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COMPBRN III - A Computer Code for Modeling Compartment Fires

Vincent Ho
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Prepared for the
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ABSTRACT

The computer code COMPBRN III deterministically models the behavior of compartment fires. This code is an improvement of the original COMPBRN codes. It employs a different air entrainment model and numerical scheme to estimate properties of the ceiling hot gas layer model. Moreover, COMPBRN III incorporates a number of improvements in shape factor calculations and error checking, which distinguish it from the COMPBRN II code. This report presents the ceiling hot gas layer model employed by COMPBRN III as well as several other modifications. Information necessary to run COMPBRN III, including descriptions of required input and resulting output, are also presented. Simulation of experiments and a sample problem are included to demonstrate the usage of the code.

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Variable	Definition
A	Area (m^2)
C_i	Doorway inflow coefficient
C_o	Doorway outflow coefficient
C_S	Surface controlled burning rate constant (kg/J)
C_V	Ventilation controlled burning rate constant
F_{1-2}	Configuration factor from object 1 to object 2
g	Gravitational constant ($9.8\ m/s^2$)
h	Convective heat transfer coefficient (W/m^2K)
H_D	Height of doorway (m)
H_R	Height of room (m)
k_f	Gas absorption coefficient (m^{-1})
M	Blockage factor
PLCF	Entrainment coefficient
$\dot{Q}$	Heat release rate (W)
T	Temperature (K)
t	Time (s)
U	Volumetric flow rate (m^3/s)
V	Volumetric flow rate (m^3/s)
W	Wall effect factor
$\dot{W}$	Mass flow rate (kg/s)
W_D	Door width (m)
W_R	Room width (m)

Greek Characters	Definition
ε	Emissivity
γ_r	Fraction of heat radiated to the environment
θ	Flame angle
ρ	Density (kg/m^3)
	Reflectivity
σ	Stefan-Boltzmann constant 5.67×10^{-8} (W/m^2K^4)

Subscripts	Definition
CEIL	Ceiling
E	Entrainment
e	Environment
G	Hot gas layer
o	Lower Region
PL	Plume
∞	Ambient

Chapter 1

INTRODUCTION AND SUMMARY

COMPBRN is a deterministic fire hazards computer program designed to be used in a probabilistic analysis of fire growth in a particular room. As described by Apostolakis et al. [1-2], this analysis is required when assessing the risk associated with fires in nuclear power plants. Possible output of COMPBRN includes the total heat release rate of the fire, the temperature and thickness of the hot gas layer formed near the compartment ceiling, the mass burning rate for individual fuel elements, the surface temperature of the elements, and the thermal heat flux at user-specified locations.

COMPBRN III is the most recent version of COMPBRN. The original version of COMPBRN, called COMPBRN I in this report, is described by Siu in [3], while the models employed by the code are discussed in [4-6]. The improved version by Chung et al., called COMPBRN II here, is described in [7].

While COMPBRN I has performed reasonably well in a number of analyses, it has been recognized that situations could arise where the damage time predictions of the code could be overly conservative, because radiative and convective heat losses from the surfaces of most objects being modeled have not been accounted for. COMPBRN I has therefore been modified to account for the influence of these losses on the time-temperature history of a specified object. The resulting code, COMPBRN II, which incorporates a more general damage model based on fuel element temperature, has been used to simulate three cable tray fire experiments, and has performed fairly well (both in an absolute sense and relatively to COMPBRN I) in two of them [7]. In the one instance where the predictions of the code are not good, the source of error has been traced to the hot gas layer model employed by both COMPBRN I and II.

COMPBRN III employs a different air entrainment submodel in the hot gas layer model and incorporates a better numerical scheme in the subroutines CGAS, CSOLVE, CNEWTN and CGASHT to solve for the hot gas layer properties. A number of minor changes, including changes to the plume heat transfer, mean plume temperature correlation, cylindrical shape factor, and vertical fuel cell calculations have also been incorporated in COMPBRN III. Numerous input error checking statements and comment cards have been added to make the code more user friendly.

COMPBRN III follows a quasi-static approach to simulate the process of fire growth during the pre-flashover period in an enclosure. Briefly, the compartment is modeled using two zones (or control volumes), which means that the enclosure is divided into two distinct, homogeneous, stably-stratified regions. The hot gases accumulating under the ceiling due to fire plume entrainment and negative buoyancy are defined as the upper layer (the ceiling hot gas layer). The lower region is assumed to be thermally inert and contains relatively quiescent cool air, which remains at ambient conditions at all times. The hot gas layer can play a significant part in the growth rate of the fire. Heat fluxes from this gas layer preheat non-burning fuel elements, reducing their time to damage. The burning rate of a fuel element is used to determine the heat output rate of that element. This burning rate depends on the physical properties of the fuel and on the compartment ventilation rate. Using standard shape factor analysis and idealizing the flame as a cylinder, the heat transferred to other fuel elements, the walls, and ceiling via radiation is computed.

Correlations are used to determine the convective heat transfer in the buoyant plume of hot gases above the flames. Provisions are also made to simply model the layer of hot gases accumulating near the ceiling as a thermal source. The temperature profile within each "fuel element" (including the compartment walls and ceiling) is computed as a function of its thermal environment. An element is considered ignited (or damaged) if its surface temperature exceeds the user-specified ignition (damage) temperature. Time is incremented, and the process starts over, with newly ignited fuel elements adding their contributions to the total rate of heat release. The flow chart of this process is shown in Figure 1.

The various steady state models and submodels used to construct COMPBRN III are obtained from the fire research literature. Efforts are made to keep the model complexity to a low level due to the large uncertainties inherent in the modeling of accidental fires. Model simplicity is desirable from an economical point of view, since computing costs can be significant in a probabilistic analysis. However, simplification in modeling naturally leads to some loss of accuracy for certain types of scenarios. The assumptions made in COMPBRN III are geared towards the modeling of relatively small fires in large enclosures and the hot gas layer is assumed to be formed within the first time step of simulation (which is usually taken to be one minute). Thus, the code's predictions are expected to be most reasonable for fire scenarios involving large fuel loads during their pre-flashover burning period.

The models used to describe individual phenomena which comprise the overall model are, with the exception of the hot gas layer model, algebraically simple. The main role of the computer in COMPBRN III is to keep track of the heat input and output of each of the many fuel elements used to model a complex fuel bed.

Chapter 2 describes the phenomena of a typical fire in an enclosure following a general two zones approach. The hot-gas-layer model (HGLM) employed in COMPBRN III is defined and a detailed discussion on the various submodels used in the HGLM is also presented in this chapter. Chapter 3 lists other major modeling changes in COMPBRN. The results of simulations of several experiments are presented in Chapter 4 and they demonstrate that COMPBRN III can predict the behavior of compartment fires reasonable well. Chapter 5 provides a users guide to operate COMPBRN III including a description of required input and resulting output. A sample problem with a description of its input and output to demonstrate the usage of COMPBRN III can be found in the Appendix.

Chapter 2

THE HOT GAS LAYER MODEL

2.1 BACKGROUND

In recent years, various mathematical models have been developed to predict the fire growth processes in compartment fires. Much of the current research efforts on understanding the development of room fires have concentrated on the construction of zone models, which divide the room into distinct, homogeneous regions. A simple model for smoke movement was first used by Kawagoe [8], who studied the movement of gases through an opening connecting two regions (i.e., the ambient air region and the room region which was considered to be a well-mixed, homogeneous region). A few years later, Thomas et al. [9], studied flows in rooms with well defined stratified hot and cold gas layers. Other works which use similar models are discussed in papers by Rockett [10], and Quintiere et al. [11-14].

The zone model predicts the average (in the sense of well-mixed) gas and wall temperatures in various well-defined regions. Of course, this approximation does not provide information at specific points inside the room; thus, some processes are ignored. However, the use of spatially averaged quantities requires only a few equations for each region and for the coupling between regions.

Typical features of an enclosure fire are described in Section 2.2. The HGLM employed in COMPBRN III, which is developed from the phenomena described in Section 2.2 with further modifications and assumptions, is defined in Section 2.3. A detailed discussion of the energy balance equations and various submodels used in the HGLM is presented in this chapter.

2.2 BASIC FEATURES OF A ROOM FIRE

The basic features of room fires described by a typical two zone model are shown in Figure 2. A fire starts at a distance, Z_0, above the floor and releases energy at the rate of $\dot{Q}$. This energy causes the gas pressure in the flame zone to rise. The products of combustion, with temperature higher than that of the environment, are driven upward by buoyancy forces. A hot turbulent plume is generated and begins to rise. The upward momentum of the plume depends on the distance between the fire source and the ceiling, the fire strength, and the thermal stratification of the room. Indeed, in some conditions the plume may not even reach the ceiling.

The fraction of $\dot{Q}$ which effectively drives the plume gases upward is taken to be $(1 - \gamma_r)\dot{Q}$, where γ_r is the fraction of $\dot{Q}$ lost by radiation from the flame zone and the plume itself. Along the axis of the plume, relatively quiescent air at ambient temperature is entrained into the plume and mixes with the plume gases as they continue their ascent toward the ceiling. As a result of the air entrainment, the total upward mass flux in the plume, $\dot{W}_{PL}$, continuously increases, while its temperature, T_{PL}, decreases. When the plume gases impinge on the ceiling, they spread and form a relatively thin turbulent ceiling jet. As this hot jet moves radially outward, it transfers energy by convection, conduction and radiation to the ceiling causing its temperature to rise. When this ceiling jet (which is composed of plume gases and ambient air that has been entrained into the ceiling jet from below) is blocked by the room boundaries, it turns downward at the ceiling-wall juncture, thereby initiating a downward directed wall jet. This wall jet, $\dot{W}_W$, is of higher temperature and lower density than the ambient air into which it is being driven. The wall jet, retarded by its relative negative buoyancy, turns upward and entrains an additional amount of cooler air from the lower region on its way up. Eventually, a relatively quiescent upper gas layer is formed below the continuing jet flow activities. Thus, stratified regions are formed as the fire grows and the room is divided into several regions with distinct thermal boundaries.

With the presence of a doorway, hot gases leave the room through the opening above the thermal interface, and in exchange, fresh air is driven into the room due to pressure differences to replace the air entrained into the plume. Near the doorway, the motions of the hot gases and fresh air are in opposite directions and a shear layer is formed between the two layers. Inside this shear layer, hot gases are entrained into the lower region by the incoming fresh air. Such mixing flow, $\dot{W}_J$, and the wall jet, $\dot{W}_W$, as well, may cause the lower region temperature to rise.

The momentum of the inflowing fresh air creates an aerodynamic disturbance and drives the originally undisturbed plume gases into a tilted position with an angle θ, as shown in Figure 2. This tilted plume travels a longer distance than before on its way up into the hot gas region; thus, more air from the lower region is entrained in the plume flow. As this tilted plume enters the hot gas region, it continues to entrain gases with lower temperature from its surrounding and turns into a ceiling jet and then a wall jet. The upper region entrainment and the jet flow activities provide a stirring effect and mix the gases in the upper region. The presence of forced air ventilation flow enhances the mixing of hot gases in the upper region. Thus, the gas layer can be approximated as a zone with uniform properties.

2.3 COMPBRN III HOT GAS LAYER MODEL

COMPBRN III models a room fire having features similar to the above description with further simplifications and assumptions. Figure 3 depicts the features in the COMPBRN III hot gas layer model. The HGLM separates the room into two zones: the upper hot gas region and the lower cooler fresh air region. These regions are separated by a thermal interface with uniform height inside the room and a higher elevation at the doorway. This interface is formed within the first time step of the code simulation period. The ceiling jet, plume gases, wall jet and the doorway mixing region are all considered to be part of the upper region. The doorway mixing jet and the wall jet are combined with the plume flow model to form the air entrainment model, since they all take part in the entrainment of fresh air from the lower region into the HGL. They are the only mechanisms that allow direct mass exchange between the two regions.

The lower region is assumed to be thermally inert and its temperature remains at ambient room temperature all the time. At each time step, the HGLM computes the thermal interface heights (Z_D and Z_N), the HGL temperature (T_G) and the heat fluxes to fuel elements by solving several coupled mass and heat steady state balance equations. The HGLM, like all quasi-static models, performs best when the quantities of interest do not change rapidly and steady state is achieved within a reasonably short time period. Experimental results (e.g., [11], [12], [15]) have verified that after the initial transient response of a fire ignition inside an enclosure, thermal and flow characteristics of room gases are reasonably constant within thirty seconds to five minutes from ignition depending on the room configuration and fire source properties.

2.4 MASS TRANSFER MODEL

Mass is conserved in the HGLM. The rate of mass gained by a zone is equal to the rate at which it is lost at any moment. For continuity,

$$\text{Rate of Mass Gained} = \text{Rate of Mass Lost}$$

When this balance equation is applied to each region in the HGLM (see Figure 3), the following mass flow relations are obtained:

For the Upper Region:

$$\text{Rate of Mass Gained} = \dot{W}_E + \dot{W}_{V,IN}$$

$$\text{Rate of Mass Lost} = \dot{W}_{OUT} + \dot{W}_{V,OUT}$$

For the Lower Region:

$$\text{Rate of Mass Gained} = \dot{W}_{IN} + \dot{W}_{U,IN} + \dot{W}_F$$

$$\text{Rate of Mass Lost} = \dot{W}_E + \dot{W}_{U,OUT}$$

For the Compartment:

$$\text{Rate of Mass Gained} = \dot{W}_{IN} + \dot{W}_{V,IN} + \dot{W}_{U,IN} + \dot{W}_F$$

$$\text{Rate of Mass Lost} = \dot{W}_{OUT} + \dot{W}_{V,OUT} + \dot{W}_{U,OUT}$$

where

$\dot{W}_F$ = Fuel mass burning rate.

$\dot{W}_{U,IN}$ = Mass flow rate of fresh air into the lower region by forced ventilation.

$\dot{W}_{U,OUT}$ = Mass flow rate of gases out of the lower region by forced ventilation.

$\dot{W}_{V,IN}$ = Mass flow rate of fresh air into the HGL by forced ventilation.

$\dot{W}_{V,OUT}$ = Mass flow rate of hot gases out of the HGL by forced ventilation.

$\dot{W}_{IN}$ = Mass flow rate of incoming fresh air through the doorway.

$\dot{W}_{OUT}$ = Mass flow rate of outgoing hot gases through the doorway.

$\dot{W}_{E}$ = Mass flow rate of air entrainment due to plume flow ($\dot{W}_{PL}$), wall jet ($\dot{W}_{W}$) and doorway mixing jet ($\dot{W}_{J}$).

$= \dot{W}_{PL} + \dot{W}_{W} + \dot{W}_{J}$

From the above expressions, the mass balances for the upper and lower regions are obtained as follows:

$$\dot{W}_{E} + \dot{W}_{V,IN} = \dot{W}_{OUT} + \dot{W}_{V,OUT} \qquad (1)$$

$$\dot{W}_{IN} + \dot{W}_{U,IN} + \dot{W}_{F} = \dot{W}_{U,OUT} + \dot{W}_{PL} \qquad (2)$$

2.5 THERMAL TRANSFER MODEL

Since the lower region is assumed to be thermally inert, it is not necessary to write a heat balance equation. For the upper region, the HGL, thermal energy is conserved, i.e.,

Rate of Heat Gained = Rate of Heat Lost

By tracing the heat flow path in Figure 3, the following relation is obtained:

For the HGL:

$$\dot{Q}_{PL} = \dot{Q}_{OUT} + \dot{Q}_{RAD} + \dot{Q}_{CONV} + \dot{Q}_{V} \qquad (3)$$

where

$\dot{Q}_{PL}$ = Rate of heat gained by the HGL through plume flow.

$\dot{Q}_{OUT}$ = Rate of heat lost from the HGL through doorway outflow.

$\dot{Q}_{RAD}$ = Rate of heat lost from the HGL due to radiation.

$\dot{Q}_{CONV}$ = Rate of heat lost from the HGL due to convection.

$\dot{Q}_V$ = Rate of heat lost from the HGL due to forced air ventilation.

As well as shown in the following sections, the mass flow rates and energy flow rates depend upon T_G, Z_D and Z_N. Thus, Equations 1, 2 and 3 form a coupled system of non-linear algebraic equations which can be solved iteratively for the unknown variables of the HGLM (T_G, Z_D and Z_N), using a variety of approaches (e.g., a Newton-Raphson iteration scheme).

2.6 THE MASS TRANSFER MODELS

2.6.1 Mass Burning Rate ($\dot{W}_F$)

The mass burning rate model used in the HGLM is described in [4]. Briefly, such model is as follows:

For ventilation controlled fires,

$$\dot{W}_F = C_V \dot{W}_{IN} \qquad (4)$$

For surface controlled fires,

$$\dot{W}''_F = \dot{m}''_0 + C_S \dot{q}''_{EXT} \qquad (5)$$

where

$\dot{W}_{IN}$ = Mass flow rate of incoming fresh air through the doorway.

C_V = Ventilation controlled burning rate constant.

$\dot{m}''_0$ = Specific burning rate constant.

C_S = Surface controlled burning coefficient.

$\dot{q}''_{EXT}$ = External heat flux impinging on the fuel element.

2.6.2 Forced Ventilation Mass Flow Rate ($\dot{W}_U$ and $\dot{W}_V$)

The forced air ventilation system mass exchange rates are functions of the volumetric flow rate of air and hot gases flowing through the vents. To avoid pressure built up in the compartment, the volumetric inflow and outflow rate should be identical at all times if the door is closed. The vents in the HGLM are assumed to be located either at the ceiling, or on the floor, or both, to allow gaseous exchange. The fractions of incoming air going into, or outflowing hot gases going out of the room via the ceiling vent are taken to be FC and FH, and those through the floor vents are (1 - FC) and (1 - FH), respectively.

Assuming ideal gas properties, the density and temperature relationship is as follows:

$$\rho T = \text{Constant}$$

Therefore, the mass flow rate of gases going through the vents is:

$$\dot{W} = \dot{V}\rho$$

or, if the reference temperature is set to be the room temperature, T_0, then

$$\dot{W} = \dot{V}\frac{\rho_0 T_0}{T}$$

The forced ventilation mass flow rates can then be expressed as follows:

$$\dot{W}_{V,IN} = (FC)\dot{V}\rho_0 \tag{6}$$

$$\dot{W}_{U,IN} = (1 - FC)\dot{V}\rho_0 \tag{7}$$

$$\dot{W}_{U,OUT} = (1 - FH)\dot{V}\rho_0 \tag{8}$$

$$\dot{W}_{V,OUT} = (FH)\dot{V}\frac{\rho_0 T_0}{T} \tag{9}$$

where

ρ_0 = Ambient air density.

T_0 = Ambient air temperature.

T_G = HGL temperature

$\dot{V}$ = Volumetric flow rate of the forced air ventilation system.

FC, (1 - FC) = Fractions of air being pumped into the room through the ceiling and floor vents, respectively ($0 \leq FC \leq 1$).

FH, (1 - FH) = Fraction of gases being pumped out of the room through the ceiling and floor vents, respectively ($0 \leq FH \leq 1$).

This is a simple but effective model for assessing the forced ventilation mass flow rates. Since these flow rates are usually small compared to the flow rate through the doorway, they become important in rooms with small openings or without any opening at all. In these cases, the introduction of cool air into the HGL and/or the removal of hot gases from the HGL through forced ventilation may decrease the HGL temperature by a significant amount due to extra convective heat losses by these processes.

COMPBRN III has been found to perform well in most simulations with the presence of forced air ventilation, while previous versions of COMPBRN may generate unreasonable results or may not even generate a solution at all.

2.6.3 Fire Induced Door Flow ($\dot{W}_{IN}$ and $\dot{W}_{OUT}$)

The temperature difference between the room and its environment creates a pressure difference which causes fluid flow through the opening. The correlations used to quantify the mass flow rates of the incoming fresh air and the outgoing hot gases may be viewed as equivalent to satisfying the fluid dynamic equations of mass and momentum conservation subject to a constraint (the height of the thermal interface). They are developed by tracing the pressure changes around a loop [10]: 0 → 1 → 2 → 3 → 0, as shown in Figure 4.

From Bernoulli's equation, the kinetic energy, $\frac{\rho U^2}{2}$, of fluid per unit mass which is accelerated from rest is equal to the change in static pressure, ΔP:

$$\Delta P = \rho \frac{U^2}{2}$$

or

$$\rho U = [2\rho \Delta P]^{\frac{1}{2}}$$

where

U = Velocity of fluid flow.

ρ = Density of fluid.

Let the elevation of point 2 be Z, such that $Z_N < Z < H_D$; furthermore, let point 3 be a stagnation point outside the room with the same elevation. Then

$$\rho_2 U = [2\rho_2 \Delta P]^{\frac{1}{2}}$$

$$\Delta P = P_2 - P_3$$

The fluid mass flow rate is defined as:

$$\dot{W} = \rho\dot{V} = \rho UA$$

where

$\dot{V}$ = Volumetric fluid flow rate.
A = Orifice cross-sectional area.

Therefore, a differential mass flow rate, $d\dot{W}$, can be obtained:

$$d\dot{W} = \rho_2 UA = [2\rho_2 \Delta P]^{\frac{1}{2}} W_D \, dz$$

Integrating the differential mass flow rate from Z_N to H_D, we obtain the mass outflow rate,

$$\dot{W}_{OUT} = \int_{Z_N}^{H_D} C_o \, d\dot{W}$$

$$= \int_{Z_N}^{H_D} C_o W_D [2\rho_2 \Delta P]^{\frac{1}{2}} \, dz$$

where

C_o = Doorway outflow coefficient to be discussed in Section 2.6.3.1.

Applying Euler's equation:

$$\frac{dP}{dz} = -\rho g$$

$$\int_{P(Z_N)}^{P(Z)} dP = \int_{Z_N}^{Z} (-\rho g)\, dz$$

$$P(Z) = P(Z_N) - \rho g(Z - Z_N)$$

$$P_2 = P(Z_N) - \rho_2 g(Z - Z_N)$$

$$P_3 = P(Z_N) - \rho_3 g(Z - Z_N)$$

By the ideal gas law,

$$\rho_2 = \rho_3 \frac{T_3}{T_G} = \rho_0 \frac{T_0}{T_G}$$

$$\Delta P = \rho_0 g(1 - \frac{T_0}{T_G})(Z - Z_N)$$

Therefore, the total mass outflow rate is:

$$\dot{W}_{OUT} = \int_{Z_N}^{H_D} C_o W_D \{2\rho_0 \frac{T_0}{T_G}[(1 - \frac{T_0}{T_G})\rho_0 g(Z - Z_N)]\}^{\frac{1}{2}}\, dz$$

$$= \frac{2}{3} C_0 W_D \rho_0 \{2g \frac{T_0}{T_G}(1 - \frac{T_0}{T_G})\}^{\frac{1}{2}} (H_D - Z_N)^{3/2} \qquad (10)$$

The inflow rate can be obtained in a similar way with a slightly more complicated integral.

$$\dot{W}_{IN} = \int_{Z_0}^{Z_D} C_i W_D \{2\rho_0 [\rho_0 g(1 - \frac{T_0}{T_G})(Z_N - Z_D)\}^{\frac{1}{2}}\, dz$$

$$+ \int_{Z_D}^{Z_N} C_i W_D \{2\rho_0 [\rho_0 g(1 - \frac{T_0}{T_G})(Z_N - z)\}^{\frac{1}{2}}\, dz$$

$$= \frac{2}{3} C_i W_D \rho_0 \{2g(1 - \frac{T_0}{T_G})(Z_N - Z_D)\}^{\frac{1}{2}} (Z_N + \frac{Z_D}{2}) \qquad (11)$$

where

C_i = Inflow doorway coefficient to be discussed in Section 2.6.3.1.

2.6.3.1 Doorway Coefficients (C_i and C_o)

The doorway coefficients are a measure of how efficiently the pressure difference of the fluid across the opening is converted into velocity head. A coefficient value of zero represents complete resistance to flow in and out of the compartment, i.e., the compartment is sealed off. A value of unity is equivalent to an ideal opening where air flows without restriction. Necking effects at the door may cause a slower gas flow into the compartment, therefore, in most cases, we expect the inflow coefficient (C_i) to be smaller than the outflow coefficient (C_o). However, in some cases, where the fire source acts as a jet pump and creates a high velocity turbulent plume flow, the fresh air is virtually driven into the room and gives the inflow coefficient a value greater than 1.0.

When data on the inflow and outflow mass flow rates are available, the doorway flow coefficients can be obtained by the following relationship:

$$C = \frac{\dot{W}_{(MEASURED)}}{\dot{W}_{(THEORETICAL)}}$$

Since it is impossible to measure the velocity of gases at every location, average values for the coefficients are used. The exact values of the coefficients depend on many factors, such as the room configuration, fire strength, doorway dimensions and materials used to construct the room. From the experimental data available in the literature, the outflow coefficient seems to be nearly constant and has an average value close to 0.7 in most cases. However, the value of the inflow coefficient seems to vary from experiment to experiment. Different conditions give different inflow coefficients. For example, in Quintiere and McCaffrey's wood crib experiment [12], C_o has an average value of 0.68 and C_i can be quantified by the following correlation:

$$C_i = 0.58 - 0.31 W_D; \qquad 0 \le W_D \le 1$$

Of course, these values may not be applicable to other experimental configurations.

To provide additional perspective on typical values for C_i and C_o, we note that in the first fourteen of the fifty-three experiments reported in [13] (a description of the experiments can be found in Chapter 4), C_o has an average value of 0.74 with a standard deviation of 0.06 and the average value of C_i is 1.13 with standard deviation of 0.35, if we use the measured values of T_G, Z_D and Z_N to calculate the theoretical mass flow rate (using Equations 10 and 11 in Section 2.6.3). Although Quintiere et al. had computed an average value of 0.73 for C_i, the calculational methods used were not consistent with the assumption of a two zone approach, in which the hot gas layer should be represented by an average temperature value instead of having separate inner and outer room temperature values.

When a situation arises which requires the quantification of the coefficients as input to COMPBRN III, and the user has no previous knowledge in assessing the flow coefficient values, the use of a typical value of 0.7 for C_o is recommended. If it is a free burning situation, C_i may be approximated as 0.6; if it is a fuel injected situation (e.g., the fire source is a jet burner), a value of 1.0 for C_i is recommended.

2.6.4 Air Entrainment Model ($\dot{W}_E$)

The air entrainment model is the major modeling difference between COMPBRN II and III. As described in Section 2.2, fresh air is entrained into the fire plume and lowers the plume temperature while increasing its mass flow rate. In COMPBRN III, the air entrainment model consists of a new plume entrainment model, a wall jet entrainment model and a model for the doorway mixing effect. COMPBRN II ignored the latter two phenomena.

The air entrainment model employed in the previous COMPBRN series (which was composed of plume entrainment only) followed the notation and analysis of Fang [16]. The mass entrained at height Z by a combusting plume is:

$$\dot{W}_{PL} = \dot{W}_F \omega (\beta \frac{Z_D - Z_0}{D_f/2} + 1)^{5/3} + \dot{W}_F (1 - \omega) \qquad (12)$$

where

Z_0 = Fire base height.

D_f = Fire base diameter.

β, ω = Plume entrainment coefficients.

The weaknesses in this entrainment model as employed in COMPBRN II can be listed as follows:

1. The equation provides a model of a free burning fire and is not an appropiate model for enclosure fires;

2. The shape of the fire source (i.e., axisymmetric, line fire, wall fire, etc.) and drafts in the room which affect the orientation of the flame are not incorporated in the above correlation;

3. The model neglects the wall jet and doorway mixing effect, which may play a significant role in some situations;

4. Quantification of $\dot{W}_{PL}$ depends on the prediction of the flame diameter (D_f), flame height, fuel burning rate ($\dot{W}_F$), and other parameters (β and ω), which carry significant uncertainties themselves.

In recent years research activities have been directed toward the modeling of fire plumes employing different approaches. A number of them have been found to be accurate, but applicable only to specific conditions. Zukoski et al. [17] have developed a plume flow model resulting from the theory of a weakly buoyant point source of heat and the Boussinesq approximation. The model requires fewer parameters and is more applicable to room fire situations than Fang's model described above. To improve COMPBRN, we have changed the original plume entrainment model of Fang to the more versatile model by Zukoski described below. This plume flow model, combined with a wall jet and doorway mixing effect model, forms the new air entrainment model for the HGLM of COMPBRN III.

2.6.4.1 Plume Entrainment Model

The plume entrainment model in the HGLM is based on the model developed by Zukoski et al. [17]. Briefly, the fire source is modeled as a weak point source, with the Boussinesq density approximation; it is assumed that the vertical velocity U and temperature difference ΔT have gaussian profiles in the radial direction. The plume mass flow rate, $\dot{W}_{PL}$, is approximated by the following correlation:

$$\dot{W}_{PT} = 0.210\, \rho_\infty \sqrt{gZ}\; Z^2 (\dot{Q}^*)^{1/3} \qquad (13)$$

where

$$\dot{Q}^* = \frac{(1 - \chi_r)\dot{Q}}{\rho_\infty C_p T_\infty Z^2 \sqrt{gZ}}$$

Zukoski et al. have demonstrated that the above correlation agrees with experimental values within approximately ±30%. Disturbances to the plume flow due to side wind and wall effects in the lower region have been found to be the causes of the deviation.

Aerodynamic Disturbance

Fresh air coming into the room through the doorway may cause an aerodynamic disturbance, known as the side wind effect, to the plume gases. The originally vertical plume flow becomes tilted to an angle, θ, depending on the strength of such incoming wind (see Figure 2). The plume, then, has to travel a longer distance before it reaches the hot gas layer. Thus, the mass flow rate is increased due to more air being entrained into the plume.

To take into account such a deviation, the elevation term, Z, in the plume entrainment correlation (Equation 13) has been changed to Z/sin θ, where θ is the flame angle. Complicated correlations have been developed to estimated the flame angle. However, these correlations are not always consistent. Zukoski has also pointed out that the presence of room boundaries affects the flame angle. Experimental data have shown that the side wind effect can be represented by a parameter, called the blockage factor, M. The values of this factor under different room boundary conditions are shown in Figure 5 [17]. The mathematical relation between the blockage factor and the flame angle may be described as follows:

$$M = \{\frac{1}{\sin\theta}\}^{5/3} \qquad (14)$$

The value of the blockage factor for a room fire, M = 1.28, which corresponds to a flame angle of 60°, has been found to be quite reasonable in estimating the side wind effect on the plume flow in most room fire situations.

Wall Effect

The effect of placing a vertical wall near the fire source is to reduce the plume mass flow rate by decreasing the effective area for the plume to entrain fresh air from its surroundings. The reduction of air entrainment causes the average plume and hot gas layer temperature to rise. Since less air is entrained into the plume, the thickness of the hot gas layer also decreases.

Experimental results [11] have revealed that the plume mass flux can be reduced by as much as 45% depending on the position of the wall. Figure 6 shows the effect of a vertical wall on the plume mass flow rate.

In COMPBRN III, the reduction in plume flow is represented by a wall effect factor, W, such that

$W \simeq 1.0$, if the fire source is away from the wall.
$W \simeq 0.75$, if the fire source is next to a vertical wall.
$W \simeq 0.5$, if the fire source is at a corner.

COMPBRN III employs a plume entrainment correlation incorporating the blockage factor (M) and the wall effect (W). The combined plume entrainment correlation can be expressed as follow:

$$\dot{W}_{PL} = M \, W \, \dot{W}_{PT} \qquad (15)$$

where $\dot{W}_{PT}$ is the original plume entrainment correlation developed by Zukoski et al. (Equation 13).

2.6.4.2 Doorway Mixing and Wall Jet Mass Flow Rate ($\dot{W}_J$ and $\dot{W}_W$)

In addition to the plume entrainment, fresh air can also be introduced into the hot gas layer region by the doorway mixing and wall jet effects. The result of these effects is to increase the total amount of fresh air being entrained into the hot gas layer.

Doorway Mixing Rate ($\dot{W}_J$)

Experiments have verified the existence of doorway mixing which occurs between the hot gas layer and the lower region. This mixing effect increases the temperature of the lower region and decreases its oxygen concentration by dilution with combustion products. The nature of this mixing is a turbulent shear entrainment that occurs as cold fresh air enters the doorway and hot gases leave the room above the thermal interface. Part of the outgoing hot gases is driven into the lower region by this shearing process. The negatively buoyant hot gases turn upward and entrain an additional amount of fresh air from the lower region on their way back to the upper region. This extra amount of fresh air entrainment ($\dot{W}_J$) is ignored by previous COMPBRN codes.

A model for this mixing process has been proposed by Quintiere and McCaffrey [12] as follows:

$$\dot{W}_J = \rho_J A_J U_J$$

where

ρ_J = The density of the fluid entrained.

A_J = The effective jet surface area.

U_J = The velocity normal to the jet surface.

With further assumptions [12], the mixing rate can be expressed as follows:

$$\dot{W}_J = K_e \frac{T_0}{T_G}(1 - \frac{Z_D}{Z_N})(\frac{W_R}{W_D})^{1/4}\, \dot{W}_{IN}$$

where K_e is the entrainment coefficient (with suggested value of 0.5).

If we neglect the fuel burning rate and forced ventilation and approximate $\dot{W}_{IN} = \dot{W}_{PL}$, then

$$\dot{W}_J = f(T_G,\ Z_D,\ Z_N)\ \dot{W}_{PL}$$

Quintiere and McCaffrey [18] have estimated ratios of the entrainment flow rate to the incoming flow rate of 0.2 to 1.5, depending on the vent dimensions, the temperature of the upper and lower layer, the thermal interface height and the room configuration. In COMPBRN III, we assume that $f(T_G,\ Z_D,\ Z_N)$ is a constant and has a value equal to 0.5; this value appears to lead to reasonable results for a number of room fires.

$$\dot{W}_J = 0.5\ \dot{W}_{PL} \qquad (16)$$

Wall Jet Mass Flow Rate ($\dot{W}_W$):

At solid vertical boundaries within a compartment, the downward-directed wall jet, which results from the ceiling jet, is negatively buoyant relative to the cool air in the lower region. This wall jet is buoyed back upward and away from the wall. It contaminates the lower layer air and entrains an additional (i.e., in addition to the fire plume) amount of lower layer air into the upper layer. Since the HGLM in COMPBRN III assumes an undisturbed lower region, this contamination effect is ignored. Whatever the eventual disposition of the wall flow contaminants, the basic wall flow phenomenon could significantly alter the rate of development of hazardous conditions in the enclosure. If, for example, the flow is buoyed upward as a wall plume and re-enters the upper hot gas layer, then, having entrained additional lower layer air, the depth of the upper layer grows more rapidly than it would otherwise, albeit at a reduced temperature and product concentration. This significantly affects the determination of what kind of environment a fuel element is exposed to in a fire involved compartment.

Such flows have been estimated by Jaluria [19] and Cooper [20] for specific situations. However, an accurate generic assessment of such jet flow is not available. In COMPBRN III, this wall jet activity is approximated as

$$\dot{W}_W = 0.1\,\dot{W}_{PL} \qquad (17)$$

These entrainment models (the plume entrainment model, Equation 15, the doorway mixing model, Equation 16, and the wall jet entrainment model, Equation 17) comprise the air entrainment model in COMPBRN III. The combined mathematical model to describe the overall air entrainment is as follows:

$$\dot{W}_E = 0.210\,(PLCF)\rho_\infty\sqrt{g\,Z}\;Z^2\dot{Q}^{*\,1/3} \qquad (18)$$

where

PLCF	=	1.6 M W
M	=	1.28 in normal room floor fire situations.
	=	1.10 in no wall boundary fire situations.
	=	1.49 if only two walls are present (see Figure 5).
W	=	1.0 if the fire source is away from wall boundaries.
	=	0.75 if the fire source is next to a wall boundary.
	=	0.5 if the fire source is at a corner.

Therefore, in most room fire simulations using COMPBRN III,

PLCF ≈ 2.0, if the fire source is away from the room boundaries.
PLCF ≈ 1.5, if the fire source is located next to a wall.
PLCF ≈ 1.25, if the fire source is at a corner.

Mass Balance Without a Doorway

In the case of fire in a room without any doorway, hot gases are assumed to completely fill up the room (unless the forced ventilation is strong enough to pump out all the combustion products and contaminated air such that hot gas layer does not form at all). The mass balance of the room is reduced to:

$$\dot{W}_F + \dot{W}_{U,V,IN} = \dot{W}_{U,V,OUT} \qquad (19)$$

To avoid pressure built up in the room, leakage of hot gases through the room boundaries is assumed. Equation 19 is used to determine whether the hot gas layer is formed or not. The unknowns of the HGLM are obtained by solving only Equation 3. The value of PLCF then, has no significance in the computation of the hot gas layer properties. Thus, PLCF = 0.0, if there is no doorway.

2.7 THERMAL TRANSFER MODELS

2.7.1 Plume Heat Transfer

The rate of heat gained by the hot gas layer due to the fire plume flow is approximated by the following expression [4]:

$$\dot{Q}_{PL} = (1 - \gamma_r)\dot{Q} \qquad (20)$$

where

$$\dot{Q} = \eta \dot{W}_F \Delta H$$

and

$\dot{Q}$ = The total heat release rate from the fire source.
η = Combustion efficiency.
ΔH = Heat of combustion of the fuel.

$\dot{W}_F$ = Fuel mass burning rate.

γ_r = Fraction of $\dot{Q}$ lost to the environment by radiation from the combustion zone and the plume. For flaming fires, γ_r is typically in the range 0.3 to 0.5 depending on the fuel properties. This parameter is found to be very sensitive to what is being burnt.

2.7.2 Heat Transfer Due to Gas Flows

The heat lost from the hot gas layer due to hot gases flowing through the doorway and forced ventilation system, and the heat gained from incoming ambient air arriving through forced ventilation can be quantified by the following equation:

$$\dot{Q}_{FLOW} = \dot{W}_{FLOW} C_p \Delta T \qquad (21)$$

where

$\dot{Q}_{FLOW}$ = $\dot{Q}_{OUT}$ or $\dot{Q}_V$ as described in Section 2.5.

$\dot{W}_{FLOW}$ = $\dot{W}_{OUT}$ or $\dot{W}_V$ as described in Section 2.4.

C_p = Specific Heat Capacity of hot gas or ambient air.

ΔT = Temperature difference between the transfer media.

2.7.3 Convective Heat Transfer ($\dot{Q}_{CONV}$)

The heat lost from the hot gas layer to the ceiling and walls due to convection is given by Newton's law of cooling,

$$\dot{Q}_{CONV} = h_c \Delta T A_{WALL} \qquad (22)$$

where

h_c = Convective heat transfer coefficient.

ΔT = Temperature difference between hot gas and the heat exchange surface.

A_{WALL} = Heat exchange surface area.

During a room fire, convective heat transfer is dominated by the high velocity ceiling jet flow; therefore, only the ceiling area is considered in the computation of the convective heat exchange between the hot gas and the room boundaries in COMPBRN III.

2.7.4 Radiative Heat Transfer ($\dot{Q}_{RAD}$ and $\dot{q}''_{EXTC}$)

Since COMPBRN does not predict particulate concentrations in room fires, the assessment of radiative heat transfer between the room boundaries and the ceiling is performed empirically. Similar to the quantification of convective heat transfer, only the ceiling area is used to compute the radiative heat loss of the hot gas layer to the room boundaries. Assuming that the hot gas layer is an infinite slab with thickness D_G and that the absorption coefficient of the hot gas layer is wavelength independent (i.e., following the gray body approximation), the radiative heat lost from the hot gas layer to the ceiling is given by the Stefan-Boltzmann law:

$$\dot{Q}_{RAD} = A_{CEIL} F_{HGL-CEIL} (T_G^4 - T_{CEIL}^4) \qquad (23)$$

where F is the effective shape factor.

Further assumming that only surfaces are responsible for the radiative heat exchange between the hot gas layer and the ceiling (which is also assumed to be an infinite gray slab), the radiative heat transfer can be expressed as follows [21]:

$$\dot{Q}_{RAD} = \frac{A_{CEIL}\, \sigma\, (T_G^4 - T_{CEIL}^4)}{(1/\varepsilon_G + 1/\varepsilon_W - 1)} \qquad (24)$$

where

ε_W = Emissivity of ceiling.

= $1 - \rho_W$ (ρ_W is the wall reflectivity).

ε_G = Emissivity of hot gas.

= $1 - \exp(-k_f D_G)$; (k_f is the gas absorption coefficient).

= α_G, the absorptivity of the hot gas layer (following the gray body approximation approach).

σ = Stefan-Boltzmann constant.

= $5.6697\text{x}10^{-8}$) W/m^2K^4

The radiative heat flux, $\dot{q}''_{CEIL}$, which a fuel element outside the hot gas layer receives (see Figure 7) can be expressed as:

$$\dot{q}''_{CEIL} = \dot{q}''_{CEILING} + \dot{q}''_{HGL} \qquad (25)$$

where

$$\dot{q}''_{CEILING} = \dot{q}''_{EXTC}\,(1 - \alpha_G)(1 - \frac{1}{(1/\varepsilon_G + 1/\varepsilon_W - 1)})(1 - \alpha_G) \;+$$

$$\frac{1}{(1/\varepsilon_G + 1/\varepsilon_W - 1)}\,\sigma\, T_{CEIL}^4(1 - \alpha_G) \;+$$

$$+\; \sigma\, T_G^4\, [\varepsilon_G - (\frac{1}{1/\varepsilon_G + 1/\varepsilon_W - 1})]\,(1 - \alpha_G)$$

= The absolute radiative heat flux a fuel element receives due to reflection of radiative energy from external sources and to reflection of radiation from the hot gas layer to the ceiling.

$\dot{q}''_{HGL} = \sigma \, \varepsilon_G \, T_G^4$

= The absolute radiative heat flux the hot gas layer emits.

Chapter 3

SUMMARY OF MODIFICATIONS

In this chapter, we outline the most important modeling changes to COMPBRN I which are incorporated in COMPBRN III. Some, but not all of these changes were included in COMPBRN II; they are discussed here for completeness. These changes are grouped by the subroutine in which they appear. The numerous NAMELIST, DIMENSION, COMMON, and CALL statements needed to help implement these changes are not listed in this chapter, nor are the numerous FORMAT statement changes, used to improve the appearance of the output.

SUBROUTINE MAIN

1. A set of simple error checking statements has been added. These primarily check for out-of-bound problem dimensions and for non-physical real variable values. In general, parameter input values less than or equal to zero should be avoided unless specifically intended. If any input errors are discovered, the job will be terminated.

2. The effective fuel cell radius computations have been corrected. They now are

$$R = \begin{cases} \sqrt{\text{Area}/\pi} & \text{for horizontal objects} \\ \text{Width}/2 & \text{for vertical objects} \end{cases}$$

   In previous versions of COMPBRN, these formulae were reversed.

3. The problem input parameter list has been expanded and is discussed in Chapter 5. Changes have also been made in the list of variables which may be output. Specifically, consider a fuel cell whose surface temperature is T_s. The environment temperature is T_e, the total impinging radiative heat flux from other objects in the room is $\dot{q}''_{EXTC}$.

   COMPBRN III allows the user to output

   a) $\dot{q}''_{EXTC}$ (called QEXT).

b) h (the local heat transfer coefficient HCOEF).
c) T_e (called TSURR).

d) $\varepsilon \dot{q}_e'' + \sigma\varepsilon T_e^4 + hT_e$ (called QEXTOT).

e) $\varepsilon \dot{q}_e'' + \sigma\varepsilon(T_e^4 - T_c^4) + h(T_e - T_c)$ (called QEXCAL).

f) $\varepsilon \dot{q}_e'' + \sigma\varepsilon(T_e^4 - T_s^4) + h(T_e - T_s)$ (called QEXNET).

where

ε = fuel emissivity

T_c = fixed "calorimeter temperature" (CALTEM) specified by the user in NAMELIST &MISC.
If T_c is set equal to room temperature, QEXCAL represents the "cold wall heat flux" at the fuel cell's location.

4. Unlike the previous versions of COMPBRN, COMPBRN III assumes that the steady state is achieved within the first time step (typical value is 60 seconds), instead of instantaneously.

SUBROUTINE SOURCE

1. The gas emissivity is updated at each time step to provide improved accuracy,

$$\varepsilon = 1 - \exp(k_f D_G)$$

where

k_f = Gas absorption coefficient.

D_G = Thickness of hot gas layer.

2. Steady state is assumed to be formed within the first time step instead of instantaneouly after the fire ignition.

SUBROUTINE TRANSF

1. In COMPBRN I, a fuel cell's environment was completely specified by the total heat flux impinging on the fuel cell. In COMPBRN III, the environment is specified by the radiative heat flux from discrete objects (QEXT), the fuel cell environment temperature (TSURR), and the local heat transfer coefficient (HCOEF). TRANSF has been modified accordingly to compute and store all three variables. The latter two, TSURR and HCOEF, are functions of the fuel cell location, i.e., whether it is in the flame, plume, hot gas layer, or cold layer.

2. The plume temperature correlation has been changed. The new correlation developed by Zukoski et al. [22] is:

$$T_{PL,MAX} = T_{\infty}\{1 + 9.11\ g^{1/3}(\frac{(1 - \gamma_r)\dot{Q}}{\rho_{\infty}C_p T_{\infty}})^{2/3}\ Z^{5/3}\}$$

Assuming a Guassian velocity and density (temperature) profile, the mean plume temperature is $1/\sqrt{2}$ times the maximum plume temperature as described above.

3. The correlation for the heat transfer coefficient within the fire plume has been modified. In Siu [3] the correlation used in COMPBRN I was derived using an average over the surface of the fuel cell. In COMPBRN III, values of temperatures and heat fluxes at distinct points are used. To make the calculation of the heat transfer coefficient consistent with this approach, the original correlation, which was used as the basis for the averaging procedure of Siu [3], is directly adopted.

SUBROUTINE IGNIT

1. This subroutine has been revised to allow the calculation of the temperature profile within all objects. In COMPBRN I, an analytical approximate solution for the time to reach a specified surface temperature was employed. As discussed by Chung et al. [7], this model did not account for the surface heat losses to the environment. In COMPBRN III, the temperature profile is now solved numerically (by calling SUBROUTINE DIFFUS) for every object, using an exact boundary condition for the exposed face. (Note that DIFFUS was available in previous COMPBRN, but was only employed for calculating the temperatures within the compartment walls and ceiling).

SUBROUTINE OUTPUT

1. This subroutine now allows the user to output 17 variables, instead of 11, as described in Section 5.18.

SUBROUTINE BARR

1. This subroutine, which was used in previous versions of COMPBRN to calculate the steady-state temperature in a slab, is no longer required.

SUBROUTINE CYLPAR

1. This subroutine, which is used to compute the shape factor

from a vertical cylinder to a differential surface parallel to the cylinder's base, is a corrected version of the subroutine documented by Siu [7].

SUBROUTINE DIFFUS

1. Changes have been made to allow treatment of more general boundary conditions for the back face of the slab. This is useful for treating barriers (a barrier's back face is assumed to be exposed to the same environment temperature at its front face). The method of solution of the transient heat conduction equation is described in Chung et al. [7].

SUBROUTINE CEILNG AND ZDNEW

1. These subroutines, which were used in previous versions of COMPBRN to calculate the ceiling hot gas layer properties, are replaced by subroutines CGAS, CNEWTN, CSOLVE and CGASHT.

SUBROUTINE CGAS

1. This subroutine replaces the subroutine CEILNG to estimate the hot gas layer properties. CGAS is able to predict the unknown properties in a wider range of room fire scenarios than the previous COMPBRN.

2. The presence of strong forced air ventilation may affect the location of the thermal interface. If a large amount of hot gas is pumped out of the room through the ceiling vent, the hot gas layer thermal interface may be formed at the door soffit region or may not form at all. CGAS identifies such phenomena by comparing the plume mass flow going into the hot gas layer at different elevations (at the door height and the ceiling) with the net ventilation outflow rate through the ceiling vent. Figure 8 depicts the flow chart of the logical decision in the subroutine CGAS.

3. The room is assumed to be rectangular in shape; if other room configuration is used, this assumption can be changed by replacing a statment in CGAS.

4. CGAS calls subroutines CNEWTN, CSOLVE, CGASHT, and function subroutine RADEQ to compute the unknowns of the hot gas layer properties. With the above subroutines, CGAS can be run independently from the rest of COMPBRN III to estimate the properties of the hot gas layer formed in room fires. Part of the simulations performed in Chapter 4 employ such a program.

5. CGAS computes the heat flux that a fuel element receives due to external heat sources, the hot gas layer and the ceiling (Equation 25).

SUBROUTINE CNEWTN

1. This is a new subroutine employed by COMPBRN III to search for the root (T_G) of the mass flow balance equations (Equation 1 and 2) utilizing a Newton-Raphson numerical scheme.

2. If the new iterated root is out of the permissible range, a bisection method will be used to obtain a better estimate of the unknown. A warning message will be printed if such situations arise.

3. The iteration limit has been set to 30 and can be changed easily. If this limit is exceeded, a best guess solution will be provided and a warning message will be given.

SUBROUTINE CSOLVE

1. This subroutine, when called by CNEWTN, estimates the first derivatives of the mass flow equations using a forward different (two point) scheme.

SUBROUTINE CGASHT

1. This subroutine updates the thermal interface heights (Z_D, Z_N) by solving the thermal balance equation using the estimated hot gas layer temperature (T_G) from the previous time step.

Chapter 4

SIMULATION OF EXPERIMENTS

In this chapter COMPBRN III is compared to COMPBRN II by simulating cable tray experiments performed by Underwriters Laboratories (UL) for Sandia National Laboratories (SNL) [15]. The room fire experiments performed by Quintiere et al. [13] are also simulated.

4.1 SIMULATION OF SNL/UL CABLE TRAY FIRE EXPERIMENTS

In [7], Chung et al. simulate the room fire experiments conducted by SNL/UL using COMPBRN II. The goal of these experiments is to test the validity of the claim that a 6.10 m (20 ft) separation distance without intervening combustibles or fire hazards (as specified by Section III.G.2.b of Appendix R to 10CFR50) would be sufficient to ensure that at least one train of cables would remain functional [15]. The results provided by [15] are in such a form that a detailed comparison with the predictions of COMPBRN II and III can be readily made. In [7], three of the four preliminary cable tray fire experiments are simulated. COMPBRN II gives satisfactory results in Experiments 1 and 3, while it under-predicts the results of Experiment 2 and does not generate a solution for Experiment 4. COMPBRN III is able to simulate all four experiments with satisfactory results. Significant improvement can be seen by comparing the simulation results.

4.1.1 Description of the Cable Tray Tests

The room configurations of Experiments 1-4 are modeled as shown in Figures 9 to 11. In all experiments, the compartment is 4.27 m (14 ft) wide and 3.05 m (10 ft) high. In Experiment 1, the length of the compartment is 9.14 m (30 ft) and the heptane tank is placed 1.52 m (6.5 ft) from the left wall, whereas, in experiments 2 to 4, the compartment is 7.62 m (25 ft) long and the heptane tank is placed against the wall. The heptane tank contains a fuel load of 10 gallons and is common to all experiments. One difference between the room configurations of Experiments 1 to 4 is the size of the compartment door opening: Experiments 1 and 2 have a 2.44 m (8 ft) by 2.44 m (8 ft) door, Experiment 3 has a 1.22 m (4 ft) by 2.44 m (8 ft) door, and Experiment 4 has a sealed off doorway.

The horizontal cable trays are separated from the heptane pool fire by a horizontal distance of at least 6.1 m (20 ft). The two trays, one of which is directly above the other, are located in the far corner, close to the ceiling [0.305 m (1 ft) and 0.458 m (1.5ft) below] and above the door. Instruments are placed throughout the compartment and within the cable trays to measure the external heat fluxes and the gas and cable jacket temperatures.

4.1.2 Comparison of Simulation Results

The hot gas layer temperatures, heat fluxes, and cable jacket temperatures predicted by COMPBRN II and III are compared with observed values from Experiments 1 to 3 in Figures 12 to 20. Parameters used by both COMPBRN II and III are kept constant to provide a meaningful comparison. Two values (0.7 and 1.0) of the fuel combustion efficiency (η) are used in the comparisons to serve as a general guideline of the codes' sensitivity and performance. The value η = 1.0 implies perfect burning with a free supply of oxygen and is an ideal value. During an actual fire, local oxygen starvation prevents complete combustion; thus, ideal combustion is rarely seen unless air with enriched oxygen is supplied. Heptane is a highly flammable substance with combustion efficiency ranging from 0.7 to nearly 1.0, therefore, the actual combustion efficiency should be somewhere within this range. The values of the common parameters used in the comparison are shown in Table 1 and the differences in some important input parameters are shown in Table 2. These parameters are empirical and depend upon such detailed characteristics of the fire scenario as the location of the fire source with respect to the room boundaries and door. In general, these parameters are not well known for an arbitrary scenario; uncertainties in their values must be accounted for when analyzing the behavior of fire in a room.

The following observations can be deduced from the comparison:

1. In the simulation of the hot gas layer temperature, COMPBRN III is able to bracket the actual asymptotic temperature by using η = 0.7 and 1.0 in all three experiments, while COMPBRN II underpredicts the steady state results (see Figures 12, 15 and 18).

2. Both versions of COMPBRN perform reasonably well in predicting the measured heat flux and the lower tray cable jacket temperature (Figures 13, 14, 16, 17, 19 and 20).

3. Predictions performed by COMPBRN III using η = 1.0 (ideal combustion) can be interpreted as the upper bound of the experiment data. This assumption is clearly verified in Figures 12-20.

Using the parameters listed in Table 3, COMPBRN III is found to provide excellent results in all experiments including Experiment 4,

TABLE 1

Common Parameters Used in the Simulation Comparison

Combustion Efficiency (EFF)	0.7 and 1.0
Convective Heat Transfer Coefficient (HCEIL)	10.0
Fraction of Heat Lost by Radiation (GAMMA)	0.4
Gas Absorption Coefficient (GABSRP)	1.4

TABLE 2

Other Parameters Used in the Simulation Comparison

<u>COMPBRN II</u>	
Doorway Coefficient (DCF)	0.7
Plume Entrainment Coefficients (PLCF1 and PLCF2)	1.5 and 0.5
Convergence Acceleration Parameter (THETA)	1.5
<u>COMPBRN III</u>	
Doorway Inflow Coefficient (DCFIN)	0.6
Doorway Outflow Coefficient (DCFOUT)	0.7
Plume Entrainment Coefficient (PLCF) for Experiment 1	2.0
Plume Entrainment Coefficient (PLCF) for Experiment 2-3	1.5

which COMPBRN II is unable to simulate. In this experiment, the absence of a doorway gives poor air ventilation and the combustion efficiency is believed to drop to as low a value as 0.65. The other three experiments are well ventilated by the doorway, giving a combustion efficiency of around 0.85. The results of such simulations are shown in Figures 21 to 32.

In these simulations COMPBRN III predicts the steady state values of the experiments with high accuracy. In Experiment 4 the fire is originally surface controlled, and as the oxygen content in the room decreases due to combustion, the fire changes to ventilation controlled burning and eventually self-extinguishes.

TABLE 3

Parameter List for Simulation of Cable Tray Fire by COMPBRN III

Air Entrainment Coefficient (PLCF) (Experiment 1)	2.00
Air Entrainment Coefficient (PLCF) (Experiment 2-3)	1.50
Air Entrainment Coefficient (PLCF) (Experiment 4)	0.00
Combustion Efficiency (EFF) (Experiment 1-3)	0.85
Combustion Efficiency (EFF) (Experiment 4)	0.65
Convective Heat Transfer Coefficient (HCEIL)	10.0
Doorway Inflow Coefficient (DCFIN)	0.60
Doorway Outflow Coefficient (DCFOUT)	0.70
Fraction of Heat Lost by Radiation (GAMMA)	0.45
Gas Absorption Coefficient (GABSRP)	1.30

4.2 SIMULATION OF STEADY-STATE FLOW EXPERIMENTS

Fifty-five steady-state experiments (in a relatively small room) have been conducted by Quintiere et al. [13] to study the flow induced by a simulated pool fire in a compartment under conditions characteristic of the developing fire period. The steady-state flow experiments are conducted in a room as shown in Figure 33. The light-weight walls and ceiling are covered with a ceramic fiber insulation board to establish near-steady conditions within 30 minutes following ignition of a 30 cm diameter porous plate diffusion burner. The burner is supplied with commercial grade methane at a fixed rate.

Movable bidirectional velocity probes and bare wire thermocouples within the room opening measure the velocities and temperatures of the opening flows on a two-dimentional grid of 28-144 points depending on the size of the opening. A fixed array of aspirated thermocouples in the front corner of the room measure the gas temperature profile. A similar array of bare-wire thermocouples measure the near-ambient temperature profile within the large well-ventilated area outside the room. The experiments are conducted using different fire strengths (31.6, 62.9, 105.3, and 158 kW), and different door and window sizes.

Since these experiments do not involve the assessment of damage of components inside the room, it is not necessary to run the entire COMPBRN III code to simulate them. A separate program has been written utilizing the subroutines CGAS, CNEWTN, CSOLVE and CGASHT from COMPBRN III to simulate ten out of the fifty five experiments conducted. The predicted hot gas layer properties (T_G, Z_D and Z_N) are compared to the measured steady-state values. The results are shown in Figures 34 to 36.

Since the fire source is a methane diffusion burner, the combustion efficiency is close to 1.0. The doorway coefficients are calculated from the measured mass flow rates and the theoretical mass flow rates; these values are different in each experiment. The input parameters are listed in Table 4. The values of the parameters DCFIN and DCFOUT used are listed in Table 5. These values are obtained by substituting the experimental data into Equations 10 and 11.

TABLE 4

Parameter List for Simulation of the Room Fire Experiments

Air Entrainment Coefficient (PLCF)	2.00
Combustion Efficiency (EFF)	1.00
Convective Heat Transfer Coeffieient (HCEIL)	10.0
Doorway Inflow Coefficient (DCFIN)	Varies
Doorway Outflow Coefficient (DCFOUT)	Varies
Fraction of Heat Lost by Radiation (GAMMA)	0.15
Gab Absorption Coefficient (GABSRP)	1.30

TABLE 5

Values of DCFIN and DCFOUT Used in Table 4

Experiment #	DCFIN	DCFOUT
1	0.73	0.70
2	0.87	0.73
3	1.06	0.75
4	1.01	0.76
5	1.02	0.75
6	1.20	0.72
7	0.86	0.71
12	1.04	0.70
13	1.60	0.69
14	1.07	0.90

In this simulation, COMPBRN III is able to predict the experimental results with high accuracy when the values of the input parameters DCFIN and DCFOUT are well known. This clearly reveals the potential of COMPBRN III in the prediction of room fires. It also shows that future research on the estimation of DCFIN and DCFOUT for arbitrary fires will be helpful in predicting the behavior of these fires.

Chapter 5

USERS GUIDE TO COMPBRN III

The current version of COMPBRN III can be run on IBM, CDC, and Prime computers (a PROGRAM statement is needed for the CDC machines, however, and NAMELISTS for both the CDC and Prime machines should be preceded by "$" instead of "&"). Running time on a mainframe computer are relatively short (on the order of a few seconds) for most problems; they are directly related to the number of time steps and the total number of fuel cells used in the scenario of interest.

In this chapter, we describe the input and output for COMPBRN III. We also provide some notes which are intended to aid the user in modeling compartment fires using COMPBRN III.

5.1 ADDITIONAL MODELING DURING APPLICATION

Because there are a number of assumptions implicit in COMPBRN III's various models, further modeling of the compartment is required before an actual fire can be analyzed.

In general, a compartment fire will involve a fuel bed of arbitrary geometry, location, and orientation. Furthermore, the fuel bed may be composed of a number of different fuel types, the relative amounts of which may vary with location.

In preparing the input data for COMPBRN III, the analyst must proceed as follows:

1. A Cartesian coordinate system is defined with respect to some arbitrary location in the compartment. The z-axis always represents the vertical direction. The compartment walls and ceiling are rectangular in shape, and are parallel to the planes defined by the coordinate axes.

2. The fuel bed is modeled with a series of homogeneous, two-dimensional rectangular slabs, called "super modules." The long axis of each slab defines its "direction," and must be parallel to one of the coordinate axes. The direction normal to the slab's face defines its "orientation," and also must be parallel to one of the coordinate axes. The imposition of a regular geometry on the fuel bed is not always a severe modeling restriction, since a physical fuel element can be modeled as a number

of contiguous super modules. However, COMPBRN III is presently incapable of modeling fires progressing along an inclined surface.

3. The super modules are then further discretized (along the direction of their long axes) into contiguous fuel packets, called "fuel cells." These fuel cells should be almost square in dimension when modeling horizontal fuel beds, since COMPBRN III's flame models for this configuration are based on results from flames over nearly square or round pools of fuel.

4. The fuel bed is further modeled using the "porosity factor" and the "communication matrix." The porosity factor is required since a "rough" fuel element (e.g. cables in a cable tray section) will have more surface area available for burning than provided by the representing flat super module of the same nominal dimensions. This factor is simply the actual area available for burning per unit base (super module) area.

   The communication matrix is constructed by the analyst. It allows him to specify which super modules or fuel cells are contiguous, and which ones cannot transmit heat to others (due to intervention by other fuel elements, barriers, etc.). If instructions to the contrary are not provided, all fuel elements are assumed to be able to "communicate with," i.e. transmit heat to, all other fuel elements.

   The porosity factor and the communication matrix allow some fine-tuning of COMPBRN III's simple modeling. It must be realized however that the memory space requirement for the communication matrix expands as the square of the number of fuel cells, and this is a practical limiting factor in the ability of COMPBRN III to handle complex problems in detail.

5.2 PROGRAM FLOW

COMPBRN III is a single precision FORTRAN computer code which is divided into a main program, a group of primary subroutines, and a number of auxiliary subroutines and function subprograms. The modular nature of the code is not necessary for execution efficiency, but is intended to allow the analyst to incorporate improved models as they become available. All of the subroutines incorporate variably-dimensioned arrays; if the fuel bed configuration requires a large number of fuel cells, only the main program need be modified and recompiled.

As can be seen in Figure 37, COMPBRN III execution begins with the MAIN program. Fuel bed geometry, initial fire characteristics, fuel type characteristics, communication matrix data, compartment parameters, model variation factors, and output format data are read using NAMELIST directed input. A simple input error checking routine is employed to determine if any obvious errors have been made. MAIN calls subroutine INCHK, in which various portions of the input data can be printed for verification, and then the two initialization subroutines, INIT and TINIT.

After problem definition and initialization is complete, subroutine SOURCE is used to compute the fuel burning rate, the resulting rate of heat output, and the flame height, for each burning fuel cell. The models vary according to the degree of compartment ventilation and whether the fuel element is horizontal or vertical. The strength of each element as a source of heat flux is then calculated. The auxiliary subroutine CGAS may be called by SOURCE to determine the heat flux from the ceiling. Subroutine CGAS, if called, requires the use of function subroutine RADEQ, which solves a special version of the quartic equation to obtain an improved value for the hot gas layer temperature, subroutine CGASHT, which updates the height of the natural density plane within the compartment given an updated hot gas layer temperature, subroutine CNEWTN, which solves for the root of the coupled equations and subroutine CSOLVE, which solves for the mass flow rates.

Subroutine TRANSF follows SOURCE, and transfers the heat fluxes from the various sources to the target elements via convective and/or radiative pathways. The shape factors used in the flame radiation transfer calculations are computed using the function subroutines CYLPAR and CYLPER. The shape factors for transfer from rectangular sources (e.g. the ceiling) were computed earlier using SHAPE and RECT, and are stored in the communication matrix. Special models are used to account for the feedback radiation of a flame over a vertical slab back to the slab, and for the conduction of heat to contiguous (and non-burning) fuel elements.

Subroutine IGNIT is used to determine if non-burning fuel elements have absorbed enough heat to ignite. This subroutine employs the subroutine DIFFUS to solve the transient heat conduction equation (slab geometry) for every object modeled (except for detectors, which are described in Section 5.11). Subroutine OUTPUT prints data desired by the analyst for each time step.

5.3 PROGRAMMING NOTES

As discussed in Chapter 1, COMPBRN III, as well as COMPBRN I and II, performs best in situations where the fire is fairly small with respect to the room. The quantitative relationship between the fire size and room size which determines the boundary of the region of problems for which COMPBRN III is applicable has not yet been established. This relationship is also a function of the room door size, the forced ventilation rate for the room, and the location of the fuel in the room.

To the user, this means that solution convergence may not be obtained in a limited number of cases. The following notes, derived from the experience of others who have used the code, as well as that of the authors, may be useful:

1. The code will almost always achieve a reasonable solution if the effects of the enclosure are neglected (i.e., IROOM is set equal to zero)

2. Failure when IROOM=0 will occur when the midpoint of a fuel cell falls within the effective radius ($R = \sqrt{Area/\pi}$) of a burning fuel cell and the z-coordinates of the two cells are identical. This condition will also lead to failure when IROOM=1, and can be avoided by suitably chosen problem input parameters.

3. Oscillations may occur in the solution of the fuel cell surface temperature (subroutine DIFFUS) if the fuel cell is immersed in a very high temperature flame. This condition, which may occur regardless of the values specified for IROOM, can be remedied by ensuring that

$$\frac{81*THK*DELT}{DENS*SPHT*(SDEP)^2} < 0.1$$

   where the variables are explained in Section 5.11. In general, the solution accuracy improves as the above ratio decreases.

4. When IROOM=1, failure may occur if the fire is too small or too large with respect to the room or if the only source of flames is located too high within the room.

5.4 OUTPUTS

COMPBRN III prints two sections of output data. The first is used to verify the problem input data, while the second lists user-specified variables during computations.

The input data check is regulated using the indicator variable INCHCK. If INCHCK equals 0, only heading material and the model variation parameters stored in the array FCTR are output. These variation parameters can be used to multiply the computed results of a particular correlation, if individual model uncertainties are to be propagated through the code. A list of the models which can be modified with FCTR is given in Section 5.17. If INCHCK equals 1, the physical parameters characterizing the fuel are also output. If INCHCK is not equal to 0 or 1, all input data, with two exceptions, are printed. In the case of the super module coordinates, the super module midpoints input (SMX, SMY, and SMZ in Section 5.9) are not printed when INCHCK is not equal to 0 or 1. Instead, the code outputs the coordinates of the first fuel cell in each super module, where the cells are numbered as described in Section 5.9. Similarly, while the mass of each super module is an input parameter, the code prints out the mass of each fuel cell in the super module.

The output data listed each time step is specified with the indicator variables IOUTPT and NSMOUT, and the arrays MOUTPT and MSMOUT. IOUTPT determines the number of output variables to be printed, and the elements of MOUTPT specify which variables are to be printed (see Section 5.18). Similarly, NSMOUT determines the number of super modules for which output data is to be printed, and the elements of MSMOUT specify which particular super modules are included in this number. If IOUTPT and NSMOUT equal 0, only the elapsed time since initiation and the total mass burning rate in the compartment are printed. If IOUTPT equals 0 and NSMOUT is not equal to 0, the elapsed time, the burning rate, and a logical variable array, LBURN, which specifies which fuel cells (if any) in the specified super module are burning, are printed.

5.5 INPUTS

COMPBRN III requires a large amount of input data to specify each particular problem. These data are read using NAMELIST format, and the NAMELISTs must be input in the order presented. If there are any errors in the input file, the computer bypasses execution.

With respect to the problem input, the COMPBRN III changes to COMPBRN I are small. The variables EFF and FTDAM (the combustion efficiency and fuel damage temperature) have been added to NAMELIST &FUELT, the variables HROOM and CALTEM (the heat transfer coefficient outside the hot gas layer and plume, and the temperature of any calorimeter) have been added to NAMELIST &MISC, and the definitions of the entries in the FCTR and MOUTPT arrays (NAMELISTS &MODVAR and &OUTF) have been modified, in NAMELIST &ROOM, variables PLCF1 and PLCF2 are replaced by PLCF, variable DCF is replaced by DCFIN, and DCFOUT. Variable THETA is deleted from this NAMELIST.

This data block defines parameters which are in effect for all of the jobs to be performed. All subsequent data blocks apply only for the particular job being executed.

5.6 OVERALL JOB PARAMETERS (&STRT)

Data Set Members

- NJOB = The number of jobs to be run. In general, the entire set of input data (starting with NAMELIST &SIZE) must be repeated for each job.
- NTIME = The maximum number of time steps for each job. Jobs may end earlier if certain iterative calculations do not converge sufficiently quickly or if all fuel which can be ignited has been exhausted.
- NREAD = The logical unit number off which remaining data is to be read. (Default = 5)
- NWRITE = The logical unit number on which output is to be written. (Default = 6)
- DELT = The time step increment in seconds. (Typical value = 60.0)

5.7 INDIVIDUAL JOB PARAMETERS (&SIZE)

The limits given in this data block are for the COMPBRN III version currently compiled.

Data Set Members

- NSM = The number of super modules. (NSM ≤ 30)
- NFUEL = The maximum number of fuel types. (NFUEL ≤ 5)
- NCOM = The number of entries for the construction of the adjacency portion of the communication matrix ICOMM. See Section 5.13 (NCOM ≤ 30). (Default=0)
- NNCOM = The number of non-communicating entries for the construction of ICOMM. See Section 5.14 (NNCOM ≤ 200). (Default=0)
- NPILOT = The number of fuel cells initially on fire (NPILOT ≤ 10).
- IROOM = The indicator variable which determines if compartment data are to be included or not. This latter option is useful when the fire is sufficiently small with respect to the room such that enclosure effects can be neglected.
  IROOM=1 => compartment data are input.
  IROOM≠1 => no compartment data are input.
  In the output, this choice is indicated indirectly by printing the input parameters specified in NAMELIST &ROOM.

- INITG = The indicator variable which shows if the hot gas layer has some initial characteristics and/or if the initial external heat fluxes are non-zero. Input only if IROOM = 1.
  - INITG=1 => Initial values for gas layer and/or heat fluxes are input.
  - INITG≠1 => TG (Gas Layer Temperature) = RTEMP
DG (Gas Layer Thickness) = 0.0 m
QEXT (External Heat Fluxes for All Fuel Elements) = 0.0 W/m^2.

5.8 TITLE CARD

The first 80 characters on this card will be reproduced as the job title in the code output.

5.9 FUEL BED DEFINITION (&FUELB)

This data block must be entered once for each super module, i.e. NSM times. The first entry corresponds to super module number 1, the second to module 2, etc. Except for SMX, SMY, and SMZ, negative values or zero values are not allowed.

Data Set Members

- SMX = x-coordinate midpoint of super module (m).
- SMY = y-coordinate midpoint of super module (m).
- SMZ = z-coordinate midpoint of super module (m).
- SLNG = Super module length (m).
- SWID = Super module width (m).
- SDEP = Super module depth (see point 3 of Section 5.1).
- SMASS = Super module mass (kg).
  The fuel mass affects the duration of burning. For nonburning items, this variable is not used. Note that COMPBRN III prints out the fuel mass per fuel cell, not SMASS.
- SPOR = Super module porosity factor f_p (Dimensionless).
- SLOSS = Undefined variable. (This variable is not used).
- NFCL = Number of fuel cells in super module. Should be set equal to unity for a ceiling.
- IORNT = Orientation of super module.
  - IORNT=1 => Normal axis is in the x-direction.
  - IORNT=2 => Normal axis is in the y-direction.
  - IORNT=3 => Normal axis is in the z-direction.
- IDIREC = Direction of super module.
  - IDIREC=1 => Long axis is in the x-direction.
  - IDIREC=2 => Long axis is in the y-direction.
  - IDIREC=3 => Long axis is in the z-direction.
- IFTYP = Super module fuel name/identification number, used as super module fuel type location identifier. This parameter

identifies the particular location in the array IFUEL of NAMELIST block &FUELT (Section 5.11) which corresponds to the fuel for the super module described.

Example: "IFTYP=3" means that the super module fuel is type 3, where fuel type 3 is defined by position 3 of array IFUEL. Note that IFTYP ≤ NFUEL.

COMPBRN III will automatically compute the locations of the fuel cells in each super module. It will also number the fuel cells, the numbers increasing with distance in the direction of the long axis. Thus, if the super module is directed along the x-axis, a fuel cell at X = 3.0 will have a lower number than a fuel cell at X = 5.5.

Note that a warning message will be given if IDIREC and IORNT have the same value.

5.10 PILOT FUEL PARAMETERS (&PILOT)

COMPBRN III assumes that a compartment fire starts on top of a small number of selected fuel cells in the fuel bed. These initial fires, called pilot fires, may involve materials not comprising the main fuel bed. For example, a segment of cable tray may be overlaid by an amount of oil which is used to initiate the compartment fire. The location of this pilot fire is, however, treated as being identical with the location of the underlying fuel cell.

Each item in this data block is an array, with the first entry corresponding to the first pilot fuel cell, the second with the second cell, and so forth. NPILOT entries should be made for each array.

Data Set Members

- IPIL = Array listing the super modules of the pilot fuels.
- JPIL = Array listing the particular fuel cells (within the given super module) which are assigned pilot fires.
  Example: If NPILOT=2, IPIL=(3,2), and JPIL=(4,5), this means that there are two pilot fires, the first being located on the top of the fourth fuel cell of the third super module, and the second being on top of the fifth fuel cell of the second super module.
- IPFUEL = Pilot fuel type array. This entry corresponds to IFTYP defined in Section 5.9. Fuel types are numbered consecutively. Thus, if the third entry of IPFUEL is '5', this means that the third pilot fire involves fuel type 5.
- PMASS = Pilot fuel mass array (kg).
  Note that pilot fuels are considered separately from the underlying main fuel. PMASS kg of fuel are assumed to lie on top of the fuel cell, regardless of what SMASS is. PMASS can not be negative or zero-valued.

5.11 PHYSICAL FUEL PARAMETERS (&FUELT)

Each of the items in this data block represents an array of dimension NFUEL. The first entry in each array corresponds to fuel type 1, the second entry corresponds to fuel type 2, and so forth.

Data Set Members

- IFUEL = Array of identification numbers (names) assigned to each fuel type.
  - $0 < IFUEL(I) < 10$ => Super module is combustible fuel.
  - $10 \le IFUEL(I) < 20$ => Super module is a detector (useful for measuring heat fluxes and local temperature).
  - $20 \le IFUEL(I) < 30$ => Super module is a wall.
  - $30 \le IFUEL(I) < 40$ => Super module is a thermal barrier.
  - $40 \le IFUEL(I) < 50$ => Super module is the room ceiling.

  Note that the room ceiling can only be modeled with one super module and that those super modules modeling the ceiling and the walls may only have one fuel cell each.

  Detectors are passive objects used to indicate the thermal environment at their location. They are not used in any source or response calculations. Barriers are slabs whose back sides may act as heat sources. The front and back of the barriers are exposed to the environment temperature; their prime function is to block radiative heat fluxes.

In the following list, entries must be provided for all fuel types, but realistic entries are optional for the ranges of IFUEL noted below [where for notational simplicity, we let K=IFUEL(I)]. Note: Do not input 0's for nonessential parameters.

- DENS = Density (kg/m^3); ($10 \le K < 20$).
- SPHT = Specific heat (J/kgK); ($10 \le K < 20$).
- THK = Thermal conductivity (W/mK); ($10 \le K < 20$).
- HEAT = Heating value (J/kg); ($10 \le K < 50$).
- FIGTP = Piloted ignition temperature (K); ($10 \le K < 50$). This is used when flames touch a combustible.
- FIGTS = Spontaneous ignition temperature (K); ($10 \le K < 50$). This is used when the combustible is not touched by any flame.
- FTDAM = Damage temperature (K); ($10 \le K < 50$).
- BRATV = Ventilation controlled burning rate constant C_V (dimensionless); ($10 \le K < 50$). The program uses this parameter only when IROOM=1.
  Suggested values:
  0.12 for wood,
  0.025 for oil,
  and 0.05 for cable.

- BRATS0 = Specific burning rate constant $\dot{m}''_0$ (kg/m²s); ($10 \le K < 50$).
- BRATS1 = Surface controlled burning rate constant C_S (kg/J); ($10 \le K < 50$).
- EFF = Combustion efficiency (dimensionless); ($10 \le K < 50$). Suggested values:
  0.8 for heptane in well ventilated condition;
  0.6 for heptane in poorly ventilated condition;
  0.035 for cable, PMMA.
- GAMMA = Fraction of flame heat released as radiation (dimensionless); ($10 \le K < 50$).
- FABSRP = Absorption coefficient for flame gases (m^{-1}); ($10 \le K < 50$).
- REFL = Reflectivity (dimensionless); ($10 \le K < 20$).

5.12 MISCELLANEOUS DATA (&MISC)

Data Set Members

- RTEMP = Room temperature (K). (Default = 298.0)
- FLCF = Heat transfer coefficient for heat transfer in a flame (W/m²K).
- HROOM = Convective heat transfer coefficient outside of hot gas layer (W/m²K).
- CALTEM = Calorimeter temperature (K). Used in computation of net heat flux to a calorimeter.

5.13 COMMUNICATION DATA (&SEE)

This data block is used to input information defining if a given fuel cell touches another fuel cell. This affects the heat transfer models used, transfer between contiguous cells being somewhat greater than transfer between disconnected cells.

COMPBRN III automatically establishes adjacency for consecutive fuel cells in each super module. Furthermore, by default, all fuel cells can transmit heat to all other fuel cells (i.e., they "communicate"). The purpose of this data block is to define some exceptions to these general rules (non-communication is handled in Section 5.14). NCOM entries must be made, one for each exception.

Data Set Members

- IV = 4 element array containing adjacency data. If fuel cell j of super module i is adjacent to fuel cell l of super module k, IV would be (i,j,k,l). If super modules i and k are parallel, have the same number of fuel cells, are of the same length, and are adjacent, IV would be (i,999,k,0). The '999' tells COMPBRN that the jth. cell of super module i is adjacent to the jth cell of super module k, j ≤ NFCL. Note that the adjacency relationship is symmetrical. Two separate entries, (i,j,k,l) and (k,l,i,j) are not required; only enter one of the two.

5.14 NON-COMMUNICATION DATA (&NSEE)

This data block defines which fuel cells cannot transmit heat to certain other fuel cells. It is treated similarly to the preceding data block, NNCOM entries being required.

Data Set Members

- NV = 4 element array containing non-communication data. If fuel cell j of super module i cannot transmit heat to fuel cell l of super module k, NV would be (i,j,k,l). If all of the fuel cells in super module i cannot transmit heat to all of the fuel cells in super module k, NV would be (i,999,k,0). If all of the fuel cells in super module i cannot transmit heat to all of the fuel cells in super modules j through j', NV would be (i,888,j,j'). Note that the non-communication relationship is asymmetrical.

5.15 ROOM DATA (&ROOM)

This data block should be entered only if IROOM = 1. Default values are assigned for some of the parameters.

Data Set Members

- DCFIN = Coefficient of inflow air through doorway (dimensionless). (Default = 1.0)
  Suggested values:
  1.0 for jet burner.
  0.6 for other fire source.
- DCFOUT = Coefficient of discharge for doorway (dimensionless). (Default = 1.0, Suggested value: 0.7)
- DHGT = Height of doorway (m).
- DWID = Width of doorway (m).
- FC = Fraction of forced ventilation inflow which enters the gas layer (dimensionless). (0.0 ≤ FC ≤ 1.0)

- FH = Fraction of forced ventilation outflow which leaves the gas layer (dimensionless). ($0.0 \le FH \le 1.0$)
- GABSRP = Absorption coefficient of hot gas (dimensionless). (Default = 1.3)
- HCEIL = Heat transfer coefficient for ceiling (W/m^2K). Also used for heat transfer to objects in the hot gas layer.
- PLCF = Buoyant plume entrainment coefficient, (dimensionless). (Default = 2.0)
  Suggested values:
  2.0 for undisturbed room fire.
  1.5 for a fire source which is next to a vertical wall.
  0.0 for a room fire without any doorway.
- VFV = Forced ventilation volumetric airflow (m^3/s).

5.16 INITIALIZATION DATA (&GINIT)

This data block should be entered only if IROOM = 1 and INITG = 1.

Data Set Members

- TG = Initial gas layer temperature (K).
- DG = Initial gas layer thickness (m).
- QEXT = Two dimensional array containing initial external heat fluxes impinging on each fuel cell, the (i,j) entry corresponding to fuel cell j of super module i (W/m^2).

5.17 MODEL VARIATION FACTORS (&MODVAR)

This data block allows the user to multiply the results of various models by a specified factor. By default, all factors are set to 1.0.

Data Set Members

- FCTR = 15 element array containing the modification factors for 15 models:

  1. Modifies room-averaged value for C_V (ventilation controlled burning rate constant).
  2. Modifies surface controlled burning rate of fuel.
  3. Modifies flame height over horizontal fuel slabs.
  4. Modifies flame height over vertical fuel slabs.
  5. Modifies radiative heat flux received by target element.
  6. Modifies buoyant plume temperature above flame.

7. Modifies heat transfer coefficient for vertical surfaces in the plume.

8. Modifies heat transfer coefficient for horizontal surfaces in the plume.

9. Modifies gas layer temperature seen by an object.

10. Modifies heat transfer from flame over vertical fuel bed back to fuel bed.

11. Modifies conductive heat flux to adjacent fuel cells.

12. Modifies radiative heat flux from the gas layer to objects below.

13. Modifies heat flux from reflections off of walls and barriers.

14. Modifies mass burnout fraction. Mass burnout is normally assumed to occur when 30% of the fuel is remaining. If 100% of fuel is believed to be used up before burnout, The fraction needs to be changed to 1/0.3.

15. Undefined.

5.18 OUTPUT DEFINITION (&OUTF)

This data block allows the user to specify the printed output desired (see Section 5.4).

Data Set Members

- INCHCK = Indicator variable controlling the amount of input data to be printed.
  - INCHCK=0 => Only heading material and FCTR.
  - INCHCK=1 => Above, plus fuel parameters (Section 5.11).
  - INCHCK=2 => All input data.
- IOUTPT = Number of output variables to be printed (IOUPT ≤ 17).
- MOUTPT = Array whose ith element is the identification number of the output variable desired. IOUTPT elements should be input. I.D. Number:

  1. Total mass burning rate TMDOT (kg/s).

  2. Total heat release rate TQDOT (W).

  3. Gas layer temperature TG (K).

  4. Gas layer thickness DG (m).

5. Fuel cell indicator for damage LDAMGE; LDAMGE(i,j)=.True. => fuel cell j of super module i is damaged.

6. Fuel cell indicator variable for burning LBURN; LBURN(i,j)=.TRUE. => fuel cell j of super module i is burning. A fuel cell stops burning when 70% or more of the fuel mass is consumed (see Section 5.17, item 14). Also note that whether or not a currently nonburning fuel cell ignites is determined at the end of a time step.

7. Fuel cell source heat flux QDOT2P (W/m^2). For barriers, the source flux is the flux leaving the rear face of the barrier. For walls and ceilings, it is flux leaving from the front face. For fuel cells, it includes both radiative and convective energy from the flame.

8. Fuel cell radiative external heat flux QEXT (W/m^2). This is the purely radiative heat flux from distant objects which impinge on the given module (before reflection). The radiation from the module environment is not included.

9. Fuel cell total source heat flux QEXTOT (W/m^2). Includes radiative contributions from all sources (minus reflection), plus convection. Does not include any losses due to re-radiation or re-convection.

10. Calorimeter heat flux at fuel cell QEXCAL (W/m^2). Same as QEXTOT, except that re-radiation and re-convection losses based on the calorimeter temperature CALTEM are accounted for. Can be output for any fuel cell, regardless of that fuel cell's actual fuel type.

11. Fuel cell net heat flux QEXNET (W/m^2). Same as QEXTOT, except that re-radiation and re-convection losses based on the fuel cell surface temperature are accounted for.

12. Fuel cell mass FMASS (kg). This does not include the pilot mass on top of the fuel cells.

13. Flame height over fuel cell FLHT (m). The flame height is measured from the base of the fire.

14. Fuel cell flame temperature FLTEMP (K).

15. Fuel cell surface temperature TEMP (K). For barriers, the front face temperature is printed.

16. Fuel cell heat transfer coefficient HCOEF (W/m^2K). Local convective heat transfer coefficient for fuel cell.

17. Fuel cell local environment temperature TSURR (K).

- NSMOUT = Number of super modules for which variables (I.D. numbers 5 through 17) are to be printed.
- MSMOUT = Array whose ith element is the identification number of the super module to be documented.
  For example, if the input card is:
  &OUTF IOUPT=3, MOUTPT=1,7,10, NSMOUT=2, MSMOUT=1,2, &END
  COMPBRN III will print the total mass burning rate for the compartment, and the source and calorimeter heat fluxes for each fuel cell in super modules 1 and 2.

Notes: 1. IOUTPT=0 and NSMOUT=0 => Only TMDOT, the total mass burning rate, is printed.
2. IOUTPT=0 and NSMOUT≠0 => TMDOT and LBURN, an array which shows which fuel cells are burning, are printed.

Chapter 6

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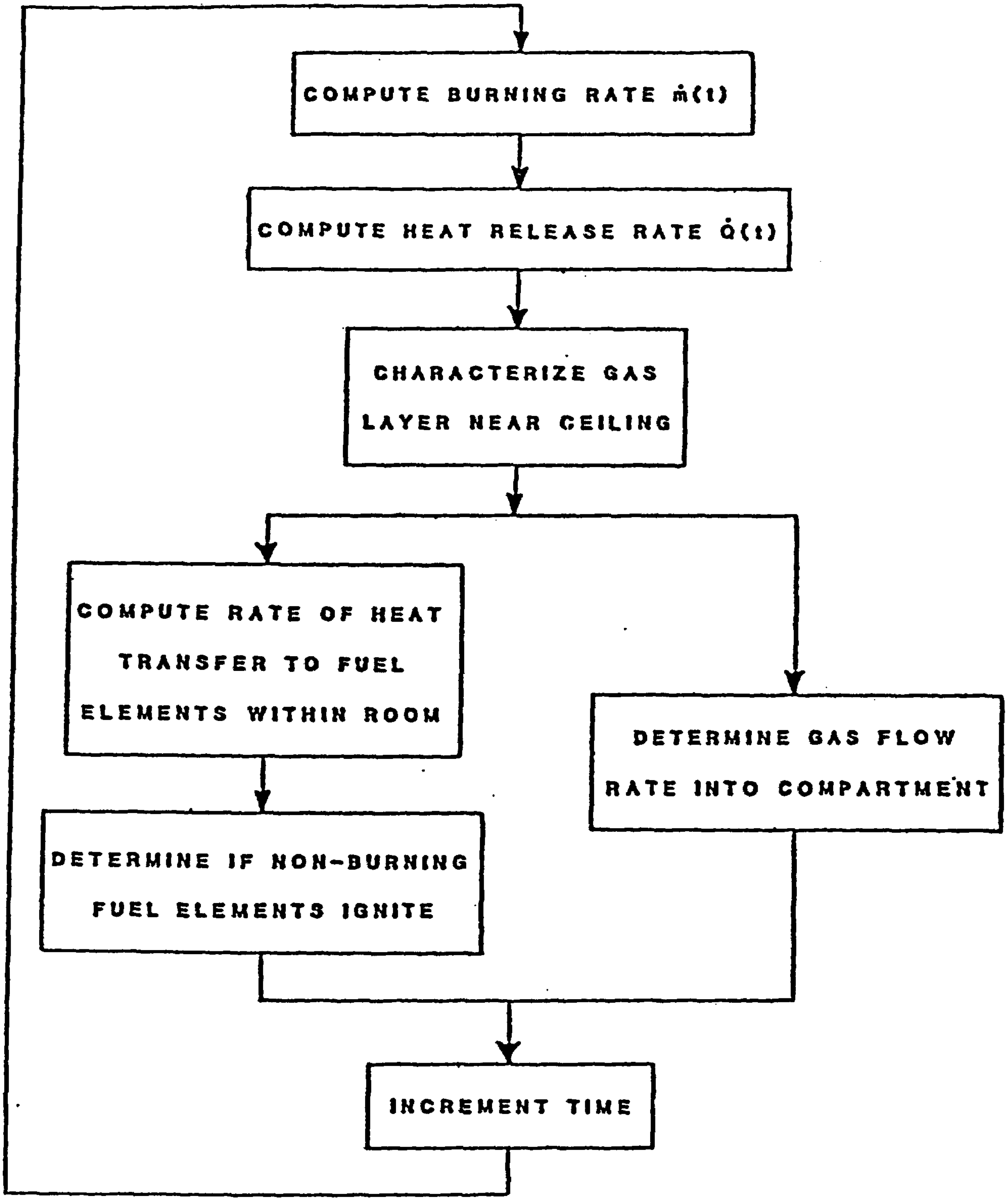


Figure 1: Flow Chart of Computation Processes in COMPBRN

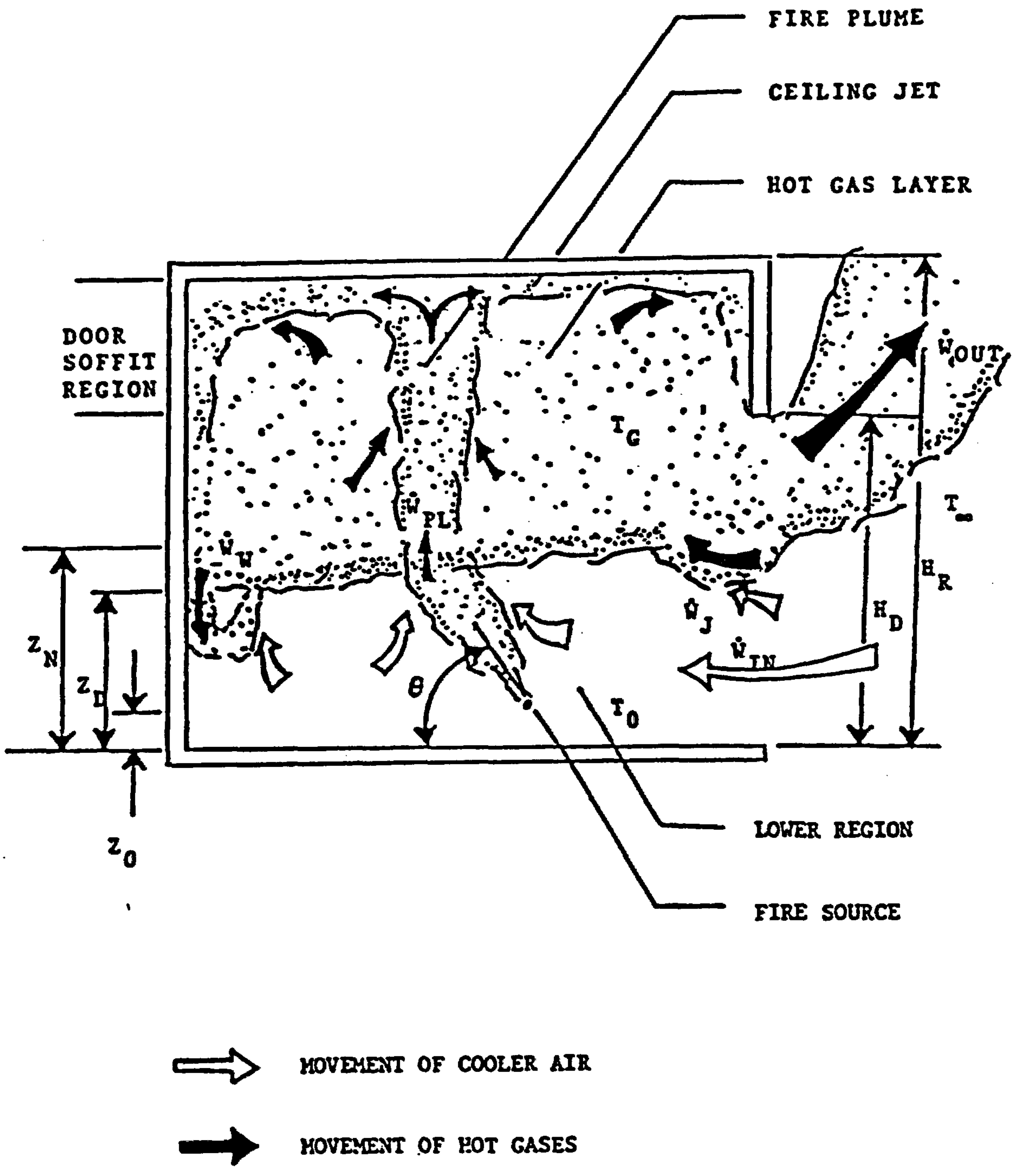


Figure 2: Typical Features of Room Fire in a Two Zone Model

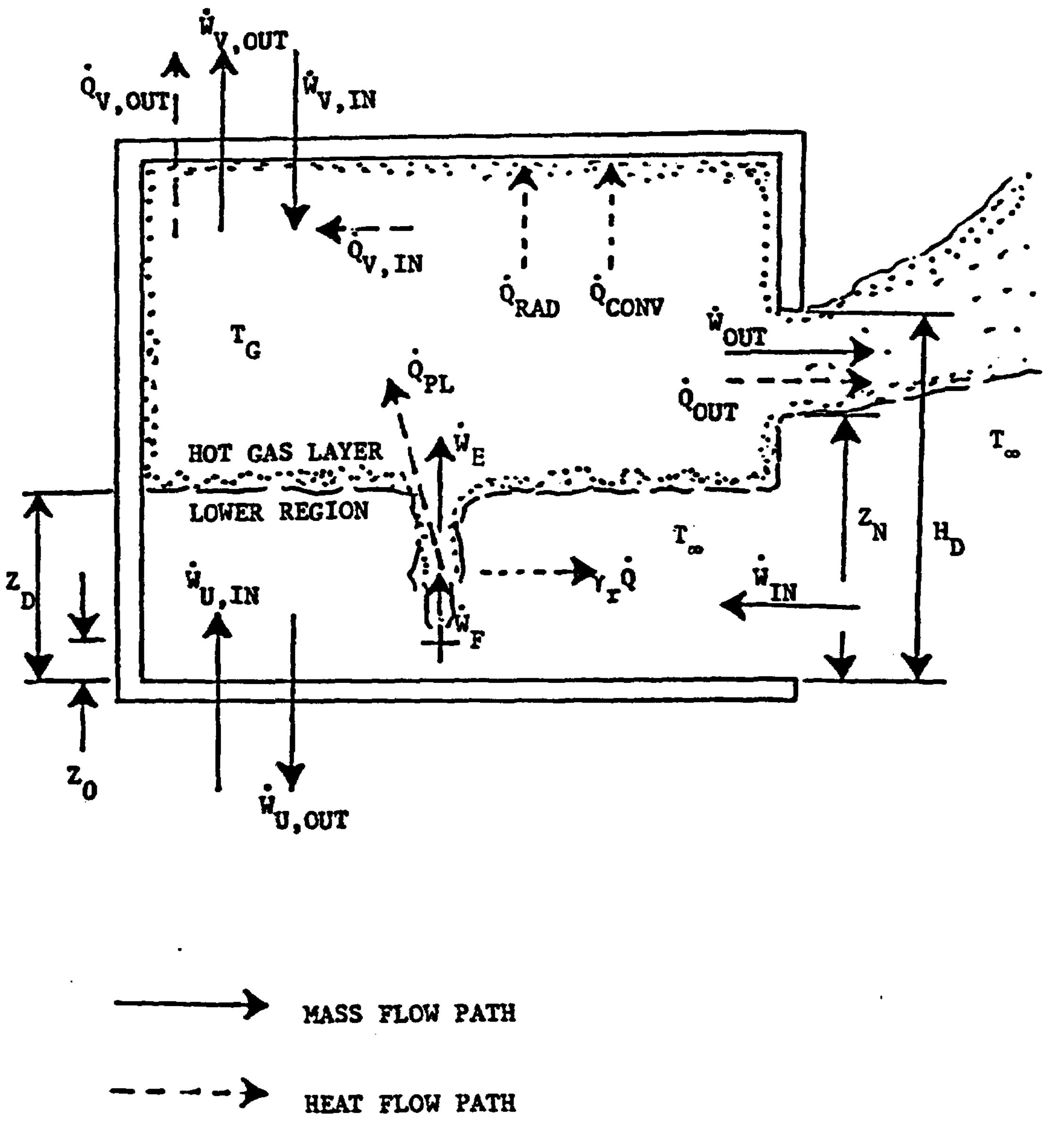


Figure 3: Features of Room Fire in COMPBRN III HGLM

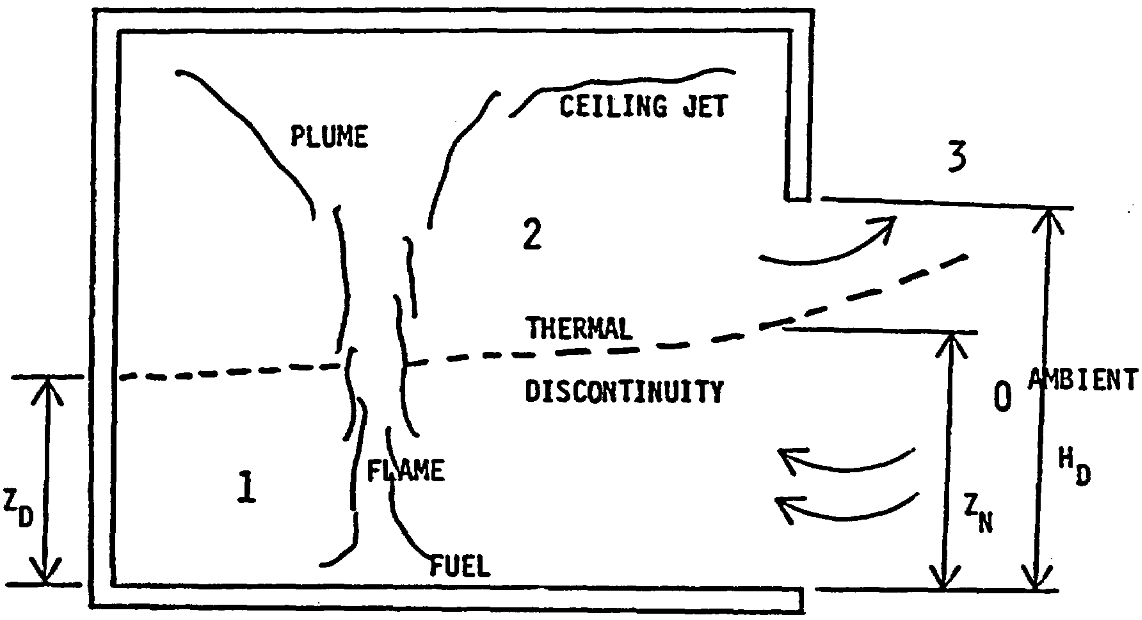


Figure 4: Room Geometry of Rockett's Air Flow Model [10]

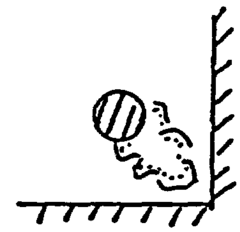
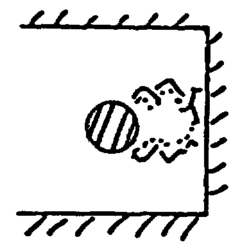
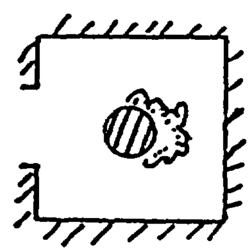
FIRE SCENARIO	BLOCKAGE FACTOR	TOP VIEW
NO BLOCKAGE	M = 1.10	
CORNER FLOW	M = 1.49	
THREE SIDES BLOCKED	M = 1.28	
DOOR FLOOR	M = 1.28	

Figure 5: Effect of Blockage on Mass Flux Ratio [17]

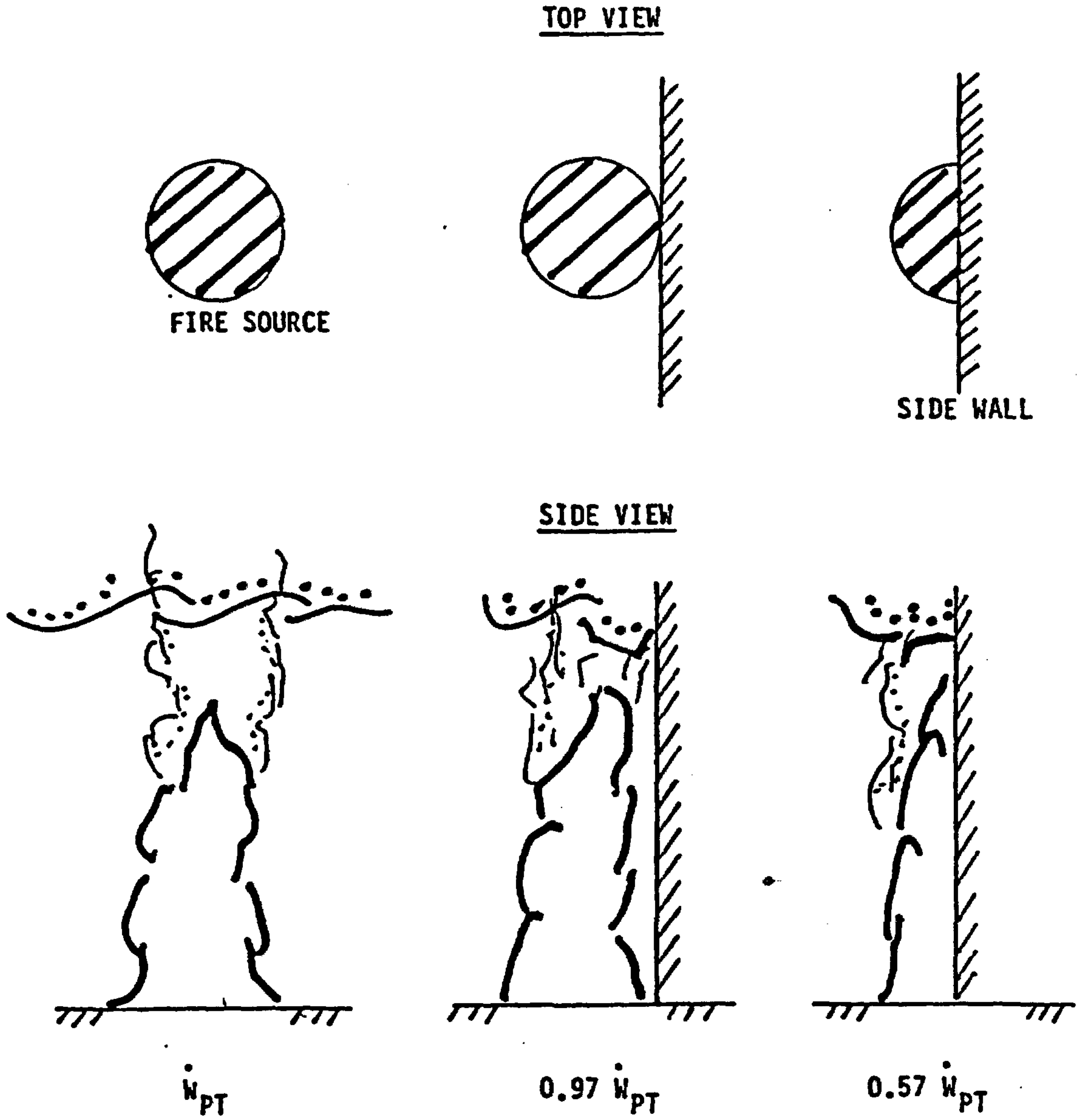


Figure 6: Effect of Vertical Wall on Plume Mass Flux [17]

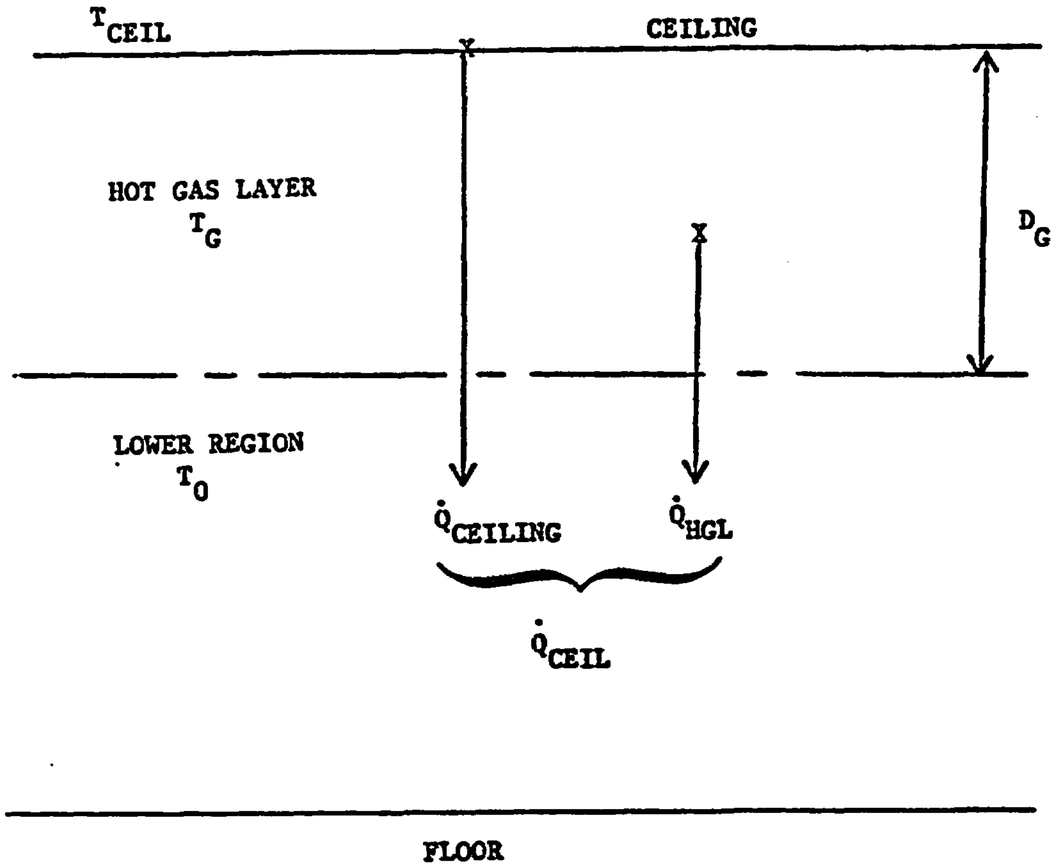


Figure 7: Radiative Heat Flux Emitted by Hot Gas Layer and Ceiling

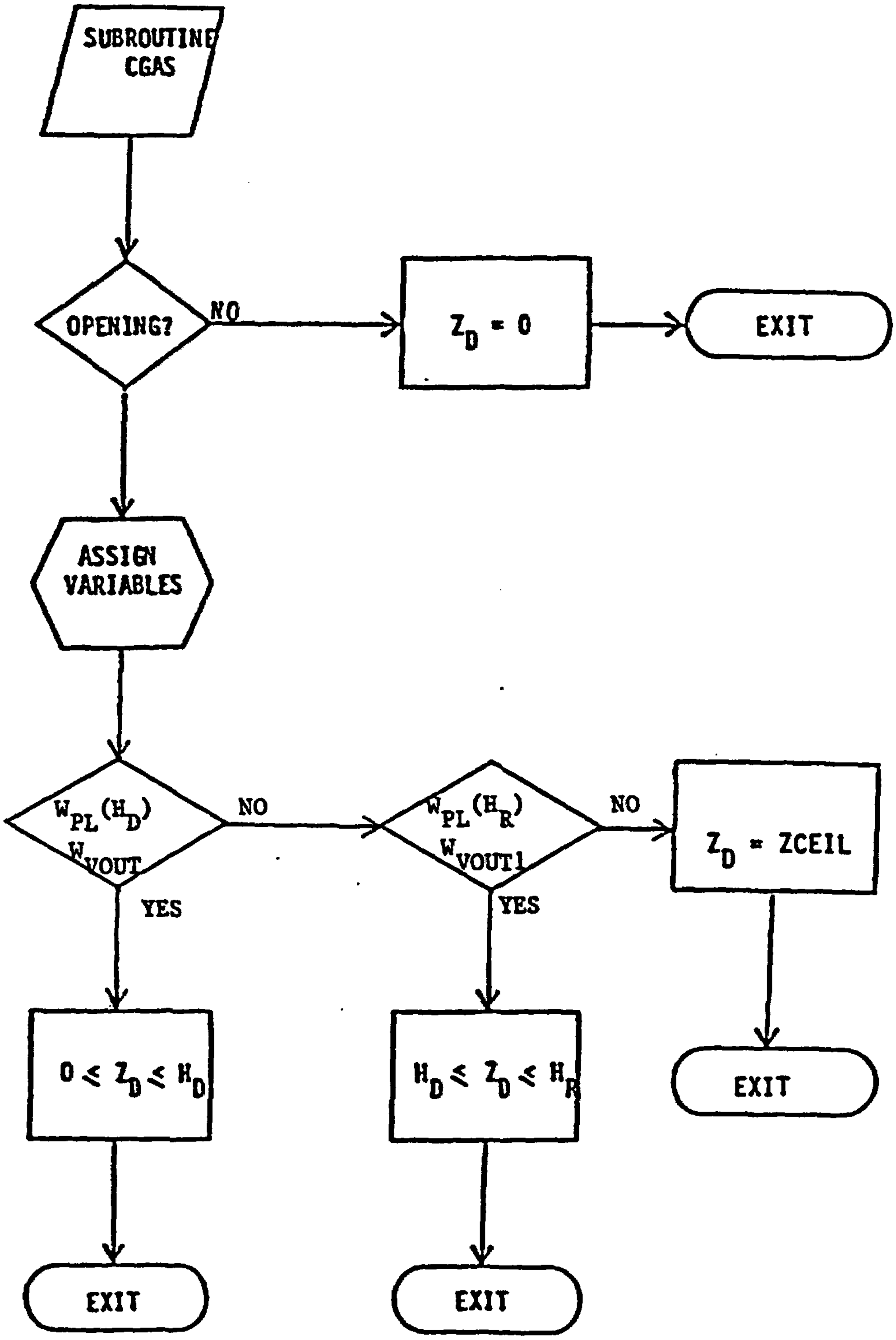


Figure 8: Flow Chart of the CGAS Subroutine

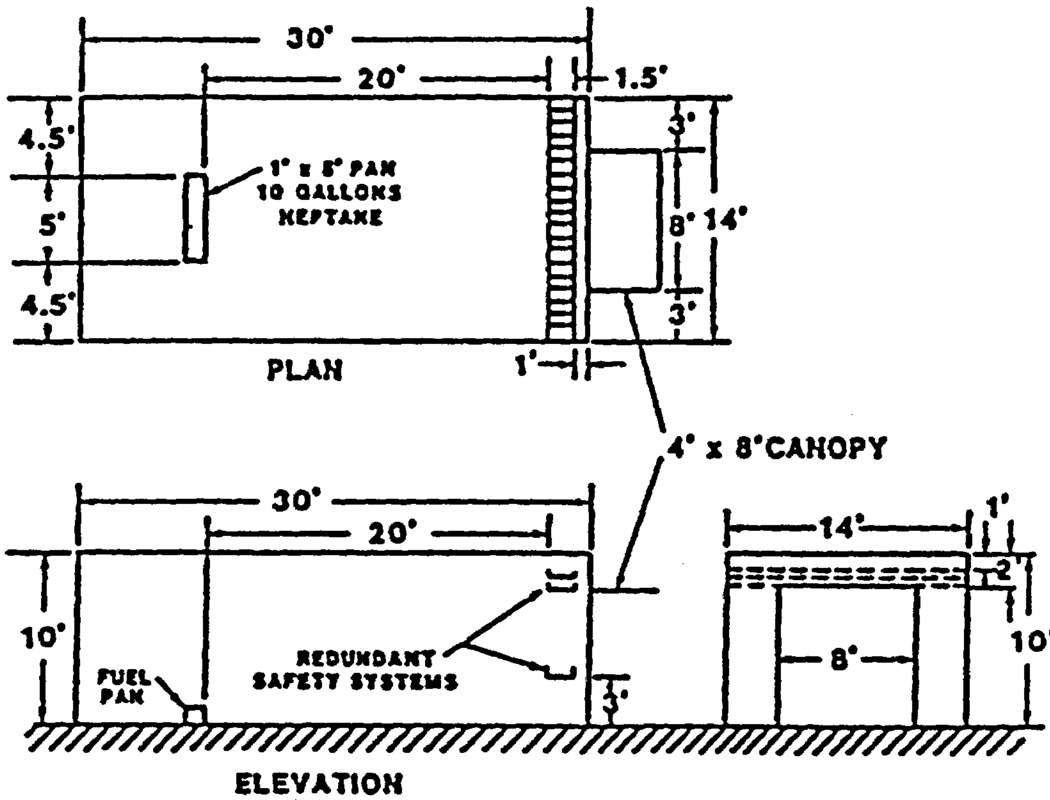


Figure 9: Enclosure Details of SNL/UL Experiment 1 [15]

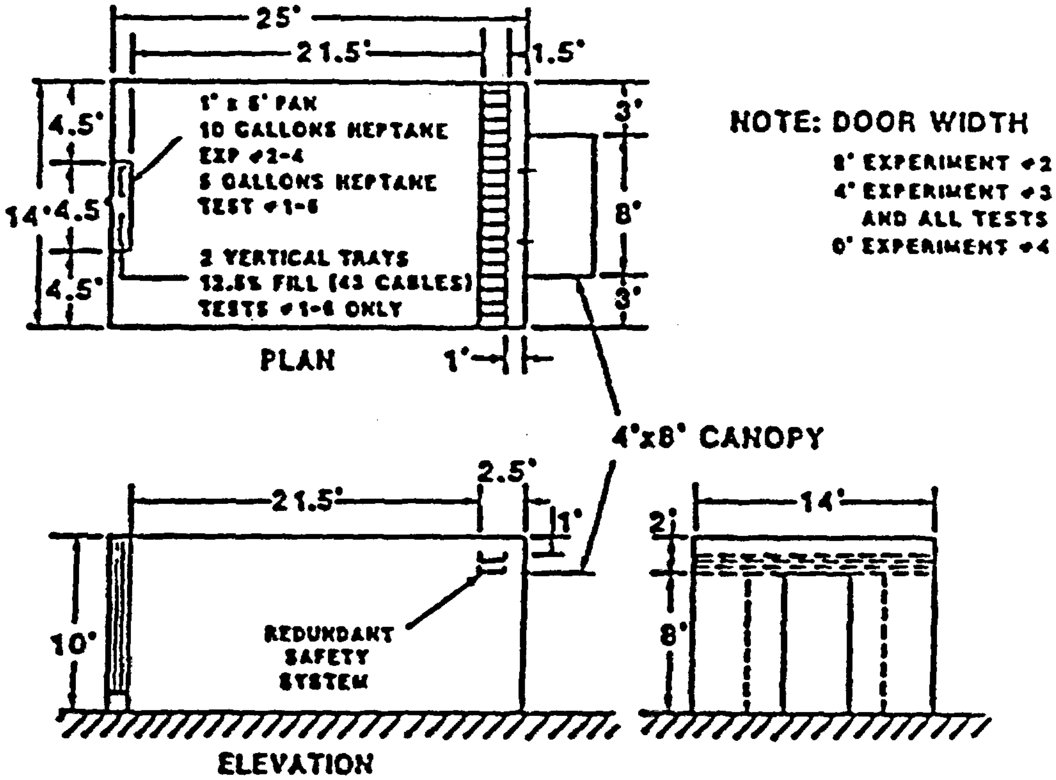


Figure 10: Enclosure Details of SNL/UL Experiments 2-4 [15]

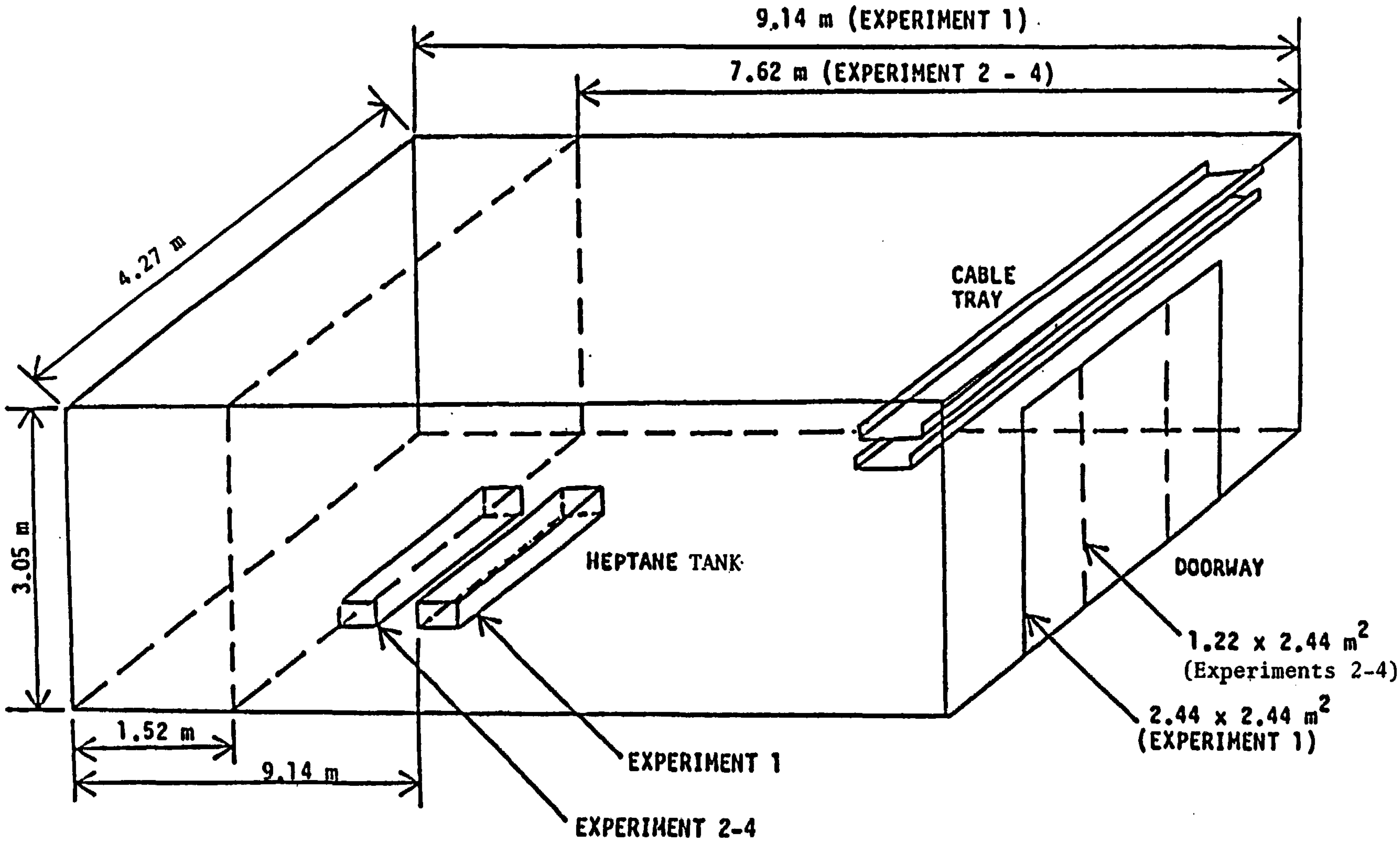


Figure 11: Enclosure Details of SNL/UL Experiments 1-4

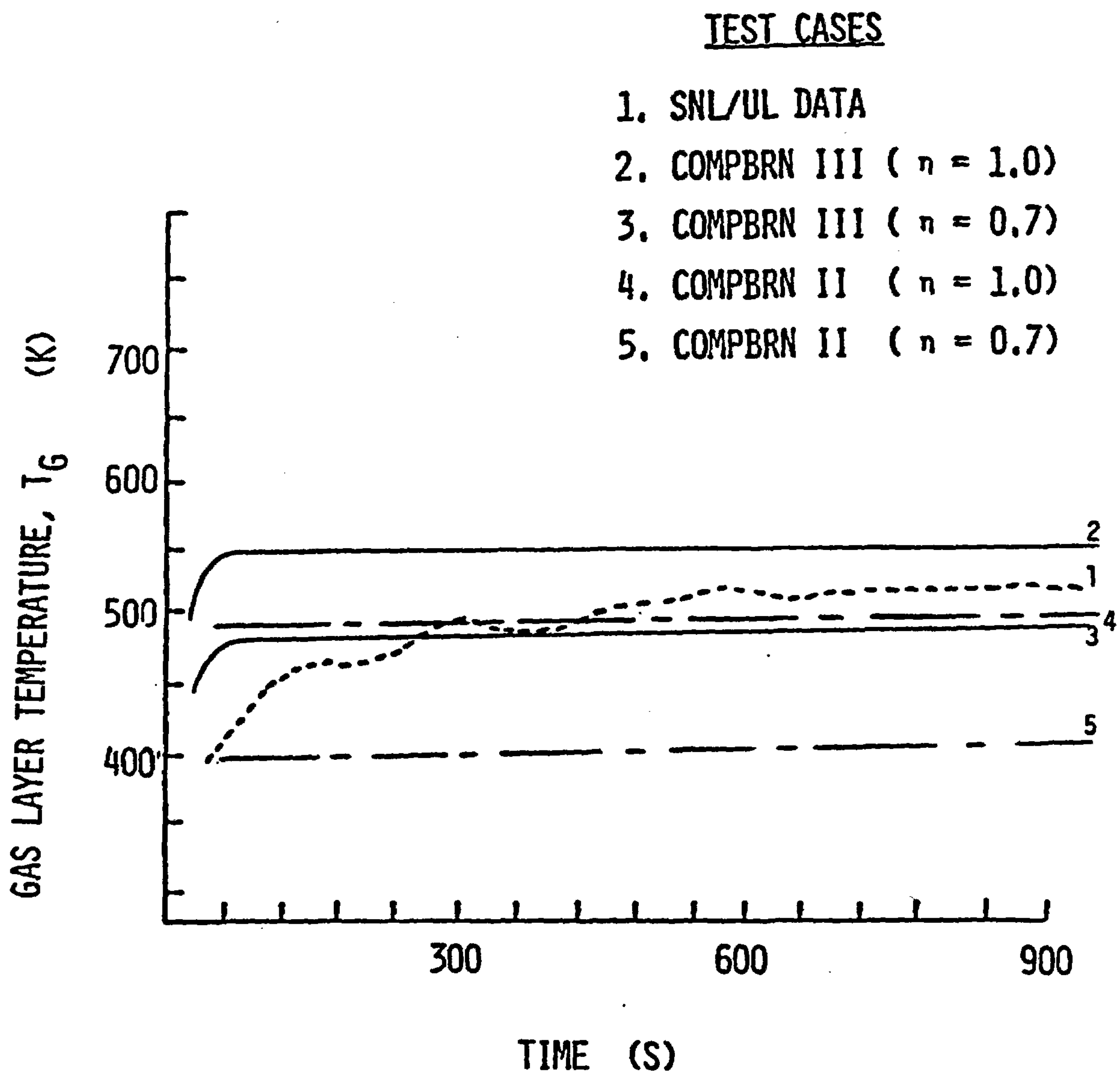


Figure 12: Simulation of SNL/UL Experiment 1: Hot Gas Layer Temperature

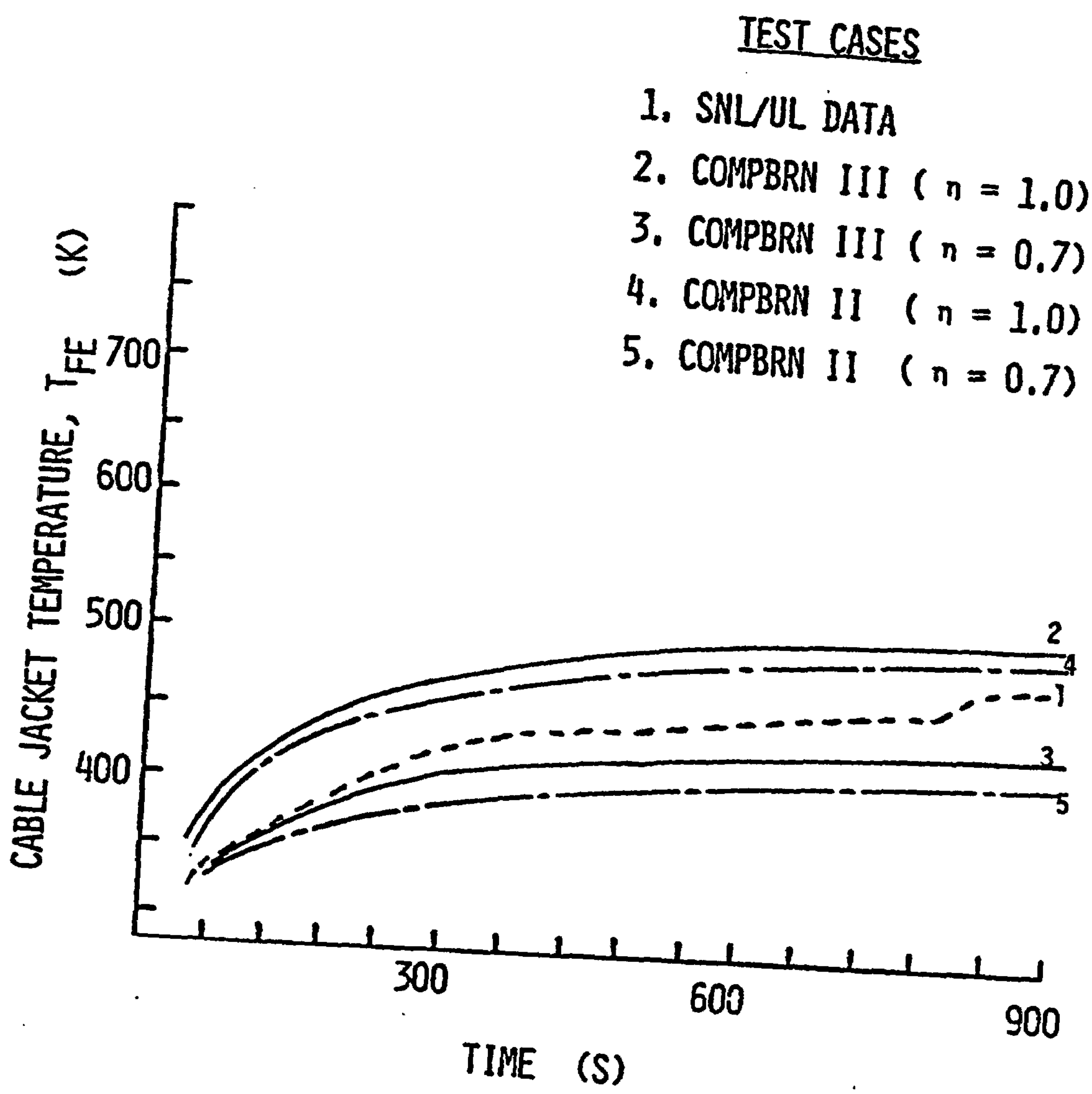


Figure 13: Simulation of SNL/UL Experiment 1: Cable Jacket Temperature

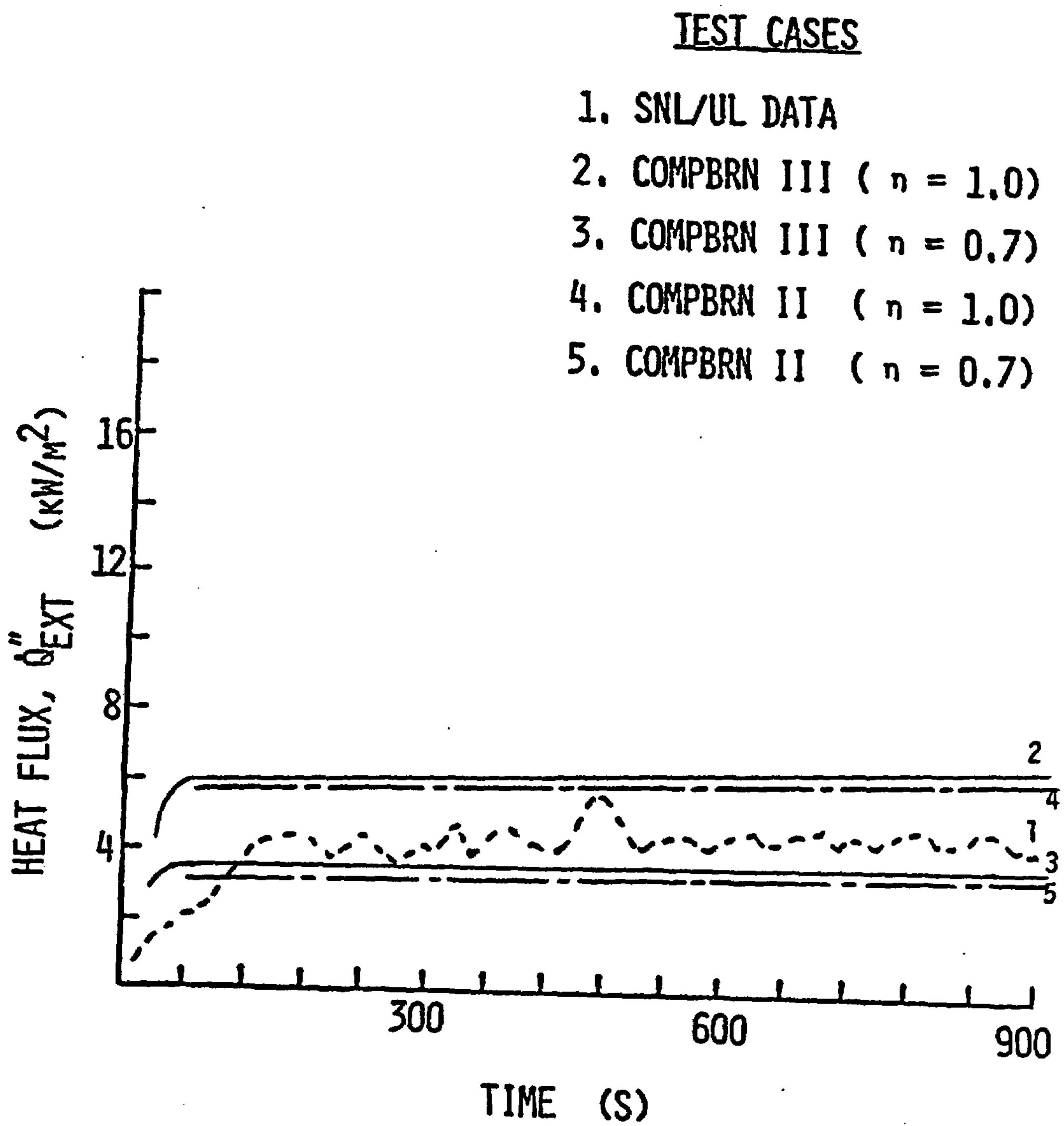


Figure 14: Simulation of SNL/UL Experiment 1: Heat Flux

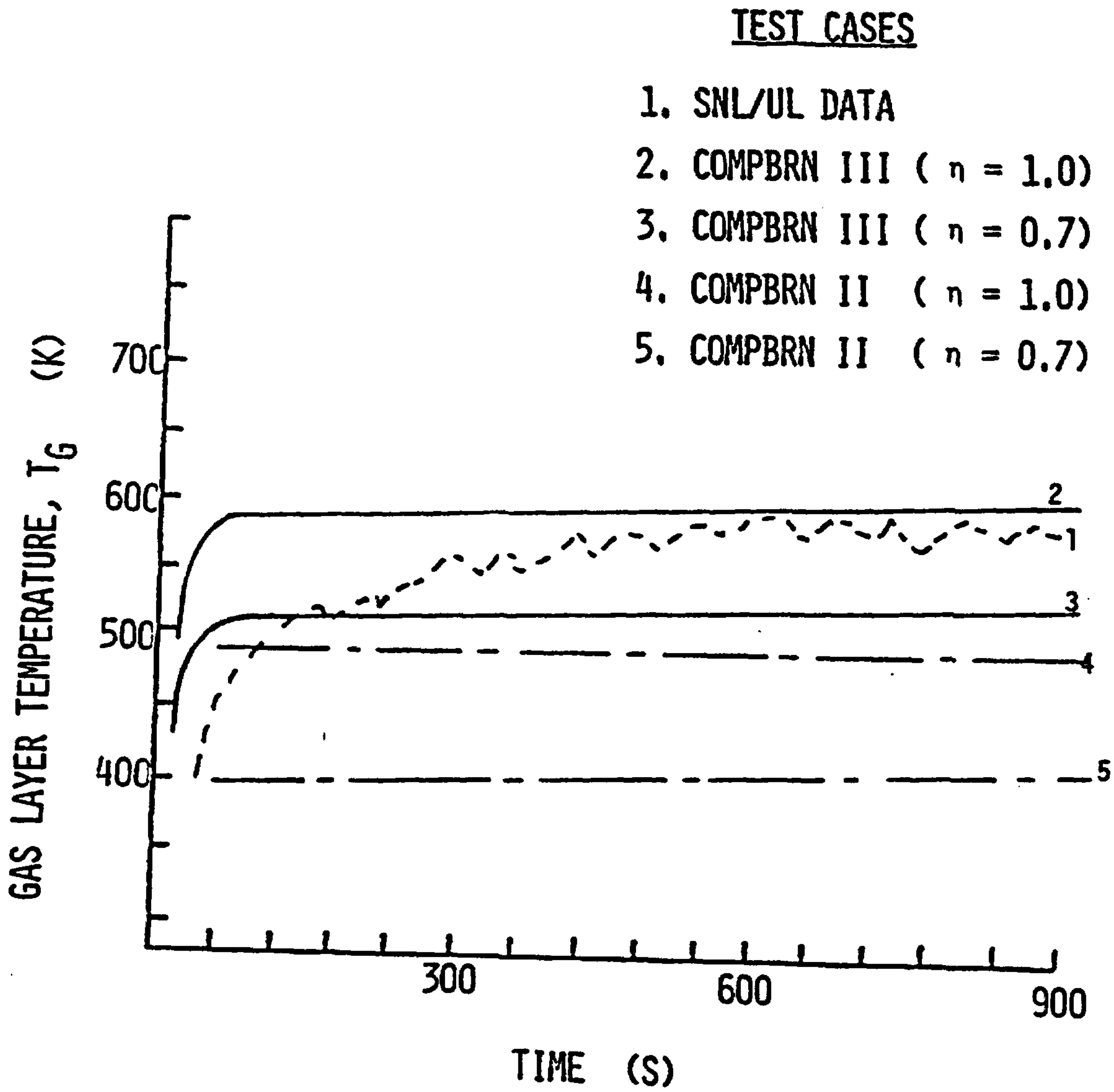


Figure 15: Simulation of SNL/UL Experiment 2: Hot Gas Layer Temperature

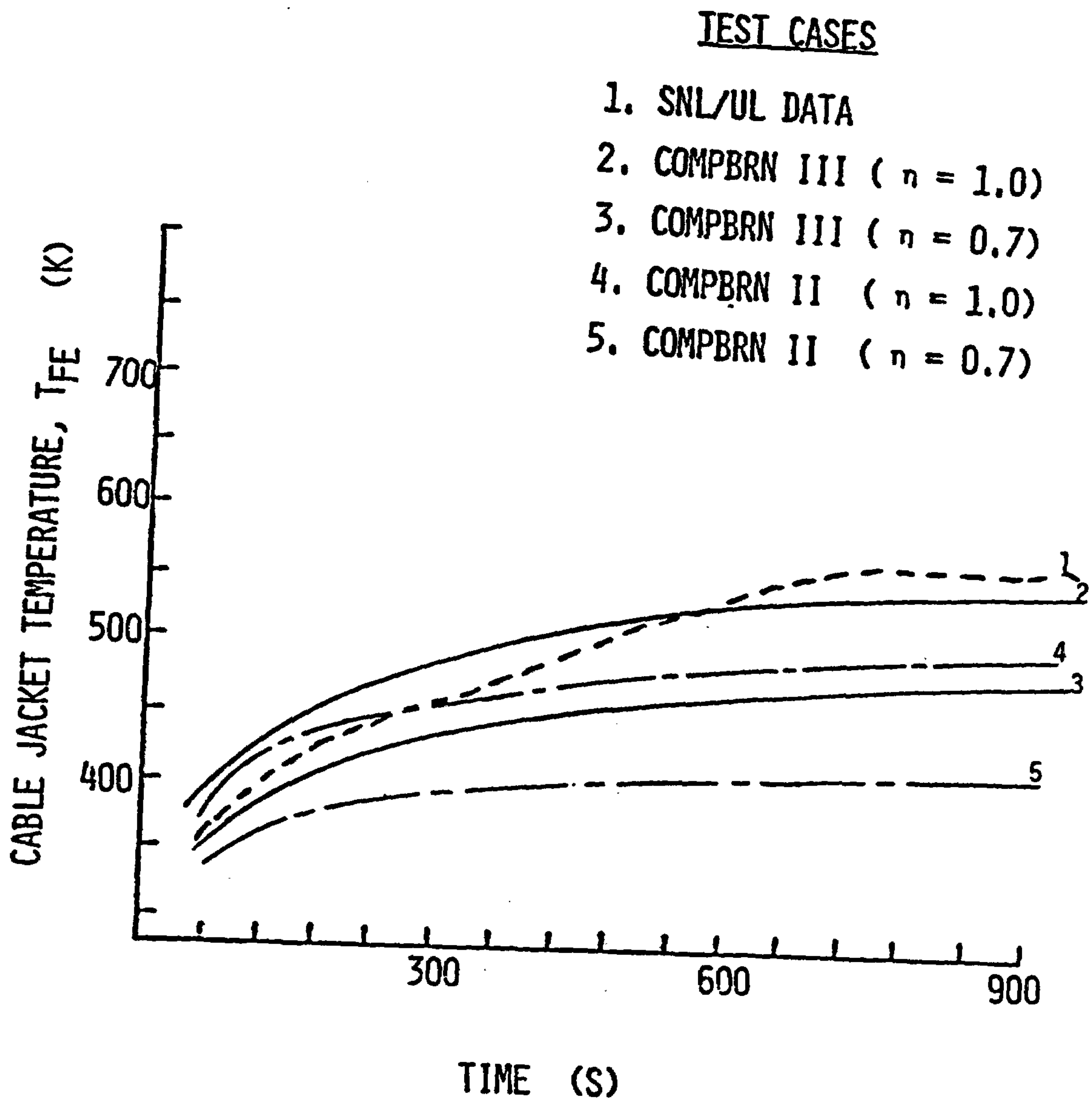


Figure 16: Simulation of SNL/UL Experiment 2: Cable Jacket Temperature

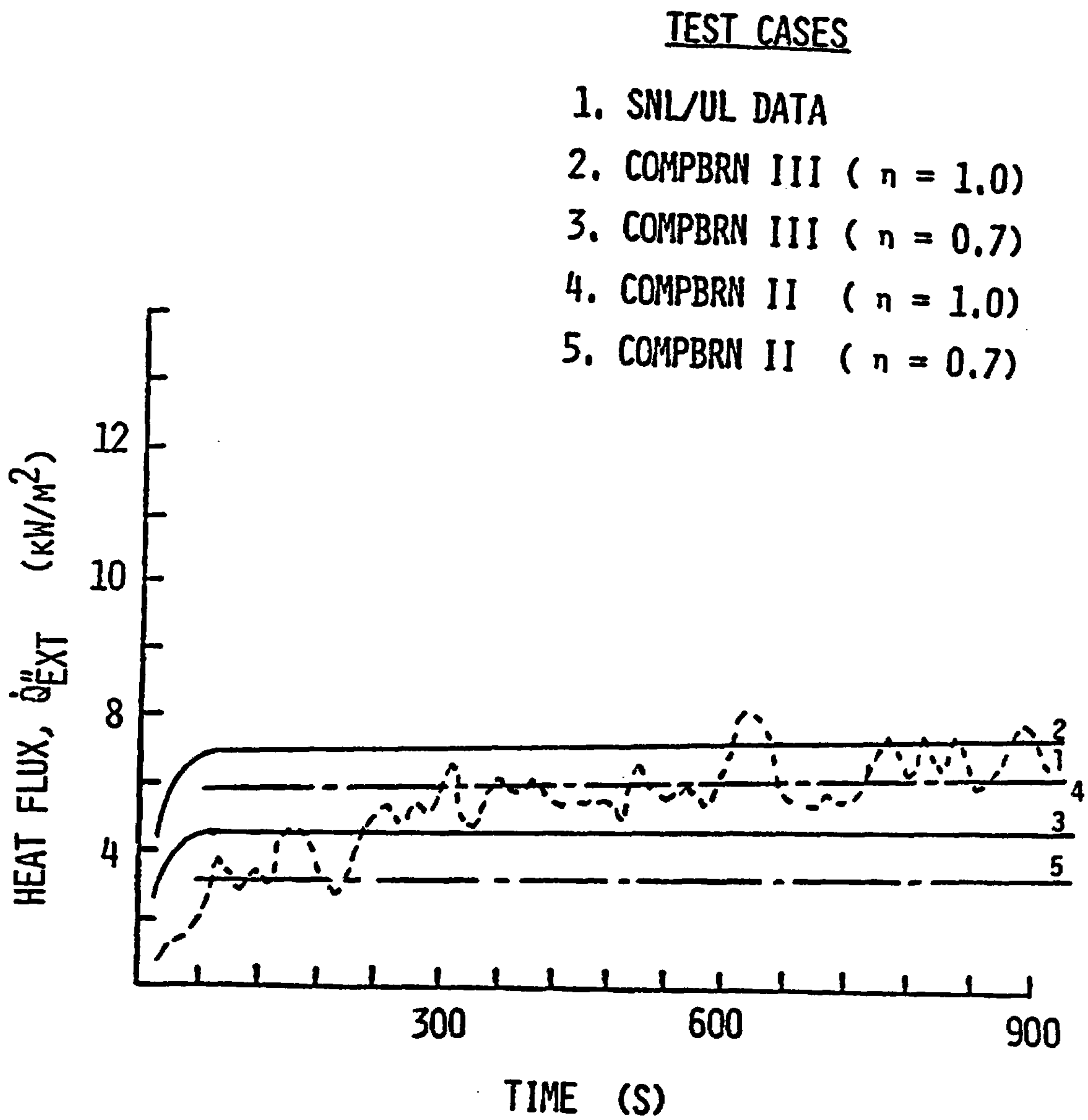


Figure 17: Simulation of SNL/UL Experiment 2: Heat Flux

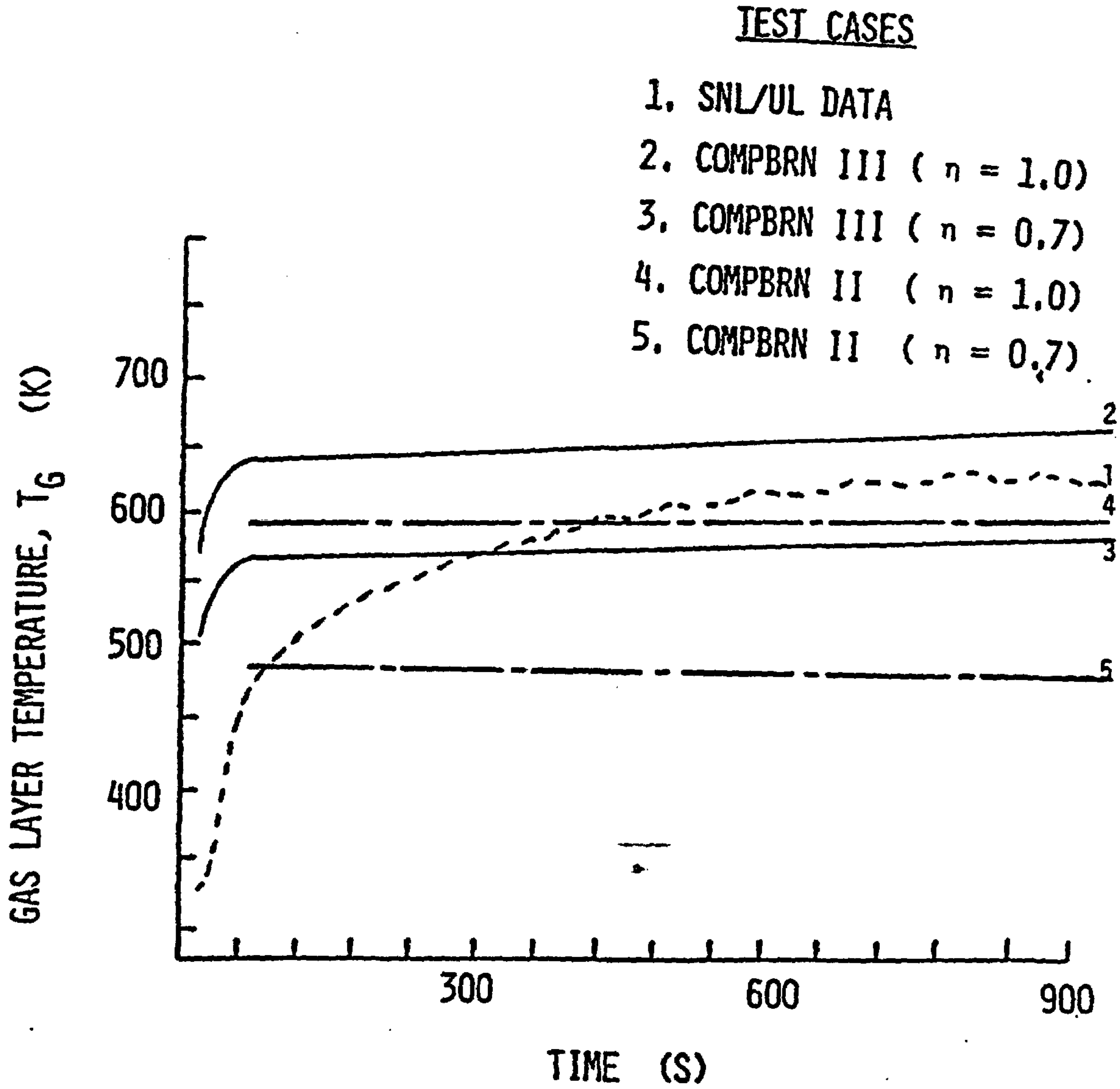


Figure 18: Simulation of SNL/UL Experiment 3: Hot Gas Layer Temperature

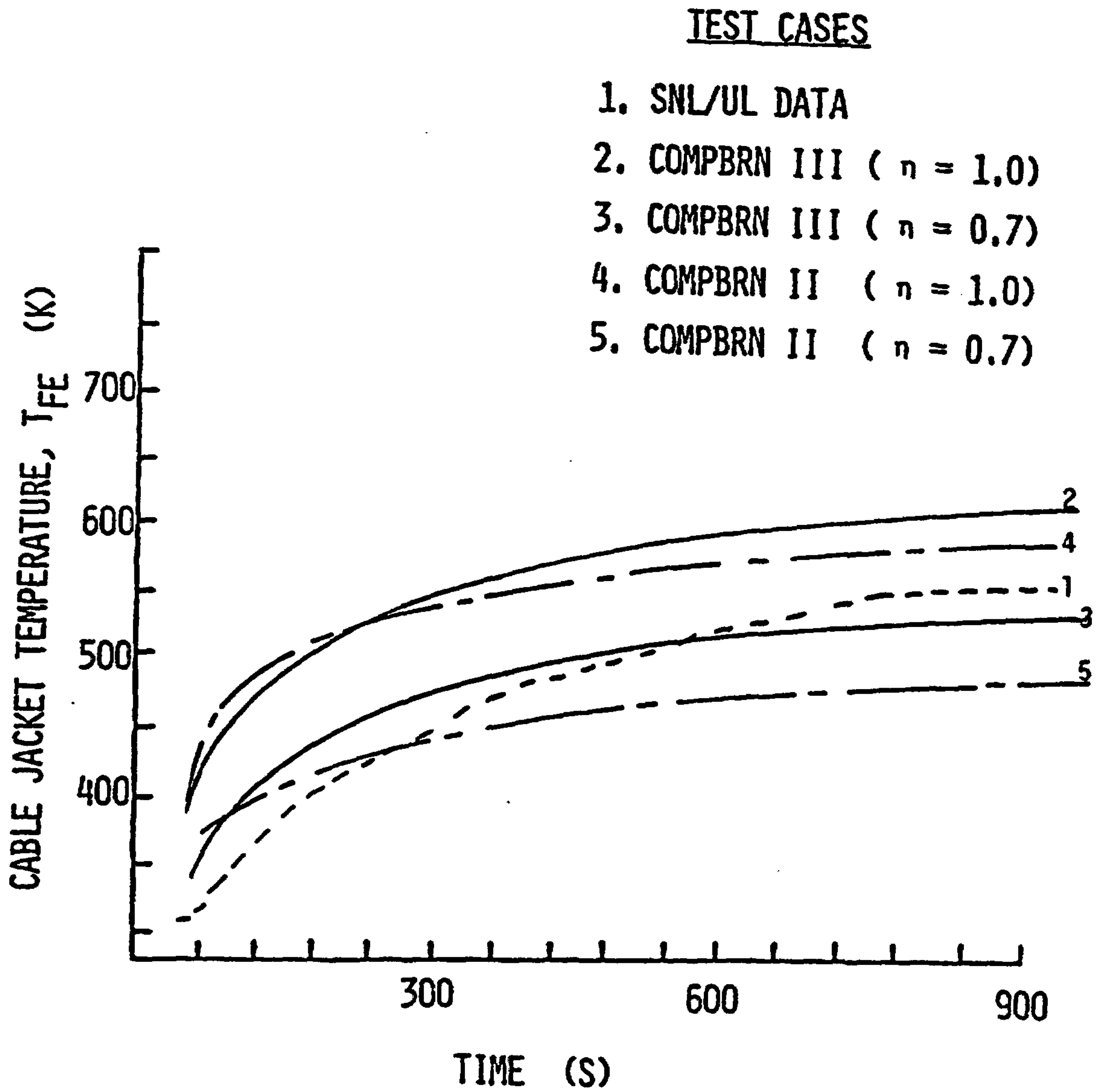


Figure 19: Simulation of SNL/UL Experiment 3: Cable Jacket Temperature

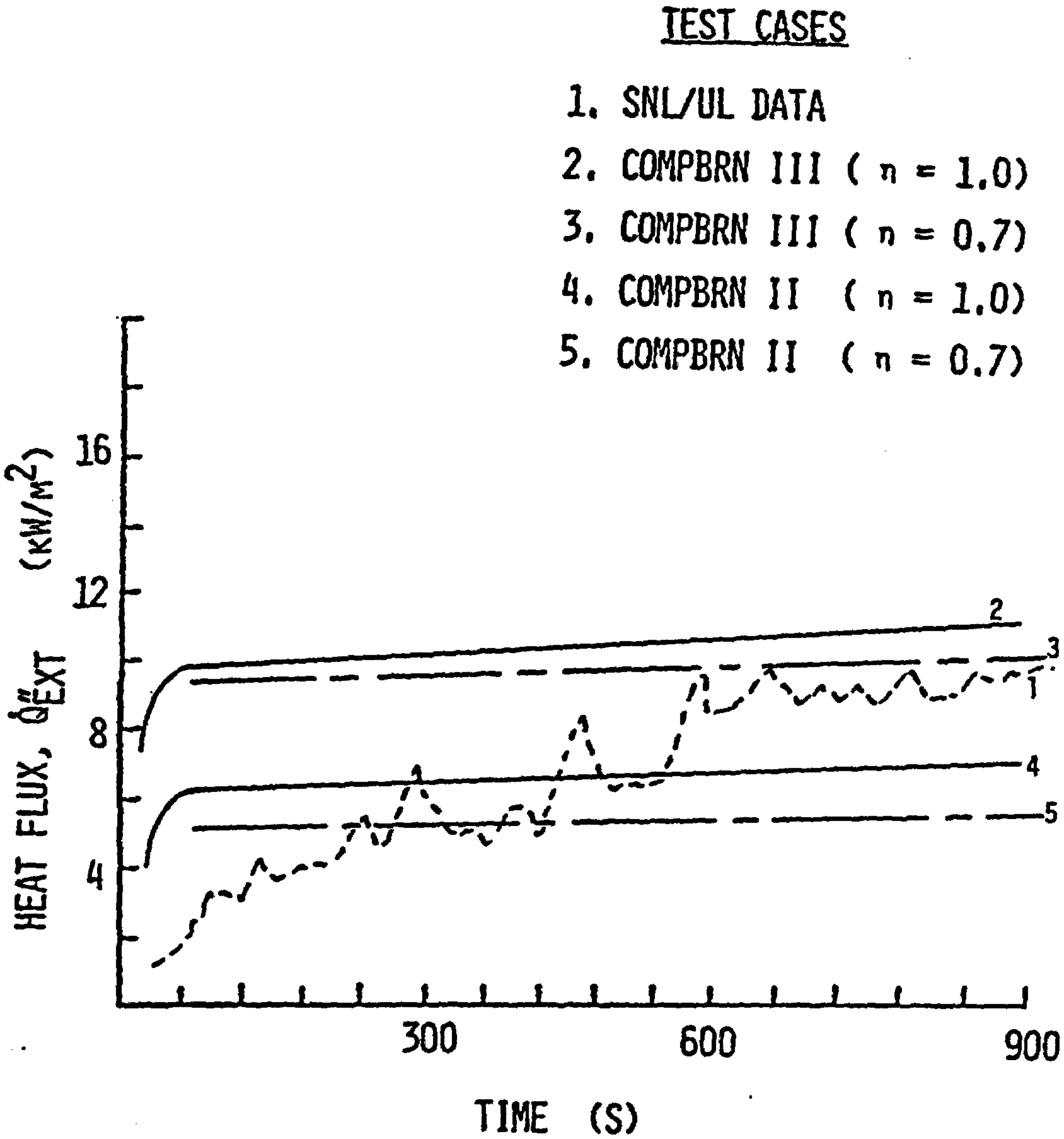


Figure 20: Simulation of SNL/UL Experiment 3: Heat Flux

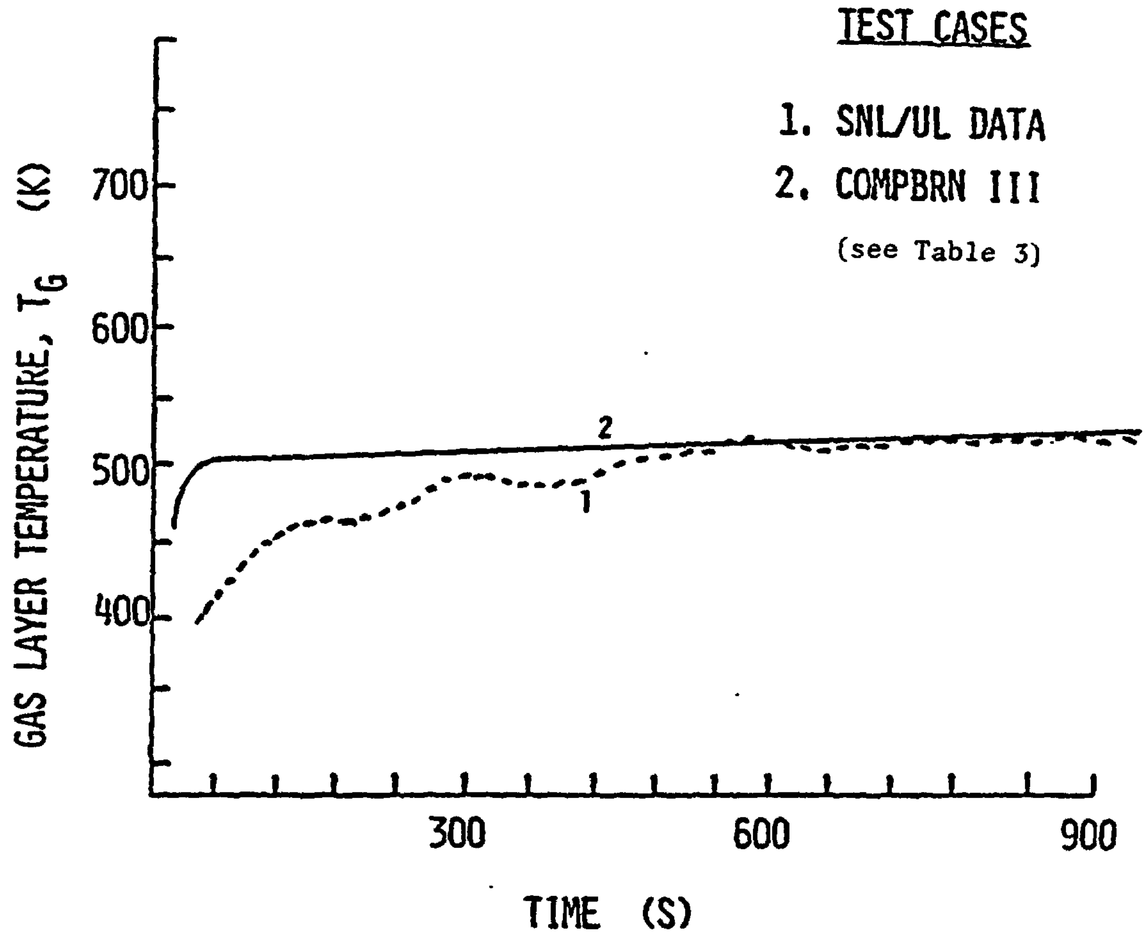


Figure 21: Simulation of SNL/UL Experiment 1: Hot Gas Layer Temperature

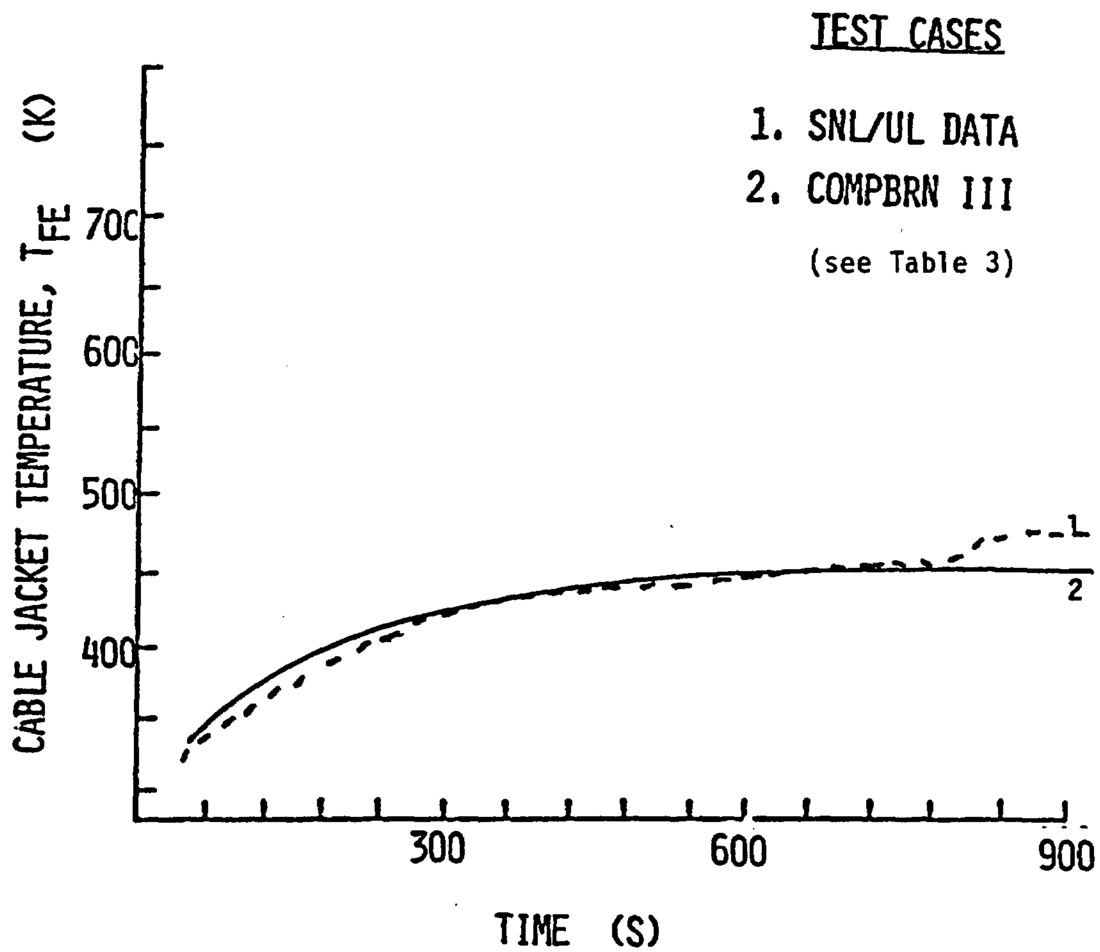


Figure 22: Simulation of SNL/UL Experiment 1: Cable Jacket Temperature

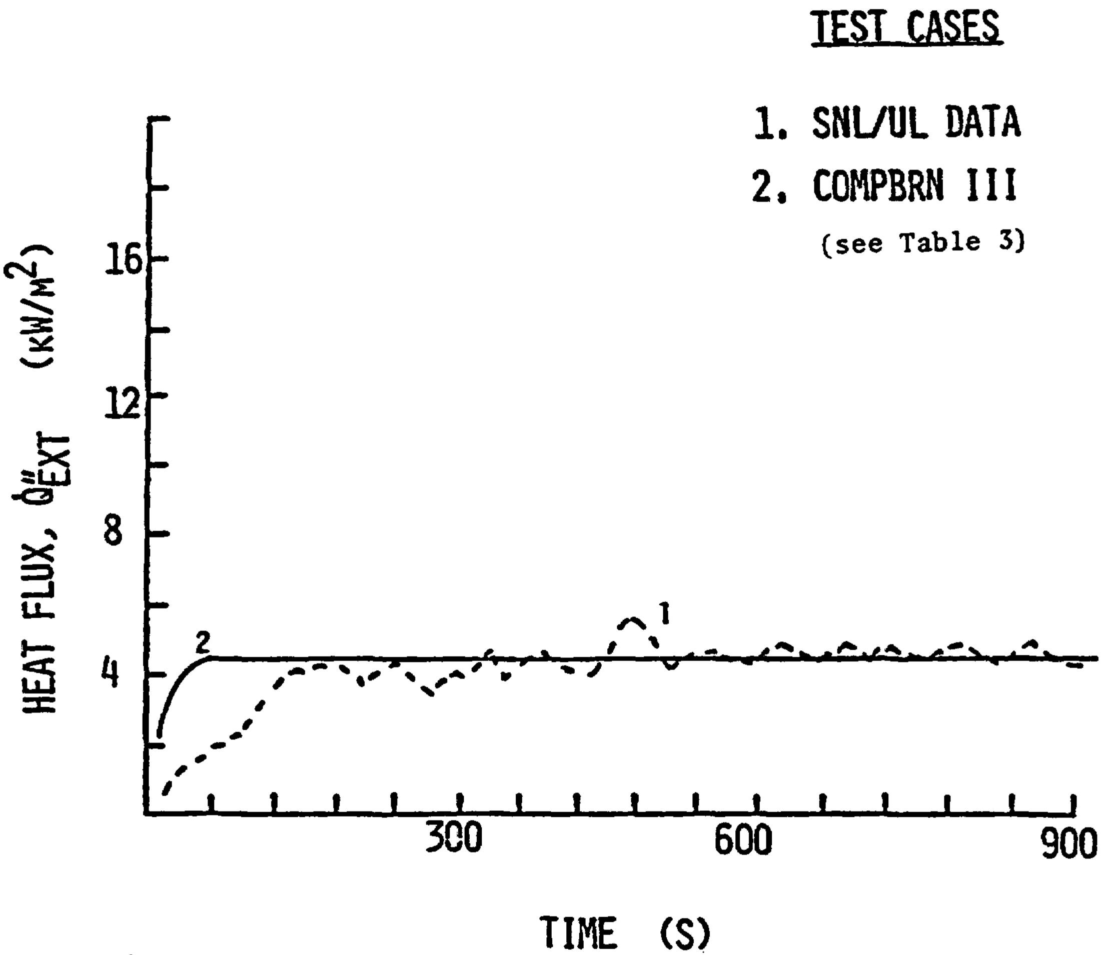


Figure 23: Simulation of SNL/UL Experiment 1: Heat Flux

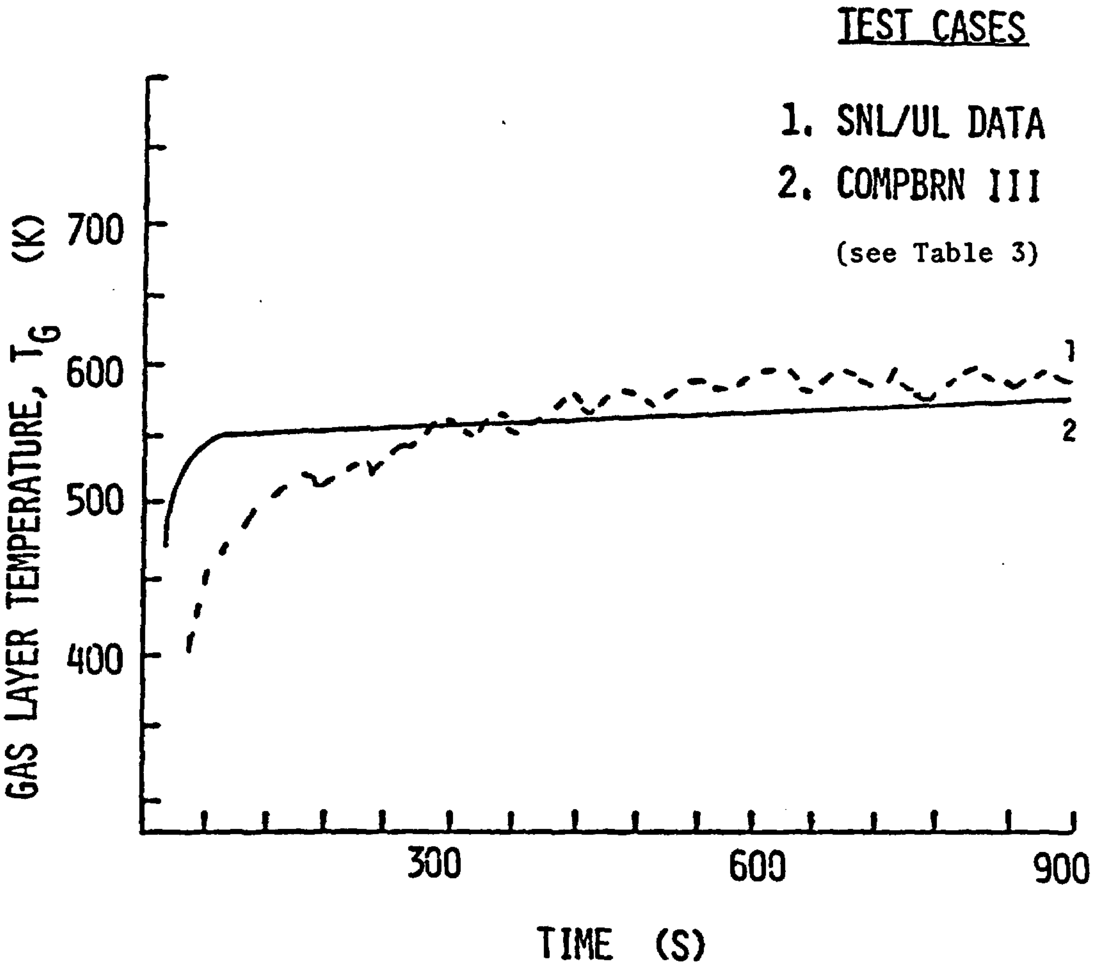


Figure 24: Simulation of SNL/UL Experiment 2: Hot Gas Layer Temperature

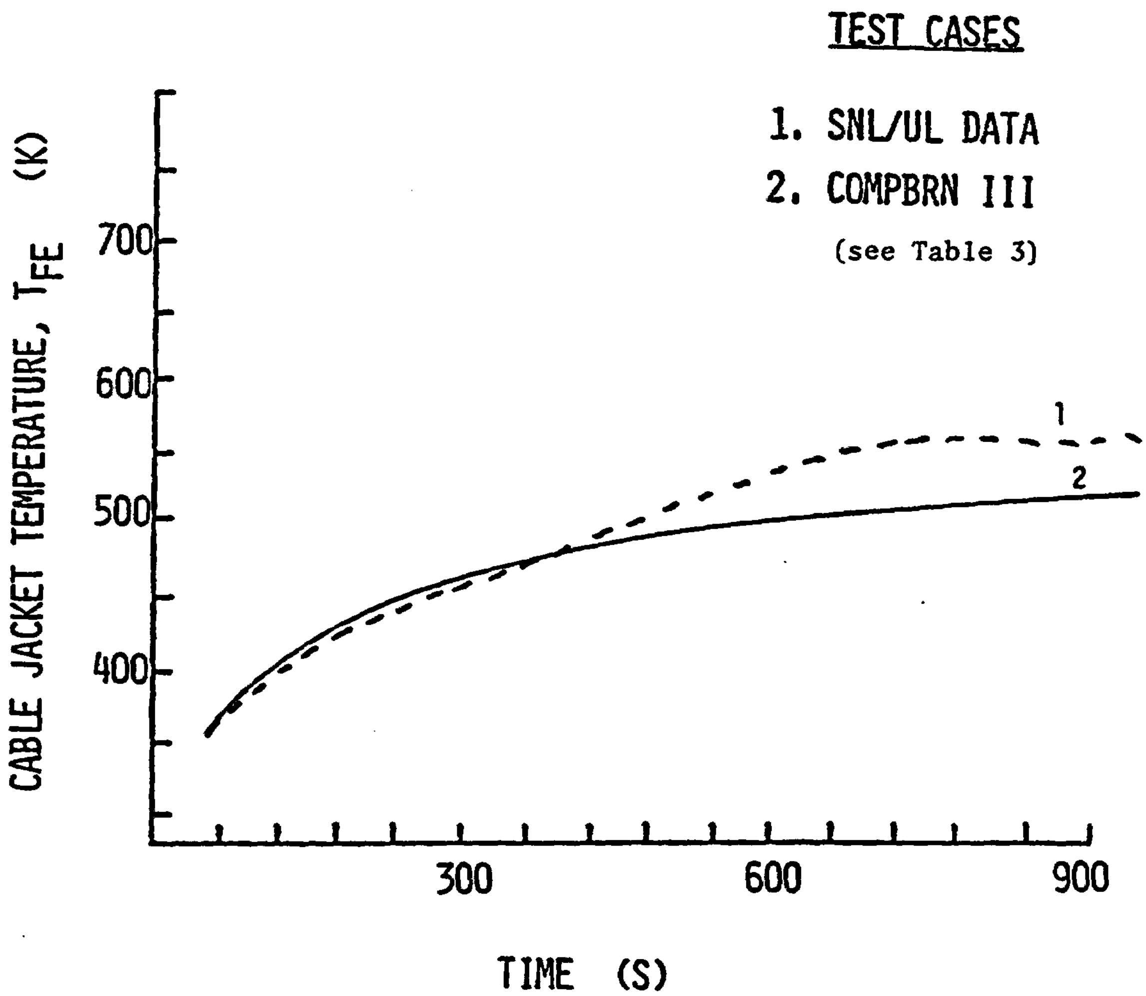


Figure 25: Simulation of SNL/UL Experiment 2: Cable Jacket Temperature

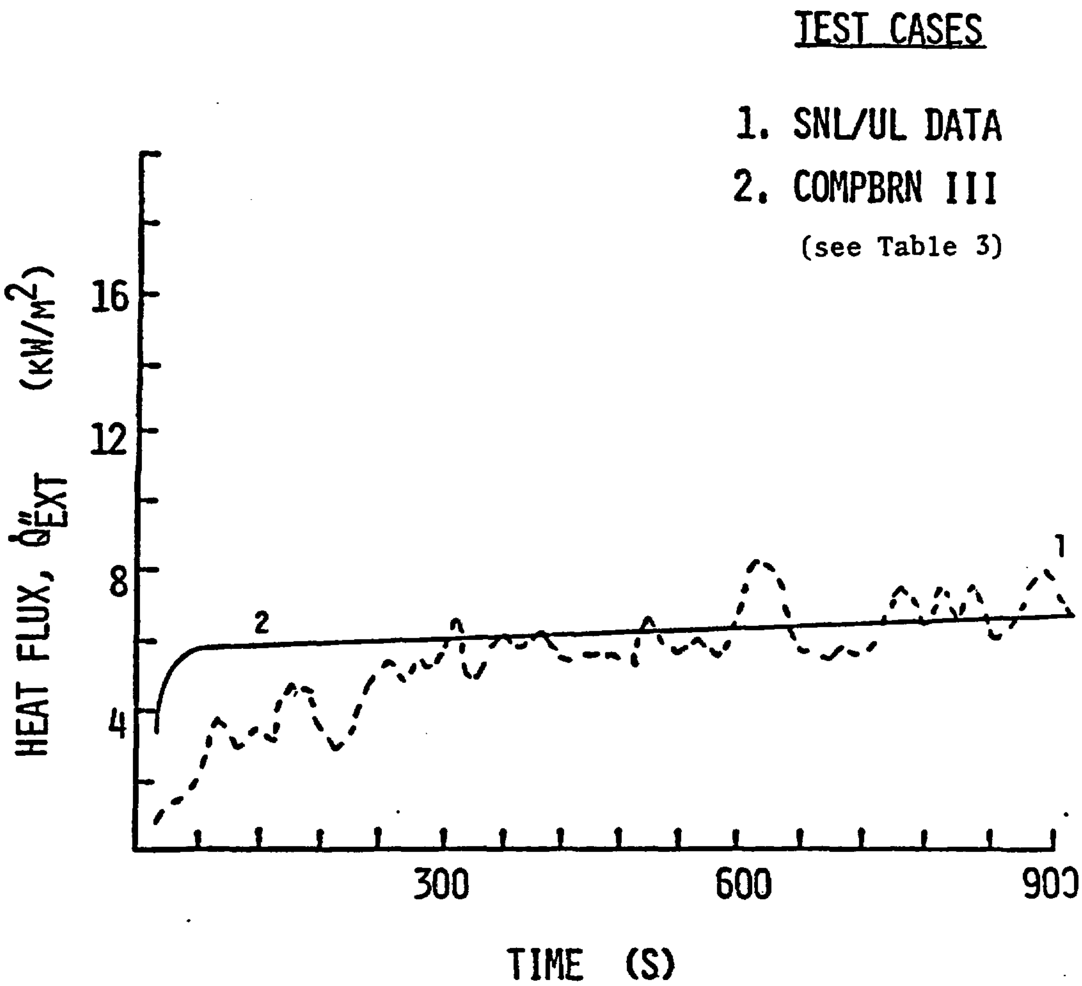


Figure 26: Simulation of SNL/UL Experiment 2: Heat Flux

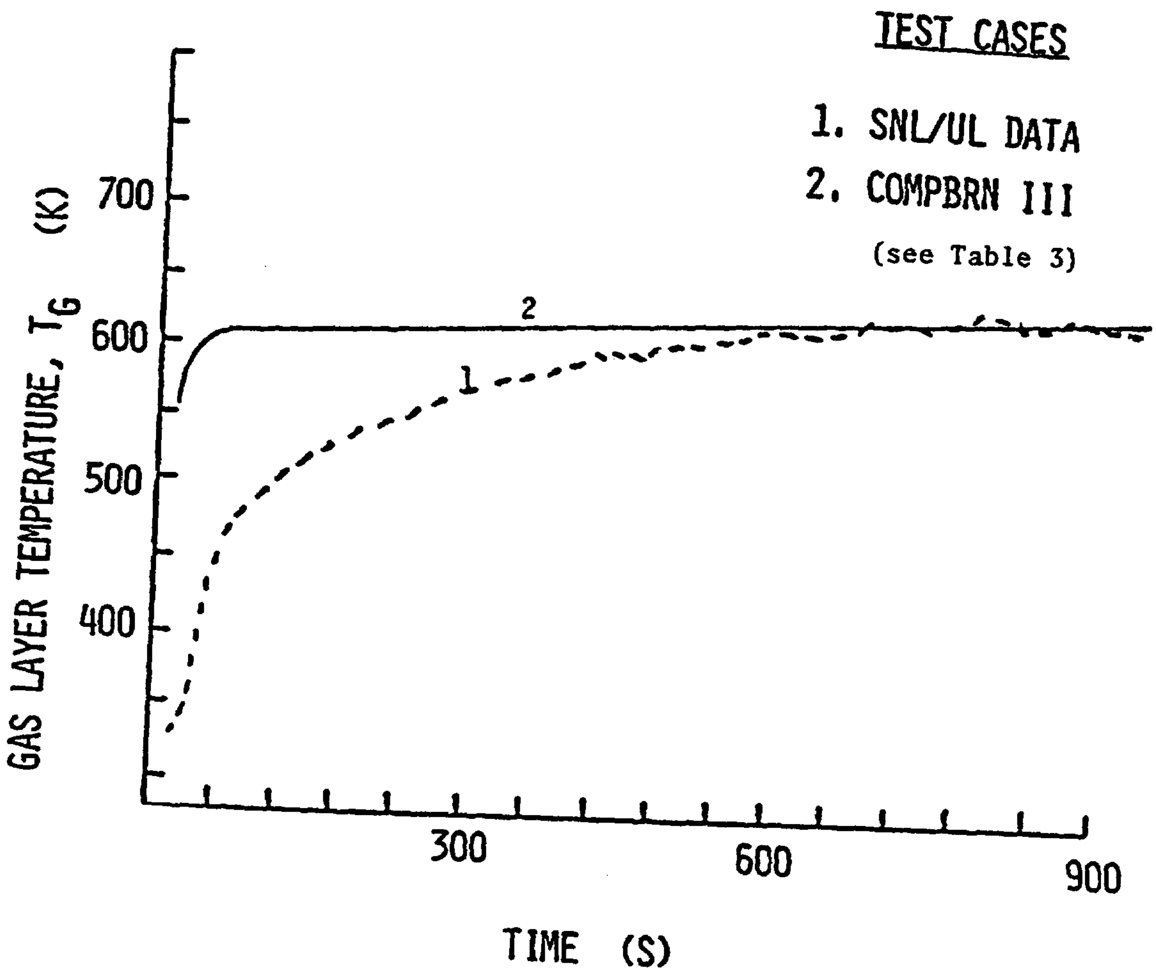


Figure 27: Simulation of SNL/UL Experiment 3: Hot Gas Layer Temperature

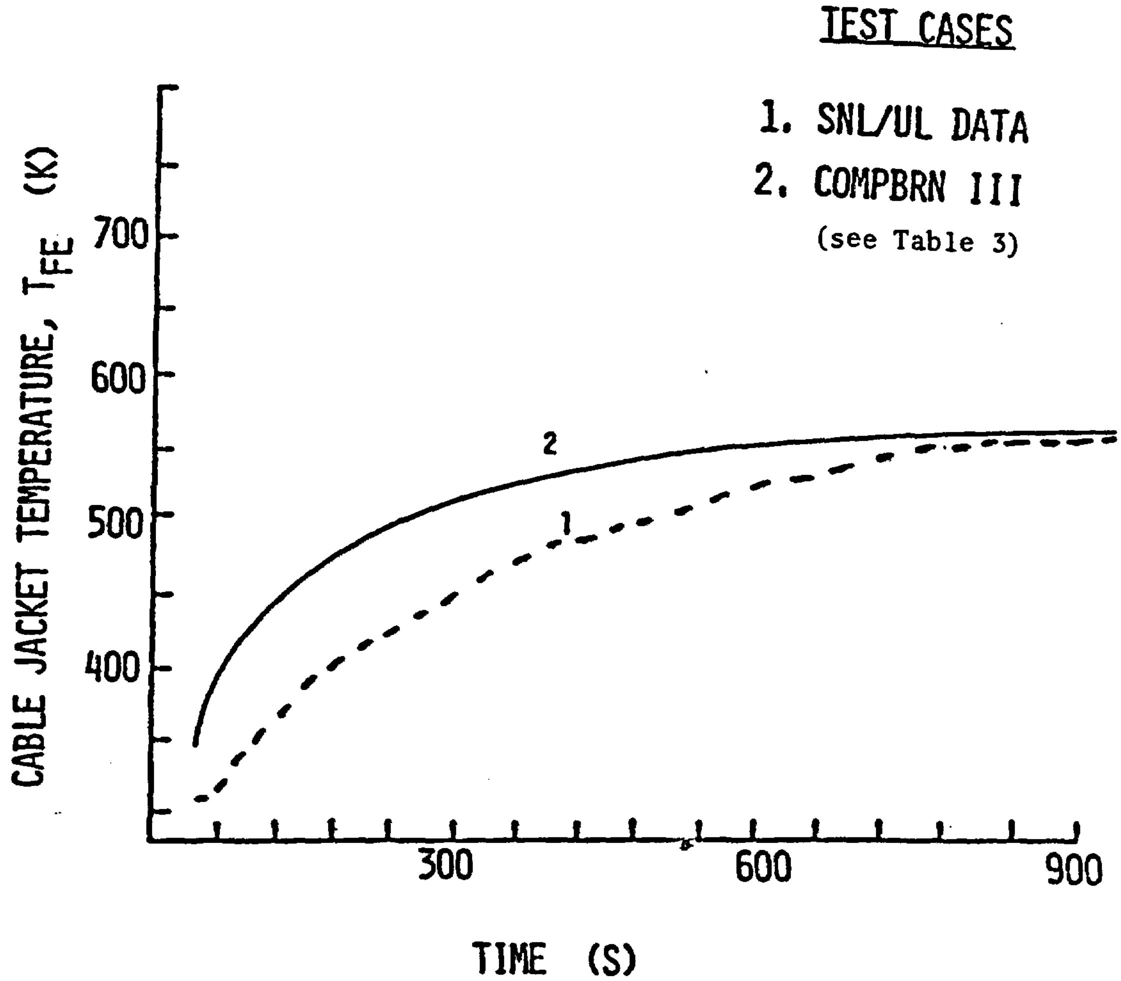


Figure 28: Simulation of SNL/UL Experiment 3: Cable Jacket Temperature

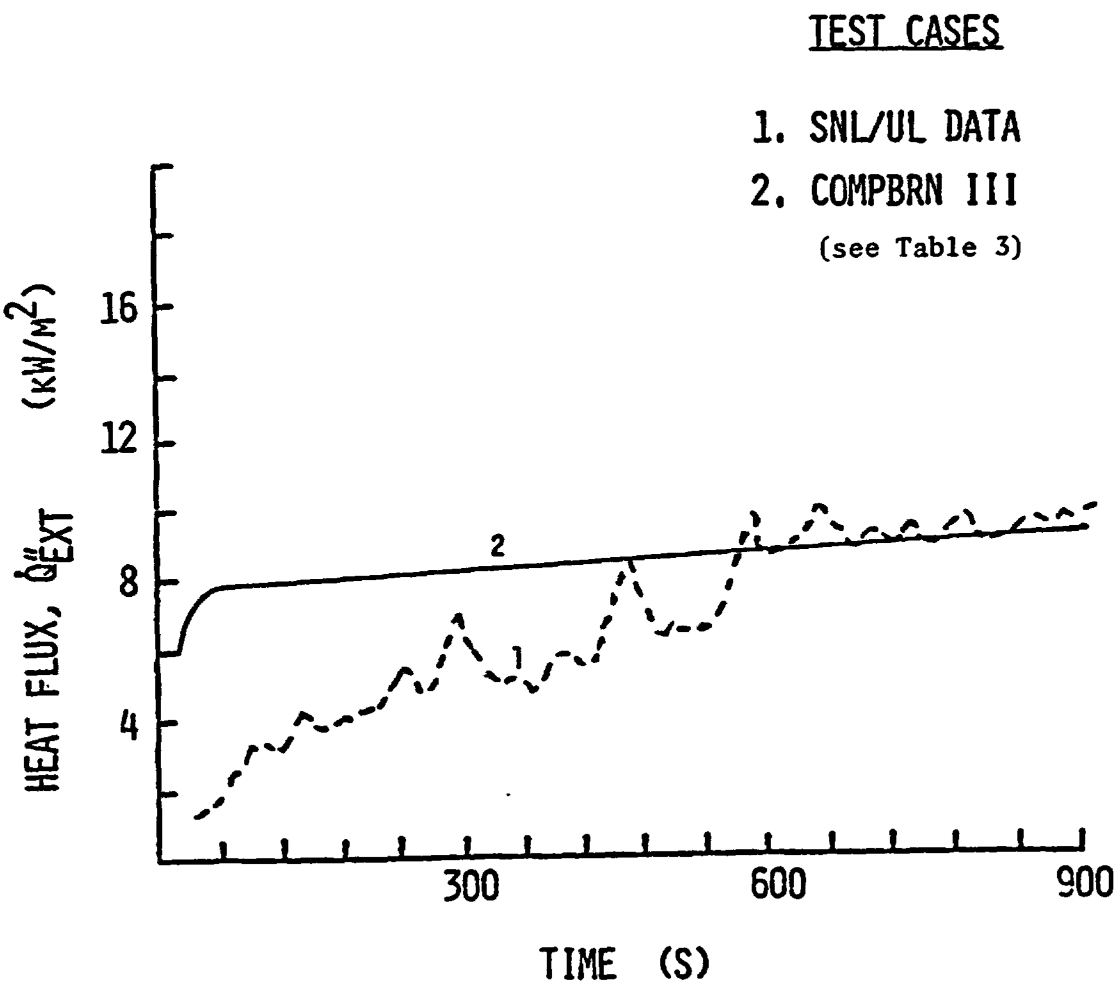


Figure 29: Simulation of SNL/UL Experiment 3: Heat Flux

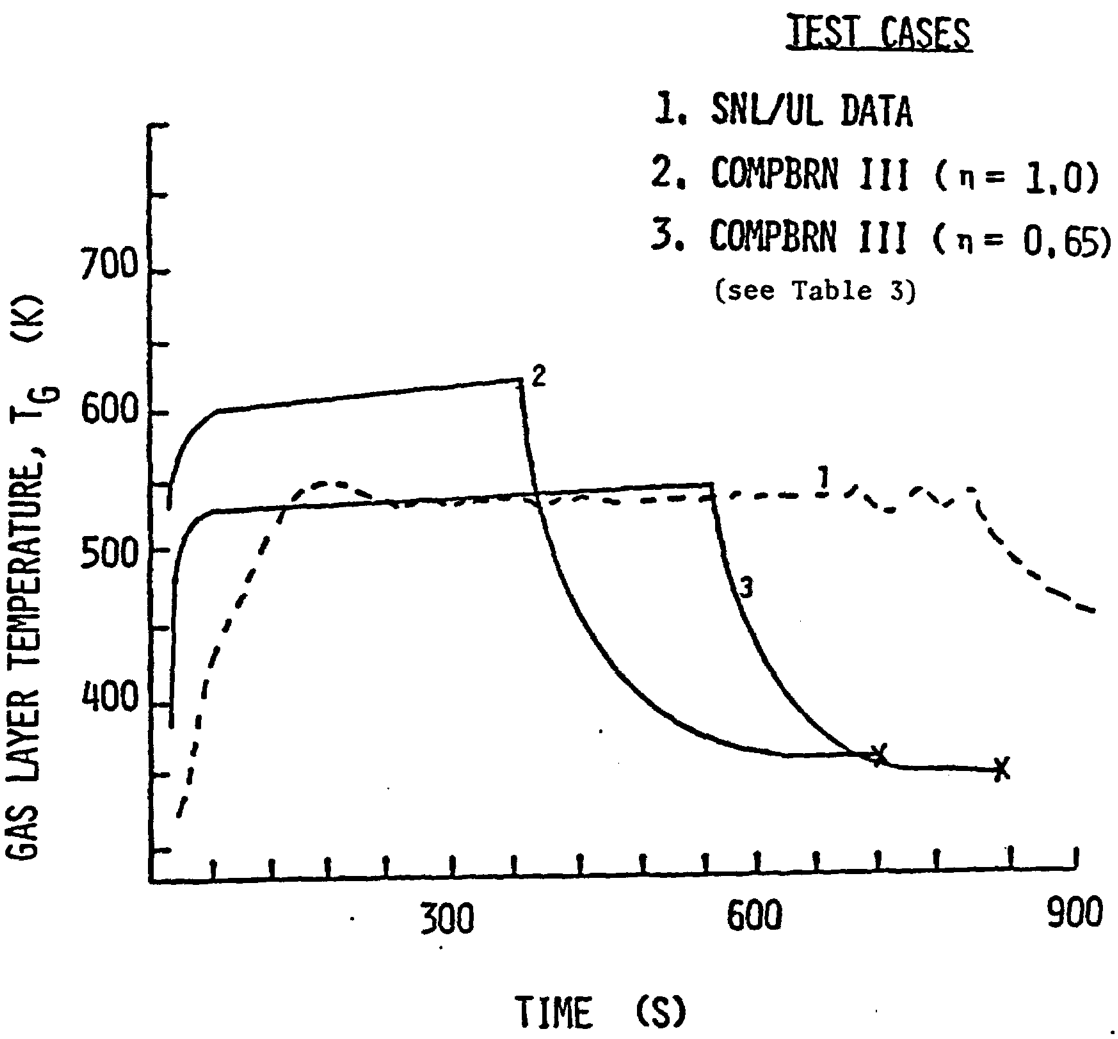


Figure 30: Simulation of SNL/UL Experiment 4: Hot Gas Layer Temperature

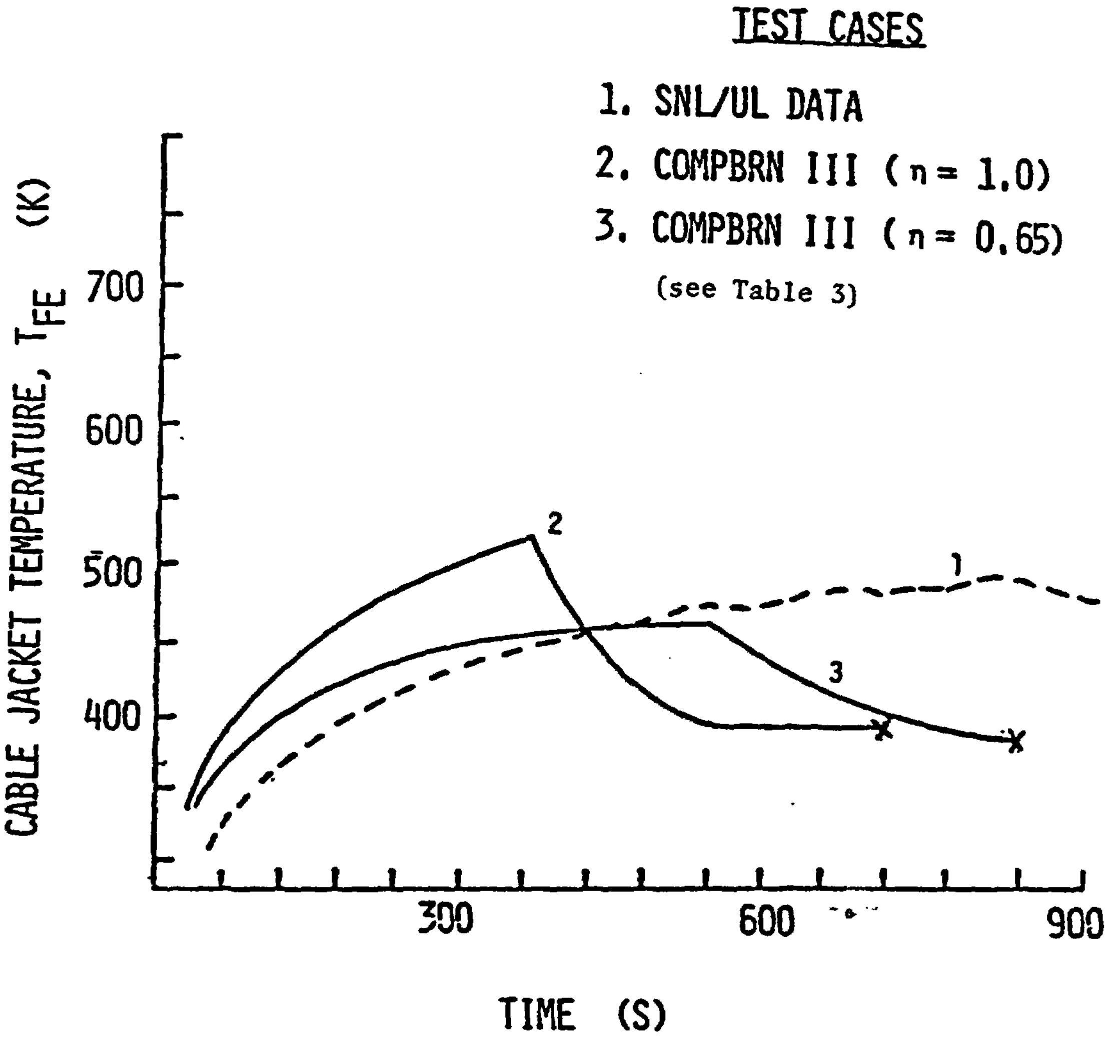


Figure 31: Simulation of SNL/UL Experiment 4: Cable Jacket Temperature

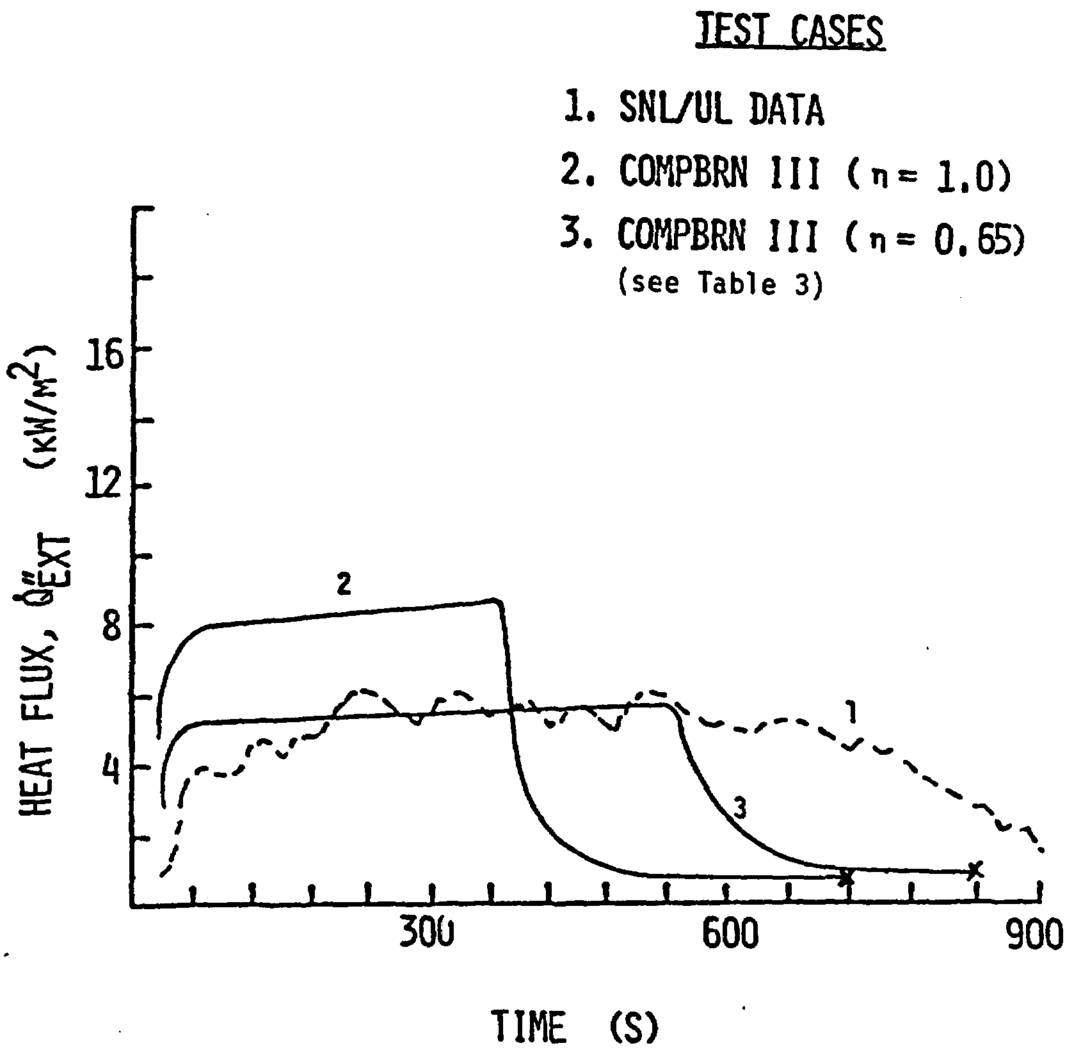


Figure 32: Simulation of SNL/UL Experiment 4: Heat Flux

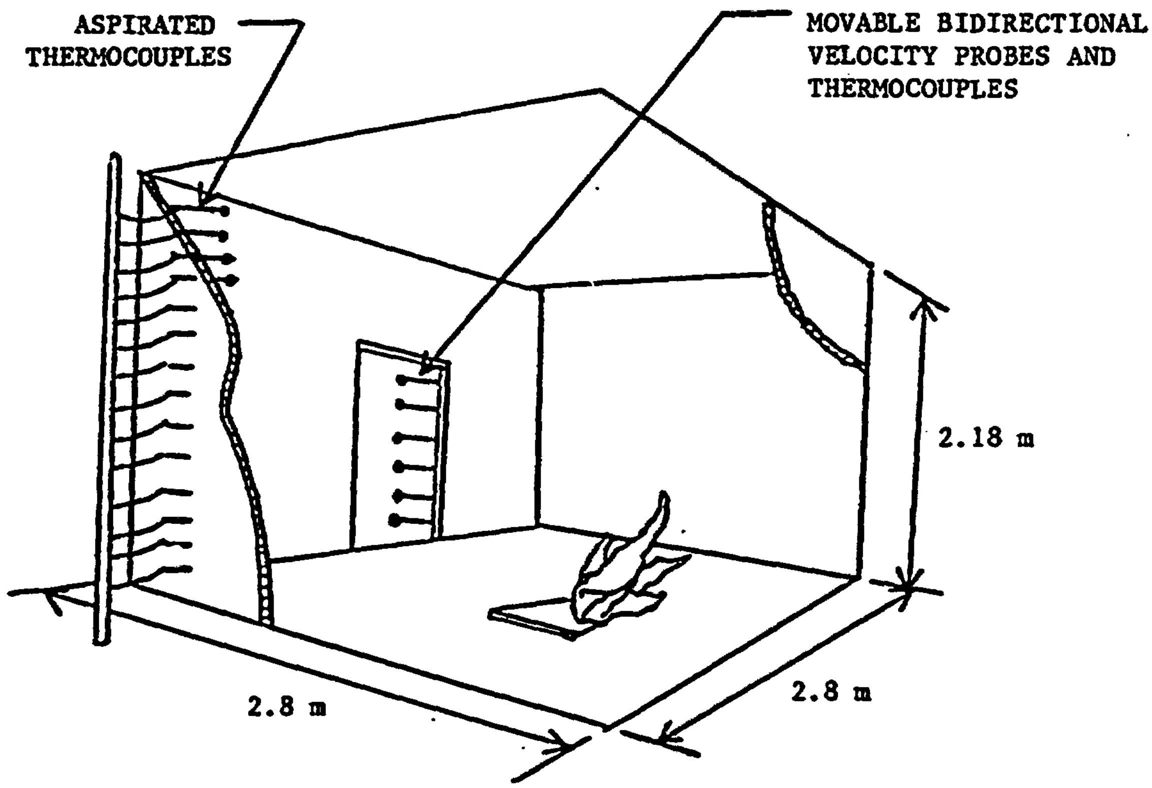


Figure 33: Experimental Arrangement of the Steady-State Flow Experiments [11]

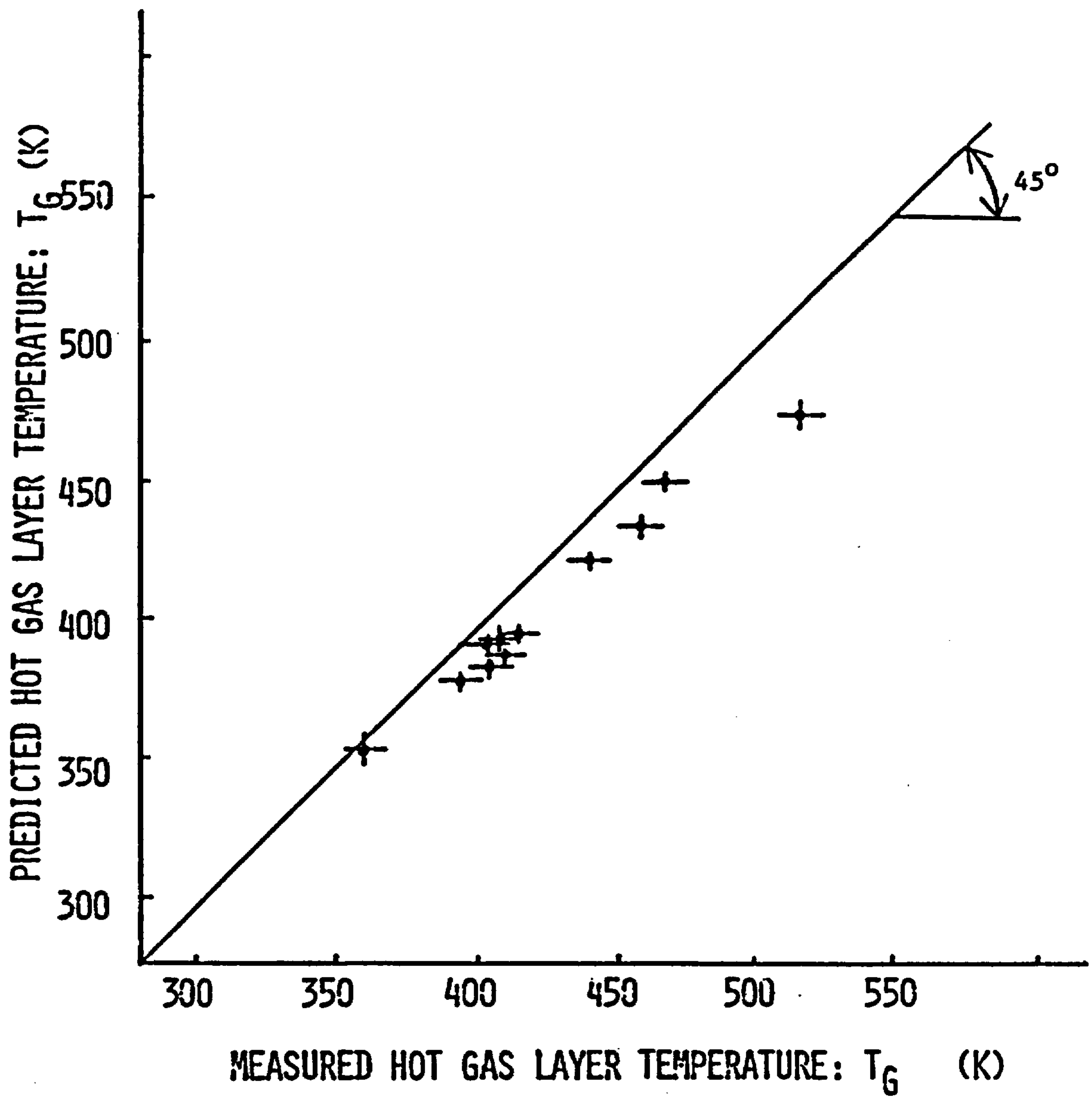


Figure 34: Simulation of the Steady-State Experiments: T_G

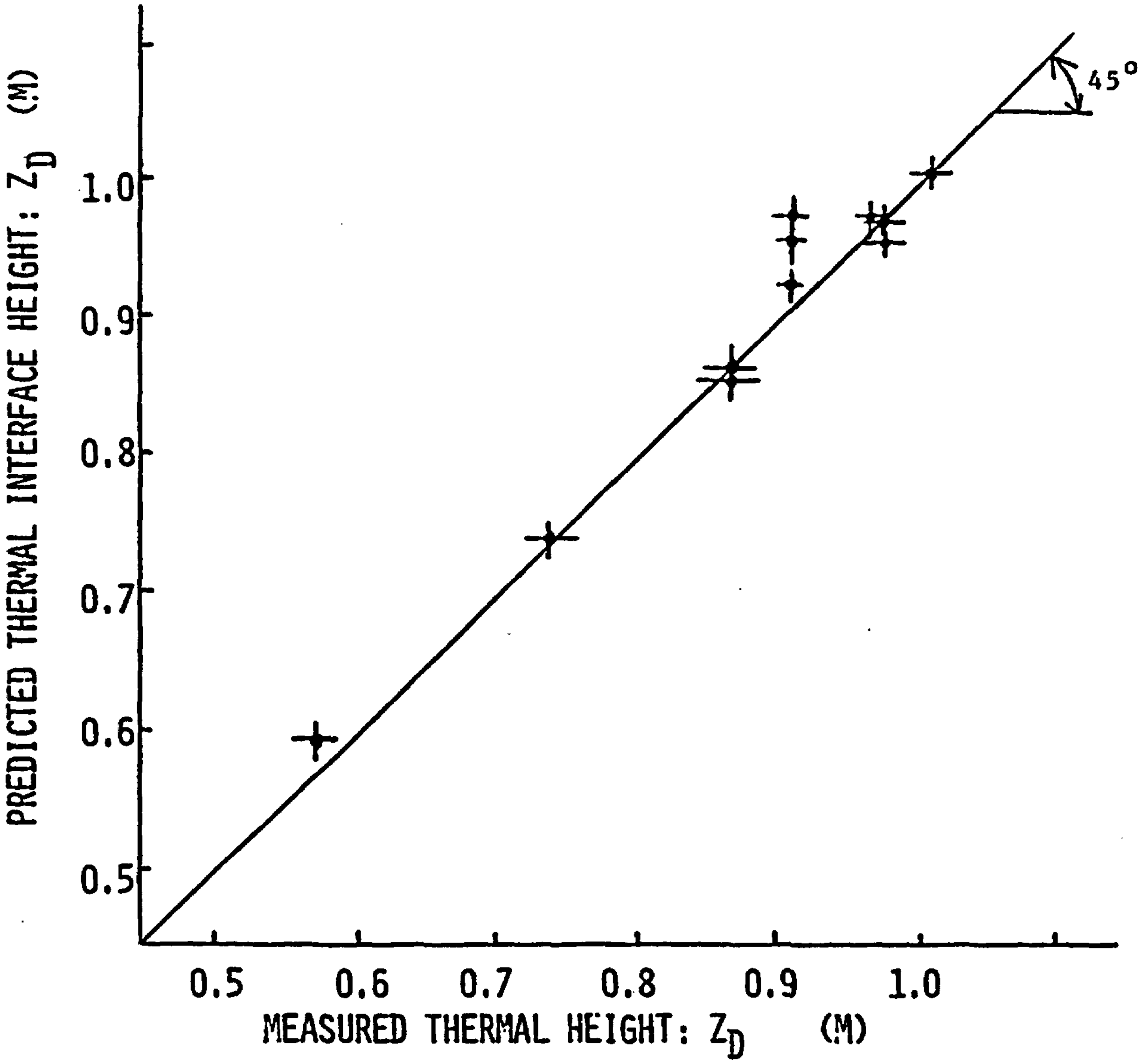


Figure 35: Simulation of the Steady-State Experiments: Z_D

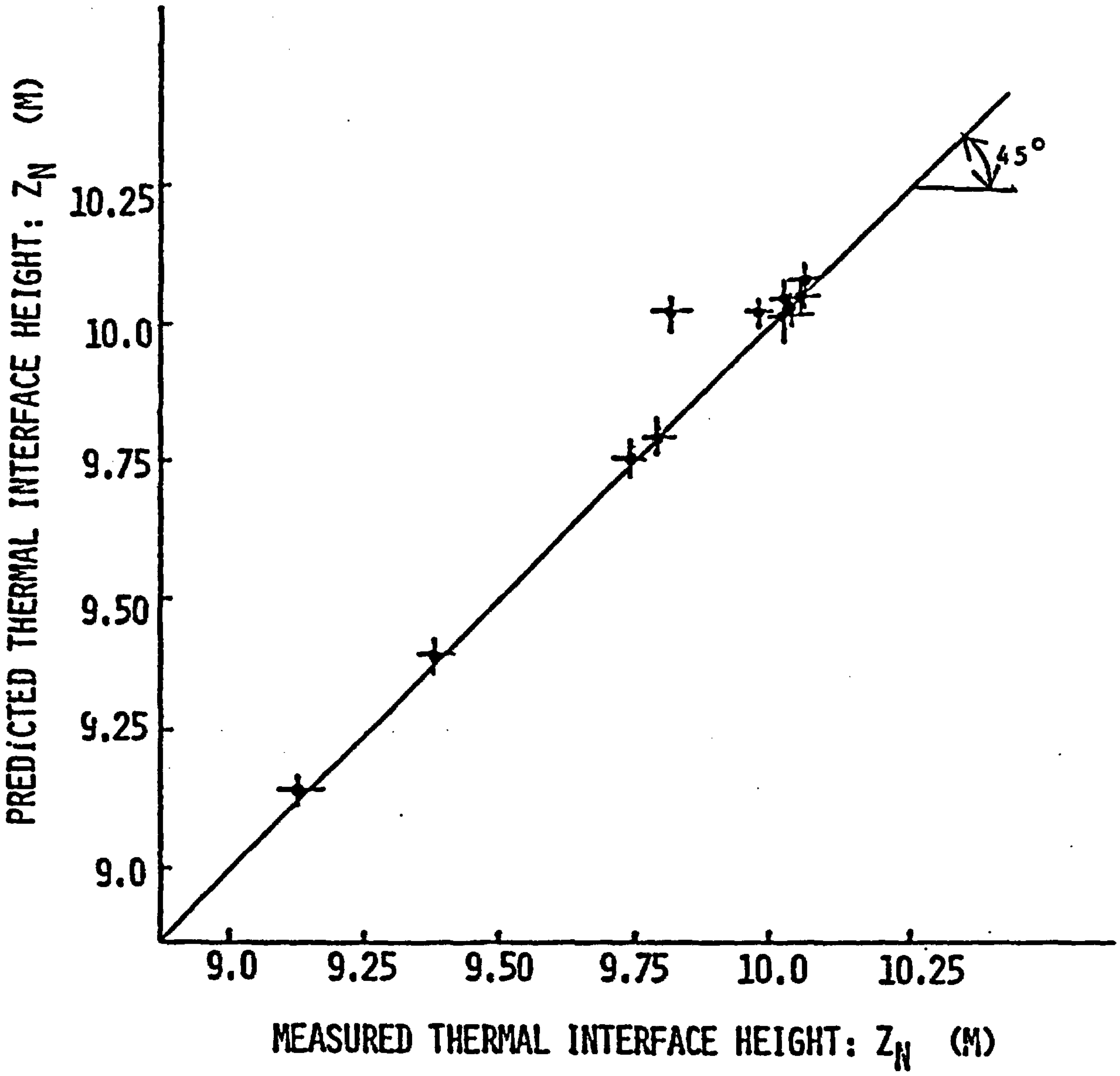


Figure 36: Simulation of the Steady-State Experiments: Z_N

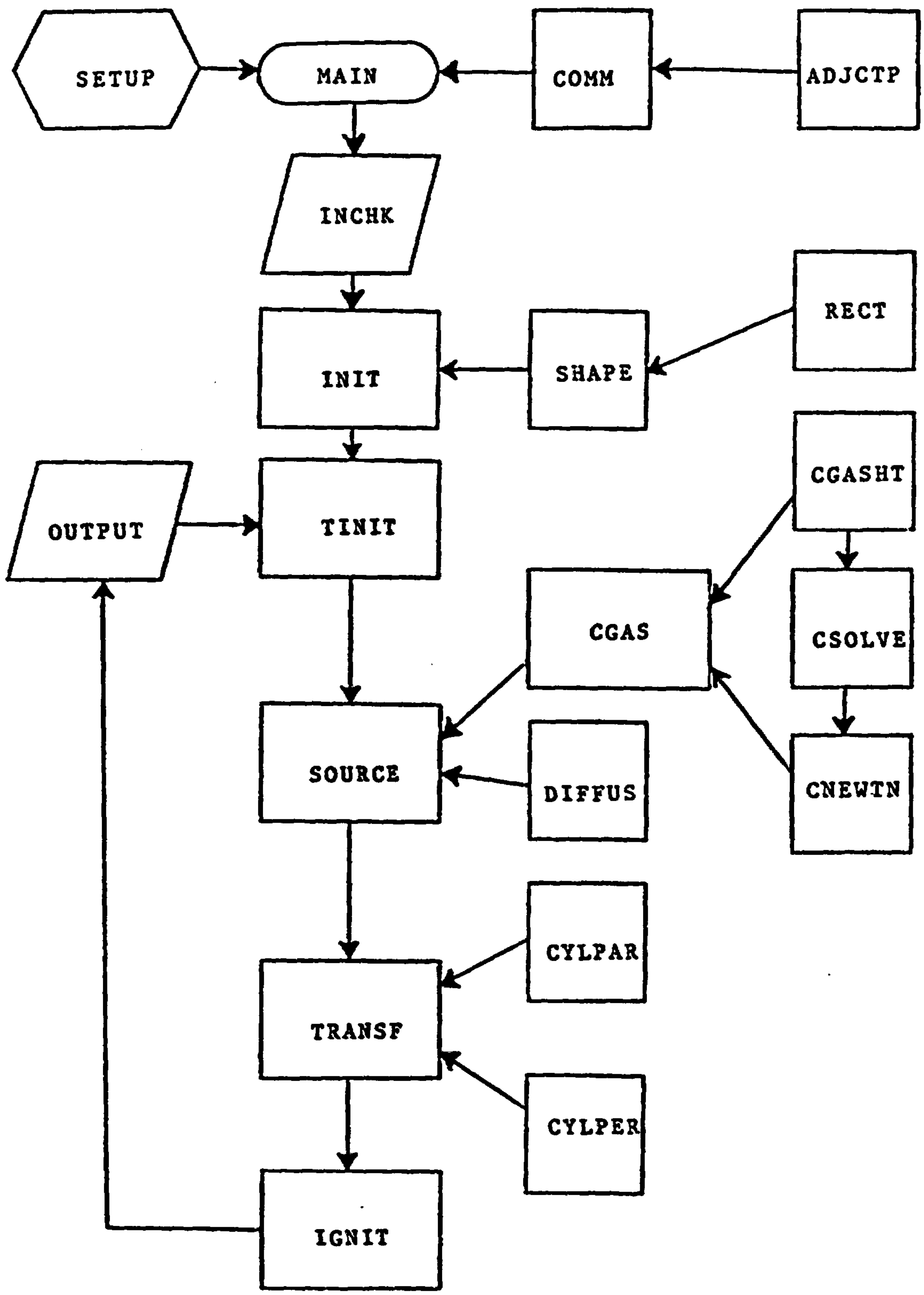


Figure 37: Programming Flow Chart of COMPBRN III

Appendix A

A SAMPLE PROBLEM

In this Appendix, we use a sample problem to demonstrate the usage of COMPBRN III. The user can utilize the sample input as a guideline for developing input files for COMPBRN.

The sample problem used here is the simulation of SNL/UL Experiment 1. The enclosure details of the experiment haves been given in Chapter 4 (see Figure 9, 10 and 11). The other details of the materials used in the experiment and the locations of the probes can be found in [15]. There is no forced ventilation in the room and the fire source is a heptane tank 9.14 m away from the wall (facing the doorway). The sample input file is shown in Table 6 and portions of the sample output can be found in Table 7. The results of the simulation are shown in Figure 21, 22 and 23.

TABLE 6

COMPBRN III Sample Problem Input

```
&STRT NJOB=1, NTIME=15, NREAD=5, NWRITE=6, DELT=60., &END
&SIZE NSM=10, NFUEL=5, NPILOT=1, NCOM=0, NNCOM=0, IROOM=1,
      INITG=0, &END
***** TEST CASE: SAMPLE PROBLEM FOR COMPBRN III (SNL/UL EXPT 1) ****
&FUELB SMX=2.14, SMY=4.57, SMZ=3.05,
       SLNG=9.14, SWID=4.27, SDEP=1.00,
       SMASS=1500., SPOR=1.0, SLOSS=1.0,
       NFIL=1, IORNT=3, IDIREC=2,
       IFTYP=1, &END  (CEILING)
&FUELB SMX=2.14, SMY=9.14, SMZ=1.52,
       SLNG=4.27, SWID=3.10, SDEP=1.00,
       SMASS=610.0, SPOR=1.0, SLOSS=1.0,
       NFIL=1, IORNT=2, IDIREC=1,
       IFTYP=2, &END (WALL)
&FUELB SMX=3.21, SMY=8.61, SMZ=2.64,
       SLNG=.323, SWID=0.46, SDEP=0.11,
       SMASS=2.25, SPOR=3.11, SLOSS=1.0,
       NFIL=1, IORNT=3, IDIREC=1,
       IFTYP=3, &END   (CABLE)
&FUELB SMX=2.14, &END
&FUELB SMX=1.07, &END
&FUELB SMX=3.21, SMZ=2.44, &END
&FUELB SMX=2.14, &END
&FUELB SMX=1.07, &END
&FUELB SMX=2.14, SMZ=0.914, &END
&FUELB SMX=2.14, SMY=2.13, SMZ=.152,
       SLNG=1.53, SWID=0.31, SDEP=0.31,
       SMASS=12.87, SPOR=1.0, SLOSS=1.0,
       NFCL=1, IORNT=3, IDIREC=1,
       IFTYP=4, &END   (HEPTANE FUEL)
&PILOT IPIL=10, JPIL=1, IPFUEL=4,
       PMASS=21.88, &END
&FUELT IFUEL=40, 20, 1, 2, 10,
       DENS=2*2243.1, 1715., 679., 1.0,
       SPHT=2*751.7, 1045., 2192.4, 2.0,
       THK=2*1.72, .092, .128, 1.0,
       BRATV=2*0.0, 2*0.110, 0.0,
       FABSRP=0.0, 0.0, 2*1.4, 0.0,
       REFL=4*0.35, 0.1,
       BRATS1=0.0, 0.0, 1.8E-7, 0.0, 0.0,
       GAMMA=4*.0.45, 0.0,
       BRATS0=2*0.0, 0.001, 0.061, 0.0,
       HEAT=2*0.0, 2.4E+7, 4.84E+7, 0.0,
       EFF=5*0.85,
       FIGTP=2*0.0, 789.0, 2*0.0,
       FIGTS=2*0.0, 839.0, 2*0.0,
       FTDAM=2*0., 543.0, 2*0.0, &END
&MISC RTEMP=298.0, FLCF=22.0, HROOM=10.0, CALTEM=298.0, &END
&ROOM DCFIN=0.6, DCFOUT=0.7, DHGT=2.44, DWID=2.44, FC=0.0, FH=0.0,
```

```
      GABSRP=1.3, HCEIL=10.0, PLCF=2.0, VFV=0.0,  &END
&MODVAR FCTR=15*1.0, &END
&OUTF INCHCK=2, IOUTPT=17,
      MOUTPT=1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,
      NSMOUT=10, MSMOUT=1,2,3,4,5,6,7,8,9,10, &END
```

TABLE 7

COMPBRN III SAMPLE PROBLEM OUTPUT

```
PROGRAM COMPBRN III - A DETERMINISTIC CODE TO COMPUTE THE PROGRESS OF FIRE
                      OVER A GIVEN FUEL ARRAY WITHIN ENCLOSING BOUNDARIES.
                      ALL UNITS ARE IN THE MKS SYSTEM.

***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****


INPUT DATA:

JOB  1 OF  1 JOBS
```

VARIABILITY FACTORS FOR FIRE MODELS:

VENTILATION CONTROLLED BURNING RATE	0.100000E+01
FUEL-SURFACE CONTROLLED BURNING RATE	0.100000E+01
FLAME HEIGHT FOR HORIZONTAL FUEL	0.100000E+01
FLAME HEIGHT FOR VERTICAL FUEL	0.100000E+01
RADIATIVE HEAT FLUX INTERCHANGE	0.100000E+01
BUOYANT PLUME TEMPERATURE	0.100000E+01
CONVECTIVE HEAT TRANSFER COEFFICIENT FOR VERTICAL OBJECTS IN PLUME	0.100000E+01
CONVECTIVE HEAT TRANSFER COEFFICIENT FOR HORIZONTAL OBJECTS IN PLUME	0.100000E+01
GAS LAYER LOCAL TEMPERATURE	0.100000E+01
HEAT TRANSFER TO SELF FOR VERTICAL FUEL	0.100000E+01
HEAT TRANSFER TO ADJACENT FUEL	0.100000E+01
HEAT FLUX FROM CEILING HOT GAS LAYER	0.100000E+01
HEAT FLUX FROM REFLECTIONS OFF WALLS AND BARRIERS	0.100000E+01
MASS BURNOUT FRACTION	0.100000E+01
CURRENTLY UNDEFINED	0.100000E+01

NUMBER OF FUEL TYPES: 5

DATA FOR FUEL TYPE 1:

FUEL TYPE: (CEILING)	40
THERMAL CONDUCTIVITY (W/M-K):	0.172000E+01
THERMAL DIFFUSIVITY (M**2/S):	0.102008E-05
REFLECTIVITY:	0.350000E+00

DATA FOR FUEL TYPE 2:

FUEL TYPE: (WALL)	20
THERMAL CONDUCTIVITY (W/M-K):	0.172000E+01
THERMAL DIFFUSIVITY (M**2/S):	0.102008E-05
REFLECTIVITY:	0.350000E+00

DATA FOR FUEL TYPE 3:

FUEL TYPE:	1
DENSITY (KG/M**3):	0.171500E+04
SPECIFIC HEAT (J/KG-K):	0.104500E+04
THERMAL CONDUCTIVITY (W/M-K):	0.920000E-01
HEAT OF COMBUSTION (J/KG):	0.240000E+08
COMBUSTION EFFICIENCY:	0.850000E+00
PILOTED IGNITION TEMPERATURE (DEG. K):	0.789000E+03
SPONTANEOUS IGNITION TEMPERATURE (DEG. K):	0.839000E+03
DAMAGE TEMPERATURE (DEG. K):	0.543000E+03
VENTILATION CONTROLLED BURNING RATE FACTOR (KG/M**2.5-S):	0.110000E+00
SURFACE CONTROLLED SPECIFIC BURNING RATE (KG/M**2-S):	0.100000E-02
SPECIFIC BURNING RATE RADIATION AUGMENTATION (KG/J-M**2):	0.180000E-06
FRACTION OF HEAT RELEASED AS RADIATION:	0.450000E+00
SMOKE ATTENUATION FACTOR (M**-1):	0.140000E+01
REFLECTIVITY:	0.350000E+00

DATA FOR FUEL TYPE 4:

FUEL TYPE:	2
DENSITY (KG/M**3):	0.679000E+03
SPECIFIC HEAT (J/KG-K):	0.219240E+04
THERMAL CONDUCTIVITY (W/M-K):	0.128000E+00
HEAT OF COMBUSTION (J/KG):	0.484000E+08
COMBUSTION EFFICIENCY:	0.850000E+00
PILOTED IGNITION TEMPERATURE (DEG. K):	0.0
SPONTANEOUS IGNITION TEMPERATURE (DEG. K):	0.0
DAMAGE TEMPERATURE (DEG. K):	0.0
VENTILATION CONTROLLED BURNING RATE FACTOR (KG/M**2.5-S):	0.110000E+00
SURFACE CONTROLLED SPECIFIC BURNING RATE (KG/M**2-S):	0.610000E-01
SPECIFIC BURNING RATE RADIATION AUGMENTATION (KG/J-M**2):	0.0
FRACTION OF HEAT RELEASED AS RADIATION:	0.450000E+00
SMOKE ATTENUATION FACTOR (M**-1):	0.140000E+01
REFLECTIVITY:	0.350000E+00

DATA FOR FUEL TYPE 5:

FUEL TYPE: (DETECTOR)	10

ROOM PARAMETERS:

CEILING LENGTH, WIDTH, HEIGHT (M):	0.914000E+01	0.427000E+01	0.305000E+01
DOOR HEIGHT (M):			0.244000E+01
DOOR WIDTH (M):			0.244000E+01
DOORWAY INFLOW COEFFICIENT:			0.600000E+00
DOORWAY OUTFLOW COEFFICIENT:			0.700000E+00
FORCED VENTILATION (M**3/S):			0.0
FORCED VENTILATION CONSTANTS (FH AND FC):		0.0	0.0
PLUME ENTRAINMENT CONSTANTS (PLCF)			0.200000E+01
GAS ABSORPTION COEFFICIENT (GABSRP):,			0.130000E+01
CEILING HEAT TRANSFER COEFFICIENT (W/M**2 DEG.K):			0.100000E+02

PILOT FIRE DATA:

NUMBER OF PILOT FIRES: 1

DATA FOR PILOT FIRE 1:

LOCATION OF PILOT FIRE (FUEL ARRAY,FUEL CELL):	10, 1
FUEL TYPE:	4
MASS (KG):	0.218800E+02

```
NUMBER OF FUEL ARRAYS:   10

DATA FOR FUEL ARRAY  1:
     INITIAL FUEL CELL X-Y-Z COORDINATES (M):      0.214000E+01 0.457000E+01 0.305000E+01
     DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):          0.914000E+01 0.427000E+01 0.100000E+01
     NUMBER OF FUEL CELLS:                                                             1
     DIRECTION OF AXIS, ORIENTATION:                                          Y        Z
     MASS (KG):                                                            0.150000E+04
     POROSITY FACTOR (DIMENSIONLESS):                                      0.100000E+01
     HEAT LOSS FACTOR (UNDEFINED):                                         0.100000E+01
     FUEL TYPE:                                                                        1

DATA FOR FUEL ARRAY  2:

     INITIAL FUEL CELL X-Y-Z COORDINATES (M):      0.214000E+01 0.914000E+01 0.152000E+01
     DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):          0.427000E+01 0.310000E+01 0.100000E+01
     NUMBER OF FUEL CELLS:                                                             1
     DIRECTION OF AXIS, ORIENTATION:                                          X        Y
     MASS (KG):                                                            0.610000E+03
     POROSITY FACTOR (DIMENSIONLESS):                                      0.100000E+01
     HEAT LOSS FACTOR (UNDEFINED):                                         0.100000E+01
     FUEL TYPE:                                                                        2

DATA FOR FUEL ARRAY  3:

     INITIAL FUEL CELL X-Y-Z COORDINATES (M):      0.321000E+01 0.861000E+01 0.264000E+01
     DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):          0.323000E+00 0.460000E+00 0.110000E-01
     NUMBER OF FUEL CELLS:                                                             1
     DIRECTION OF AXIS, ORIENTATION:                                          X        Z
     MASS (KG):                                                            0.225000E+01
     POROSITY FACTOR (DIMENSIONLESS):                                      0.311000E+01
     HEAT LOSS FACTOR (UNDEFINED):                                         0.100000E+01
     FUEL TYPE:                                                                        3

DATA FOR FUEL ARRAY  4:

     INITIAL FUEL CELL X-Y-Z COORDINATES (M):      0.214000E+01 0.861000E+01 0.264000E+01
     DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):          0.323000E+00 0.460000E+00 0.110000E-01
     NUMBER OF FUEL CELLS:                                                             1
     DIRECTION OF AXIS, ORIENTATION:                                          X        Z
     MASS (KG):                                                            0.225000E+01
     POROSITY FACTOR (DIMENSIONLESS):                                      0.311000E+01
     HEAT LOSS FACTOR (UNDEFINED):                                         0.100000E+01
     FUEL TYPE:                                                                        3
```

DATA FOR FUEL ARRAY 5:

INITIAL FUEL CELL X-Y-Z COORDINATES (M):	0.107000E+01	0.861000E+01	0.264000E+01
DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):	0.323000E+00	0.460000E+00	0.110000E-01
NUMBER OF FUEL CELLS:			1
DIRECTION OF AXIS, ORIENTATION:			X Z
MASS (KG):			0.225000E+01
POROSITY FACTOR (DIMENSIONLESS):			0.311000E+01
HEAT LOSS FACTOR (UNDEFINED):			0.100000E+01
FUEL TYPE:			3

DATA FOR FUEL ARRAY 6:

INITIAL FUEL CELL X-Y-Z COORDINATES (M):	0.321000E+01	0.861000E+01	0.244000E+01
DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):	0.323000E+00	0.460000E+00	0.110000E-01
NUMBER OF FUEL CELLS:			1
DIRECTION OF AXIS, ORIENTATION:			X Z
MASS (KG):			0.225000E+01
POROSITY FACTOR (DIMENSIONLESS):			0.311000E+01
HEAT LOSS FACTOR (UNDEFINED):			0.100000E+01
FUEL TYPE:			3

DATA FOR FUEL ARRAY 7:

INITIAL FUEL CELL X-Y-Z COORDINATES (M):	0.214000E+01	0.861000E+01	0.244000E+01
DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):	0.323000E+00	0.460000E+00	0.110000E-01
NUMBER OF FUEL CELLS:			1
DIRECTION OF AXIS, ORIENTATION:			X Z
MASS (KG):			0.225000E+01
POROSITY FACTOR (DIMENSIONLESS):			0.311000E+01
HEAT LOSS FACTOR (UNDEFINED):			0.100000E+01
FUEL TYPE:			3

DATA FOR FUEL ARRAY 8:

INITIAL FUEL CELL X-Y-Z COORDINATES (M):	0.107000E+01	0.861000E+01	0.244000E+01
DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):	0.323000E+00	0.460000E+00	0.110000E-01
NUMBER OF FUEL CELLS:			1
DIRECTION OF AXIS, ORIENTATION:			X Z
MASS (KG):			0.225000E+01
POROSITY FACTOR (DIMENSIONLESS):			0.311000E+01
HEAT LOSS FACTOR (UNDEFINED):			0.100000E+01
FUEL TYPE:			3

DATA FOR FUEL ARRAY 9:

INITIAL FUEL CELL X-Y-Z COORDINATES (M):	0.214000E+01	0.861000E+01	0.914000E+00
DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):	0.323000E+00	0.460000E+00	0.110000E-01
NUMBER OF FUEL CELLS:			1
DIRECTION OF AXIS, ORIENTATION:			X Z
MASS (KG):			0.225000E+01
POROSITY FACTOR (DIMENSIONLESS):			0.311000E+01
HEAT LOSS FACTOR (UNDEFINED):			0.100000E+01
FUEL TYPE:			3

DATA FOR FUEL ARRAY 10:

INITIAL FUEL CELL X-Y-Z COORDINATES (M):	0.214000E+01	0.213000E+01	0.152000E+00
DIMENSIONS (LENGTH,WIDTH,DEPTH) (M):	0.153000E+01	0.310000E+00	0.310000E+00
NUMBER OF FUEL CELLS:			1
DIRECTION OF AXIS, ORIENTATION:			X Z
MASS (KG):			0.128700E+02
POROSITY FACTOR (DIMENSIONLESS):			0.100000E+01
HEAT LOSS FACTOR (UNDEFINED):			0.100000E+01
FUEL TYPE:			4

MISCELLANEOUS:

ROOM TEMPERATURE (DEG. K):	0.298000E+03
CALORIMETER TEMPERATURE (DEG. K):	0.298000E+03
CONVECTIVE HEAT TRANSFER COEFFICIENT FOR FLAME (W/M**2-K):	0.220000E+02
CONVECTIVE HEAT TRANSFER COEFFICIENT FOR ROOM (W/M**2-K):	0.100000E+02
(FOR OBJECTS OUTSIDE OF HOT GAS LAYER)	
TIME INCREMENT (S):	0.600000E+02
NUMBER OF TIME STEPS FOR JOB:	5

```
 ***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****
TIME (SEC):    0.

TOTAL MASS BURNING RATE (KG/S):   .0
TOTAL HEAT RELEASE RATE (W)   :   .0
HOT GAS LAYER TEMPERATURE (K) :   298.0
HOT GAS LAYER THICKNESS (M)   :   .0

MODULE:   1   DAMAGE ?                  F
MODULE:   2   DAMAGE ?                  F
MODULE:   3   DAMAGE ?                  F
MODULE:   4   DAMAGE ?                  F
MODULE:   5   DAMAGE ?                  F
MODULE:   6   DAMAGE ?                  F
MODULE:   7   DAMAGE ?                  F
MODULE:   8   DAMAGE ?                  F
MODULE:   9   DAMAGE ?                  F
MODULE:  10   DAMAGE ?                  F

MODULE:   1   BURNING?                  F
MODULE:   2   BURNING?                  F
MODULE:   3   BURNING?                  F
MODULE:   4   BURNING?                  F
MODULE:   5   BURNING?                  F
MODULE:   6   BURNING?                  F
MODULE:   7   BURNING?                  F
MODULE:   8   BURNING?                  F
MODULE:   9   BURNING?                  F
MODULE:  10   BURNING?                  T

MODULE:   1   SOURCE FLUX        .0
MODULE:   2   SOURCE FLUX        .0
MODULE:   3   SOURCE FLUX        .0
MODULE:   4   SOURCE FLUX        .0
MODULE:   5   SOURCE FLUX        .0
MODULE:   6   SOURCE FLUX        .0
MODULE:   7   SOURCE FLUX        .0
MODULE:   8   SOURCE FLUX        .0
MODULE:   9   SOURCE FLUX        .0
MODULE:  10   SOURCE FLUX        .0
```

MODULE:	1	EXTERNAL FLUX	.0
MODULE:	2	EXTERNAL FLUX	.0
MODULE:	3	EXTERNAL FLUX	.0
MODULE:	4	EXTERNAL FLUX	.0
MODULE:	5	EXTERNAL FLUX	.0
MODULE:	6	EXTERNAL FLUX	.0
MODULE:	7	EXTERNAL FLUX	.0
MODULE:	8	EXTERNAL FLUX	.0
MODULE:	9	EXTERNAL FLUX	.0
MODULE:	10	EXTERNAL FLUX	.0

MODULE:	1	TOTAL FLUX	.0
MODULE:	2	TOTAL FLUX	.0
MODULE:	3	TOTAL FLUX	.0
MODULE:	4	TOTAL FLUX	.0
MODULE:	5	TOTAL FLUX	.0
MODULE:	6	TOTAL FLUX	.0
MODULE:	7	TOTAL FLUX	.0
MODULE:	8	TOTAL FLUX	.0
MODULE:	9	TOTAL FLUX	.0
MODULE:	10	TOTAL FLUX	.0

MODULE:	1	MEAS'D FLUX	.0
MODULE:	2	MEAS'D FLUX	.0
MODULE:	3	MEAS'D FLUX	.0
MODULE:	4	MEAS'D FLUX	.0
MODULE:	5	MEAS'D FLUX	.0
MODULE:	6	MEAS'D FLUX	.0
MODULE:	7	MEAS'D FLUX	.0
MODULE:	8	MEAS'D FLUX	.0
MODULE:	9	MEAS'D FLUX	.0
MODULE:	10	MEAS'D FLUX	.0

MODULE:	1	NET FLUX	.0
MODULE:	2	NET FLUX	.0
MODULE:	3	NET FLUX	.0
MODULE:	4	NET FLUX	.0
MODULE:	5	NET FLUX	.0
MODULE:	6	NET FLUX	.0
MODULE:	7	NET FLUX	.0
MODULE:	8	NET FLUX	.0
MODULE:	9	NET FLUX	.0
MODULE:	10	NET FLUX	.0

MODULE:	1	FUEL MASS	.150E+04
MODULE:	2	FUEL MASS	610.
MODULE:	3	FUEL MASS	2.25
MODULE:	4	FUEL MASS	2.25
MODULE:	5	FUEL MASS	2.25
MODULE:	6	FUEL MASS	2.25
MODULE:	7	FUEL MASS	2.25
MODULE:	8	FUEL MASS	2.25
MODULE:	9	FUEL MASS	2.25
MODULE:	10	FUEL MASS	12.9

MODULE:	1	FLAME HGT	.0
MODULE:	2	FLAME HGT	.0
MODULE:	3	FLAME HGT	.0
MODULE:	4	FLAME HGT	.0
MODULE:	5	FLAME HGT	.0
MODULE:	6	FLAME HGT	.0
MODULE:	7	FLAME HGT	.0
MODULE:	8	FLAME HGT	.0
MODULE:	9	FLAME HGT	.0
MODULE:	10	FLAME HGT	.0

MODULE:	1	FLAME TEMP	.0
MODULE:	2	FLAME TEMP	.0
MODULE:	3	FLAME TEMP	.0
MODULE:	4	FLAME TEMP	.0
MODULE:	5	FLAME TEMP	.0
MODULE:	6	FLAME TEMP	.0
MODULE:	7	FLAME TEMP	.0
MODULE:	8	FLAME TEMP	.0
MODULE:	9	FLAME TEMP	.0
MODULE:	10	FLAME TEMP	.0

MODULE:	1	FUEL TEMP	298.
MODULE:	2	FUEL TEMP	298.
MODULE:	3	FUEL TEMP	298.
MODULE:	4	FUEL TEMP	298.
MODULE:	5	FUEL TEMP	298.
MODULE:	6	FUEL TEMP	298.
MODULE:	7	FUEL TEMP	298.
MODULE:	8	FUEL TEMP	298.
MODULE:	9	FUEL TEMP	298.
MODULE:	10	FUEL TEMP	298.

MODULE:	1	HEAT TRANS COEF	10.0
MODULE:	2	HEAT TRANS COEF	10.0
MODULE:	3	HEAT TRANS COEF	10.0
MODULE:	4	HEAT TRANS COEF	10.0
MODULE:	5	HEAT TRANS COEF	10.0
MODULE:	6	HEAT TRANS COEF	10.0
MODULE:	7	HEAT TRANS COEF	10.0
MODULE:	8	HEAT TRANS COEF	10.0
MODULE:	9	HEAT TRANS COEF	10.0
MODULE:	10	HEAT TRANS COEF	10.0

MODULE:	1	ENVIRONMENT TEMP	298.
MODULE:	2	ENVIRONMENT TEMP	298.
MODULE:	3	ENVIRONMENT TEMP	298.
MODULE:	4	ENVIRONMENT TEMP	298.
MODULE:	5	ENVIRONMENT TEMP	298.
MODULE:	6	ENVIRONMENT TEMP	298.
MODULE:	7	ENVIRONMENT TEMP	298.
MODULE:	8	ENVIRONMENT TEMP	298.
MODULE:	9	ENVIRONMENT TEMP	298.
MODULE:	10	ENVIRONMENT TEMP	298.

***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****
TIME (SEC): 60.

TOTAL MASS BURNING RATE (KG/S):	.2893E-01
TOTAL HEAT RELEASE RATE (W) :	.1190E+07
HOT GAS LAYER TEMPERATURE (K) :	504.2
HOT GAS LAYER THICKNESS (M) :	1.446

MODULE:	1	DAMAGE ?	F
MODULE:	2	DAMAGE ?	F
MODULE:	3	DAMAGE ?	F
MODULE:	4	DAMAGE ?	F
MODULE:	5	DAMAGE ?	F
MODULE:	6	DAMAGE ?	F
MODULE:	7	DAMAGE ?	F
MODULE:	8	DAMAGE ?	F
MODULE:	9	DAMAGE ?	F
MODULE:	10	DAMAGE ?	F

MODULE:	1	BURNING?	F
MODULE:	2	BURNING?	F
MODULE:	3	BURNING?	F
MODULE:	4	BURNING?	F
MODULE:	5	BURNING?	F
MODULE:	6	BURNING?	F
MODULE:	7	BURNING?	F
MODULE:	8	BURNING?	F
MODULE:	9	BURNING?	F
MODULE:	10	BURNING?	T

MODULE:	1	SOURCE FLUX	.329E+04
MODULE:	2	SOURCE FLUX	291.
MODULE:	3	SOURCE FLUX	.0
MODULE:	4	SOURCE FLUX	.0
MODULE:	5	SOURCE FLUX	.0
MODULE:	6	SOURCE FLUX	.0
MODULE:	7	SOURCE FLUX	.0
MODULE:	8	SOURCE FLUX	.0
MODULE:	9	SOURCE FLUX	.0
MODULE:	10	SOURCE FLUX	.158E+06

MODULE:	1	EXTERNAL FLUX	.238E+04
MODULE:	2	EXTERNAL FLUX	526.
MODULE:	3	EXTERNAL FLUX	295.
MODULE:	4	EXTERNAL FLUX	308.
MODULE:	5	EXTERNAL FLUX	295.
MODULE:	6	EXTERNAL FLUX	282.
MODULE:	7	EXTERNAL FLUX	293.
MODULE:	8	EXTERNAL FLUX	282.
MODULE:	9	EXTERNAL FLUX	.177E+04
MODULE:	10	EXTERNAL FLUX	.161E+04

MODULE:	1	TOTAL FLUX	.897E+04
MODULE:	2	TOTAL FLUX	.777E+04
MODULE:	3	TOTAL FLUX	.762E+04
MODULE:	4	TOTAL FLUX	.762E+04
MODULE:	5	TOTAL FLUX	.762E+04
MODULE:	6	TOTAL FLUX	.761E+04
MODULE:	7	TOTAL FLUX	.762E+04
MODULE:	8	TOTAL FLUX	.761E+04
MODULE:	9	TOTAL FLUX	.442E+04
MODULE:	10	TOTAL FLUX	.432E+04

MODULE:	1	MEAS'D FLUX	.570E+04
MODULE:	2	MEAS'D FLUX	.450E+04
MODULE:	3	MEAS'D FLUX	.435E+04
MODULE:	4	MEAS'D FLUX	.435E+04
MODULE:	5	MEAS'D FLUX	.435E+04
MODULE:	6	MEAS'D FLUX	.434E+04
MODULE:	7	MEAS'D FLUX	.434E+04
MODULE:	8	MEAS'D FLUX	.434E+04
MODULE:	9	MEAS'D FLUX	.115E+04
MODULE:	10	MEAS'D FLUX	.105E+04

MODULE:	1	NET FLUX	.570E+04
MODULE:	2	NET FLUX	.450E+04
MODULE:	3	NET FLUX	.435E+04
MODULE:	4	NET FLUX	.435E+04
MODULE:	5	NET FLUX	.435E+04
MODULE:	6	NET FLUX	.434E+04
MODULE:	7	NET FLUX	.434E+04
MODULE:	8	NET FLUX	.434E+04
MODULE:	9	NET FLUX	.115E+04
MODULE:	10	NET FLUX	.105E+04

MODULE:	1	FUEL MASS	.150E+04
MODULE:	2	FUEL MASS	610.
MODULE:	3	FUEL MASS	2.25
MODULE:	4	FUEL MASS	2.25
MODULE:	5	FUEL MASS	2.25
MODULE:	6	FUEL MASS	2.25
MODULE:	7	FUEL MASS	2.25
MODULE:	8	FUEL MASS	2.25
MODULE:	9	FUEL MASS	2.25
MODULE:	10	FUEL MASS	12.9

MODULE:	1	FLAME HGT	.0
MODULE:	2	FLAME HGT	.0
MODULE:	3	FLAME HGT	.0
MODULE:	4	FLAME HGT	.0
MODULE:	5	FLAME HGT	.0
MODULE:	6	FLAME HGT	.0
MODULE:	7	FLAME HGT	.0
MODULE:	8	FLAME HGT	.0
MODULE:	9	FLAME HGT	.0
MODULE:	10	FLAME HGT	2.88

MODULE:	1	FLAME TEMP	.0
MODULE:	2	FLAME TEMP	.0
MODULE:	3	FLAME TEMP	.0
MODULE:	4	FLAME TEMP	.0
MODULE:	5	FLAME TEMP	.0
MODULE:	6	FLAME TEMP	.0
MODULE:	7	FLAME TEMP	.0
MODULE:	8	FLAME TEMP	.0
MODULE:	9	FLAME TEMP	.0
MODULE:	10	FLAME TEMP	.129E+04

MODULE:	1	FUEL TEMP	301.
MODULE:	2	FUEL TEMP	300.
MODULE:	3	FUEL TEMP	346.
MODULE:	4	FUEL TEMP	346.
MODULE:	5	FUEL TEMP	346.
MODULE:	6	FUEL TEMP	346.
MODULE:	7	FUEL TEMP	346.
MODULE:	8	FUEL TEMP	346.
MODULE:	9	FUEL TEMP	311.
MODULE:	10	FUEL TEMP	298.

MODULE:	1	HEAT TRANS COEF	10.0
MODULE:	2	HEAT TRANS COEF	10.0
MODULE:	3	HEAT TRANS COEF	10.0
MODULE:	4	HEAT TRANS COEF	10.0
MODULE:	5	HEAT TRANS COEF	10.0
MODULE:	6	HEAT TRANS COEF	10.0
MODULE:	7	HEAT TRANS COEF	10.0
MODULE:	8	HEAT TRANS COEF	10.0
MODULE:	9	HEAT TRANS COEF	10.0
MODULE:	10	HEAT TRANS COEF	10.0

MODULE:	1	ENVIRONMENT TEMP	504.
MODULE:	2	ENVIRONMENT TEMP	504.
MODULE:	3	ENVIRONMENT TEMP	504.
MODULE:	4	ENVIRONMENT TEMP	504.
MODULE:	5	ENVIRONMENT TEMP	504.
MODULE:	6	ENVIRONMENT TEMP	504.
MODULE:	7	ENVIRONMENT TEMP	504.
MODULE:	8	ENVIRONMENT TEMP	504.
MODULE:	9	ENVIRONMENT TEMP	298.
MODULE:	10	ENVIRONMENT TEMP	298.

***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****
TIME (SEC): 120.

TOTAL MASS BURNING RATE (KG/S):	.2893E-01
TOTAL HEAT RELEASE RATE (W) :	.1190E+07
HOT GAS LAYER TEMPERATURE (K) :	504.6
HOT GAS LAYER THICKNESS (M) :	1.446

MODULE:	1	DAMAGE ?	F
MODULE:	2	DAMAGE ?	F
MODULE:	3	DAMAGE ?	F
MODULE:	4	DAMAGE ?	F
MODULE:	5	DAMAGE ?	F
MODULE:	6	DAMAGE ?	F
MODULE:	7	DAMAGE ?	F
MODULE:	8	DAMAGE ?	F
MODULE:	9	DAMAGE ?	F
MODULE:	10	DAMAGE ?	F

MODULE:	1	BURNING?	F
MODULE:	2	BURNING?	F
MODULE:	3	BURNING?	F
MODULE:	4	BURNING?	F
MODULE:	5	BURNING?	F
MODULE:	6	BURNING?	F
MODULE:	7	BURNING?	F
MODULE:	8	BURNING?	F
MODULE:	9	BURNING?	F
MODULE:	10	BURNING?	T

MODULE:	1	SOURCE FLUX	.333E+04
MODULE:	2	SOURCE FLUX	483.
MODULE:	3	SOURCE FLUX	.0
MODULE:	4	SOURCE FLUX	.0
MODULE:	5	SOURCE FLUX	.0
MODULE:	6	SOURCE FLUX	.0
MODULE:	7	SOURCE FLUX	.0
MODULE:	8	SOURCE FLUX	.0
MODULE:	9	SOURCE FLUX	.0
MODULE:	10	SOURCE FLUX	.158E+06

MODULE:	1	EXTERNAL FLUX	.239E+04
MODULE:	2	EXTERNAL FLUX	526.
MODULE:	3	EXTERNAL FLUX	386.
MODULE:	4	EXTERNAL FLUX	403.
MODULE:	5	EXTERNAL FLUX	386.
MODULE:	6	EXTERNAL FLUX	383.
MODULE:	7	EXTERNAL FLUX	399.
MODULE:	8	EXTERNAL FLUX	383.
MODULE:	9	EXTERNAL FLUX	.190E+04
MODULE:	10	EXTERNAL FLUX	.163E+04

MODULE:	1	TOTAL FLUX	.899E+04
MODULE:	2	TOTAL FLUX	.778E+04
MODULE:	3	TOTAL FLUX	.769E+04
MODULE:	4	TOTAL FLUX	.770E+04
MODULE:	5	TOTAL FLUX	.769E+04
MODULE:	6	TOTAL FLUX	.768E+04
MODULE:	7	TOTAL FLUX	.770E+04
MODULE:	8	TOTAL FLUX	.768E+04
MODULE:	9	TOTAL FLUX	.451E+04
MODULE:	10	TOTAL FLUX	.433E+04

MODULE:	1	MEAS'D FLUX	.572E+04
MODULE:	2	MEAS'D FLUX	.451E+04
MODULE:	3	MEAS'D FLUX	.442E+04
MODULE:	4	MEAS'D FLUX	.443E+04
MODULE:	5	MEAS'D FLUX	.442E+04
MODULE:	6	MEAS'D FLUX	.441E+04
MODULE:	7	MEAS'D FLUX	.442E+04
MODULE:	8	MEAS'D FLUX	.441E+04
MODULE:	9	MEAS'D FLUX	.123E+04
MODULE:	10	MEAS'D FLUX	.106E+04

MODULE:	1	NET FLUX	.568E+04
MODULE:	2	NET FLUX	.448E+04
MODULE:	3	NET FLUX	.370E+04
MODULE:	4	NET FLUX	.370E+04
MODULE:	5	NET FLUX	.370E+04
MODULE:	6	NET FLUX	.370E+04
MODULE:	7	NET FLUX	.370E+04
MODULE:	8	NET FLUX	.370E+04
MODULE:	9	NET FLUX	.105E+04
MODULE:	10	NET FLUX	.106E+04

MODULE:	1	FUEL MASS	.150E+04
MODULE:	2	FUEL MASS	610.
MODULE:	3	FUEL MASS	2.25
MODULE:	4	FUEL MASS	2.25
MODULE:	5	FUEL MASS	2.25
MODULE:	6	FUEL MASS	2.25
MODULE:	7	FUEL MASS	2.25
MODULE:	8	FUEL MASS	2.25
MODULE:	9	FUEL MASS	2.25
MODULE:	10	FUEL MASS	12.9
MODULE:	1	FLAME HGT	.0
MODULE:	2	FLAME HGT	.0
MODULE:	3	FLAME HGT	.0
MODULE:	4	FLAME HGT	.0
MODULE:	5	FLAME HGT	.0
MODULE:	6	FLAME HGT	.0
MODULE:	7	FLAME HGT	.0
MODULE:	8	FLAME HGT	.0
MODULE:	9	FLAME HGT	.0
MODULE:	10	FLAME HGT	2.88
MODULE:	1	FLAME TEMP	.0
MODULE:	2	FLAME TEMP	.0
MODULE:	3	FLAME TEMP	.0
MODULE:	4	FLAME TEMP	.0
MODULE:	5	FLAME TEMP	.0
MODULE:	6	FLAME TEMP	.0
MODULE:	7	FLAME TEMP	.0
MODULE:	8	FLAME TEMP	.0
MODULE:	9	FLAME TEMP	.0
MODULE:	10	FLAME TEMP	.129E+04
MODULE:	1	FUEL TEMP	306.
MODULE:	2	FUEL TEMP	304.
MODULE:	3	FUEL TEMP	388.
MODULE:	4	FUEL TEMP	389.
MODULE:	5	FUEL TEMP	388.
MODULE:	6	FUEL TEMP	388.
MODULE:	7	FUEL TEMP	389.
MODULE:	8	FUEL TEMP	388.
MODULE:	9	FUEL TEMP	323.
MODULE:	10	FUEL TEMP	298.

MODULE:	1	HEAT TRANS COEF	10.0
MODULE:	2	HEAT TRANS COEF	10.0
MODULE:	3	HEAT TRANS COEF	10.0
MODULE:	4	HEAT TRANS COEF	10.0
MODULE:	5	HEAT TRANS COEF	10.0
MODULE:	6	HEAT TRANS COEF	10.0
MODULE:	7	HEAT TRANS COEF	10.0
MODULE:	8	HEAT TRANS COEF	10.0
MODULE:	9	HEAT TRANS COEF	10.0
MODULE:	10	HEAT TRANS COEF	10.0

MODULE:	1	ENVIRONMENT TEMP	505.
MODULE:	2	ENVIRONMENT TEMP	505.
MODULE:	3	ENVIRONMENT TEMP	505.
MODULE:	4	ENVIRONMENT TEMP	505.
MODULE:	5	ENVIRONMENT TEMP	505.
MODULE:	6	ENVIRONMENT TEMP	505.
MODULE:	7	ENVIRONMENT TEMP	505.
MODULE:	8	ENVIRONMENT TEMP	505.
MODULE:	9	ENVIRONMENT TEMP	298.
MODULE:	10	ENVIRONMENT TEMP	298.

```
***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****
TIME (SEC):  180.

TOTAL MASS BURNING RATE (KG/S):   .2893E-01
TOTAL HEAT RELEASE RATE (W)   :   .1190E+07
HOT GAS LAYER TEMPERATURE (K) :   505.4
HOT GAS LAYER THICKNESS (M)   :   1.445

MODULE:   1   DAMAGE ?            F
MODULE:   2   DAMAGE ?            F
MODULE:   3   DAMAGE ?            F
MODULE:   4   DAMAGE ?            F
MODULE:   5   DAMAGE ?            F
MODULE:   6   DAMAGE ?            F
MODULE:   7   DAMAGE ?            F
MODULE:   8   DAMAGE ?            F
MODULE:   9   DAMAGE ?            F
MODULE:  10   DAMAGE ?            F

MODULE:   1   BURNING?            F
MODULE:   2   BURNING?            F
MODULE:   3   BURNING?            F
MODULE:   4   BURNING?            F
MODULE:   5   BURNING?            F
MODULE:   6   BURNING?            F
MODULE:   7   BURNING?            F
MODULE:   8   BURNING?            F
MODULE:   9   BURNING?            F
MODULE:  10   BURNING?            T

MODULE:   1   SOURCE FLUX      .335E+04
MODULE:   2   SOURCE FLUX      500.
MODULE:   3   SOURCE FLUX      .0
MODULE:   4   SOURCE FLUX      .0
MODULE:   5   SOURCE FLUX      .0
MODULE:   6   SOURCE FLUX      .0
MODULE:   7   SOURCE FLUX      .0
MODULE:   8   SOURCE FLUX      .0
MODULE:   9   SOURCE FLUX      .0
MODULE:  10   SOURCE FLUX      .158E+06
```

MODULE:	1	EXTERNAL FLUX	.239E+04
MODULE:	2	EXTERNAL FLUX	526.
MODULE:	3	EXTERNAL FLUX	394.
MODULE:	4	EXTERNAL FLUX	411.
MODULE:	5	EXTERNAL FLUX	394.
MODULE:	6	EXTERNAL FLUX	392.
MODULE:	7	EXTERNAL FLUX	409.
MODULE:	8	EXTERNAL FLUX	392.
MODULE:	9	EXTERNAL FLUX	.192E+04
MODULE:	10	EXTERNAL FLUX	.165E+04
MODULE:	1	TOTAL FLUX	.901E+04
MODULE:	2	TOTAL FLUX	.780E+04
MODULE:	3	TOTAL FLUX	.771E+04
MODULE:	4	TOTAL FLUX	.773E+04
MODULE:	5	TOTAL FLUX	.771E+04
MODULE:	6	TOTAL FLUX	.771E+04
MODULE:	7	TOTAL FLUX	.772E+04
MODULE:	8	TOTAL FLUX	.771E+04
MODULE:	9	TOTAL FLUX	.452E+04
MODULE:	10	TOTAL FLUX	.434E+04
MODULE:	1	MEAS'D FLUX	.574E+04
MODULE:	2	MEAS'D FLUX	.453E+04
MODULE:	3	MEAS'D FLUX	.444E+04
MODULE:	4	MEAS'D FLUX	.446E+04
MODULE:	5	MEAS'D FLUX	.444E+04
MODULE:	6	MEAS'D FLUX	.444E+04
MODULE:	7	MEAS'D FLUX	.445E+04
MODULE:	8	MEAS'D FLUX	.444E+04
MODULE:	9	MEAS'D FLUX	.125E+04
MODULE:	10	MEAS'D FLUX	.107E+04
MODULE:	1	NET FLUX	.563E+04
MODULE:	2	NET FLUX	.444E+04
MODULE:	3	NET FLUX	.299E+04
MODULE:	4	NET FLUX	.300E+04
MODULE:	5	NET FLUX	.299E+04
MODULE:	6	NET FLUX	.299E+04
MODULE:	7	NET FLUX	.300E+04
MODULE:	8	NET FLUX	.299E+04
MODULE:	9	NET FLUX	885.
MODULE:	10	NET FLUX	.107E+04

MODULE:	1	FUEL MASS	.150E+04
MODULE:	2	FUEL MASS	610.
MODULE:	3	FUEL MASS	2.25
MODULE:	4	FUEL MASS	2.25
MODULE:	5	FUEL MASS	2.25
MODULE:	6	FUEL MASS	2.25
MODULE:	7	FUEL MASS	2.25
MODULE:	8	FUEL MASS	2.25
MODULE:	9	FUEL MASS	2.25
MODULE:	10	FUEL MASS	12.9

MODULE:	1	FLAME HGT	.0
MODULE:	2	FLAME HGT	.0
MODULE:	3	FLAME HGT	.0
MODULE:	4	FLAME HGT	.0
MODULE:	5	FLAME HGT	.0
MODULE:	6	FLAME HGT	.0
MODULE:	7	FLAME HGT	.0
MODULE:	8	FLAME HGT	.0
MODULE:	9	FLAME HGT	.0
MODULE:	10	FLAME HGT	2.88

MODULE:	1	FLAME TEMP	.0
MODULE:	2	FLAME TEMP	.0
MODULE:	3	FLAME TEMP	.0
MODULE:	4	FLAME TEMP	.0
MODULE:	5	FLAME TEMP	.0
MODULE:	6	FLAME TEMP	.0
MODULE:	7	FLAME TEMP	.0
MODULE:	8	FLAME TEMP	.0
MODULE:	9	FLAME TEMP	.0
MODULE:	10	FLAME TEMP	.129E+04

MODULE:	1	FUEL TEMP	311.
MODULE:	2	FUEL TEMP	308.
MODULE:	3	FUEL TEMP	400.
MODULE:	4	FUEL TEMP	400.
MODULE:	5	FUEL TEMP	400.
MODULE:	6	FUEL TEMP	399.
MODULE:	7	FUEL TEMP	400.
MODULE:	8	FUEL TEMP	399.
MODULE:	9	FUEL TEMP	327.
MODULE:	10	FUEL TEMP	298.

MODULE:	1	HEAT TRANS COEF	10.0
MODULE:	2	HEAT TRANS COEF	10.0
MODULE:	3	HEAT TRANS COEF	10.0
MODULE:	4	HEAT TRANS COEF	10.0
MODULE:	5	HEAT TRANS COEF	10.0
MODULE:	6	HEAT TRANS COEF	10.0
MODULE:	7	HEAT TRANS COEF	10.0
MODULE:	8	HEAT TRANS COEF	10.0
MODULE:	9	HEAT TRANS COEF	10.0
MODULE:	10	HEAT TRANS COEF	10.0

MODULE:	1	ENVIRONMENT TEMP	505.
MODULE:	2	ENVIRONMENT TEMP	505.
MODULE:	3	ENVIRONMENT TEMP	505.
MODULE:	4	ENVIRONMENT TEMP	505.
MODULE:	5	ENVIRONMENT TEMP	505.
MODULE:	6	ENVIRONMENT TEMP	505.
MODULE:	7	ENVIRONMENT TEMP	505.
MODULE:	8	ENVIRONMENT TEMP	505.
MODULE:	9	ENVIRONMENT TEMP	298.
MODULE:	10	ENVIRONMENT TEMP	298.

***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****
TIME (SEC): 240.

TOTAL MASS BURNING RATE (KG/S):	.2893E-01
TOTAL HEAT RELEASE RATE (W) :	.1190E+07
HOT GAS LAYER TEMPERATURE (K) :	506.2
HOT GAS LAYER THICKNESS (M) :	1.445

MODULE:	1	DAMAGE ?	F
MODULE:	2	DAMAGE ?	F
MODULE:	3	DAMAGE ?	F
MODULE:	4	DAMAGE ?	F
MODULE:	5	DAMAGE ?	F
MODULE:	6	DAMAGE ?	F
MODULE:	7	DAMAGE ?	F
MODULE:	8	DAMAGE ?	F
MODULE:	9	DAMAGE ?	F
MODULE:	10	DAMAGE ?	F

MODULE:	1	BURNING?	F
MODULE:	2	BURNING?	F
MODULE:	3	BURNING?	F
MODULE:	4	BURNING?	F
MODULE:	5	BURNING?	F
MODULE:	6	BURNING?	F
MODULE:	7	BURNING?	F
MODULE:	8	BURNING?	F
MODULE:	9	BURNING?	F
MODULE:	10	BURNING?	T

MODULE:	1	SOURCE FLUX	.337E+04
MODULE:	2	SOURCE FLUX	518.
MODULE:	3	SOURCE FLUX	.0
MODULE:	4	SOURCE FLUX	.0
MODULE:	5	SOURCE FLUX	.0
MODULE:	6	SOURCE FLUX	.0
MODULE:	7	SOURCE FLUX	.0
MODULE:	8	SOURCE FLUX	.0
MODULE:	9	SOURCE FLUX	.0
MODULE:	10	SOURCE FLUX	.158E+06

MODULE:	1	EXTERNAL FLUX	.239E+04
MODULE:	2	EXTERNAL FLUX	526.
MODULE:	3	EXTERNAL FLUX	402.
MODULE:	4	EXTERNAL FLUX	420.
MODULE:	5	EXTERNAL FLUX	402.
MODULE:	6	EXTERNAL FLUX	401.
MODULE:	7	EXTERNAL FLUX	418.
MODULE:	8	EXTERNAL FLUX	401.
MODULE:	9	EXTERNAL FLUX	.194E+04
MODULE:	10	EXTERNAL FLUX	.166E+04

MODULE:	1	TOTAL FLUX	.904E+04
MODULE:	2	TOTAL FLUX	.782E+04
MODULE:	3	TOTAL FLUX	.774E+04
MODULE:	4	TOTAL FLUX	.775E+04
MODULE:	5	TOTAL FLUX	.774E+04
MODULE:	6	TOTAL FLUX	.774E+04
MODULE:	7	TOTAL FLUX	.775E+04
MODULE:	8	TOTAL FLUX	.774E+04
MODULE:	9	TOTAL FLUX	.453E+04
MODULE:	10	TOTAL FLUX	.435E+04

MODULE:	1	MEAS'D FLUX	.577E+04
MODULE:	2	MEAS'D FLUX	.455E+04
MODULE:	3	MEAS'D FLUX	.447E+04
MODULE:	4	MEAS'D FLUX	.448E+04
MODULE:	5	MEAS'D FLUX	.447E+04
MODULE:	6	MEAS'D FLUX	.447E+04
MODULE:	7	MEAS'D FLUX	.448E+04
MODULE:	8	MEAS'D FLUX	.447E+04
MODULE:	9	MEAS'D FLUX	.126E+04
MODULE:	10	MEAS'D FLUX	.108E+04

MODULE:	1	NET FLUX	.558E+04
MODULE:	2	NET FLUX	.441E+04
MODULE:	3	NET FLUX	.281E+04
MODULE:	4	NET FLUX	.281E+04
MODULE:	5	NET FLUX	.281E+04
MODULE:	6	NET FLUX	.281E+04
MODULE:	7	NET FLUX	.282E+04
MODULE:	8	NET FLUX	.281E+04
MODULE:	9	NET FLUX	837.
MODULE:	10	NET FLUX	.108E+04

MODULE:	1	FUEL MASS	.150E+04
MODULE:	2	FUEL MASS	610.
MODULE:	3	FUEL MASS	2.25
MODULE:	4	FUEL MASS	2.25
MODULE:	5	FUEL MASS	2.25
MODULE:	6	FUEL MASS	2.25
MODULE:	7	FUEL MASS	2.25
MODULE:	8	FUEL MASS	2.25
MODULE:	9	FUEL MASS	2.25
MODULE:	10	FUEL MASS	12.9

MODULE:	1	FLAME HGT	.0
MODULE:	2	FLAME HGT	.0
MODULE:	3	FLAME HGT	.0
MODULE:	4	FLAME HGT	.0
MODULE:	5	FLAME HGT	.0
MODULE:	6	FLAME HGT	.0
MODULE:	7	FLAME HGT	.0
MODULE:	8	FLAME HGT	.0
MODULE:	9	FLAME HGT	.0
MODULE:	10	FLAME HGT	2.88

MODULE:	1	FLAME TEMP	.0
MODULE:	2	FLAME TEMP	.0
MODULE:	3	FLAME TEMP	.0
MODULE:	4	FLAME TEMP	.0
MODULE:	5	FLAME TEMP	.0
MODULE:	6	FLAME TEMP	.0
MODULE:	7	FLAME TEMP	.0
MODULE:	8	FLAME TEMP	.0
MODULE:	9	FLAME TEMP	.0
MODULE:	10	FLAME TEMP	.129E+04

MODULE:	1	FUEL TEMP	316.
MODULE:	2	FUEL TEMP	312.
MODULE:	3	FUEL TEMP	414.
MODULE:	4	FUEL TEMP	415.
MODULE:	5	FUEL TEMP	414.
MODULE:	6	FUEL TEMP	414.
MODULE:	7	FUEL TEMP	415.
MODULE:	8	FUEL TEMP	414.
MODULE:	9	FUEL TEMP	332.
MODULE:	10	FUEL TEMP	298.

MODULE:	1	HEAT TRANS COEF	10.0
MODULE:	2	HEAT TRANS COEF	10.0
MODULE:	3	HEAT TRANS COEF	10.0
MODULE:	4	HEAT TRANS COEF	10.0
MODULE:	5	HEAT TRANS COEF	10.0
MODULE:	6	HEAT TRANS COEF	10.0
MODULE:	7	HEAT TRANS COEF	10.0
MODULE:	8	HEAT TRANS COEF	10.0
MODULE:	9	HEAT TRANS COEF	10.0
MODULE:	10	HEAT TRANS COEF	10.0

MODULE:	1	ENVIRONMENT TEMP	506.
MODULE:	2	ENVIRONMENT TEMP	506.
MODULE:	3	ENVIRONMENT TEMP	506.
MODULE:	4	ENVIRONMENT TEMP	506.
MODULE:	5	ENVIRONMENT TEMP	506.
MODULE:	6	ENVIRONMENT TEMP	506.
MODULE:	7	ENVIRONMENT TEMP	506.
MODULE:	8	ENVIRONMENT TEMP	506.
MODULE:	9	ENVIRONMENT TEMP	298.
MODULE:	10	ENVIRONMENT TEMP	298.

***** TEST CASE: SNL CABLE TRAY EXPERIMENT #1 (EFF=0.8) COMP3 *****
TIME (SEC): 300.

TOTAL MASS BURNING RATE (KG/S):	.2893E-01
TOTAL HEAT RELEASE RATE (W) :	.1190E+07
HOT GAS LAYER TEMPERATURE (K) :	506.9
HOT GAS LAYER THICKNESS (M) :	1.445

MODULE:	1	DAMAGE ?	F
MODULE:	2	DAMAGE ?	F
MODULE:	3	DAMAGE ?	F
MODULE:	4	DAMAGE ?	F
MODULE:	5	DAMAGE ?	F
MODULE:	6	DAMAGE ?	F
MODULE:	7	DAMAGE ?	F
MODULE:	8	DAMAGE ?	F
MODULE:	9	DAMAGE ?	F
MODULE:	10	DAMAGE ?	F

MODULE:	1	BURNING?	F
MODULE:	2	BURNING?	F
MODULE:	3	BURNING?	F
MODULE:	4	BURNING?	F
MODULE:	5	BURNING?	F
MODULE:	6	BURNING?	F
MODULE:	7	BURNING?	F
MODULE:	8	BURNING?	F
MODULE:	9	BURNING?	F
MODULE:	10	BURNING?	T

MODULE:	1	SOURCE FLUX	.340E+04
MODULE:	2	SOURCE FLUX	535.
MODULE:	3	SOURCE FLUX	.0
MODULE:	4	SOURCE FLUX	.0
MODULE:	5	SOURCE FLUX	.0
MODULE:	6	SOURCE FLUX	.0
MODULE:	7	SOURCE FLUX	.0
MODULE:	8	SOURCE FLUX	.0
MODULE:	9	SOURCE FLUX	.0
MODULE:	10	SOURCE FLUX	.158E+06

MODULE:	1	EXTERNAL FLUX	.239E+04
MODULE:	2	EXTERNAL FLUX	526.
MODULE:	3	EXTERNAL FLUX	410.
MODULE:	4	EXTERNAL FLUX	428.
MODULE:	5	EXTERNAL FLUX	410.
MODULE:	6	EXTERNAL FLUX	411.
MODULE:	7	EXTERNAL FLUX	428.
MODULE:	8	EXTERNAL FLUX	411.
MODULE:	9	EXTERNAL FLUX	.196E+04
MODULE:	10	EXTERNAL FLUX	.167E+04

MODULE:	1	TOTAL FLUX	.906E+04
MODULE:	2	TOTAL FLUX	.784E+04
MODULE:	3	TOTAL FLUX	.777E+04
MODULE:	4	TOTAL FLUX	.778E+04
MODULE:	5	TOTAL FLUX	.777E+04
MODULE:	6	TOTAL FLUX	.777E+04
MODULE:	7	TOTAL FLUX	.778E+04
MODULE:	8	TOTAL FLUX	.777E+04
MODULE:	9	TOTAL FLUX	.455E+04
MODULE:	10	TOTAL FLUX	.436E+04

MODULE:	1	MEAS'D FLUX	.579E+04
MODULE:	2	MEAS'D FLUX	.457E+04
MODULE:	3	MEAS'D FLUX	.450E+04
MODULE:	4	MEAS'D FLUX	.451E+04
MODULE:	5	MEAS'D FLUX	.450E+04
MODULE:	6	MEAS'D FLUX	.450E+04
MODULE:	7	MEAS'D FLUX	.451E+04
MODULE:	8	MEAS'D FLUX	.450E+04
MODULE:	9	MEAS'D FLUX	.128E+04
MODULE:	10	MEAS'D FLUX	.108E+04

MODULE:	1	NET FLUX	.553E+04
MODULE:	2	NET FLUX	.437E+04
MODULE:	3	NET FLUX	.254E+04
MODULE:	4	NET FLUX	.254E+04
MODULE:	5	NET FLUX	.254E+04
MODULE:	6	NET FLUX	.254E+04
MODULE:	7	NET FLUX	.254E+04
MODULE:	8	NET FLUX	.254E+04
MODULE:	9	NET FLUX	779.
MODULE:	10	NET FLUX	.108E+04

MODULE:	1	FUEL MASS	.150E+04
MODULE:	2	FUEL MASS	610.
MODULE:	3	FUEL MASS	2.25
MODULE:	4	FUEL MASS	2.25
MODULE:	5	FUEL MASS	2.25
MODULE:	6	FUEL MASS	2.25
MODULE:	7	FUEL MASS	2.25
MODULE:	8	FUEL MASS	2.25
MODULE:	9	FUEL MASS	2.25
MODULE:	10	FUEL MASS	12.9

MODULE:	1	FLAME HGT	.0
MODULE:	2	FLAME HGT	.0
MODULE:	3	FLAME HGT	.0
MODULE:	4	FLAME HGT	.0
MODULE:	5	FLAME HGT	.0
MODULE:	6	FLAME HGT	.0
MODULE:	7	FLAME HGT	.0
MODULE:	8	FLAME HGT	.0
MODULE:	9	FLAME HGT	.0
MODULE:	10	FLAME HGT	2.88

MODULE:	1	FLAME TEMP	.0
MODULE:	2	FLAME TEMP	.0
MODULE:	3	FLAME TEMP	.0
MODULE:	4	FLAME TEMP	.0
MODULE:	5	FLAME TEMP	.0
MODULE:	6	FLAME TEMP	.0
MODULE:	7	FLAME TEMP	.0
MODULE:	8	FLAME TEMP	.0
MODULE:	9	FLAME TEMP	.0
MODULE:	10	FLAME TEMP	.129E+04

MODULE:	1	FUEL TEMP	321.
MODULE:	2	FUEL TEMP	316.
MODULE:	3	FUEL TEMP	421.
MODULE:	4	FUEL TEMP	421.
MODULE:	5	FUEL TEMP	421.
MODULE:	6	FUEL TEMP	421.
MODULE:	7	FUEL TEMP	421.
MODULE:	8	FUEL TEMP	421.
MODULE:	9	FUEL TEMP	335.
MODULE:	10	FUEL TEMP	298.

MODULE:	1	HEAT TRANS COEF	10.0
MODULE:	2	HEAT TRANS COEF	10.0
MODULE:	3	HEAT TRANS COEF	10.0
MODULE:	4	HEAT TRANS COEF	10.0
MODULE:	5	HEAT TRANS COEF	10.0
MODULE:	6	HEAT TRANS COEF	10.0
MODULE:	7	HEAT TRANS COEF	10.0
MODULE:	8	HEAT TRANS COEF	10.0
MODULE:	9	HEAT TRANS COEF	10.0
MODULE:	10	HEAT TRANS COEF	10.0

MODULE:	1	ENVIRONMENT TEMP	507.
MODULE:	2	ENVIRONMENT TEMP	507.
MODULE:	3	ENVIRONMENT TEMP	507.
MODULE:	4	ENVIRONMENT TEMP	507.
MODULE:	5	ENVIRONMENT TEMP	507.
MODULE:	6	ENVIRONMENT TEMP	507.
MODULE:	7	ENVIRONMENT TEMP	507.
MODULE:	8	ENVIRONMENT TEMP	507.
MODULE:	9	ENVIRONMENT TEMP	298.
MODULE:	10	ENVIRONMENT TEMP	298.

Appendix B

CODE LISTING

```
C***********************************************************************
C                                                                      *
C   COMPBRN III - REVISED COMPUTER CODE FOR MODELING THE BEHAVIOR      *
C                 OF COMPARTMENT FIRES                                 *
C                                                                      *
C   AUTHORS     - VINCENT HO AND NATHAN SIU                            *
C                                                                      *
C***********************************************************************
C                                                                      *
C   MAIN PROGRAM (READS INPUT DATA, CALLS SUBROUTINES)                 *
C                                                                      *
C***********************************************************************
      IMPLICIT LOGICAL (L)
      DOUBLE PRECISION XNAME
C
C   FUEL CELL ARRAYS: DIMENSION=(IDIM1 X IDIM2)
C
      DIMENSION BRAT(30,5), FLHT(30,5), FLTEMP(30,5), FMASS(30,5),
     1          FX(30,5), FY(30,5), FZ(30,5), GAMN(30,5), HCOEF(30,5),
     2          HCOEFO(30,5), Q(30,5), QDOTC(30,5), QDOT2P(30,5),
     3          QEXCAL(30,5), QEXNET(30,5), QEXT(30,5), QEXTOT(30,5),
     4          QEXTO(30,5), TSURR(30,5), TSURRO(30,5), TEMP(30,5,10),
     5          ICOUNT(30,5), LBURN(30,5), LDAMGE(30,5), LFMASS(30,5),
     6          LPIGN(30,5), LPLUME(30,5), LSTRTO(30,5), LTOP(30,5)
C
C   SUPER-MODULE VECTORS: DIMENSION=(IDIM1)
C
      DIMENSION AREA(30), DELS(30), DEP(30), FLNG(30), FLOSS(30),
     1          FMASSO(30), RAD(30), POR(30), WID(30),
     2          IDIR(30), IORT(30), ITYP(30), MSMOUT(30), NFC(30),
     3          LB(30), LC(30), LD(30), LW(30)
C
C   FUEL TYPE VECTORS: DIMENSION=(IDIM6)
C
      DIMENSION BRATSO(5), BRATS1(5), BRATV(5), DENS(5), DIFF(5),
     1          EFF(5), FABSRP(5), FIGTP(5), FIGTS(5), GAMMA(5),
     2          HEAT(5), FTDAM(5),SPHT(5), REFL(5), THK(5),
     3          IFUEL(5),
     4          LBF(5), LCF(5), LDF(5), LWF(5)
C
C   PILOT FIRE VECTORS: DIMENSION=(IDIM7)
C
      DIMENSION PBRATV(10), PBRTSO(10), PBRTS1(10), PEFF(10),
     1          PHEAT(10), PMASS(10), PMDOTS(10),
     2          IPIL(10), IPFUEL(10), JPIL(10),
     3          LPMASS(10)
C
C   COMMUNICATION ARRAYS AND VECTORS:
C
C           ICOMM DIMENSION=(IDIM1*IDIM2 X IDIM1*IDIM2)
C           IAD DIMENSION=(IDIM4 X 4)
C           NAD DIMENSION=(IDIM5 X 4)
C
      DIMENSION IV(4), NV(4), ICOMM(150,150), IAD(30,4), NAD(200,4)
```

```
C
C   MISCELLANEOUS VECTORS
C
      DIMENSION XNAME(12)
C
C   NAMELIST DESIGNATIONS
C
      NAMELIST /STRT/ NJOB,NTIME, NREAD, NWRITE, DELT
      NAMELIST /SIZE/ NSM, NCOM, NFUEL, NNCOM, NPILOT, IROOM, INITG
      NAMELIST /FUELB/ SMX, SMY, SMZ, SLNG, SWID, SDEP, SMASS, SPOR,
     1         SLOSS, NFCL, IORNT, IDIREC, IFTYP
      NAMELIST /PILOT/ IPIL, JPIL, IPFUEL, PMASS
      NAMELIST /FUELT/ IFUEL, DENS, SPHT, THK, HEAT, EFF, FIGTP, FTDAM,
     1         FIGTS, BRATV, BRATS0, BRATS1, GAMMA, FABSRP, REFL
      NAMELIST /SEE/ IV
      NAMELIST /NSEE/ NV
      NAMELIST /MISC/ RTEMP, FLCF, HROOM, CALTEM
C
C  OLD VERSION:
C     NAMELIST /ROOM/ DWID, DHGT, DCF, FC, FH, GABSRP, HCEIL, PLCF1,
C    1                PLCF2, THETA, VFV
C
C  NEW VERSION:
C
      NAMELIST /ROOM/ DCFIN, DCFOUT, DHGT, DWID, FC, FH, GABSRP,
     1                HCEIL, PLCF, VFV
      NAMELIST /GINIT/ TG, DG, QEXT
      NAMELIST /MODVAR/ FCTR
      NAMELIST /OUTF/ INCHCK, IOUTPT, MOUTPT, NSMOUT, MSMOUT
C
C   COMMON STATEMENTS
C
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
C
C   DATA STATEMENTS
C
      DATA IDIM1/30/, IDIM2/5/, IDIM3/150/, IDIM4/30/, IDIM5/200/,
     1     IDIM6/5/, IDIM7/10/, IDIM8/17/, NREAD/5/, NWRITE/6/
      DATA XNAME/8H$STRT    ,8H$SIZE    ,8H$FUELB  ,8H$PILOT   ,
     1          8H$FUELT   ,8H$SEE     ,8H$NSEE   ,8H$MISC    ,
     2          8H$ROOM    ,8H$GINIT   ,8H$MODVAR ,8H$OUTF    /
C
C   BEGIN DATA INPUT
C
      LINERR = .FALSE.
      READ (NREAD,STRT)
C   ERROR CHECKING AND DEFAULT SETTINGS FOR NAMELIST STRT
```

```
      IF ((NJOB*NTIME*NREAD*NWRITE).GT.0) GO TO 100
      WRITE (NWRITE,9501) XNAME(1)
      NJOB = MAX0(1,NJOB)
      NTIME = MAX0(1,NTIME)
      IF (NREAD.LE.0) NREAD = 5
      IF (NWRITE.LE.0) NWRITE = 6
  100 IF (DELT.GT.0.) GO TO 200
      LINERR = .TRUE.
      WRITE (NWRITE,9502) XNAME(1)
C
C   IF (NJOB.LE.0) NJOB = 1
  200 DO 8000 IJOB=1,NJOB
C
C   JOB-SPECIFIC INPUT DATA
C
      READ (NREAD,SIZE)
C   ERROR CHECKING FOR NAMELIST SIZE
      IF ((NSM*NFUEL*NPILOT).GT.0) GO TO 300
      LINERR = .TRUE.
      WRITE (NWRITE,9503) XNAME(2), IJOB
  300 IF (NSM.LE.IDIM1) GO TO 310
      LINERR = .TRUE.
      WRITE (NWRITE,9504) XNAME(2), IJOB, IDIM1
  310 IF (NFUEL.LE.IDIM6) GO TO 320
      LINERR = .TRUE.
      WRITE (NWRITE,9505) XNAME(2), IJOB, IDIM6
  320 IF (NPILOT.LE.IDIM7) GO TO 330
      LINERR = .TRUE.
      WRITE (NWRITE,9506) XNAME(2), IJOB, IDIM7
  330 IF (NCOM.LE.IDIM4) GO TO 340
      LINERR = .TRUE.
      WRITE (NWRITE,9507) XNAME(2), IJOB, IDIM4
  340 IF (NNCOM.LE.IDIM5) GO TO 350
      LINERR = .TRUE.
      WRITE (NWRITE,9508) XNAME(2), IJOB, IDIM5
C
  350 READ (NREAD,9100) TITLE
C
C   READ FUEL BED CHARACTERISTICS
C
      DO 1000 I=1,NSM
      READ (NREAD,FUELB)
C   ERROR CHECKING FOR NAMELIST FUELB
      IF ((NFCL*IORNT*IDIREC*IFTYP).GT.0) GO TO 400
      LINERR = .TRUE.
      WRITE (NWRITE,9509) XNAME(3), IJOB, I
  400 IF (NFCL.LE.IDIM2) GO TO 410
      LINERR = .TRUE.
      WRITE (NWRITE,9510) XNAME(3), IJOB, I, IDIM2
  410 IF (IORNT.LE.3) GO TO 420
      LINERR = .TRUE.
      WRITE (NWRITE,9511) XNAME(3), IJOB, I
  420 IF (IDIREC.LE.3) GO TO 430
      LINERR = .TRUE.
```

```
      WRITE (NWRITE,9512) XNAME(3), IJOB, I
  430 IF (IFTYP.LE.NFUEL) GO TO 440
      LINERR = .TRUE.
      WRITE (NWRITE,9513) XNAME(3), IJOB, I, NFUEL
  440 IF (IORNT.NE.IDIREC) GO TO 450
      WRITE (NWRITE,9514) XNAME(3), IJOB, I
  450 IF ((SLNG*SWID*SDEP*SMASS*SPOR).GT.0.) GO TO 460
      LINERR = .TRUE.
      WRITE (NWRITE,9515) XNAME(3), IJOB, I
C
  460 XNFCL = FLOAT(NFCL)
      DELS(I) = SLNG/XNFCL
      AREA(I) = DELS(I)*SWID
      RAD(I) = SQRT(AREA(I)/3.14159)
C
C   CORRECTION TO COMPUTATION OF FUEL CELL RADIUS
C
C   OLD VERSION:
C     IF (IORNT.EQ.3) RAD(I) = SWID/2.
C
C   NEW VERSION:
C
      IF (IORNT.NE.3) RAD(I) = SWID/2.
C
      FMASSO(I) = SMASS/XNFCL
      WID(I) = SWID
      POR(I) = SPOR
      FLOSS(I) = SLOSS
      FLNG(I) = SLNG
      DEP(I) = SDEP
      IDIR(I) = IDIREC
      IORT(I) = IORNT
      ITYP(I) = IFTYP
      NFC(I) = NFCL
      LD(I) = .FALSE.
      LW(I) = .FALSE.
      LB(I) = .FALSE.
      LC(I) = .FALSE.
      CALL SETUP(I,IDIREC,IDIM1,IDIM2,NFCL,SMX,SMY,SMZ,SLNG,DELS(I),
     1           FX,FY,FZ)
      DO 500 J=1,NFCL
      FMASS(I,J) = FMASSO(I)
  500 CONTINUE
 1000 CONTINUE
C
C   READ PILOT FIRE CHARACTERISTICS
C
      READ (NREAD,PILOT)
C   ERROR CHECKING FOR NAMELIST PILOT
      DO 2000 I=1,NPILOT
      IF ((IPIL(I)*JPIL(I)*IPFUEL(I)).GT.0) GO TO 1100
      LINERR = .TRUE.
      WRITE (NWRITE,9516) XNAME(4), IJOB, I
 1100 IF (IPIL(I).LE.NSM) GO TO 1200
```

```
      LINERR = .TRUE.
      WRITE (NWRITE,9517) XNAME(4), IJOB, I, NSM
 1200 IF (JPIL(I).LE.NFC(IPIL(I))) GO TO 1300
      LINERR = .TRUE.
      WRITE (NWRITE,9518) XNAME(4), IJOB, I, NFC(IPIL(I))
 1300 IF (IPFUEL(I).LE.NFUEL) GO TO 1400
      LINERR = .TRUE.
      WRITE (NWRITE,9519) XNAME(4), IJOB, I, NFUEL
 1400 IF (PMASS(I).GT.0.) GO TO 2000
      LINERR = .TRUE.
      WRITE (NWRITE,9520) XNAME(4), IJOB, I
 2000 CONTINUE
C
C
C   READ FUEL TYPE CHARACTERISTICS
C
      READ (NREAD,FUELT)
      DO 2900 I=1,NFUEL
C   ERROR CHECKING FOR NAMELIST FUELT
      IF (IFUEL(I).GT.0) GO TO 2100
      LINERR = .TRUE.
      WRITE (NWRITE,9521) XNAME(5), IJOB, I
 2100 IF ((DENS(I)*SPHT(I)*THK(I)).GT.0.) GO TO 2200
      LINERR = .TRUE.
      WRITE (NWRITE,9522) XNAME(5), IJOB, I
 2200 IF (IFUEL(I).GE.10) GO TO 2400
      IF ((HEAT(I)*EFF(I)*GAMMA(I)).GT.0.) GO TO 2300
      LINERR = .TRUE.
      WRITE (NWRITE,9523) XNAME(5), IJOB,I
 2300 IF ((EFF(I).LE.1.).OR.(GAMMA(I).LE.1.)) GO TO 2400
      LINERR = .TRUE.
      WRITE (NWRITE,9524) XNAME(5), IJOB, I
C
 2400 DIFF(I) = THK(I)/(DENS(I)*SPHT(I))
      LDF(I) = .FALSE.
      LWF(I) = .FALSE.
      LBF(I) = .FALSE.
      LCF(I) = .FALSE.
      ITYPE = IFUEL(I)
      IF (ITYPE.LT.10) GO TO 2900
      IF ((ITYPE.GE.10).AND.(ITYPE.LT.20)) LDF(I) = .TRUE.
      IF ((ITYPE.GE.20).AND.(ITYPE.LT.30)) LWF(I) = .TRUE.
      IF ((ITYPE.GE.30).AND.(ITYPE.LT.40)) LBF(I) = .TRUE.
      IF ((ITYPE.GE.40).AND.(ITYPE.LT.50)) LCF(I) = .TRUE.
      DO 2500 J=1,NSM
      IF (ITYP(J).NE.I) GO TO 2500
      IF (LDF(I)) LD(J) = .TRUE.
      IF (LWF(I)) LW(J) = .TRUE.
      IF (LBF(I)) LB(J) = .TRUE.
      IF (.NOT.LCF(I)) GO TO 2500
      LC(J) = .TRUE.
      ICEIL = J
 2500 CONTINUE
 2900 CONTINUE
```

```
      READ (NREAD,MISC)
C   DEFAULT SETTING FOR NAMELIST MISC
      RTEMP = AMAX1(0.,RTEMP)
C
      DO 3100 I=1,IDIM3
      DO 3000 J=1,IDIM3
      ICOMM(I,J) = 1
 3000 CONTINUE
 3100 CONTINUE
      IF (NCOM.LE.0) GO TO 3500
      DO 3300 I=1,NCOM
      READ (NREAD,SEE)
      DO 3200 J=1,4
      IAD(I,J) = IV(J)
 3200 CONTINUE
 3300 CONTINUE
 3500 IF (NNCOM.LE.0) GO TO 3900
      DO 3800 I=1,NNCOM
      READ (NREAD,NSEE)
      DO 3700 J=1,4
      NAD(I,J) = NV(J)
 3700 CONTINUE
 3800 CONTINUE
 3900 CALL COMM(NCOM,NNCOM,NSM,IDIM1,IDIM3,IDIM4,IDIM5,NFC,IAD,NAD,
     1          ICOMM)
      LROOM = (IROOM.EQ.1)
      IF (.NOT.LROOM) GO TO 5000
C
C   READ ROOM CHARACTERISTICS
C
      READ (NREAD,ROOM)
C   DEFAULT SETTINGS FOR NAMELIST ROOM
      IF (DCFIN.EQ.0.) DCFIN = 1.
      IF (DCFOUT.EQ.0.) DCFOUT=1.
      IF (GABSRP.EQ.0.) GABSRP=1.3
      IF (PLCF.EQ.0.) PLCF = 2.
      CFV = 352.6*VFV
      IF (INITG.EQ.1) READ (NREAD,GINIT)
C
C   THE VARIABLE WFVC IS NO LONGER NEEDED
C     WFVC = CFV/RTEMP
C
 5000 READ (NREAD,MODVAR)
C   DEFAULT SETTINGS FOR NAMELIST MODVAR
      DO 6000 I=1,15
      IF (FCTR(I).LE.0.0) FCTR(I) = 1.0
 6000 CONTINUE
      READ (NREAD,OUTF)
C   ERROR CHECKING FOR NAMELIST OUTF
      IF (IOUTPT.GE.0) GO TO 6500
      LINERR = .TRUE.
      WRITE (NWRITE,9525) XNAME(12), IJOB
      IF (IOUTPT.EQ.0) GO TO 6500
      DO 6400 I=1,IOUTPT
```

```
      IF (MOUTPT(I).GT.0) GO TO 6200
      LINERR = .TRUE.
      WRITE (NWRITE,9526) XNAME(12), IJOB, I
      GO TO 6400
 6200 IF (MOUTPT(I).LE.IDIM8) GO TO 6400
      LINERR = .TRUE.
      WRITE (NWRITE,9527) XNAME(12), IJOB, I, IDIM8
 6400 CONTINUE
 6500 IF (NSMOUT.LE.NSM) GO TO 6900
      LINERR = .TRUE.
      WRITE (NWRITE,9528) XNAME(12), IJOB
      IF (NSMOUT.LE.0) GO TO 6900
      DO 6800 I=1,NSMOUT
      IF (MSMOUT(I).GT.0) GO TO 6600
      LINERR = .TRUE.
      WRITE (NWRITE,9529) XNAME(12), IJOB, I
      GO TO 6800
 6600 IF (MSMOUT(I).LE.NSM) GO TO 6800
      LINERR = .TRUE.
      WRITE (NWRITE,9530) XNAME(12), IJOB, I
 6800 CONTINUE
C
C   JOB AND ALL SUBSEQUENT JOBS FAIL IF ANY INPUT ERORS ARE DETECTED
C
 6900 IF (LINERR) GO TO 8000
C
C
C   MAIN PROGRAM SUBROUTINES
C
C
C   ECHO CHECK FOR INPUT DATA
C
      CALL INCHK (FX,FY,FZ,QEXT,DEP,FLNG,FLOSS,FMASS0,POR,WID,BRATS0,
     1 BRATS1,BRATV,DENS,DIFF,EFF,FABSRP,FIGTP,FIGTS,FTDAM,GAMMA,HEAT,
     2 REFL,SPHT,THK,PMASS,IDIR,IORT,ITYP,NFC,IFUEL,IPIL,IPFUEL,JPIL,
     3 IAD,NAD,LBF,LCF,LDF,LWF,IDIM1,IDIM2,IDIM4,IDIM5,NCOM,
     4 NFUEL,NJOB,NNCOM,NPILOT,NSM,NTIME,NWRITE)
C
C   INITIALIZE JOB VARIABLES
C
      CALL INIT(FX,FY,FZ,HCOEF,QEXT,TSURR,TEMP,LBURN,LDAMGE,LFMASS,AREA,
     1 DELS,POR,WID,BRATS0,BRATS1,BRATV,EFF,HEAT,PBRATV,PBRTS0,PBRTS1,
     2 PEFF,PHEAT,PMASS,IDIR,IORT,NFC,IPIL,IPFUEL,JPIL,LPMASS,ICOMM,
     3 LB,LC,LW,IDIM1,IDIM2,IDIM3,NFUEL,NPILOT,NSM)
C
C  IN NEW VERSION, AT TIME=0, THE OUTPUT WOULD BE THE INITIAL CONDITION,
C  THE STEADY STATE IS ASSUMED TO BE FORMED WITHIN THE FIRST TIME STEP
C
      IF (TG.LT.RTEMP) TG = RTEMP
      TIME = 0.0
      TQDOT = 0.0
      TMDOT = 0.0
      TG = RTEMP
      DG = 0.0
```

```
      CALL OUTPUT(FLHT,FLTEMP,FMASS,HCOEF,QDOT2P,QEXCAL,QEXNET,QEXT,
     1 QEXTOT,TEMP,TSURR,LBURN,LDAMGE,NFC,MSMOUT,
     2 IDIM1,IDIM2,NSM,NSMOUT,NWRITE)
      TIME = TIME + DELT
      DO 7000 ITIME=1,NTIME
C
C    TIME-STEP INITIALIZATIONS
C
      CALL TINIT(FLHT,FLTEMP,HCOEF,HCOEF0,Q,QDOT2P,QEXT,QEXT0,TSURR,
     1 TSURR0,LPIGN,LPLUME,LSTRT0,NFC,IDIM1,IDIM2,NSM)
C
C    COMPUTE SOURCE HEAT FLUXES
C
      CALL SOURCE(BRAT,FLHT,FLTEMP,FMASS,FZ,GAMN,Q,QDOTC,QDOT2P,QEXT,
     1 QEXT0,TEMP,AREA,DELS,DEP,FMASS0,POR,RAD,WID,PBRATV,PBRTS0,PBRTS1,
     2 PEFF,PHEAT,PMASS,PMDOTS,BRATS0,BRATS1,BRATV,DIFF,EFF,GAMMA,HEAT,
     3 REFL,THK,ICOUNT,IORT,ITYP,NFC,IPIL,IPFUEL,JPIL,LBURN,LFMASS,
     4 LSTRT0,LTOP,LB,LC,LD,LW,LPMASS,LDAMGE,IDIM1,IDIM2,NFUEL,NPILOT,
     5 NSM,NWRITE)
      IF (LEND) GO TO 8000
C
C    COMPUTE HEAT FLUX TRANSFER TO RECEIVERS
C
      CALL TRANSF(FLHT,FLTEMP,FX,FY,FZ,HCOEF,QDOTC,QDOT2P,QEXCAL,
     1 QEXNET,QEXT,QEXTOT,TSURR,TEMP,AREA,DELS,RAD,WID,FABSRP,GAMMA,
     2 REFL,ICOMM,ICOUNT,IORT,ITYP,NFC,LBURN,LDAMGE,LPIGN,LPLUME,
     3 LB,LC,LD,LW,IDIM1,IDIM2,IDIM3,NFUEL,NSM,NWRITE)
      IF (LEND) GO TO 8000
C
C    DETERMINE IF OTHER FUEL CELLS IGNITE
C
      CALL IGNIT(HCOEF,HCOEF0,QEXT,QEXT0,TSURR,TSURR0,TEMP,DEP,DIFF,
     1 FIGTP,FIGTS,FTDAM,REFL,THK,ITYP,NFC,LBURN,LDAMGE,LFMASS,LPIGN,
     2 LPLUME,LB,LC,LD,LW,IDIM1,IDIM2,NFUEL,NSM,NWRITE)
C
C    OUTPUT FOR EACH TIME STEP
C
C    UPDATED TO ALLOW OUTPUT OF LOCAL CONVECTIVE HEAT TRANSFER
C    COEFFICIENT (HCOEF) AND LOCAL ENVIRONMENT TEMPERATURE (TSURR)
C
C    OLD VERSION:
C
C     CALL OUTPUT(FLHT,FLTEMP,FMASS,QDOT2P,QEXCAL,QEXNET,QEXT,QEXTOT,
C    1 TEMP,LBURN,LDAMGE,NFC,MSMOUT,IDIM1,IDIM2,NSM,NSMOUT,NWRITE)
C    2 IDIM1,IDIM2,NSM,NSMOUT,NWRITE)
C
C    NEW VERSION:
C
      CALL OUTPUT(FLHT,FLTEMP,FMASS,HCOEF,QDOT2P,QEXCAL,QEXNET,QEXT,
     1 QEXTOT,TEMP,TSURR,LBURN,LDAMGE,NFC,MSMOUT,
     2 IDIM1,IDIM2,NSM,NSMOUT,NWRITE)
      TIME = TIME + DELT
C
 7000 CONTINUE
```

```
8000 CONTINUE
9100 FORMAT (20A4)
9501 FORMAT (1H0,44HWARNING: DEFAULT VALUES ASSIGNED IN NAMELIST,A8)
9502 FORMAT (1H0,18HERROR IN NAMELIST ,A8,12H: DELT MUST ,
    1        20HBE GREATER THAN ZERO)
9503 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,12H: NSM, NFUEL,
    1        37H AND NPILOT MUST BE GREATER THAN ZERO)
9504 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,13H: NSM MUST BE,
    1        24H LESS THAN IDIM1 (IDIM1=,I2,1H))
9505 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H: JOB,I3,12H: NFUEL MUST,
    1        27H BE LESS THAN IDIM6 (IDIM6=,I2,1H))
9506 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,13H: NPILOT MUST,
    1        27H BE LESS THAN IDIM7 (IDIM7=,I2,1H))
9507 FORMAT (1H0,18HERROR IN NAMELIST ;A8,5H, JOB,I3,11H: NCOM MUST,
    1        27H BE LESS THAN IDIM4 (IDIM4=,I2,1H))
9508 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,12H: NNCOM MUST,
    1        27H BE LESS THAN IDIM5 (IDIM5=,I2,1H))
9509 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,7H, ENTRY,I3,1H:,
    1        52H NFCL, IORNT, IDIREC, AND IFTYP MUST BE GREATER THAN,
    2        5H ZERO)
9510 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,7H: ENTRY,I3,1H:,
    1        37H NFCL MUST BE LESS THAN IDIM2 (IDIM2=,I2,1H))
9511 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,7H, ENTRY,I3,1H:,
    1        26H IORNT MUST BE LESS THAN 3)
9512 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,7H, ENTRY,I3,1H:,
    1        27H IDIREC MUST BE LESS THAN 3)
9513 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,7H, ENTRY,I3,1H:,
    1        38H IFTYP MUST BE LESS THAN NFUEL (NFUEL=,I2,1H))
9514 FORMAT (1H0,21HWARNING FOR NAMELIST ,A8,5H, JOB,I3,7H, ENTRY,I3,
    1        16H: IORNT = IDIREC)
9515 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,7H, ENTRY,I3,1H:,
    1        50H SLNG, SWID, SDEP, SMASS, AND SPOR MUST BE GREATER,
    2        10H THAN ZERO)
9516 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        54H: IPIL(I), JPIL(I), AND IPFUEL(I) MUST BE GREATER THAN,
    2        5H ZERO)
9517 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        37H: IPIL(I) MUST BE LESS THAN NSM (NSM=,I2,1H))
9518 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        43H: JPIL(I) MUST BE LESS THAN NFC(IPIL(I)) (=,I2,1H))
9519 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        43H: IPFUEL(I) MUST BE LESS THAN NFUEL (NFUEL=,I2,1H))
9520 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        33H: PMASS MUST BE GREATER THAN ZERO)
9521 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        36H: IFUEL(I) MUST BE GREATER THAN ZERO)
9522 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        46H: DENS(I), SPHT(I),AND THK(I) MUST BE GREATER,
    2        10H THAN ZERO)
9523 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        47H: HEAT(I), EFF(I),AND GAMMA(I) MUST BE GREATER,
    2        32H THAN ZERO FOR COMBUSTIBLE FUELS)
9524 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1        48H: EFF(I) AND GAMMA(I) MUST BE LESS THAN OR EQUAL,
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    2         31H TO UNITY FOR COMBUSTIBLE FUELS)
9525 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,13H: IOUTPT MUST,
    1         33H BE GREATER THAN OR EQUAL TO ZERO)
9526 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1         37H: MOUTPT(I) MUST BE GREATER THAN ZERO)
9527 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1         30H: MOUTPT(I) MUST BE LESS THAN ,I2)
9528 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,13H: NSMOUT MUST,
    1         29H BE LESS THAN OR EQUAL TO NSM)
9529 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1         37H: MSMOUT(I) MUST BE GREATER THAN ZERO)
9530 FORMAT (1H0,18HERROR IN NAMELIST ,A8,5H, JOB,I3,10H, POSITION,I3,
    1         45H: MSMOUT(I) MUST BE LESS THAN OR EQUAL TO NSM)
9000 STOP
     END
```

```
C***********************************************************************
C                                                                      *
C   SUBROUTINE INCHK (READ CHECK FOR INPUT DATA)                       *
C                                                                      *
C***********************************************************************
      SUBROUTINE INCHK (FX,FY,FZ,QEXT,DEP,FLNG,FLOSS,FMASSO,POR,WID,
     1 BRATSO,BRATS1,BRATV,DENS,DIFF,EFF,FABSRP,FIGTP,FIGTS,FTDAM,GAMMA,
     2 HEAT,REFL,SPHT,THK,PMASS,IDIR,IORT,ITYP,NFC,IFUEL,IPIL,IPFUEL,
     3 JPIL,IAD,NAD,LBF,LCF,LDF,LWF,IDIM1,IDIM2,IDIM4,IDIM5,NCOM,
     4 NFUEL,NJOB,NNCOM,NPILOT,NSM,NTIME,NWRITE)
      IMPLICIT LOGICAL (L)
      DIMENSION FX(IDIM1,IDIM2), FY(IDIM1,IDIM2), FZ(IDIM1,IDIM2),
     1          QEXT(IDIM1,IDIM2)
      DIMENSION DEP(NSM), FLNG(NSM), FLOSS(NSM), FMASSO(NSM), POR(NSM),
     1          WID(NSM), IDIR(NSM), IORT(NSM), ITYP(NSM), NFC(NSM)
      DIMENSION BRATSO(NFUEL), BRATS1(NFUEL), BRATV(NFUEL), DENS(NFUEL),
     1          DIFF(NFUEL), FABSRP(NFUEL), FIGTP(NFUEL), FIGTS(NFUEL),
     2          GAMMA(NFUEL), HEAT(NFUEL), REFL(NFUEL), SPHT(NFUEL),
     3          THK(NFUEL), IFUEL(NFUEL), FTDAM(NFUEL), EFF(NFUEL),
     4          LBF(NFUEL), LCF(NFUEL), LDF(NFUEL), LWF(NFUEL)
      DIMENSION PMASS(NPILOT),
     1          IPIL(NPILOT), IPFUEL(NPILOT), JPIL(NPILOT)
      DIMENSION IAD(IDIM4,4), NAD(IDIM5,4)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      DATA X/1HX/, Y/1HY/, Z/1HZ/
      WRITE (NWRITE,9000) TITLE, IJOB, NJOB
      WRITE (NWRITE,9100)
      WRITE (NWRITE,9101) FCTR(1)
      WRITE (NWRITE,9102) FCTR(2)
      WRITE (NWRITE,9103) FCTR(3)
      WRITE (NWRITE,9104) FCTR(4)
      WRITE (NWRITE,9105) FCTR(5)
      WRITE (NWRITE,9106) FCTR(6)
      WRITE (NWRITE,9107) FCTR(7)
      WRITE (NWRITE,9108) FCTR(8)
      WRITE (NWRITE,9109) FCTR(9)
      WRITE (NWRITE,9110) FCTR(10)
      WRITE (NWRITE,9111) FCTR(11)
      WRITE (NWRITE,9112) FCTR(12)
      WRITE (NWRITE,9113) FCTR(13)
      WRITE (NWRITE,9114) FCTR(14)
      WRITE (NWRITE,9115) FCTR(15)
      IF (INCHCK.EQ.0) RETURN
      WRITE (NWRITE,9200) NFUEL
      DO 6000 I=1,NFUEL
      WRITE (6,9210) I
      IF (LDF(I)) GO TO 1000
```

```
      IF (LWF(I)) GO TO 2000
      IF (LBF(I)) GO TO 3000
      IF (LCF(I)) GO TO 4000
      WRITE (NWRITE,9220) IFUEL(I)
      WRITE (NWRITE,9230) DENS(I)
      WRITE (NWRITE,9240) SPHT(I)
      WRITE (NWRITE,9250) THK(I)
      WRITE (NWRITE,9255) HEAT(I)
      WRITE (NWRITE,9258) EFF(I)
      WRITE (NWRITE,9260) FIGTP(I)
      WRITE (NWRITE,9270) FIGTS(I)
      WRITE (NWRITE,9275) FTDAM(I)
      WRITE (NWRITE,9280) BRATV(I)
      WRITE (NWRITE,9290) BRATS0(I)
      WRITE (NWRITE,9300) BRATS1(I)
      WRITE (NWRITE,9310) GAMMA(I)
      WRITE (NWRITE,9320) FABSRP(I)
      WRITE (NWRITE,9330) REFL(I)
      GO TO 6000
 1000 WRITE (NWRITE,9340) IFUEL(I)
      GO TO 6000
 2000 WRITE (NWRITE,9350) IFUEL(I)
      GO TO 5000
 3000 WRITE (NWRITE,9360) IFUEL(I)
      GO TO 5000
 4000 WRITE (NWRITE,9370) IFUEL(I)
 5000 WRITE (NWRITE,9250) THK(I)
      WRITE (NWRITE,9400) DIFF(I)
      WRITE (NWRITE,9330) REFL(I)
 6000 CONTINUE
      IF (INCHCK.EQ.1) RETURN
      IF (.NOT.LROOM) GO TO 7000
      WRITE (NWRITE,9500)
      WRITE (NWRITE,9501) FLNG(ICEIL), WID(ICEIL), FZ(ICEIL,1)
      WRITE (NWRITE,9510) DHGT, DWID, DCFIN, DCFOUT
      WRITE (NWRITE,9520) VFV
      WRITE (NWRITE,9525) FH, FC
      WRITE (NWRITE,9530) PLCF
      WRITE (NWRITE,9540) GABSRP
      WRITE (NWRITE,9570) HCEIL
      IF (INITG.EQ.0) GO TO 7000
      WRITE (NWRITE,9580) TG, DG
      WRITE (NWRITE,9585)
      DO 6900 I=1,NSM
      NFCI = NFC(I)
      WRITE (NWRITE,9590) (QEXT(I,J),J=1,NFCI)
 6900 CONTINUE
 7000 WRITE (NWRITE,9600) NPILOT
      DO 7500 I=1,NPILOT
      WRITE (NWRITE,9605) I
      WRITE (NWRITE,9610) IPIL(I), JPIL(I)
      WRITE (NWRITE,9620) IPFUEL(I)
      WRITE (NWRITE,9630) PMASS(I)
 7500 CONTINUE
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```
      WRITE (NWRITE,9700) NSM
      DO 8000 I=1,NSM
      WRITE (NWRITE,9705) I
      WRITE (NWRITE,9710) FX(I,1), FY(I,1), FZ(I,1)
      WRITE (NWRITE,9720) FLNG(I), WID(I), DEP(I)
      WRITE (NWRITE,9730) NFC(I)
      IF (IDIR(I).EQ.1) DIREC = X
      IF (IDIR(I).EQ.2) DIREC = Y
      IF (IDIR(I).EQ.3) DIREC = Z
      IF (IORT(I).EQ.1) ORNT = X
      IF (IORT(I).EQ.2) ORNT = Y
      IF (IORT(I).EQ.3) ORNT = Z
      WRITE (NWRITE,9740) DIREC, ORNT
      WRITE (NWRITE,9750) FMASSO(I)
      WRITE (NWRITE,9760) POR(I)
      WRITE (NWRITE,9770) FLOSS(I)
      WRITE (NWRITE,9780) ITYP(I)
 8000 CONTINUE
      IF ((NCOM.NE.0).OR.(NNCOM.NE.0)) WRITE (NWRITE,9790)
      IF (NCOM.EQ.0) GO TO 8500
      WRITE (NWRITE,9800) NCOM
      DO 8200 I=1,NCOM
      WRITE (NWRITE,9810) I, (IAD(I,J),J=1,4)
 8200 CONTINUE
 8500 IF (NNCOM.EQ.0) GO TO 8900
      WRITE (NWRITE,9820) NNCOM
      DO 8800 I=1,NNCOM
      WRITE (NWRITE,9810) I, (NAD(I,J),J=1,4)
 8800 CONTINUE
 8900 WRITE (NWRITE,9900)
      WRITE (NWRITE,9910) RTEMP
      WRITE (NWRITE,9915) CALTEM
      WRITE (NWRITE,9920) FLCF
      WRITE (NWRITE,9925) HROOM
      WRITE (NWRITE,9930) DELT
      WRITE (NWRITE,9940) NTIME
C
C    FORMAT STATEMENTS
C
 9000 FORMAT (1H1,45HPROGRAM COMPBRN III - A DETERMINISTIC CODE TO,
     1  29H COMPUTE THE PROGRESS OF FIRE,/,23X,17HOVER A GIVEN FUEL,
     2  35H ARRAY WITHIN ENCLOSING BOUNDARIES.,/,23X,
     3  32HALL UNITS ARE IN THE MKS SYSTEM.,///,1X,20A4,///////,
     4  12H INPUT DATA:,///,4H JOB,I3,3H OF,I3,5H JOBS)
 9100 FORMAT (1H1,36HVARIABILITY FACTORS FOR FIRE MODELS:)
 9101 FORMAT (1H0,5X,35HVENTILATION CONTROLLED BURNING RATE,T83,E13.6)
 9102 FORMAT (1H0,5X,36HFUEL-SURFACE CONTROLLED BURNING RATE,T83,E13.6)
 9103 FORMAT (1H0,5X,32HFLAME HEIGHT FOR HORIZONTAL FUEL,T83,E13.6)
 9104 FORMAT (1H0,5X,30HFLAME HEIGHT FOR VERTICAL FUEL,T83,E13.6)
 9105 FORMAT (1H0,5X,31HRADIATIVE HEAT FLUX INTERCHANGE,T83,E13.6)
 9106 FORMAT (1H0,5X,25HBUOYANT PLUME TEMPERATURE,T83,E13.6)
 9107 FORMAT (1H0,5X,41HCONVECTIVE HEAT TRANSFER COEFFICIENT FOR ,
     1                 25HVERTICAL OBJECTS IN PLUME,T83,E13.6)
 9108 FORMAT (1H0,5X,41HCONVECTIVE HEAT TRANSFER COEFFICIENT FOR ,
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      1              27HHORIZONTAL OBJECTS IN PLUME,T83,E13.6)
 9109 FORMAT (1H0,5X,27HGAS LAYER LOCAL TEMPERATURE,T83,E13.6)
 9110 FORMAT (1H0,5X,39HHEAT TRANSFER TO SELF FOR VERTICAL FUEL,
      1                 T83,E13.6)
 9111 FORMAT (1H0,5X,30HHEAT TRANSFER TO ADJACENT FUEL,T83,E13.6)
 9112 FORMAT (1H0,5X,36HHEAT FLUX FROM CEILING HOT GAS LAYER,T83,E13.6)
 9113 FORMAT (1H0,5X,36HHEAT FLUX FROM REFLECTIONS OFF WALLS,
      1              13H AND BARRIERS,T83,E13.6)
 9114 FORMAT (1H0,5X,21HMASS BURNOUT FRACTION,T83,E13.6)
 9115 FORMAT (1H0,5X,19HCURRENTLY UNDEFINED,T83,E13.6)
 9200 FORMAT (1H1,5X,21HNUMBER OF FUEL TYPES:,I5)
 9210 FORMAT (1H0,5X,18HDATA FOR FUEL TYPE,I3,1H:)
 9220 FORMAT (1H0,10X,10HFUEL TYPE:,T91,I5)
 9230 FORMAT (1H0,10X,18HDENSITY (KG/M**3):,T83,E13.6)
 9240 FORMAT (1H ,10X,23HSPECIFIC HEAT (J/KG-K):,T83,E13.6)
 9250 FORMAT (1H ,10X,29HTHERMAL CONDUCTIVITY (W/M-K):,T83,E13.6)
 9255 FORMAT (1H ,10X,26HHEAT OF COMBUSTION (J/KG):,T83,E13.6)
 9258 FORMAT (1H ,10X,22HCOMBUSTION EFFICIENCY:,T83,E13.6)
 9260 FORMAT (1H ,10X,38HPILOTED IGNITION TEMPERATURE (DEG. K):,
      1              T83,E13.6)
 9270 FORMAT (1H ,10X,42HSPONTANEOUS IGNITION TEMPERATURE (DEG. K):,
      1              T83,E13.6)
 9275 FORMAT (1H ,10X,28HDAMAGE TEMPERATURE (DEG. K):,
      1              T83,E13.6)
 9280 FORMAT (1H ,10X,42HVENTILATION CONTROLLED BURNING RATE FACTOR,
      1              15H (KG/M**2.5-S):,T83,E13.6)
 9290 FORMAT (1H ,10X,41HSURFACE CONTROLLED SPECIFIC BURNING RATE ,
      1              12H(KG/M**2-S):,T83,E13.6)
 9300 FORMAT (1H ,10X,44HSPECIFIC BURNING RATE RADIATION AUGMENTATION,
      1              13H (KG/J-M**2):,T83,E13.6)
 9310 FORMAT (1H ,10X,39HFRACTION OF HEAT RELEASED AS RADIATION:,
      1              T83,E13.6)
 9320 FORMAT (1H ,10X,33HSMOKE ATTENUATION FACTOR (M**-1):,T83,E13.6)
 9330 FORMAT (1H ,10X,13HREFLECTIVITY:,T83,E13.6)
 9340 FORMAT (1H0,10X,21HFUEL TYPE: (DETECTOR),T91,I5)
 9350 FORMAT (1H0,10X,17HFUEL TYPE: (WALL),T91,I5)
 9360 FORMAT (1H0,10X,20HFUEL TYPE: (BARRIER),T91,I5)
 9370 FORMAT (1H0,10X,20HFUEL TYPE: (CEILING),T91,I5)
 9400 FORMAT (1H ,10X,29HTHERMAL DIFFUSIVITY (M**2/S):,T83,
      1               E13.6)
 9500 FORMAT (1H1,5X,16HROOM PARAMETERS:)
 9501 FORMAT (1H0,10X,34HCEILING LENGTH, WIDTH, HEIGHT (M):,T57,3E13.6)
 9510 FORMAT (1H ,10X,16HDOOR HEIGHT (M):,T83,E13.6,
      1             /,11X,15HDOOR WIDTH (M):,T83,E13.6,
      2             /,11X,27HDOORWAY INFLOW COEFFICIENT:,T83,E13.6,
      3             /,11X,28HDOORWAY OUTFLOW COEFFICIENT:,T83,E13.6)
 9520 FORMAT (1H ,10X,28HFORCED VENTILATION (M**3/S):,T83,E13.6)
 9525 FORMAT (1H ,10X,41HFORCED VENTILATION CONSTANTS (FH AND FC):,
      1              T70,2E13.6)
 9530 FORMAT (1H ,10X,34HPLUME ENTRAINMENT CONSTANTS (PLCF),
      1              T83,E13.6)
 9540 FORMAT (1H ,10X,37HGAS ABSORPTION COEFFICIENT (GABSRP):,
      1              T83,E13.6)
 9570 FORMAT (1H ,10X,34HCEILING HEAT TRANSFER COEFFICIENT ,
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     1                 15H(W/M**2 DEG.K):,T83,E13.6)
9580 FORMAT (1H0,//,6X,37HINITIAL CEILING GAS LAYER PARAMETERS:,//,
     1               11X,24HAVERAGE GAS TEMPERATURE:,T83,E13.6,/,
     2               11X,16HGAS LAYER DEPTH:,T83,E13.6)
9585 FORMAT (1H1,32HINITIAL HEAT FLUXES TO FUEL BED:,//)
9590 FORMAT (1H ,7HMODULE:,I3,(/,1X,10E12.4))
9600 FORMAT (1H1,16HPILOT FIRE DATA:,/,6X,22HNUMBER OF PILOT FIRES:,I5)
9605 FORMAT (1H0,5X,19HDATA FOR PILOT FIRE,I3,1H:)
9610 FORMAT (1H0,10X,45HLOCATION OF PILOT FIRE (FUEL ARRAY,FUEL CELL),
     1                 1H:,T89,I3,1H,,I3)
9620 FORMAT (1H ,10X,10HFUEL TYPE:,T91,I5)
9630 FORMAT (1H ,10X,10HMASS (KG):,T83,E13.6)
9700 FORMAT (1H1,5X,22HNUMBER OF FUEL ARRAYS:,I5)
9705 FORMAT (1H0,5X,19HDATA FOR FUEL ARRAY,I3,1H:)
9710 FORMAT (1H0,10X,40HINITIAL FUEL CELL X-Y-Z COORDINATES (M):,
     1                 T57,3E13.6)
9720 FORMAT (1H ,10X,36HDIMENSIONS (LENGTH,WIDTH,DEPTH) (M):,
     1                 T57,3E13.6)
9730 FORMAT (1H ,10X,21HNUMBER OF FUEL CELLS:,T91,I5)
9740 FORMAT (1H ,10X,31HDIRECTION OF AXIS, ORIENTATION:,T86,A1,8X,A1)
9770 FORMAT (1H ,10X,29HHEAT LOSS FACTOR (UNDEFINED):,T83,E13.6)
9750 FORMAT (1H ,10X,10HMASS (KG):,T83,E13.6)
9760 FORMAT (1H ,10X,32HPOROSITY FACTOR (DIMENSIONLESS):,T83,E13.6)
9780 FORMAT (1H ,10X,10HFUEL TYPE:,T91,I5)
9790 FORMAT (1H1,5X,19HCOMMUNICATION DATA:,/)
9800 FORMAT (1H0,5X,46HNUMBER OF ADJACENT FUEL CELLS NOT IN SAME FUEL,
     2               7H ARRAY:,I5,//,14X,14HFUEL CELL PAIR,3X,
     3               47H(FUEL ARRAY,FUEL CELL) , (FUEL ARRAY,FUEL CELL),/)
9810 FORMAT (1H ,19X,I3,12X,I3,8X,I3,11X,I3,8X,I3)
9820 FORMAT (1H0,//,6X,23HNON-COMMUNICATION DATA:,/,11X,10HNUMBER OF ,
     1              29HNON-COMMUNICATING FUEL CELLS:,I5,//,
     2              14X,14HFUEL CELL PAIR,3X,
     3              47H(FUEL ARRAY,FUEL CELL) , (FUEL ARRAY,FUEL CELL),/)
9900 FORMAT (1H1,6X,14HMISCELLANEOUS:)
9910 FORMAT (1H ,10X,26HROOM TEMPERATURE (DEG. K):,T83,E13.6)
9915 FORMAT (1H ,10X,33HCALORIMETER TEMPERATURE (DEG. K):,T83,E13.6)
9920 FORMAT (1H ,10X,46HCONVECTIVE HEAT TRANSFER COEFFICIENT FOR FLAME,
     1                 12H (W/M**2-K):,T83,E13.6)
9925 FORMAT (1H ,10X,45HCONVECTIVE HEAT TRANSFER COEFFICIENT FOR ROOM,
     1                 12H (W/M**2-K):,T83,E13.6,/,11X,
     2                 38H(FOR OBJECTS OUTSIDE OF HOT GAS LAYER))
9930 FORMAT (1H ,10X,19HTIME INCREMENT (S):,T83,E13.6)
9940 FORMAT (1H ,10X,29HNUMBER OF TIME STEPS FOR JOB:,T91,I5)
     RETURN
     END
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C*************************************************************************
C                                                                        *
C   SUBROUTINE INIT (INITIALIZATION OF PROBLEM PARAMETERS)               *
C                                                                        *
C*************************************************************************
      SUBROUTINE INIT(FX,FY,FZ,HCOEF,QEXT,TSURR,TEMP,LBURN,LDAMGE,
     1 LFMASS,AREA,DELS,POR,WID,BRATS0,BRATS1,BRATV,EFF,HEAT,PBRATV,
     2 PBRTS0,PBRTS1,PEFF,PHEAT,PMASS,IDIR,IORT,NFC,IPIL,IPFUEL,JPIL,
     3 LPMASS,ICOMM,LB,LC,LW,IDIM1,IDIM2,IDIM3,NFUEL,NPILOT,NSM)
      IMPLICIT LOGICAL (L)
      DIMENSION FX(IDIM1,IDIM2), FY(IDIM1,IDIM2), FZ(IDIM1,IDIM2),
     1     HCOEF(IDIM1,IDIM2), QEXT(IDIM1,IDIM2),
     2     TSURR(IDIM1,IDIM2), TEMP(IDIM1,IDIM2,10),
     3     LBURN(IDIM1,IDIM2), LDAMGE(IDIM1,IDIM2), LFMASS(IDIM1,IDIM2)
      DIMENSION AREA(NSM), DELS(NSM), POR(NSM), WID(NSM),
     1          IDIR(NSM), IORT(NSM), NFC(NSM),
     2          LB(NSM), LC(NSM), LW(NSM)
      DIMENSION BRATS0(NFUEL), BRATS1(NFUEL), BRATV(NFUEL), EFF(NFUEL),
     1          HEAT(NFUEL)
      DIMENSION PBRATV(NPILOT), PBRTS0(NPILOT), PBRTS1(NPILOT),
     1          PEFF(NPILOT), PMASS(NPILOT), PHEAT(NPILOT),
     2          IPIL(NPILOT), IPFUEL(NPILOT), JPIL(NPILOT),
     3          LPMASS(NPILOT)
      DIMENSION ICOMM(IDIM3,IDIM3)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUEL0, CVA, CVA0, QMAX,
     1               QTOT, QTOT0, QTOT1, QTOT2, TMDOT, TMDOT0,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURN0,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
C
C   COMPUTE SHAPE FACTORS FROM WALLS, BARRIERS, AND CEILING TO OBJECTS
C
      IJ = 0
      DO 1900 I=1,NSM
      NFCI = NFC(I)
      IF (LW(I).OR.LB(I).OR.LC(I)) GO TO 1100
      IJ = IJ + NFCI
      GO TO 1900
 1100 DO 1700 J=1,NFCI
      IJ = IJ + 1
      KM = 0
      DO 1500 K=1,NSM
      NFCK = NFC(K)
      DO 1300 M=1,NFCK
      KM = KM + 1
      IF (I.EQ.K) ICOMM(IJ,KM) = 0
```

```
      IF (ICOMM(IJ,KM).EQ.0) GO TO 1300
      F12 = SHAPE(IORT(I),IORT(K),IDIR(I),FX(I,J),FY(I,J),
     1            FZ(I,J),FX(K,M),FY(K,M),FZ(K,M),DELS(I),WID(I))
      ICOMM(IJ,KM) = IFIX(F12*1000.)
 1300 CONTINUE
 1500 CONTINUE
 1700 CONTINUE
 1900 CONTINUE
      IF (.NOT.LROOM) GO TO 3000
      ZD =0
      IF ((INITG.EQ.1).AND.(ZD.GT.0.)) GO TO 2500
      TG = RTEMP
      ZD = 0.2*DHGT
      ZN = 2.*ZD
C
C  OLD VERSION:
C2500 IF (TG.EQ.0.) TG = 300.
C  NEW VERSION:
 2500 IF (TG.LT.RTEMP) TG = RTEMP
      CVA = 0.
      QTOT = 0.
      QTOT0 = 0.
      QTOT1 = 0.
      QTOT2 = 0.
      AWALL = 2.*FZ(ICEIL,1)*(DELS(ICEIL) + WID(ICEIL))
      ACEIL = AREA(ICEIL)
C   MAXIMUM HEAT RELEASED FOR A CLOSED ROOM
      QMAX = 4.21E6*FZ(ICEIL,1)*ACEIL
      LVENT = .FALSE.
      LVCONT = .FALSE.
      LDECAY = .FALSE.
      LFLUX1 = .FALSE.
 3000 TMDOT = 0.
      TMDOTS = 0.
      DO 3700 I=1,NSM
      NFCI = NFC(I)
      DO 3500 J=1,NFCI
      LDAMGE(I,J) = .FALSE.
      LBURN(I,J) = .FALSE.
      LFMASS(I,J) = .FALSE.
      TSURR(I,J) = RTEMP
      HCOEF(I,J) = HROOM
      IF (LROOM.AND.(INITG.EQ.1)) GO TO 3200
      QEXT(I,J) = 0.
 3200 DO 3300 K=1,10
      TEMP(I,J,K) = RTEMP
 3300 CONTINUE
 3500 CONTINUE
 3700 CONTINUE
      LEND = .FALSE.
      AFUEL = 0.
      NBURN = 0
C
C   INITIALIZE PILOT FIRES
```

```
C
      DO 4000 I=1,NPILOT
      NBURN = NBURN + 1
      AFUEL = AFUEL + POR(IPIL(I))*AREA(IPIL(I))
      LBURN(IPIL(I),JPIL(I)) = .TRUE.
      IPTYP = IPFUEL(I)
      PBRATV(I) = BRATV(IPTYP)
      PBRTS0(I) = BRATS0(IPTYP)
      PBRTS1(I) = BRATS1(IPTYP)
      PHEAT(I) = HEAT(IPTYP)
      PEFF(I) = EFF(IPTYP)
      LPMASS(I) = .TRUE.
 4000 CONTINUE
      RETURN
      END
```

```
C***********************************************************************
C                                                                      *
C   SUBROUTINE TINIT (PERFORMS TIME STEP INITIALIZATIONS)              *
C                                                                      *
C***********************************************************************
      SUBROUTINE TINIT(FLHT,FLTEMP,HCOEF,HCOEFO,Q,QDOT2P,QEXT,
     1 QEXTO,TSURR,TSURRO,LPIGN,LPLUME,LSTRTO,NFC,IDIM1,IDIM2,NSM)
      IMPLICIT LOGICAL (L)
      DIMENSION FLHT(IDIM1,IDIM2), FLTEMP(IDIM1,IDIM2),
     1      HCOEF(IDIM1,IDIM2), HCOEFO(IDIM1,IDIM2), Q(IDIM1,IDIM2),
     2      QDOT2P(IDIM1,IDIM2), QEXT(IDIM1,IDIM2), QEXTO(IDIM1,IDIM2),
     3      TSURR(IDIM1,IDIM2), TSURRO(IDIM1,IDIM2),
     4      LPIGN(IDIM1,IDIM2), LPLUME(IDIM1,IDIM2), LSTRTO(IDIM1,IDIM2)
      DIMENSION NFC(NSM)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
      IF (.NOT.LROOM) GO TO 1000
      CVAO = CVA*FCTR(1)
      CVA = 0.
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  FHTA AND FUELA ARE NO LONGER NEEDED
C     FHTA = 0.
C     FUELA = 0.
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      ZOA = 0.
      LFLUX2 = LFLUX1
      LFLUX1 = .FALSE.
      LSMALL=.FALSE.
 1000 AFUELO = AFUEL
      AFUEL = 0.
      TMDOTO = TMDOT
      TMDOT = 0.
      TMDOTS = 0.
      TQDOT = 0.
      TQDOTC = 0.
      NBURNO = NBURN
      NBURN = 0
      DO 2500 I=1,NSM
      NFCI = NFC(I)
      DO 2000 J=1,NFCI
      QEXTO(I,J) = QEXT(I,J)
      QEXT(I,J) = 0.
      LPIGN(I,J) = .FALSE.
```

```
      LSTRTO(I,J) = .FALSE.
      FLTEMP(I,J) = 0.
      FLHT(I,J) = 0.
      QDOT2P(I,J) = 0.
      Q(I,J) = 0.
      TSURRO(I,J) = TSURR(I,J)
      HCOEFO(I,J) = HCOEF(I,J)
      TSURR(I,J) = RTEMP
      LPLUME(I,J) = .FALSE.
C
C   NOTE USE OF CONSTANT CONVECTIVE HEAT TRANSFER COEFFICIENT
C   (UNLESS OBJECT IS IN THE FLAME, PLUME OR HOT GAS LAYER)
C
      HCOEF(I,J) = HROOM
 2000 CONTINUE
 2500 CONTINUE
      RETURN
      END
```

```
C***********************************************************************
C                                                                      *
C   SUBROUTINE SOURCE (COMPUTES HEAT FLUX SOURCE STRENGTH OF FUEL      *
C                      ELEMENTS, WALLS, BARRIERS, AND CEILING/GAS      *
C                      LAYER)                                          *
C                                                                      *
C***********************************************************************
      SUBROUTINE SOURCE(BRAT,FLHT,FLTEMP,FMASS,FZ,GAMN,Q,QDOTC,
     1 QDOT2P,QEXT,QEXTO,TEMP,AREA,DELS,DEP,FMASSO,POR,RAD,WID,PBRATV,
     2 PBRTSO,PBRTS1,PEFF,PHEAT,PMASS,PMDOTS,BRATSO,BRATS1,BRATV,DIFF,
     3 EFF,GAMMA,HEAT,REFL,THK,ICOUNT,IORT,ITYP,NFC,IPIL,IPFUEL,JPIL,
     4 LBURN,LFMASS,LSTRTO,LTOP,LB,LC,LD,LW,LPMASS,LDAMGE,IDIM1,IDIM2,
     5 NFUEL,NPILOT,NSM,NWRITE)
      IMPLICIT LOGICAL (L)
      DIMENSION BRAT(IDIM1,IDIM2), FLHT(IDIM1,IDIM2),
     1    FLTEMP(IDIM1,IDIM2), FMASS(IDIM1,IDIM2), FZ(IDIM1,IDIM2),
     2    GAMN(IDIM1,IDIM2), Q(IDIM1,IDIM2), QDOTC(IDIM1,IDIM2),
     3    QDOT2P(IDIM1,IDIM2), QEXT(IDIM1,IDIM2), QEXTO(IDIM1,IDIM2),
     4    TEMP(IDIM1,IDIM2,10),
     5    ICOUNT(IDIM1,IDIM2), LBURN(IDIM1,IDIM2),LDAMGE(IDIM1,IDIM2),
     6    LFMASS(IDIM1,IDIM2), LSTRTO(IDIM1,IDIM2), LTOP(IDIM1,IDIM2)
      DIMENSION AREA(NSM), DELS(NSM), DEP(NSM), FMASSO(NSM), POR(NSM),
     1          RAD(NSM), WID(NSM),
     2          IORT(NSM), ITYP(NSM), NFC(NSM),
     3          LB(NSM), LC(NSM), LD(NSM), LW(NSM)
      DIMENSION PBRATV(NPILOT), PBRTSO(NPILOT), PBRTS1(NPILOT),
     1      PEFF(NPILOT), PHEAT(NPILOT), PMASS(NPILOT), PMDOTS(NPILOT),
     2      IPIL(NPILOT), IPFUEL(NPILOT), JPIL(NPILOT), LPMASS(NPILOT)
      DIMENSION BRATSO(NFUEL), BRATS1(NFUEL), BRATV(NFUEL), DIFF(NFUEL),
     1          EFF(NFUEL), GAMMA(NFUEL), HEAT(NFUEL), REFL(NFUEL),
     2          THK(NFUEL)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
C
C   PILOT FIRE BURNING RATE
C
      DO 1900 I=1,NPILOT
      IF (.NOT.LPMASS(I)) GO TO 1900
      IPILOT = IPIL(I)
      JPILOT = JPIL(I)
      PAREA = AREA(IPILOT)
      IF (PMASS(I).GT.0.0) GO TO 1500
C
```

```
C   PILOT FIRE BURNOUT
C
      PAREA = 0.0
      PMASS(I) = 0.0
      LPMASS(I) = .FALSE.
 1500 PMDOTS(I) = (PBRTS0(I) + PBRTS1(I)*QEXTO(IPILOT,JPILOT))*
     1            PAREA*POR(IPILOT)*FCTR(2)
      LSTRT0(IPILOT,JPILOT) = (LPMASS(I))
 1900 CONTINUE
      DO 8000 I=1,NSM
C
C   PERFORM THE FOLLOWING SOURCE CALCULATIONS ONLY FOR COMBUSTIBLE
C   FUELS
C
      IF (LD(I).OR.LW(I).OR.LB(I).OR.LC(I)) GO TO 8000
C   ASSIGNMENT OF BURNOUT MASS FOR EACH FUEL CELL
      FRMASS = .3*FMASS0(I)*FCTR(14)
      ITYPE = ITYP(I)
      NFCI = NFC(I)
      LORNT = (IORT(I).NE.3)
      DO 4000 J=1,NFCI
      IF (.NOT.LBURN(I,J)) GO TO 4000
      NBURN = NBURN + 1
      LSTRT = LSTRT0(I,J)
      IF (.NOT.LSTRT) GO TO 2500
      DO 2000 II=1,NPILOT
      IF ((I.NE.IPIL(II)).OR.(J.NE.JPIL(II))) GO TO 2000
      INDEX = II
      GO TO 2500
 2000 CONTINUE
C
C
C   BURNING RATES (VENTILATION AND FUEL SURFACE CONTROLLED)
C
C
 2500 AFUEL = AFUEL + AREA(I)*POR(I)
C
C   SURFACE-CONTROLLED BURNING PER UNIT AREA: ASSUMES LINEAR
C   DEPENDENCE ON HEAT FLUX
C
      FMDOTS = (BRATS0(ITYPE) + BRATS1(ITYPE)*QEXTO(I,J))*
     1         AREA(I)*POR(I)*FCTR(2)
      IF (LSTRT) FMDOTS = PMDOTS(INDEX)
      IF (FMDOTS.GT.0.) GO TO 2700
C
C   STOP BURNING IF BURNING RATE IS NEGATIVE (FOR THRESHOLD FUELS)
C
      BRAT(I,J) = 0.
      LBURN(I,J) = .FALSE.
      GO TO 4000
 2700 FMDOT = FMDOTS
      IF (.NOT.LROOM) GO TO 2900
C
C   VENTILATION CONTROLLED BURNING: ASSUMES A LINEAR DEPENDENCE
```

```
C   ON SURFACE AREA, INPUT AIRFLOW. EMPLOYS AN AVERAGE BURNING
C   RATE CONSTANT (AVERAGED OVER TOTAL BURNING AREA)
C
      FBV = BRATV(ITYPE)
      IF (LSTRT) FBV = PBRATV(INDEX)
      CVA = CVA + FBV*AREA(I)*POR(I)
      IF (LVENT) FMDOT = WIN*AREA(I)*POR(I)*CVA0*FCTR(1)/AFUEL0**2
 2900 TMDOT = TMDOT + FMDOT
      TMDOTS = TMDOTS + FMDOTS
      BRAT(I,J) = FMDOT
C
C   HEAT PRODUCTION RATE
C
      QCOMB = EFF(ITYPE) * HEAT(ITYPE)
      IF (LSTRT) QCOMB = PEFF(INDEX) * PHEAT(INDEX)
      Q(I,J) = FMDOT*QCOMB
      TQDOT = TQDOT + Q(I,J)
      GAMN(I,J) = 1. - GAMMA(ITYPE)
      IF (LSTRT) GAMN(I,J) = 1. - GAMMA(IPFUEL(INDEX))
C
C   DECREMENT FUEL MASS,STOP BURNING ON FUEL CELL IF BURNOUT OCCURS
C
      IF (LSTRT) GO TO 3000
      XMASS = FMASS(I,J) - FMDOT*DELT
      IF (XMASS.GT.FRMASS) GO TO 3500
      LBURN(I,J) = .FALSE.
      LFMASS(I,J) = .TRUE.
      FMASS(I,J) = FRMASS
      GO TO 4000
C
C   DECREMENT PILOT MASS
C
 3000 PMASS(INDEX) = PMASS(INDEX) - FMDOT*DELT
      GO TO 4000
 3500 FMASS(I,J) = XMASS
 4000 CONTINUE
C
C   FLAME HEIGHTS
C
      VMDOT = 0.0
      KCOUNT = 0
      DO 5900 J=1,NFCI
      IF (.NOT.LBURN(I,J)) GO TO 5900
      FMDOT = BRAT(I,J)
      IF (LORNT) GO TO 5100
C
C   FLAMES OVER HORIZONTAL FUEL SLABS
C
      FHT = (30.64*RAD(I)*(BRAT(I,J)/(AREA(I)*SQRT(RAD(I))))**.61)
     1       *FCTR(3)
C
C   SUMS NEEDED IN WEIGHTED AVERAGES FOR FUEL BASE HEIGHT
C   (FOR PLUME FLOW MODEL) AND FLAME HEIGHT.  POSITION OF
C   STATEMENTS RE-ARRANGED FOR HORIZONTAL FIRES.
```

```
C
C   OLD VERSION:
C
C      IF (LROOM) ZOA = ZOA + FZ(I,J)*FMDOT
C
C   NEW VERSION:
C
       IF (.NOT.LROOM) GO TO 5700
       ZOA= ZOA + FZ(I,J)*FMDOT
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  FHTA IS NO LONGER NEEDED
C      FHTA = FHTA+ FHT*FMDOT
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
       GO TO 5700
C
C   FLAMES OVER VERTICAL FUEL SLABS
C
 5100 VMDOT = VMDOT + FMDOT
       KCOUNT = KCOUNT + 1
       IF (J.EQ.NFCI) GO TO 5200
       IF (LBURN(I,J+1)) GO TO 5500
 5200 FHT = (29.7*(VMDOT/WID(I))**.6667)*FCTR(4) + DELS(I)
C
C   AVERAGE FUEL ABASE ELEVATION (FOR VERTICAL FIRES) IS BASED
C   ON LOWEST BURNING CELL (PER FIRE).  NEW VERSION CORRECTS
C   AVERAGING PROCEDURE FOR ZOA (GIVEN LATER).
C   THE BURNING RATE FOR THE ENTIRE FIRE NOW WEIGHTS THE FLAME
C   HEIGHT AND BASE ELEVATION; THE PREVIOUS VERSION USED ONLY
C   THE BURNING RATE FROM THE TOP ELEMENT FOR ZOA, AND WEIGHTED
C   THE FLAME HEIGHT FROM EACH FUEL CELL IN THE VERTICAL FIRE
C   SEPARATELY.
C
C   OLD VERSION:
C
C      IF (LROOM) ZOA = ZOA + FZ(I,J-KCOUNT+1)*FMDOT
C   NEW VERSION:
C
       IF (.NOT.LROOM) GO TO 5300
       ZOA = ZOA + FZ(I,J-KCOUNT+1)*VMDOT
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  FHTA IS NO LONGER NEEDED
C      FHTA = FHTA + (FHT + (KCOUNT-1)*DELS(I))*VMDOT
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 5300 VMDOT = 0.0
       KCOUNT = 0
       LTOP(I,J) = .TRUE.
       GO TO 5700
 5500 FHT = DELS(I)
       LTOP(I,J) = .FALSE.
 5700 FLHT(I,J) = FHT
C
C   SEE ABOVE NOTES
C
C   OLD VERSION:
```

```
C      IF (.NOT.LROOM) GO TO 5900
C      FUELA = FUELA + AREA(I)
C      FHTA = FHTA + FHT*FMDOT
C
C   NEW VERSION: FHTA AND FUELA ARE NO LONGER NEEDED
C
C      IF (LROOM) FUELA = FUELA + AREA(I)
C
 5900 CONTINUE
C
C
C   SOURCE STRENGTH OF FLAMES(HEAT FLUX, TEMPERATURE)
C
C
      IF (LORNT) GO TO 7000
C
C   HORIZONTAL FUEL SLABS
C
      DO 6000 J=1,NFCI
      IF (.NOT.LBURN(I,J)) GO TO 6000
      HTFLUX = Q(I,J)/(3.14159*RAD(I)*(RAD(I) + 2.*FLHT(I,J)))
      QDOT2P(I,J) = HTFLUX
      FLTEMP(I,J) = SQRT(SQRT(HTFLUX/5.6697E-8))
      QDOTC(I,J) = GAMN(I,J)*Q(I,J)
      TQDOTC = TQDOTC + QDOTC(I,J)
 6000 CONTINUE
      GO TO 8000
C
C   VERTICAL FUEL SLABS (ALLOWS FOR MULTIPLE FIRES ON A SUPER MODULE
C
 7000 IBOTP = 1
C   INDEX BURNING CELLS IN A SINGLE FLAME, STARTING WITH THE LOWEST
 7100 JCOUNT = 0
      LBOT = .FALSE.
      IBOT = IBOTP
      DO 7300 J=IBOT,NFCI
      IF (.NOT.LBURN(I,J)) GO TO 7300
      IF (.NOT.LBOT) IBOTP = J
      LBOT = .TRUE.
      JCOUNT = JCOUNT + 1
      ICOUNT(I,J) = JCOUNT
      IF (LTOP(I,J)) GO TO 7500
 7300 CONTINUE
      GO TO 8000
 7500 ITOP = IBOTP + JCOUNT - 1
      TFLHT = 0.0
      VQDOT = 0.0
C
C   DETERMINE TOTAL FLAME HEIGHT, HEAT PRODUCTION RATE
C
      DO 7700 J=IBOTP,ITOP
      TFLHT = TFLHT + FLHT(I,J)
      VQDOT = VQDOT + Q(I,J)
 7700 CONTINUE
```

```
C
C   DETERMINE AVERAGE HEAT FLUX, FLAME TEMPERATURE (USED FOR ALL CELLS)
C
      QDOTC(I,ITOP) = VQDOT*GAMN(I,ITOP)
      HTFLUX = VQDOT/(2.*TFLHT*WID(I))
      FLAMT = SQRT(SQRT(HTFLUX/5.6697E-8))
      DO 7900 J=IBOTP,ITOP
      QDOT2P(I,J) = HTFLUX
      FLTEMP(I,J) = FLAMT
 7900 CONTINUE
      IBOTP = ITOP + 1
      IF (IBOTP.LE.NFCI) GO TO 7100
 8000 CONTINUE
      IF ((NBURN.EQ.0).OR.(TMDOT.LE.1.E-30)) GO TO 9500
      IF (.NOT.LROOM) GO TO 8200
C
C   THE FOLLOWING STATEMENTS USED TO
C   COMPUTE AVERAGE FUEL RADIUS, AND FLAME HEIGHT
C   (USED IN PLUME FLOW MODEL) ARE DELETED FROM THE OLD VERSION
C   THE FLAME BASE ELEVATION STEP IS RETAINED
C
C     FRADA = SQRT(FUELA/3.14159)
C     FHTA = FHTA/TMDOT
C
      ZOA = ZOA/TMDOT
C
C   HEAT SOURCE CALCULATINS FOR BARRIERS, CEILING, AND WALLS
C
 8200 DO 8900 I=1,NSM
C
      IF (.NOT.(LB(I).OR.LC(I).OR.LW(I))) GO TO 8900
C
      ITYPE = ITYP(I)
      NFCI = NFC(I)
      EPS = 1. - REFL(ITYPE)
C     TK = THK(ITYPE)
C     TDIFF = DIFF(ITYPE)
C     DELX = DEP(I)/10.
C
C   MODIFICATION INCORPORATES TRANSIENT HEAT CONDUCTION EDUATION
C   IN BARRIER MODEL, AS SELL AS CEILING AND WALL MODELS.
C   HEAT CONDUCTIOIN CALCULATIONS ARE NOW PERFORMED IN IGNIT;
C   SURFACE TEMPERATURES AND HEAT FLUXES ARE ASSUMED TO BE GIVEN.
C
C   OLD VERSION:
C
C     IF (LW(I).OR.LC(I)) GO TO 8500
C     IF (LB(I)) CALL BARR(IDIM1,IDIM2,I,NFCI,NWRITE,TK,EPS,
C    1                     DEP(I),FZ,QDOT2P,QEXTO,TEMP)
C     IF (LEND) GO TO 9000
C     GO TO 8900
C8500 DO 8560 K=1,NSM
C     DO 8550 J=1,NFCI
C     IF (LBURN(K,J)) GO TO 8570
```

```
C8550 CONTINUE
C8560 CONTINUE
C     GO TO 8600
C8570 IF (LC(I)) CALL CEILNG(EPS, REFL(ITYPE),QDOT2P(ICEIL,1),
C    1             QEXTO(ICEIL,1),TEMP(ICEIL,1,1),FZ(ICEIL,1),NWRITE)
C     IF (LEND) GO TO 9000
C8600 DO 8700 J=1,NFCI
C     HL = HCEIL
C     IF (LW(I)) QDOT2P(I,J) = 5.6697E-8*EPS*TEMP(I,J,1)**4
C    1                       + REFL(ITYPE)*QEXTO(I,J)
C
C   NEW VERSION:
C
      IF (NBURN.EQ.0) GO TO 8600
C
C   CEILING COMPUTATIONS
C
      IF (.NOT.LC(I)) GO TO 8600
C
C  SUBROUTINE CGAS WILL BE CALLED ONCE AT THE FIRST TIME STEP TO
C  COMPUTE THE THICKNESS OF THE HOT GAS LAYER AND THEN
C  USES THIS THICKNESS TO ESTIMATE THE HOT GAS EMISSIVITY
C  WHICH HAS BEEN FOUND TO BE INSENSITIVE TO THE HGL
C  THICKNESS.  THE EMISSIVITY WILL BE UPDATED AT EACH TIME STEP
C
      IF (GEMS.GT.0.) GOTO 8350
      CALL CGAS(EPS,REFL(ITYPE),QDOT2P(ICEIL,1),
     1             QEXTO(ICEIL,1),TEMP(ICEIL,1,1),FZ(ICEIL,1),NWRITE)
      GEMS = 1. - EXP(-GABSRP*DG)
 8350 IF ((TQDOTC.LE.1.).OR.(TQDOT.LE.1.)) GOTO 9500
      CALL CGAS(EPS,REFL(ITYPE),QDOT2P(ICEIL,1),
     1             QEXTO(ICEIL,1),TEMP(ICEIL,1,1),FZ(ICEIL,1),NWRITE)
      GEMS = 1. - EXP(-GABSRP*DG)
      QDOT2P(ICEIL,1) = QDOT2P(ICEIL,1)*FCTR(12)
      IF (LEND) GO TO 9000
C
C   WALLS AND BARRIERS
C
 8600 IF (.NOT.(LW(I).OR.LB(I))) GO TO 8900
      DO 8700 J=1,NFCI
      TEMPS = TEMP(I,J,1)
      REFLEC = REFL(ITYPE)
C
C   WALL SOURCE IS FRONT SIDE OF THE WALL.  INCLUDES REFLECTION OF
C   EXTERNAL RADIATION.  BARRIER SOURCE IS BACKSIDE OF BARRIER.
C   DOES NOT INCLUDE EXTERNAL RADIATION REFLECTION (ASSUMED TO ONLY
C   STRIKE FRONT.
C
      IF (LW(I)) GO TO 8650
      TEMPS = TEMP(I,J,10)
      REFLEC = 0.
 8650 QDOT2P(I,J) = 5.6697E-8*EPS*TEMPS**4 + REFLEC*QEXTO(I,J)*
     1               FCTR(13)
C
```

```
      IF (LEND) GO TO 9000
 8700 CONTINUE
 8900 CONTINUE
 9000 RETURN
 9500 WRITE (NWRITE,9600)
 9600 FORMAT (1H0,35HEND OF JOB: NO FLAMES OVER FUEL BED)
      LEND = .TRUE.
      RETURN
      END
```

```
C***********************************************************************
C                                                                      *
C   SUBROUTINE TRANSF (COMPUTES HEAT FLUX TRANSMITTED TO FUEL          *
C                      ELEMENTS, WALLS, BARRIERS, AND CEILING,         *
C                      AND SURROUDING TEMPERATURES)                    *
C                                                                      *
C***********************************************************************
      SUBROUTINE TRANSF(FLHT,FLTEMP,FX,FY,FZ,HCOEF,QDOTC,QDOT2P,QEXCAL,
     1 QEXNET,QEXT,QEXTOT,TSURR,TEMP,AREA,DELS,RAD,WID,FABSRP,
     2 GAMMA,REFL,ICOMM,ICOUNT,IORT,ITYP,NFC,LBURN,LDAMGE,LPIGN,LPLUME,
     3 LB,LC,LD,LW,IDIM1,IDIM2,IDIM3,NFUEL,NSM,NWRITE)
      IMPLICIT LOGICAL (L)
      DIMENSION FLHT(IDIM1,IDIM2), FLTEMP(IDIM1,IDIM2), FX(IDIM1,IDIM2),
     1     FY(IDIM1,IDIM2), FZ(IDIM1,IDIM2), HCOEF(IDIM1,IDIM2),
     2     QDOTC(IDIM1,IDIM2), QDOT2P(IDIM1,IDIM2), QEXCAL(IDIM1,IDIM2),
     3     QEXNET(IDIM1,IDIM2), QEXT(IDIM1,IDIM2), QEXTOT(IDIM1,IDIM2),
     4     TSURR(IDIM1,IDIM2),TEMP(IDIM1,IDIM2,10), ICOUNT(IDIM1,IDIM2),
     5     LBURN(IDIM1,IDIM2), LDAMGE(IDIM1,IDIM2),
     6     LPIGN(IDIM1,IDIM2), LPLUME(IDIM1,IDIM2)
      DIMENSION AREA(NSM), DELS(NSM), RAD(NSM), WID(NSM),
     1          IORT(NSM), ITYP(NSM), NFC(NSM),
     2          LB(NSM), LC(NSM), LD(NSM), LW(NSM)
      DIMENSION FABSRP(NFUEL), GAMMA(NFUEL), REFL(NFUEL)
      DIMENSION  ICOMM(IDIM3,IDIM3)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
      IJ = 0
C
C   HEAT FLUX SOURCE LOOP
C
      DO 5900 I=1,NSM
      NFCI = NFC(I)
      IF (.NOT.LD(I)) GO TO 1000
      IJ = IJ + NFCI
      GO TO 5900
 1000 FRAD = RAD(I)
      ITYPE = ITYP(I)
      LWALBR = (LW(I).OR.LB(I).OR.LC(I))
      LCEIL = LC(I)
      LORNT = (IORT(I).NE.3)
      DO 5800 J=1,NFCI
      IJ = IJ + 1
      IF (LWALBR) GO TO 2000
```

```
      IF (.NOT.LBURN(I,J)) GO TO 5800
C
C   FLAME LOCATION
C
      FLX = FX(I,J)
      FLY = FY(I,J)
      FLZ1 = FZ(I,J)
      IF (LORNT) FLZ1 = FLZ1 - DELS(I)/2.
      FLZ2 = FLZ1 + FLHT(I,J)
      HTFLUX = GAMMA(ITYPE)*QDOT2P(I,J)
 2000 KM = 0
C
C   HEAT FLUX RECEIVER LOOP  (NON-ADJACENT FUEL CELLS)
C
      DO 5500 K=1,NSM
      NFCK = NFC(K)
      LIK = (I.EQ.K)
 3000 IF (LWALBR) GO TO 3500
      LORNT2 = (IORT(K).NE.3)
      LORNT3 = (LORNT.AND.LORNT2)
 3500 DO 5000 M=1,NFCK
      KM = KM + 1
      IF (ICOMM(IJ,KM).EQ.0) GO TO 5000
      IF (LWALBR) GO TO 4700
      IF ((ICOMM(IJ,KM).EQ.2).OR.(LVCONT.AND.LBURN(K,M))) GO TO 5000
C
C   RECEIVER LOCATION (FLAME LOOP)
C
      FZKM = FZ(K,M)
      FR = SQRT((FX(K,M) - FLX)**2 + (FY(K,M) - FLY)**2)
      DELZ1 = ABS(FZKM - FLZ1)
      DELZ2 = ABS(FZKM - FLZ2)
      IF (FR.LE.RAD(I)) GO TO 4300
C
C
C   RADIATIVE HEAT FLUXES (WHEN FR.GT.FRAD)
C
C
      IF (LORNT2) GO TO 4000
      Q1 = CYLPAR(DELZ1,FR,FRAD)
      Q2 = CYLPAR(DELZ2,FR,FRAD)
      GO TO 4100
 4000 Q1 = CYLPER(DELZ1,FR,FRAD)
      Q2 = CYLPER(DELZ2,FR,FRAD)
 4100 IF (FZKM.GT.FLZ2) Q2 = -Q2
      IF (FZKM.LT.FLZ1) Q1 = -Q1
      DELTQ = ((DELZ1*Q1 + DELZ2*Q2)/FLHT(I,J))*HTFLUX*FCTR(5)
      GO TO 4800
C
C
C   RECEIVER ENVIRONMENT (TEMPERATURE, HEAT TRANSFER COEFFICIENT)
C   WHEN RECEIVER IS ABOVE OR BELOW FLAME.  USES MAXIMUM TEMPERATURE
C   AND ASSOCIATED COEFFICIENT IF MORE THAN ONE VALUE IS POSSIBLE.
C
```

```
C
 4300 IF ((QDOTC(I,J).LT.100.).OR.(FZKM.LT.FLZ1).OR.
     1            ((I.EQ.K).AND.LBURN(K,M))) GO TO 5000
      IF (FZKM.GE.FLZ2) GO TO 4400
C
C   FLAME ENVIRONMENT
C
      DELTQ = 0.
      IF (FLTEMP(I,J).LT.TSURR(K,M)) GO TO 4800
      TSURR(K,M) = FLTEMP(I,J)
      HCOEF(K,M) = FLCF
      LPIGN(K,M) = .TRUE.
      LPLUME(K,M) = .TRUE.
      GO TO 4800
C
C   PLUME TEMPERATURE USING ALPERT'S CORRELATION IS CHANGED TO
C   ZUKOSKI'S CORRELATION IN ORDER TO BE CONSISTENT WITH THE
C   PLUME ENTRAINMENT MODEL
C   OLD VERSION:
C
C     PLTEMP = .169*(QDOTC(I,J)**.6667)/(DELZ1**1.6667) + RTEMP
C
C   NEW VERSION:
C
 4400 PLTEMP = RTEMP*(1. + 3.814E-2*(QDOTC(I,J)/RTEMP)**(2./3.)
     1        /DELZ1**(5./3.))
      PLTEMP = AMIN1(PLTEMP,FLTEMP(I,J))*FCTR(6)
      IF (.NOT.LORNT2) GO TO 4500
C
C   FOR VERTICAL OBJECTS, HEAT TRANSFER COEFFICIENT = FLAME COEFFICIENT
C
      PLCOEF = FLCF*FCTR(7)
      GO TO 4600
C
C   HEAT TRANSFER COEFFICIENT FOR HORIZONTAL OBJECTS
C
C   MODIFICATION TO COMPUTE A POINT VALUE FOR H, RATHER THAN AN
C   AVERAGE VALUE (8/22/84).  CORRELATION USED IS STILL FROM
C   VELDMAN, ET AL.  OLD VERSION:
C
C4500 RKM = SQRT(DELS(K)*WID(K)/3.14159)/DELZ1
C     PLCOEF = .64
C     IF (RKM.LT.0.18) PLCOEF = 2.06
C     PLCOEF = (PLCOEF*(QDOTC(I,J)/DELZ1)**.3333)*FCTR(8)
C
C   NEW VERSION:
 4500 RDZ = AMAX1(0.1,FR/DELZ1)
      PLCOEF = 0.9*(RDZ**(-.65))*((QDOTC(I,J)/DELZ1)**.3333)*FCTR(8)
C
C   PLUME ENVIRONMENT
C
 4600 DELTQ = 0.
      IF (PLTEMP.LT.TSURR(K,M)) GO TO 4800
      TSURR(K,M) = PLTEMP
```

```
      HCOEF(K,M) = PLCOEF
      LPLUME(K,M) = .TRUE.
      GO TO 4800
C
C   RADIATIVE HEAT TRANSFER FROM
C   WALL, BARRIER, AND CEILING SOURCES
C
C
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C  THIS IS THE NEW VERSION TO BE INCORPORATED AFTER TESTING
C
 4700 DELTQ = 0.
      IF ((.NOT.LROOM).OR.(FZ(K,M).LT.ZD).OR.(.NOT.LCEIL))
     1                DELTQ = ICOMM(IJ,KM)*QDOT2P(I,J)/1000.
 4800 QEXT(K,M) = QEXT(K,M) + DELTQ
      LFLUX1 = .TRUE.
C
C   CEILING HOT GAS LAYER ENVIRONMENT
C
      IF ((.NOT.LROOM).OR.(FZ(K,M).LT.ZD).OR.(TSURR(K,M).GT.TG))
     1        GO TO 5000
      TSURR(K,M) = TG*FCTR(9)
      HCOEF(K,M) = HCEIL
      LPLUME(K,M) = .FALSE.
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C   THIS IS THE OLD 'INCORRECT' VERSION (CEILING DOES NOT SEE THE
C   HOT GAS LAYER ENVIRONMENT)
C
C4700 DELTQ = ICOMM(IJ,KM)*QDOT2P(I,J)/1000.
C     IF ((.NOT.LROOM).OR.(.NOT.LCEIL).OR.(FZ(K,M).LT.ZD).OR.
C    1    (TSURR(K,M).GT.TG)) GO TO 4800
C
C   CEILING HOT GAS LAYER ENVIRONMENT
C
C     TSURR(K,M) = TG*FCTR(9)
C     HCOEF(K,M) = HCEIL
C     LPLUME(K,M) = .FALSE.
C     DELTQ = 0.
C4800 QEXT(K,M) = QEXT(K,M) + DELTQ
C     LFLUX1 = .TRUE.
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 5000 CONTINUE
 5500 CONTINUE
C
C   HEAT TRANSFER TO SELF FOR VERTICAL FUEL CELLS
C   (USING A BEST-FIT FOR THE SHAPE FACTOR FROM FLAME TO FUEL)
C
      IF ((.NOT.LORNT).OR.LVCONT.OR.LWALBR) GO TO 5800
      XCOUNT = ICOUNT(I,J)
      VSHAPE = -.197 + .24*WID(I) + .02*FLHT(I,J) + .0538*DELS(I)
     1         * (XCOUNT - .5) + .0256*DELS(I)*(XCOUNT-.5)/FLHT(I,J)
     2         + .0724*FABSRP(ITYPE)
```

```
      VSHAPE = AMIN1(1.,AMAX1(0.,VSHAPE))
      DELTQ = GAMMA(ITYPE)*QDOT2P(I,J)*VSHAPE*FCTR(10)
      QEXT(I,J) = QEXT(I,J) + DELTQ
 5800 CONTINUE
 5900 CONTINUE
      IF (.NOT.LROOM) GO TO 6000
C
C   DETERMINE IF VENTILATION CONTROLLED (USING SIMPSON'S RULE
C   EXTRAPOLATION FOR HEAT SUPPORT BY AIR INITIALLY IN ROOM
C
      QTOT2 = TQDOT
      DQTOT = DELT*(-QTOT0 + 8.*QTOT1 + 5.*QTOT2)/12.
      QTOT = QTOT + DQTOT
      QTOT0 = QTOT1
      QTOT1 = QTOT2
C   INDICATOR VARIABLE TO SHOW IF FIRE HAS BEEN BURNING FOR THE
C   TWO PREVIOUS TIME STEPS
      LFLUX = (LFLUX1.AND.LFLUX2)
      IF ((.NOT.LVENT).OR.(LVENT.AND.LDECAY.AND.LFLUX)) TMDTS0 = TMDOTS
      TMDOTV = CVA0*WIN/AFUEL0
      LVENT = ((TMDOTV.LT.TMDTS0).AND.(QTOT.GE.QMAX))
      LDECAY = (LDECAY.OR.(NBURN.LT.NBURN0))
      LVCONT = (LVENT.AND..NOT.LDECAY)
C
C   HEAT TRANSFER TO ADJACENT (NON-BURNING) FUEL CELLS FROM
C   CONTINUOUS PROPAGATION OF FLAMES
C
 6000 IJ = 0
      DO 6900 I=1,NSM
      NFCI = NFC(I)
      IF (.NOT.(LD(I).OR.LW(I).OR.LB(I).OR.LC(I))) GO TO 6050
      IJ = IJ + NFCI
      GO TO 6900
 6050 ITYPE = ITYP(I)
      LORNT = (IORT(I).NE.3)
      DO 6600 J=1,NFCI
      IJ = IJ + 1
      IF (.NOT.LBURN(I,J)) GO TO 6600
      FLZ = FZ(I,J)
C
C   CONDUCTIVE HEAT TERM
C
      QCOND = (.01157+5.6697D-5*FLTEMP(I,J))*(FLTEMP(I,J)-TEMP(I,J,1))*
     1         WID(I)
      KM = 0
      DO 6400 K=1,NSM
      AREAK = WID(K)*DELS(K)
      NFCK = NFC(K)
      LORNT2 = (LORNT.AND.(IORT(K).NE.3))
      DO 6300 M=1,NFCK
      KM = KM + 1
      IF ((ICOMM(IJ,KM).NE.2).OR.LBURN(K,M)) GO TO 6300
      IF (LORNT2) GO TO 6100
      QRAD = GAMMA(ITYPE)*QDOT2P(I,J)*AREA(I)
```

```
      DELTQ = (QRAD + QCOND)/AREAK
      GO TO 6200
 6100 DELTQ = QCOND/AREAK
C
C   REVISE CHARACTERIZATION OF ENVIRONMENT OF ADJACENT VERTICAL
C   CELLS, TO BE CONSISTEN WITH TREATMENT FO HORIZONTAL CELLS
C
C   OLD VERSION:
C
C     IF ((I.EQ.K).AND.(M.GT.J)) DELTQ = QDOT2P(I,J)
C
C   NEW VERSION:
C
      IF ((FZ(K,M).LT.FLZ).OR.(TSURR(K,M).GT.FLTEMP(I,J)))
     1    GO TO 6200
      TSURR(K,M) = FLTEMP(I,J)
      HCOEF(K,M) = FLCF
      LPLUME(K,M) = .TRUE.
C
 6200 QEXT(K,M) = QEXT(K,M) + DELTQ*FCTR(11)
      LPIGN(K,M) = .TRUE.
 6300 CONTINUE
 6400 CONTINUE
 6600 CONTINUE
 6900 CONTINUE
C
C   COMPUTE NET HEAT FLUX AT SURFACE (FOR OUTPUT PURPOSES ONLY)
C
      DO 7500 I=1,NSM
      NFCI = NFC(I)
      EPS = 1. - REFL(ITYP(I))
      FSIG = EPS*5.6697E-8
      DO 7000 J=1,NFCI
      QEXTOT(I,J) = EPS*QEXT(I,J) + HCOEF(I,J)*TSURR(I,J)
     1                  + FSIG*TSURR(I,J)**4
      QEXCAL(I,J) = QEXTOT(I,J) - HCOEF(I,J)*CALTEM
     1                  - FSIG*CALTEM**4
      QEXNET(I,J) = QEXTOT(I,J) - HCOEF(I,J)*TEMP(I,J,1)
     1                  - FSIG*TEMP(I,J,1)**4
 7000 CONTINUE
 7500 CONTINUE
      RETURN
      END
```

```
C***********************************************************************
C                                                                      *
C   SUBROUTINE IGNIT (DETERMINES THERMAL RESPONSE OF OBJECTS IN        *
C                     ROOM, IF OBJECTS ARE DAMAGED, AND IF FUEL        *
C                     CELLS ARE IGNITED)                               *
C                                                                      *
C***********************************************************************
      SUBROUTINE IGNIT(HCOEF,HCOEFO,QEXT,QEXTO,TSURR,TSURRO,TEMP,
     1 DEP,DIFF,FIGTP,FIGTS,FTDAM,REFL,THK,ITYP,NFC,LBURN,LDAMGE,
     2 LFMASS,LPIGN,LPLUME,LB,LC,LD,LW,IDIM1,IDIM2,NFUEL,NSM,NWRITE)
      IMPLICIT LOGICAL (L)
      DIMENSION HCOEF(IDIM1,IDIM2), HCOEFO(IDIM1,IDIM2),
     1  QEXT(IDIM1,IDIM2), QEXTO(IDIM1,IDIM2),
     2  TSURR(IDIM1,IDIM2), TSURRO(IDIM1,IDIM2), TEMP(IDIM1,IDIM2,10),
     3  LBURN(IDIM1,IDIM2), LDAMGE(IDIM1,IDIM2), LFMASS(IDIM1,IDIM2),
     4  LPIGN(IDIM1,IDIM2), LPLUME(IDIM1,IDIM2)
      DIMENSION DIFF(NFUEL), FIGTP(NFUEL), FIGTS(NFUEL), FTDAM(NFUEL),
     1          REFL(NFUEL), THK(NFUEL)
      DIMENSION DEP(NSM), ITYP(NSM), NFC(NSM), LB(NSM), LC(NSM),
     1          LD(NSM), LW(NSM)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      DO 8000 I=1,NSM
C
C   SUBROUTINE NOW PERFORMS HEAT CONDUCTION CALCULATIONS FOR BARRIERS,
C   AS WELL AS OTHER FUEL CELLS.  SUBROUTINE BARR IS NO LONGER NEEDED.
C
C   OLD VERSION:
C
C     IF (LD(I).OR.LB(I)) GO TO 8000
C
C   NEW VERSION:
C
      IF (LD(I)) GO TO 8000
C
      LBCW = (LW(I).OR.LC(I).OR.LB(I))
      ITYPE = ITYP(I)
      NFCI = NFC(I)
C
C   ASSIGNMENT OF RIGHT-HAND-SIDE BOUNDARY CONDITION TYPE
C
      IBC = 1
      IF (LB(I)) IBC = 3
C
      TK = THK(ITYPE)
      EPSI = 1. - REFL(ITYPE)
      TDIFF = DIFF(ITYPE)
C
C   CORRECTION TO EARLIER CALCULATION OF INTERVAL WIDTH WITHIN A
C   FUEL CELL (10 NODES ARE ASSIGNED PER FUEL CELL).
C
C   OLD VERSION:
```

```
C
C     DELX = DEP(I)/10.
C
C   NEW VERSION:
C
      DELX = DEP(I)/9.
C
      DO 7000 J=1,NFCI
      IF (LBURN(I,J).OR.LFMASS(I,J)) GO TO 7000
      EPS = EPSI
      IF (LPLUME(I,J)) EPS = 0.
C
C   NEW VERSION ALLOWS VARIED BOUNDARY CONDITIONS AT THE BACK
C   SIDE OF THE FUEL ELEMENT (OLD VERSION CORRESPONDS TO IBC=1)
C
C      IBC=1: BACK SIDE FIXED AT RTEMP (SEMI-INFINITE MODEL)
C      IBC=2: ADIABATIC BACK SIDE (NOT CURRENTLY IMPLEMENTED IN
C             COMPBRN II
C      IBC=3: FULL CONVECTION AND RADIATION (USED FOR BARRIERS)
C
C   OLD VERSION:
C
C     CALL DIFFUS(TEMP,DELX,EPS,HCOEF(I,J),HCOEF0(I,J),QEXT(I,J),
C    1            QEXT0(I,J),TDIFF,TK,TSURR(I,J),TSURR0(I,J),
C    2            IDIM1,IDIM2,I,J,NWRITE)
C
C   NEW VERSION:
C
      CALL DIFFUS(TEMP,DELX,EPS,HCOEF(I,J),HCOEF0(I,J),QEXT(I,J),
     1            QEXT0(I,J),TDIFF,TK,TSURR(I,J),TSURR0(I,J),
     2            IBC,IDIM1,IDIM2,I,J,NWRITE)
C
      IF (LBCW) GO TO 7000
      IF (TEMP(I,J,1).GT.FTDAM(ITYPE)) LDAMGE(I,J) = .TRUE.
      TIG = FIGTS(ITYPE)
      IF (LPIGN(I,J)) TIG = FIGTP(ITYPE)
      IF ((TEMP(I,J,1).LT.TIG).OR.(TIME.EQ.0.).OR.(TIME.EQ.DELT))
     1    GOTO 7000
      LBURN(I,J) = .TRUE.
C     LPIGN(I,J) = .TRUE.
 7000 CONTINUE
 8000 CONTINUE
      RETURN
      END
```

```
C***************************************************************************
C                                                                          *
C   SUBROUTINE OUTPUT (PRINTS PROGRAM OUTPUT)                              *
C                                                                          *
C***************************************************************************
C   NEW VERSION ALLOWS USER TO OUTPUT LOCAL HEAT TRANSFER COEFFICIENT
C   AND LOCAL ENVIRONMENT TEMPERATURE FOR A FUEL CELL.
C
C   OLD VERSION:
C
C     SUBROUTINE OUTPUT(FLHT,FLTEMP,FMASS,QDOT2P,QEXCAL,QEXNET,QEXT,
C    1 QEXTOT,TEMP,LBURN,LDAMGE,NFC,MSMOUT,IDIM1,IDIM2,NSM,NSMOUT,
C    2 NWRITE)
C
C   NEW VERSION:
C
      SUBROUTINE OUTPUT(FLHT,FLTEMP,FMASS,HCOEF,QDOT2P,QEXCAL,QEXNET,
     1 QEXT,QEXTOT,TEMP,TSURR,LBURN,LDAMGE,NFC,MSMOUT,IDIM1,IDIM2,
     2 NSM,NSMOUT,NWRITE)
C
      IMPLICIT LOGICAL (L)
      DIMENSION FLHT(IDIM1,IDIM2), FLTEMP(IDIM1,IDIM2),
     1          FMASS(IDIM1,IDIM2), QDOT2P(IDIM1,IDIM2),
     2          QEXCAL(IDIM1,IDIM2), QEXNET(IDIM1,IDIM2),
     3          QEXT(IDIM1,IDIM2), QEXTOT(IDIM1,IDIM2),
     4          TEMP(IDIM1,IDIM2,10), LBURN(IDIM1,IDIM2),
     5          LDAMGE(IDIM1,IDIM2), NFC(NSM), MSMOUT(NSMOUT)
C
      DIMENSION HCOEF(IDIM1,IDIM2), TSURR(IDIM1,IDIM2)
C
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVA0, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
      WRITE (NWRITE,9000) TITLE, TIME
C     LOUT = (NSMOUT.EQ.0)
      LOUT = (NSMOUT.LE.0)
C
      IF (IOUTPT.NE.0) GO TO 2000
      WRITE (NWRITE,9100) TMDOT
      IF (LOUT) RETURN
      DO 1000 I=1,NSMOUT
      K = MSMOUT(I)
      NFCK = NFC(K)
      WRITE (NWRITE,9500) K, (LBURN(K,J),J=1,NFCK)
```

```
 1000 CONTINUE
      RETURN
 2000 DO 5000 II=1,IOUTPT
      INDEX = MOUTPT(II)
C
      GO TO (2100,2300,2500,2700,2900,2900,2900,2900,2900,2900,2900,
     1       2900,2900,2900,2900,2900,2900), INDEX
C
 2100 WRITE (NWRITE,9100) TMDOT
      GO TO 5000
 2300 WRITE (NWRITE,9200) TQDOT
      GO TO 5000
 2500 WRITE (NWRITE,9300) TG
      GO TO 5000
 2700 WRITE (NWRITE,9400) DG
      GO TO 5000
 2900 IF (LOUT) GO TO 5000
      WRITE (NWRITE,9450)
      DO 4000 I=1,NSMOUT
      K = MSMOUT(I)
      NFCK = NFC(K)
C
      GO TO (4000,4000,4000,4000,3000,3050,3100,3200,3300,3350,3400,
     1       3500,3600,3700,3800,3900,3950), INDEX
C
 3000 WRITE (NWRITE,9500) K, (LDAMGE(K,J),J=1,NFCK)
      GO TO 4000
 3050 WRITE (NWRITE,9550) K, (LBURN(K,J), J=1,NFCK)
      GO TO 4000
 3100 WRITE (NWRITE,9600) K, (QDOT2P(K,J),J=1,NFCK)
      GO TO 4000
 3200 WRITE (NWRITE,9650) K, (QEXT(K,J),J=1,NFCK)
      GO TO 4000
 3300 WRITE (NWRITE,9700) K, (QEXTOT(K,J),J=1,NFCK)
      GO TO 4000
 3350 WRITE (NWRITE,9725) K, (QEXCAL(K,J),J=1,NFCK)
      GO TO 4000
 3400 WRITE (NWRITE,9750) K, (QEXNET(K,J),J=1,NFCK)
      GO TO 4000
 3500 WRITE (NWRITE,9800) K, (FMASS(K,J),J=1,NFCK)
      GO TO 4000
 3600 WRITE (NWRITE,9900) K, (FLHT(K,J),J=1,NFCK)
      GO TO 4000
 3700 WRITE (NWRITE,9930) K, (FLTEMP(K,J),J=1,NFCK)
      GO TO 4000
 3800 WRITE (NWRITE,9950) K, (TEMP(K,J,1),J=1,NFCK)
      GO TO 4000
C
C   ADDED WRITE STATEMENTS:
C
 3900 WRITE (NWRITE,9960) K, (HCOEF(K,J),J=1,NFCK)
      GO TO 4000
 3950 WRITE (NWRITE,9970) K, (TSURR(K,J),J=1,NFCK)
C
```

```
 4000 CONTINUE
 5000 CONTINUE
 9000 FORMAT (1H1,20A4,/,1X,11HTIME (SEC):,F6.0,//)
 9100 FORMAT (1H ,31HTOTAL MASS BURNING RATE (KG/S):,G12.4)
 9200 FORMAT (1H ,31HTOTAL HEAT RELEASE RATE (W)    :,G12.4)
 9300 FORMAT (1H ,31HHOT GAS LAYER TEMPERATURE (K) :,G12.4)
 9400 FORMAT (1H ,31HHOT GAS LAYER THICKNESS (M)   :,G12.4)
 9450 FORMAT (1H0)
C
C   MODIFIED FORMAT STATEMENTS:
C
 9500 FORMAT (1H ,7HMODULE:,I4,3X,16HDAMAGE ?        ,10G11.3)
 9550 FORMAT (1H ,7HMODULE:,I4,3X,16HBURNING?        ,10G11.3)
 9600 FORMAT (1H ,7HMODULE:,I4,3X,16HSOURCE FLUX     ,10G11.3)
 9650 FORMAT (1H ,7HMODULE:,I4,3X,16HEXTERNAL FLUX   ,10G11.3)
 9700 FORMAT (1H ,7HMODULE:,I4,3X,16HTOTAL FLUX      ,10G11.3)
 9725 FORMAT (1H ,7HMODULE:,I4,3X,16HMEAS'D FLUX     ,10G11.3)
 9750 FORMAT (1H ,7HMODULE:,I4,3X,16HNET FLUX        ,10G11.3)
 9800 FORMAT (1H ,7HMODULE:,I4,3X,16HFUEL MASS       ,10G11.3)
 9900 FORMAT (1H ,7HMODULE:,I4,3X,16HFLAME HGT       ,10G11.3)
 9930 FORMAT (1H ,7HMODULE:,I4,3X,16HFLAME TEMP      ,10G11.3)
 9950 FORMAT (1H ,7HMODULE:,I4,3X,16HFUEL TEMP       ,10G11.3)
C
C   ADDED FORMAT STATEMENTS:
C
 9960 FORMAT (1H ,7HMODULE:,I4,3X,16HHEAT TRANS COEF ,10G11.3)
 9970 FORMAT (1H ,7HMODULE:,I4,3X,16HENVIRONMENT TEMP,10G11.3)
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   SUBROUTINE ADJCTP FILLS IN BLOCKS OF THE ADJACENCY MATRIX.         -
C   IF NADJ(IND,2) EQUALS '999', MODULE NADJ(IND,1) DOES NOT           -
C   COMMUNICATE WITH MODULE NADJ(3).  IF NADJ(2) EQUALS '888',         -
C   MODULE NADJ(IND,1) DOES NOT COMMUNICATE WITH MODULES NADJ(IND,3)   -
C   THRU NADJ(IND,4)                                                   -
C                                                                      -
C-----------------------------------------------------------------------
      SUBROUTINE ADJCTP(IJ,KM,NFCL,NSTOP,IDIM3,ICOMM)
      IMPLICIT LOGICAL (L)
      DIMENSION ICOMM(IDIM3,IDIM3)
      IIJ = IJ
      DO 2000 MI=1,NFCL
      KKM = KM
      DO 1000 MM=1,NSTOP
      KKM = KKM + 1
      ICOMM(IIJ,KKM) = 0
 1000 CONTINUE
      IIJ = IIJ + 1
 2000 CONTINUE
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   SUBROUTINE COMM CONSTRUCTS THE ADJACENCY (COMMUNICATION) MATRIX    -
C   FOR THE INDIVIDUAL FUEL CELLS - 0 = NO COMMUNICATION,              -
C   1 = COMMUNICATION, 2 = ADJACENCY                                   -
C                                                                      -
C-----------------------------------------------------------------------
      SUBROUTINE COMM(NCOM,NNCOM,NSM,IDIM1,IDIM3,IDIM4,IDIM5,NFC,IAD,
     1                NAD,ICOMM)
      IMPLICIT LOGICAL (L)
      DIMENSION IAD(IDIM4,4), NAD(IDIM5,4), ICOMM(IDIM3,IDIM3),
     1          NFC(IDIM1)
      IF (NCOM.EQ.0) GO TO 1000
      DO 900 IND=1,NCOM
      IJ = 0
      DO 800 I=1,NSM
      NFCI = NFC(I)
      IF (IAD(IND,1).EQ.I) GO TO 100
      IJ = IJ + NFCI
      GO TO 800
  100 DO 700 J=1,NFCI
      IJ = IJ + 1
      LIADJ = (IAD(IND,2).EQ.999)
      LID = (LIADJ.OR.(IAD(IND,2).EQ.J))
      IF (.NOT.LID) GO TO 700
      KM = 0
      DO 600 K=1,NSM
      NFCK = NFC(K)
      IF (IAD(IND,3).EQ.K) GO TO 200
      KM = KM + NFCK
      GO TO 600
  200 IF (LIADJ) GO TO 400
      DO 300 M=1,NFCK
      KM = KM + 1
      IF (IAD(IND,4).NE.M) GO TO 300
      ICOMM(IJ,KM) = 2
      ICOMM(KM,IJ) = 2
      GO TO 900
  300 CONTINUE
  400 DO 500 M=1,NFCK
      KM = KM + 1
      ICOMM(IJ,KM) = 2
      ICOMM(KM,IJ) = 2
      IJ = IJ + 1
  500 CONTINUE
      GO TO 900
  600 CONTINUE
  700 CONTINUE
  800 CONTINUE
  900 CONTINUE
 1000 IF (NNCOM.EQ.0) GO TO 2000
      DO 1900 IND=1,NNCOM
      IJ = 0
      DO 1800 I=1,NSM
```

```
      NFCI = NFC(I)
      IF (NAD(IND,1).EQ.I) GO TO 1100
      IJ = IJ + NFCI
      GO TO 1800
 1100 DO 1700 J=1,NFCI
      IJ = IJ + 1
      LNADJP = (NAD(IND,2).EQ.888)
      LNADJ = (NAD(IND,2).EQ.999)
      LND = (LNADJ.OR.LNADJP.OR.(NAD(IND,2).EQ.J))
      IF (.NOT.LND) GO TO 1700
      KM = 0
      DO 1600 K=1,NSM
      NFCK = NFC(K)
      IF (NAD(IND,3).EQ.K) GO TO 1200
      KM = KM + NFCK
      GO TO 1600
 1200 IF (LNADJP) GO TO 1330
      IF (LNADJ) GO TO 1380
      IF (NAD(IND,4).EQ.999) GO TO 1400
      DO 1300 M=1,NFCK
      KM = KM + 1
      IF (NAD(IND,4).NE.M) GO TO 1300
      ICOMM(IJ,KM) = 0
      GO TO 1900
 1300 CONTINUE
 1330 NSTOP = 0
      KM1 = NAD(IND,3)
      KM2 = NAD(IND,4)
      DO 1350 KMDUM=KM1,KM2
      NSTOP = NSTOP + NFC(KMDUM)
 1350 CONTINUE
      CALL ADJCTP(IJ,KM,NFCI,NSTOP,IDIM3,ICOMM)
      GO TO 1900
 1380 NSTOP = NFCK
      CALL ADJCTP(IJ,KM,NFCI,NSTOP,IDIM3,ICOMM)
      GO TO 1900
 1400 DO 1500 M=1,NFCK
      KM = KM + 1
      ICOMM(IJ,KM) = 0
 1500 CONTINUE
      GO TO 1900
 1600 CONTINUE
 1700 CONTINUE
 1800 CONTINUE
 1900 CONTINUE
 2000 IJ = 0
      DO 3000 I=1,NSM
      NFCI = NFC(I)
      DO 2500 J=1,NFCI
      IJ = IJ + 1
      ICOMM(IJ,IJ) = 0
      KM = IJ + 1
      IF (J.EQ.NFCI) GO TO 3000
      ICOMM(IJ,KM) = 2
```

```
      ICOMM(KM,IJ) = 2
 2500 CONTINUE
 3000 CONTINUE
      RETURN
      END
```

```
C----------------------------------------------------------------------
C                                                                     -
C   FUNCTION CYLPAR FINDS THE HEAT FLUX FROM A CYLINDRICAL FLAME TO   -
C   AN INFINITESIMAL SURFACE PARALLEL TO THE GROUND. OLD VERSION IS   -
C   A CORRECTED VERSION OF SUBROUTINE GIVEN IN COMPBRN I MANUAL, BUT  -
C   IS ONLY GOOD FOR OBJECTS A SMALL DISTANCE AWAY FROM SMALL RADIUS  -
C   FLAMES. NEW VERSION IS OBTAINED AS A LIMITING CASE FOR THE SHAPE  -
C   FACTOR FROM A FRUSTRUM (TRUNCATED CONE) TO A DIFFERENTIAL SURFACE. -
C   NEW VERSION ALSO ALLOWS FOR OBJECTS WITHIN THE FLAME (THE SHAPE   -
C   FACTOR IS SET TO UNITY, INSTEAD OF LEADING TO AN ERROR).          -
C                                                                     -
C----------------------------------------------------------------------
      FUNCTION CYLPAR(Z,FR,FRAD)
      IMPLICIT LOGICAL (L)
C
C   OLD VERSION:
C
C     IF (Z.GT.0.0) GO TO 100
C     CYLPAR = 0.0
C     RETURN
C 100 X = FR/Z
C     R = FRAD/Z
C     A = 1. + X**2 - R**2
C     B = 1. + X**2 + R**2
C     RAT = SQRT((X+R)/(X-R))
C     CYLPAR = (ATAN(RAT) - (A/B)*ATAN(1./RAT))/3.14159
C
C   NEW VERSION:
C
      IF (Z.GT.0.0) GO TO 100
      CYLPAR = 0.0
      RETURN
  100 IF (FR.GT.FRAD) GO TO 200
      CYLPAR = 1.0
      RETURN
  200 A = FR + FRAD
      B = FR - FRAD
      AA = SQRT(Z**2 + A**2)
      BB = SQRT(Z**2 + B**2)
      RAT = SQRT(A/B)
      CYLPAR = ATAN(RAT) - (Z**2 + FR**2 - FRAD**2)*
     1         ATAN(AA/(BB*RAT))/(AA*BB)
      CYLPAR = CYLPAR/3.14159
C
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   FUNCTION CYLPER FINDS THE HEAT FLUX FROM A CYLINDRICAL FLAME TO    -
C   AN INFINITESIMAL SURFACE PERPENDICULAR TO THE GROUND               -
C                                                                      -
C-----------------------------------------------------------------------
      FUNCTION CYLPER(Z,FR,FRAD)
      IMPLICIT LOGICAL (L)
      PI = 3.14159
      IF (Z.NE.0.0) GO TO 100
      CYLPER = 0.0
      RETURN
  100 X = Z/FRAD
      Y = FR/FRAD
      A = (1.+Y)**2 + X**2
      B = (1.-Y)**2 + X**2
      YMIN = Y - 1.
      YPLS = Y + 1.
      CYLPER = (1./(PI*Y))*ATAN(X/SQRT(Y**2-1.)) + (X/PI)*
     1   ((A-2.*Y)*ATAN(SQRT(A*YMIN/(B*YPLS)))/(Y*SQRT(A*B))
     2   - (1./Y)*ATAN(SQRT(YMIN/YPLS)))
      RETURN
      END
```

```
C--------------------------------------------------------------------------
C                                                                         -
C   SUBROUTINE DIFFUS SOLVES THE TIME-DEPENDENT HEAT CONDUCTION           -
C   EQUATION FOR GEOMETRY USING A CRANK-NICOLSON SCHEME. THIS             -
C   UPDATED VERSION ALLOWS THE USE OF THREE BOUNDARY CONDITIONS           -
C   AT THE RIGHT SIDE OF THE SLAB:                                        -
C                                                                         -
C        IRBC=1 => THE RHS TEMPERATURE IS FIXED AT RTEMP                  -
C        IRBC=2 => THE NET HEAT FLUX AT THE RHS IS 0 (ADIABATIC)          -
C        IRBC=3 => GENERAL NEWTON COOLING + RADIATION (SAME AS LHS)       -
C                                                                         -
C--------------------------------------------------------------------------
C
C   OLD VERSION (USED IN COMPBRN II SIMULATIONS):
C
C     SUBROUTINE DIFFUS(TEMP,DELX,EPS,HL,HLO,QXT,QXTO,TDIFF,TK,TENV,
C    1            TENVO,IDIM1,IDIM2,I1,J1,NWRITE)
C   NEW VERSION:
C
      SUBROUTINE DIFFUS(TEMP,DELX,EPS,HL,HLO,QXT,QXTO,TDIFF,TK,TENV,
     1            TENVO,IRBC,IDIM1,IDIM2,I1,J1,NWRITE)
C
      IMPLICIT LOGICAL (L)
      DIMENSION BETA(9), GAMMA(9), D(9), U(10), V(10),
     1          TEMP(IDIM1,IDIM2,10)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
C
C   INITIALIZATIONS
C
      DO 1000 I=1,10
      U(I) = TEMP(I1,J1,I)
 1000 CONTINUE
      FSIG = EPS*5.6697E-8
      TLAM = .5*TDIFF*DELT/DELX**2
      DX3 = 3.*DELX
      BJ = 1. + 2.*TLAM
C   LHS CONSTANT COEFFICIENTS
C
      A1P = 1. + 3.5*TLAM + DX3*TLAM*HL/TK
C
      B1 = -4.*TLAM
      C1 = .5*TLAM
      CHECK = ABS(U(1)-TENVO)
      D1 = (1. - 3.5*TLAM)*U(1) + 4.*TLAM*U(2) - .5*TLAM*U(3)
     1     + (DX3*TLAM/TK)*(HL*TENV + FSIG*TENV**4 + EPS*(QXT + QXTO))
      IF(CHECK.GT.1)
     1 D1 = D1 + (DX3*TLAM/TK)*( HLO*(TENVO - U(1))
     2                          + FSIG*(TENVO**4 - U(1)**4) )
C   RHS CONSTANT COEFFICIENTS
C
      IF (IRBC.EQ.1) GO TO 1500
```

```
      A10 = .5*TLAM
      B10 = -4.*TLAM
      C10 = 1. + 3.5*TLAM
      C10P = C10 + DX3*TLAM*HL/TK
      D10 = (1. - 3.5*TLAM)*U(10) + 4.*TLAM*U(9) - .5*TLAM*U(8)
      D10P = D10
 1500 A9P = -TLAM
      B9P = BJ
C
C   INTERIOR CONSTANT COEFFICIENTS
C
C     DO 2000 J=2,8
      DO 2000 J=2,9
C
      D(J) = U(J) + TLAM*(U(J-1) - 2.*U(J) + U(J+1))
 2000 CONTINUE
C
C   IMPROVE INITIAL GUESS FOR V(1) (USE AVERAGE OF ENVIORNMENT
C   TEMPERATURE AND INITIAL TEMPERATURE).
C
C
C   OLD VERSION
C
C     V1OLD = U(1)
C   NEW VERSION
C
      V1OLD = (U(1) + TENV)/2.
C
      IF (IRBC.EQ.1)
     1   D(9) = TLAM*U(8) + (1. - 2.*TLAM)*U(9) + 2.*TLAM*RTEMP
      V10OLD = U(10)
C
C   BEGIN ITERATIONS
C
      DO 8000 ITR=1,20
C   LHS BOUNDARY
      A1 = A1P + DX3*TLAM*FSIG*V1OLD**3/TK
      C2 = -TLAM*(1. - C1/A1)
      D2 = D(2) + TLAM*D1/A1
C
C   ADDED TREATMENT OF RHS
C
C   RHS BOUNDARY
      IF (IRBC.LT.3) GO TO 3000
      C10 = C10P + DX3*TLAM*FSIG*V10OLD**3/TK
      CHECK = ABS(U(10) - TENV0)
      D10 = D10P + (DX3*TLAM/TK)*(HL*TENV + FSIG*TENV**4)
      IF (CHECK.GT.1.)
     1 D10 = D10 + (DX3*TLAM/TK)*(HL0*(TENV - U(10))
     2                             + FSIG*(TENV0**4 - U(10)**4))
 3000 A9 = A9P
      B9 = B9P
      D9 = D(9)
      IF (IRBC.EQ.1) GO TO 5000
```

```
      A9 = A9 + A10*TLAM/C10
      B9 = B9 + B10*TLAM/C10
      D9 = D9 + D10*TLAM/C10
C
C
C   TRANSFORMED COEFFICIENTS (BETA AND GAMMA)
C
 5000 BETA(2) = BJ + TLAM*B1/A1
      GAMMA(2) = D2/BETA(2)
      BETA(3) = BJ + TLAM*C2/BETA(2)
      GAMMA(3) = (D(3) + TLAM*GAMMA(2))/BETA(3)
C     DO 6000 I=4,9
      DO 6000 I=4,8
C
      BETA(I) = BJ - TLAM*TLAM/BETA(I-1)
      GAMMA(I) = (D(I) + TLAM*GAMMA(I-1))/BETA(I)
 6000 CONTINUE
C
      BETA(9) = B9 + A9*TLAM/BETA(8)
      GAMMA(9) = (D9 - A9*GAMMA(8))/BETA(9)
C
C
C   SOLVE FOR TEMPERATURES
C
      V(9) = GAMMA(9)
      DO 7000 I=2,7
      K = 10 - I
      V(K) = GAMMA(K) + TLAM*V(K+1)/BETA(K)
 7000 CONTINUE
      V(2) = GAMMA(2) - C2*V(3)/BETA(2)
      V(1) = (D1 - B1*V(2) - C1*V(3))/A1
      V(10) = RTEMP
      IF (IRBC.GT.1) V(10) = (D10 - A10*V(8) - B10*V(9))/C10
C
C   CONVERGENCE BASED ON BOUNDARY TEMPERATURE ERROR
C
      ERRL = ABS(V(1) - V1OLD)
C
C   MODIFIED CONVERGENCE TREATMENT
C
C   OLD VERSION:
C
C     IF (ERRL.LT.1.) GO TO 8900
C     V1OLD = V(1)
C
C   NEW VERSION:
C
      ERRR = 0.
      LEL = (ERRL.LT.1.)
      LER = .TRUE.
      IF (IRBC.EQ.1) GO TO 7500
      ERRR = ABS(V(10) - V10OLD)
      LER = (ERRR.LT.1.)
 7500 IF (LEL.AND.LER) GO TO 8900
```

```
      V1OLD = V(1)
      V10OLD = V(10)
C
 8000 CONTINUE
C
C   TEMPERATURE DUMP IF ITERATION MAXIMUM EXCEEDED
C
C   PRINT OUT RHS ERROR
C
C   OLD VERSION:
C     WRITE (NWRITE,8100) I1, J1, V(1), ERRL
C8100 FORMAT (1H0,44HITERATION MAX EXCEEDED IN SUBROUTINE DIFFUS:,
C    1   /,1X,7HMODULE:,I4,3X,10HFUEL CELL:,I4,/,1X,16HITERATION NO. 20,
C    2   /,1X,20HSURFACE TEMPERATURE:,E15.7,3X,6HERROR:,E15.7)
C
C   NEW VERSION:
C
      WRITE (NWRITE,8100) I1, J1, V(1), ERRL, V(10), ERRR
 8100 FORMAT (1H0,44HITERATION MAX EXCEEDED IN SUBROUTINE DIFFUS:,
     1   /,1X,7HMODULE:,I4,3X,10HFUEL CELL:,I4,/,1X,16HITERATION NO. 20,
     2   /,1X,22HSURFACE TEMPERATURE  :,E15.7,3X,6HERROR:,E15.7,
     3   /,1X,22HBACK-SIDE TEMPERATURE:,E15.7,3X,6HERROR:,E15.7)
C
      LEND = .TRUE.
      GO TO 9000
 8900 DO 8950 I=1,10
      TEMP(I1,J1,I) = V(I)
 8950 CONTINUE
 9000 RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   FUNCTION RADEQ SOLVES THE QUARTIC EQUATION: X**4 + A3*X + A4 = 0   -
C                                                                      -
C-----------------------------------------------------------------------
      FUNCTION RADEQ (A3,A4)
      IMPLICIT LOGICAL (L)
      R = 0.5*A3**2
      Q = -4.*A4/3.
      D = R**2 + Q**3
      Y1 = (R + SQRT(D))**(1./3.) - (SQRT(D) - R)**(1./3.)
      RADEQ = .5*(SQRT(2.*SQRT(Y1**2 - 4.*A4) - Y1) - SQRT(Y1))
      RETURN
      END
```

```
C--------------------------------------------------------------------------
C                                                                         -
C   FUNCTION RECT(A,B,C,LP) FINDS THE SHAPE FACTOR FROM A DIFFERENTIAL -
C   ELEMENT TO A RECTANGLE OF DIMENSIONS A X B, AND SPACED C AWAY       -
C   FROM THE ELEMENT.  LP=.TRUE. => ELEMENT IS PARALLEL TO RECTANGLE,  -
C   LP=.FALSE. => ELEMENT IS PERPENDICULAR                              -
C                                                                         -
C--------------------------------------------------------------------------
      FUNCTION RECT(ZDEP,XLEN,YWID,LPARL)
      IMPLICIT LOGICAL (L)
      IF ((ZDEP.EQ.0.D0).OR.(XLEN.EQ.0.D0).OR.(YWID.EQ.0.D0))
     1                                                   GO TO 200
      PI = 3.14159
      IF (.NOT.LPARL) GO TO 100
      X = XLEN/ZDEP
      Y = YWID/ZDEP
      A = SQRT(1. + X**2)
      B = SQRT(1. + Y**2)
      RECT = .5*(X*ATAN(Y/A)/A + Y*ATAN(X/B)/B)/PI
      RETURN
  100 X = XLEN/YWID
      Y = ZDEP/YWID
      A = SQRT(XLEN**2 + ZDEP**2)
      RECT = .5*(ATAN(YWID/ZDEP) - ZDEP*ATAN(YWID/A)/A)/PI
      RETURN
  200 IF (LPARL.AND.(ZDEP.EQ.0.D0)) RECT = .5
      IF (.NOT.LPARL.AND.(ZDEP.EQ.0.D0)) RECT = .25
      IF ((XLEN.EQ.0.D0).OR.(YWID.EQ.0.D0)) RECT = 0.
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   SUBROUTINE SETUP COMPUTES THE FUEL CELL LOCATIONS FROM THE INPUT   -
C   SUPER-MODULE DATA                                                  -
C                                                                      -
C-----------------------------------------------------------------------
      SUBROUTINE SETUP(I,IDIREC,IDIM1,IDIM2,NFCL,SMX,SMY,SMZ,SLNG,
     1                 DS,FX,FY,FZ)
      IMPLICIT LOGICAL (L)
      DIMENSION FX(IDIM1,IDIM2), FY(IDIM1,IDIM2), FZ(IDIM1,IDIM2)
      IF (IDIREC.EQ.3) GO TO 400
      IF (IDIREC.EQ.2) GO TO 200
      FXO = SMX - (SLNG + DS)/2.
      DO 100 J=1,NFCL
      FX(I,J) = FXO + J*DS
      FY(I,J) = SMY
      FZ(I,J) = SMZ
  100 CONTINUE
      GO TO 600
  200 FYO = SMY - (SLNG + DS)/2.
      DO 300 J=1,NFCL
      FY(I,J) = FYO + J*DS
      FX(I,J) = SMX
      FZ(I,J) = SMZ
  300 CONTINUE
      GO TO 600
  400 FZO = SMZ - (SLNG + DS)/2.
      DO 500 J=1,NFCL
      FZ(I,J) = FZO + J*DS
      FX(I,J) = SMX
      FY(I,J) = SMY
  500 CONTINUE
  600 CONTINUE
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   FUNCTION SHAPE FINDS THE SHAPE FACTOR FROM A DIFFERENTIAL FUEL     -
C   ELEMENT TO AN ARBITRARILY LOCATED RECTANGLE, USING FUNCTION RECT   -
C                                                                      -
C-----------------------------------------------------------------------
      FUNCTION SHAPE(IOR,KOR,IDIRC,X1,Y1,Z1,X2,Y2,Z2,D1,D2)
      IMPLICIT LOGICAL (L)
      DU = ABS(X1 - X2)
      IF (IOR.EQ.2) DU = ABS(Y1 - Y2)
      IF (IOR.EQ.3) DU = ABS(Z1 - Z2)
      GO TO (100,200,300), IDIRC
  100 W0 = X2
      W1 = X1 - D1/2.
      V0 = Y2
      V1 = Y1 - D2/2.
      IF (IOR.NE.2) GO TO 400
      V0 = Z2
      V1 = Z1 - D2/2.
      GO TO 400
  200 W0 = Y2
      W1 = Y1 - D1/2.
      V0 = X2
      V1 = X1 - D2/2.
      IF (IOR.NE.1) GO TO 400
      V0 = Z2
      V1 = Z1 - D2/2.
      GO TO 400
  300 W0 = Z2
      W1 = Z1 - D1/2.
      V0 = X2
      V1 = X1 - D2/2.
      IF (IOR.NE.1) GO TO 400
      V0 = Y2
      V1 = Y1 - D2/2.
  400 W2 = W1 + D1
      V2 = V1 + D2
      WSIGN = 1.
      VSIGN = 1.
      IF ((W0.GT.W2).OR.(W0.LT.W1)) WSIGN = -1.
      IF ((V0.GT.V2).OR.(V0.LT.V1)) VSIGN = -1.
      DW2 = ABS(W2 - W0)
      DW1 = ABS(W1 - W0)
      DV2 = ABS(V2 - V0)
      DV1 = ABS(V1 - V0)
      DWA = AMAX1(DW2,DW1)
      DWB = AMIN1(DW2,DW1)
      DVA = AMAX1(DV2,DV1)
      DVB = AMIN1(DV2,DV1)
      LPR = (KOR.EQ.IOR)
      IF (.NOT.LPR.AND.(KOR.NE.IDIRC)) GO TO 500
      SHAPE = RECT(DU,DWA,DVA,LPR) + VSIGN*RECT(DU,DWA,DVB,LPR)
     1  WSIGN*RECT(DU,DWB,DVA,LPR) + VSIGN*WSIGN*RECT(DU,DWB,DVB,LPR)
      RETURN
```

```
500 SHAPE = RECT(DU,DVA,DWA,LPR) + VSIGN*RECT(DU,DVB,DWA,LPR)
   1  WSIGN*RECT(DU,DVA,DWB,LPR) + VSIGN*WSIGN*RECT(DU,DVB,DWB,LPR)
    RETURN
    END
```

```
C---------------------------------------------------------------------
C                                                                    -
C   SUBROUTINE CGAS REPLACES SUBROUTINE CEILNG TO CALCULATE          -
C   THE CEILING HOT GAS LAYER PROPERTIES BY SOLVING THREE HIGHLY     -
C   NON-LINEAR HEAT AND MASS BALANCE EQUATIONS WITH NEW PLUME        -
C   FLOW CORRELATION.                                                -
C                                                                    -
C---------------------------------------------------------------------
      SUBROUTINE CGAS(EPS, WREFL, QCEIL, QEXTC, TCEIL, RHGT, NWRITE)
      IMPLICIT LOGICAL (L)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
C
C
C   CHARACTERIZE HOT GAS LAYER
C
C   DENSITY OF AIR = 1.18 KG/M**3 AND CP = 1000 J/KG/K AT 298K
C
C   1.18*298 = 351.6
C
      CFV = VFV*3.516E2
C
C IF THE GAS EMISSIVITY HAS NOT BEEN ASSESSED
C IT IS ASSUMED TO BE EQUAL TO WALL EMISSIVITY
C AND WILL BE UPDATED AFTER THE FIRST TIME STEP
C
      IF ((GEMS.LT.1.).AND.(GEMS.GT.0.)) GOTO 100
      RADCON = 5.6697E-8*EPS
      GOTO 150
 100  RADCON = 5.6697E-8*GEMS*EPS/(GEMS + EPS - GEMS*EPS)
 150  CVENT = (FH - FC)*CFV
C
C   0.21*1.18**.6667*(9.8/1000)**.3333 = 0.05018
C   ENTRAINMENT RATE = PLUCON*(Z)**(5./3.)
C
      PLUCON = 5.018E-2*PLCF*(TQDOTC/RTEMP)**(1./3.)
C
C   THE MAXIMUM HGL TEMPERATURE CAN BE SOLVED BY HEAT BALANCE EQUATION
C
      A1 = HCEIL/RADCON
      WHEAT = ACEIL*TCEIL*(HCEIL + RADCON*TCEIL**3)
      A2 = -1.*(TQDOTC + WHEAT)/ACEIL/RADCON
      TGMAX = RADEQ(A1, A2)
```

```
C
C   WPLRH = PLUME ENTRAINMENT RATE AT CEILING HEIGHT
C   TPLRH = MEAN CEILING JET TEMPERATURE
C   WVOUT = AIR OUTFLOW AT CEILING DUE TO FORCED VENTILATION
C
      WPLRH = PLUCON*(RHGT - Z0A)**(5./3.)
      TPLRH = RTEMP*(1. + 3.814E-2*(TQDOTC/RTEMP)**(2./3.)
     1        /RHGT**(5./3.))/SQRT(2.)
      WVOUT = CFV*(FH/TPLRH - FC/RTEMP)
      DAREA = DHGT*DWID
C
C   IF OPENINGS ARE PRESENT GOTO 4000
C
      IF (DAREA.GT.0.01) GOTO 4000
C
C   THE FOLLOWING PROCEDURES ARE TO ASSESSED THE HGL PROPERTIES
C   WHEN OPENINGS ARE TOO SMALL TO ALLOW FREE AIR FLOW
C
C   IF WPLRH IS SMALLER THAN THE NET FORCED VENTILATION OUTFLOW
C   THROUGH CEILING, THEN THERE WILL NOT BE ANY HGL FORMED
C
      IF (WPLRH.GE.WVOUT) GOTO 500
C
C   ELSE, ONLY CEILING JET WILL BE PRESENT AND A WARNING MESSAGE
C   WILL BE PRINTED
C
 800  WIN = WPLRH
      DG = 0.
      ZD = RHGT - Z0A
      TG = TPLRH
      WRITE(NWRITE, 710)
 710  FORMAT(3X,49H*********** WARNING:  HOT GAS LAYER DOESNOT FORM,
     1        37H DUE TO STRONG FORCED AIR VENTILATION,
     2       /, 26X, 45H ARTIFICIAL SOLUTION IS PROVIDED  ***********)
      GOTO 9000
C
C   IF HGL IS FORMED, THE ONLY POSSIBLE STEADY STATE WILL BE ACHIEVED
C   IS WHEN THE WHOLE ROOM IS FILLED UP WITH HOT GAS
C
 500  ZD = 0.
      DG = RHGT
C
C   THE SIDE WALL AREA WILL BE LARGE COMPARE TO THE CEILING
C   THEREFORE, THE ROOM SURFACE AREA IS RESPONSIBLE FOR HEAT
C   TRANSFER INSTEAD OF CEILING ONLY
C
C   AN EXTRA AMOUNT OF HOT GAS WILL FLOW OUT OF THE ROOM DUE TO
C   PRESSURE DIFFERENT   MEXTRA + WVOUT = TMDOT + MVIN
C                                       = TMDOT + CFV/RTEMP
C
C   THE ROOM IS ASSUMED TO BE RECTANGULAR IN SHAPE
C   IF OTHER SHAPE IS CONSIDERED, THE FOLLOWING STATEMENT
C   HAS TO BE CHANGED ACCORDINGLY
C
```

```
      RAREA = ACEIL + AWALL
      A1 = (HCEIL*RAREA + 2.*1.E3*(TMDOT + CFV/RTEMP))/RADCON/RAREA
      A2 = (-TQDOTC - TCEIL*HCEIL*RAREA - RADCON*RAREA*TCEIL**4
     1     - 2.*1.E3*(TMDOT + CFV/RTEMP))/RADCON/RAREA
      TG = RADEQ(A1, A2)
      WIN = TMDOT + CFV/RTEMP
      GOTO 9000
C
C   THE FOLLOWING PROCEDURES ARE TO BE EXECUTED WHEN OPENINGS ARE
C   LARGE ENOUGH TO PROVIDE FREE AIR VENTILATION
C
C   SINCE TG > RTEMP, FH MUST BE GREATER THAN FC TO GIVE WVOUT > 0
C   OTHERWISE STATEMENT 6000 WILL BE EXECUTED WITHOUT TESTING THE
C   FOLLOWING CONDITIONS.
C
 4000 IF ((FC.GT.FH).OR.(VFV.LT.1.E-3)) GOTO 6000
      IF (FH.EQ.0.) GOTO 6000
C
C   WITH THE PRESENT OF FORCED VENTILATION, THE NEUTRAL PLANE OF
C   THE HOT GAS LAYER MAY BE FORMED IN THE DOOR SOFFIT REGION
C
C   WPLDH = PLUME MASS FLOW AT ZD=DHGT-Z0A
C
      WPLDH = PLUCON*(DHGT - Z0A)**(5./3.)
      WVOUT1 = CFV*(FH/TGMAX - FC/RTEMP)
      IF (WPLDH.GE.WVOUT1) GOTO 6000
C
C   IF WPLDH > WVOUT1 THEN THE HGL FORMS UNDER THE DOORWAY(GOTO 6000)
C   ELSE HGL EITHER FORMS IN THE DOOR SOFFIT REGION OR
C   DOES NOT FORM AT ALL
C
      IF (WPLRH.GE.WVOUT) GOTO 5000
C
C   ELSE, ONLY CEILING JET WILL BE PRESENT AND A WARNING MESSAGE
C   WILL BE PRINTED
C
      GOTO 800
C
C   NEUTRAL PLANE FORMS AT DHGZRHGT
C
 5000 TG = TGMAX
      ZD = (WVOUT1/PLUCON)**0.6 + Z0A
      DG = RHGT - ZD
      WIN = WVOUT1
      WRITE(NWRITE, 720)
 720  FORMAT(3X,48H***********  WARNING:  HOT GAS LAYER FORM IN THE,
     1   56H DOOR SOFFIT REGION DUE TO STRONG FORCED AIR VENTILATION,
     2       /, 26X, 45H ARTIFICIAL SOLUTION IS PROVIDED  ***********)
      GOTO 9000
C
C   WHEN THE ABOVE CONDITIONS DO NOT HOLD, THEN THE HGL FORMS AT
C   DHGT>ZD>0.
C
C   2/3*1.18*(19.8)**.5 = 3.483
```

```
C
 6000 FLOCON = 3.483*DWID*SQRT(RTEMP)
C   INITIAL GUESS VALUE IS CHOSEN TO SOLVE FOR THREE NON-LINEAR
C   SIMULTANEOUSLY EQUATIONS
C
      TGLOW = RTEMP + (TGMAX - RTEMP)/10.
C
C   SUBROUTINE CNEWTN IS CALLED TO SOLVE FOR THE MINIMUM ALLOWABLE
C   HOT GAS LAYER TEMPERATURE
C
      CALL CNEWTN(TGLOW,1,TGMAX,RTEMP,NWRITE)
      IF (LEND) GOTO 9900
      IF (LSMALL) GOTO 8000
      IF (TGLOW.LT.RTEMP) TGLOW = RTEMP
C
C   SECOND GUESS VALUE IS ASSIGNED TO CALCULATE THE HOT GAS LAYER
C   TEMPERATURE
C
      TG = TGLOW + 5.
C
C   SUBROUTINE CNEWTN IS CALLED TO SOLVE FOR THE HOT GAS LAYER
C   TEMPERATURE BY SOLVING THE MASS BALANCE EQUATION OF THE HOT GAS
C   LAYER USING EITHER NEWTON-RAPHSON OR BISECTION METHOD
C
      CALL CNEWTN(TG,2,TGMAX,TGLOW,NWRITE)
      IF (LEND) GOTO 9900
      IF (LSMALL) GOTO 8000
C
C   THE FINAL ESTIMATE OF THE HOT GAS LAYER PROPERTIES IS COMPUTED:
C
      CALL CGASHT(TG,ZN,ZD)
      IF (LSMALL) GOTO 8000
      WFL = PLUCON*ZD**(5./3.)
      WIN = WFL
      DG = RHGT - ZD - Z0A
      GOTO 9000
 8000 WIN = WPLRH
      DG = 0.
      ZD = RHGT - Z0A
      TG = TPLRH
      WRITE(NWRITE, 8010)
 8010 FORMAT(3X,49H*********** WARNING:  HOT GAS LAYER DOESNOT FORM,
     1       24H DUE TO WEAK FIRE SOURCE,
     2       /, 26X, 45H ARTIFICIAL SOLUTION IS PROVIDED  ***********)
 9000 IF (WIN.LE.0) WIN = (1. - FC)*CFV/RTEMP + TMDOT
      IF (TG.LT.RTEMP) TG = RTEMP
C
C  QCEIL HAS BEEN CHANGED TO ACCOMODATE THE INTRODUCTION OF GAS
C  EMMISSIVITY AND THE ASSUMPTION OF GREY GAS PROPERTIES
C
C  OLD VERSION:
C     EX1 = EXP(-1.5*GABSRP*DG)
C     QCEIL = 5.6697E-8*(EPS*EX1*TCEIL**4 C    1        (1.-
FL*EX1)*TG**4) + WREFL*QEXTC*EX1**2
C
```

```
C  NEW VERSION:
C
      GTRANS = 1. - GEMS
      QCEIL = RADCON*GTRANS*TCEIL**4 + (GEMS*5.6697E-8*(1.
     1        GTRANS) - RADCON*GTRANS)*TG**4
     2        QEXTC*(1. - RADCON/5.6697E-8)*GTRANS**2
 9900 RETURN
      END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C  SUBROUTINE CNEWTN PERFORMS THE ACTUAL NEWTON-RAPHSON ITERATION      -
C  SCHEME TO SOLVE FOR THE REQUIRED ESTIMATION OF THE HOT GAS LAYER    -
C  PROPERTIES.     BISECTION METHOD WILL BE EMPLOYED IF THE UPDATED    -
C  ESTIMATON IS OUT OF THE PERMISSIBLE BOUNDARIES                      -
C                                                                      -
C-----------------------------------------------------------------------
      SUBROUTINE CNEWTN(TGUESS, IEQN, TMAX, TMIN, NWRITE)
      IMPLICIT LOGICAL (L)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
C
C  IF TGUESS IS OUT OF BOUND, BISECTION METHOD IS USED
C
      IF ((TGUESS.GE.TMAX).OR.(TGUESS.LE.TMIN))
     1     TGUESS = (TMAX + TMIN)/2.
      ICOUNT = 0
      DO 8000 I=1,30
      ICOUNT = ICOUNT + 1
      CALL CSOLVE(TGUESS,FTG,DFTG,IEQN,NWRITE)
      IF (LEND.OR.LSMALL) GOTO 9000
      DELTAX = FTG/DFTG
      TGNEW = TGUESS - DELTAX
      LTEST = .FALSE.
      IF ( TGNEW.LT.TMAX) GOTO 1500
      LTEST = .TRUE.
C
C  IF LTEST = TRUE THEN BISECTION METHOD WILL BE USED TO SOLVE FOR
C  THE REQUIRED ROOT
C
      TGNEW = (TGUESS + TMAX)/2.
 1500 IF (TGNEW.GT.TMIN) GOTO 2000
      LTEST = .TRUE.
      TGNEW = (TGUESS + TMIN)/2.
 2000 IF (ABS(TGUESS - TGNEW).LE.0.1) GOTO 9000
      TGUESS = TGNEW
      IF (ICOUNT.EQ.30) GOTO 8500
      IF (LTEST.OR.(ABS(DELTAX).GT.0.1)) GOTO 8000
      RETURN
 8000 CONTINUE
 8500 WRITE(NWRITE, 8600)
 8600 FORMAT(/,43H*********WARNING: CONVERGENCE LIMIT EXCEEDS,
```

```
    1       47H, SOLUTION PROVIDED IS THE BEST-GUESS**********)
 9000 RETURN
      END
```

```
C---------------------------------------------------------------------
C                                                                    -
C   SUBROUTINE CSOLVE COMPUTES F(ZN-ZD) AND DF(ZN-ZD)/DTG WHICH ARE  -
C   USED TO CALCULATE THE MINIMUM ALLOWABLE HOT GAS LAYER TEMPERATURE, -
C   OR F(TG) AND DF(TG)/DTG WHICH ARE USED TO SOLVE FOR THE HOT GAS  -
C   LAYER TEMPERATURE.  THE DERIVATIVE OF THE CORRESPONDING FUNCTIONS -
C   ARE COMPUTED BY USING THE FIRST PRINCIPLE OF DIFFERENTIATION:    -
C   LIM (F(H+DH) - F(H-DH))/2DH = DF/DH                              -
C                                                                    -
C---------------------------------------------------------------------
      SUBROUTINE CSOLVE(TSOLVE, FN, DFN, IEQN, NWRITE)
      IMPLICIT LOGICAL (L)
      DIMENSION TGUESS(3), ZDTG(3), ZNTG(3), DWIN(3), DWOUT(3), CTGFN(3)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
      DELTA = 1.E-2
      TGUESS(1) = TSOLVE
      TGUESS(2) = TSOLVE - DELTA
      TGUESS(3) = TSOLVE + DELTA
      DO 100 I=1,3
      CALL CGASHT(TGUESS(I),ZNTG(I),ZDTG(I))
      IF (LSMALL) GOTO 5000
 100  CONTINUE
C
C  IF IEQN = 1 THE SUBROUTINE COMPUTES F(ZN - ZD)
C  IF IEQN = 2 THE SUBROUTINE COMPUTES F(TG)
C
      IF (IEQN.EQ.2) GOTO 1000
C
C  SOLVE FN = ZN(TG) - ZD(TG) = 0
C
      FN = ZNTG(1) - ZDTG(1)
      DFN = (ZNTG(3) - ZDTG(3) - ZNTG(2) + ZDTG(2))/(2.*DELTA)
      RETURN
 1000 DO 1100 I=1,3
C
C  SOLVE CTGFN = SUMIN + TMDOT - SUMOUT
C
      IF (ZNTG(I).LT.ZDTG(I)) GOTO 2000
      DWIN(I) = DCFIN*FLOCON*SQRT((1./RTEMP - 1./TGUESS(I))*(ZNTG(I)
     1          - ZDTG(I)))*(ZNTG(I) + .5*ZDTG(I))
      DWOUT(I) = DCFOUT*FLOCON*SQRT(1./TGUESS(I) - RTEMP/TGUESS(I)**2)
     1           *(DHGT - ZNTG(I))**1.5
```

```
1100 CTGFN(I) = DWIN(I) + TMDOT - DWOUT(I) + FH*CFV*(1./RTEMP -
    1   1./TGUESS(I))
     FN = CTGFN(1)
     DFN = (CTGFN(3) - CTGFN(2))/(2.*DELTA)
     RETURN
2000 LEND = .TRUE.
     WRITE(NWRITE, 3000)
3000 FORMAT(/,53H**********WARNING: ZD, ZN GOES OUT OF BOUNDS IN CSOLVE,
    1      33H, EXECUTION TERMINATED**********)
5000 RETURN
     END
```

```
C-----------------------------------------------------------------------
C                                                                      -
C   SUBROUTINE CGASHT FINDS THE CURRENT ZN AND ZN IN TERMS OF THE      -
C   CURRENT HOT GAS LAYER TEMPERATURE                                  -
C                                                                      -
C-----------------------------------------------------------------------
      SUBROUTINE CGASHT(TGUESS, ZNTG, ZDTG)
      IMPLICIT LOGICAL (L)
      COMMON /ALL/ ACEIL, AWALL, CALTEM, DELT, FCTR(15), FLCF, HROOM,
     1             RTEMP, TIME, TITLE(20),
     2             ICEIL, IJOB, INCHCK, INITG, IOUTPT, MOUTPT(17),
     3             LEND, LROOM
      COMMON /GAS/ CFV, CVENT, DCFIN, DCFOUT, DG, DHGT, DWID,
     1             FC, FH, FLOCON, GABSRP, GEMS, HCEIL, PLCF, PLUCON,
     2             RADCON, TG, VFV, WHEAT, ZD, ZN,
     3             LSMALL
      COMMON /VENTC/ AFUEL, AFUELO, CVA, CVAO, QMAX,
     1               QTOT, QTOTO, QTOT1, QTOT2, TMDOT, TMDOTO,
     2               TMDOTS, TQDOT, TQDOTC, WIN, ZOA,
     3               NBURN, NBURNO,
     4               LDECAY, LFLUX1, LFLUX2, LVENT, LVCONT
C
C   THE HEIGHT OF THE PLANES ARE FOUND AS A FUNCTION OF HOT GAS TEMPERATURE
C
      QGAIN = TQDOTC - ACEIL*HCEIL*TGUESS - ACEIL*RADCON*TGUESS**4
     1        + WHEAT
      IF ((QGAIN.LE.10.).OR.(TGUESS.LE.RTEMP)) GOTO 50
      WDOUT = QGAIN/1.E3/(TGUESS - RTEMP) - CFV*(FH/TGUESS + FC/RTEMP)
      IF (WDOUT.LT.0.) GOTO 50
      ZDTG = (WDOUT/PLUCON)**0.6
      ZNTG = DHGT - (WDOUT/DCFOUT/FLOCON/SQRT(1./TGUESS
     1       - RTEMP/TGUESS**2))**(2./3.)
      RETURN
 50   LSMALL = .TRUE.
      RETURN
      END
```

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16. ABSTRACT (200 words or less)

The computer code COMPBRN III deterministically models the behvior of compartment fires. This code is an improvement of the original COMPBRN codes. It employs a different air entrainment model and numerical scheme to estimate properties of the ceiling hot gas layer model. Moreover, COMPBRN III incorporates a number of improvements in shape factor calculations and error checking, which distinguish it from the COMPBRN II code. This report presents the ceiling hot gas layer model employed by COMPBRN III as well as several other modifications. Information necessary to run COMPBRN III, including descriptions of required input and resulting output, are also presented. Simulation of experiments and a sample problem are included to demonstrate the usage of the code.

17. KEY WORDS AND DOCUMENT ANALYSIS

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17b. IDENTIFIERS/OPEN ENDED TERMS

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