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Calculating Available Safe Egress Time (ASET) - A Computer Program and User's Guide

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Fire Research
Washington, DC 20234

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Final Report

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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A	area of enclosure
ASET	Available Safe Egress Time
$\dot{C}$	rate of generation of a combustion product
H	height of enclosure ceiling above fire
M	concentration of a combustion product
$\dot{Q}$	rate of fire's energy release
RSET	Required Safe Egress Time
T	temperature
t	time
t_{DET}	time at detection
t_{HAZ}	time at onset of hazardous conditions
u_c	dimensional unit of a product of combustion
Z_i	elevation of interface
Δ	height of fire above floor
λ_c	fraction of $\dot{Q}$ transfered to enclosure surfaces
λ_r	fraction of $\dot{Q}$ radiated from combustion zone

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* In this paper, the symbol Ø, appearing in a variable name, will be used to indicate the number 0, and the symbol O, appearing in a variable name, will be used to indicate the letter O.

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Abstract

In the event of a fire in a building compartment the time available for occupants to safely evacuate the compartment, the Available Safe Egress Time (ASET), depends on the time of fire detection and on the time of the onset of hazardous conditions. In order to estimate these two times a dynamic simulation of the developing fire environment in the compartment is required. Also required are specific criteria for the simulation of detection and onset of hazard. A user oriented computer program which carries out the required simulations and provides estimates for the ASET has been developed. This document provides a listing of the program and a manual for its use. For fire growth in a particular fuel assembly, a single program run can be used to evaluate the ASET from enclosures (which are assumed to contain the fuel assembly) of different heights and areas, and under a variety of different detection and hazard criteria. The program can be used in either an interactive or batch mode. It is written in ANSI FORTRAN and requires no computer specific subroutines.

KEY WORDS: Combustion products; compartment fires; egress; fire detection; fire growth; hazard analysis; mathematical models; room fires; smoke movement; tenability limits.

1. INTRODUCTION

1.1 Background

The concept of life safety in buildings through designed safe egress has been introduced in references [1]-[4]*. The basic idea of the concept is that occupants of a building will be safe under fire conditions provided they will be able to successfully egress from threatened spaces prior to the time, t_{HAZ}, when hazardous conditions start to prevail. It is evident that occupants can only be expected to initiate an egress activity subsequent to the time, t_{DET}, of detection of the fire. The Available Safe Egress Time (ASET) is, therefore, simply computed as the time interval between detection and the onset of hazard. Thus, ASET = $t_{HAZ} - t_{DET}$.

If a building design is to be considered safe, from this standpoint the ASET from each of the building spaces which may be threatened must be longer than the time actually required for people to successfully evacuate these spaces. These latter time intervals are referred to as the Required Safe Egress Times (RSET). Thus, according to the Designed Safe Egress concept, in the event of a fire a building is safe if ASET > RSET for all threatened spaces.

A general methodology for computing the ASET was discussed in reference [1] and [4]. The basic outline of the methodology is:

1. Identify the burning characteristics of fuel assemblies (combustible contents) exposed to likely ignition scenarios which are typical of the occupancy of interest. Provide a physical description of the building spaces.

*Numbers in brackets refer to literature references at the end of this paper.

2. Use an appropriate enclosure fire model to simulate analytically the dynamic environment which evolves in each building space.

3. Identify criteria for fire detection and onset of hazard. These would be compatible with the characteristics of existing detection hardware and the characteristics of likely building occupants, respectively.

4. Apply the criteria of No. 3 to the computed environment of No. 2, and thereby estimate t_{DET} and t_{HAZ} for the threatened spaces. Compute ASET = $t_{HAZ} - t_{DET}$.

For a single compartment of fire origin, a simple enclosure fire model which could be used in the above computation procedure was presented in [1] and [2]. A user oriented computer program which carries out the procedure with this model has been written. It is the purpose of this document to provide a listing of the program and a manual for its use.

The computer program described here can be used to study many features of enclosure fires. However, the program was specifically designed to answer questions related to life safety in fires. For this reason this work makes frequent use of terminology derived from the word "hazard." In this regard, it is not the intent of the authors to ascribe any precise definition to this terminology, and in many cases it would have been possible to have substituted terminology derived from words such as "untenable," "risk," etc. Hopefully the meaning of the "hazard" terminology will be clear from the context of its use.

1.2 Some Basic Enclosure Fire Phenomena

To use the program successfully, a user should be familiar with some basic enclosure fire phenomena. These are illustrated in figure 1.

A fire is initiated in a fuel assembly which is contained by an enclosure whose ceiling is a distance H above the base of the fire, and whose area is A. The base of the fire is a distance, Δ, above the floor. An estimate of the total energy release rate of the fire, $\dot{Q}$, as a function of time, t, is assumed to be available, as is the fire's generation rate $\dot{C}$ of a product of combustion of interest (e.g., for the purpose of establishing detection or hazard). In practice it is recommended that the free burn energy release rate and product generation rate be used as surrogates for $\dot{Q}$ and $\dot{C}$, respectively. (An estimate of these free burn characteristics will be the basis of a portion of the program input data.) In this paper, free burn is defined as "a burn of the fuel assembly in a large (compared to the combustion zone) ventilated space which contains a relatively quiescent atmosphere."

As the fire develops from ignition, buoyancy forces drive the high temperature products of combustion upward toward the ceiling. In this way a plume of upward moving elevated temperature gases is formed above the fire. All along the axis of the plume, relatively quiescent and cool ambient air is laterally entrained and mixed with the plume gases as they continue their ascent to the ceiling. As a result of this entrainment the total mass flow rate in the plume continuously increases, and the average temperature and average concentration of products of combustion in the plume continuously decreases with increasing height.

When the plume gases impinge on the ceiling, they spread across it forming a relatively thin, stably stratified upper layer. As the plume gas upward filling process continues, the upper gas layer grows in depth, and the relatively sharp interface between it and the cool ambient air layer, below continuously drops.

In the model being used to describe the above phenomena it is assumed that at every instant of time a fully mixed upper gas layer is a reasonable approximation to the actual state of affairs. Accordingly, the model provides a time-dependent description of the environment in the enclosure by predicting the elevation, $Z_i(t)$, of the interface (or the upper layer thickness), the upper layer temperature, $T(t)$, and the combustion product concentration, $M(t)$. It is with the use of the computed histories of these variables and with required input data, to be described below, that the computer program proceeds to establish and invoke appropriate hazard and detection criteria.

1.3 An Overview of the Computer Program

In the computer program, input data describing the fire's elevation, and energy and product of combustion generation rates are used together with enclosure size (height and area) and user specified detection and hazard criteria to determine t_{DET}, t_{HAZ}, and the ASET. The ambient temperature at the initiation of all fire scenarios is taken to be 21.1°C (70°F).

For detection criteria, the user can specify a detectable upper smoke layer temperature, rate-of-temperature rise or concentration of a detectable product of combustion. Instantaneous detection may be specified by inputing a zero or "small" detectable upper smoke layer temperature or rate-of-temperature rise.

When the smoke layer interface is above some characteristic, user-specified face elevation, hazard is assumed to occur if and when a hazardous radiation exposure from the upper layer is attained. Such an exposure is defined by a critical, user-specified, upper layer temperature. If the interface is below face elevation, then hazard is assumed to occur if and when a second, critical, user-specified upper layer temperature is attained. However, the latter critical temperature would be lower than the former one, and hazardous conditions are now initiated as a result of direct burns or inhalation of hot gases. When the interface has dropped below face elevation, hazard is also assumed to occur if and when a critical, user-specified concentration of some hazardous product of combustion is attained.

The program allows the user to model the energy generation rate of the fire (fire growth) by either one of two methods. The first method uses continuous, user-specified, exponential growth curve segments. The other method uses pairs of user-specified data points (energy generation rate, time) with linear interpolation between them. Either of these methods would be used to describe the time-varying energy release rate of the free burning fuel assembly whose hazard is being evaluated. There would be different types of data inputs required depending on which model is chosen.

The computer program allows the user to model a product of combustion generation rate of the fire by one of two methods. The model of the first method is defined by an unchanging, user-specified constant of proportionality between the product of combustion generation rate and the previously specified energy generation rate. The other method uses pairs of user-specified data points (product generation rate, time) with linear interpolation between them. The product generation rate is specified in units of u_c per unit time, where u_c is a dimensional unit appropriate for the particular product. For example, u_c could have the dimension of mass, number of particles, etc.

The program has a capability of modeling up to two different product of combustion species, and of simulating their respective upper layer concentrations. The first of these is a product whose upper layer concentration would be the basis of a detection criterion, and the second is a product whose concentration would be the basis of a hazard criterion. In general, the fire's generation rate of each of these products would be modeled differently, according to either of the two methods described above, and each with its appropriate u_c.

For a user specified fire type and elevation above the floor, a single computer run of the program can be used to evaluate the ASET which corresponds to each of a multiple number of enclosure sizes and pairs of detection and hazard criteria.

By solving the mathematical fire modeling equations outlined in reference 2, the program simulates the changing environment (thickness, temperature, and product concentration of the smoke layer) in the enclosure. At every time step into the simulation, the prevailing conditions in the space are checked against the detection and hazard criteria being invoked. In this way the times t_{DET} and t_{HAZ}, corresponding to every room geometry and to each pair of detection and hazard criteria, are eventually identified. The ASETs are computed and displayed in the computer output along with other potentially useful results of the computations. Each simulation continues in time until the onset of hazard or until a maximum, user-specified time is attained. If detection has not occured by the time of the onset of hazard in a given simulation, then detection is assumed to occur simultaneously with onset of hazard, and the computed ASET is zero.

1.4 Some Assumptions and Limitations

The assumptions and limitations of the fire model are presented and discussed in [1] and [2]. The user of the program is referred to those references for a complete treatment of the concepts and equations used in the development of this computer program. A few of the more significant of the assumptions and limitations are:

1. The computer model may not be reliable when applied to enclosures with length-to-width aspect ratios greater than 10:1, or with a ratio of height to minimum horizontal dimension exceeding one.

2. All doors, windows, and other significant partition penetrations to adjacent spaces are assumed to be closed. However, prior to the onset of hazardous conditions, sufficient oxygen is assumed to be available for free-burning combustion.

3. The enclosure is assumed to be divided into two horizontal layers with a sharp interface separating an elevated temperature, products of combustion contaminated "smoke" mixture above, from cool ambient air below. The upper layer is assumed to be uniformly mixed. The computer model is not reliable once the upper layer temperature exceeds a level of approximately 350-450°C, at which time radiation feedback to the fuel will significantly alter the initial free-burn-like behavior of the fire.

4. Some leakage from the room is inevitable. This leakage is assumed to occur through leakage paths close to the floor. Thus, at least up to the time that the interface drops to the floor, it is assumed that the enclosure will leak cool ambient air at low elevation rather than, say, elevated temperature products of combustion at a near-ceiling elevation.

2. DESCRIPTION OF THE INPUT DATA

2.1 General Comments

This program has been designed to be useable in either an interactive or batch mode. When in the interactive mode, the program guides the user through the data input process.

The data input has been divided into the following seven elements:

General Data

Detection Criteria

Hazard Criteria

Room Characteristics

Fire Data: Energy Generation Rate

Fire Data: Detectable Product of Combustion Generation Rate

Fire Data: Hazardous Product of Combustion Generation Rate

The input data described here will be the same for both the interactive and batch modes. Extra input data may be required in the interactive mode to answer error check and "Pause" questions. The basic required input data are described in detail in the next seven sections. Each line started by CARD indicates a line of input data at a computer terminal or a computer punch card. Where the CARD is followed by (S), this indicates that there may be more than one card or line used if necessary. Numerical values should be placed as indicated by their variable names. Unless otherwise stated, this data may be entered unformatted, that is, numbers do not have to be placed in specific card columns. Different numerical values entered on the same computer punch card or line (at a computer terminal) must be separated by either a comma or a blank. When information is contained in parentheses on the CARD line, this indicates the range of values which may be substituted for the particular variable. The data is described in the order in which it must be entered into the program.

This last card in the general data group should contain four values. There should be one value for each of the above variables. A determination of the appropriate values to substitute for these variables must be made by the user.

ALAMR is the parameter λ_r of [2]. As defined above, it is the fraction of the fire's energy release rate which is instantaneously lost by radiation from the combustion zone. The value $(1-\lambda_r)$ is used in the program to determine the fraction of the energy release rate which effectively acts to drive the fire plume's upward momentum. In [2] it is concluded that $\lambda_r = 0.35$ is a reasonable choice for typical, hazardous, flaming fires.

ALAMC is the parameter λ_c of [2] and [4], and it is defined as the instantaneous fraction of the energy release rate which is lost to the bounding surfaces of the room and its contents. The total rate of energy loss which is characterized by λ_c occurs as a result of a variety of different convective and radiative heat transfer exchanges between the room's gases and the above mentioned surfaces. It is not presently possible to obtain an exact value for λ_c. (Indeed, although λ_c is taken as a constant, it is, in fact, a time-varying parameter.) However, using $\lambda_r = 0.35$, it is concluded in the Appendix of [4] that during the early stages of fires in single rooms the value of λ_c is relatively constant and in the range 0.6 - 0.9. The lower, 0.6 value, would relate to high aspect ratio spaces (ratio of ceiling span to room height) with smooth ceilings and with fires positioned far away from the walls. The intermediate values and the high, 0.9 value for λ_c would relate to low aspect ratio spaces, fire scenarios where the fire position is within a room height or so from walls, and/or to spaces with highly irregular ceiling surfaces. Some further guidelines on an appropriate choice for the value of λ_c are presented in [2].

The user must specify a value for ZEYEF, the characteristic height, in feet, of eyelevel from the floor. This value is important because it has significant effect on how and when hazard occurs. When the smoke layer interface is above eyelevel (or facelevel), hazard could occur due to downward directed radiation produced by an excessively high smoke layer temperature which exceeds some critical temperature (to be specified below). When the smoke layer interface is below eye elevation, then hazard could occur due to inhalation of gases with an excessive concentration of some hazardous product of combustion or due to direct burns and inhalation of hot gases whose temperature exceeds a second critical upper layer temperature. The latter critical temperature would be lower than the former one. The specified value for ZEYEF does not necessarily have to be the "true" height of eyelevel, but its value must be chosen as not greater than the room height or less than zero. An appropriate value would be one which indicates a likely change in potential mode of hazard initiation from radiation from the upper layer to visual obscuration.

The value specified for DELTA, the height, in feet, of the base of the fire above the floor should be according to the user's understanding of the physical conditions under investigation.

2.3 Detection Criteria

CARD(S):TMDSPF(I)

TMDSPF - the upper layer temperature, in degrees F, which will initiate detection.

2.2 General Data

CARD: TITLE

This card should contain the title for the run. It may be any string of up to 80 characters which describes the particular computer run.

CARD: WRC (WRC = 1, 2, 3 or 4)

WRC = 1, summary output. Only the fire environment characteristics at detection and hazard, and egress time will be printed. (132 characters per line)

WRC = 2, summary output. (80 characters per line)

WRC = 3, full output. The time-temperature-layer thickness-rate of rise-concentration history will be printed along with summary output. (132 characters per line)

WRC = 4, full output. (80 characters per line)

The write code, or output code, is used to determine whether full or only limited output should be printed. The write code will be an integer value of 1, 2, 3, or 4. It should be chosen based on the amount of information the user desires and the printing capability of the user's computer. If a 1 is selected, summary output, which includes the times of detection and hazard, descriptions of the room environments at these times, and the ASET from the space, will be printed. The enclosure environment descriptions include the temperature, thickness, products of combustion concentrations and interface elevation of the smoke layer. In addition, the detection and hazard criteria being considered are printed along with the height and area of the room. This information will be printed using 132 characters per line. Output form 2 will print the same information using 80 characters per line. If output form 3 is chosen, then in addition to summary output the entire history of the fire will be printed. In this case, the state of the fire environment is displayed at specified instants of time which span the entire time frame of the simulation. In particular, at five second intervals the computed values of the fire's energy generation rate (normalized by the rate at ignition if desired) and the smoke layer's thickness, interface elevation, temperature, rate-of-temperature rise and combustion product concentrations are provided in a single line of output. This line will be 132 characters long. Output type 4 will print the same information as type 3, but the lines will be 80 characters long.

CARD: ALAMR, ALAMC, ZEYEF, DELTA

ALAMR - the fraction of the fire's energy generation rate instantaneously lost by radiation from the combustion zone and plume.

ALAMC - the fraction of the fire's energy generation rate instantaneously lost to the bounding surfaces of the room and its contents.

ZEYEF - the specified characteristic height, in feet, of eyelevel from the floor.

DELTA - the height, in feet, of the base of the fire above the floor.

CARD(S):RRDSPF(I)

RRDSPF - the upper layer rate-of-temperature rise, in degrees F per minute, which will initiate detection.

CARD(S):CNDS(I)

CNDS - the concentration of the detectable product of combustion, in units of u_c per gram of bulk upper layer gas, which will initiate detection. (See discussion below under Fire Data: Detectable Product of Combustion Generation Rate.)

Any or all of the above detection criteria may be used, and there may be from zero to as many as ten different values entered for each mode of detection. Use of at least one criterion and one entry is required. (Note that one possible way of specifying immediate detection, i.e., detection at the time of ignition, is to specify detection when the smoke layer's rate-of-temperature rise exceeds zero degrees F per minute.) When using a computer terminal, input each value separately until all desired values for a particular detection mode have been entered. When all values for a particular mode of detection have been entered, type an end of file mark (UNIVAC: @EOF). If data is to be entered using cards, type each value on a different card. A card containing an end of file mark should separate each set of values for a particular detection criterion.

The program uses the elements of the list of input values for each detection mode, one at a time, to determine the time of detection in a given fire scenario.

2.4 Hazard Criteria

CARD(S):TMHSUF(I)

TMHSUF - the hazardous temperature, in degrees F, of the smoke layer when the interface is above eyelevel.

CARD(S):TMHSLF(I)

TMHSLF - the hazardous temperature, in degrees F, of the smoke layer when the interface is below eyelevel.

CARD(S):CNHS(I)

CNHS - the concentration of the hazardous product of combustion, in units of u_c per gram of bulk upper layer gas, which will initiate a hazardous condition when the interface is below eyelevel.

A minimum of one and a maximum of ten different values may be entered for each of the three modes of hazard. All combinations of the hazard mode entries will be considered, and each of the combinations will be used, one at a time, to determine the time to hazard in a given fire scenario. For example, assuming one entry for TMHSUF, three entries for TMHSLF, and two entries for CNHS, then one of the six (1 x 3 x 2 = 6) overall criteria for hazard that will be invoked will be:

Onset of hazard occurs when

the upper layer temperature is greater than TMHSUF(1), AND the layer interface elevation is greater than ZEYEF, OR the upper layer temperature is greater than TMHSLF(2), AND the layer interface elevation is less than ZEYEF,

OR the upper layer concentration of the combustion product is greater than CNHS(2), AND the layer interface elevation is less than ZEYEF.

Hazard criteria input data should be entered in the same way as detection criteria input data, with each of the three lists of hazard mode entries terminating with an end of file mark (UNIVAC: @EOF).

The critical temperature values assigned by the input TMHSUF(I) are directly related to those temperatures of overhead smoke layers which would supply a potentially hazardous flux of downward directed thermal radiation. A TMHSUF value of 361, i.e., 183°C (361°F), has been recommended in [1]. Assuming that an upper layer radiates as a black body and with a view factor of 1, this temperature would correspond to a flux of 2.5 kW/m^2, which has been identified as a flux level near the threshold of human tenability [5].

Once the interface is below "eyelevel", the new critical upper layer temperature, input as TMHSLF, will generally be significantly less than TMHSUF. Hazard would now occur on account of direct external or internal (due to inhalation of hot gases) burns. Realistic values of TMHSLF would likely be of the order of 212, i.e., 100°C (212°F).

With the interface below eyelevel, hazard could also occur as a result of a high concentration (in excess of the critical value, CNHS) of the hazardous product of combustion, e.g., on account of the product's toxicity. If one does not wish to invoke this aspect of the overall hazard criterion, then at this stage of the input the user simply enters any single positive value for CNHS. At the appropriate place, to be described below, the user would then enter input data that models the hazardous product generation rate as identically zero.

2.5 Room Characteristics

CARD(S):HF(I)

HF - the height, in feet, of the compartment

CARD(S):SF(I)

SF - the floor area, in square feet, of the compartment

At least one height and one area must be specified. The program can handle as many as twenty room heights and thirty areas during one run, and rooms defined by all combinations of the HF(I) and SF(I) entries are evaluated.

The room data should be entered in the same way as the detection and hazard data, with each of the HF and SF entry lists terminating with an end of file (UNIVAC: @EOF).

2.6 Fire Data: Energy Generation Rate

The first card in this fire data series determines how the energy generation rate of the fire, $\dot{Q}(t)$, will be modeled and what input data will be required. The variable FIRE may be assigned an integer value of 1, 2, or 3. Two types of fire growth models, requiring different forms of input data, have been included in the computer program. The third available location (FIRE = 3) has been left so that a user can add another fire modeling subroutine, if desired.

CARD:FIRE (FIRE = 1, 2, or 3)

FIRE = 1, a multi-exponential energy generation rate curve made up of NSEGQ continuous segments of the form:

$$\dot{Q}(t) = \begin{cases} Q(1)\exp\{AKAP(1)t\}, \text{ 1st segment,} \\ \quad 0 \leq t < TAUQ(1); \\ Q(2)\exp\{AKAP(2)[tTAUQ(1)]\}, \text{ 2nd segment,} \\ \quad TAUQ(1) \leq t < TAUQ(2); \\ \quad \vdots \\ Q(NSEGQ1)\exp\{AKAP(NSEGQ1)[tTAUQ(NSEQ-2)]\}, \text{ (NSEGQ1)segment,} \\ \quad TAUQ(NSEGQ2) \leq t < TAUQ(NSEGQ1); \\ Q(NSEGQ)\exp\{AKAP(NSEGQ)[tTAUQ(NSEGQ1)]\}, \text{ NSEGQth segment,} \\ \quad TAUQ(NSEGQ1) \leq t \end{cases}$$

where the NSEGQ values, Q(1), Q(2), . . . , Q(NSEGQ), and the NSEGQ values, AKAP(1), AKAP(2), . . ., AKAP(NSEGQ) are supplied as input.

FIRE = 2, an energy generation rate curve made up of NSEGQ continuous linear segments. The curve would be defined by

$$\dot{Q}(t) = \begin{cases} Q\emptyset \text{ at } t = 0; \\ Q(1) \text{ at } t = TAUQ(1); \\ \vdots \\ Q(NSEGO) \text{ at } t = TAUQ(NSEQO) \end{cases}$$

with linear interpolation between the above NSEGQ + 1 data points. As described below, QØ and the NSEGQ pair of values TAUQ(1), Q(1); TAUQ(2), Q(2); . . .; TAUQ(NSEGQ), Q(NSEGQ) are supplied as input.

FIRE = 3, not used (space left available for a user developed subroutine describing the fire's energy generation rate).

Multi-exponential curve:

If a multi-exponential energy generation rate curve is selected (FIRE = 1), then the following input entries will be required:

CARD:TAULIM

TAULIM - the maximum time for which the fire environment will be simulated.

CARD(S):Q(I),AKAP(I)

Q(I) - the value of the energy generation rate, in kW, at the beginning of the Ith segment of the multi-exponential growth curve. All Q(I) must be greater than zero.

AKAP(I) - the value of the exponential growth factor, in units of 1/second, for the Ith segment.

The NSEGQ pairs of data should be entered one pair at a time. The user may enter as many as 100 pairs of data. After the last pair of data has been entered, an end of file mark (UNIVAC: @EOF) should be entered.

CARD: (YES OR NO) - NORMALIZED OUTPUT

If desired, the fire energy generation rates may be printed in normalized form, Q(t)/Q(1).

The following example will clarify the data input required for a multi-exponential fire:

Assume that the growth of a fire in some typical fuel assembly has the following characteristics:

Fire ignition source is 10 kW (e.g., fire in a wastepaper basket).

Fire grows exponentially from 10 kW to 400 kW with an exponential growth factor of 0.025/s (i.e., the fire doubles in power output every 27.7 s).

Fire grows exponentially from 400 kW to 3000 kW with an exponential growth factor of 0.010/s (a doubling time of 69.3 s).

Fire continues to grow exponentially from 3000 kW to an unknown peak value with an exponential growth factor of 0.005/s (a doubling time of 138.6 s).

Assume further, that for whatever reason the environment which develops within the fire enclosure will never be of interest beyond the first 1200 s following ignition.

Then the Fire Data: Energy Generation Rate set of inputs should appear as follows (for a UNIVAC computer):

CARD:1

CARD:1200

CARD:10.,0.025

CARD:400.,0.010

CARD:3000.,0.005

CARD:@EOF

CARD: YES - NORMALIZED OUTPUT

and the program will compute Q(t) according to

$$\dot{Q}(t) = \begin{cases} 10 \exp\{0.025t\}, & 0 \le t < 147.6 \\ 400 \exp\{0.010[t-147.6]\}, & 147.6 \le t < 349.1 \\ 3000 \exp\{0.05[t-349.1]\}, & 349.1 \le t \end{cases}$$

where t is in seconds. Note that the segment end-points at 147.6 s and 349.1 s were not entered as input data. Rather, the program itself computes these times from the requirement that the three exponential segments form a continuous energy generation rate curve.

Linear Segmented Curve

If a linearly segmented fire growth curve is selected (FIRE = 2), then the following input entries will be required.

CARD:TAULIM, HCOMB

TAULIM - the maximum time for which the fire enviornment will be simulated.

HCOMB - the effective heat of combustion, in kilojoules per kilogram, of the fuel assembly. This multiplier is used to convert input data in the form of fuel assembly mass loss rate (kilograms per second) to energy generation rate, in kW. If the input data to be described below is given directly in kW, then HCOMB = 1.0.

CARD:QØ

QØ - the initial energy generation rate of the fire.

CARD(S):TAUQ(I),Q(I)

TAUQ(I) - the value of time, in seconds, at the end of the Ith segment of the energy generation rate curve (or mass loss rate curve, if HCOMB ≠ 1.0).

Q(I) - the value of the energy generation rate, in kW, at the end of the Ith segment of the energy generation rate curve (or, the value of the mass loss rate, in kilograms per second, at the end of the Ith segment of the mass loss rate curve, if HCOMB ≠ 1.0).

Each data point should be entered on a separate card or line at a computer terminal. In total, there will be NSEGQ data points entered. The user may enter as many as 100 data points. The value of TAUQ(NSEGQ) should be greater than or equal to TAULIM. After the last data point has been entered, type an end of file mark (UNIVAC:@EOF).

CARD: (YES OR NO) - NORMALIZED OUTPUT

If desired, the fire energy generation rates may be printed in normalized form, Q(t)/QØ.

2.7 Fire Data: Detectable Product of Combustion Generation Rate

No input should appear in this set if there were no entries for CNDS in the Detection Criteria set. Under such a circumstance, the user should now go directly to the next set of inputs, Fire Data: Hazardous Product of Combustion Generation Rate.

Provided that there is at least one entry for CNDS in the Detection Criteria set, the first card in this set will establish how the fire's detectable product of combustion generation rate, $\dot{C}(t)$, will be modeled, and what subsequent input data will be required. The variable PRODD may be assigned an integer of 1, 2, or 3. Two types of product generation rate models, requiring different forms of input data have been included in the computer program. A third available location (PRODD = 3) has been left so that a user can add another product generation rate model subroutine, if desired.

The product generation rate, $\dot{C}(t)$, is specified in units of u_c per second, where u_c is a dimensional unit which is appropriate for the particular combustion product being generated. For example, if u_c is taken as mass in grams, then $\dot{C}(t)$ must be described in dimensions of grams (of product) per second; if u_c is taken as number of particles, then $\dot{C}(t)$ must be described in units of number of particles (of product) per second; etc.

The choice of the units u_c will have direct impact on the dimensionality of the computed upper layer product concentration, $M(t)$. As discussed earlier, the program computed $M(t)$ in units of u_c per gram of bulk upper layer mixture. Thus, if u_c is in grams, and $\dot{C}(t)$ is in grams per second, then $M(t)$

will be computed in units of grams (of detectable combustion product) per gram of bulk upper layer mixture; if u_c is in number of particles, and $\dot{C}(t)$ is in number of particles per second, then M(t) will be computed in units of number of particles (of detectable combustion product) per gram of bulk upper layer mixture; etc.

CARD:PRODD(PRODD = 1, 2, or 3)

PRODD = 1, detectable product generation rate is directly proportional to the energy generation rate through a fixed constant, BETAD, i.e., $\dot{C}(t) = \text{BETAD} \cdot \dot{Q}(t)$.

PRODD = 2, a product generation rate curve made up of NSEGPD continuous linear segments. The curve would be defined by

$$\dot{C}(t) = \begin{cases} \text{PRDØ at } t = 0; \\ \text{PRD(1) at } t = \text{TAUPRD(1)}, \\ \cdot \\ \cdot \\ \cdot \\ \text{PRD(NSEGPD) at } t = \text{TAUPRD(NSEGPD)} \end{cases}$$

with linear interpolation between the above NSEGPD + 1 data points. As described below, PRDØ and the NSEGPD pair of values TAUPRD(1), PRD(1); TAUPRD(2), PRD(2); ....; TAUPRD(NSEGPD), PRD(NSEGPD) are supplied as input.

PRODD = 3, not used (space left available for a user developed subroutine describing the product generation rate).

Constant Proportionality:

If a fixed constant of proportionality for the product generation rate is selected (PRODD = 1), then a value for BETAD must be provided as follows:

CARD:BETAD

BETAD - a constant of proportionality between the detectable product of combustion generation rate and the energy generation rate, i.e., $\dot{C}(t) = \text{BETAD} \cdot \dot{Q}(t)$. BETAD is entered in units of u_c per second per kW.

Linear Segmented Curve:

If a linear segmented product generation rate is selected (PRODD = 2), then the following input entries will be required:

CARD:PRDØ

PRDØ - the initial detectable product generation rate in units of u_c per second.

CARD(S):TAUPRD(I), PRD(I)

TAUPRD(I) - the value of time, in seconds, at the end of the Ith segment of the detectable product generation rate curve.

PRD(I) - the value of the product of combustion generation rate, in units of u_c per second, at the end of the Ith segment of the product generation rate curve.

Each data point should be entered on a separate card or line at a computer terminal. In total, there will be NSEGPD data points entered. The user may enter as many as 100 data points. The value of TAUPRD(NSEGPD) should be greater than or equal to TAULIM. After the last data point has been entered, type an end of file mark (UNIVAC: @EOF).

2.8 Fire Data: Hazardous Product of Combustion Generation Rate

Input data describing a hazardous product of combustion generation rate curve must be included in this set.

The first card in the set will establish how the fire's hazardous product generation rate, $\dot{C}(t)$, will be modeled, and what subsequent input data will be required. The variable PRODH may be assigned an integer of 1, 2, or 3. Two types of product generation rate models, requiring different forms of input data have been included in the computer program. A third location (PRODH = 3) has been left so that a user can add another product generation rate model subroutine, if desired.

The question of the units of $\dot{C}(t)$ has been addressed above in the initial discussion of Section 2.7 on the Detectable Product card set. That discussion is also relevant to the Hazardous Product dimensionality, and it should be revisited and applied in the present context.

CARD:PRODH(PRODH = 1, 2, or 3)

PRODH = 1, hazardous product generation rate is directly proportional to the energy generation rate through a fixed constant, BETAH, i.e., $\dot{C}(t)$ = BETAH · $\dot{Q}$(t,.

PRODH = 2, a product generation rate curve made up of NSEGPH continuous linear segments. The curve would be defined by

$$\dot{C}(t) = \begin{cases} \text{PRH}\emptyset \text{ at } t = 0; \\ \text{PRH(1) at } t = \text{TAUPRH(1)}, \\ \cdot \\ \cdot \\ \cdot \\ \text{PRH(NSEGPH) at } t = \text{TAUPRH(NSEGPH)}. \end{cases}$$

with linear interpolation between the above NSEGPH + 1 data points. As described below, PRHØ and the NSEGPH pair of values TAUPRH(1), PRH(1); TAUPRH(2), PRH(2); ....; TAUPRH(NSEGPH), PRH(NSEGPH) are supplied as input.

PRODH = 3, not used (space left available for a user developed subroutine describing the product generation rate).

Constant Proportionality

If a fixed constant of proportionality for the product generation rate is selected (PRODH = 1), then a value for BETAH must be provided as follows:

CARD:BETAH

BETAH - a constant of proportionality between the hazardous product of combustion generation rate and the energy generation rate, i.e., $\dot{C}(t) = \text{BETAH} \cdot \dot{Q}(t)$. BETAH is entered in units of u_c per second per kW.

If adequate quantitative information on hazardous product generation rate is unavailable, then the user may prefer to eliminate its consideration from the definitions of hazard criteria. This would most readily be accomplished by specifying PRODH = 1, and BETAH = 0 (i.e., the fire's hazardous product generation rate is specified to be zero, and the program computes a zero upper layer hazardous product concentration at every instant of time). As recommended at the end of Section 2.4, this default specification would be implemented together with an arbitrary positive value for CNHS.

Linear Segmented Curve:

If a linear segmented product generation rate is selected (PRODH = 2), then the following input entries will be required:

CARD:PRHØ

PRHØ - the initial hazardous product generation rate in units of u_c per second.

CARD(S):TAUPRH(I), PRH(I)

TAUPRH(I) - the value of time, in seconds, at the end of the Ith segment of the hazardous product generation rate curve.

PRH(I) - the value of the product of combustion generation rate, in units of u_c per second, at the end of the Ith segment of the product generation rate curve.

The data points should be entered one at a time. There should be a total of NSEGPH data points, up to 100. An end of file mark (UNIVAC: @EOF) should follow the last data point.

3. DATA INPUT EXAMPLES

The following examples should aid in developing an understanding of what data is required by the program and how to enter this data into the runstream. The arrangement of input data will be described for both interactive and batch use. In the interactive examples, words spelled with all capital letters indicate information printed at a computer terminal by the computer program. The user's response is proceeded by "ENTER:" and will always be in lower case letters and underlined. The batch input data will be listed as it would appear on a group of data cards. For each example, the interactive mode data input will be described first. This will be followed by the batch mode data, and, finally, the computer generated results will be presented. (These examples are from the National Bureau of Standards UNIVAC 1100/80 computer.)

In the interactive mode, "Pause" statements have been used at selected places to temporarily suspend printing of the computer generated results. This will enable the user to examine the results more carefully and make notes if desired. In order to continue program execution, the user must type a carriage return.

3.1 Example 1 - A Constant Size Fire

This example will deal with a problem of estimating the ASET from a room with a fire of constant energy release rate. This type of example is useful since many potentially threatening fires tend to release energy at an approximately constant rate for a significant time subsequent to ignition.

The problem is to estimate the ASET under the following fire scenario:

A fire due to a gasoline spill in a 8.9 ft^2 (0.83 m^2) dike is initiated on the floor of a room of height 10 ft (3.0 m) and area 10,000 ft^2 (929 m^2). The rate of the fire's energy release per unit area of spill is approximately constant at 140 BTU/(ft^2 s) (1.6 MW/m^2) [6] for a total energy release rate of 1250 BTU/s (1320 kW).

On account of the fact that occupants are likely to be awake and alert it is assumed that the fire is detected immediately after ignition. Put another way, detection is assumed to occur when the rate-of-temperature rise, RRDSPF, is zero.

The fire is assumed to be away from the walls, and the room has a relatively smooth ceiling. Based on remarks in section 2.2, the fraction of energy release instantaneously lost to the bounding surfaces of the room and its contents, ALAMC, is taken to be 0.6. Also, the fraction of the energy release instantaneously lost by radiation from the combustion zone, ALAMR, is taken to be 0.35.

The elevation of eyelevel will be taken as 4 ft (1.2 m). When the interface is above this height it is assumed that hazard will occur if and when the upper layer temperature rises to 361.4°F (183°C). Once the interface has dropped below the 4 ft (1.2 m) elevation it is assumed that onset of hazard will occur if and when the upper layer temperature reaches 240°F (115°C), or if and when the upper layer oxygen mass fraction is depleted from the oxygen mass fraction at ambient conditions (0.23 g_{O_2} per g of ambient air) to 0.18 g_{O_2} per g of upper layer mixture. Thus, depleted oxygen is taken to be the hazardous product of combustion, the unit u_c is taken to be grams of depleted oxygen, $g_{depleted\ O_2}$, and the hazardous concentration is taken to be 0.05 $g_{depleted\ O_2}$ per g_{upper} which corresponds to CNHS = 0.05.

Based on the work of Huggett [7], the rate at which oxygen is depleted in fires is approximately proportional to the fire's energy release rate according to

$$\dot{C}_{depleted\ O_2} = [0.076\ g_{depleted\ O_2}/(kWs)]\dot{Q}$$

The input data required to describe the above depleted oxygen generation rate are PRODH = 1 and BETAH = 0.076.

Note that in this example, detection does not occur as a result of a detectable product of combustion. Accordingly, it will not be necessary to enter input data which describe the generation of a detectable product.

Finally, it is assumed that Available Safe Egress Times in excess of 30 minutes are of no particular interest, and the fire conditions will not be modeled beyond this time.

Interactive Data Input:

WILL DATA BE ENTERED INTERACTIVELY (Y/N)?

ENTER: yes

PROGRAM WILL BE EXECUTED IN THE INTERACTIVE MODE.

INSTRUCTIONS

```
TO ENTER DATA:  TYPE REQUESTED VALUE OR VALUES (MULTIPLE VALUES
SEPARATED BY A COMMA OR BLANK), THEN PRESS CARRIAGE RETURN.

ENTER A RUN TITLE, UP TO 80 CHARACTERS LONG.

ENTER:  constant fire, q = 1320 kW

ENTER CODE NUMBER OF THE DESIRED FORM OF OUTPUT:

TYPE 1 FOR SUMMARY OUTPUT, 132 CHARACTERS PER LINE
     2 FOR SUMMARY OUTPUT, 80 CHARACTERS PER LINE
     3 FOR FULL OUTPUT, 132 CHARACTERS PER LINE
     4 FOR FULL OUTPUT, 80 CHARACTERS PER LINE

ENTER:  2

SUMMARY OUTPUT, 80 CHARACTERS PER LINE HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER:  yes

ENTER:  1.  LAMDA R,
        2.  LAMDA C,
        3.  EYELEVEL HEIGHT, IN FEET, AND
        4.  FIRE HEIGHT, IN FEET.

DO YOU NEED MORE INFORMATION (Y/N)?

ENTER:  no

ENTER THE REQUESTED VALUES.

ENTER:  .35, .6, 4., 0.0

        LAMDA R         = .35000
        LAMDA C         = .60000
        EYELEVEL HEIGHT = 4.0000
        FIRE HEIGHT     = 0.0000

IS THIS CORRECT (Y/N)?

ENTER:  yes
```

DATA WILL BE ENTERED IN THE FOLLOWING ORDER:

I. DETECTION CRITERIA

II. HAZARD CRITERIA

III. ROOM SIZES

IV. FIRE DATA

V. PRODUCTS OF COMBUSTION DATA

I. DETECTION CRITERIA

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F (DETECTION).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY RATE OF RISE.

ENTER: @eof

ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).

(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY CONCENTRATION.

ENTER: 0.0

0.0000 (INSTANTANEOUS DETECTION)

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).

(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY CONCENTRATION.

ENTER: @eof

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (DETECTION).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD CRITERIA DATA INPUT.

ENTER: @eof

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE ABOVE SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD

BY LAYER TEMPERATURE WHEN INTERFACE BELOW EYELEVEL.

ENTER: 361.4

361.40

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE ABOVE SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD

BY LAYER TEMPERATURE WHEN INTERFACE BELOW EYELEVEL.

ENTER: @eof

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE BELOW SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.

ENTER: 240.0

240.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE BELOW SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.

ENTER: @eof

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.

ENTER: <u>0.05</u>

5.0000-02

IS THIS CORRECT (Y/N)?

ENTER: <u>yes</u>

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.

ENTER: <u>@eof</u>

III. ROOM SIZE DATA

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: <u>10.0</u>

10.000

IS THIS CORRECT (Y/N)?

ENTER: <u>yes</u>

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: <u>@eof</u>

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: <u>11000.</u>

11000.

IS THIS CORRECT (Y/N)?

ENTER: no

ENTER THE CORRECT VALUE(S).

ENTER: 10000.

10000.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: @eof

IV. FIRE DATA

SELECT THE REPRESENTATIVE FORM OF FIRE ENERGY GENERATION.

TYPE 1 FOR AN EXPONENTIAL FIRE GROWTH CURVE.

2 FOR DIGITAL DATA INPUT.

ENTER: 2

DIGITAL DATA INPUT HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER: 1. THE MAXIMUM TIME, IN SECONDS, FOR WHICH THE FIRE WILL BE MODELED,

AND

2. THE HEAT OF COMBUSTION, IN KJ/KG.

ENTER: 1800.0, 1.0

MAXIMUM TIME = 1800.0

HEAT OF COMBUSTION = 1.0000

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER THE INITIAL ENERGY GENERATION RATE.

ENTER: <u>1320.0</u>

Q0 = .1320+04

IS THIS CORRECT (Y/N)?

ENTER: <u>yes</u>

ENTER THE REST OF THE DIGITAL DATA POINTS ONE AT A TIME.

EACH DATA POINT SHOULD CONSIST OF A TIME, IN SECONDS,

AND A CORRESPONDING ENERGY GENERATION RATE.

WHEN ALL HAVE BEEN ENTERED, TYPE AN END OF FILE (UNIVAC: @EOF).

ENTER: <u>1800.0, 1320.0</u>

ENTER: <u>@eof</u>

TAUQ(1) = 1800.0   Q(1) = .1320+04

ARE THESE DATA POINTS CORRECT (Y/N)?

ENTER: <u>yes</u>

DO YOU WANT FIRE ENERGY GENERATION RATE DATA

PRESENTED IN NORMALIZED FORM, Q(T)/Q0 (Y/N)?

ENTER: <u>no</u>

V.1 DETECTABLE PRODUCT OF COMBUSTION DATA

SINCE THERE WERE NO DETECTABLE CONCENTRATIONS SPECIFIED,

DATA DESCRIBING THE GENERATION OF A DETECTABLE PRODUCT

OF COMBUSTION WILL NOT BE REQUIRED.

V.2 HAZARDOUS PRODUCT OF COMBUSTION DATA

SELECT THE REPRESENTATIVE FORM OF PRODUCT GENERATION RATE.

TYPE 1 FOR A METHOD USING A CONSTANT OF PROPORTIONALITY.

2 FOR DIGITAL DATA INPUT.

ENTER: <u>1</u>

A METHOD USING A CONSTANT OF PROPORTIONALITY HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER BETAH,

IN PRODUCT UNITS PER SEC PER KW OF FIRE GENERATION RATE.

PRODUCT GENERATION RATE = BETAH X ENERGY GENERATION RATE

ENTER: 0.076

7.6000-02

IS THIS CORRECT (Y/N)?

ENTER: yes

Batch Data Input:

The data required to solve the problem will now be shown in batch form. Each line of data represents either a computer punch card or a line of data typed at a computer terminal in batch mode. The extended form of output (132 characters/line) is desired so the write code has been changed to 3. The first card in a batch data group must contain the words "BATCH DATA".

I. General Data

	BATCH DATA
Run title	CONSTANT FIRE, Q = 1320 kW
Write code	3
λ_r, λ_c, eyelevel, fire height	.35, .60, 4., 0.0

2. Detection Criteria

Layer temperature	@EOF
Rate of temperature rise	0.0 @EOF
Concentration	@EOF

3. Hazard Criteria

Temperature when interface above eyelevel	361.4 @EOF
Temperature when interface below eyelevel	240.0 @EOF
Concentration	0.05 @EOF

4. Room Characteristics

Height	10.0 @EOF
Area	10000. @EOF

5. Fire Data: Energy Generation Rate

Fire type	2
Maximum time, heat of combustion	1800., 1.0

Initial energy generation rate	1320.
Data points	1800., 1320. @EOF
Normalized Output?	NO - NORMALIZED OUTPUT

6. Fire Data: Detectable Product of Combustion Generation Rate

7. Fire Data: Hazardous Product of Combustion Generation Rate

Product generation code	1
Beta, constant of proportionality	0.076

Results:

The relevant portion of the computer output from the batch run is presented in Figure 2. These results indicate that for a fire with a constant energy generation rate equal to 1250 BTU/s (1320 kW) in a room with a 10 ft (3.05 m) high ceiling and an area of 10,000 ft^2 (929.0 m^2), the available safe egress time, assuming immediate detection and alarm, is 191 seconds or about 3.2 minutes. The onset of hazardous conditions occurs when the upper layer temperature reaches 361.4°F (183.0°C). At this point, the smoke layer interface has reached a position 6.95 ft (2.12 m) above the floor, the concentration of the (unspecified) detectable product is zero, and the concentration of the hazardous product, $g_{depleted\ O_2}$ per g_{upper} in the present example, is 0.03 (i.e., at the time of hazard, the mass fraction of oxygen in the upper layer is 0.23 - 0.03 = 0.20, which is still large enough for vitiation effects to be considered as negligible). Notice in Figure 2, that at the time of detection, which immediately follows ignition, the concentration of depleted oxygen in the newly forming upper layer is already nonzero. These upper layer gases have, in fact, come from the fire-generated plume gases, which are always a source of depleted oxygen.

Using the results of this run, it is possible to determine the available safe egress time if the fire is detected at some nonzero time subsequent to ignition. For example, if detection occurred 60 seconds after ignition of the fire, the available safe egress time would be (191-60) seconds = 131 seconds or about 2.2 minutes.

3.2 Example 2 - A Semi-Universal Growing Fire Hazard

In this example the hazard which develops from a semi-universal growing fire will be studied. The results of applying several different methods of detection will be evaluated.

The semi-universal fire is the result of a fit of data from free burn tests on a variety of different types of commodities to a three-segment, multi-exponential fire growth curve [2]. The fire is initiated from a 10 kW (9.5 BTU/s) ignition source. It grows exponentially at a rate characteristic of a fire initiated in a polyurethane mattress with bedding [8]. This early growth rate may also be appropriate for use in characterizing the early growth of fires in upholstered polyurethane cushioning and large assemblies of commodities stacked on pallets. The fire growth rate beyond 400 kW (379 BTU/s), described in two segments, is similar to that observed for fires initiated in a variety of different types of commodities stacked on pallets [8]. These latter portions of the semi-universal fire would be representative of fires in large mercantile, storage, and/or business occupancies. The equations which characterize this semi-universal fire and the associated input data have been described earlier in Section 2.6 under the subheading: Multi-exponential curve.

The fire will be assumed to occur in an occupied 5,000 ft^2 (465 m^2) nominal 20 ft (6.1 m) high ceiling auditorium outfitted with polyurethane cushion seats. Since life safety considerations are likely to be key, the auditorium is assumed to be occupied and detection by the occupants is assumed to be immediate (rate-of-rise at detection is 0.°F/min).

For illustrative purposes, cases of detection when the average upper layer reaches 135°F (54°C), and detection when the rate of upper layer temperature rise reaches 15°F/min (8.33°C/min) will also be examined. These cases may be useful in evaluating the use of thermal sensor detectors for providing property protection of the auditorium during unoccupied periods of time.

If the smoke layer interface is located more than 3 ft (0.91 m) from the floor, hazardous conditions will be assumed to occur when and if the average upper layer temperature reaches 361°F (183°C). Once the interface reaches the 3 ft (0.91 m) elevation, the onset of hazardous conditions will be assumed to occur if the average upper layer temperature reaches 240°F (115.6°C) or if the concentration of CO exceeds 2500 parts per million (ppm) (0.0025 grams of CO per gram of upper layer mixture), whichever comes first. The CO generation rate will be taken as proportional to the energy release rate through a constant of proportionality of 0.007 $g_{CO}/(skW)$. This latter value can be deduced from [9] for smoldering combustion in polyurethane. Flaming combustion would likely result in a smaller constant of proportionality.

For the moderate span-to-height aspect ratio of the present auditorium [assume the span to be approximately $(5000\ ft^2)^{1/2}$ 70 ft (22 m), for a span-to-height ratio of approximately 3.5], it is reasonable to assume that 75 percent of the total energy release is instantaneously transfered to the surfaces of the auditorium and its contents. As in the previous example, the instantaneous radiation loss from the combustion zone is assumed to be 35 percent of the energy release.

The ASET's for the above scenario will be determined under the condition that the fire is located 2 ft (0.6 m) above the floor.

If hazardous conditions are not attained by 20 minutes after ignition, then the analysis will be terminated.

Interactive Data Input:

```
WILL DATA BE ENTERED INTERACTIVELY (Y/N)?
ENTER:  yes
PROGRAM WILL BE EXECUTED IN THE INTERACTIVE MODE.
INSTRUCTIONS
TO ENTER DATA:  TYPE REQUESTED VALUE OR VALUES (MULTIPLE VALUES
SEPARATED BY A COMMA OR BLANK), THEN PRESS CARRIAGE RETURN.
ENTER A RUN TITLE, UP TO 80 CHARACTERS LONG.
ENTER:  multi-exponential fire growth
ENTER CODE NUMBER OF THE DESIRED FORM OF OUTPUT:
TYPE 1  FOR SUMMARY OUTPUT, 132 CHARACTERS PER LINE
     2  FOR SUMMARY OUTPUT, 80 CHARACTERS PER LINE
     3  FOR FULL OUTPUT, 132 CHARACTERS PER LINE
     4  FOR FULL OUTPUT, 80 CHARACTERS PER LINE
ENTER:  2
SUMMARY OUTPUT, 80 CHARACTERS PER LINE HAS BEEN SELECTED.
```

IS THIS CORRECT (Y/N)?

ENTER: <u>yes</u>

ENTER: 1. LAMDA R,

2. LAMDA C,

3. EYELEVEL HEIGHT, IN FEET, AND

4. FIRE HEIGHT, IN FEET.

DO YOU NEED MORE INFORMATION (Y/N)?

ENTER: <u>no</u>

ENTER THE REQUESTED VALUES.

ENTER: <u>.35, .75, 3., 2.</u>

LAMDA R = .35000

LAMDA C = .75000

EYELEVEL HEIGHT = 3.0000

FIRE HEIGHT = 2.0000

IS THIS CORRECT (Y/N)?

ENTER: <u>yes</u>

DATA WILL BE ENTERED IN THE FOLLOWING ORDER:

I. DETECTION CRITERIA

II. HAZARD CRITERIA

III. ROOM SIZES

IV. FIRE DATA

V. PRODUCTS OF COMBUSTION DATA

I. DETECTION CRITERIA

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F (DETECTION).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY RATE OF RISE.

ENTER: <u>135.0</u>

135.00

IS THIS CORRECT (Y/N)?

ENTER: <u>yes</u>

```
ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F (DETECTION).
TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO DETECTION BY RATE OF RISE.
ENTER:  @eof
ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).
(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)
TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO DETECTION BY CONCENTRATION.
ENTER:  0.0
        0.0000 (INSTANTANEOUS DETECTION)
IS THIS CORRECT (Y/N)?
ENTER:  yes
ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).
(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)
TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO DETECTION BY CONCENTRATION.
ENTER:  15.0
        15.000
IS THIS CORRECT (Y/N)?
ENTER:  yes
ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).
(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)
TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO DETECTION BY CONCENTRATION.
ENTER:  @eof
ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,
IN PRODUCT UNITS/GRAM OF BULK GAS (DETECTION).
TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO HAZARD CRITERIA DATA INPUT.
ENTER:  @eof
```

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F,

(INTERFACE ABOVE SPECIFIED EYELEVEL)(HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD

BY LAYER TEMPERATURE WHEN INTERFACE BELOW EYELEVEL.

ENTER: 361.4

361.40

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE ABOVE SPECIFIED EYELEVEL)(HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD

BY LAYER TEMPERATURE WHEN INTERFACE BELOW EYELEVEL.

ENTER: @eof

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE BELOW SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.

ENTER: 240.0

240.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE BELOW SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.

ENTER: @eof

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.

ENTER: 0.0025

2.5000-03

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.

ENTER: @eof

III. ROOM SIZE DATA

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: 20.0

20.000

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: @eof

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 5000.0

5000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: @eof

IV. FIRE DATA

SELECT THE REPRESENTATIVE FORM OF FIRE ENERGY GENERATION.

TYPE 1 FOR AN EXPONENTIAL FIRE GROWTH CURVE.

2 FOR DIGITAL DATA INPUT.

ENTER: 1

AN EXPONENTIAL FIRE GROWTH CURVE HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

GENERAL FORM: Q=Q1 EXP(ALPHA(T-T1))

ENTER THE MAXIMUM TIME, IN SECONDS, FOR WHICH THE FIRE WILL BE MODELED.

ENTER: 1200.0

1200.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER: 1. THE ENERGY GENERATION RATE (Q1), IN KILOWATTS, AT THE BEGINNING OF EACH TIME SEGMENT, AND

2. THE ENERGY GENERATION RATE EXPONENTIAL FACTOR (ALPHA), IN UNITS OF 1/SECOND, FOR THAT TIME SEGMENT.

ENTER ONE PAIR FOR EACH TIME SEGMENT IN THE CURVE.

ENTER THEM ONE AT A TIME.

WHEN ALL HAVE BEEN ENTERED, TYPE AN END OF FILE (UNIVAC: @EOF).

ENTER: 10.0, 0.025

ENTER: 400.0, 0.010

ENTER: 3000.0, 0.005

ENTER: @eof

1. Q = 10.0 EXP(.025(T-T1))

2. Q = 400.0 EXP(.010(T-T1))

3. Q = 3000.0 EXP(.005(T-T1))

ARE THE EQUATIONS CORRECT (Y/N)?

ENTER: yes

DO YOU WANT FIRE ENERGY GENERATION RATE DATA

PRESENTED IN NORMALIZED FORM, Q(t)/Q(1) (Y/N)?

ENTER: yes

V.1. DETECTABLE PRODUCT OF COMBUSTION DATA

SINCE THERE WERE NO DETECTABLE CONCENTRATIONS SPECIFIED,

DATA DESCRIBING THE GENERATION OF A DETECTABLE PRODUCT

OF COMBUSTION WILL NOT BE REQUIRED.

V.2. HAZARDOUS PRODUCT OF COMBUSTION DATA

SELECT THE REPRESENTATIVE FORM OF PRODUCT GENERATION RATE.

TYPE 1 FOR A METHOD USING A CONSTANT OF PROPORTIONALITY.

2 FOR DIGITAL DATA INPUT.

ENTER: 1

A METHOD USING A CONSTANT OF PROPORTIONALITY HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER BETAH,

IN PRODUCT UNITS PER SEC PER KW OF FIRE ENERGY GENERATION RATE.

PRODUCT GENERATION RATE = BETAH X ENERGY GENERATION RATE.

ENTER: 0.007

7.0000-03

IS THIS CORRECT (Y/N)?

ENTER: yes

Batch Data Input:

The data required to solve the problem will now be shown in batch form. Each line of data represents either a computer punch card or a line of data typed at a computer terminal in batch mode. The extended form of output (132 characters/line) is desired so the write code value will be changed to 3. The first card in a batch data group must contain the words "BATCH DATA".

1. General Data

	BATCH DATA
Run title	MULTI-EXPONENTIAL FIRE GROWTH
Write code	3
λ_r, λ_c, eyelevel, fire height	.35, .75, 3., 2.0

2. Detection Criteria

Layer temperature	135.0
	@EOF
Rate of temperature rise	0.0
	15.0
	@EOF
Concentration	@EOF

3. Hazard Criteria

Temperature when interface above eyelevel	361.4 @EOF
Temperature when interface below eyelevel	240.0 @EOF
Concentration	0.0025
	@EOF

4. Room Characteristics

Height	20.0 @EOF
Area	5000.0 @EOF

5. Fire Data: Energy Generation Rate

Fire type	1
Maximum time	1200.0
Energy generation rates, exponential factors	10.0, 0.025 400.0, 0.010 3000.0, 0.005 @EOF
Normalized Output?	YES - NORMALIZED OUTPUT

6. Fire Data: Detectable Product of Combustion Generation Rate

7. Fire Data: Hazardous Product of Combustion Generation Rate

Product generation code	1
Beta, constant of proportionality	0.007

Results:

The immediate detection (rate of rise is 0.°F/min) portion of the computer output from the batch run is presented in Figure 3. These results indicate that for a fire 2 ft (0.6 m) above the floor of a room of ceiling height 20 ft (6.1 m) and area 5000 ft^2 (465 m^2), whose rate-of-energy release is reasonably described by the semi-universal fire described earlier, the onset of hazardous conditions occurs approximately 523 seconds or 8.7 minutes after ignition. Thus, for a case of immediate fire detection and successful alarm, the ASET is also 8.7 minutes.

At the time of onset of hazardous conditions the average upper layer temperature is 355.5°F (179.7°C), the smoke layer interface is 3 ft (0.91 m) from the floor, and the average concentration of CO in the upper layer is 0.004 grams of CO per gram of upper layer mixture. Hazardous conditions are initiated when the interface reaches the specified 3 ft (0.91 m) height of eyelevel on account of the fact that the upper layer is of untenably high temperature (vis a vis potential internal and/or external burns from ingestion and/or direct skin contact) at that time.

If fire detection and alarm is not immediate, but occurs when the upper layer temperature reaches 135°F (57.2°C), then the time of detection is 318 seconds and the ASET is reduced to 205 seconds. If detection occurs when the upper layer rate-of-temperature-rise reaches 15°F/min (8.33°C/min), then the time of detection is 219 seconds and the ASET is 304 seconds.

3.3 Example 3 - Flashover Potential Due to a Fire in an Assembly of Bedding Combustibles

In this last example the potential for room flashover due to a fire confined to a wastepaper basket-(polyurethane) single mattress-bedding fuel assembly will be evaluated. An estimate of the energy release rate during the free burn of such a grouping of combustibles from ignition and on through fuel depletion has been obtained from data of Babrauskas [5], and is plotted in Figure 3 of [2]. From ignition to t = 900 seconds this energy release rate history can be approximated by the following ten pair of points with linear interpolation between them:

Time (s)	Energy Release Rate (kW)
0	2.
70	36.
140	1.
210	27.
290	200.
390	1200.
525	290.
650	106.
775	55.
900	38.

While a survey of literature by Peacock [10] indicated that an upper layer temperature criterion for flashover is typically taken to be in the range of 1020-1420°F (550-770°C), the present model is not formulated in a manner as to yield reliable results at temperatures beyond the approximate range 660-840°F (350-450°C). Accordingly, for the present evaluations a criterion for flashover potential will be conservatively set at 750°F (400°C).

The fire described by the above energy release rate history will be "placed" in rooms of ceiling height 8 and 12 ft (2.4 and 3.7 m) and areas ranging from 100-10000 ft^2 (9.3 - 929 m^2). As in Example 2, ALAMC and ALAMR will be taken as 0.70 and 0.35, respectively. The time of detection will be taken to be the time of ignition. Onset of hazard will be interpreted as occuring when the potential for flashover exists, i.e., when the upper layer temperature reaches 750°F (400°C), no matter what the elevation of the interface. Under these conditions, the ASET to be computed is to be interpreted as the time from ignition to the time of potential flashover.

In a manner similar to that of Example 1, depleted oxygen will be assigned the role of hazardous combustion product, where its hazardous concentration will be taken as 0.09 $g_{depleted\ O_2}$ per g_{upper} (corresponding to a total oxygen concentration of 0.23 - 0.09 = 0.14 g_{O_2} per g_{upper}). Also, eyelevel as well as fire elevation will be taken as 2 ft (0.6 m). If the interface is below the 2 ft (0.6 m) fire elevation, and the oxygen concentration is below 0.12-0.14 g_{O_2} per g_{upper}, then the fire will be submerged in a vitiated environment whose oxygen level may not support continued flaming combustion. By using the hazardous product criterion in the manner suggested, the calculation would be appropriately terminated under such circumstances, and the event would be clearly identified as onset of extreme vitiation. Indeed, even if extreme vitiation does not occur prior to potential flashover, the depleted oxygen concentration at the time of flashover would be an interesting output of the calculation.

Interactive Data Input:

```
WILL DATA BE ENTERED INTERACTIVELY (Y/N)?
ENTER:  yes
PROGRAM WILL BE EXECUTED IN THE INTERACTIVE MODE.
INSTRUCTIONS
TO ENTER DATA:  TYPE REQUESTED VALUE OR VALUES (MULTIPLE VALUES
SEPARATED BY A COMMA OR BLANK), THEN PRESS CARRIAGE RETURN.
ENTER A RUN TITLE, UP TO 80 CHARACTERS LONG.
ENTER:  flashover potential
ENTER CODE NUMBER OF THE DESIRED FORM OF OUTPUT:
TYPE 1 FOR SUMMARY OUTPUT, 132 CHARACTERS PER LINE
     2 FOR SUMMARY OUTPUT, 80 CHARACTERS PER LINE
```

3 FOR FULL OUTPUT, 132 CHARACTERS PER LINE

4 FOR FULL OUTPUT, 80 CHARACTERS PER LINE

ENTER: 2

SUMMARY OUTPUT, 80 CHARACTERS PER LINE HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER: 1. LAMDA R,

2. LAMDA C,

3. EYELEVEL HEIGHT, IN FEET, AND

4. FIRE HEIGHT, IN FEET.

DO YOU NEED MORE INFORMATION (Y/N)?

ENTER: no

ENTER THE REQUESTED VALUES

ENTER: .35, .70, 2., 2.

```
LAMDA R         = .35000
LAMDA C         = .70000
EYELEVEL HEIGHT = 2.0000
FIRE HEIGHT     = 2.0000
```

IS THIS CORRECT (Y/N)?

ENTER: yes

DATA WILL BE ENTERED IN THE FOLLOWING ORDER:

I. DETECTION CRITERIA

II. HAZARD CRITERIA

III. ROOM SIZES

IV. FIRE DATA

V. PRODUCTS OF COMBUSTION DATA

I. DETECTION CRITERIA

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F (DETECTION).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY RATE OF RISE.

ENTER: @eof

ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).

(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY CONCENTRATION.

ENTER: 0.0

0.0000 (INSTANTANEOUS DETECTION)

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN (DETECTION).

(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY CONCENTRATION.

ENTER: @eof

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS DETECTION.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD CRITERIA DATA INPUT.

ENTER: @eof

II. HAZARD CRITERIA

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE ABOVE SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD

BY LAYER TEMPERATURE WHEN INTERFACE BELOW EYELEVEL.

ENTER: 750.0

750.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE ABOVE SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD

BY LAYER TEMPERATURE WHEN INTERFACE BELOW EYELEVEL.

ENTER: @eof

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE BELOW SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.

ENTER: 750.0

750.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F

(INTERFACE BELOW SPECIFIED EYELEVEL) (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.

ENTER: @eof

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.

ENTER: 0.09

9.0000-02

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,

IN PRODUCT UNITS/GRAM OF BULK GAS (HAZARD).

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.

ENTER: @eof

III. ROOM SIZE DATA

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: 8.0

8.0000

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: 12.0

12.000

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.

ENTER: @eof

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT

ENTER: 100.0

100.00

```
IS THIS CORRECT (Y/N)?

ENTER:  yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER:  120.0

        120.00

IS THIS CORRECT (Y/N)?

ENTER:  yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER:  200.0

        200.00

IS THIS CORRECT (Y/N)?

ENTER:  yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER:  250.0

        250.00

IS THIS CORRECT (Y/N)?

ENTER:  yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER:  300.0

        300.00

IS THIS CORRECT (Y/N)?

ENTER:  yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC:  @EOF) TO MOVE TO FIRE DATA INPUT.
```

ENTER: 400.0

400.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 500.0

500.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 600.0

600.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 800.0

800.00

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 1000.0

1000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 1200.0

1200.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 2000.0

2000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 3000.0

3000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 4000.0

4000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 5000.0

5000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 6000.0

6000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 8000.0

8000.0

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: 10000.0

10000.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.

TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.

ENTER: @eof

IV. FIRE DATA

SELECT THE REPRESENTATIVE FORM OF FIRE ENERGY GENERATION.

TYPE 1 FOR AN EXPONENTIAL FIRE GROWTH CURVE.

2 FOR DIGITAL DATA INPUT.

ENTER: 2

DIGITAL DATA INPUT HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER: 1. THE MAXIMUM TIME, IN SECONDS, FOR WHICH THE FIRE WILL BE MODELED, AND

2. THE HEAT OF COMBUSTION, IN KJ/KG.

ENTER: 900.0, 1.0

MAXIMUM TIME = 900.0

HEAT OF COMBUSTION = 1.000

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER THE INITIAL ENERGY GENERATION RATE.

ENTER: 2.0

QØ = .2000+01

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER THE REST OF THE DIGITAL DATA POINTS ONE AT A TIME.

EACH DATA POINT SHOULD CONSIST OF A TIME, IN SECONDS, AND

A CORRESPONDING ENERGY GENERATION RATE.

WHEN ALL HAVE BEEN ENTERED, TYPE AN END OF FILE (UNIVAC: @EOF).

ENTER: 70., 36.

ENTER: 140., 1.4

ENTER: 210., 27.

ENTER: 290., 200.

ENTER: 390., 1200.

ENTER: 525., 290.

ENTER: 650., 106.

ENTER: 775., 55.

ENTER: 900., 38.

ENTER: @eof

TAUQ(1) = 70.0	Q(1) = .3600+02
TAUQ(2) = 140.0	Q(2) = .1400+01
TAUQ(3) = 210.0	Q(3) = .2700+02
TAUQ(4) = 290.0	Q(4) = .2000+03
TAUQ(5) = 390.0	Q(5) = .1200+04
TAUQ(6) = 525.0	Q(6) = .2900+03
TAUQ(7) = 650.0	Q(7) = .1060+03
TAUQ(8) = 775.0	Q(8) = .5500+02
TAUQ(9) = 900.0	Q(9) = .3800+02

ARE THESE DATA POINTS CORRECT (Y/N)?

ENTER: yes

DO YOU WANT FIRE ENERGY GENERATION RATE DATA

PRESENTED IN NORMALIZED FORM, Q(T)/QØ (Y/N)?

ENTER: no

V.1. DETECTABLE PRODUCT OF COMBUSTION DATA

SINCE THERE WERE NO DETECTABLE CONCENTRATIONS SPECIFIED,

DATA DESCRIBING THE GENERATION OF A DETECTABLE PRODUCT

OF COMBUSTION WILL NOT BE REQUIRED.

V.2. HAZARDOUS PRODUCT OF COMBUSTION DATA

SELECT THE REPRESENTATIVE FORM OF PRODUCT GENERATION RATE.

TYPE 1 FOR A METHOD USING A CONSTANT OF PROPORTIONALITY.

2 FOR DIGITAL DATA INPUT.

ENTER: 1

A METHOD USING A CONSTANT OF PROPORTIONALITY HAS BEEN SELECTED.

IS THIS CORRECT (Y/N)?

ENTER: yes

ENTER BETAH,

IN PRODUCT UNITS PER SEC PER KW OF FIRE ENERGY GENERATION RATE.

PRODUCT GENERATION RATE = BETAH X ENERGY GENERATION RATE

ENTER: 0.076

7.6000-02

IS THIS CORRECT (Y/N)?

ENTER: yes

Batch Data Input:

The data required to solve the problem will now be shown in batch form. Each line of data represents either a computer punch card or a line of data typed at a computer terminal in batch mode. The extended form of output is not desired in this example, so the write code value will be 1. The first card in a batch data group should contain the words "BATCH DATA".

1. General Data

	BATCH DATA
Run title	FLASHOVER POTENTIAL
Write code	1
λ_r, λ_c, eyelevel, fire height	.35, .70, 2., 2.

2. Detection Criteria

Layer temperature	@EOF
Rate of temperature rise	0.0
	@EOF
Concentration	@EOF

3. Hazard Criteria

Temperature when interface above eyelevel	750.0
	@EOF
Temperature when interface below eyelevel	750.0
	@EOF
Concentration	0.09
	@EOF

4. Room Characteristics

Height	8.0
	12.0
	@EOF
Area	100.
	120.
	200.
	250.
	300.
	400.
	500.
	600.
	800.
	1000.
	1200.
	2000.
	3000.
	4000.
	5000.

	6000.
	8000.
	10000.
	@EOF

5. Fire Data: Energy Generation Rate

Fire type	2
Maximum time, heat of combustion	900., 1.0
Initial energy generation rate	2.0
Data points	70., 36.
	140., 1.4
	210., 27.
	290., 200.
	390., 1200.
	525., 290.
	650., 106.
	775., 55.
	900., 38.
	@EOF
Normalized Output?	NO - NORMALIZED OUTPUT

6. Fire Data: Detectable Product of Combustion Generation Rate

7. Fire Data: Hazardous Product of Combustion Generation Rate

Product generation code	1
Beta, constant of proportionality	0.076

Results:

The relevant portion of the computer output from the batch run is presented in Figure 4. The results from this have been plotted in Figure 5. There, the time to reach potential flashover [750°F (400°C)] is plotted against room area for the two room heights considered. From this figure it is possible to reach the following conclusions: For a fire confined to the subject fuel assembly:

(a) Flashover is not likely to take place in 8 ft (2.4 m) high rooms of area larger than 2000 ft^2 (186 m^2) or in 12 ft (3.7 m) high rooms of area larger than 800 ft^2 (74 m^2); for rooms of smaller area the times of potential flashover can be identified from the plots.

(b) At the time of potential flashover the oxygen concentration of the environment which surrounds the combustion zone is always large enough (approximately 0.14) so that extinction on account of oxygen vitiation may still not have occured.

4. FUTURE EFFORTS

As indicated by the example calculations of the last section, the ASET computer program should prove useful as a tool for providing practical estimates of enclosure fire environments, in general, and of Available Safe Egress Times, in particular.

The present ASET computer program is intended to represent an initial, rather than a final, stage of development. Indeed, by measure of the numbers and general interest of users which are attracted to it, the more successful this computer program proves to be, the more likely it is that advanced versions will be developed. In this regard, future ASET computer programs would incorporate more detailed and more extensive mathematical simulations of the essential features of enclosure fire phenomena. Advanced computer programs would also provide a capability for invoking more sophisticated criteria for detection and onset of hazard, criteria which were not constrained to one, or even a few discrete environment descriptor end-points. Finally, it is evident that future ASET programs could be significantly improved in terms of the method of inputing data and of retrieving computer generated results. The potential for adding these last types of improvements is clearly constrained only by decisions on priorities in distributing available resources.

In short, the future of the ASET computer program concept is strongly dependent on the nature of user feedback, which is heartily encouraged.

5. REFERENCES

[1] Cooper, L.Y., A Concept for Estimating Safe Available Egress Time in Fires, submitted for publication in Fire Safety Journal.

[2] Cooper, L.Y., A Mathematical Model for Estimating Safe Available Egress Time in Fires, to appear in Fire and Materials.

[3] Cooper, L.Y., Calculating Escape Time from Fires, Proceedings of 1980 SFPE/CFR Workshop on Engineering Applications of Fire Technology.

[4] Cooper, L.Y., Estimating Safe Available Egress Time from Fires, NBSIR 80-2172, National Bureau of Standards, Feb., 1981.

[5] Babrauskas, V., Combustion of Mattresses Exposed to Flaming Ignition Sources. Part I. Full-Scale Tests and Hazard Analysis, NBSIR 77-1290, National Bureau of Standards, Sept., 1977.

[6] Butcher, E.G., and Parnell, A.C., Smoke Control in Fire Safety Design, E. and F.N. Spon, London, 1979.

[7] Huggett, C., Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements, Fire and Materials, Vol. 4, No. 2, 1980.

[8] Friedman, R., Quantification of Threat from a Rapidly Growing Fire in Terms of Relative Material Properties, Fire and Materials, Vol. 2, No. 1, 1978.

[9] Quintiere, J.G., Birky, M., Smith, G., and Macdonald, F., An Analysis of Smoldering Fires in Closed Compartments and Their Hazard Due to Carbon Monoxide, to appear in Fire and Materials.

[10] Peacock, R.D. and Breese, J.N., Computer Fire Modeling for the Prediction of Flashover, NBSIR 82-2516, National Bureau of Standards, May, 1982.

APPENDIX A: PROGRAM DESCRIPTION

General Comments

This computer program was written in ASCII Fortran (FTN) for the Univac 1100/80 computer located at the National Bureau of Standards. This program may also be used on any computer with an ANSI FORTRAN compiler. It contains about 2300 source program statements and can be run on almost any digital computer of adequate capacity. The program does not require any UNIVAC or other computer specific subroutines. Output may be in either 80 characters per line or 132 characters per line format.

A program listing is provided in Appendix B. The main program and subroutines are described below.

MAIN Program

The MAIN program reads the required input data and governs the overall execution of the program. Statements in this part of the program allow it to be run in either the interactive or batch mode. When in the interactive mode, error checks have been provided to ensure that the data is entered correctly.

A "COMPUTED GO TO" statement in this part of the program allows the user to select any one of three representative forms of fire energy generation rate. Only two models have been provided; the user may add a third, if desired. In the first fire simulation model the energy generation rate is simulated by joined, exponentially growing curve segments. The number of segments and the specific equations for each segment are deduced from user-supplied input data. In the second fire simulation model the energy generation rate is simulated by joined, linear curve segments, where, again, the number of segments and the linear interpolation between segment endpoints are deduced from user-supplied data.

Another "COMPUTED GO TO" statement allows the user to describe the generation of a detectable product of combustion in one of three ways. One method uses a constant of proportionality to relate the products of combustion generation rate to the energy generation rate. Another method uses linear interpolation between user supplied data points to describe the generation rate history of some detectable product of combustion. Again, the user may add some other model of detectable product of combustion generation, if desired.

A third "COMPUTED GO TO" statement allows the user to choose one of three ways to describe the generation of a hazardous product of combustion. The choices are the same as those used to describe the generation of a detectable product of combustion.

For each detection mode, the room sizes are evaluated for hazard occurrence. A maximum of twenty room ceiling heights and thirty compartment areas may be specified for each run of the program. As many as ten values may be used for each detection or hazard mode. Any combination of detection modes, hazard criteria, and room sizes may be used. It is not necessary to use all detection modes, hazard criteria, and room sizes, but at least one of each must be specified.

EXFIRE Subroutine

If the multi-exponential growth option is selected in MAIN, then this routine which is called one time, takes the input data and computes the initial times for each of the exponentially growing curve segments of the energy generation rate curve. In particular, the curve segments satisfy $\dot{Q} = \dot{Q}_i \exp[K_{i+1}(t-t_i)]$ for $i \geq 1$, and this routine finds all t_i from user-supplied $\dot{Q}_i$ and K_{i+1}. Having done this, the routine then provides a printout which explicitly describes the multi-exponential growth algorithm ultimately used to compute $\dot{Q}$.

FUNQ Subroutine

This subroutine calculates the energy generation rate at any given time. This routine is referenced by the SUBAINT and SUBF subroutines. It is currently divided into two parts. If the user wishes to develop another model of energy generation, then a third part may be added to this subroutine.

The first part of this subroutine uses the multi-exponential fire growth curve to compute energy generation rates. The other part computes energy generation rates using linear interpolation between digital data points.

FUNPRD Subroutine

This routine calculates the generation rate of some detectable product of combustion at any given time. This subroutine has also been divided into two parts. A third model of the generation of a detectable product of combustion may be added by the user.

One part of FUNPRD uses a constant of proportionality, relating product of combustion generation rate to energy generation rate, to calculate detectable product of combustion generation rates. The other uses linear interpolation between digital data points to compute the detectable product of combustion generation rates.

FUNPRH Subroutine

This routine calculates the generation rate of some hazardous product of combustion at any given time. It is exactly the same as the FUNPRD subroutine.

SUBAINT Subroutine

This routine sets up the numerical integration necessary for obtaining the smoke layer interface position as it drops from the ceiling. It also sets up the integrations required to compute the history of the average upper layer temperature, detectable product of combustion concentration, and hazardous product of combustion concentration. The integrations are done in specified time intervals. Results from these integrations are checked against detection and hazard criteria to determine when detection and hazard occur. If detection or hazard occurs within a time interval, linear interpolation is used to obtain the time and fire environment characteristics at detection or hazard.

Finally, this subroutine will print the times of detection and hazard, the fire environment characteristics at detection and hazard, and the safe available egress time. If desired, it will print a history of these charactersitics as the fire grows.

INTGR Subroutine

This subroutine is called by the SUBAINT subroutine to integrate the differential equations describing the smoke layer interface elevation, average upper layer temperature, detectable product of combustion concentration, and hazardous product of combustion concentration over a given time step size. It will segment the specified step size as necessary to obtain specified accuracy in the integration. If convergence has not been obtained after the original step size has been subdivided by a factor of 100, an error message is printed, the integration is terminated, and program execution continues with the next fire scenario.

SUBF Subroutine

This routine contains the differential equations which describe the development of the smoke layer interface elevation, the average upper layer temperature, the concentration of a detectable product of combustion, and the concentration of a hazardous product of combustion. It is required by the INTGR subroutine.

This subroutine has been divided into four parts. Each part consists of the four equations in forms appropriate for use during a certain time period. All but the first of these periods have been defined in terms of the location of the smoke layer interface. "IF" statements are used to determine which set of equations is appropriate at any given time.

The first part of this subroutine handles the special case at time equal to 0 when the fire is initiated. After the fire has been ignited and until such time as the smoke layer interface reaches the height of the fire, the general forms of the equations are used to determine interface elevation, layer temperature, and combustion product concentrations. Once the smoke layer interface reaches the height of the fire, the plume entrainment part of each equation may be eliminated. A third set of equations has been provided to handle this condition. When the smoke layer interface reaches the floor, the last set of equations is used.

INPUT Subroutine

When in the interactive mode, this subroutine is called by the MAIN program. It asks the user to confirm input values. If the value is incorrect, it solicits a new value. This routine is used to check almost all input values. It does not check the digital data input or some other values checked by the MAIN program.

INPUT2 Subroutine

When in the interactive mode, this subroutine is called by the MAIN program. It asks the user to confirm input values. If the value is incorrect, it solicits a new value. This routine is used to check the digital data point input (fire and product of combustion).

APPENDIX B: PROGRAM LISTING

MAIN PROGRAM

```
C*********************************************************************
C*********************************************************************
C*                                                                   *
C*       CALCULATING AVAILABLE SAFE EGRESS TIME (ASET)               *
C*                                                                   *
C*********************************************************************
C*********************************************************************
C*                                                                   *
C*       WRITTEN BY LEONARD Y. COOPER AND                            *
C*                  DAVID W. STROUP                                  *
C*                                                                   *
C*                  CENTER FOR FIRE RESEARCH                         *
C*                  NATIONAL ENGINEERING LABORATORY                  *
C*                  NATIONAL BUREAU OF STANDARDS                     *
C*                  U.S. DEPARTMENT OF COMMERCE                      *
C*                  WASHINGTON, D.C. 20234                           *
C*                                                                   *
C*********************************************************************
C*                                                                   *
C*       PROGRAM DOCUMENTATION:                                      *
C*                                                                   *
C*                        NBSIR 82-2578                              *
C*         CALCULATING AVAILABLE SAFE EGRESS TIME (ASET) -           *
C*              A COMPUTER PROGRAM AND USER'S GUIDE                  *
C*                                                                   *
C*********************************************************************
C*                                                                   *
C*       REVISED  SEPTEMBER 13, 1982                                 *
C*                                                                   *
C*********************************************************************
C*********************************************************************
C
C THIS IS EGRESS*ASET.MAIN.  IT REQUIRES EGRESS*ASET.EXFIRE
C  AND EGRESS*ASET.SUBAINT
C
C*********************************************************************
C
C                            NOTATION
C
C*********************************************************************
C AKAP(N) ENERGY GENERATION RATE EXPONENTIAL FACTOR IN THE NTH TIME
C          SEGMENT. READ IN AND USED TO CHARACTERIZE THE MULTI-EXPONEN-
C          TIAL ENERGY GENERATION RATE HISTORY.
C ALAMC   THE FRACTION OF ENERGY GENERATION RATE INSTANTANEOUSLY LOST TO
C         THE BOUNDING SURFACES OF THE ROOM AND ITS CONTENTS.
C ALAMR   THE FRACTION OF ENERGY GENERATION RATE INSTANTANEOUSLY LOST BY
C         RADIATION FROM THE COMBUSTION ZONE AND THE PLUME.
C AHF     ARGUMENT - HF(K)
C ASF     ARGUMENT - SF(M)
C ASM     ARGUMENT - SM(M)
C BETAD   CONSTANT OF PROPORTIONALITY BETWEEN DETECTABLE PRODUCT
C         GENERATION RATE AND ENERGY GENERATION RATE.
C         SPECIFICALLY DEFINED AS:
C
C              PRODUCT GENERATION RATE = BETAD * ENERGY GENERATION RATE
C
```

```
C          OR
C
C               (PRODUCT GENERATION RATE / PRDO) = (BETAD * QO/PRDO)
C                                          *(ENERGY GENERATION RATE / QO)
C
C          USED WHEN PRODD=1.
C          READ IN DIMENSIONS OF PRODUCT UNITS/(SEC*KW).
C BETAH    CONSTANT OF PROPORTIONALITY BETWEEN HAZARDOUS PRODUCT
C          GENERATION RATE AND ENERGY GENERATION RATE.
C          SPECIFICALLY DEFINED AS:
C
C               PRODUCT GENERATION RATE = BETAH * ENERGY GENERATION RATE
C
C          OR
C
C               (PRODUCT GENERATION RATE / PRHO) = (BETAH * QO/PRHO)
C                                          *(ENERGY GENERATION RATE / QO)
C
C          USED WHEN PRODH=1.
C          READ IN DIMENSIONS OF PRODUCT UNITS/(SEC*KW).
C C1       DIMENSIONLESS GROUP.
C C2       DIMENSIONLESS GROUP.
C C3D      DIMENSIONLESS GROUP.
C C3H      DIMENSIONLESS GROUP.
C CNDSP    DIMENSIONLESS SPECIFIED DETECTABLE PRODUCT CONCENTRATION
C          CORRESPONDING TO CNDS(I).
C CNHAZS SPECIFIED HAZARDOUS PRODUCT CONCENTRATION CORRESPONDING TO
C          A PARTICULAR CNHS(L). IN UNITS OF AMOUNT OF PRODUCT PER UNIT
C          MASS OF BULK GAS.
C CNDS(I)   SPECIFIED DETECTABLE PRODUCT CONCENTRATION. UNITS OF AMOUNT
C          OF PRODUCT PER UNIT MASS OF BULK GAS.
C CNHS(L) SPECIFIED HAZARDOUS PRODUCT CONCENTRATION. UNITS OF AMOUNT
C          OF PRODUCT PER UNIT MASS OF BULK GAS.
C DELTA    THE HEIGHT OF THE FIRE ABOVE THE FLOOR IN FEET.
C DELTAM THE HEIGHT OF THE FIRE ABOVE THE FLOOR IN METERS.
C DPHI     DPHI/DTAU GENERATED IN SUBF DURING COURSE OF INTEGRATION.
C DPHIDS DIMENSIONLESS RATE OF TEMP RISE CORRESPONDING TO RRDSPF(I).
C DPRDTO DPRD/DTAU AT TIME TAU=0. (DETECTABLE PRODUCT)
C DPRHTO DPRH/DTAU AT TIME TAU=0. (HAZARDOUS PRODUCT)
C DQDTO    DQ/DTAU AT TIME TAU=0.
C FIRE     INDICATES THE REPRESENTATIVE FORM OF ENERGY GENERATION RATE FOR
C          THE PARTICULAR COMPUTER RUN;  WHEN FIRE=1, MULTI-EXPONENTIAL
C          FIRE GROWTH CURVE. WHEN FIRE=2, DIGITAL DATA INPUT. WHEN
C          FIRE=3, SOME OTHER ANALYTIC FIRE GROWTH FUNCTION (NONE
C          PRESENTLY INCORPORATED INTO THE PROGRAM).
C FLAG     INDICATOR OF WHICH DETECTION METHOD IS UNDER CONSIDERATION.
C          WHEN FLAG=1, DETECTION BY POC CONCENTRATION.
C          WHEN FLAG=2, DETECTION BY UPPER LAYER TEMPERATURE.
C          WHEN FLAG=3, DETECTION BY RATE OF TEMPERATURE RISE.
C          THE VALUE OF FLAG IS ASSIGNED BY THE PROGRAM.  THE VALUE,
C          1, 2, OR 3, IT RECEIVES IS DEPENDENT ON THE INPUT VALUES
C          OF NCND, NTMD, AND NRRD.
C HCOMB    THE HEAT OF COMBUSTION (IN KJ/KG) USED TO CONVERT DIGITAL
C          DATA, QDATA(N), INPUT AS MASS LOSS RATES TO ENERGY RELEASE
C          RATES. IF QDATA(N) ARE INPUT DIRECTLY AS ENERGY RELEASE RATES
C          IN KW, THEN INPUT HCOMB=1.0.
C HF(I)    COMPARTMENT CEILING HEIGHT IN FEET.
C HM(I)    COMPARTMENT CEILING HEIGHT IN METERS.
```

MAIN PROGRAM

```
C IDETH   INDICATOR OF WHETHER OR NOT DETECTION BY CONCENTRATION
C         IS TO BE CONSIDERED IN SUBROUTINE AINT.
C         IF IDETH=0, DETECTION BY CONCENTRATION WILL BE
C                     CONSIDERED.
C         IF IDETH=1, DETECTION BY CONCENTRATION WILL NOT BE
C                     CONSIDERED.
C         THE VALUE, 1 OR 0, OF IDETH IS ASSIGNED BY THE PROGRAM
C         BASED ON THE PRESENT VALUE OF FLAG.  IDETH IS A
C         VARIABLE.
C IDETR   ANALOGOUS TO IDETH FOR DETECTION BY RATE OF TEMPERATURE
C         RISE OF UPPER LAYER.
C IDETT   ANALOGOUS TO IDETH FOR DETECTION BY UPPER LAYER TEMP.
C INTER   INDICATOR OF WHETHER INTERACTIVE OR BATCH MODE IS BEING USED.
C         IF INTER=YES, INTERACTIVE MODE.
C         IF INTER=NO, BATCH MODE.
C LINTER  LOGICAL EQUIVALENT TO INTER.
C         IF LINTER=TRUE, INTERACTIVE MODE.
C         IF LINTER=FALSE, BATCH MODE.
C LNORM   LOGICAL EQUIVALENT TO NORM.
C         IF LNORM=TRUE, NORMALIZED OUTPUT.
C         IF LNORM=FALSE, DO NOT NORMALIZE OUTPUT.
C NCND    THE NUMBER OF CASES OF DETECTION BY CONCENTRATION.
C NCNH    THE NUMBER OF HAZARDOUS PRODUCT CONCENTRATIONS CONSIDERED.
C NDET    UPPER BOUND OF A DO LOOP.  NDET IS SET EQUAL TO THE NUMBER
C         OF CASES OF DETECTION BY THE SPECIFIC MEANS OF DETECTION OF
C         INTEREST.  I.E., THE PROGRAM GOES THROUGH NCND FIRST (IF
C         NCND IS NOT EQUAL TO 0), SETTING NDET=NCND AND GOING
C         THROUGH ALL CASES OF DETECTION BY CONCENTRATION.  THE
C         NUMBER OF CASES OF DETECTION BY UPPER LAYER TEMPERATURE,
C         NTMD, IS GONE THROUGH SECOND AND NRRD THIRD.
C NH      THE NUMBER OF ROOM HEIGHTS TO BE CONSIDERED.
C NORM    INDICATOR OF WHETHER OR NOT FIRE DATA OUTPUT SHOULD BE
C           NORMALIZED.
C         IF NORM=YES, NORMALIZED OUTPUT.
C         IF NORM=NO, DO NOT NORMALIZE OUTPUT.
C NPTSP   THE NUMBER OF (TIME,PRODUCT) DIGITAL DATA POINTS TO BE INPUT
C         WHEN WORKING WITH DIGITAL DATA.
C NPTSQ   THE NUMBER OF (TIME,ENERGY GENERATION RATE) DIGITAL DATA POINTS
C         TO BE INPUT WHEN WORKING WITH DIGITAL DATA.
C NRRD    THE NUMBER OF CASES FOR DETECTION BY RATE OF TEMPERATURE
C         RISE OF THE UPPER LAYER.
C NS      THE NUMBER OF ROOM AREAS TO BE CONSIDERED.
C NSEGPD  USED WHEN PRODD=2. NUMBER OF SEGMENTS OF THE PRODUCT GENERATION
C         RATE HISTORY (DETECTABLE PRODUCT).
C NSEGPH  USED WHEN PRODH=2. NUMBER OF SEGMENTS OF THE PRODUCT GENERATION
C         RATE HISTORY (HAZARDOUS PRODUCT).
C NSEGQ   USED WHEN FIRE =1 OR 2. THE NUMBER OF SEGMENTS OF THE ENERGY
C         GENERATION RATE HISTORY.
C NSEGM1  THE NUMBER OF SEGMENTS MINUS 1.  I.E., NSEGQ-1.
C NTMD    THE NUMBER OF CASES FOR DETECTION BY TEMP OF THE LAYER.
C NTMHU   THE NUMBER OF SPECIFIED HAZARDOUS LAYER TEMPERATURES TO
C         BE CONSIDERED WHEN INTERFACE IS ABOVE ZETEYE.
C NTMHL   THE NUMBER OF SPECIFIED HAZARDOUS LAYER TEMPERATURES TO
C         BE CONSIDERED WHEN INTERFACE IS BELOW ZETEYE.
C PHIDSP  DIMENSIONLESS DETECTION TEMPERATURE CORRESPONDING TO TMDSPF(I).
C PHIHSU  DIMENSIONLESS HAZARDOUS TEMPERATURE CORRESPONDING TO
C         TMHSUF(I).
C PHIHSL  DIMENSIONLESS HAZARDOUS TEMPERATURE CORRESPONDING TO
```

```
C          TMHSLF(I).
C PRD(N)   IF PRODD =2 (LINEAR INTERPOLATION BETWEEN DATA POINTS):
C                AT INPUT, THE PRD(N) ARE READ IN AS PRODUCT GENERATION
C                RATES IN PRODUCT UNITS PER SECOND AT THE END OF SEGMENT N.
C                THIS VECTOR IS NORMALIZED BY DIVIDING EACH COMPONENT
C                BY PRD0. HERE N=1,.....,NSEGPD. (DETECTABLE PRODUCT)
C PRH(N)   IF PRODH =2 (LINEAR INTERPOLATION BETWEEN DATA POINTS):
C                AT INPUT, THE PRH(N) ARE READ IN AS PRODUCT GENERATION
C                RATES IN PRODUCT UNITS PER SECOND AT THE END OF SEGMENT N.
C                THIS VECTOR IS NORMALIZED BY DIVIDING EACH COMPONENT
C                BY PRH0. HERE N=1,.....,NSEGPH. (HAZARDOUS PRODUCT)
C PRODD   INDICATES THE REPRESENTITIVE FORM OF DETECTABLE COMBUSTION
C         PRODUCT GENERATION RATE FOR THE PARTICULAR COMPUTER RUN. WHEN
C         PRODD=1 PRODUCT GENERATION RATE IS DIRECTLY PROPORTIONAL
C         TO ENERGY GENERATION RATE THROUGH A FIXED CONSTANT OF PROPOR-
C         TIONALITY, BETAD. WHEN PRODD=2, DIGITAL DATA FOR PRODUCT
C         GENERATION WITH LINEAR INTERPOLATION IS SUPPLIED. WHEN
C         PRODD=3, SOME ANALYTIC GENERATION IS PRESCRIBED (NONE PRESENTLY
C         AVAILABLE).
C PRODH   INDICATES THE REPRESENTITIVE FORM OF HAZARDOUS COMBUSTION
C         PRODUCT GENERATION RATE FOR THE PARTICULAR COMPUTER RUN. WHEN
C         PRODH=1 PRODUCT GENERATION RATE IS DIRECTLY PROPORTIONAL
C         TO ENERGY GENERATION RATE THROUGH A FIXED CONSTANT OF PROPOR-
C         TIONALITY, BETAH. WHEN PRODH=2 DIGITAL DATA FOR PRODUCT
C         GENERATION WITH LINEAR INTERPOLATION IS SUPPLIED. WHEN
C         PRODH=3 SOME ANALYTIC GENERATION IS PRESCRIBED (NONE PRESENTLY
C         AVAILABLE).
C PRD0    INITIAL DETECTABLE PRODUCT GENERATION RATE IN PRODUCT UNITS
C         PER SECOND.
C PRH0    INITIAL HAZARDOUS PRODUCT GENERATION RATE IN PRODUCT UNITS
C         PER SECOND.
C Q(N)    IF FIRE =2 (LINEAR INTERPOLATION BETWEEN DATA POINTS):
C                AT INPUT, THE Q(N) ARE READ IN AS ENERGY GENERATION
C                RATES IN KW (OR MASS LOSS RATE IF HCOMB#1.) AT THE END
C                OF SEGMENT N. THIS VECTOR IS THEN NORMALIZED BY DIVID-
C                ING EACH COMPONENT BY Q0. HERE N=1,.....,NSEGQ.
C         IF FIRE =1 (EXPONENTIAL INTERPOLATION BETWEEN DATA POINTS):
C                AT INPUT, THE Q(N) ARE IMMEDIATELY READ IN A NORMAL-
C                IZED FORM AS ENERGY GENERATION RATES IN KW AT THE END
C                OF SEGMENT N DIVIDED BY Q0. HERE N=1,....,NSEGQ-1.
C                IF NSEGQ=1 THEN Q(N) IS NOT USED.
C Q0      THE INITIAL POWER OF THE FIRE IN KW. INPUT FOR
C         DIGITAL DATA. DETERMINED BY PROGRAM FOR MULTI-EXPONENTIAL
C         CURVE.
C RRDSPC(I) SPECIFIED RATE OF TEMPERATURE RISE OF LAYER FOR
C                DETECTION IN DEGREES C PER MINUTE.
C RRDSPF(I) SPECIFIED RATE OF TEMPERATURE RISE OF LAYER FOR
C                DETECTION IN DEGREES F PER MINUTE.
C SF(I)   ROOM AREA IN SQUARE FEET.
C SM(I)   ROOM AREA IN SQUARE METERS.
C TAULIM MAXIMUM TAU FOR WHICH FIRE IS MODELED OR TAU WHEN FIRE IS OUT.
C         DIMENSIONS IN SECONDS.
C TAUPRD(N) TIME IN SECONDS AT THE END OF THE NTH DETECTABLE PRODUCT
C         SEGMENT. READ IN FOR LINEAR INTERPOLATION BETWEEN DATA
C         POINTS. I.E., IF PRODD=2.
C TAUPRH(N) TIME IN SECONDS AT THE END OF THE NTH HAZARDOUS PRODUCT
C         SEGMENT. READ IN FOR LINEAR INTERPOLATION BETWEEN DATA
C         POINTS. I.E., IF PRODH=2.
```

```
C TAUQ(N) TIME IN SECONDS AT THE END OF THE NTH ENERGY SEGMENT. READ
C         IN FOR LINEAR INTERPOLATION BETWEEN DATA POINTS, I.E., IF
C         FIRE=2. COMPUTED FOR EXPONENTIAL INTERPOLATION BETWEEN DATA
C         POINTS, I.E., IF FIRE=1.
C TMDSPC(I) SPECIFIED LAYER TEMPERATURE FOR DETECTION IN DEGREES C.
C TMDSPF(I) SPECIFIED LAYER TEMPERATURE FOR DETECTION IN DEGREES F.
C TMHSUC(I) SPECIFIED HAZARDOUS LAYER TEMPERATURE WHEN INTERFACE IS
C         ABOVE ZETEYE IN DEGREES C.
C TMHSUF(I) SPECIFIED HAZARDOUS LAYER TEMPERATURE WHEN INTERFACE IS
C         ABOVE ZETEYE IN DEGREES F.
C TMHSLC(I) SPECIFIED HAZARDOUS LAYER TEMPERATURE WHEN INTERFACE IS
C         BELOW ZETEYE IN DEGREES C.
C TMHSLF(I) SPECIFIED HAZARDOUS LAYER TEMPERATURE WHEN INTERFACE IS
C         BELOW ZETEYE IN DEGREES F.
C WRC     WRITE/SUPPRESS CODE
C         IF WRC=1, SUMMARY OUTPUT, 132 CHARACTERS PER LINE.
C         IF WRC=2, SUMMARY OUTPUT, 80 CHARACTERS PER LINE.
C         IF WRC=3, FULL OUTPUT, 132 CHARACTERS PER LINE.
C         IF WRC=4, FULL OUTPUT, 80 CHARACTERS PER LINE.
C ZETEYE  THE SPECIFIED HEIGHT OF EYELEVEL ABOVE THE FLOOR IN FEET. IF
C         INTERFACE DROPS BELOW THIS LEVEL THEN THE ONSET OF HAZARDOUS
C         CONDITIONS WILL OCCUR WHEN UPPER LAYER TEMPERATURE EXCEEDS
C         TMHSLF(I).
C ZETO    THE INITIAL HEIGHT OF THE INTERFACE FROM THE FLOOR = HF(K)
C ZEYEF   THE INPUT SPECIFIED HEIGHT (IN FEET) OF EYELEVEL FROM THE FLOOR
C         FOR HAZARD.
C ZEYEM   THE INPUT SPECIFIED HEIGHT (IN METERS) OF EYELEVEL FROM THE
C         FLOOR FOR HAZARD.
C
C*********************************************************************
C
      INTEGER FIRE,FLAG,WRC,TITLE(20),PRODD,PRODH
      DIMENSION CNDS(10),TMDSPF(10),TMDSPC(10),CNHS(10),HF(20),HM(20),
     2          SF(30),SM(30),TMHSUF(10),TMHSLF(10),TMHSUC(10),
     3          TMHSLC(10),RRDSPF(10),RRDSPC(10)
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4       DPRHT0,Q0,LNORM
      LOGICAL LINTER,LNORM
      CHARACTER YES,NO,BATCH,INTER,NORM,ICHECK,INFO,CHARTR
      EXTERNAL F
      DATA YES,NO,BATCH/'Y','N','B'/
C
      WRITE (6,2400)
      WRITE (6,2430)
      WRITE (6,2400)
      WRITE (6,1860)
      READ (5,1530) INTER
      IF (INTER.EQ.YES) LINTER=.TRUE.
      IF ((INTER.EQ.NO).OR.(INTER.EQ.BATCH)) LINTER=.FALSE.
      IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1870)
      IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1510)
 10   IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1880)
      READ (5,1520) TITLE
```

```
      IF (LINTER) WRITE (6,2410)
      WRITE (6,1570) TITLE
      IF (.NOT.(LINTER)) GO TO 20
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 10
 20   IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1890)
      READ (5,1550,ERR=30) WRC
      IF (LINTER) WRITE (6,2410)
      IF (WRC.EQ.1) WRITE (6,1900)
      IF (WRC.EQ.2) WRITE (6,1910)
      IF (WRC.EQ.3) WRITE (6,1920)
      IF (WRC.EQ.4) WRITE (6,1930)
      IF (.NOT.(LINTER)) GO TO 50
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 20
      GO TO 50
 30   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 20
 40   WRITE (6,2450)
      STOP 1
C
C INPUT DATA IN ENGLISH UNITS AND CONVERT SAME TO METRIC UNITS.
C
 50   IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1950)
      IF (.NOT.(LINTER)) GO TO 60
      READ (5,1530) INFO
      IF (INFO.EQ.YES) WRITE (6,1960)
      WRITE (6,1970)
 60   READ (5,*,ERR=70) ALAMR,ALAMC,ZEYEF,DELTA
      IF (LINTER) WRITE (6,2410)
      WRITE (6,1540) ALAMR,ALAMC,ZEYEF,DELTA
      IF (.NOT.(LINTER)) GO TO 80
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 50
      GO TO 80
 70   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 50
      GO TO 40
 80   DELTAM=DELTA*0.3048
      ZEYEM=ZEYEF*0.3048
      IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1980)
      IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,1990)
      IF (LINTER) WRITE (6,2400)
      I=1
      NTMD=0
 90   IF (LINTER) WRITE (6,2000)
      READ (5,*,ERR=100,END=110) TMDSPF(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) TMDSPF(I)
      IEND=0
      IF (LINTER) CALL INPUT (TMDSPF(I),IEND)
```

```
      IF (IEND.EQ.999) GO TO 110
      NTMD=NTMD+1
      TMDSPC(I)=(TMDSPF(I)-32.)/1.8
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 90
100   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 90
      GO TO 40
110   I=1
      NRRD=0
      IF (LINTER) WRITE (6,2400)
120   IF (LINTER) WRITE (6,2010)
      READ (5,*,ERR=130,END=140) RRDSPF(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) RRDSPF(I)
      IF ((RRDSPF(I).GT.-0.0001).AND.(RRDSPF(I).LT.0.0001))
     2     WRITE (6,2020)
      IEND=0
      IF (LINTER) CALL INPUT (RRDSPF(I),IEND)
      IF (IEND.EQ.999) GO TO 140
      NRRD=NRRD+1
      RRDSPC(I)=RRDSPF(I)/1.8
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 120
130   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 120
      GO TO 40
140   I=1
      NCND=0
      IF (LINTER) WRITE (6,2400)
150   IF (LINTER) WRITE (6,2030)
      READ (5,*,ERR=160,END=170) CNDS(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) CNDS(I)
      IEND=0
      IF (LINTER) CALL INPUT (CNDS(I),IEND)
      IF (IEND.EQ.999) GO TO 170
      NCND=NCND+1
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 150
160   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 150
      GO TO 40
170   IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,2040)
      I=1
      NTMHU=0
      IF (LINTER) WRITE (6,2400)
180   IF (LINTER) WRITE (6,2050)
      READ (5,*,ERR=190,END=200) TMHSUF(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) TMHSUF(I)
      IEND=0
      IF (LINTER) CALL INPUT (TMHSUF(I),IEND)
      IF (IEND.EQ.999) GO TO 200
```

```
      NTMHU=NTMHU+1
      TMHSUC(I)=(TMHSUF(I)-32.)/1.8
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 180
 190  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 180
      GO TO 40
 200  I=1
      NTMHL=0
      IF (LINTER) WRITE (6,2400)
 210  IF (LINTER) WRITE (6,2060)
      READ (5,*,ERR=220,END=230) TMHSLF(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) TMHSLF(I)
      IEND=0
      IF (LINTER) CALL INPUT (TMHSLF(I),IEND)
      IF (IEND.EQ.999) GO TO 230
      NTMHL=NTMHL+1
      TMHSLC(I)=(TMHSLF(I)-32.)/1.8
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 210
 220  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 210
      GO TO 40
 230  I=1
      NCNH=0
      IF (LINTER) WRITE (6,2400)
 240  IF (LINTER) WRITE (6,2070)
      READ (5,*,ERR=250,END=260) CNHS(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) CNHS(I)
      IEND=0
      IF (LINTER) CALL INPUT (CNHS(I),IEND)
      IF (IEND.EQ.999) GO TO 260
      NCNH=NCNH+1
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 240
 250  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 240
      GO TO 40
 260  IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,2080)
      IF (LINTER) WRITE (6,2400)
      I=1
      NH=0
 270  IF (LINTER) WRITE (6,2090)
      READ (5,*,ERR=280,END=290) HF(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) HF(I)
      IEND=0
      IF (LINTER) CALL INPUT (HF(I),IEND)
      IF (IEND.EQ.999) GO TO 290
      NH=NH+1
      I=I+1
      IF (LINTER) WRITE (6,2410)
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```
      GO TO 270
280   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 270
      GO TO 40
290   DO 310 IS=1,NH
          DO 300 JS=1,NH
              IF (HF(IS).LE.HF(JS)) GO TO 300
              IF (IS.GE.JS) GO TO 300
              TSTORE=HF(IS)
              HF(IS)=HF(JS)
              HF(JS)=TSTORE
300           CONTINUE
310       CONTINUE
      DO 320 IM=1,NH
320       HM(IM)=HF(IM)*0.3048
      I=1
      NS=0
      IF (LINTER) WRITE (6,2400)
330   IF (LINTER) WRITE (6,2100)
      READ (5,*,ERR=340,END=350) SF(I)
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) SF(I)
      IEND=0
      IF (LINTER) CALL INPUT (SF(I),IEND)
      IF (IEND.EQ.999) GO TO 350
      NS=NS+1
      I=I+1
      IF (LINTER) WRITE (6,2410)
      GO TO 330
340   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 330
      GO TO 40
350   DO 370 IS=1,NS
          DO 360 JS=1,NS
              IF (SF(IS).LE.SF(JS)) GO TO 360
              IF (IS.GE.JS) GO TO 360
              TSTORE=SF(IS)
              SF(IS)=SF(JS)
              SF(JS)=TSTORE
360           CONTINUE
370       CONTINUE
      DO 380 IM=1,NS
380       SM(IM)=SF(IM)*0.0929
C
C THIS SECTION INPUTS DATA FOR FIRE ENERGY GENERATION RATE.
C
      IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,2110)
      IF (LINTER) WRITE (6,2400)
390   IF (LINTER) WRITE (6,2120)
      READ (5,1550,ERR=400) FIRE
      IF (LINTER) WRITE (6,2410)
      IF (FIRE.EQ.1) WRITE (6,2130)
      IF (FIRE.EQ.2) WRITE (6,2140)
      IF (.NOT.(LINTER)) GO TO 410
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 390
```

```
      GO TO 410
400   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 390
      GO TO 40
410   GO TO (420,500,590), FIRE
C
C INPUT DATA FOR MULTI-EXPONENTIAL FIRE GROWTH CURVE.
C
420   IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2150)
      READ (5,*,ERR=430) TAULIM
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) TAULIM
      IF (LINTER) CALL INPUT (TAULIM,0)
      IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2160)
      GO TO 440
430   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 420
      GO TO 40
440   N=1
450   READ (5,*,ERR=460,END=470) Q(N),AKAP(N)
      N=N+1
      GO TO 450
460   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 450
      GO TO 40
470   NSEGQ=N-1
      ITYPE=1
      IF (LINTER) WRITE (6,2410)
      WRITE (6,2170) (N,Q(N),AKAP(N),N=1,NSEGQ)
      IF (LINTER) CALL INPUT2 (AKAP,Q,ITYPE)
      Q0=Q(1)
      NSEGM1=NSEGQ-1
      DO 480 N=1,NSEGM1
           Q(N)=Q(N+1)/Q0
480        CONTINUE
      DQDT0=AKAP(1)
490   IF (LINTER) WRITE (6,2180)
      READ (5,1530) NORM
      IF (NORM.EQ.YES) LNORM=.TRUE.
      IF (NORM.EQ.NO) LNORM=.FALSE.
      IF (LNORM) WRITE (6,2190)
      IF (.NOT.(LNORM)) WRITE (6,2200)
      IF (.NOT.(LINTER)) GO TO 600
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 490
      GO TO 600
C
C INPUT THE VALUE OF TAUQ AND Q AT EACH DIGITAL DATA
C SEGMENT, NSEGQ.
C
500   IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2210)
      READ (5,*,ERR=510) TAULIM,HCOMB
      IF (LINTER) WRITE (6,2410)
      WRITE (6,2220) TAULIM,HCOMB
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      IF (.NOT.(LINTER)) GO TO 520
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 500
      GO TO 520
510   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 500
      GO TO 40
520   IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2230)
      READ (5,*,ERR=530) Q0
      IF (LINTER) WRITE (6,2410)
      WRITE (6,2240) Q0
      IF (LINTER) CALL INPUT (Q0,0)
      IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2250)
      GO TO 540
530   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 520
      GO TO 40
540   N=1
550   READ (5,*,ERR=560,END=570) TAUQ(N),Q(N)
      N=N+1
      GO TO 550
560   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 550
      GO TO 40
570   NSEGQ=N-1
      ITYPE=2
      IF (LINTER) WRITE (6,2410)
      WRITE (6,1730) (N,TAUQ(N),N,Q(N),N=1,NSEGQ)
      IF (LINTER) CALL INPUT2 (TAUQ,Q,ITYPE)
580   IF (LINTER) WRITE (6,2260)
      READ (5,1530) NORM
      IF (NORM.EQ.YES) LNORM=.TRUE.
      IF (NORM.EQ.NO) LNORM=.FALSE.
      IF (LNORM) WRITE (6,2190)
      IF (.NOT.(LNORM)) WRITE (6,2200)
      IF (.NOT.(LINTER)) GO TO 600
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 580
      GO TO 600
C
C ENERGY GENERATION RATE GIVEN BY ANALYTIC FUNCTION
C
590   WRITE (6,1600)
      IF (LINTER) GO TO 350
      STOP 2
C
C THIS SECTION INPUTS DATA FOR DETECTABLE PRODUCT GENERATION RATE.
C
600   IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,2270)
      IF (LINTER) WRITE (6,2400)
      IF (NCND.EQ.0) WRITE (6,2380)
      IF (NCND.EQ.0) GO TO 650
610   IF (LINTER) WRITE (6,2280)
```

```
      READ (5,1550,ERR=620) PRODD
      IF (LINTER) WRITE (6,2410)
      IF (PRODD.EQ.1) WRITE (6,2290)
      IF (PRODD.EQ.2) WRITE (6,2300)
      IF (.NOT.(LINTER)) GO TO 630
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 610
      GO TO 630
 620  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 610
      GO TO 40
 630  GO TO (640,670,730), PRODD
C
C INPUT BETAD FOR DETECTABLE PRODUCT GENERATION RATE
C PROPORTIONAL TO ENERGY RELEASE.
C
 640  IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2310)
      READ (5,*,ERR=660) BETAD
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) BETAD
      IF (LINTER) CALL INPUT (BETAD,0)
 650  IF (NCND.EQ.0) BETAD=0.0
      IF (NCND.EQ.0) PRODD=1
      GO TO 740
 660  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 640
      GO TO 40
C
C INPUT THE VALUE OF TAUPRD AND PRD AT THE END OF EACH DIGITAL
C DATA SEGMENT, NSEGPD.
C
 670  IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2340)
      READ (5,*,ERR=680) PRD0
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) PRD0
      IF (LINTER) CALL INPUT (PRD0,0)
      IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2350)
      GO TO 690
 680  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 670
      GO TO 40
 690  N=1
 700  READ (5,*,ERR=710,END=720) TAUPRD(N),PRD(N)
      N=N+1
      GO TO 700
 710  IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 700
      GO TO 40
 720  NSEGPD=N-1
      ITYPE=3
      IF (LINTER) WRITE (6,2410)
      WRITE (6,1710) (N,TAUPRD(N),N,PRD(N),N=1,NSEGPD)
      IF (LINTER) CALL INPUT2 (TAUPRD,PRD,ITYPE)
      GO TO 740
```

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C
C DETECTABLE PRODUCT GENERATION RATE GIVEN BY ANALYTIC FUNCTION
C
730   WRITE (6,1660)
      IF (LINTER) GO TO 600
      STOP 3
C
C THIS SECTION INPUTS DATA FOR HAZARDOUS PRODUCT GENERATION RATE.
C
740   IF (LINTER) WRITE (6,2400)
      IF (LINTER) WRITE (6,2330)
      IF (LINTER) WRITE (6,2400)
750   IF (LINTER) WRITE (6,2280)
      READ (5,1550,ERR=760) PRODH
      IF (LINTER) WRITE (6,2410)
      IF (PRODH.EQ.1) WRITE (6,2290)
      IF (PRODH.EQ.2) WRITE (6,2300)
      IF (.NOT.(LINTER)) GO TO 770
      WRITE (6,1940)
      READ (5,1530) ICHECK
      IF (ICHECK.EQ.NO) GO TO 750
      GO TO 770
760   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 750
      GO TO 40
770   GO TO (780,800,860), PRODH
C
C INPUT BETAH FOR HAZARDOUS PRODUCT GENERATION RATE
C PROPORTIONAL TO ENERGY RELEASE.
C
780   IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2320)
      READ (5,*,ERR=790) BETAH
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) BETAH
      IF (LINTER) CALL INPUT (BETAH,0)
      GO TO 870
790   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 780
      GO TO 40
C
C INPUT THE VALUE OF TAUPRH AND PRH AT THE END OF EACH DIGITAL
C DATA SEGMENT, NSEGPH.
C
800   IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2360)
      READ (5,*,ERR=810) PRH0
      IF (LINTER) WRITE (6,2410)
      WRITE (6,*) PRH0
      IF (LINTER) CALL INPUT (PRH0,0)
      IF (LINTER) WRITE (6,2410)
      IF (LINTER) WRITE (6,2370)
      GO TO 820
810   IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 800
      GO TO 40
820   N=1
830   READ (5,*,ERR=840,END=850) TAUPRH(N),PRH(N)
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```
      N=N+1
      GO TO 830
  840 IF (LINTER) WRITE (6,2440)
      IF (LINTER) GO TO 830
      GO TO 40
  850 NSEGPH=N-1
      ITYPE=4
      IF (LINTER) WRITE (6,2410)
      WRITE (6,1720) (N,TAUPRH(N),N,PRH(N),N=1,NSEGPH)
      IF (LINTER) CALL INPUT2 (TAUPRH,PRH,ITYPE)
      GO TO 870
C
C HAZARDOUS PRODUCT GENERATION RATE ANALYTIC FUNCTION
C
  860 WRITE (6,1660)
      IF (LINTER) GO TO 740
      STOP 4
  870 IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      IF ((WRC.EQ.2).OR.(WRC.EQ.4)) GO TO 1050
      WRITE (6,1560) TITLE
      IF (FIRE.EQ.2) GO TO 880
      WRITE (6,1580) TAULIM,Q0
      IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      CALL EXFIRE
      GO TO 930
  880 WRITE (6,1610) TAULIM,Q0,HCOMB
      IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      DO 890 N=1,NSEGQ
          WRITE (6,1730) N,TAUQ(N),N,Q(N)
  890     CONTINUE
      IF (Q0.GT.0.0) GO TO 910
      DO 900 N=1,NSEGQ
          IF (Q(N).GT.0.0) Q0=Q(N)/100.0
          IF (Q0.GT.0.0) GO TO 910
  900     CONTINUE
  910 Q0=Q0*HCOMB
      DO 920 N=1,NSEGQ
  920     Q(N)=Q(N)*HCOMB/Q0
      DQDT0=(Q(1)-1.)/TAUQ(1)
  930 IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      WRITE (6,1740) ALAMR,ALAMC,DELTA,DELTAM
      IF (NCND.EQ.0.0) PRD0=0.0
      IF (NCND.EQ.0.0) DPRDT0=0.0
      IF (NCND.EQ.0) GO TO 990
      IF (PRODD.EQ.2) GO TO 940
      WRITE (6,1620) BETAD
      PRD0=BETAD*Q0
      DPRDT0=DQDT0
      GO TO 990
  940 WRITE (6,1670) PRD0
      DO 950 N=1,NSEGPD
          WRITE (6,1710) N,TAUPRD(N),N,PRD(N)
  950     CONTINUE
      IF (PRD0.GT.0.0) GO TO 970
```

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      DO 960 N=1,NSEGPD
          IF (PRD(N).GT.0.0) PRDO=PRD(N)/100.0
          IF (PRDO.GT.0.0) GO TO 970
960       CONTINUE
970   DO 980 N=1,NSEGPD
980       PRD(N)=PRD(N)/PRDO
      DPRDTO=(PRD(N)-1.)/TAUPRD(1)
990   IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      IF (PRODH.EQ.2) GO TO 1000
      WRITE (6,1630) BETAH
      PRDO=BETAH*Q0
      DPRHTO=DQDTO
      GO TO 1230
1000  WRITE (6,1680) PRHO
      DO 1010 N=1,NSEGPH
          WRITE (6,1720) N,TAUPRH(N),N,PRH(N)
1010      CONTINUE
      IF (PRHO.GT.0.0) GO TO 1030
      DO 1020 N=1,NSEGPH
          IF (PRH(N).GT.0.0) PRHO=PRH(N)/100.0
          IF (PRHO.GT.0.0) GO TO 1030
1020      CONTINUE
1030  DO 1040 N=1,NSEGPH
1040      PRH(N)=PRH(N)/PRHO
      DPRHTO=(PRH(1)-1.)/TAUPRH(1)
      GO TO 1230
1050  WRITE (6,1570) TITLE
      IF (FIRE.EQ.2) GO TO 1060
      WRITE (6,1590) TAULIM,Q0
      IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      CALL EXFIRE
      GO TO 1110
1060  WRITE (6,1610) TAULIM,Q0,HCOMB
      IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      DO 1070 N=1,NSEGQ
          WRITE (6,1730) N,TAUQ(N),N,Q(N)
1070      CONTINUE
      IF (Q0.GT.0.0) GO TO 1090
      DO 1080 N=1,NSEGQ
          IF (Q(N).GT.0.0) Q0=Q(N)/100.0
          IF (Q0.GT.0.0) GO TO 1090
1080      CONTINUE
1090  Q0=Q0*HCOMB
      DO 1100 N=1,NSEGQ
1100      Q(N)=Q(N)*HCOMB/Q0
      DQDTO=(Q(1)-1.)/TAUQ(1)
1110  IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      WRITE (6,1750) ALAMR,ALAMC,DELTA,DELTAM
      IF (NCND.EQ.0) PRDO=0.0
      IF (NCND.EQ.0) DPRDTO=0.0
      IF (NCND.EQ.0) GO TO 1170
      IF (PRODD.EQ.2) GO TO 1120
      WRITE (6,1640) BETAD
      PRDO=BETAD*Q0
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      DPRDTO=DQDTO
      GO TO 1170
 1120 WRITE (6,1690) PRDO
      DO 1130 N=1,NSEGPD
          WRITE (6,1710) N,TAUPRD(N),N,PRD(N)
 1130     CONTINUE
      IF (PRDO.GT.0.0) GO TO 1150
      DO 1140 N=1,NSEGPD
          IF (PRD(N).GT.0.0) PRDO=PRD(N)/100.0
          IF (PRDO.GT.0.0) GO TO 1150
 1140     CONTINUE
 1150 DO 1160 N=1,NSEGPD
 1160     PRD(N)=PRD(N)/PRDO
      DPRDTO=(PRD(1)-1.)/TAUPRD(1)
 1170 IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      IF (PRODH.EQ.2) GO TO 1180
      WRITE (6,1650) BETAH
      PRHO=BETAH*QO
      DPRHTO=DQDTO
      GO TO 1230
 1180 WRITE (6,1700) PRHO
      DO 1190 N=1,NSEGPH
          WRITE (6,1720) N,TAUPRH(N),N,PRH(N)
 1190     CONTINUE
      IF (PRHO.GT.0.0) GO TO 1210
      DO 1200 N=1,NSEGPH
          IF (PRH(N).GT.0.0) PRHO=PRH(N)/100.0
          IF (PRHO.GT.0.0) GO TO 1210
 1200     CONTINUE
 1210 DO 1220 N=1,NSEGPH
 1220     PRH(N)=PRH(N)/PRHO
      DPRHTO=(PRH(1)-1.)/TAUPRH(1)
 1230 IF (LINTER) WRITE (6,2390)
      IF (LINTER) READ (5,1530) CHARTR
      IF (NCND.EQ.0) GO TO 1240
      NDET=NCND
      FLAG=1
      GO TO 1260
 1240 IF (NTMD.EQ.0) GO TO 1250
      NDET=NTMD
      FLAG=2
      GO TO 1260
 1250 IF (NRRD.EQ.0) GO TO 1500
      NDET=NRRD
      FLAG=3
C
C GO THROUGH NDET VALUES OF SPECIFIC UPPER LAYER DETECTION METHOD
C UNDER CONSIDERATION.
C
 1260 DO 1490 I=1,NDET
C
C GO THROUGH NTMHU VALUES OF MINIMUM TEMPERATURES WHICH MAKE UPPER LAYER
C HAZARDOUS DUE TO RADIATION EVEN WHEN INTERFACE IS ABOVE ZEYEF.
C
          DO 1480 J=1,NTMHU
C
C GO THROUGH NTMHL VALUES OF MINIMUM TEMPERATURES WHICH MAKE UPPER
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C LAYER HAZARDOUS DUE TO DIRECT BURNS OR INHALING OF HOT GASES (I.E..
C WHEN INTERFACE IS BELOW ZEYEF).
C
                  DO 1470 N=1,NTMHL
C
C GO THROUGH NCNH VALUES OF PRODUCT CONCENTRATIONS WHICH MAKE UPPER
C LAYER HAZARDOUS WHEN INTERFACE IS BELOW ZEYEF.
C
                         DO 1460 L=1,NCNH
C
C PRINT CRITERIA FOR DETECTION AND HAZARD.
C
                              IF ((WRC.EQ.2).OR.(WRC.EQ.4)) GO TO 1300
                              GO TO (1270,1280,1290), FLAG
                              WRITE (6,1560) TITLE
 1270                         WRITE (6,1760) CNDS(I),ZEYEF,ZEYEM,TMHSUF(J),
                               TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),TMHSLC(N),
     2                         CNHS(L)
     3                        GO TO 1340
                              WRITE (6,1560) TITLE
 1280                         WRITE (6,1780) TMDSPF(I),TMDSPC(I),ZEYEF,ZEYEM
                               ,TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
     2                         TMHSLC(N),CNHS(L)
     3                        GO TO 1340
                              WRITE (6,1560) TITLE
 1290                         WRITE (6,1800) RRDSPF(I),RRDSPC(I),ZEYEF,ZEYEM
                              ,TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
     2                        TMHSLC(N),CNHS(L)
     3                        GO TO 1340
                              GO TO (1310,1320,1330), FLAG
 1300                         WRITE (6,1570) TITLE
 1310                         WRITE (6,1770) CNDS(I),ZEYEF,ZEYEM,TMHSUF(J),
                               TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),TMHSLC(N),
     2                         CNHS(L)
     3                        GO TO 1340
                              WRITE (6,1570) TITLE
 1320                         WRITE (6,1790) TMDSPF(I),TMDSPC(I),ZEYEF,ZEYEM
                               ,TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
     2                         TMHSLC(N),CNHS(L)
     3                        GO TO 1340
                              WRITE (6,1570) TITLE
 1330                         WRITE (6,1810) RRDSPF(I),RRDSPC(I),ZEYEF,ZEYEM
                               ,TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
     2                         TMHSLC(N),CNHS(L)
     3
C
C GO THROUGH NH VALUES OF COMPARTMENT HEIGHTS.
C                             IF (LINTER) WRITE (6,2390)
 1340                         IF (LINTER) READ (5,1530) CHARTR
                              DO 1450 K=1,NH
                                   IF ((WRC.EQ.1).OR.(WRC.EQ.3))
                                       WRITE (6,1820) HF(K),HM(K)
     2                             IF ((LINTER).AND.(WRC.EQ.1))
                                       WRITE (6,2390)
     2                             IF ((LINTER).AND.(WRC.EQ.1))
                                       READ (5,1530) CHARTR
     2                             IF (WRC.EQ.1) WRITE (6,1560) TITLE
                                   IF ((WRC.EQ.1).AND.(LNORM))
```

```
     2                                   WRITE (6,1840)
     2                              IF ((WRC.EQ.1).AND.(.NOT.(LNORM)))
C                                       WRITE (6,1850)
C  SET DIMENSIONLESS INITIAL VALUES AND HAZARD CRITERIA PARAMETERS
C  FOR FILLING PROBLEM.
C
 1350                               GO TO (1350,1360,1370), FLAG
                                    CNDSP=CNDS(I)
 1360                               GO TO 1380
                                    PHIDSP=(TMDSPF(I)+460.)/530.
 1370                               GO TO 1380
 1380                               DPHIDS=(RRDSPF(I)/31800.0)
                                    ZETEYE=ZEYEF
                                    ZETO=HF(K)-DELTA
                                    PHIHSU=(TMHSUF(J)+460.)/530.
                                    PHIHSL=(TMHSLF(N)+460.)/530.
                                    CNHAZS=CNHS(L)
                                    IDETH=1
                                    IDETT=1
                                    IDETR=1
C                                   LIMIT=0
C GO THROUGH ALL INPUT COMPARTMENT AREAS.
C
                                    DO 1440 M=1,NS
     2                                  IF ((WRC.EQ.2).OR.(WRC.EQ.4))
                                           WRITE (6,1820) HF(K),HM(K)
     2                                  IF ((WRC.EQ.2).OR.(WRC.EQ.3).OR.
     3                                     (WRC.EQ.4))
                                            WRITE (6,1830) SF(M),SM(M)
     2                                  IF ((.NOT.(LINTER)).OR.(WRC.EQ.1))
                                           GO TO 1390
                                        WRITE (6,2390)
 1390                                   READ (5,1530) CHARTR
                                        C1=(1.-ALAMC)*0.1070*Q0/SF(M)
     2                                  C2=0.210*((32./(.0735*.24*530.*1.054
     3                                     ))**(1./3.))
     4                                     *((((1.-ALAMR)*Q0)
                                           **(1./3.))/SF(M)
                                        C3D=0.02943*PRD0/SF(M)
                                        C3H=0.02943*PRH0/SF(M)
 1400                                   GO TO (1400,1410,1420), FLAG
                                        IDETH=0
 1410                                   GO TO 1430
                                        IDETT=0
 1420                                   GO TO 1430
 1430                                   IDETR=0
                                        ASF=SF(M)
                                        ASM=SM(M)
C                                       AHF=HF(K)
C CALL SUBROUTINE AINT TO
C INTEGRATE EQN. FOR INTERFACE POSITION AND COMPUTE TIMES AND PARA-
C METERS FOR DETECTION AND HAZARD. PRINT RESULTS AND GO ON TO THE
C NEXT ROOM AREA.
C
                                        CALL AINT(IDETH,IDETT,IDETR,PHIHSU,
```

MAIN PROGRAM

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                                                       PHIHSL,CNHAZS,PHIDSP,
     2                                                 CNDSP,ZETEYE,DPHIDS,ASF,
     3                                                 ASM,AHF,WRC,TITLE)
     4
C
C IF DIGITAL DATA IS BEING USED AND IF THE UPPER LIMIT OF THAT DATA
C HAS BEEN REACHED (LIMIT=1), BYPASS THE REMAINING COMPARTMENT
C AREAS FOR HEIGHT M AND GO TO THE NEXT COMPARTMENT HEIGHT
C
                                             IF (LIMIT.EQ.1) GO TO 1450
                                             CONTINUE
 1440                                   CONTINUE
 1450                              CONTINUE
 1460                         CONTINUE
 1470                    CONTINUE
 1480               CONTINUE
 1490          CONTINUE
      GO TO (1240,1250,1500), FLAG
 1500 WRITE (6,2420)
      STOP 5
C
C
 1510 FORMAT(' INSTRUCTIONS'/' TO ENTER DATA: TYPE IN REQUESTED VALUE OR
     2 VALUES (MULTIPLE VALUES'/' SEPARATED BY A COMMA OR BLANK), THEN P
     3RESS CARRIAGE RETURN.')
 1520 FORMAT (20A4)
 1530 FORMAT(A1)                                                  = ',F5.3/
 1540 FORMAT(5X,'LAMDA R            = ',F5.3/5X,'LAMDA C
     25X,'EYELEVEL HEIGHT = ',F7.3/5X,'FIRE HEIGHT        = ',F7.3)
 1550 FORMAT(I1)
 1560 FORMAT (1H1,20X,20A4/)
 1570 FORMAT(1H1,20A4/)
 1580 FORMAT (1H0,4X,'THE INTEGRATIONS WILL NOT BE CARRIED OUT BEYOND ',
     2F5.0,'SECONDS FOLLOWING IGNITION'//4X,'THE FOLLOWING DESCRIBES THE
     3 TIME HISTORY OF THE MULTI-EXPONENTIAL FIRE GROWTH CURVE:'//5X,
     4'Q(TIME=0.0) = Q0 = ',F8.2,' KW '//)
 1590 FORMAT(1H0,'THE INTEGRATIONS WILL NOT BE CARRIED OUT BEYOND ',F5.0
     2,' SECONDS'/' FOLLOWING IGNITION.'/' THE TIME HISTORY OF THE MULTI
     3-EXPONENTIAL FIRE GROWTH CURVE:'/4X,'Q(TIME=0.0)=Q0=',F8.2,' KW')
 1600 FORMAT (1H0,'ADD AN ANALYTIC FIRE GROWTH FUNCTION')
 1610 FORMAT (1H0,3X,'THE INTEGRATIONS WILL NOT BE CARRIED OUT BEYOND ',
     2F5.0,'SECONDS'/' FOLLOWING IGNITION.'//3X,'THE FOLLOWING DATA CHAR
     3ACTERIZE THE HISTORY OF THE FIRE:'//
     45X,'Q(TIME=0.0) = Q0 = ',F8.2,' KW '//
     55X,'HCOMB = ',E12.4//)
 1620 FORMAT('0THE DETECTABLE PRODUCT OF COMBUSTION GENERATION RATE IS P
     2ROPORTIONAL TO ENERGY GENERATION RATE ACCORDING TO:'//20X,'RATE OF
     3 PRODUCT GENERATION = (',E12.4,' UNTS PER SECOND PER KW)*RATE OF E
     4NERGY GENERATION')
 1630 FORMAT('0THE HAZARDOUS PRODUCT OF COMBUSTION GENERATION RATE IS PR
     2OPORTIONAL TO ENERGY GENERATION RATE ACCORDING TO:'//20X,'RATE OF
     3PRODUCT GENERATION = (',E12.4,' UNTS PER SECOND PER KW)*RATE OF EN
     4ERGY GENERATION')
 1640 FORMAT('0THE DETECTABLE PRODUCT OF COMBUSTION GENERATION RATE IS P
     2ROPORTIONAL TO'/' ENERGY GENERATION RATE ACCORDING TO:'/' RATE OF
     3PRODUCT GENERATION = (',E12.4,' UNTS/SEC/KW)*ENERGY GENERATION RAT
     4E')
 1650 FORMAT('0THE HAZARDOUS PRODUCT OF COMBUSTION GENERATION RATE IS PR
     2OPORTIONAL TO'/' ENERGY GENERATION RATE ACCORDING TO:'/' RATE OF P
     3RODUCT GENERATION = (',E12.4,' UNTS/SEC/KW)*ENERGY GENERATION RATE
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     4')
1660  FORMAT (1H0,' ADD AN ANALYTIC PRODUCT GENERATION')
1670  FORMAT (1H0,3X,'THE FOLLOWING DATA CHARACTERIZE THE HISTORY OF'
     2' THE DETECTABLE PRODUCT OF COMBUSTION GENERATION RATE:'//
     35X,' P(TIME=0.0)=P0=',E10.4,' UNITS PER SECOND '//)
1680  FORMAT (1H0,3X,'THE FOLLOWING DATA CHARACTERIZE THE HISTORY OF'
     2' THE HAZARDOUS PRODUCT OF COMBUSTION GENERATION RATE:'//
     35X,' P(TIME=0.0)=P0=',E10.4,' UNITS PER SECOND '//)
1690  FORMAT('0 THE HISTORY OF THE DETECTABLE PRODUCT OF COMBUSTION GENE
     2RATION RATE:'//5X,' P(TIME=0.0)=P0=',E10.4,' UNITS PER SECOND'//)
1700  FORMAT('0 THE HISTORY OF THE HAZARDOUS PRODUCT OF COMBUSTION GENER
     2ATION RATE:'//5X,' P(TIME=0.0)=P0=',E10.4,' UNITS PER SECOND'//)
1710  FORMAT(1H ,'TAUPRD(',I3,') = ',F6.0,5X,'PRD(',I3,') = ',E12.4)
1720  FORMAT(1H ,'TAUPRH(',I3,') = ',F6.0,5X,'PRH(',I3,') = ',E12.4)
1730  FORMAT (1H ,'TAUQ(',I3,') = ',F6.0,5X,'Q(',I3,') = ',E12.4)
1740  FORMAT (1H0,1X,'FRACTION OF FIRE ENERGY WHICH IS LOST TO WALLS AND
     2 FLOOR BY RADIATION AND WHICH IS NOT EFFECTIVE IN DRIVING PLUME =
     3',F5.3,/2X,'FRACTION OF FIRE ENERGY LOST TO ALL SURFACES = '
     4,F5.3/
     51H0,'THE FIRE IS LOCATED ',F7.3,' FEET ( ',F7.3,' METERS) ABOVE TH
     6E FLOOR.')
1750  FORMAT(1H0,1X,'FRACTION OF FIRE ENERGY WHICH IS LOST TO WALLS AND
     2FLOOR BY RADIATION'/' AND WHICH IS NOT EFFECTIVE IN DRIVING PLUME
     3= ',F5.3/2X,'FRACTION OF FIRE ENERGY LOST TO ALL SURFACES = ',F5.3
     4/1H0,'THE FIRE IS LOCATED ',F7.3,' FEET ( ',F7.3,' METERS) ABOVE T
     5HE FLOOR.')
1760  FORMAT(1H0,' FIRE DETECTED WHEN DETECTABLE UPPER LAYER PRODUCT CON
     2CENTRATION EXCEEDS',E10.4,' UNITS OF MASS PER UNIT MASS OF BULK UP
     3PER LAYER GAS.'/
     42X,' IF LAYER INTERFACE IS HIGHER THAN ',F6.2,' FT (',F6.2,' M) FR
     5OM FLOOR THEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM
     6PERATURE EXCEEDS ',F6.1,'DEG F (',F6.1,' DEGC).'/2X,' IF LAYER INT
     7ERFACE IS AT OR BELOW ',F6.2,' FT (',F6.2,' M) FROM FLOOR THEN '/2
     8X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE EXCEEDS
     9',F6.1,' DEG F (',F6.1,' DEG C)'/2X,'OR UPPER LAYER PRODUCT CONCEN
     *TRATION EXCEEDS',E10.4,' UNITS OF MASS PER UNIT MASS OF BULK UPPER
     1 LAYER GAS.'///)
1770  FORMAT(1H0,' FIRE DETECTED WHEN DETECTABLE UPPER LAYER PRODUCT CON
     2CENTRATION EXCEEDS'/5X,E10.4,' UNITS OF MASS PER UNIT MASS OF BULK
     3 UPPER LAYER GAS.'/
     42X,' IF LAYER INTERFACE IS HIGHER THAN ',F6.2,' FT (',F6.2,' M) FR
     5OM FLOOR THEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM
     6PERATURE EXCEEDS ',F6.1,' DEG F.'/63X,'(',F6.1,' DEGC)'/2X,' IF LA
     7YER INTERFACE IS AT OR BELOW ',F6.2,' FT (',F6.2,' M) FROM FLOOR T
     8HEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE E
     9XCEEDS ',F6.1,' DEG F.'/63X,'(',F6.1,' DEG C)'/2X,'OR UPPER LAYER
     *PRODUCT CONCENTRATION EXCEEDS'/10X,E9.4,' UNITS OF MASS PER UNIT M
     1ASS OF BULK UPPER LAYER GAS.')
1780  FORMAT (1H0,1X,'FIRE DETECTED WHEN UPPER LAYER TEMPERATURE IS ',F6
     2.1,' DEG F (',F6.1,' DEG C).'/
     32X,' IF LAYER INTERFACE IS HIGHER THAN ',F6.2,' FT (',F6.2,' M) FR
     4OM FLOOR THEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM
     5PERATURE EXCEEDS ',F6.1,'DEG F (',F6.1,' DEGC).'/2X,' IF LAYER INT
     6ERFACE IS AT OR BELOW ',F6.2,' FT (',F6.2,' M) FROM FLOOR THEN '/2
     7X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE EXCEEDS
     8',F6.1,' DEG F (',F6.1,' DEG C)'/2X,'OR UPPER LAYER PRODUCT CONCEN
     9TRATION EXCEEDS',E9.4,' UNITS OF MASS PER UNIT MASS OF BULK UPPER
     *LAYER GAS.'///)
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1790  FORMAT (1H0,1X,'FIRE DETECTED WHEN UPPER LAYER TEMPERATURE IS ',F6
     2.1,' DEG F'/62X,'(',F6.1,' DEG C).'/
     32X,' IF LAYER INTERFACE IS HIGHER THAN ',F6.2,' FT (',F6.2,' M) FR
     4OM FLOOR THEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM
     5PERATURE EXCEEDS ',F6.1,' DEG F.'/63X,'(',F6.1,' DEGC)'/2X,' IF LA
     6YER INTERFACE IS AT OR BELOW ',F6.2,' FT (',F6.2,' M) FROM FLOOR T
     7HEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE E
     8XCEEDS ',F6.1,' DEG F.'/63X,'(',F6.1,' DEG C)'/2X,'OR UPPER LAYER
     9PRODUCT CONCENTRATION EXCEEDS'/10X,E9.4,' UNITS OF MASS PER UNIT M
     *ASS OF BULK UPPER LAYER GAS.')
1800  FORMAT (1H0,1X,'FIRE DETECTED WHEN RATE OF TEMPERATURE RISE OF UPP
     2ER LAYER IS ',F6.2,' DEG F/MIN (',F6.2,' DEG C/MIN).'/
     32X,' IF LAYER INTERFACE IS HIGHER THAN ',F6.2,' FT (',F6.2,' M) FR
     4OM FLOOR THEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM
     5PERATURE EXCEEDS ',F6.1,'DEG F (',F6.1,' DEGC).'/2X,' IF LAYER INT
     6ERFACE IS AT OR BELOW ',F6.2,' FT (',F6.2,' M) FROM FLOOR THEN '/2
     7X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE EXCEEDS
     8',F6.1,' DEG F (',F6.1,' DEG C)'/2X,'OR UPPER LAYER PRODUCT CONCEN
     9TRATION EXCEEDS',E9.4,' UNITS OF MASS PER UNIT MASS OF BULK UPPER
     *LAYER GAS.'///)
1810  FORMAT (1H0,1X,'FIRE DETECTED WHEN RATE OF TEMPERATURE RISE OF UPP
     2ER LAYER IS ',F6.2,' DEG F/MIN (',F6.2,' DEG C/MIN).'/
     32X,' IF LAYER INTERFACE IS HIGHER THAN ',F6.2,' FT (',F6.2,' M) FR
     4OM FLOOR THEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM
     5PERATURE EXCEEDS ',F6.1,' DEG F.'/63X,'(',F6.1,' DEGC)'/2X,' IF LA
     6YER INTERFACE IS AT OR BELOW ',F6.2,' FT (',F6.2,' M) FROM FLOOR T
     7HEN '/2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE E
     8XCEEDS ',F6.1,' DEG F.'/63X,'(',F6.1,' DEG C)'/2X,'OR UPPER LAYER
     9PRODUCT CONCENTRATION EXCEEDS'/10X,E9.4,' UNITS OF MASS PER UNIT M
     *ASS OF BULK UPPER LAYER GAS.')
1820  FORMAT(1H ///1H ,19H HEIGHT OF ROOM IS ,F6.2 , 5H FT (,F6.2  ,
     25H M). /)
1830  FORMAT(' AREA OF ROOM IS ',F8.2,' FT**2 ( ',F8.2,' M**2)')
1840  FORMAT(1H0,31X,'LAYER     RATE OF',14X,'DETECTABLE',19X,'INTERFACE'
     2,13X,'HAZARDOUS'/4X,'AREA        TIME       TEMP.    THICKNESS      RISE',
     36X,'Q/Q0       CONCEN.     TIME       TEMP.    ELEVATION     Q/Q0',5X,'
     4CONCEN.  AVAILABLE'/14X,'AT',7X,'AT',8X,'AT',9X,'AT',8X,'AT',9X,'A
     5T',8X,'AT',7X,'AT',8X,'AT',9X,'AT',9X,'AT',6X,'EGRESS'/10X,'DETECT
     6ION DETECTION DETECTION DETECTION  DETECTION   DETECTION   HAZARD
     7HAZARD     HAZARD      HAZARD       HAZARD          TIME'//3X,'FT**2',6X,'S
     8EC       DEG F',6X,'FT',6X,'DEGF/M',28X,'SEC        DEG F',6X,'FT',30X,
     9'SEC'/3X,'(M**2)',12X,'(DEG C)      (M)           (DEGC/M)',33X,'(DEG C)
     *    (M)'///)
1850  FORMAT(1H0,31X,'LAYER     RATE OF',14X,'DETECTABLE',19X,'INTERFACE'
     2,13X,'HAZARDOUS'/4X,'AREA        TIME       TEMP.    THICKNESS      RISE',
     36X,' Q          CONCEN.     TIME       TEMP.    ELEVATION      Q  ',5X,'
     4CONCEN.  AVAILABLE'/14X,'AT',7X,'AT',8X,'AT',9X,'AT',8X,'AT',9X,'A
     5T',8X,'AT',7X,'AT',8X,'AT',9X,'AT',9X,'AT',6X,'EGRESS'/10X,'DETECT
     6ION DETECTION DETECTION DETECTION  DETECTION   DETECTION   HAZARD
     7HAZARD     HAZARD      HAZARD       HAZARD          TIME'//3X,'FT**2',6X,'S
     8EC       DEG F',6X,'FT',6X,'DEGF/M',7X,'KW',19X,'SEC       DEG F',6X,'
     9FT',10X,'KW',18X,'SEC'/3X,'(M**2)',12X,'(DEG C)      (M)        (DEGC/
     *M)',33X,'(DEG C)      (M)'///)
1860  FORMAT(' WILL DATA BE ENTERED INTERACTIVELY (Y/N) ?')
1870  FORMAT(' PROGRAM WILL BE EXECUTED IN INTERACTIVE MODE.')
1880  FORMAT(' ENTER A RUN TITLE, UP TO 80 CHARACTERS LONG.')
1890  FORMAT(' ENTER CODE NUMBER OF THE DESIRED FORM OF OUTPUT:'/3X,
     2'TYPE 1 FOR SUMMARY OUTPUT, 132 CHARACTERS PER LINE'/
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     3  8X,'2 FOR SUMMARY OUTPUT, 80 CHARACTERS PER LINE'/
     4  8X,'3 FOR FULL OUTPUT, 132 CHARACTERS PER LINE'/
     5  8X,'4 FOR FULL OUTPUT, 80 CHARACTERS PER LINE')
1900  FORMAT(' SUMMARY OUTPUT, 132 CHARACTERS PER LINE HAS BEEN SELECTED
     2.')
1910  FORMAT(' SUMMARY OUTPUT, 80 CHARACTERS PER LINE HAS BEEN SELECTED.
     2')
1920  FORMAT(' FULL OUTPUT, 132 CHARACTERS PER LINE HAS BEEN SELECTED.')
1930  FORMAT(' FULL OUTPUT, 80 CHARACTERS PER LINE HAS BEEN SELECTED.')
1940  FORMAT(/10X,'IS THIS CORRECT (Y/N) ?')
1950  FORMAT(' ENTER: 1. LAMDA R,'/8X,'2. LAMDA C,'/8X,'3. EYELEVEL HEIG
     2HT, IN FEET, AND'/8X,'4. FIRE HEIGHT, IN FEET.'/
     3' DO YOU NEED MORE INFORMATION (Y/N) ?')
1960  FORMAT('0 *** LAMDA R - THE FRACTION OF THE ENERGY GENERATION RATE
     2 INSTANTANEOUSLY ***'/'  ***',11X,'LOST BY RADIATION FROM THE COMB
     3USTION ZONE AND PLUME.',6X,'***'/'  *** LAMDA C - THE FRACTION OF
     4THE ENERGY GENERATION RATE LOST TO THE     ***'/'  ***',11X,'BOUND
     5ING SURFACES OF THE ROOM AND ITS CONTENTS.',12X,'***'/
     6'  *** EYELEVEL HEIGHT - THE SPECIFIED CHARACTERISTIC HEIGHT, IN F
     7EET, OF   ***'/'  ***',19X,'EYELEVEL FROM THE FLOOR.',27X,'***'/
     8'  *** FIRE HEIGHT - THE HEIGHT, IN FEET, OF THE BASE OF THE FIRE
     9ABOVE     ***'/'  ***',15X,'THE FLOOR.',45X,'***')
1970  FORMAT(' >>ENTER THE REQUESTED VALUES.<<')
1980  FORMAT(' DATA WILL BE ENTERED IN THE FOLLOWING ORDER:'/'   I. DETE
     2TION CRITERIA       IV. FIRE DATA'/'  II. HAZARD CRITERIA       V
     3. PRODUCTS OF COMBUSTION DATA'/' III. ROOM SIZES')
1990  FORMAT(26X,'I. DETECTION CRITERIA')
2000  FORMAT(' ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F (DETECTION)
     2'/'  TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY RA
     3TE OF RISE.')
2010  FORMAT(' ENTER A RATE OF LAYER TEMPERATURE RISE, IN DEGREES F/MIN
     2(DETECTION).'/7X,'***(TYPE 0.0 FOR INSTANTANEOUS DETECTION.)***'/'
     3 TYPE AN END OF FILE (UNIVAC: @EOF) TO MOVE TO DETECTION BY CONCEN
     4TRATION.')
2020  FORMAT(3X,'***INSTANTANEOUS DETECTION***')
2030  FORMAT(' ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,'/' IN P
     2RODUCT UNITS/GRAM OF BULK GAS (DETECTION).'/'  TYPE AN END OF FILE
     3 (UNIVAC: @EOF) TO MOVE TO HAZARD CRITERIA DATA INPUT.')
2040  FORMAT(26X,'II. HAZARD CRITERIA')
2050  FORMAT('  ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F'/'   (INTE
     2RFACE ABOVE SPECIFIED EYELEVEL)  (HAZARD).'/' TYPE AN END OF FILE
     3(UNIVAC: @EOF) TO MOVE TO HAZARD'/' BY LAYER TEMPERATURE, WHEN INT
     4ERFACE BELOW EYELEVEL.')
2060  FORMAT('  ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F'/'   (INTE
     2RFACE BELOW SPECIFIED EYELEVEL)  (HAZARD).'/' TYPE AN END OF FILE
     3(UNIVAC: @EOF) TO MOVE TO HAZARD BY POC CONCENTRATION.')
2070  FORMAT(' ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,'/' IN P
     2RODUCT UNITS/GRAM OF BULK GAS (HAZARD).'/'  TYPE AN END OF FILE (U
     3NIVAC: @EOF) TO MOVE TO ROOM SIZE DATA INPUT.')
2080  FORMAT(26X,'III. ROOM SIZE DATA')
2090  FORMAT(' ENTER A COMPARTMENT CEILING HEIGHT, IN FEET.'/'  TYPE AN
     2END OF FILE (UNIVAC: @EOF) TO MOVE TO COMPARTMENT AREA INPUT.')
2100  FORMAT(' ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.'/'  TYPE
     2AN END OF FILE (UNIVAC: @EOF) TO MOVE TO FIRE DATA INPUT.')
2110  FORMAT(29X,'IV. FIRE DATA')
2120  FORMAT(' SELECT THE REPRESENTATIVE FORM OF FIRE ENERGY GENERATION
     2RATE.'/4X,
     3'TYPE 1 FOR AN EXPONENTIAL FIRE GROWTH CURVE.'/
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     4  9X,'2 FOR DIGITAL DATA INPUT.')
2130  FORMAT(' AN EXPONENTIAL FIRE GROWTH CURVE HAS BEEN SELECTED.')
2140  FORMAT(' DIGITAL DATA INPUT HAS BEEN SELECTED.')
2150  FORMAT('  GENERAL FORM: Q = Q1 * EXP(ALPHA(T-T1))'/
     2' ENTER THE MAXIMUM TIME, IN SECONDS, FOR WHICH THE FIRE WILL BE M
     3ODELED.')
2160  FORMAT(' ENTER: 1. THE ENERGY GENERATION RATE (Q1), IN KILOWATTS,
     2'/11X,'AT THE BEGINNING OF EACH TIME SEGMENT, AND'/
     38X,'2. THE ENERGY GENERATION RATE EXPONENTIAL FACTOR (ALPHA),'/11X
     4,'IN UNITS OF 1/SECOND, FOR THAT TIME SEGMENT.'//
     5' ENTER ONE PAIR FOR EACH TIME SEGMENT IN THE CURVE.'/' ENTER THEM
     6 ONE AT A TIME.'/' WHEN ALL HAVE BEEN ENTERED, TYPE AN END OF FILE
     7 (UNIVAC: @EOF).')
2170  FORMAT(5X,I3,') Q = ',F8.2,' EXP(',F7.4,'(T-T1))'/)
2180  FORMAT('  DO YOU WANT FIRE ENERGY GENERATION RATE DATA'/'  PRESEN
     2TED IN NORMALIZED FORM, Q(T)/Q(1) (Y/N) ?')
2190  FORMAT(' THE FIRE DATA OUTPUT WILL BE NORMALIZED.')
2200  FORMAT(' THE FIRE DATA OUTPUT WILL NOT BE NORMALIZED.')
2210  FORMAT(' ENTER: 1. THE MAXIMUM TIME, IN SECONDS, FOR WHICH THE FIR
     2E WILL BE MODELED,'/11X,'AND'/8X,'2. THE HEAT OF COMBUSTION, IN KJ
     3/KG.')
2220  FORMAT(5X,'MAXIMUM TIME          = ',F5.0/5X,'HEAT OF COMBUSTION = ',
     2F12.4)
2230  FORMAT('  ENTER THE INITIAL ENERGY GENERATION RATE.')
2240  FORMAT(5X,'Q0 = ',F8.2)
2250  FORMAT('  ENTER THE REST OF THE DIGITAL DATA POINTS ONE AT A TIME.
     2'/' EACH DATA POINT SHOULD CONSIST OF A TIME, IN SECONDS,'/' AND A
     3 CORRESPONDING ENERGY GENERATION RATE.'/' WHEN ALL HAVE BEEN ENTER
     4ED, TYPE AN END OF FILE (UNIVAC: @EOF).')
2260  FORMAT('  DO YOU WANT FIRE ENERGY GENERATION RATE DATA'/'  PRESEN
     2TED IN NORMALIZED FORM, Q(T)/Q0 (Y/N) ?')
2270  FORMAT(20X,'V.1. DETECTABLE PRODUCT OF COMBUSTION DATA')
2280  FORMAT(' SELECT THE REPRESENTATIVE FORM OF PRODUCT GENERATION RATE
     2.'/5X,
     3'TYPE 1 FOR A METHOD USING A CONSTANT OF PROPORTIONALITY (BETA).'/
     410X, '2 FOR DIGITAL DATA INPUT.')
2290  FORMAT(' A METHOD USING A CONSTANT OF PROPORTIONALITY HAS BEEN SEL
     2ECTED.')
2300  FORMAT(' DIGITAL DATA INPUT HAS BEEN SELECTED.')
2310  FORMAT(' ENTER BETAD,'/' IN PRODUCT UNITS PER SEC PER KW OF FIRE E
     2NERGY GENERATION RATE.'/5X,'PRODUCT GENERATION RATE = BETAD * ENER
     3GY GENERATION RATE.')
2320  FORMAT(' ENTER BETAH,'/' IN PRODUCT UNITS PER SEC PER KW OF FIRE E
     2NERGY GENERATION RATE.'/5X,'PRODUCT GENERATION RATE = BETAH * ENER
     3GY GENERATION RATE.')
2330  FORMAT(20X,'V.2. HAZARDOUS PRODUCT OF COMBUSTION DATA')
2340  FORMAT('  ENTER THE INITIAL DETECTABLE PRODUCT GENERATION RATE.')
2350  FORMAT('  ENTER THE REST OF THE DIGITAL DATA POINTS ONE AT A TIME.
     2'/' EACH DATA POINT SHOULD CONSIST OF A TIME, IN SECONDS, AND'/' A
     3 CORRESPONDING DETECTABLE PRODUCT GENERATION RATE.'/' WHEN ALL HAV
     4E BEEN ENTERED, TYPE AN END OF FILE (UNIVAC: @EOF).')
2360  FORMAT('  ENTER THE INITIAL HAZARDOUS PRODUCT GENERATION RATE.')
2370  FORMAT('  ENTER THE REST OF THE DIGITAL DATA POINTS ONE AT A TIME.
     2'/' EACH DATA POINT SHOULD CONSIST OF A TIME, IN SECONDS, AND'/' A
     3 CORRESPONDING HAZARDOUS PRODUCT GENERATION RATE.'/' WHEN ALL HAVE
     4 BEEN ENTERED, TYPE AN END OF FILE (UNIVAC: @EOF).')
2380  FORMAT(4X,'*** SINCE THERE WERE NO DETECTABLE CONCENTRATIONS SPECI
     2FIED,  ***'/4X,'*** DATA DESCRIBING THE GENERATION OF A DETECTABLE
```

```
     3 PRODUCT    ***'/4X,'*** OF COMBUSTION WILL NOT BE REQUIRED.',23X,
     4'***')
2390  FORMAT('0 PRESS CARRIAGE RETURN TO CONTINUE.')
2400  FORMAT('0***********************************************************
     2****************')
2410  FORMAT('0-----------------------------------------------------------
     2----------------')
2420  FORMAT('0 ****> PROGRAM EXECUTION COMPLETED <****')
2430  FORMAT('  *** THIS PROGRAM WILL CALCULATE THE AVAILABLE SAFE EGRES
     2S TIME    ***'/'  ***   FROM A ROOM.',48X,'***'/'  ***',63X,'***'/
     3'  *** DOCUMENTATION: NBSIR 82-2578 BY LEONARD Y. COOPER AND',9X,
     4'***'/'  ***',33X,'DAVID W. STROUP',15X,'***')
2440  FORMAT('  ====> INCORRECT INPUT - TRY AGAIN <====')
2450  FORMAT('  ====> INPUT ERROR - RUN TERMINATED <====')
C
      END
```

SUBROUTINE EXFIRE

```
C THIS IS FGRESS*ASET.EXFIRE
C
C**********************************************************************
C THIS SUBROUTINE USES THE APPROPRIATE INPUT DATA TO CHARACTERIZE
C THE MULTI-EXPONENTIAL FIRE GROWTH CURVE FOR USE
C IN FUNQ BY COMPUTING THE TAUQ(N) FROM THE AKAP(N) AND THE Q(N).
C THE SUBROUTINE ALSO PRINTS A DESCRIPTION OF THE ENERGY
C GENERATION RATE HISTORY.
C**********************************************************************
C
      SUBROUTINE EXFIRE
C
C     ****************************************************************
C
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4       DPRHT0,Q0,LNORM
      LOGICAL LINTER,LNORM
      IF (.NOT.(LNORM)) GO TO 50
C
C THIS SECTION CALCULATES TAUQ(N) FOR NORMALIZED FIRE DATA.
C
      IF (NSEGQ.GT.1) GO TO 10
      WRITE (6,100) AKAP(1)
      RETURN
10    NSEGM1=NSEGQ-1
      TAUQ(1)=ALOG(Q(1))/AKAP(1)
      IF (NSEGQ.GT.2) GO TO 20
      WRITE (6,110) AKAP(1),TAUQ(1),Q(1)
      WRITE (6,120) Q(1),AKAP(2),TAUQ(1),TAUQ(1),Q(1)
      RETURN
20    DO 30 N=2,NSEGM1
         TAUQ(N)=ALOG(Q(N)/Q(N-1))/AKAP(N)+TAUQ(N-1)
30       CONTINUE
      WRITE (6,110) AKAP(1),TAUQ(1),Q(1)
      NSEGM2=NSEGQ-2
      DO 40 N=1,NSEGM2
         WRITE (6,130) Q(N),AKAP(N+1),TAUQ(N),TAUQ(N),TAUQ(N+1),Q(N),Q
     2                  (N+1)
40       CONTINUE
      WRITE (6,120) Q(NSEGM1),AKAP(NSEGQ),TAUQ(NSEGM1),TAUQ(NSEGM1),Q(NS
     2              EGM1)
      RETURN
C
C THIS SECTION CALCULATES TAUQ(N) FOR UN-NORMALIZED FIRE DATA.
C
50    IF (NSEGQ.GT.1) GO TO 60
      WRITE (6,140) Q0,AKAP(1)
      RETURN
60    NSEGM1=NSEGQ-1
      TAUQ(1)=ALOG(Q(1))/AKAP(1)
      IF (NSEGQ.GT.2) GO TO 70
      WQ1=Q(1)*Q0
      WRITE (6,150) Q0,AKAP(1),TAUQ(1),Q0,WQ1
      WRITE (6,160) WQ1,AKAP(2),TAUQ(1),TAUQ(1),WQ1
```

```
      RETURN
70    DO 80 N=2,NSEGM1
            TAUG(N)=ALOG(Q(N)/Q(N-1))/AKAP(N)+TAUQ(N-1)
80          CONTINUE
      WQ1=Q(1)*Q0
      WRITE (6,150) Q0,AKAP(1),TAUQ(1),Q0,WQ1
      NSEGM2=NSEGQ-2
      DO 90 N=1,NSEGM2
            WQN=Q(N)*Q0
            WCN1=Q(N+1)*Q0
            WRITE (6,170) WQN,AKAP(N+1),TAUQ(N),TAUQ(N),TAUQ(N+1),WQN,WQN
     2                 1
90          CONTINUE
      WQL=Q(NSEGM1)
      WRITE (6,160) WQL,AKAP(NSEGQ),TAUQ(NSEGM1),TAUQ(NSEGM1),WQL
      RETURN
C
C
100   FORMAT (1H0,5X,'Q/Q0 = EXP(',F5.4,' * TIME/SEC) IF 0.0 < TIME/SEC'
     2)
110   FORMAT(1H0,5X,'Q/Q0 = ',9X,'EXP(',F5.4,' * (TIME/SEC))'/' IF    0.
     20 < TIME/SEC < ',F6.1,', THAT IS, IF ',3X,'1.0 < Q/Q0 < ',F5.0)
120   FORMAT(1H0,5X,'Q/Q0 = ',F6.0,' * EXP(',F5.4,' * (TIME/SEC - ',F6.1
     2,'))'/' IF ',F6.1,' < TIME/SEC',9X,', THAT IS, IF ',F6.0,' < Q/Q0'
     3)
130   FORMAT(1H0,5X,'Q/Q0 = ',F6.0,' * EXP(',F5.4,' * (TIME/SEC - ',F6.1
     2,'))'/' IF ',F6.1,' < TIME/SEC < ',F6.1,', THAT IS, IF ',F6.0,' <
     3Q/Q0 < ',F6.0)
140   FORMAT(1H0,5X,'Q = ',F6.0,' * EXP(',F5.4,' * TIME) IF 0.0 < TIME')
150   FORMAT(1H0,5X,'Q = ',F6.0,' * EXP(',F5.4,' * (TIME))'/' IF 0.0 < T
     2IME < ',F6.1,', THAT IS, IF ',F6.0,' < Q < ',F6.0)
160   FORMAT(1H0,5X,'Q = ',F6.0,' * EXP(',F5.4,' * (TIME - ',F6.1,') )'/
     2' IF ',F6.1,' < TIME',9X,', THAT IS, IF ',F6.0,' < Q')
170   FORMAT(1H0,5X,'Q = ',F6.0,' * EXP(',F5.4,' * (TIME - ',F6.1,') )'/
     2' IF ',F6.1,' < TIME < ',F6.1,', THAT IS, IF ',F6.0,' < Q < ',F6.0
     3)
C
      END
```

SUBROUTINE FUNQ

```
C THIS IS EGRESS*ASET.FUNQ
C
C***********************************************************************
C THIS IS FUNQ. IT COMPUTES:
C
C      QDQ0(T) = ENERGY GENERATION RATE AT TIME TAU=T / Q0
C***********************************************************************
C
      FUNCTION QDQ0 (T)
C
C     ******************************************************************
C
      INTEGER FIRE
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4       DPRHT0,Q0,LNORM
      LOGICAL LINTER,LNORM
      GO TO (10,60,90), FIRE
C
C THE FOLLOWING SEGMENT OF FUNQ IS USED TO COMPUTE QDQ0(T) FOR A
C MULTI-EXPONENTIAL FIRE GROWTH CURVE.
C
10    IF (T.EQ.0.) QDQ0=1.
      IF (T.EQ.0.) RETURN
      IF (NSEGQ.EQ.1) GO TO 20
      IF (T.GE.TAUQ(1)) GO TO 30
20    QDQ0=EXP(AKAP(1)*T)
      RETURN
30    IF (NSEGQ.EQ.2) GO TO 50
      NSEGM2=NSEGQ-2
      DO 40 N=1,NSEGM2
            IF (T.GE.TAUQ(N+1)) GO TO 40
            QDQ0=Q(N)*EXP(AKAP(N+1)*(T-TAUQ(N)))
            RETURN
40          CONTINUE
50    QDQ0=Q(NSEGQ-1)*EXP(AKAP(NSEGQ)*(T-TAUQ(NSEGQ-1)))
      RETURN
C
C THE FOLLOWING SEGMENT OF FUNQ IS USED TO COMPUTE QDQ0(T) FOR DIGITAL
C DATA AND LINEAR INTERPOLATION.
C
60    IF (T.EQ.0.) QDQ0=1.
      IF (T.EQ.0.) RETURN
      IF (T.GT.TAUQ(1)) GO TO 70
      QDQ0=Q(1)-((Q(1)-1.)/TAUQ(1))*(TAUQ(1)-T)
      RETURN
70    DO 80 N=1,NSEGQ
            IF (T.GT.TAUQ(N)) GO TO 80
            QDQ0=Q(N)-((Q(N)-Q(N-1))/(TAUQ(N)-TAUQ(N-1)))*(TAUQ(N)-T)
            RETURN
80          CONTINUE
90    RETURN
      END
```

SUBROUTINE FUNPRD

```
C THIS IS FGRESS*ASET.FUNPRD
C
C*************************************************************************
C THIS IS FUNPRD. IT COMPUTES
C
C        PRDPRO(T) = PRODUCT GENERATION RATE AT TIME TAU=T /PRD0
C*************************************************************************
C
      FUNCTION PRDPRO (T)
C
C     ********************************************************************
C
      INTEGER  PRODD
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4       DPRHT0,Q0,LNORM
      EXTERNAL QDQ0
      LOGICAL LINTER,LNORM
      GO TO (10,20,50), PRODD
C
C THE FOLLOWING SEGMENT OF FUNPRD IS USED TO COMPUTE PRDPRO(T) FOR A
C CASE WHERE THERE IS A CONSTANT OF PROPORTIONALITY BETWEEN PRODUCT
C GENERATION RATE AND ENERGY GENERATION RATE. THIS CONSTANT, BETAD,
C IS DEFINED AS
C
C       PRODUCT GENERATION RATE = BETAD * (ENERGY GENERATION RATE).
C
C IN THIS CASE, PRODD=1.
C
10    PRDPRO=QDQ0(T)
      RETURN
C
C THE FOLLOWING SEGMENT OF FUNPRD IS USED TO COMPUTE PRDPRO(T) FOR A
C CASE WHERE PRODUCT GENERATION RATE IS GIVEN BY LINEAR INTERPOLATION
C BETWEEN DIGITAL DATA POINTS. IN THIS CASE PRODD=2.
C
20    IF (T.EQ.0.) PRDPRO=1.
      IF (T.EQ.0.) RETURN
      IF (T.GT.TAUPRD(1)) GO TO 30
      PRDPRO=PRD(1)-((PRD(1)-1.)/TAUPRD(1))*(TAUPRD(1)-T)
      RETURN
30    DO 40 N=1,NSEGPD
          IF (T.GT.TAUPRD(N)) GO TO 40
          PRDPRO=PRD(N)-((PRD(N)-PRD(N-1))/(TAUPRD(N)-TAUPRD(N-1)))*(TA
     2          UPRD(N)-T)
          RETURN
40        CONTINUE
50    RETURN
      END
```

SUBROUTINE FUNPRH

```
C THIS IS EGRESS*ASET.FUNPRH
C
C*******************************************************************
C THIS IS FUNPRH. IT COMPUTES
C
C        PRHPRO(T) = PRODUCT GENERATION RATE AT TIME TAU=T /PRHO
C*******************************************************************
C
      FUNCTION PRHPRO (T)
C
C     *************************************************************
C
      INTEGER  PRODH
      COMMON NSEGQ,NSEGPO,NSEGPH,TAUQ(100),TAUPRO(100),TAUPRH(100),
     1       Q(100),PRO(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     2       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDTO,DPRDTO,
     3       DPRHTO,QO,LNORM
      EXTERNAL QDQO
      LOGICAL LINTER,LNORM
      GO TO (10,20,50), PRODH
C
C THE FOLLOWING SEGMENT OF FUNPRH IS USED TO COMPUTE PRHPRO(T) FOR A
C CASE WHERE THERE IS A CONSTANT OF PROPORTIONALITY BETWEEN PRODUCT
C GENERATION RATE AND ENERGY GENERATION RATE. THIS CONSTANT, BETAH,
C IS DEFINED AS
C
C       PRODUCT GENERATION RATE = BETAH * (ENERGY GENERATION RATE).
C
C IN THIS CASE, PRODH=1.
C
10    PRHPRO=QDQO(T)
      RETURN
C
C THE FOLLOWING SEGMENT OF FUNPRH IS USED TO COMPUTE PRHPRO(T) FOR A
C CASE WHERE PRODUCT GENERATION RATE IS GIVEN BY LINEAR INTERPOLATION
C BETWEEN DIGITAL DATA POINTS. IN THIS CASE PRODH=2.
C
20    IF (T.EQ.0.) PRHPRO=1.
      IF (T.EQ.0.) RETURN
      IF (T.GT.TAUPRH(1)) GO TO 30
      PRHPRO=PRH(1)-((PRH(1)-1.)/TAUPRH(1))*(TAUPRH(1)-T)
      RETURN
30    DO 40 N=1,NSEGPH
         IF (T.GT.TAUPRH(N)) GO TO 40
         PRHPRO=PRH(N)-((PRH(N)-PRH(N-1))/(TAUPRH(N)-TAUPRH(N-1)))*(TA
     2         UPRH(N)-T)
         RETURN
40       CONTINUE
50    RETURN
      END
```

SUBROUTINE SUBAINT

```
C THIS IS EGRESS*ASET.SUBAINT. IT REQUIRES EGRESS*ASET.SUBF AND INTGR.
C
C*********************************************************************
C THIS SUBROUTINE SETS UP THE NUMERICAL INTEGRATION FOR OBTAINING THE
C INTERFACE POSITION AS IT DROPS FROM THE CEILING. THE HISTORY OF
C TEMPERATURE AND PRODUCT CONCENTRATION IN THE UPPER LAYER ARE ALSO
C COMPUTED. THE INTEGRATION IS DONE IN SPECIFIED TIME INTERVALS. AFTER
C EACH INTERVAL, CRITERIA FOR DETECTION AND HAZARD ARE EVALUATED. LINEAR
C INTERPOLATION WITHIN THESE INTERVALS ARE USED TO OBTAIN TIME AND
C PARAMETER VALUES FOR DETECTION AND HAZARD.
C*********************************************************************
C
C                               NOTATION
C
C*********************************************************************
C
C AQDQO  Q/QO AT END OF TIME STEP.
C CNDETD DETECTABLE PRODUCT CONCENTRATION AT TIME OF DETECTION.
C CNDETH HAZARDOUS PRODUCT CONCENTRATION AT TIME OF DETECTION.
C CNDSP  DIMENSIONLESS SPECIFIED DETECTABLE PRODUCT CONCENTRATION
C        FOR DETECTION.
C CNHAZD DETECTABLE PRODUCT CONCENTRATION AT TIME OF HAZARD.
C CNHAZH HAZARDOUS PRODUCT CONCENTRATION AT TIME OF HAZARD.
C CND    DETECTABLE PRODUCT CONCENTRATION OF UPPER LAYER AT END OF TIME
C        STEP.
C CNH    HAZARDOUS PRODUCT CONCENTRATION OF UPPER LAYER AT END OF TIME
C        STEP.
C CNHTST A TEST VALUE FOR HAZARDOUS CONCENTRATION.
C CNDO   INITIAL DETECTABLE PRODUCT CONCENTRATION OF UPPER LAYER.
C CND1
C CND2
C CNHO   INITIAL HAZARDOUS PRODUCT CONCENTRATION OF UPPER LAYER.
C CNH1
C CNH2
C DELTA  THE HEIGHT OF THE FIRE ABOVE THE FLOOR IN FEET.
C DELTAM THE HEIGHT OF THE FIRE ABOVE THE FLOOR IN METERS.
C DPHI   DIMENSIONLESS RATE OF TEMPERATURE RISE OF UPPER LAYER,
C        DPHI/DTAU, GENERATED IN SUBF DURING THE COURSE OF THE INTEGRA-
C        TION.
C DPHID  DIMENSIONLESS RATE OF TEMPERATURE RISE OF UPPER LAYER AT
C        TIME OF DETECTION.
C DPHIDS DIMENSIONLESS RATE OF TEMPERATURE RISE OF UPPER LAYER FOR
C        DETECTION SPECIFIED.
C DPHIO  INITIAL DIMENSIONLESS RATE OF TEMPERATURE RISE OF UPPER LAYER.
C DPHI1
C DPHI2
C DZDETF UPPER LAYER THICKNESS AT TIME OF DETECTION IN FEET.
C DZDETM UPPER LAYER THICKNESS AT TIME OF DETECTION IN METERS.
C DZF    UPPER LAYER THICKNESS AFTER EACH TIME INTERVAL IN FEET.
C DZM    UPPER LAYER THICKNESS AFTER EACH TIME INTERVAL IN METERS.
C HF     HEIGHT OF COMPARTMENT UNDER CONSIDERATON IN FEET.
C ITMEGS TIME AVAILABLE FOR SAFE EGRESS, IN SECONDS.
C PHIDET DIMENSIONLESS UPPER LAYER TEMP AT TIME OF DETECTION.
C PHIDSP DIMENSIONLESS UPPER LAYER TEMP FOR DETECTION SPECIFIED.
C PHIHAZ DIMENSIONLESS UPPER LAYER TEMP AT TIME OF HAZARD.
C PHIHSU DIMENSIONLESS SPECIFIED UPPER LAYER TEMPERATURE WHEN INTERFACE
```

```
C         IS ABOVE ZETEYE.
C PHIHSL  DIMENSIONLESS SPECIFIED UPPER LAYER TEMPERATURE WHEN INTERFACE
C         IS BELOW ZETEYE.
C PHITST  A TEST VALUE FOR PHI.
C PHIO    INITIAL UPPER LAYER TEMPERATURE.
C PHI1
C PHI2
C QDETQ0  Q AT THE TIME OF DETECTION / Q0
C QHAZQ0  Q AT THE TIME OF HAZARD / Q0
C RRC     RATE OF TEMPERATURE RISE OF UPPER LAYER IN DEGREES C PER
C         MINUTE AT END OF TIME STEP.
C RRDETC  RATE OF TEMP RISE OF UPPER LAYER AT TIME OF DETECTION IN
C         DEGREES C PER MINUTE.
C RRDETF  RATE OF TEMP RISE OF UPPER LAYER AT TIME OF DETECTION IN
C         DEGREES F PER MINUTE.
C RRF     RATE OF TEMPERATURE RISE OF UPPER LAYER IN DEGREES F PER
C         MINUTE AT END OF TIME STEP.
C TAUDET  DIMENSIONLESS TIME AT TIME OF DETECTION.
C TAUHAZ  DIMENSIONLESS TIME AT TIME OF HAZARD.
C TAU1    DIMENSIONLESS TIME AT LOWER LIMIT OF INTEGRATION.
C TAU2    DIMENSIONLESS TIME AT UPPER LIMIT OF INTEGRATION.
C TAUTSC  A TEST VALUE FOR TAU.
C TAUTSP  A TEST VALUE FOR TAU.
C TAUTST  A TEST VALUE FOR TAU.
C TIMDS   TIME REQUIRED FOR DETECTION IN SECONDS.
C TIMHS   TIME TO REACH HAZARD IN SECONDS.
C TMC     LAYER TEMPERATURE AT END OF TIME STEP IN DEGREES C.
C TMDETC  UPPER LAYER TEMP AT TIME OF DETECTION IN DEGREES C.
C TMDETF  UPPER LAYER TEMP AT TIME OF DETECTION IN DEGREES F.
C TMF     LAYER TEMPERATURE AT END OF TIME STEP IN DEGREES F.
C TMHAZC  UPPER LAYER TEMP AT TIME OF HAZARD IN DEGREES C.
C TMHAZF  UPPER LAYER TEMP AT TIME OF HAZARD IN DEGREES F.
C SF      COMPARTMENT AREA UNDER CONSIDERATION IN SQUARE FEET.
C SM      COMPARTMENT AREA UNDER CONSIDERATION IN SQUARE METERS.
C UAQDQ0  Q AT END OF TIME STEP.
C UQDTDQ  Q AT THE TIME OF DETECTION.
C UQHZDQ  Q AT THE TIME OF HAZARD.
C ZETDET  DIMENSIONLESS LAYER INTERFACE ELEVATION AT TIME OF DETECTION.
C ZETEYE  DIMENSIONLESS ELEVATION OF EYELEVEL.
C ZETHAZ  DIMENSIONLESS LAYER INTERFACE ELEVATION AT TIME OF HAZARD.
C ZHAZF   LAYER INTERFACE ELEVATION AT TIME OF HAZARD IN FEET.
C ZHAZM   LAYER INTERFACE ELEVATION AT TIME OF HAZARD IN METERS.
C ZF      LAYER ELEVATION AT END OF TIME STEP IN FEET .
C ZM      LAYER ELEVATION AT END OF TIME STEP IN METERS.
C Z1
C Z2
C
C*****************************************************************
C
      SUBROUTINE AINT (IDETH,IDETT,IDETR,PHIHSU,PHIHSL,CNHAZS,PHIDSP,
     2                 CNDSP,ZETEYE,DPHIDS,SF,SM,HF,WRC,TITLE)
C
C     ************************************************************
C
      INTEGER FIRE, WRC, TITLE(20),PRODD,PRODH
      DIMENSION Y(4),WB(20)
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       C(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
```

```
     3        PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4        DPRHT0,Q0,LNORM
      EXTERNAL F
      EXTERNAL QDQ0
      LOGICAL LINTER,LNORM
      CHARACTER CHARTR
C
C COMPUTE INITIAL LAYER TEMPERATURE, INITIAL RATE OF LAYER
C TEMPERATURE RISE, AND INITIAL CONCENTRATIONS.
C
      PHI0=1./(1.-C1/(C1+C2*(ZET0**(5./3.))))
      DPHI0=(C1/C2)*(1./6.)*(2.*DQDT0-5.*(-C1-C2*(ZET0**(5./3.))))/(ZET0
     2     **(8./3.))
      CND0=C3D/(C2*(ZET0**(5./3.)))
      CNH0=C3H/(C2*(ZET0**(5./3.)))
C
C IF IDETH=1, DETECTION BY POC CONCENTRATION IS NOT UNDER
C CONSIDERATION.
C
      IF (IDETH.EQ.1) GO TO 20
      IF (CND0.LT.CNDSP) GO TO 40
      IDETH=1
10    ZETDET=HF
      TAUDET=0.
      CNDETD=CND0
      CNDETH=CNH0
      DPHID=DPHI0
      PHIDET=PHI0
      GO TO 40
C
C IF IDETT=1, DETECTION BY LAYER TEMPERATURE IS NOT UNDER CONSIDERATION
C
20    IF (IDETT.GT.0) GO TO 30
      IF (PHI0.LT.PHIDSP) GO TO 40
      IDETT=1
      GO TO 10
C
C DETECTION IS BY RATE OF TEMPERATURE RISE AND IDETR=0. DOES DETECTION
C OCCUR AT TIME=0.?
C
30    IF (DPHI0.LT.DPHIDS) GO TO 40
      IDETR=1
      GO TO 10
C
C SINCE HF>ZETEYE AT THIS INITIAL TIME, HAZARD CAN ONLY BE BY TEMPER-
C ATURE. DOES HAZARD OCCUR AT TIME=0.?
C
40    IF (PHI0.LT.PHIHSU) GO TO 50
      TAUHAZ=0.
      ZETHAZ=HF
      CNHAZD=CND0
      CNHAZH=CNH0
      PHIHAZ=PHI0
      TAUDET=0.
      ZETDET=HF
      CNDETD=CND0
      CNDETH=CNH0
      DPHID=DPHI0
```

```
      PHIDET=PHIO
      GO TO 230
C
C INITIALIZE VARIABLES FOR INTEGRATION.
C
50    Y(1)=ZETO
      Y(2)=PHIO
      Y(3)=CNDO
      Y(4)=CNHO
      DPHI=DPHIO
      TAU2=0.0
      IF ((WRC.EQ.1).OR.(WRC.EQ.2)) GO TO 60
      IF (WRC.EQ.3) WRITE (6,280) TITLE
      IF (WRC.EQ.4) WRITE (6,290) TITLE
      IF ((WRC.EQ.3).AND.(LNORM)) WRITE (6,360)
      IF ((WRC.EQ.4).AND.(LNORM)) WRITE (6,380)
      IF ((WRC.EQ.3).AND.(.NOT.(LNORM))) WRITE (6,370)
      IF ((WRC.EQ.4).AND.(.NOT.(LNORM))) WRITE (6,390)
      DZF=HF-(Y(1)+DELTA)
      DZM=DZF*0.3048
      TMF=(Y(2)*530.0)-460.0
      TMC=(TMF-32.0)/1.8
      AQDQ0=QDQ0(TAU2)
      UAQDQ0=AQDQ0*Q0
      RRF=DPHI*31800.0
      RRC=RRF/1.8
      ZF=Y(1)+DELTA
      ZM=(Y(1)+DELTA)*0.3048
      CND=Y(3)
      CNH=Y(4)
      ITAU2=IFIX(TAU2)
      IF ((WRC.EQ.3).AND.(LNORM)) WRITE (6,400) ITAU2,AQDQ0,DZF,DZM,ZF,
     2                                 ZM,TMF,TMC,RRF,RRC,CND,CNH
      IF ((WRC.EQ.4).AND.(LNORM)) WRITE (6,410) ITAU2,TMF,RRF,DZF,ZF,
     2                                 AQDQ0,CND,CNH,TMC,RRC,DZM,ZM
      IF ((WRC.EQ.3).AND.(.NOT.(LNORM))) WRITE (6,400) ITAU2,UAQDQ0,DZF,
     2                                        DZM,ZF,ZM,TMF,TMC,RRF,RRC,CND,
     3                                        CNH
      IF ((WRC.EQ.4).AND.(.NOT.(LNORM))) WRITE (6,410) ITAU2,TMF,RRF,DZF
     2                                        ,ZF,UAQDQ0,CND,CNH,TMC,RRC,
     3                                        DZM,ZM
C
C INCREMENT TIME STEP AND CONTINUE.
C
60    TAU1=TAU2
      TAU2=TAU2+5.
      IF ((((FIRE.EQ.2).AND.(TAU2.GT.TAUQ(NSEGQ))).OR.
     2((PRODD.EQ.2).AND.(TAU2.GT.TAUPRD(NSEGPD))).OR.
     3((PRODH.EQ.2).AND.(TAU2.GT.TAUPRH(NSEGPH)))) GO TO 250
      IF (TAU2.GT.TAULIM) GO TO 260
      Z1=Y(1)+DELTA
      Z1I=Y(1)
      PHI1=Y(2)
      CND1=Y(3)
      CNH1=Y(4)
      DELTH=0.5
      DPHI1=DPHI
C
```

SUBROUTINE SUBAINT

```
C CALL INTGR TO PERFORM THE INTEGRATION FROM TAU1 TO TAU2.
C
      CALL INTGR (F,TAU1,TAU2,DELTH,4,Y,WB,IER)
C
      IF (IER.LT.32) GO TO 70
C
C THERE IS AN ERROR IN THE INTEGRATION, WRITE ERROR MESSAGE AND
C RETURN TO MAIN.
C
      WRITE (6,330)
      RETURN
70    Z2I=Y(1)
      Z2=Y(1)+DELTA
      PHI2=Y(2)
      CND2=Y(3)
      CNH2=Y(4)
      DPHI2=DPHI
      IF ((WRC.EQ.1).OR.(WRC.EQ.2)) GO TO 80
      DZF=HF-Z2
      DZM=DZF*0.3048
      TMF=(PHI2*530.0)-460.0
      TMC=(TMF-32.0)/1.8
      AQDQ0=QDQ0(TAU2)
      UAQDQ0=AQDQ0*Q0
      RRF=DPHI2*31800.0
      RRC=RRF/1.8
      ZF=Z2
      ZM=ZF*0.3048
      CND=CND2
      CNH=CNH2
      ITAU2=IFIX(TAU2)
      IF ((WRC.EQ.3).AND.(LNORM)) WRITE (6,400) ITAU2,AQDQ0,DZF,DZM,ZF,
     2                                  ZM,TMF,TMC,RRF,RRC,CND,CNH
      IF ((WRC.EQ.4).AND.(LNORM)) WRITE (6,410) ITAU2,TMF,RRF,DZF,ZF,
     2                                  AQDQ0,CND,CNH,TMC,RRC,DZM,ZM
      IF ((WRC.EQ.3).AND.(.NOT.(LNORM))) WRITE (6,400) ITAU2,UAQDQ0,DZF,
     2                                         DZM,ZF,ZM,TMF,TMC,RRF,RRC,CND,
     3                                         CNH
      IF ((WRC.EQ.4).AND.(.NOT.(LNORM))) WRITE (6,410) ITAU2,TMF,RRF,DZF
     2                                         ,ZF,UAQDQ0,CND,CNH,TMC,RRC,DZM
     3                                         ,ZM
C
C IF DETECTION OCCURED BEFORE THE LAST TIME INTERVAL THEN WILL PASS FROM
C HERE TO 120 WITH NO CHANGES. IF DETECTION DID NOT OCCUR BEFORE THE
C LAST TIME INTERVAL THEN CHECK IF DETECTION OCCURED IN LAST TIME INTER-
C VAL. IF SO, THEN FLAG THIS FACT (E.G., SET IDETT=1), COMPUTE PARAME-
C TERS AT THE TIME OF DETECTION AND GO TO 120.
C
80    IF (IDETH.GT.0) GO TO 100
      IF (CND2.LT.CNDSP) GO TO 120
      TAUDET=TAU1+(TAU2-TAU1)*(CNDSP-CND1)/(CND2-CND1)
      IDETH=1
90    ZETDET=Z1+(Z2-Z1)*(TAUDET-TAU1)/(TAU2-TAU1)
      CNDETD=CND1+(CND2-CND1)*(TAUDET-TAU1)/(TAU2-TAU1)
      CNDETH=CNH1+(CNH2-CNH1)*(TAUDET-TAU1)/(TAU2-TAU1)
      PHIDET=PHI1+(PHI2-PHI1)*(TAUDET-TAU1)/(TAU2-TAU1)
      DPHID=DPHI1+(DPHI2-DPHI1)*(TAUDET-TAU1)/(TAU2-TAU1)
      GO TO 120
```

SUBROUTINE SUBAINT

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100   IF (IDETT.GT.0) GO TO 110
      IF (PHI2.LT.PHIDSP) GO TO 120
      TAUDET=TAU1+(TAU2-TAU1)*(PHIDSP-PHI1)/(PHI2-PHI1)
      IDETT=1
      GO TO 90
110   IF (IDETR.GT.0) GO TO 120
      IF (DPHI2.LT.DPHIDS) GO TO 120
      TAUDET=TAU1+(TAU2-TAU1)*(DPHIDS-DPHI1)/(DPHI2-DPHI1)
      IDETR=1
      GO TO 90
C
C DID HAZARD OCCUR DURING THE LAST TIME INTERVAL?
C
120   IF (Z2.LT.ZETEYE) GO TO 140
      IF (PHI2.GE.PHIHSU) GO TO 130
      GO TO 60
130   TAUHAZ=TAU1+(TAU2-TAU1)*(PHIHSU-PHI1)/(PHI2-PHI1)
      GO TO 200
140   IF (Z1.GE.ZETEYE) GO TO 150
      GO TO 160
C
C DID HAZARD OCCUR BY HIGH LAYER TEMPERATURE WITHIN THE TIME INTERVAL
C BEFORE Z<ZETEYE? TO ANSWER THIS, COMPUTE TIME WHEN Z=ZETEYE, COMPUTE
C THE TEMPERATURE AT THIS TIME, AND SEE IF THIS TEMPERATURE IS GREATER
C THAN PHITST.
C
150   TAUTST=TAU1+(TAU2-TAU1)*(ZETEYE-Z1)/(Z2-Z1)
      PHITST=PHI1+(PHI2-PHI1)*(TAUTST-TAU1)/(TAU2-TAU1)
      IF (PHITST.GE.PHIHSU) GO TO 130
C
C DID HAZARDOUS CONCENTRATION EXIST PRIOR TO OR AT THE TIME THAT THE
C INTERFACE REACHED ZETEYE? TO ANSWER, COMPUTE THE CONCENTRATION,
C CNHTST, AT TIME TAUTST WHEN THE INTERFACE REACHES ZETEYE, AND COMPARE
C IT TO CNHAZS.
C
      CNHTST=CNH1+(CNH2-CNH1)*(TAUTST-TAU1)/(TAU2-TAU1)
      IF ((CNHTST.LT.CNHAZS).AND.(PHITST.LT.PHIHSL)) GO TO 160
      TAUHAZ=TAUTST
      GO TO 200
160   IF (CNH2.GE.CNHAZS) GO TO 180
      IF (PHI2.LT.PHIHSL) GO TO 60
170   TAUHAZ=TAU1+(TAU2-TAU1)*(PHIHSL-PHI1)/(PHI2-PHI1)
      GO TO 200
180   IF (PHI2.LT.PHIHSL) GO TO 190
C
C COMPUTE TIME WHEN CN=CNHAZS, COMPUTE TIME WHEN PHI=PHIHSL, WHICHEVER
C TIME IS SMALLER IS TAUHAZ.
C
      TAUTSC=TAU1+(TAU2-TAU1)*(CNHAZS-CNH1)/(CNH2-CNH1)
      TAUTSP=TAU1+(TAU2-TAU1)*(PHIHSL-PHI1)/(PHI2-PHI1)
      IF (TAUTSC.LE.TAUTSP) GO TO 190
      GO TO 170
190   TAUHAZ=TAU1+(TAU2-TAU1)*(CNHAZS-CNH1)/(CNH2-CNH1)
200   PHIHAZ=PHI1+(PHI2-PHI1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
      ZETHAZ=Z1+(Z2-Z1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
      CNHAZD=CND1+(CND2-CND1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
      CNHAZH=CNH1+(CNH2-CNH1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
      DPHIH=DPHI1+(DPHI2-DPHI1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
```

```
C
C HAZARD DID OCCUR IN THE LAST TIME INTERVAL. DID DETECTION OCCUR IN THE
C LAST OR ANY PREVIOUS TIME INTERVAL? IF NOT, THEN ASSUME DETECTION
C EVENT TO OCCUR AT THE TIME OF THE ONSET OF HAZARD, AND APPROPRIATELY
C SET THE DETECTION PARAMETERS.
C
      IF (((IDETH.EQ.1).AND.(IDETT.EQ.1)).AND.(IDETR.EQ.1)) GO TO 210
      GO TO 220
210   IF (TAUHAZ.LT.TAUDET) GO TO 220
      GO TO 230
220   TAUDET=TAUHAZ
      PHIDET=PHIHAZ
      ZETDET=ZETHAZ
      CNDETD=CNHAZD
      CNDETH=CNHAZH
      DPHID=DPHI1+(DPHI2-DPHI1)*(TAUDET-TAU1)/(TAU2-TAU1)
C
C CHANGE DIMENSIONLESS RESULTS CORRESPONDING TO THE DETECTION AND
C ONSET OF HAZARD EVENTS TO DIMENSIONAL VALUES AND PRINT THEM OUT.
C
230   TMDETF=PHIDET*530.-460.
      TMDETC=(TMDETF-32.)/1.8
      TMHAZF=PHIHAZ*530.-460.
      TMHAZC=(TMHAZF-32.)/1.8
      RRDETF=DPHID*31800.0
      RRDETC=RRDETF/1.8
      TIMDS=TAUDET
      TIMHS=TAUHAZ
      QDETDQ=QDQ0(TAUDET)
      QHAZDQ=QDQ0(TAUHAZ)
      UQDTDQ=QDETDQ*Q0
      UQHZDQ=QHAZDQ*Q0
      ZDETF=ZETDET
      ZDETM=ZDETF*0.3048
      DZDETF=HF-ZETDET
      DZDETM=DZDETF*0.3048
      ZHAZF=ZETHAZ
      ZHAZM=ZHAZF*0.3048
      DZHAZF=HF-ZETHAZ
      DZHAZM=DZHAZF*0.3048
      RRHAZF=DPHIH*31800.0
      RRHAZC=RRHAZF/1.8
      ITIMDS=IFIX(TIMDS)
      ITIMHS=IFIX(TIMHS)
      ITMEGS=ITIMHS-ITIMDS
C
C WRITE RESULTS FOR THE COMPARTMENT HEIGHT AND AREA UNDER CONSIDERATION.
C
      IF ((WRC.EQ.2).OR.(WRC.EQ.4)) GO TO 240
      IF (WRC.EQ.3) WRITE (6,280) TITLE
      IF ((WRC.EQ.3).AND.(LNORM)) WRITE (6,420)
      IF ((WRC.EQ.3).AND.(.NOT.(LNORM))) WRITE (6,430)
      IF (LNORM) WRITE (6,310) SF,ITIMDS,TMDETF,DZDETF,RRDETF,QDETDQ,
     2              CNDETD,ITIMHS,TMHAZF,ZHAZF,QHAZDQ,CNHAZH,ITMEGS,SM,
     3              TMDETC,DZDETM,RRDETC,TMHAZC,ZHAZM
      IF (.NOT.(LNORM)) WRITE (6,310) SF,ITIMDS,TMDETF,DZDETF,RRDETF,
     2                        UQDTDQ,CNDETD,ITIMHS,TMHAZF,ZHAZF,UQHZDQ,CNHAZH
     3                        ,ITMEGS,SM,TMDETC,DZDETM,RRDETC,TMHAZC,ZHAZM
```

```
      IF (LINTER) WRITE (6,460)
      IF (LINTER) READ (5,300) CHARTR
      RETURN
C
240   WRITE (6,290) TITLE
      IF (LNORM) WRITE (6,440)
      IF (.NOT.(LNORM)) WRITE (6,450)
      WRITE (6,470)
      IF (LNORM) WRITE (6,320) ITIMDS,TMDETF,DZDETF,ZDETF,RRDETF,QDETDQ,
     2              CNDETD,CNDETH,TMDETC,DZDETM,ZDETM,RRDETC
      IF (.NOT.(LNORM)) WRITE (6,320) ITIMDS,TMDETF,DZDETF,ZDETF,RRDETF,
     2                     UQDTDQ,CNDETD,CNDETH,TMDETC,DZDETM,ZDETM,RRDETC
      WRITE (6,480)
      IF (LNORM) WRITE (6,320) ITIMHS,TMHAZF,DZHAZF,ZHAZF,RRHAZF,QHAZDQ,
     2              CNHAZD,CNHAZH,TMHAZC,DZHAZM,ZHAZM,RRHAZC
      IF (.NOT.(LNORM)) WRITE (6,320) ITIMHS,TMHAZF,DZHAZF,ZHAZF,RRHAZF,
     2                     UQHZDQ,CNHAZD,CNHAZH,TMHAZC,DZHAZM,ZHAZM,RRHAZC
      WRITE (6,490) ITMEGS
      IF (LINTER) WRITE (6,460)
      IF (LINTER) READ (5,300) CHARTR
      RETURN
C
250   WRITE (6,350)
      GO TO 270
260   WRITE (6,340)
270   LIMIT=1
      IF (LINTER) WRITE (6,460)
      IF (LINTER) READ (5,300) CHARTR
      RETURN
C
C
280   FORMAT (1H1,20X,20A4/)
290   FORMAT(1H1,20A4/)
300   FORMAT(A1)
310   FORMAT(1H0,1X,F8.0,3X,I5,3(3X,F7.2),3X,F8.2,3X,E9.4,3X,I5,2(3X,F7.
     22),3X,F8.2,3X,E9.4,3X,I5/1X,'(',F8.2,')',9X,'(',F7.2,')',1X,'(',F7
     3.2,') (',F7.2,')',32X,'(',F7.2,') (',F7.2,')'/)
320   FORMAT(1H0,I5,4(2X,F7.2),2X,F8.2,2(2X,E10.5)/7X,'(',F7.2,')(',F7.2
     2,')(',F7.2,')(',F7.2,')'/)
330   FORMAT (34H PROBLEM IN INTEGRATION  IER GT 32/)
340   FORMAT (1H0,3X,                          '--THE TIME TAULIM HAS BEEN EXC
     2EEDED.'/' CONTINUE WITH THE NEXT COMPARTMENT HEIGHT OR SPECIFIED '
     3/5X,'DETECTION CRITERIA.--')
350   FORMAT (1H0,3X,'--THE UPPER LIMIT OF THE DIGITAL DATA HAS BEEN EXC
     2EEDED.'/' CONTINUE WITH THE NEXT COMPARTMENT HEIGHT OR SPECIFIED '
     3/5X,'DETECTION CRITERIA.--')
360   FORMAT(1H0,1X,'TIME',8X,'Q/Q0',7X,'LAYER THICKNESS    INTERFACE EL
     2EVATION   LAYER TEMPERATURE',7X,'RATE OF RISE',10X,'CONCENTRATION'
     3/' (SECS)',19X,'(FT)',6X,'(M)',8X,'(FT)',6X,'(M)',7X,'(F)',6X,'(C)
     4',9X,'(F/MIN)  (C/MIN)     DETECTABLE  HAZARDOUS'/1H ,111X,'POC',8X
     5,'POC')
370   FORMAT(1H0,1X,'TIME',8X,' Q  ',7X,'LAYER THICKNESS    INTERFACE EL
     2EVATION   LAYER TEMPERATURE',7X,'RATE OF RISE',10X,'CONCENTRATION'
     3/' (SEC)',8X,'KW',9X,'(FT)',6X,'(M)',8X,'(FT)',6X,'(M)',8X,'(F)',6
     4X,'(C)',9X,'(F/MIN)  (C/MIN)     DETECTABLE  HAZARDOUS'/1H ,111X,'P
     5OC',8X,'POC')
380   FORMAT(1H0,17X,'RATE OF   LAYER    LAYER',13X,'DETECTABLE HAZARDOU
     2S'/2X,'TIME    TEMP.    RISE   THICKNESS ELEVAT.    Q/Q0',7X,'POC'
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     3,8X,'POC'/56X,'CONCEN.    CONCEN.'/2X,'SEC      DEG F    DEGF/M
     4FT',7X,'FT'/9X,'(DEG C) (DEGC/M)    (M)       (M)')
300   FORMAT(1H0,17X,'RATE OF   LAYER    LAYER',13X,'DETECTABLE HAZARDOU
     2S'/2X,'TIME    TEMP.    RISE   THICKNESS ELEVAT.     Q   ',7X,'POC'
     3,8X,'POC'/56X,'CONCEN.    CONCEN.'/2X,'SEC      DEG F    DEGF/M
     4FT',7X,'FT',8X,'KW'/9X,'(DEG C) (DEGC/M)    (M)       (M)')
400   FORMAT(1H0,I5,5X,F8.2,4(5X,F7.2,2X,F7.2),5X,E9.4,2X,E9.4/)
410   FORMAT(1H0,1X,I5,4(2X,F7.2),2X,F8.2,2(2X,E9.4)/8X,4('(',F7.2,')')/)
     2)
420   FORMAT(1H0,31X,'LAYER     RATE OF',14X,'DETECTABLE',19X,'INTERFACE'
     2,13X,'HAZARDOUS'/4X,'AREA      TIME      TEMP.    THICKNESS    RISE',
     36X,'Q/Q0        CONCEN.     TIME       TEMP.    ELEVATION      Q/Q0',5X,'
     4CONCEN.  AVAILABLE'/14X,'AT',7X,'AT',8X,'AT',9X,'AT',8X,'AT',9X,'A
     5T',8X,'AT',7X,'AT',8X,'AT',9X,'AT',9X,'AT',6X,'EGRESS'/10X,'DETECT
     6ION DETECTION DETECTION DETECTION  DETECTION  DETECTION  HAZARD
     7HAZARD    HAZARD     HAZARD     HAZARD      TIME'//3X,'FT**2',6X,'S
     8EC      DEG F',6X,'FT',6X,'DEGF/M',28X,'SEC        DEG F',6X,'FT',30X,
     9'SEC'/3X,'(M**2)',12X,'(DEG C)     (M)       (DEGC/M)',33X,'(DEG C)
     *   (M)'///)
430   FORMAT(1H0,31X,'LAYER     RATE OF',14X,'DETECTABLE',19X,'INTERFACE'
     2,13X,'HAZARDOUS'/4X,'AREA      TIME      TEMP.    THICKNESS    RISE',
     36X,' Q          CONCEN.     TIME       TEMP.    ELEVATION      Q   ',5X,'
     4CONCEN.  AVAILABLE'/14X,'AT',7X,'AT',8X,'AT',9X,'AT',8X,'AT',9X,'A
     5T',8X,'AT',7X,'AT',8X,'AT',9X,'AT',9X,'AT',6X,'EGRESS'/10X,'DETECT
     6ION DETECTION DETECTION DETECTION  DETECTION  DETECTION  HAZARD
     7HAZARD    HAZARD     HAZARD     HAZARD      TIME'//3X,'FT**2',6X,'S
     8EC      DEG F',6X,'FT',6X,'DEGF/M',7X,'KW',19X,'SEC        DEG F',6X,'
     9FT',10X,'KW',18X,'SEC'/3X,'(M**2)',12X,'(DEG C)     (M)       (DEGC/
     *M)',33X,'(DEG C)     (M)'///)
440   FORMAT(1H0,8X,'LAYER     LAYER     INTER.  RATE OF',12X,'DETECTABLE
     2 HAZARDOUS'/2X,'TIME    TEMP.   THICKNESS ELEVAT.    RISE',6X,'Q/Q0',
     37X,'POC',9X,'POC'/3X,'SEC    DEG F       FT',7X,'FT       DEGF/M',14X,'
     4CONCEN.      CONCEN.'/8X,'(DEG C)      (M)',6X,'(M)    (DEGC/M)')
450   FORMAT(1H0,8X,'LAYER     LAYER     INTER.  RATE OF',12X,'DETECTABLE
     2 HAZARDOUS'/2X,'TIME    TEMP.   THICKNESS ELEVAT.    RISE',6X,' Q   ',
     37X,'POC',9X,'POC'/3X,'SEC    DEG F       FT',7X,'FT       DEGF/M',6X,'K
     4W',6X,'CONCEN.      CONCEN.'/8X,'(DEG C)      (M)',6X,'(M)    (DEGC/M)
     5')
460   FORMAT('0PRESS CARRIAGE RETURN TO CONTINUE.')
470   FORMAT(' ****DETECTION CHARACTERISTICS****')
480   FORMAT(' ****HAZARD CHARACTERISTICS****')
490   FORMAT(' ****SAFE AVAILABLE EGRESS TIME = ',I5,' SECONDS****')
C
      END
```

SUBROUTINE INTGR

```
C THIS IS EGRESS*ASET.INTGR. IT REQUIRES EGRESS*ASET.SUBF.
C
C*******************************************************************************
C THIS SUBROUTINE WILL INTEGRATE THE EQUATIONS FOR COMPUTING THE
C INTERFACE POSITION AS IT DROPS FROM THE CEILING. THE HISTORY OF THE
C AVERAGE UPPER LAYER TEMPERATURE, AND THE HISTORY OF THE PRODUCTS OF
C COMBUSTION CONCENTRATIONS IN THE UPPER LAYER.
C*******************************************************************************
C
      SUBROUTINE INTGR (F,A,B,H,N,X0,WK,IER)
C
C     ******************************************************************
C
      DIMENSION WK(1),X0(1)
      INTEGER ZXR
      LOGICAL LD,LH,LI,LJ
      DATA ES/.5E-4/
      IER=0
      IF (A-B) 30,10,30
 10   DO 20 I=1,N
            X0(I)=0.0
 20         CONTINUE
      RETURN
 30   IN1=N+N
      IN2=IN1+N
      HMIN=0.01*ABS(H)
      LH=.TRUE.
      LI=.TRUE.
      LJ=.TRUE.
      H=SIGN(ABS(H),B-A)
      X=A
 40   XS=X
      DO 50 J=1,N
            IWK0=N+J
            WK(IWK0)=X0(J)
 50         CONTINUE
 60   HS=H
      D=X+H-B
      LD=.TRUE.
      IF (.NOT.((H.GT.0.0.AND.D.GE.0.0).OR.(H.LT.0.0.AND.D.LE.0.0))) GO
     2TO 70
      H=B-X
      LI=.FALSE.
 70   H3=H/3.
      DO 210 ZXR=1,5
            CALL F (X0,X,WK)
            DO 170 I=1,N
                  D=H3*WK(I)
                  IWK0=N+I
                  IWK1=IN1+I
                  IWK2=IN2+I
                  GO TO (80,90,100,110,120), ZXR
 80               T=D
                  WK(IWK1)=D
                  GO TO 130
 90               T=0.5*(D+WK(IWK1))
```

```
                   GO TO 130
  100              T=3.*D
                   WK(IWK2)=T
                   T=.375*(T+WK(IWK1))
                   GO TO 130
  110              T=WK(IWK1)+4.*D
                   WK(IWK1)=T
                   T=1.5*(T-WK(IWK2))
                   GO TO 130
  120              T=0.5*(D+WK(IWK1))
                   D=ABS(T+T-1.5*(D+WK(IWK2)))
  130              X0(I)=WK(IWK0)+T
                   IF (ZXR.NE.5) GO TO 170
                   R=ABS(X0(I))
                   T=E5
                   IF (R.GE.1.E-3) T=R*E5
                   IF (D.LT.T.OR.(.NOT.LH)) GO TO 160
                   LI=.TRUE.
                   LJ=.FALSE.
                   H=H/2.
                   IF (ABS(H).GE.HMIN) GO TO 140
                   H=SIGN(1.,H)*HMIN
                   LH=.FALSE.
  140              DO 150 J=1,N
                       IWK0=N+J
                       X0(J)=WK(IWK0)
  150                  CONTINUE
                   X=XS
                   GO TO 60
  160              IF (D.GE.0.03125*T) LD=.FALSE.
  170              CONTINUE
              GO TO (180,210,190,200,210), ZXR
  180         X=X+H3
              GO TO 210
  190         X=X+0.5*H3
              GO TO 210
  200         X=X+0.5*H
  210         CONTINUE
         IF (.NOT.(LD.AND.LI.AND.LJ)) GO TO 220
         H=2.*H
         LH=.TRUE.
  220    LJ=.TRUE.
         IF (LI) GO TO 40
         H=HS
         IF (LH.OR.LD) RETURN
         IER=33
         WRITE (6,230)
         RETURN
C
C
230      FORMAT(' WARNING CONVERGENCE WAS NOT OBTAINED IN INTGR SUBROUTINE'
        2)
C
         END
```

SUBROUTINE SUBF

```
C THIS IS EGRESS*ASET.SUBF. IT IS REQUIRED BY INTGR.
C
C*************************************************************************
C THIS IS USED IN INTGR INTEGRATING ROUTINE.
C THUS  DX/DT=F(X(T),T)
C*************************************************************************
C
      SUBROUTINE F (X0,T,XP)
C
C     ********************************************************************
C
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZET0,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4       DPRHT0,Q0,LNORM
      DIMENSION X0(4),XP(4)
      EXTERNAL QDQ0
      EXTERNAL PRDPRO
      EXTERNAL PRHPRO
      LOGICAL LINTER,LNORM
      IF (T.GT.0.0) GO TO 10
      XP(1)=-C1-C2*(ZET0**(5./3.))
      XP(2)=(C1/C2)*(1./6.)*(2.*DQDT0-5.*XP(1))/(ZET0**(8./3.))
      XP(3)=((5.*C1*C3D)/(6.*C2*(ZET0**(8./3))))*(1.+(3.*ZET0*DPRDT0)/(5
     2.*C1)-ZET0*DQDT0/(5.*C1)+C2*(ZET0**(5./3.))/C1)
      XP(4)=((5.*C1*C3H)/(6.*C2*(ZET0**(8./3))))*(1.+(3.*ZET0*DPRHT0)/(5
     2.*C1)-ZET0*DQDT0/(5.*C1)+C2*(ZET0**(5./3.))/C1)
      GO TO 40
 10   IF (X0(1).LE.0.0) GO TO 20
      XP(1)=-C1*QDQ0(T)
      XP(1)=XP(1)-C2*(QDQ0(T)**(1./3.))*(X0(1)**(5./3.))
      XP(2)=(X0(2)**2.)*(C1*QDQ0(T)+(1.-(1./X0(2)))*XP(1))/(ZET0-X0(1))
      XP(3)=X0(2)*(C3D*PRDPRO(T)-X0(3)*C2*(QDQ0(T)**(1./3.))*(X0(1)**(5.
     2/3.)))/(ZET0-X0(1))
      XP(4)=X0(2)*(C3H*PRHPRO(T)-X0(4)*C2*(QDQ0(T)**(1./3.))*(X0(1)**(5.
     2/3.)))/(ZET0-X0(1))
      GO TO 40
 20   IF (X0(1).LE.-DELTA) GO TO 30
      XP(1)=-C1*QDQ0(T)
      XP(2)=(X0(2)*C1*QDQ0(T))/(ZET0-X0(1))
      XP(3)=(X0(2)*C3D*PRDPRO(T))/(ZET0-X0(1))
      XP(4)=(X0(2)*C3H*PRHPRO(T))/(ZET0-X0(1))
      GO TO 40
 30   XP(1)=0.0
      XP(2)=(X0(2)*C1*QDQ0(T))/(ZET0+DELTA)
      XP(3)=(X0(2)*C3D*PRDPRO(T))/(ZET0+DELTA)
      XP(4)=(X0(2)*C3H*PRHPRO(T))/(ZET0+DELTA)
 40   DPHI=XP(2)
      RETURN
      END
```

SUBROUTINE INPUT

```
C THIS IS EGRESS*ASET.INPUT
C
C*************************************************************************
C THIS IS AN ERROR CHECKING ROUTINE. IT CHECKS THE INPUT DATA TO
C INSURE THAT IT IS CORRECT.
C*************************************************************************
C
      SUBROUTINE INPUT (VARIBL,IEND)
C
C     *********************************************************************
C
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDTO,DPRDTO,
     4       DPRHTO,Q0,LNORM
      LOGICAL LINTER,LNORM
      CHARACTER L,ICHECK
      DATA L/'Y'/
10    WRITE (6,50)
      READ (5,60) ICHECK
      IF (ICHECK.EQ.L) RETURN
      WRITE (6,70)
20    READ (5,*,ERR=40,END=30) VARIBL
      WRITE (6,*) VARIBL
      GO TO 10
30    IEND=999
      RETURN
40    WRITE (6,80)
      GO TO 20
C
C
50    FORMAT(' IS THIS CORRECT (Y/N) ?')
60    FORMAT(A1)
70    FORMAT(' ENTER THE CORRECT VALUE(S).')
80    FORMAT('  ====> INCORRECT INPUT - TRY AGAIN <====')
C
      END
```

SUBROUTINE INPUT2

```
C THIS IS EGRESS*ASET.INPUT2
C
C**********************************************************************
C THIS IS AN ERROR CHECKING ROUTINE. IT CHECKS THE DATA POINT
C INPUT TO INSURE THAT IT IS CORRECT.
C**********************************************************************
C
      SUBROUTINE INPUT2 (TAUVAR,RATVAR,ITYPE)
C
C     ******************************************************************
C
      COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
     2       Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
     3       PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDT0,DPRDT0,
     4       DPRHT0,Q0,LNORM
      LOGICAL LINTER,LNORM
      DIMENSION TAUVAR(100),RATVAR(100)
      CHARACTER L,ICHECK
      DATA L/'Y'/
10    IF (ITYPE.EQ.1) WRITE (6,40)
      IF (ITYPE.NE.1) WRITE (6,50)
      READ (5,60) ICHECK
      IF (ICHECK.EQ.L) RETURN
      IF (ITYPE.EQ.1) WRITE (6,70)
      IF (ITYPE.NE.1) WRITE (6,80)
20    IF (ITYPE.EQ.1) READ (5,*,ERR=30) N,RATVAR(N),TAUVAR(N)
      IF (ITYPE.NE.1) READ (5,*,ERR=30) N,TAUVAR(N),RATVAR(N)
      IF (ITYPE.EQ.1) WRITE (6,90) (N,RATVAR(N),TAUVAR(N),N=1,NSEGQ)
      IF (ITYPE.EQ.2) WRITE (6,120) (N,TAUVAR(N),N,RATVAR(N),N=1,NSEGQ)
      IF (ITYPE.EQ.3) WRITE (6,100) (N,TAUVAR(N),N,RATVAR(N),N=1,NSEGPD)
      IF (ITYPE.EQ.4) WRITE (6,110) (N,TAUVAR(N),N,RATVAR(N),N=1,NSEGPH)
      GO TO 10
30    WRITE (6,130)
      GO TO 20
C
C
40    FORMAT(' ARE THE EQUATIONS CORRECT (Y/N) ?')
50    FORMAT(' ARE THE DATA POINTS CORRECT (Y/N) ?')
60    FORMAT(A1)
70    FORMAT(' ENTER THE NUMBER OF AN INCORRECT EQUATION, THE CORRECT RA
     2TE,'/'  AND THE CORRECT EXPONENTIAL FACTOR.')
80    FORMAT(' ENTER THE NUMBER OF AN INCORRECT DATA POINT, THE CORRECT
     2TIME,'/'  AND THE CORRECT RATE.')
90    FORMAT(5X,I3,') Q = ',F8.2,' EXP(',F7.4,'(T-T1))'/)
100   FORMAT(1H ,'TAUPRD(',I3,') = ',F6.0,5X,'PRD(',I3,') = ',E12.4)
110   FORMAT(1H ,'TAUPRH(',I3,') = ',F6.0,5X,'PRH(',I3,') = ',E12.4)
120   FORMAT (1H ,'TAUQ(',I3,') = ',F6.0,5X,'Q(',I3,') = ',E12.4)
130   FORMAT('  ====> INCORRECT INPUT - TRY AGAIN <====')
C
      END
```

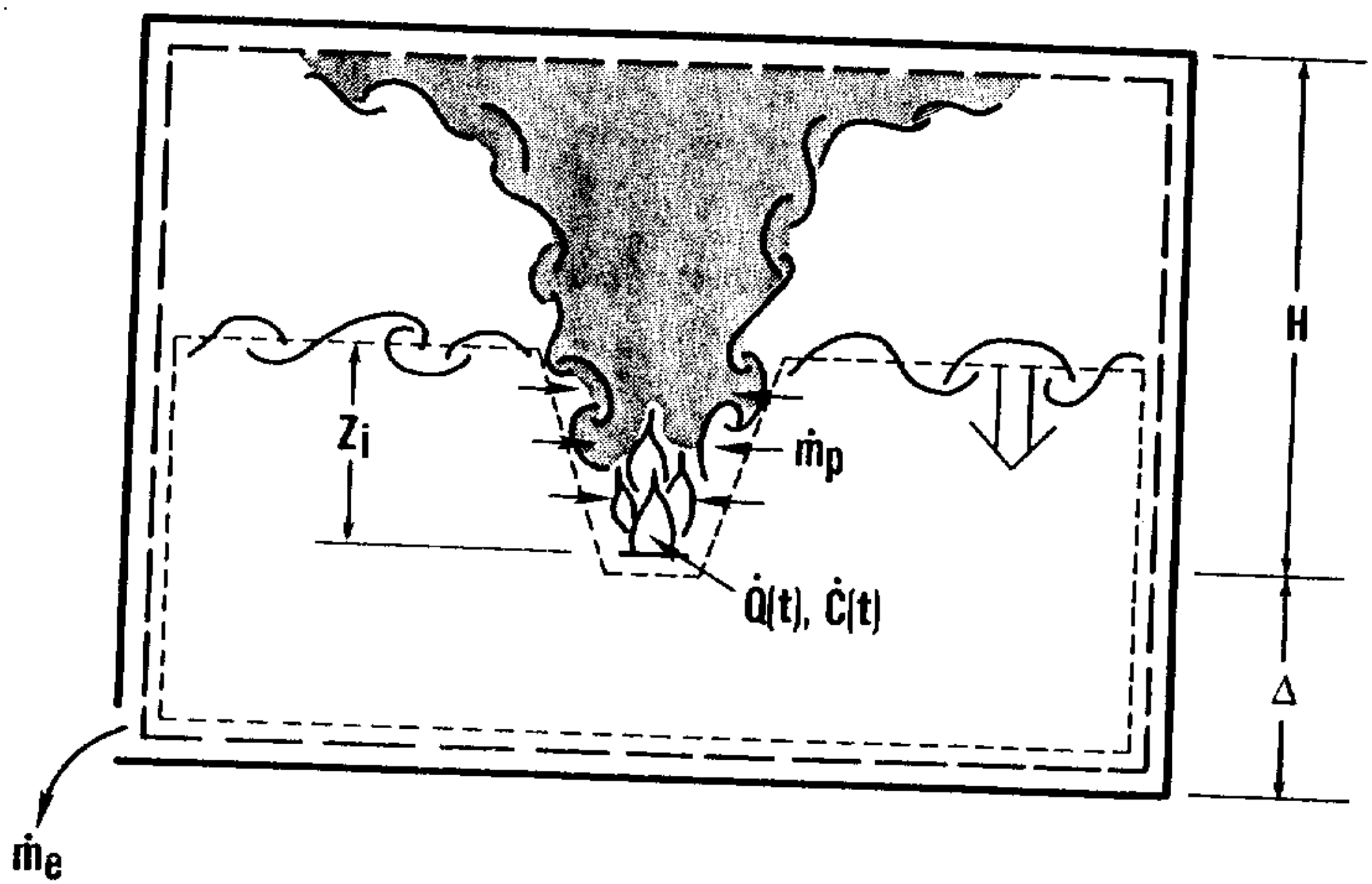

Figure 1. Simple illustration of fire-in-enclosure flow dynamics

CONSTANT FIRE, Q = 1320 KW

TIME (SEC)	Q KW	LAYER THICKNESS (FT)	LAYER THICKNESS (M)	INTERFACE ELEVATION (FT)	INTERFACE ELEVATION (M)	LAYER TEMPERATURE (F)	LAYER TEMPERATURE (C)	RATE OF RISE (F/MIN)	RATE OF RISE (C/MIN)	CONCENTRATION DETECTABLE PDC	CONCENTRATION HAZARDOUS PDC
0	1320.00	.00	.00	10.00	3.05	288.31	142.39	21.14	11.74	.0000	.2153-001
5	1320.00	.10	.03	9.90	3.02	290.07	143.37	21.23	11.79	.0000	.2170-001
10	1320.00	.19	.06	9.81	2.99	291.84	144.36	21.32	11.84	.0000	.2187-001
15	1320.00	.29	.09	9.71	2.96	293.62	145.35	21.41	11.89	.0000	.2205-001
20	1320.00	.38	.12	9.62	2.93	295.41	146.34	21.50	11.94	.0000	.2223-001
25	1320.00	.47	.14	9.53	2.90	297.21	147.34	21.59	11.99	.0000	.2240-001
30	1320.00	.56	.17	9.44	2.88	299.01	148.34	21.68	12.04	.0000	.2258-001
35	1320.00	.65	.20	9.35	2.85	300.82	149.34	21.77	12.09	.0000	.2276-001
40	1320.00	.74	.23	9.26	2.82	302.64	150.35	21.86	12.15	.0000	.2294-001
45	1320.00	.83	.25	9.17	2.80	304.46	151.37	21.95	12.20	.0000	.2312-001
50	1320.00	.92	.28	9.08	2.77	306.30	152.39	22.05	12.25	.0000	.2330-001
55	1320.00	1.00	.31	9.00	2.74	308.14	153.41	22.14	12.30	.0000	.2348-001
60	1320.00	1.09	.33	8.91	2.72	309.99	154.44	22.23	12.35	.0000	.2366-001
65	1320.00	1.17	.36	8.83	2.69	311.84	155.47	22.33	12.40	.0000	.2385-001
70	1320.00	1.26	.38	8.74	2.67	313.71	156.50	22.42	12.46	.0000	.2403-001
75	1320.00	1.34	.41	8.66	2.64	315.58	157.54	22.51	12.51	.0000	.2421-001
80	1320.00	1.42	.43	8.58	2.62	317.46	158.59	22.61	12.56	.0000	.2440-001
85	1320.00	1.50	.46	8.50	2.59	319.35	159.64	22.70	12.61	.0000	.2459-001
90	1320.00	1.58	.48	8.42	2.57	321.24	160.69	22.80	12.67	.0000	.2477-001
95	1320.00	1.66	.51	8.34	2.54	323.15	161.75	22.89	12.72	.0000	.2496-001
100	1320.00	1.74	.53	8.26	2.52	325.06	162.81	22.99	12.77	.0000	.2515-001
105	1320.00	1.82	.55	8.18	2.49	326.98	163.88	23.09	12.83	.0000	.2534-001
110	1320.00	1.89	.58	8.11	2.47	328.91	164.95	23.18	12.88	.0000	.2553-001
115	1320.00	1.97	.60	8.03	2.45	330.84	166.02	23.28	12.93	.0000	.2572-001
120	1320.00	2.05	.62	7.95	2.42	332.79	167.10	23.38	12.99	.0000	.2591-001
125	1320.00	2.12	.65	7.88	2.40	334.74	168.19	23.48	13.04	.0000	.2610-001

Figure 2. Computer output from batch run of Example 1

130	1320.00	2.19	.67	7.81	2.38	336.70	169.28	23.57	13.10	.0000	.2630-001
135	1320.00	2.27	.69	7.73	2.36	338.67	170.37	23.67	13.16	.0000	.2649-001
140	1320.00	2.34	.71	7.66	2.33	340.65	171.47	23.77	13.21	.0000	.2669-001
145	1320.00	2.41	.74	7.59	2.31	342.63	172.57	23.87	13.26	.0000	.2688-001
150	1320.00	2.48	.76	7.52	2.29	344.62	173.68	23.97	13.32	.0000	.2708-001
155	1320.00	2.55	.78	7.45	2.27	346.63	174.79	24.07	13.37	.0000	.2728-001
160	1320.00	2.62	.80	7.38	2.25	348.64	175.91	24.17	13.43	.0000	.2747-001
165	1320.00	2.69	.82	7.31	2.23	350.65	177.03	24.27	13.48	.0000	.2767-001
170	1320.00	2.76	.84	7.24	2.21	352.68	178.16	24.37	13.54	.0000	.2787-001
175	1320.00	2.83	.86	7.17	2.19	354.72	179.29	24.48	13.60	.0000	.2807-001
180	1320.00	2.90	.88	7.10	2.17	356.76	180.42	24.58	13.65	.0000	.2828-001
185	1320.00	2.96	.90	7.04	2.14	358.81	181.56	24.68	13.71	.0000	.2848-001
190	1320.00	3.03	.92	6.97	2.12	360.87	182.71	24.78	13.77	.0000	.2868-001
195	1320.00	3.09	.94	6.91	2.10	362.94	183.86	24.89	13.83	.0000	.2888-001

CONSTANT FIRE, Q = 1320 KW

AREA	TIME AT DETECTION	TEMP. AT DETECTION	LAYER THICKNESS AT DETECTION	RATE OF RISE AT DETECTION	Q AT DETECTION	DETECTABLE CONCEN. AT DETECTION	TIME AT HAZARD	TEMP. AT HAZARD	INTERFACE ELEVATION AT HAZARD	Q AT HAZARD	HAZARDOUS CONCEN. AT HAZARD	AVAILABLE EGRESS TIME
FT**2 (M**2)	SEC	DEG F (DEG C)	FT (M)	DEGF/M (DEGC/M)	KW		SEC	DEG F (DEG C)	FT (M)	KW		SEC
10000. (929.00)	0	288.31 (142.39)	.00 (.00)	21.14 (11.74)	1320.00	.0000	191	361.40 (183.00)	6.95 (2.12)	1320.00	.2873-001	191

Figure 2. continued

MULTI-EXPONENTIAL FIRE GROWTH

TIME (SECS)	Q/Q0	LAYER THICKNESS (FT)	LAYER THICKNESS (M)	INTERFACE ELEVATION (FT)	INTERFACE ELEVATION (M)	LAYER TEMPERATURE (F)	LAYER TEMPERATURE (C)	RATE OF RISE (F/MIN)	RATE OF RISE (C/MIN)	CONCENTRATION DETECTABLE PDC	CONCENTRATION HAZARDOUS PDC
0	1.00	.00	.00	20.00	6.10	71.98	22.21	.13	.07	.0000	.2871-004
5	1.13	.07	.02	19.93	6.07	72.07	22.26	1.16	.64	.0000	.3005-004
10	1.28	.15	.05	19.85	6.05	72.17	22.32	1.24	.69	.0000	.3150-004
15	1.45	.23	.07	19.77	6.03	72.27	22.37	1.33	.74	.0000	.3305-004
20	1.65	.31	.09	19.69	6.00	72.39	22.44	1.44	.80	.0000	.3473-004
25	1.87	.39	.12	19.61	5.98	72.51	22.51	1.55	.86	.0000	.3654-004
30	2.12	.48	.15	19.52	5.95	72.65	22.58	1.68	.93	.0000	.3850-004
35	2.40	.57	.17	19.43	5.92	72.79	22.66	1.81	1.01	.0000	.4061-004
40	2.72	.66	.20	19.34	5.89	72.95	22.75	1.96	1.09	.0000	.4289-004
45	3.08	.76	.23	19.24	5.86	73.12	22.85	2.12	1.18	.0000	.4536-004
50	3.49	.86	.26	19.14	5.83	73.31	22.95	2.29	1.27	.0000	.4803-004
55	3.96	.96	.29	19.04	5.80	73.50	23.06	2.48	1.38	.0000	.5092-004
60	4.48	1.07	.33	18.93	5.77	73.72	23.18	2.69	1.50	.0000	.5405-004
65	5.08	1.18	.36	18.82	5.74	73.95	23.31	2.92	1.62	.0000	.5744-004
70	5.75	1.29	.39	18.71	5.70	74.21	23.45	3.17	1.76	.0000	.6112-004
75	6.52	1.41	.43	18.59	5.67	74.48	23.60	3.44	1.91	.0000	.6512-004
80	7.39	1.53	.47	18.47	5.63	74.78	23.77	3.73	2.07	.0000	.6945-004
85	8.37	1.66	.50	18.35	5.59	75.10	23.95	4.06	2.25	.0000	.7417-004
90	9.49	1.78	.54	18.22	5.55	75.46	24.14	4.41	2.45	.0000	.7929-004
95	10.75	1.91	.58	18.09	5.51	75.84	24.36	4.80	2.67	.0000	.8486-004
100	12.18	2.05	.63	17.95	5.47	76.26	24.59	5.23	2.90	.0000	.9093-004
105	13.80	2.19	.67	17.81	5.43	76.71	24.84	5.69	3.16	.0000	.9754-004
110	15.64	2.34	.71	17.66	5.38	77.21	25.12	6.21	3.45	.0000	.1047-003
115	17.73	2.48	.76	17.52	5.34	77.76	25.42	6.77	3.76	.0000	.1126-003
120	20.09	2.64	.80	17.36	5.29	78.34	25.74	7.39	4.11	.0000	.1212-003
125	22.76	2.79	.85	17.21	5.24	78.98	26.10	8.07	4.48	.0000	.1305-003

Figure 3. Computer output from batch run of Example 2

130	25.79	2.96	.90	17.04	5.19	79.68	26.49	8.82	4.90	.0000	.1407-003
135	29.22	3.12	.95	16.88	5.14	80.45	26.92	9.65	5.36	.0000	.1519-003
140	33.12	3.29	1.00	16.71	5.09	81.29	27.39	10.56	5.86	.0000	.1641-003
145	37.52	3.47	1.06	16.53	5.04	82.22	27.90	11.56	6.42	.0000	.1775-003
150	40.99	3.65	1.11	16.35	4.98	83.21	28.45	12.03	6.69	.0000	.1920-003
155	43.09	3.83	1.17	16.17	4.93	84.21	29.01	11.94	6.63	.0000	.2065-003
160	45.30	4.01	1.22	15.99	4.87	85.20	29.56	11.91	6.61	.0000	.2209-003
165	47.62	4.19	1.28	15.81	4.82	86.20	30.11	11.93	6.63	.0000	.2363-003
170	50.07	4.37	1.33	15.63	4.76	87.19	30.66	12.01	6.67	.0000	.2498-003
175	52.63	4.55	1.39	15.45	4.71	88.20	31.22	12.14	6.75	.0000	.2648-003
180	55.33	4.73	1.44	15.27	4.66	89.22	31.79	12.31	6.84	.0000	.2793-003
185	58.17	4.91	1.50	15.09	4.60	90.25	32.36	12.53	6.96	.0000	.2943-003
190	61.15	5.09	1.55	14.91	4.55	91.31	32.96	12.78	7.10	.0000	.3096-003
195	64.29	5.27	1.61	14.73	4.49	92.38	33.55	13.06	7.26	.0000	.3282-003
200	67.58	5.44	1.66	14.56	4.44	93.49	34.16	13.39	7.44	.0000	.3413-003
205	71.05	5.62	1.71	14.38	4.38	94.62	34.79	13.74	7.64	.0000	.3577-003
210	74.69	5.80	1.77	14.20	4.33	95.78	35.43	14.14	7.85	.0000	.3746-003
215	78.52	5.98	1.82	14.02	4.27	96.97	36.10	14.56	8.09	.0000	.3919-003
220	82.54	6.16	1.88	13.84	4.22	98.20	36.78	15.02	8.34	.0000	.4098-003
225	86.76	6.33	1.93	13.67	4.17	99.48	37.49	15.51	8.62	.0000	.4283-003
230	91.22	6.51	1.98	13.49	4.11	100.79	38.22	16.04	8.91	.0000	.4474-003
235	95.90	6.69	2.04	13.31	4.06	102.15	38.97	16.61	9.23	.0000	.4672-003
240	100.82	6.87	2.09	13.13	4.00	103.56	39.76	17.21	9.56	.0000	.4877-003
245	105.99	7.04	2.15	12.96	3.95	105.02	40.57	17.85	9.92	.0000	.5089-003
250	111.42	7.22	2.20	12.78	3.90	106.54	41.41	18.53	10.29	.0000	.5309-003
255	117.14	7.40	2.25	12.60	3.84	108.11	42.28	19.25	10.69	.0000	.5538-003
260	123.14	7.57	2.31	12.43	3.79	109.75	43.19	20.01	11.12	.0000	.5775-003
265	129.45	7.75	2.36	12.25	3.73	111.45	44.14	20.82	11.56	.0000	.6023-003
270	136.09	7.93	2.42	12.07	3.68	113.22	45.12	21.67	12.04	.0000	.6280-003

Figure 3. continued

275	143.07	8.10	2.47	11.90	3.63	115.06	46.14	22.57	12.54	.0000	.6548-003
280	150.40	8.28	2.52	11.72	3.57	116.98	47.21	23.52	13.06	.0000	.6826-003
285	158.12	8.46	2.58	11.54	3.52	118.98	48.32	24.52	13.62	.0000	.7117-003
290	166.22	8.63	2.63	11.37	3.46	121.07	49.48	25.58	14.21	.0000	.7420-003
295	174.74	8.81	2.69	11.19	3.41	123.24	50.69	26.69	14.83	.0000	.7737-003
300	183.70	8.99	2.74	11.01	3.36	125.52	51.95	27.87	15.48	.0000	.8067-003
305	193.12	9.17	2.79	10.83	3.30	127.89	53.27	29.11	16.17	.0000	.8412-003
310	203.02	9.35	2.85	10.65	3.25	130.37	54.65	30.42	16.90	.0000	.8773-003
315	213.43	9.52	2.90	10.48	3.19	132.96	56.09	31.81	17.67	.0000	.9149-003
320	224.38	9.70	2.96	10.30	3.14	135.68	57.60	33.27	18.48	.0000	.9543-003
325	235.88	9.88	3.01	10.12	3.08	138.51	59.17	34.81	19.34	.0000	.9955-003
330	247.97	10.07	3.07	9.93	3.03	141.48	60.82	36.44	20.24	.0000	.1039-002
335	260.69	10.25	3.12	9.75	2.97	144.59	62.55	38.15	21.20	.0000	.1084-002
340	274.05	10.43	3.18	9.57	2.92	147.84	64.36	39.97	22.20	.0000	.1131-002
345	288.11	10.61	3.24	9.39	2.86	151.25	66.25	41.88	23.27	.0000	.1181-002
350	301.44	10.80	3.29	9.20	2.80	154.82	68.23	43.66	24.26	.0000	.1233-002
355	309.07	10.98	3.35	9.02	2.75	158.49	70.27	44.48	24.71	.0000	.1286-002
360	316.89	11.17	3.40	8.83	2.69	162.24	72.38	45.35	25.20	.0000	.1340-002
365	324.91	11.35	3.46	8.65	2.64	166.06	74.48	46.28	25.71	.0000	.1396-002
370	333.14	11.53	3.51	8.47	2.58	169.95	76.64	47.25	26.25	.0000	.1452-002
375	341.57	11.71	3.57	8.29	2.53	173.93	78.85	48.28	26.82	.0000	.1510-002
380	350.22	11.88	3.62	8.12	2.47	178.00	81.11	49.37	27.43	.0000	.1569-002
385	359.08	12.06	3.68	7.94	2.42	182.16	83.42	50.51	28.06	.0000	.1630-002
390	368.17	12.24	3.73	7.76	2.37	186.42	85.79	51.70	28.72	.0000	.1692-002
395	377.49	12.41	3.78	7.59	2.31	190.78	88.21	52.95	29.42	.0000	.1755-002
400	387.05	12.59	3.84	7.41	2.26	195.25	90.69	54.24	30.14	.0000	.1820-002
405	396.85	12.76	3.89	7.24	2.21	199.82	93.24	55.62	30.90	.0000	.1886-002
410	406.89	12.93	3.94	7.07	2.15	204.52	95.84	57.05	31.69	.0000	.1955-002
415	417.20	13.11	3.99	6.89	2.10	209.33	98.52	58.54	32.52	.0000	.2025-002

Figure 3. continued

420	427.76	13.28	4.05	6.72	2.05	214.28	101.27	60.09	33.38	.0000	.2096-002
425	438.59	13.45	4.10	6.55	2.00	219.35	104.08	61.70	34.28	.0000	.2176-002
430	449.69	13.62	4.15	6.38	1.94	224.54	106.98	63.36	35.21	.0000	.2246-002
435	461.07	13.80	4.21	6.20	1.89	229.92	109.96	65.12	36.18	.0000	.2324-002
440	472.74	13.97	4.26	6.03	1.84	235.42	113.01	66.94	37.19	.0000	.2404-002
445	484.71	14.14	4.31	5.86	1.79	241.07	116.15	68.83	38.24	.0000	.2486-002
450	496.98	14.32	4.36	5.68	1.73	246.89	119.38	70.79	39.33	.0000	.2570-002
455	509.56	14.49	4.42	5.51	1.68	252.87	122.71	72.82	40.46	.0000	.2657-002
460	522.46	14.66	4.47	5.34	1.63	259.03	126.13	74.93	41.63	.0000	.2747-002
465	535.69	14.84	4.52	5.16	1.57	265.36	129.65	77.12	42.84	.0000	.2839-002
470	549.28	15.01	4.58	4.99	1.52	271.88	133.27	79.39	44.10	.0000	.2934-002
475	563.16	15.19	4.63	4.81	1.47	278.60	137.00	81.74	45.41	.0000	.3031-002
480	577.41	15.37	4.68	4.63	1.41	285.51	140.84	84.17	46.76	.0000	.3132-002
485	592.03	15.55	4.74	4.45	1.36	292.63	144.79	86.69	48.16	.0000	.3235-002
490	607.02	15.73	4.79	4.27	1.30	299.96	148.87	89.29	49.61	.0000	.3342-002
495	622.38	15.91	4.85	4.09	1.25	307.51	153.06	91.98	51.10	.0000	.3451-002
500	638.14	16.10	4.91	3.90	1.19	315.29	157.38	94.76	52.64	.0000	.3564-002
505	654.29	16.28	4.96	3.72	1.13	323.31	161.84	97.62	54.23	.0000	.3681-002
510	670.84	16.47	5.02	3.53	1.08	331.57	166.43	100.56	55.87	.0000	.3801-002
515	687.84	16.66	5.08	3.34	1.02	340.07	171.15	103.56	57.54	.0000	.3926-002
520	705.26	16.85	5.14	3.14	.96	348.83	176.02	106.67	59.26	.0000	.4052-002
525	723.11	17.05	5.20	2.95	.90	357.85	181.03	109.84	61.02	.0000	.4183-002

MULTI-EXPONENTIAL FIRE GROWTH

AREA	TIME AT DETECTION	TEMP. AT DETECTION	LAYER THICKNESS AT DETECTION	RATE OF RISE AT DETECTION	Q/QO AT DETECTION	DETECTABLE CONCEN. AT DETECTION	TIME AT HAZARD	TEMP. AT HAZARD	INTERFACE ELEVATION AT HAZARD	Q/QO AT HAZARD	HAZARDOUS CONCEN. AT HAZARD	AVAILABLE EGRESS TIME
FT**2 (M**2)	SEC	DEG F (DEG C)	FT (M)	DEGF/M (DEGC/M)			SEC	DEG F (DEG C)	FT (M)			SEC
5000. (464.50)	0	71.98 (22.21)	.00 (.00)	.13 (.07)	1.00	.0000	523	356.46 (179.70)	3.00 (.91)	718.33	.4148-002	523

Figure 3. continued

FLASHOVER POTENTIAL

AREA FT**2 (M**2)	TIME AT DETECTION SEC	TEMP. AT DETECTION DEG F (DEG C)	LAYER THICKNESS AT DETECTION FT (M)	RATE OF RISE AT DETECTION DEGF/M (DEGC/M)	Q AT DETECTION KW	DETECTABLE CONCEN. AT DETECTION	TIME AT HAZARD SEC	TEMP. AT HAZARD DEG F (DEG C)	INTERFACE ELEVATION AT HAZARD FT (M)	Q AT HAZARD KW	HAZARDOUS CONCEN. AT HAZARD	AVAILABLE EGRESS TIME SEC
100. (9.29)	0	75.06 (23.92)	.00 (.00)	6.96 (3.87)	2.00	.0000	306	750.00 (398.89)	.00 (.00)	362.46	.8940-001	306
120. (11.15)	0	75.06 (23.92)	.00 (.00)	6.48 (3.60)	2.00	.0000	314	750.00 (398.89)	.00 (.00)	447.77	.8940-001	314
200. (18.58)	0	75.06 (23.92)	.00 (.00)	5.53 (3.07)	2.00	.0000	337	750.00 (398.89)	.00 (.00)	479.60	.8940-001	337
250. (23.22)	0	75.06 (23.92)	.00 (.00)	5.24 (2.91)	2.00	.0000	348	750.00 (398.89)	.00 (.00)	785.83	.8940-001	348
300. (27.87)	0	75.06 (23.92)	.00 (.00)	5.05 (2.81)	2.00	.0000	357	750.00 (398.89)	.00 (.00)	875.92	.8940-001	357
400. (37.16)	0	75.06 (23.92)	.00 (.00)	4.81 (2.67)	2.00	.0000	372	750.00 (398.89)	.00 (.00)	1028.22	.8940-001	372
500. (46.45)	0	75.06 (23.92)	.00 (.00)	4.67 (2.59)	2.00	.0000	384	750.00 (398.89)	.00 (.00)	1147.11	.8940-001	384
600. (55.74)	0	75.06 (23.92)	.00 (.00)	4.57 (2.54)	2.00	.0000	395	750.00 (398.89)	.00 (.00)	1168.28	.8940-001	395
800. (74.32)	0	75.06 (23.92)	.00 (.00)	4.45 (2.47)	2.00	.0000	415	750.00 (398.89)	.08 (.02)	1026.56	.8940-001	415
1000. (92.90)	0	75.06 (23.92)	.00 (.00)	4.38 (2.43)	2.00	.0000	436	750.00 (398.89)	.51 (.15)	886.85	.8940-001	436
1200. (111.48)	0	75.06 (23.92)	.00 (.00)	4.34 (2.41)	2.00	.0000	459	750.00 (398.89)	.86 (.26)	730.33	.8940-001	459

Figure 4. Computer output from batch run of Example 3

```
   2000.       0      75.06       .00       4.24        2.00    .0000          812   750.00       1.72      49.91   .8940-30;    312
(  185.80)         (  23.92) (    .00) (    2.36)                                   ( 398.89) (    .52)

   --THE UPPER LIMIT OF THE DIGITAL DATA HAS BEEN EXCESDED.
CONTINUE WITH THE NEXT COMPARTMENT HEIGHT OR SPECIFIED
    DETECTION CRITERIA.--
```

Figure 4. continued

FLASHOVER POTENTIAL

AREA FT**2 (M**2)	TIME AT DETECTION SEC	TEMP. AT DETECTION DEG F (DEG C)	LAYER THICKNESS AT DETECTION FT (M)	RATE OF RISE AT DETECTION DEGF/M (DEGC/M)	Q AT DETECTION KW	DETECTABLE CONCEN. AT DETECTION	TIME AT HAZARD SEC	TEMP. AT HAZARD DEG F (DEG C)	INTERFACE ELEVATION AT HAZARD FT (M)	Q AT HAZARD KW	HAZARDOUS CONCEN. AT HAZARD	AVAILABLE EGRESS TIME SEC
100. (9.29)	0	72.16 (22.31)	.00 (.00)	2.76 (1.53)	2.00	.0000	330	750.00 (398.89)	.00 (.00)	601.72	.8940-001	330
120. (11.15)	0	72.16 (22.31)	.00 (.00)	2.47 (1.37)	2.00	.0000	338	750.00 (398.89)	.00 (.00)	689.86	.8940-001	338
200. (18.58)	0	72.16 (22.31)	.00 (.00)	1.90 (1.06)	2.00	.0000	366	750.00 (398.89)	.00 (.00)	961.69	.8940-001	366
250. (23.22)	0	72.16 (22.31)	.00 (.00)	1.73 (.96)	2.00	.0000	379	750.00 (398.89)	.00 (.00)	1095.42	.8940-001	379
300. (27.87)	0	72.16 (22.31)	.00 (.00)	1.62 (.90)	2.00	.0000	391	750.00 (398.89)	.00 (.00)	1191.44	.8940-001	391
400. (37.16)	0	72.16 (22.31)	.00 (.00)	1.46 (.82)	2.00	.0000	415	750.00 (398.89)	.00 (.00)	1031.40	.8940-001	415
500. (46.45)	0	72.16 (22.31)	.00 (.00)	1.39 (.77)	2.00	.0000	442	750.00 (398.89)	.00 (.00)	847.96	.8940-001	442
600. (55.74)	0	72.16 (22.31)	.00 (.00)	1.33 (.74)	2.00	.0000	476	750.00 (398.89)	.00 (.00)	619.93	.8940-001	476
800. (74.32)	0	72.16 (22.31)	.00 (.00)	1.26 (.70)	2.00	.0000	656	750.00 (398.89)	.00 (.00)	103.27	.8940-001	656

--THE UPPER LIMIT OF THE DIGITAL DATA HAS BEEN EXCEEDED.
CONTINUE WITH THE NEXT COMPARTMENT HEIGHT OR SPECIFIED
DETECTION CRITERIA.--

Figure 4. continued

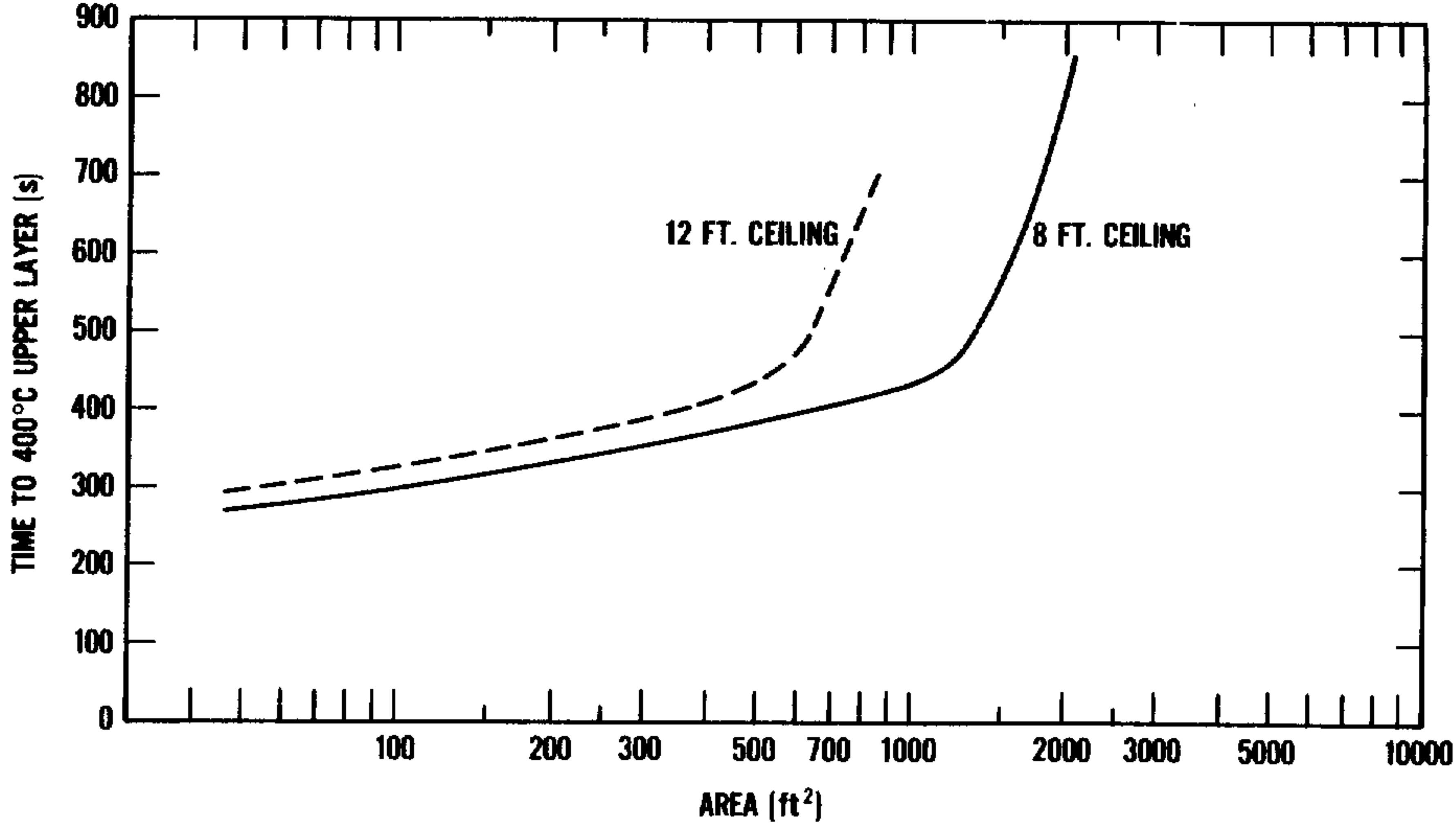

Figure 5. Example 3 results: plot of time to reach potential flashover against enclosure floor area, for a fire confined to an assembly of bedding combustibles

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5. AUTHOR(S)

Leonard Y. Cooper and David W. Stroup

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10. SUPPLEMENTARY NOTES

[X] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

In the event of a fire in a building compartment the time available for occupants to safely evacuate the compartment, the Available Safe Egress Time (ASET), depends on the time of fire detection and on the time of the onset of hazardous conditions. In order to estimate these two times a dynamic simulation of the developing fire environment in the compartment is required. Also required are specific criteria for the simulation of detection and onset of hazard. A user oriented computer program which carries out the required simulations and provides estimates for the ASET has been developed. This document provides a listing of the program and a manual for its use. For fire growth in a particular fuel assembly, a single program run can be used to evaluate the ASET from enclosures (which are assumed to contain the fuel assembly) of different heights and areas, and under a variety of different detection and hazard criteria. The program can be used in either an interactive or batch mode. It is written in ANSI Fortran and requires no computer specific subroutines.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Combustion products; compartment fires; egress; fire detection; fire growth; hazard analysis; mathematical models; room fires; smoke movement; tenability limits.

13. AVAILABILITY

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