFACE TO GAS DIRECT INTERCHANGE AREAS                           DATA6418
      DATA GSNM/'DGSA','DGSB','DGSC','DGSD','DGSE','DGSF','DGSG',      DATA6419
     1    'DGSH','DGSI','DGSJ','DGSK','DGSL','DGSM','DGSN'             DATA6420
     2,'DGSO','DGSP','DGSQ','DGSR','DGSS','DGST','DGSU','DGSV','DGSW', DATA6421
     3'DGSX'/                                                           DATA6422
C     GAS TO SURFACE DIRECT INTERCHANGE AREA                            DATA6423
      DATA SGNM/'DSGA','DSGB','DSGC','DSGD','DSGE','DSGF','DSGG',      DATA6424
     1    'DSGH','DSGI','DSGJ','DSGK','DSGL','DSGM','DSGN'             DATA6425
     2,'DSGO','DSGP','DSGQ','DSGR','DSGS','DSGT','DSGU','DSGV','DSGW', DATA6426
     3'DSGX'/                                                           DATA6427
C     GAS TO GAS DIRECT INTERCHANGE AREA                                DATA6428
      DATA GGNM/'DGGA','DGGB','DGGC','DGGD','DGGE','DGGF','DGGG',      DATA6429
     1    'DGGH','DGGI','DGGJ','DGGK','DGGL','DGGM','DGGN'             DATA6430
     2,'DGGO','DGGP','DGGQ','DGGR','DGGS','DGGT','DGGU','DGGV','DGGW', DATA6431
     3'DGGX'/                                                           DATA6432
C     NET TRANSMISSIVITY  SURFACE TO SURFACE                            DATA6433
      DATA ZSS/'ZSS1','ZSS2','ZSS3','ZSS4','ZSS5','ZSS6','ZSS7','ZSS8'/ DATA6434
C     NET TRANSMISSIVITY  SURFACE TO GAS                                DATA6435
      DATA ZSG/'ZSG1','ZSG2','ZSG3','ZSG4','ZSG5','ZSG6','ZSG7','ZSG8'/ DATA6436
C     NET TRANSMISSIVITY GAS TO SURFACE                                 DATA6437
      DATA ZGS/'ZGS1','ZGS2','ZGS3','ZGS4','ZGS5','ZGS6','ZGS7','ZGS8'/ DATA6438
C     NET TRANSMISSIVITY GAS TO GAS                                     DATA6439
      DATA ZGG/'ZGG1','ZGG2','ZGG3','ZGG4','ZGG5','ZGG6','ZGG7','ZGG8'/ DATA6440
      COMMON /GAUSS/WT(9),XY(9),ARG(9,9),NPT                            DATA6441
C     GAUSSIAN QUADATURE METHOD USING ZERO OF LEGENDRE                  DATA6442
C     POLYNOMINALS AND THE CORRESPONDING WEIGHTS                        DATA6443
C     WEIGTHS ---- WT                                                   DATA6444
      DATA WT/0.08127439 , 0.18064816 , 0.26061070 , 0.31234708 ,       DATA6445
     1  0.33023936 , 0.31234708 , 0.26061070 , .18064816 , .08127439/   DATA6446
C     ABCISSAS -- XY                                                    DATA6447
      DATA XY /-.96816024,-.83603111,-.61337143,-.32425342,0.0,         DATA6448
     1 .32425342,.61337143,.83603111,.96816024/                         DATA6449
C     NUMBER OF QUADRATURE POINTS                                       DATA6450
      DATA  NPT  /9/                                                    DATA6451
      END                                                               DATA6452
```

```
      BLOCK DATA                                                        DATA6453
      COMMON/JAZZ3/SSNM(8,4),GSNM(8,3),SGNM(8,3),GGNM(8,3),SRSNM(8,4),  DATA6454
     1SRGNM(8,3),TSSNM(8,4),TGSNM(8,3),TSGNM(8,3),TGGNM(8,3)            DATA6455
C  SURFACE TO SURFACE DIRECT INTERCHANGE AREAS                          DATA6456
      DATA SSNM/!DSSA!,!DSSB!,!DSSC!,!DSSD!,!DSSE!,!DSSF!,!DSSG!,      DATA6457
     1    !DSSH!,!DSSI!,!DSSJ!,!DSSK!,!DSSL!,!DSSM!,!DSSN!             DATA6458
     2,!DSSO!,!DSSP!,!DSSQ!,!DSSR!,!DSSS!,!DSST!,!DSSU!,!DSSV!,!DSSW!, DATA6459
     3!DSSX!,!DSSY!,!DSSZ!,!DSS1!,!DSS2!,!DSS3!,!DSS4!,!DSS5!,!DSS6!/  DATA6460
C  SURFACE TO GAS DIRECT INTERCHANGE AREAS                              DATA6461
      DATA GSNM/!DGSA!,!DGSB!,!DGSC!,!DGSD!,!DGSE!,!DGSF!,!DGSG!,      DATA6462
     1    !DGSH!,!DGSI!,!DGSJ!,!DGSK!,!DGSL!,!DGSM!,!DGSN!             DATA6463
     2,!DGSO!,!DGSP!,!DGSQ!,!DGSR!,!DGSS!,!DGST!,!DGSU!,!DGSV!,!DGSW!, DATA6464
     3!DGSX!/                                                           DATA6465
C  GAS TO SURFACE DIRECT INTERCHANGE AREA                               DATA6466
      DATA SGNM/!DSGA!,!DSGB!,!DSGC!,!DSGD!,!DSGE!,!DSGF!,!DSGG!,      DATA6467
     1    !DSGH!,!DSGI!,!DSGJ!,!DSGK!,!DSGL!,!DSGM!,!DSGN!             DATA6468
     2,!DSGO!,!DSGP!,!DSGQ!,!DSGR!,!DSGS!,!DSGT!,!DSGU!,!DSGV!,!DSGW!, DATA6469
     3!DSGX!/                                                           DATA6470
C  GAS TO GAS DIRECT INTERCHANGE AREA                                   DATA6471
      DATA GGNM/!DGGA!,!DGGB!,!DGGC!,!DGGD!,!DGGE!,!DGGF!,!DGGG!,      DATA6472
     1    !DGGH!,!DGGI!,!DGGJ!,!DGGK!,!DGGL!,!DGGM!,!DGGN!             DATA6473
     2,!DGGO!,!DGGP!,!DGGQ!,!DGGR!,!DGGS!,!DGGT!,!DGGU!,!DGGV!,!DGGW!, DATA6474
     3!DGGX!/                                                           DATA6475
C  SURFACE REFLECTIVITY WITH SURFACE AS THE EMITTER                     DATA6476
      DATA SRSNM/!SRSA!,!SRSB!,!SRSC!,!SRSD!,!SRSE!,!SRSF!,!SRSG!,     DATA6477
     1    !SRSH!,!SRSI!,!SRSJ!,!SRSK!,!SRSL!,!SRSM!,!SRSN!             DATA6478
     2,!SRSO!,!SRSP!,!SRSQ!,!SRSR!,!SRSS!,!SRST!,!SRSU!,!SRSV!,!SRSW!, DATA6479
     3!SRSX!,!SRSY!,!SRSZ!,!SRS1!,!SRS2!,!SRS3!,!SRS4!,!SRS5!,!SRS6!/  DATA6480
C  SURFACE REFLECTIVITY  WITH GAS AS THE EMITTER                        DATA6481
      DATA SRGNM/!SRGA!,!SRGB!,!SRGC!,!SRGD!,!SRGE!,!SRGF!,!SRGG!,     DATA6482
     1    !SRGH!,!SRGI!,!SRGJ!,!SRGK!,!SRGL!,!SRGM!,!SRGN!             DATA6483
     2,!SRGO!,!SRGP!,!SRGQ!,!SRGR!,!SRGS!,!SRGT!,!SRGU!,!SRGV!,!SRGW!, DATA6484
     3 !SRGX!/                                                          DATA6485
C  SURFACE TO SURFACE TOTAL INTERCHANGE AREA                            DATA6486
      DATA TSSNM/!TSSA!,!TSSB!,!TSSC!,!TSSD!,!TSSE!,!TSSF!,!TSSG!,     DATA6487
     1    !TSSH!,!TSSI!,!TSSJ!,!TSSK!,!TSSL!,!TSSM!,!TSSN!             DATA6488
     2,!TSSO!,!TSSP!,!TSSQ!,!TSSR!,!TSSS!,!TSST!,!TSSU!,!TSSV!,!TSSW!, DATA6489
     3!TSSX!,!TSSY!,!TSSZ!,!TSS1!,!TSS2!,!TSS3!,!TSS4!,!TSS5!,!TSS6!/  DATA6490
C  SURFACE TO GAS TOTAL INTERCHANGE AREA                                DATA6491
      DATA TGSNM/!TGSA!,!TGSB!,!TGSC!,!TGSD!,!TGSE!,!TGSF!,!TGSG!,     DATA6492
     1    !TGSH!,!TGSI!,!TGSJ!,!TGSK!,!TGSL!,!TGSM!,!TGSN!             DATA6493
     2,!TGSO!,!TGSP!,!DGSQ!,!TGSR!,!TGSS!,!TGST!,!TGSU!,!TGSV!,!TGSW!, DATA6494
     3!TGSX!/                                                           DATA6495
C  GAS TO SURFACE TOTAL INTERCHANGE AREA                                DATA6496
      DATA TSGNM/!TSGA!,!TSGB!,!TSGC!,!TSGD!,!TSGE!,!TSGF!,!TSGG!,     DATA6497
     1    !TSGH!,!TSGI!,!TSGJ!,!TSGK!,!TSGL!,!TSGM!,!TSGN!             DATA6498
     2,!TSGO!,!TSGP!,!DSGQ!,!TSGR!,!TSGS!,!TSGT!,!TSGU!,!TSGV!,!TSGW!, DATA6499
     3!TSGX!/                                                           DATA6500
C  GAS TO GAS TOTAL INTERCHANGE AREA                                    DATA6501
      DATA TGGNM/!TGGA!,!TGGB!,!TGGC!,!TGGD!,!TGGE!,!TGGF!,!TGGG!,     DATA6502
```

```
      1    'TGGH','TGGI','TGGJ','TGGK','TGGL','TGGM','TGGN'                  DATA6503
     2,'TGGO','TGGP','DGGQ','TGGR','TGGS','TGGT','TGGU','TGGV','TGGW',      DATA6504
     3'TGGX'/                                                               DATA6505
      END                                                                   DATA6506
```

```
      BLOCK DATA                                                        DATA6507
      COMMON/JAZZ4/ TSSNM(8,4),TGSNM(8,3),TSGNM(8,3),TGGNM(8,3),SS(8),  DATA6508
     1 GS(8),SG(8),GG(8)                                                DATA6509
C     SURFACE TO SURFACE TOTAL INTERCHANGE AREA                          DATA6510
      DATA TSSNM/'TSSA','TSSB','TSSC','TSSD','TSSE','TSSF','TSSG',      DATA6511
     1   'TSSH','TSSI','TSSJ','TSSK','TSSL','TSSM','TSSN'               DATA6512
     2,'TSSO','TSSP','TSSQ','TSSR','TSSS','TSST','TSSU','TSSV','TSSW', DATA6513
     3'TSSX','TSSY','TSSZ','TSS1','TSS2','TSS3','TSS4','TSS5','TSS6'/  DATA6514
C     SURFACE TO GAS TOTAL INTERCHANGE AREA                              DATA6515
      DATA TGSNM/'TGSA','TGSB','TGSC','TGSD','TGSE','TGSF','TGSG',      DATA6516
     1   'TGSH','TGSI','TGSJ','TGSK','TGSL','TGSM','TGSN'               DATA6517
     2,'TGSO','TGSP','DGSQ','TGSR','TGSS','TGST','TGSU','TGSV','TGSW', DATA6518
     3'TGSX'/                                                           DATA6519
C     GAS TO SURFACE TOTAL INTERCHANGE AREA                              DATA6520
      DATA TSGNM/'TSGA','TSGB','TSGC','TSGD','TSGE','TSGF','TSGG',      DATA6521
     1   'TSGH','TSGI','TSGJ','TSGK','TSGL','TSGM','TSGN'               DATA6522
     2,'TSGO','TSGP','DSGQ','TSGR','TSGS','TSGT','TSGU','TSGV','TSGW', DATA6523
     3'TSGX'/                                                           DATA6524
C     GAS TO GAS TOTAL INTERCHANGE AREA                                  DATA6525
      DATA TGGNM/'TGGA','TGGB','TGGC','TGGD','TGGE','TGGF','TGGG',      DATA6526
     1   'TGGH','TGGI','TGGJ','TGGK','TGGL','TGGM','TGGN'               DATA6527
     2,'TGGO','TGGP','DGGQ','TGGR','TGGS','TGGT','TGGU','TGGV','TGGW', DATA6528
     3'TGGX'/                                                           DATA6529
C     SURFACE TO SURFACE INTERCHANGE AREA -- REAL GAS                    DATA6530
      DATA SS/'SS-1','SS-2','SS-3','SS-4','SS-5','SS-6','SS-7','SS-8'/ DATA6531
C     SURFACE TO GAS INTERCHANGE AREA -- REAL GAS                        DATA6532
      DATA GS/'GS-1','GS-2','GS-3','GS-4','GS-5','GS-6','GS-7','GS-8'/ DATA6533
C     GAS TO SURFACE INTERCHANGE AREA REAL GAS                           DATA6534
      DATA SG/'SG-1','SG-2','SG-3','SG-4','SG-5','SG-6','SG-7','SG-8'/ DATA6535
C     GAS TO GAS INTERCHANGE AREA -- REAL GAS                            DATA6536
      DATA GG/'GG-1','GG-2','GG-3','GG-4','GG-5','GG-6','GG-7','GG-8'/ DATA6537
      END                                                               DATA6538
```

```
      1       BLOCK DATA                                                      DATA6539
      2       COMMON/JAZZ5/GS(8),SG(8),GG(8)                                  DATA6540
      3 C   SURFACE TO GAS INTERCHANGE AREA -- REAL GAS                       DATA6541
      4       DATA GS/!GS=1!,!GS=2!,!GS=3!,!GS=4!,!GS=5!,!GS=6!,!GS=7!,!GS=8!/ DATA6542
      5 C   GAS TO SURFACE INTERCHANGE AREA REAL GAS                        DATA6543
      6       DATA SG/!SG=1!,!SG=2!,!SG=3!,!SG=4!,!SG=5!,!SG=6!,!SG=7!,!SG=8!/ DATA6544
      7 C   GAS TO GAS INTERCHANGE AREA -- REAL GAS                         DATA6545
      8       DATA GG/!GG=1!,!GG=2!,!GG=3!,!GG=4!,!GG=5!,!GG=6!,!GG=7!,!GG=8!/ DATA6546
      9       END                                                             DATA6547
```

```
      BLOCK DATA                                                        DATA6548
      COMMON /JAZZ6/ SG(8),GS(8),SS(8)                                  DATA6549
C   SURFACE TO SURFACE INTERCHANGE AREA -- REAL GAS                     DATA6550
      DATA SS/1SS=1!,1SS=2!,1SS=3!,1SS=4!,1SS=5!,1SS=6!,1SS=7!,1SS=8!/  DATA6551
C   SURFACE TO GAS INTERCHANGE AREA -- REAL GAS                         DATA6552
      DATA GS/1GS=1!,1GS=2!,1GS=3!,1GS=4!,1GS=5!,1GS=6!,1GS=7!,1GS=8!/  DATA6553
C   GAS TO SURFACE INTERCHANGE AREA REAL GAS                            DATA6554
      DATA SG/1SG=1!,1SG=2!,1SG=3!,1SG=4!,1SG=5!,1SG=6!,1SG=7!,1SG=8!/  DATA6555
      END                                                               DATA6556
```