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
CALCULATING AVAILABLE SAFE EGRESS TIME (ASET) - A COMPUTER PROGRAM AND USER'S GUIDE

Leonard Y. Cooper and David W. Stroup

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<thead>
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<tr>
<td>A</td>
<td>area of enclosure</td>
</tr>
<tr>
<td>ASET</td>
<td>Available Safe Egress Time</td>
</tr>
<tr>
<td>C</td>
<td>rate of generation of a combustion product</td>
</tr>
<tr>
<td>H</td>
<td>height of enclosure ceiling above fire</td>
</tr>
<tr>
<td>M</td>
<td>concentration of a combustion product</td>
</tr>
<tr>
<td>Q</td>
<td>rate of fire's energy release</td>
</tr>
<tr>
<td>RSET</td>
<td>Required Safe Egress Time</td>
</tr>
<tr>
<td>T</td>
<td>temperature</td>
</tr>
<tr>
<td>t</td>
<td>time</td>
</tr>
<tr>
<td>tDET</td>
<td>time at detection</td>
</tr>
<tr>
<td>tHAZ</td>
<td>time at onset of hazardous conditions</td>
</tr>
<tr>
<td>uc</td>
<td>dimensional unit of a product of combustion</td>
</tr>
<tr>
<td>Zi</td>
<td>elevation of interface</td>
</tr>
<tr>
<td>Δ</td>
<td>height of fire above floor</td>
</tr>
<tr>
<td>λc</td>
<td>fraction of Q transferred to enclosure surfaces</td>
</tr>
<tr>
<td>λr</td>
<td>fraction of Q radiated from combustion zone</td>
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**Computer Program**

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*In this paper, the symbol 0, appearing in a variable name, will be used to indicate the number 0, and the symbol 0, appearing in a variable name, will be used to indicate the letter 0.*
CALCULATING AVAILABLE SAFE EGRESS TIME (ASET) -
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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 \( t_{\text{DET}} \) and \( t_{\text{HAZ}} \) for the threatened spaces.

\[
\text{Compute } ASET = t_{\text{HAZ}} - t_{\text{DET}}.
\]

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, $\Delta$, above the floor. An estimate of the total energy release rate of the fire, $Q$, as a function of time, $t$, is assumed to be available, as is the fire's generation rate $C$ 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 $Q$ and $C$, 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 $t_{\text{DET}}$, $t_{\text{HAZ}}$, 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 $u_c$. 

7
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 $t_{\text{DET}}$ and $t_{\text{HAZ}}$, 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 occurred 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.
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.
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 $\lambda_r$ 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 $\lambda_c$ 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 $\lambda_c$ 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 $\lambda_c$. (Indeed, although $\lambda_c$ 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 $\lambda_c$ 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 $\lambda_c$ 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 $\lambda_c$ 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.
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 \( \mu_c \) 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 \((1 \times 3 \times 2 = 6)\) 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,
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 (61°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/m², 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, 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:

\[ Q(t) = \begin{cases} 
Q(1)e^{AKAP(1)t}, & 0 \leq t < TAUQ(1); \\
Q(2)e^{AKAP(2)[tTAUQ(1)]}, & 2nd segment, \\
\vdots \\
Q(NSEGQ)e^{AKAP(NSEGQ)[tTAUQ(NSEGQ)]}, & NSEGQth segment,
\end{cases} \]

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

\[ Q(t) = \begin{cases} 
Q0 & at t = 0; \\
Q(1) & at t = TAUQ(1); \\
\vdots \\
Q(NSEGQ) & at t = TAUQ(NSEGQ)
\end{cases} \]

with linear interpolation between the above NSEGQ + 1 data points. As described
below, Q0 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 NSEQQ 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(I).
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):
and the program will compute \( Q(t) \) according to

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

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 environment 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: QΦ

QΦ - 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)/QΦ.
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, \( C(t) \), 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, \( C(t) \), 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 \( C(t) \) must be described in dimensions of grams (of product) per second; if \( u_c \) is taken as number of particles, then \( C(t) \) 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 \( C(t) \) 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 $C(t)$ 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., $C(t) = \text{BETAD} \cdot Q(t)$.

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

\[
\begin{align*}
&\text{PRD}0 \text{ at } t = 0; \\
&\text{PRD}(1) \text{ at } t = \text{TAUPRD}(1), \\
&C(t) = \text{PRD}(NSEGPD) \text{ at } t = \text{TAUPRD}(NSEGPD)
\end{align*}
\]

with linear interpolation between the above NSEGPD + 1 data points. As described below, PRD0 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., \( \dot{C}(t) = BETAD \cdot \dot{Q}(t) \). BETAD is entered in units of \( \frac{u_c}{s} \) 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:PRD0**

PRD0 - the initial detectable product generation rate in units of \( \frac{u_c}{s} \) 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 \( \frac{u_c}{s} \) 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 TAUULIM. 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, 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 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., C(t) = BETAH \cdot Q(t)
PRODH = 2, a product generation rate curve made up of NSEGPH continuous linear segments. The curve would be defined by

\[
\begin{align*}
\text{PRH}\phi & \text{ at } t = 0; \\
\text{PRH}(1) & \text{ at } t = \text{TAUPRH}(1), \\
\dot{C}(t) &= \\
\text{PRH}(\text{NSEGPH}) & \text{ at } t = \text{TAUPRH}(\text{NSEGPH}).
\end{align*}
\]

with linear interpolation between the above NSEGPH + 1 data points. As described below, PRH\phi and the NSEGPH pair of values TAUPRH(1), PRH(1); TAUPRH(2), PRH(2); \ldots; TAUPRH(\text{NSEGPH}), PRH(\text{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: \text{BETAH}

BETAH - a constant of proportionality between the hazardous product of combustion generation rate and the energy generation rate, i.e.,

\[ C(t) = \text{BETAH} \cdot \dot{Q}(t). \]

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: PRH0

PRH0 - 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, RRRSPF, 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, $g_{\text{depleted O}_2}$, and the hazardous concentration is taken to be $0.05 \, g_{\text{depleted O}_2}$ per $g_{\text{upper}}$ which corresponds to $\text{CNHS} = 0.05$.

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

$$\dot{C}_{\text{depleted O}_2} = [0.076 \, g_{\text{depleted O}_2}/(\text{kWs})]Q$$

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

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
   IV. FIRE DATA

II. HAZARD CRITERIA
    V. PRODUCTS OF COMBUSTION DATA

III. ROOM SIZES

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: 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: 0.05
      5.0000-02
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: 10.0
      10.000
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: 11000.
      11000.
IS THIS CORRECT (Y/N)?
ENTER: no
ENTER THE CORRECT VALUE(S).
ENTER: 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: 1320.0

Q\(\phi\) = .1320+04

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: 1800.0, 1320.0

ENTER: @eof

TAUQ(1) = 1800.0 \hspace{1cm} Q(1) = .1320+04

ARE THESE DATA POINTS CORRECT (Y/N)?

ENTER: yes

DO YOU WANT FIRE ENERGY GENERATION RATE DATA

PRESENTED IN NORMALIZED FORM, Q(T)/Q\(\phi\) (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 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".

1. General Data

<table>
<thead>
<tr>
<th>BATCH DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run title</td>
</tr>
<tr>
<td>Write code</td>
</tr>
<tr>
<td>$\lambda_\tau$, $\lambda_c$, eyelevel, fire height</td>
</tr>
</tbody>
</table>
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 ft² (929.0 m²), 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, \( g_{\text{depleted O}_2} \) per \( g_{\text{upper}} \) 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 \text{ ft}^2)^{1/2} = 70 \text{ 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 transferred 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: 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, .75, 3., 2.

LAMDA R = .35000
LAMDA C = .75000
EYELEVEL HEIGHT = 3.0000
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: 135.0
135.00

IS THIS CORRECT (Y/N)?
ENTER: yes
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
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: 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: \( Q = Q_1 \exp(\alpha(t-T_1)) \)

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 \((Q_1)\), 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
1. \[ Q = 10.0 \exp(0.025(T-T_l)) \]
2. \[ Q = 400.0 \exp(0.010(T-T_l)) \]
3. \[ Q = 3000.0 \exp(0.005(T-T_l)) \]

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 \( \beta_h \), in product units per sec per kw of fire energy generation rate.

Product generation rate = \( \beta_h \times \text{energy generation rate} \).

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

<table>
<thead>
<tr>
<th>Run title</th>
<th>BATCH DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write code</td>
<td>MULTI-EXPONENTIAL FIRE GROWTH</td>
</tr>
<tr>
<td>( \lambda_r, \lambda_c, \text{eyelevel, fire height} )</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>.35, .75, 3., 2.0</td>
</tr>
</tbody>
</table>

2. Detection Criteria

   | Layer temperature   | 135.0               |
   | Rate of temperature rise | 0.0 |
   |                      | 15.0                |
   | 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
   Area 5000.0

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
   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\(^\circ\)F (179.7\(^\circ\)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 untenantly 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\(^\circ\)F (57.2\(^\circ\)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\(^\circ\)F/min (8.33\(^\circ\)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:

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Energy Release Rate (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.</td>
</tr>
<tr>
<td>70</td>
<td>36.</td>
</tr>
<tr>
<td>140</td>
<td>1.</td>
</tr>
<tr>
<td>210</td>
<td>27.</td>
</tr>
<tr>
<td>290</td>
<td>200.</td>
</tr>
<tr>
<td>390</td>
<td>1200.</td>
</tr>
<tr>
<td>525</td>
<td>290.</td>
</tr>
<tr>
<td>650</td>
<td>106.</td>
</tr>
<tr>
<td>775</td>
<td>55.</td>
</tr>
<tr>
<td>900</td>
<td>38.</td>
</tr>
</tbody>
</table>

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 occurring 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 $0.09 \, \text{g}_{\text{depleted}} \, \text{O}_2 \, \text{per g}_{\text{upper}}$ (corresponding to a total oxygen concentration of $0.23 - 0.09 = 0.14 \, \text{g}_{\text{O}_2} \, \text{per g}_{\text{upper}}$). 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 $0.12-0.14 \, \text{g}_{\text{O}_2} \, \text{per g}_{\text{upper}}$, 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  IV. FIRE DATA
II. HAZARD CRITERIA   V. PRODUCTS OF COMBUSTION DATA
III. ROOM SIZES
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
12.0000

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: @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

400.0

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: 500.0

500.0

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: 600.0

600.0

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: 800.0

800.0

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: 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
Q0 = .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)/Q0 (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
Write code
\lambda_r, \lambda_c, eyelevel, fire height
```

```
FLASHOVER POTENTIAL

1

.35, .70, 2., 2.
```

2. Detection Criteria

```
Layer temperature
Rate of temperature rise
Concentration
```

```
@EOF

0.0
@EOF

@EOF
```
3. **Hazard Criteria**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature when interface above eyeline</td>
<td>750.0</td>
</tr>
<tr>
<td>Temperature when interface below eyeline</td>
<td>750.0</td>
</tr>
<tr>
<td>Concentration</td>
<td>0.09</td>
</tr>
</tbody>
</table>

4. **Room Characteristics**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>12.0</td>
</tr>
<tr>
<td>Area</td>
<td>100.</td>
</tr>
<tr>
<td></td>
<td>120.</td>
</tr>
<tr>
<td></td>
<td>200.</td>
</tr>
<tr>
<td></td>
<td>250.</td>
</tr>
<tr>
<td></td>
<td>300.</td>
</tr>
<tr>
<td></td>
<td>400.</td>
</tr>
<tr>
<td></td>
<td>500.</td>
</tr>
<tr>
<td></td>
<td>600.</td>
</tr>
<tr>
<td></td>
<td>800.</td>
</tr>
<tr>
<td></td>
<td>1000.</td>
</tr>
<tr>
<td></td>
<td>1200.</td>
</tr>
<tr>
<td></td>
<td>2000.</td>
</tr>
<tr>
<td></td>
<td>3000.</td>
</tr>
<tr>
<td></td>
<td>4000.</td>
</tr>
<tr>
<td></td>
<td>5000.</td>
</tr>
</tbody>
</table>
5. Fire Data: Energy Generation Rate

<table>
<thead>
<tr>
<th>Fire type</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum time, heat of combustion</td>
<td>900., 1.0</td>
</tr>
<tr>
<td>Initial energy generation rate</td>
<td>2.0</td>
</tr>
<tr>
<td>Data points</td>
<td>70., 36.</td>
</tr>
<tr>
<td></td>
<td>140., 1.4</td>
</tr>
<tr>
<td></td>
<td>210., 27.</td>
</tr>
<tr>
<td></td>
<td>290., 200.</td>
</tr>
<tr>
<td></td>
<td>390., 1200.</td>
</tr>
<tr>
<td></td>
<td>525., 290.</td>
</tr>
<tr>
<td></td>
<td>650., 106.</td>
</tr>
<tr>
<td></td>
<td>775., 55.</td>
</tr>
<tr>
<td></td>
<td>900., 38.</td>
</tr>
</tbody>
</table>

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 ft² (186 m²) or in 12 ft (3.7 m) high rooms of area larger than 800 ft² (74 m²); 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 occurred.

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 inputting 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


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
\[ Q = Q_i \exp(K_{i+1}(t-t_i)) \]
for \( i \geq 1 \), and this routine finds all \( t_i \) from user-supplied \( Q_i \) 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 \( Q \).

FUNQ Subroutine

This subroutine calculates the energy generation rate at any given time. This routine is referenced by the SUBAIN 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 characteristics 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* CALCULATING AVAILABLE SAFE EGRESS TIME (ASET)
C*
C******************************************************************************

C* WRITTEN BY LEONARD Y. COOPER AND
C* DAVID W. STROUP
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* PROGRAM DOCUMENTATION:
C* NBSIR 82-2578
C* CALCULATING AVAILABLE SAFE EGRESS TIME (ASET) -
C* A COMPUTER PROGRAM AND USER'S GUIDE
C*
C******************************************************************************

C* REVISED SEPTEMBER 13, 1982
C*
C******************************************************************************

C* THIS IS EGRESSASET.MAIN. IT REQUIRES EGRESSASET.EXFIRE
C* AND EGRESSASET.SU3AINT
C*
C******************************************************************************

NOTATION

C AKAP(N) ENERGY GENERATION RATE EXPONENTIAL FACTOR IN THE NTH TIME
C SEGMENT. READ IN AND USED TO CHARACTERIZE THE MULTI-EXPONENTIAL
C 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
PRODUCT GENERATION RATE = BETAD * ENERGY GENERATION RATE

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MAIN PROGRAM

\[
\text{C OR} \\
\text{\quad (PRODUCT GENERATION RATE / PRD0) = (BETAD \times Q0/PRD0)} \\
\text{\quad \times (ENERGY GENERATION RATE / Q0)}
\]

\text{USED WHEN PROD0=1.}
\text{READ IN DIMENSIONS OF PRODUCT UNITS/(SEC*KW).}
\text{BETAD CONSTANT OF PROPORTIONALITY BETWEEN HAZARDOUS PRODUCT}
\text{GENERATION RATE AND ENERGY GENERATION RATE.}
\text{SPECIFICALLY DEFINED AS:}
\text{PRODUCT GENERATION RATE = BETAD \times ENERGY GENERATION RATE}
\text{OR}
\text{\quad (PRODUCT GENERATION RATE / PRHO) = (BETAD \times Q0/PRHO)} \\
\text{\quad \times (ENERGY GENERATION RATE / Q0)}
\text{USED WHEN PRODH=1.}
\text{READ IN DIMENSIONS OF PRODUCT UNITS/(SEC*KW).}
\text{C1 DIMENSIONLESS GROUP.}
\text{C2 DIMENSIONLESS GROUP.}
\text{C3D DIMENSIONLESS GROUP.}
\text{C3H DIMENSIONLESS GROUP.}
\text{CNDSP DIMENSIONLESS SPECIFIED DETECTABLE PRODUCT CONCENTRATION}
\text{CORRESPONDING TO CNDS(I).}
\text{CNHAZS SPECIFIED HAZARDOUS PRODUCT CONCENTRATION CORRESPONDING TO}
\text{A PARTICULAR CNHS(L). IN UNITS OF AMOUNT OF PRODUCT PER UNIT}
\text{MASS OF BULK GAS.}
\text{CNDS(I) SPECIFIED DETECTABLE PRODUCT CONCENTRATION. UNITS OF AMOUNT}
\text{OF PRODUCT PER UNIT MASS OF BULK GAS.}
\text{CNHS(L) SPECIFIED HAZARDOUS PRODUCT CONCENTRATION. UNITS OF AMOUNT}
\text{OF PRODUCT PER UNIT MASS OF BULK GAS.}
\text{DELTA THE HEIGHT OF THE FIRE ABOVE THE FLOOR IN FEET.}
\text{DELTAH THE HEIGHT OF THE FIRE ABOVE THE FLOOR IN METERS.}
\text{DPHI DPHI/DTAU GENERATED IN SUBF DURING COURSE OF INTEGRATION.}
\text{DPHIDS DIMENSIONLESS RATE OF TEMP RISE CORRESPONDING TO RRDSPF(I).}
\text{DPRD0 DPRD/DTAU AT TIME TAU=0. (DETECTABLE PRODUCT)}
\text{DPRHD0 DPRH/DTAU AT TIME TAU=0. (HAZARDOUS PRODUCT)}
\text{DQDAT0 DQ/DTAU AT TIME TAU=0.}
\text{FIRE INDICATES THE REPRESENTATIVE FORM OF ENERGY GENERATION RATE FOR}
\text{THE PARTICULAR COMPUTER RUN; WHEN FIRE=1, MULTI-EXPONENTIAL}
\text{FIRE GROWTH CURVE. WHEN FIRE=2, DIGITAL DATA INPUT. WHEN}
\text{FIRE=3, SOME OTHER ANALYTIC FIRE GROWTH FUNCTION (NONE}
\text{PRESENTLY INCORPORATED INTO THE PROGRAM).}
\text{FLAG INDICATOR OF WHICH DETECTION METHOD IS UNDER CONSIDERATION.}
\text{WHEN FLAG=1, DETECTION BY POC CONCENTRATION.}
\text{WHEN FLAG=2, DETECTION BY UPPER LAYER TEMPERATURE.}
\text{WHEN FLAG=3, DETECTION BY RATE OF TEMPERATURE RISE.}
\text{THE VALUE OF FLAG IS ASSIGNED BY THE PROGRAM. THE VALUE,}
\text{1, 2, OR 3, IT RECEIVES IS DEPENDENT ON THE INPUT VALUES}
\text{OF NCND, NTMD, AND NRRD.}
\text{HCOMB THE HEAT OF COMBUSTION (IN KJ/KG) USED TO CONVERT DIGITAL}
\text{DATA, QDATA(N), INPUT AS MASS LOSS RATES TO ENERGY RELEASE}
\text{RATES. IF QDATA(N) ARE INPUT DIRECTLY AS ENERGY RELEASE RATES}
\text{IN KW, THEN INPUT HCOMB=1.0.}
\text{HFI(I) COMPARTMENT CEILING HEIGHT IN FEET.}
\text{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 NCHN 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 NSEG1 THE NUMBER OF SEGMENTS MINUS 1. I.E., NSEGQ-1.
C NTMD THE NUMBER OF CASES FOR DETECTION BY TEMP OF THE LAYER.
C NTHU THE NUMBER OF SPECIFIED HAZARDOUS LAYER TEMPERATURES TO
C BE CONSIDERED WHEN INTERFACE IS ABOVE ZETEYE.
C NTHL THE NUMBER OF SPECIFIED HAZARDOUS LAYER TEMPERATURES TO
C BE CONSIDERED WHEN INTERFACE IS BELOW ZETEYE.
C PHIDSP DIMENSIONLESS DETECTION TEMPERATURE CORRESPONDING TO TMSPF(I).
C PHIHSD DIMENSIONLESS HAZARDOUS TEMPERATURE CORRESPONDING TO
C THSPF(I).
C PHIHSL DIMENSIONLESS HAZARDOUS TEMPERATURE CORRESPONDING TO
MAIN PROGRAM

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,.....,NSEGP0. (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 PRHO. HERE N=1,.....,NSEGPH. (HAZARDOUS PRODUCT)
C PRODD INDICATES THE REPRESENTATIVE 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, BETA0. 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 REPRESENTATIVE 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-
CIZED FORM AS ENERGY GENERATION RATES IN KW AT THE END
C OF SEGMENT N DIVIDED BY Q0. HERE N=1,.....,NSEGQ-1.
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 TAU0LIM MAXIMUM TAU FOR WHICH FIRE IS MODELED OR TAU WHEN FIRE IS OJT.
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.
MAIN PROGRAM

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 TMDSFC(I) SPECIFIED LAYER TEMPERATURE FOR DETECTION IN DEGREES C.
C TMDSF(I) SPECIFIED LAYER TEMPERATURE FOR DETECTION IN DEGREES F.
C TMHSLF(I) SPECIFIED HAZARDOUS LAYER TEMPERATURE WHEN INTERFACE IS
C ABOVE ZETEYE IN DEGREES C.
C TMHSLF(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 ZEFYF THE INPUT SPECIFIED HEIGHT (IN FEET) OF EYELEVEL FROM THE FLOOR
C FOR HAZARD.
C ZETEYM 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), TMDSFC(10), TMDSF(10), CNHS(10), HF(20), HM(20),
2    SF(30), SM(30), TMHSLF(10), TMHSLC(10), TMHSLF(10),
3    TMHSLC(10), RRDSF(10), RRDSPC(10)
COMMON NSEQQ, NSEGP, NSEPH, TAUQ(I00), TAUPRH(100), TAUPRH(100),
2    Q(100), PRD(100), PRH(100), AKAP(100), C1, C2, C3D, C3H, ZETO, FIRE,
3    PRODD, PRODH, LIMIT, DPH, TAULIM, LINTER, DELTA, DQDT, DPRDT0,
4    DPRHT0, Q0, LNORM
LOGICAL LINTER, LNORMAL
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)
IF (LINTER) WRITE (6, 2400)
IF (LINTER) WRITE (6, 1880)
READ (5, 1520) TITLE
MAIN PROGRAM

IF (.NOT. (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 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 (6,2030)
READ (5,*,ERR=130,END=140) RRDSF(I)
IF (LINTER) WRITE (6,2410)
WRITE (6,*) RRDSF(I)
IF (RRDSF(I).GT.-0.0001).AND.(RRDSF(I).LT.0.0001))
2  WRITE (6,2020)
IEND=0
IF (LINTER) CALL INPUT (RRDSF(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
150 IF (LINTER) WRITE (6,2400)
160 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
NRDHU=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
MAIN PROGRAM

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

I = 1
NTMHL = 0
IF (LINTER) WRITE (6, 2400)
210 I = 1
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

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 = NCMH + 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

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)
MAIN PROGRAM

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
   CONTINUE
300 CONTINUE
310 CONTINUE
   DO 320 IM=1,NH
   HM(IM)=HF(IM)*0.3048
   I=1
   NS=0
   IF (LINTER) WRITE (6,2400)
   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
330 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
   CONTINUE
360 CONTINUE
370 CONTINUE
   DO 380 IM=1,NS
   SM(IM)=SF(IM)*0.0929
C C THIS SECTION INPUTS DATA FOR FIRE ENERGY GENERATION RATE. C
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)
QO=Q(1)
NSEG1=NSEGQ-1
DO 480 N=1,NSEG1
Q(N)=Q(N+1)/QO
480 CONTINUE
DQDTO=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 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
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)
MAIN PROGRAM

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) PRDO
IF (LINTER) WRITE (6,2410)
WRITE (6,*) PRDO
IF (LINTER) CALL INPUT (PRDO,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

89
MAIN PROGRAM

C DETECTABLE PRODUCT GENERATION RATE GIVEN BY ANALYTIC FUNCTION
C
750 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 (PRDH.EQ.1) WRITE (6,2290)
   IF (PRDH.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)
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 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, TAUG(N), N, Q(N)
     CONTINUE
IF (Q0 > 0.0) GO TO 910
DO 900 N = 1, NSEGQ
     IF (Q(N) > 0.0) Q0 = Q(N)/100.0
     IF (Q0 > 0.0) GO TO 910
     Q0 = Q0*HCOMB
     DO 950 N = 1, NSEGQ
         WRITE (6, 1710) N, TAUPRD(N), N, PRD(N)
     CONTINUE
     IF (PRDO > 0.0) GO TO 970

910 Q0 = Q0*HCOMB
DO 920 N = 1, NSEGQ
     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.0.0) 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)
850 CONTINUE
IF (PRDO > 0.0) GO TO 970
MAIN PROGRAM

DO 960 N=1,NSEGPD
   IF (PRD(N).GT.0.0) PRD0=PRD(N)/100.0
   IF (PRD0.GT.0.0) GO TO 970
960    CONTINUE
970   DO 980 N=1,NSEGPD
980    PRD(N)=PRD(N)/PRD0
   DPROTO=(PRD(N)-1.0)/TAUPRD(1)
990   IF (LINTER) WRITE (6,2390)
   IF (LINTER) READ (5,1530) CHARTR
   IF (PRDHD.EQ.2) GO TO 1000
   WRITE (6,1630) BETAH
   PRD0=EETAH*00
   DPROHT=DDQTO
   GO TO 1230
1000  WRITE (6,1680) PRH0
   DO 1010 N=1,NSEGPH
      WRITE (6,1720) N,TAUPRH(N),N,PRH(N)
      CONTINUE
1010   IF (PRH0.GT.0.0) GO TO 1030
   DO 1020 N=1,NSEGPH
      IF (PRH(N).GT.0.0) PRH0=PRH(N)/100.0
      IF (PRH0.GT.0.0) GO TO 1030
   CONTINUE
1020  DO 1040 N=1,NSEGPH
1040    PRH(N)=PRH(N)/PRH0
   DQHTO=(PRH(1)-1.0)/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,HCMB
   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)
      CONTINUE
1070   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
   CONTINUE
1080  Q0=Q0*HCMB
   DO 1100 N=1,NSEGQ
1100    Q(N)=Q(N)*HCMB/Q0
   DQDTO=(Q(N)-1.0)/TAUQ(1)
1110   IF (LINTER) WRITE (6,2390)
   IF (LINTER) READ (5,1530) CHARTR
   WRITE (6,1750) ALAMR,ALAMC,DELTAD,DELTAM
   IF (NCND.EQ.0) PRD0=0.0
   IF (NCND.EQ.0) DPROTO=0.0
   IF (NCND.EQ.0) GO TO 1170
   IF (PRDHD.EQ.2) GO TO 1120
   WRITE (6,1640) BETAD
   PRD0=EETAD*Q0
DPRDT0=DQDT0
GO TO 1170
1120 WRITE (6,1690) PRD0
DO 1130 N=1,NSEGPD
   WRITE (6,1710) N,TAUPRD(N),N,PRD(N)
1130 CONTINUE
   IF (PRD0.GT.0.0) GO TO 1150
   DO 1140 N=1,NSEGPD
      IF (PRD(N).GT.0.0) PRD0=PRD(N)/100.0
      IF (PRD0.GT.0.0) GO TO 1150
   CONTINUE
1150 DO 1160 N=1,NSEGPD
   PRD(N)=PRD(N)/PRD0
   DPRDT0=(PRD(1)-1.)/TAUPRD(1)
1170 IF (LINTER) WRITE (6,2390)
   IF (LINTER) READ (5,1530) CHARTR
   IF (PRDH.EQ.2) GO TO 1180
   WRITE (6,1650) BETAH
   PRHO=BETAH*Q0
   DPRHT0=DQDT0
   GO TO 1230
1180 WRITE (6,1700) PRHO
   DO 1190 N=1,NSEGPH
      WRITE (6,1720) N,TAUPRH(N),N,PRH(N)
   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
   CONTINUE
1210 DO 1220 N=1,NSEGPH
   PRH(N)=PRH(N)/PRHO
   DPRHT0=(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
C   DO 1480 J=1,NTMHU
C
C GO THROUGH NTMLH VALUES OF MINIMUM TEMPERATURES WHICH MAKE UPPER
MAIN PROGRAM

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 GC 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
1270 WRITE (6,1560) TITLE
WRITE (6,1760) CNDS(I),ZEYEF,ZEYEM,TMHSUF(J),
2 TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),TMHSLC(N),
3 CNHS(L)
GO TO 1340
1280 WRITE (6,1560) TITLE
WRITE (6,1780) TMDSPF(I),TMDSFC(I),ZEYEF,ZEYEM
2 +TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
3 TMHSLC(N),CNHS(L)
GO TO 1340
1290 WRITE (6,1560) TITLE
WRITE (6,1800) RRDSPF(I),RRDSFC(I),ZEYEF,ZEYEM
2 +TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
3 TMHSLC(N),CNHS(L)
GO TO 1340
1300 GO TO (1310,1320,1330), FLAG
1310 WRITE (6,1570) TITLE
WRITE (6,1770) CNDS(I),ZEYEF,ZEYEM,TMHSUF(J),
2 TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),TMHSLC(N),
3 CNHS(L)
GO TO 1340
1320 WRITE (6,1570) TITLE
WRITE (6,1790) TMDSPF(I),TMDSFC(I),ZEYEF,ZEYEM
2 +TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
3 TMHSLC(N),CNHS(L)
GO TO 1340
1330 WRITE (6,1570) TITLE
WRITE (6,1810) RRDSPF(I),RRDSFC(I),ZEYEF,ZEYEM
2 +TMHSUF(J),TMHSUC(J),ZEYEF,ZEYEM,TMHSLF(N),
3 TMHSLC(N),CNHS(L)
C
C GO THROUGH NH VALUES OF COMPARTMENT HEIGHTS.
C
1340 IF (LINTER) WRITE (6,2390)
IF (LINTER) READ (5,1530) CHARTR
DO 1450 K=1,NH
IF (((WRC.EQ.1).OR.(WRC.EQ.3))
2 WRITE (6,1820) HF(K),HM(K)
IF ((LINTER).AND.(WRC.EQ.1))
2 WRITE (6,2390)
IF ((LINTER).AND.(WRC.EQ.1))
2 READ (5,1530) CHARTR
IF (WRC.EQ.1) WRITE (6,1560) TITLE
IF (((WRC.EQ.1).AND.(LNORM))
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MAIN PROGRAM

2 WRITE (6,1840)
IF ((WRC.EQ.1),AND.(.NOT.(LNORM)))
WRITE (5,1850)

C SET DIMENSIONLESS INITIAL VALUES AND HAZARD CRITERIA PARAMETERS
C FOR FILLING PROBLEM.

1350 GO TO (1350, 1360, 1370), FLAG
CNDSP=CNDS(I)
GO TO 1380

1360 PHIDSP=(TMDSPF(I)+460.)/530.
GO TO 1380

1370 DPHIDS=(RRDSPF(I)/31800.0)
1380 ZETEYE=ZEYE
ZETO=HF(K)-DELTA
PHIHSL=(TMHSLF(J)+460.)/530.
PHIHSL=(TMHSLF(N)+460.)/530.
CNHAZS=CNHS(L)
IDETH=1
IDETT=1
IDETR=1
LIMIT=0

C GO THROUGH ALL INPUT COMPARTMENT AREAS.
C

DO 1440 M=1,NS
IF ((WRC.EQ.2),OR.(WRC.EQ.4))
WRITE (6,1820) HF(K),HM(K)
IF ((WRC.EQ.2),OR.(WRC.EQ.3),OR.
(WRC.EQ.4))
WRITE (6,1830) SF(M),SM(M)
IF (.NOT.(LINTER)) OR (WRC.EQ.1))
GO TO 1390

WRITE (6,2390)
READ (5,1530) CHARTR
1390 C1=(1.-ALAMC)*0.1070*Q0/SF(M)
C2=0.210*((32./(0.0735*.24*530.*1.054
))**((1./3.))
*(((1.-ALAMR)*QO)
**((1./3.))/SF(M)
C3D=0.02943*PRD0/SF(M)
C3H=0.02943*PRH0/SF(M)
GO TO (1400,1410,1420), FLAG
IDETH=0
GO TO 1430
1410 IDETT=0
GO TO 1430
1420 IDETR=0
1430 ASF=SF(M)
ASMD=SM(M)
AHF=HF(K)

C CALL SUBROUTINE AINT TO
C INTEGRATE EON. 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,IDEiT,IDETR,PHIHSL,
MAIN PROGRAM

2 PHIHS, CNHAZ, PHIDSP
3 CNDSP, ZETYE, DPHIDS, ASF
4 ASM, AHF, WRC, TITLE)

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

1440 IF (LIMIT.EQ.1) GO TO 1450
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)
1540 FORMAT(5X, 'LAMDA R = ', F5.3/5X, 'LAMDA C = ', F5.3/5X,
       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/*. 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/*. THE FOLLOWING DATA CHAR
3ACTERIZE THE HISTORY OF THE FIRE: */5X,
4 5X, 'Q(TIME=0.0) = Q0 = ', F8.2, ' KW */'
5 5X, 'HCOMB = ', E12.4/)
1620 FORMAT(' THE DETECTABLE PRODUCT OF COMBUSTION GENERATION RATE IS P
2ROPORATIONAL TO ENERGY GENERATION RATE ACCORDING TO: */20X, 'RATE OF
3 PRODUCT GENERATION = (' E12.4, ' UNITS PER SECOND PER KW)*RATE OF E
4NERGY GENERATION')
1630 FORMAT(' THE HAZARDOUS PRODUCT OF COMBUSTION GENERATION RATE IS PR
2OPORATIONAL TO ENERGY GENERATION RATE ACCORDING TO: */20X, 'RATE OF
3 PRODUCT GENERATION = (' E12.4, ' UNITS PER SECOND PER KW)*RATE OF EN
4ERGY GENERATION')
1640 FORMAT(' THE DETECTABLE PRODUCT OF COMBUSTION GENERATION RATE IS P
2ROPORATIONAL TO */ ENERGY GENERATION RATE ACCORDING TO: */ RATE OF P
3 PRODUCT GENERATION = (' E12.4, ' UNITS/SEC/KW)*ENERGY GENERATION RATE
4E')
1650 FORMAT(' THE HAZARDOUS PRODUCT OF COMBUSTION GENERATION RATE IS PR
2OPORATIONAL TO */ ENERGY GENERATION RATE ACCORDING TO: */ RATE OF P
3 PRODUCT GENERATION = (' E12.4, ' UNITS/SEC/KW)*ENERGY GENERATION RATE
MAIN PROGRAM

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1660 FORMAT (1HO,
'ADD AN ANALYTIC PRODUCT GENERATION')

1670 FORMAT (1HO,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 (1HO,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(','13,') = ',F6.0,5X,'PRD(','13,') = ',E12.4)

1720 FORMAT(1H,'TAUPRH(','13,') = ',F6.0,5X,'PRH(','13,') = ',E12.4)

1730 FORMAT (1H, 'TAUQ('','13,') = ',F6.0,5X,'Q('','13,') = ',E12.4)

1740 FORMAT (1HO,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 ',F5.3/5X,'51HO,'THE FIRE IS LOCATION ',F7.3,' FEET ('',F7.3,' METERS) ABOVE TH'
6 6E FLOOR."

1750 FORMAT(1HO,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 = ',F5.3
4/1HO,'THE FIRE IS LOCATION ',F7.3,' FEET ('',F7.3,' METERS) ABOVE T'
35HE FLOOR."

1760 FORMAT(1HO,'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'
50M FLOOR THEN ',/'2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM'
6PERATURE EXCEEDS ',F6.1,' DEG F ('',F6.1,' DEG C')/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,' IF UPPER LAYER PRODUCT CONCEN'
TRATION EXCEEDS',E10.4,' UNITS OF MASS PER UNIT MASS OF BULK UPPER'
1 LAYER GAS."

1770 FORMAT(1HO,'FIRE DETECTED WHEN DETECTABLE UPPER LAYER PRODUCT CON'
2CENTRATION EXCEEDS'/5X,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'
50M FLOOR THEN ',/'2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM'
6PERATURE EXCEEDS ',F6.1,' DEG F ('',F6.1,' DEG C')/2X,' IF LAYER INT'
7ERFACE IS AT OR BELOW ',F6.2,' FT ('',F6.2,' M) FROM FLOOR THEN ',/'2
8HEN ',/'2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEMPERATURE E'
9XCEEDS ',F6.1,' DEG F ('',F6.1,' DEG C')/2X,' IF UPPER LAYER '
PRODUCT CONCENTRATION EXCEEDS'/10X,E9.4,' UNITS OF MASS PER UNIT M'
1ASS OF BULK UPPER LAYER GAS."

1780 FORMAT (1HO,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'
40M FLOOR THEN ',/'2X,' HAZARDOUS CONDITIONS EXIST IF UPPER LAYER TEM'
5PERATURE EXCEEDS ',F6.1,' DEG F ('',F6.1,' DEG C')/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,' IF UPPER LAYER PRODUCT CONCEN'
9TRATION EXCEEDS',E9.4,' UNITS OF MASS PER UNIT MASS OF BULK UPPER'
*LAYER GAS."

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MAIN PROGRAM

1790 FORMAT (IH0+1X, 'FIRE DETECTED WHEN UPPER LAYER TEMPERATURE IS ', F6.2, ' DEG F', 'DEG C')/3


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) ')


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'
MAIN PROGRAM

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'
1910 FORMAT(' SUMMARY OUTPUT, 80 CHARACTERS PER LINE HAS BEEN SELECTED.
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 G,"/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
3JUSTION ZONE AND PLUME.,'6X,'***'/' *** LAMDA C - THE FRACTION OF
4 THE ENERGY GENERATION RATE LOST TO THE **' ***,'11X,'BOUND
5 SING SURFACES OF THE ROOM AND ITS CONTENTS.,'12X,'***'/'
6' *** EYELEVEL HEIGHT - THE SPECIFIED CHARACTERISTIC HEIGHT, IN F
7 EET, OF **'/' **' ***,'19X,'EYELEVEL FROM THE FLOOR."'27X,'***'/'
8' *** FIRE HEIGHT - THE HEIGHT, IN FEET, OF THE BASE OF THE FIRE
9 ABOVE **'/' ***,'15X,'THE FLOOR."'45X,'***'')
1970 FORMAT('>>ENTER THE REQUESTED VALUES.<<')
1980 FORMAT(' DATA WILL BE ENTERED IN THE FOLLOWING ORDER:/' IV. DETE
2 TION 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)
21/" TYPE AN END OF FILE (UNIVAC: ?EOF) TO MOVE TO DETECTION BY RA
3 TE 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
4 TRATION.')
2020 FORMAT('3X,'***INSTANTANEOUS DETECTION***')
2030 FORMAT(' ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,/*' IN P
2 RODUCT 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
2 RFACE ABOVE SPECIFIED EYELEVEL) (HAZARD)."/" TYPE AN END OF FILE
3(UNIVAC: ?EOF) TO MOVE TO HAZARD'/" BY LAYER TEMPERATURE, WHEN INT
4 RFACE BELOW EYELEVEL.')
2060 FORMAT(' ENTER A SMOKE LAYER TEMPERATURE, IN DEGREES F'/" (INTE
2 RFACE BELOW SPECIFIED EYELEVEL) (HAZARD)."/" TYPE AN END OF FILE
3(UNIVAC: ?EOF) TO MOVE TO HAZARD BY VOC CONCENTRATION.')
2070 FORMAT(' ENTER A CONCENTRATION OF A PRODUCT OF COMBUSTION,/*' IN P
2 RODUCT UNITS/GRAM OF BULK GAS (HAZARD).'/" TYPE AN END OF FILE (U
3 NIVAC: ?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
2 END OF FILE (UNIVAC: ?EOF) TO MOVE TO COMPARTMENT AREA INPUT.')
2100 FORMAT(' ENTER A COMPARTMENT FLOOR AREA, IN SQUARE FEET.'/" TYPE
2 AN 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
2 RATE./*4X,
3'TYPE 1 FOR AN EXPONENTIAL FIRE GROWTH CURVE.')/
MAIN PROGRAM

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 MODELED."
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."' 6' ENTER THEM ONCE AT A TIME."' 7' WHEN ALL HAVE BEEN ENTERED, TYPE AN END OF FILE 8 (UNIVAC: @EOF)."
2170 FORMAT(5X,'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,'Y.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 2ERGY 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 2ERGY GENERATION RATE,"/5X,"PRODUCT GENERATION RATE = BETAH * ENER 3GY GENERATION RATE."
2330 FORMAT(20X,'Y.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 HAVE 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 4E BEEN ENTERED, TYPE AN END OF FILE (UNIVAC: @EOF)."
2380 FORMAT(4X,"*** SINCE THERE WERE NO DETECTABLE CONCENTRATIONS SPECI 2IFIED. "*/4X,"*** DATA DESCRIBING THE GENERATION OF A DETECTABLE
MAIN PROGRAM

3 PRODUCT ***/4X,"*** OF COMBUSTION WILL NOT BE REQUIRED.'23X,
4"***")

2390 FORMAT('0 PRESS CARRIAGE RETURN TO CONTINUE.')
2400 FORMAT('0******************************************************************************')
2410 FORMAT('0----------------------------------------')
2420 FORMAT('0 ****> PROGRAM EXECUTION COMPLETED <****')
2430 FORMAT('0 *** THIS PROGRAM WILL CALCULATE THE AVAILABLE SAFE EGRES
25 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('0 ===> INCORRECT INPUT - TRY AGAIN ==<')
2450 FORMAT('0 ===> INPUT ERROR - RUN TERMINATED ==<')
C
END
**SUBROUTINE EXFIRE**

*THIS IS FGRESS*ASET. EXFIRE*

******************************************************************

**COMMON NSEGQ, NSEGPD, NSEGPH, TAUQ(100), TAUPRD(100), TAUPRH(100),
Q(100), PRD(100), PRH(100), AKAP(100), C1, C2, C3D, C3H, ZET0, FIRE,
PRODD, PRODH, LIMIT, DPHI, Taulim, LINTER, DELTA, DQTO, DPRDT0,
LOGICAL LINTER, LNORM

*IF (.NOT. (LNORM)) GO TO 50

*THIS SECTION CALCULATES TAUQ(N) FOR NORMALIZED FIRE DATA.

IF (NSEGQ .GT. 1) GO TO 10
WRITE (6, 100) AKAP(1)
RETURN

10 NSEG1 = 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, NSEG1
   TAUQ(N) = ALOG(Q(N)/Q(N-1))/AKAP(N) + TAUQ(N-1)
30 CONTINUE
WRITE (6, 110) AKAP(1), TAUQ(1), Q(1)
NSEG2 = NSEGQ - 2
DO 40 N = 1, NSEG2
   WRITE (6, 130) Q(N), AKAP(N+1), TAUQ(N), TAUQ(N), TAUQ(N+1), Q(N), Q(N+1)
40 CONTINUE
WRITE (6, 120) Q(NSEG1), AKAP(NSEGQ), TAUQ(NSEGQ), TAUQ(NSEG1), Q(NSEG1), Q(NSEG1)
RETURN

*THIS SECTION CALCULATES TAUQ(N) FOR UN-NORMALIZED FIRE DATA.

50 IF (NSEGQ .GT. 1) GO TO 60
WRITE (6, 140) Q0, AKAP(1)
RETURN

60 NSEG1 = NSEGQ - 1
TAUQ(1) = ALOG(Q(1))/AKAP(1)
IF (NSEGQ .GT. 2) GO TO 70
Q1 = Q(1)*Q0
WRITE (6, 150) Q0, AKAP(1), TAUQ(1), Q0, Q1
WRITE (6, 160) Q1, AKAP(2), TAUQ(1), TAUQ(1), Q1

102
SUBROUTINE EXFIRE

RETURN

70   DO 80 N=2,NSEG1
       TAUQ(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
NSEG2=NSEGQ-2
DO 90 N=1,NSEG2
       WQN=Q(N)
   90   DO 100 NSEGM1
       WQN1=Q(N+1)*Q0
       WRITE (6,170) WQN,AKAP(N+1),TAUQ(N),TAUQ(N),TAUQ(N+1),WQN,WQN
   100  CONTINUE

WQL=Q(NSEG1)
WRITE (6,160) WQL,AKAP(NSEGQ),TAUQ(NSEG1),TAUQ(NSEG1),WQL
RETURN

C

C

100  FORMAT (1H0.5X.'Q/Q0 = EXP(.'F5.4.' * TIME/SEC) IF 0.0 < TIME/SEC)
110  FORMAT(1H0.5X.'Q/Q0 = '9X.'EXP(.'F5.4.' * (TIME/SEC))' IF 0.0 < TIME/SEC < 'F6.1.'
120  FORMAT(1H0.5X.'Q/Q0 = 'F6.0.' * EXP(.'F5.4.' * (TIME/SEC - 'F6.1
130  FORMAT(1H0.5X.'Q/Q0 = 'F6.1.' < TIME/SEC < 'F6.1.'
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 < TIME
160  FORMAT(1H0.5X.'Q = 'F6.0.' < EXP(.'F5.4.' * (TIME - 'F6.1.'
170  FORMAT(1H0.5X.'Q = 'F6.0.' < EXP(.'F5.4.' * (TIME - 'F6.1.'

C

END
SUBROUTINE FUNQ

C THIS IS EGRESS*ASET*FUNQ
C
C************************************************************************************************************************
C THIS IS FUNQ. IT COMPUTES:
C
C QDQO(T) = ENERGY GENERATION RATE AT TIME TAU=T / QO
C************************************************************************************************************************
C
FUNCTION QDQO (T)
C
C************************************************************************************************************************
C
INTEGER FIRE
COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FI,
PROD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDTO,DPRDTO,
DPRHTO,QO,LDNORM
LOGICAL LINTER,LDNORM
GO TO (10,60,90), FIRE
C
C THE FOLLOWING SEGMENT OF FUNQ IS USED TO COMPUTE QDQO(T) FOR A
C MULTI-EXPONENTIAL FIRE GROWTH CURVE.
C
10 IF (T.EQ.0.) QDQO=1.
IF (T.EQ.0.) RETURN
IF (NSEGQ.EQ.1) GO TO 20
IF (T.GE.TAUQ(1)) GO TO 30
20 QDQO=EXP(AKAP(1)*T)
RETURN
30 IF (NSEGQ.EQ.2) GO TO 50
NSEG2=NSEGQ-2
DO 40 N=1,NSEGQ2
   IF (T.GE.TAUQ(N+1)) GO TO 40
   QDQO=Q(N)*EXP(AKAP(N+1)*(T-TAUQ(N)))/TAUQ(N)
RETURN
40 CONTINUE
50 QDQO=Q(NSEGQ-1)*EXP(AKAP(NSEGQ)*T-TAUQ(NSEGQ-1))
RETURN
C
C THE FOLLOWING SEGMENT OF FUNQ IS USED TO COMPUTE QDQO(T) FOR DIGITAL
C DATA AND LINEAR INTERPOLATION.
C
60 IF (T.EQ.0.) QDQO=1.
IF (T.EQ.0.) RETURN
IF (T.GT.TAUQ(1)) GO TO 70
QDQO=Q(1)-((Q(1)-Q(N))/TAUQ(1))*TAUQ(N)-T)
RETURN
70 DO 80 N=1,NSEGQ
   IF (T.GT.TAUQ(N)) GO TO 80
   QDQO=Q(N)-((Q(N)-Q(N-1))/TAUQ(N)-TAUQ(N-1))
RETURN
80 CONTINUE
50 RETURN
END
SUBROUTINE FUNPRD

C THIS IS FGRESS*ASET.FUNPRD
C*****************************************************************
C THIS IS FUNPRD. IT COMPUTES
C PRDPRO(T) = PRODUCT GENERATION RATE AT TIME TAU=T /PRD0
C*****************************************************************
C FUNCTION PRDPRO (T)
C*****************************************************************
C INTEGER PRODD
COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
  1 Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
  2 PRODD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDTO,DPRDTO,
  3 DPRHTO,GO,0,LNORM
EXTERNAL QDQO
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=QDQO(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

105
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,NSEGPD,NSEGPH,TAUQ(100),TAURD(100),TAUPRH(100),
Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
PROD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDTO,DPDPTO,
DEPHTO,Q0,LMORM
EXTERNAL QDQO
LOGICAL LINTER,LMORM
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
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)))*(T
2   AUPRH(N)-T)
40   CONTINUE
50 RETURN
END
SUBROUTINE SUBAINT

C THIS IS EGRESS*ASET.SUBAINT. IT REQUIREs EGRESS*ASET.SUBF AND INTEGRATION.
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 NOTATION
C
C******************************************************************************
C AQDQ0  Q/GO 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 CNMAZD DETECTABLE PRODUCT CONCENTRATION AT TIME OF HAZARD.
C CNMAZH 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 CND00 INITIAL DETECTABLE PRODUCT CONCENTRATION OF UPPER LAYER.
C CND1
C CND2
C CNH0 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 INTEGRATION.
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 CONSIDERATION 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 PHISU DIMENSIONLESS SPECIFIED UPPER LAYER TEMPERATURE WHEN INTERFACE
SUBROUTINE SUBAINT

C IS ABOVE ZETEYE.
C PHIHS L DIMENSIONLESS SPECIFIED UPPER LAYER TEMPERATURE WHEN INTERFACE
C IS BELOW ZETEYE.
C PHITST A TEST VALUE FOR PHI.
C PHI0 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 PDETC RATE OF TEMP RISE OF UPPER LAYER AT TIME OF DETECTION IN
C DEGREES C PER MINUTE.
C PDETF 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 TAU TSC A TEST VALUE FOR TAU.
C TAU TSP A TEST VALUE FOR TAU.
C TAU TST A TEST VALUE FOR TAU.
C TIMDS TIME REQUIRED FOR DETECTION IN SECONDS.
C TIMHS TIME TO REACH HAZARD IN SECONDS.
C TM C 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 UOQDQ0 Q AT THE TIME OF DETECTION.
C UOHZDQ Q AT THE TIME OF HAZARD.
C ZETDET DIMENSIONLESS LAYER INTERFACE ELEVATION AT TIME OF DETECTION.
C ZETEYE DIMENSIONLESS ELEVATION OF EYEL EVEL.
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 SUBROUTINE AINT (IDETH, IDETT, IDETR, PHIHSU, PHIHS L, 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 NSEQ0, NSEPD, NSEGPH, TAUSQ(100), TAUPRD(100), TAUPRH(100),
2 G(100), PRD(100), PRH(100), AKAP(100), C1, C2, C3D, C3H, ZETO, FIRE,
SUBROUTINE SUBAINT

3      PRODD, PRODH, LIMIT, DPHI, TAUJM, LINTER, DELTA, DQDTO, DPRDTO,
        DPRHT0, QO, LNORM
EXTERNA F
EXTERNAL QDQO
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*(ZETO**((5./3.)))))
   DPHIO=(C1/C2)*(1./6.)*(2.*DQDTO-5.*(-C1-C2*(ZETO**((5./3.))))/(ZETO
   **(8./3.))
   CNDO=C3D/(C2*(ZETO**((5./3.))))
   CNHO=C3H/(C2*(ZETO**((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 (CNDO.LT.CNDSP) GO TO 40
   IDETH=1
10   ZETDET=HF
    TAUDET=0.
    CNDETD=CNDO
    CNDET=CNHO
    DPHID=DPHIO
    PHIDET=PHIO
    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 (PHIO.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 (DPHIO.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-
CATURE. DOES HAZARD OCCUR AT TIME=0.?
C
40   IF (PHIO.LT.PHIHSU) GO TO 50
    TAUHAZ=0.
    ZETHA=HF
    CNHAZD=CNDO
    CNHAZH=CNHO
    PHIHAZ=PHIO
    TAUDET=0.
    ZETDET=HF
    CNDETD=CNDO
    CNDET=CNHO
    DPHID=DPHIO
SUBROUTINE SUBAINT

PHIDET=PHI0
GO TO 230

C INITIALIZE VARIABLES FOR INTEGRATION.
C
50

Y(1)=ZETO
Y(2)=PHI0
Y(3)=CNO0
Y(4)=CN00
DPHI=DPHI0
TAU2=0.0
IF (((WRC.EQ.1).OR.(WRC.EQ.2)) GO TO 50
IF (WRC.EQ.3) WRITE (6,280) TITLE
IF (WRC.EQ.4) WRITE (6,290) TITLE
IF (((WRC.EQ.3).AND.(/NORM)) WRITE (6,360)
IF (((WRC.EQ.4).AND.(/NORM)) WRITE (6,380)
IF (((WRC.EQ.3).AND.(.NOT.(/NORM))) WRITE (6,370)
IF (((WRC.EQ.4).AND.(.NOT.(/NORM))) 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
AQDQQ=QDQQ(TAU2)
UAQDQQ=AQDQQ*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./NORM)) WRITE (6,400) ITAU2,AQDQQ,DZF,DZM,ZF,
2 ZM,TMF,TMC,RRF,RRC,CND,CNH
IF (((WRC.EQ.4).AND./NORM)) WRITE (6,410) ITAU2,TMF,RRF,DZF,ZF,
2 AQDQQ,CND,CNH,TMC,RRC,DZM,ZM
IF (((WRC.EQ.3).AND.(.NOT./NORM))) WRITE (6,420) ITAU2,UAQDQQ,DZF,
2 DZM,ZF,ZM,TMF,TMC,RRF,RRC,CND,
3 CNH
IF (((WRC.EQ.4).AND.(.NOT./NORM))) WRITE (6,440) ITAU2,TMF,RRF,DZF,
2 ZF,UAQDQQ,CND,CNH,TMC,RRC,
3 DZM,ZM

C INCREMENT TIME STEP AND CONTINUE.
C
60

TAU1=TAU2
TAU2=TAU2+5.
IF (((F7'1E.EQ.2).AND.(TAU2.GT.TAUQ(NSEGQ))).OR.
2((PROD.EQ.2).AND.(TAU2.GT.TAUPR(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
ZII=Y(1)
PHII=Y(2)
CND1=Y(3)
CNH1=Y(4)
DELTH=0.5
DPHI1=DPHI

C
SUBROUTINE SUBAINT

CALL INTGR TO PERFORM THE INTEGRATION FROM TAU1 TO TAU2.

CALL INTGR (F,TAU1,TAU2,DELT,4,Y,wb,IER)

IF (IER.LT.32) GO TO 70

C THERE IS AN ERROR IN THE INTEGRATION, WRITE ERROR MESSAGE AND
C RETURN TO MAIN.

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=GDQ(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,
                              ZM,TMF,TMC,RRF,RRC,CND,CNH
2
IF ((WRC.EQ.4).AND.(LNORM)) WRITE (6,410) ITAU2,TMF,RRF,DZF,ZF,
                              AQDQ0,CND,CNH,TMC,RRC,DZM,ZM
2
IF ((WRC.EQ.3).AND.(.NOT.(LNORM))) WRITE (6,400) ITAU2,AQDQ0,DZF,
                              DZM,ZF,ZM,TMF,TMC,RRC,DZM,ZM
3
IF ((WRC.EQ.4).AND.(.NOT.(LNORM))) WRITE (6,410) ITAU2,TMF,RRF,DZF,
                              ZF,UAQDQ0,CND,CNH,TMC,RRC,DZM,ZM
3

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 IDET=1), COMPUTE PARAME-
C TERs AT THE TIME OF DETECTION AND GO TO 120.

80
IF (IDETH.GT.0) GO TO 100
IF (CND2.LT.CNDSP) GO TO 120
TAUDET=TAU1+(TAU2-TAU1)*(CNDSP-CND1)/(CND2-CND1)

100

ZDET=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

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-DFH1)/(DPHI2-DFH1)
IDETR=1
GO TO 90

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 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 TAUHTST=TAU1+(TAU2-TAU1)*(ZETEYE-Z1)/(Z2-Z1)
PHITST=PHI1+(PHI2-PHI1)*(TAUHTST-TAU1)/(TAU2-TAU1)
IF (PHITST.GE.PHIHSU) GO TO 130

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 TAUHTST WHEN THE INTERFACE REACHES ZETEYE, AND COMPARE
C IT TO CNHAZS.
C

CNHTST=CNH1+(CNH2-CNH1)*(TAUHTST-TAU1)/(TAU2-TAU1)
IF ((CNHTST.LT.CNHAZS).AND.(PHITST.LT.PHIHSL)) GO TO 160
TAUHAZ=TAUHTST
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 COMPUTE TIME WHEN CN=CNHAZS. COMPUTE TIME WHEN PHI=PHIHSU. 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-CN1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
CNHAZH=CNH1+(CNH2-CNH1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
DPHIH=DPHI1+(DPHI2-DPH1)*(TAUHAZ-TAU1)/(TAU2-TAU1)
SUBROUTINE SUBAINT

C HAZARD DID OCCUR IN THE LAST TIME INTERVAL. DID DETECTION OCCUR IN THE
LAST OR ANY PREVIOUS TIME INTERVAL? IF NOT, THEN ASSUME DETECTION
EVENT TO OCCUR AT THE TIME OF THE ONSET OF HAZARD, AND APPROPRIATELY
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 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)
UGDTDQ=UGDTDG*Q0
UQHZDQ=UQHZDG*Q0
ZDET=ZETDET
ZDEMT=ZDET*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 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
SUBROUTINE SUBAIN

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,DZDET,M,ZDETM,RRDETC
IF (.NOT.(LNORM)) WRITE (6,320) ITIMDS,TMDETF,DZDETF,ZDETF,RRDETF,
2 UQDTDQ,CNDETD,CNDETH,TMDETC,DZDET,M,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 UQHHAZD,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,15.3(3X,F7.2),3X,F9.2,3X,E9.4,3X,15.2(3X,F7.
22),3X,F8.2,3X,E9.4,3X,15/1X,'(',*F8.2')','9X,'(',*F7.2')','1X,'(',*F7.
32')','(',*F7.2')','32X,'(',*F7.2')')
320 FORMAT(1H0,15.4(2X,F7.2),2X,F8.2,2(2X,E10.5)/7X,'(',*F7.2')','F7.2
2')','(',*F7.2')')
330 FORMAT (34H PROBLEM IN INTEGRATION IER GT 32/)
340 FORMAT (1H0,3X,'--THE TIME TAU Lim HAS BEEN EXC
2NEEDED.
/') 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
2NEEDED. 
/') CONTINUE WITH THE NEXT COMPARTMENT HEIGHT OR SPECIFIED '3/5X,'DETECTION CRITERIA.---')
360 FORMAT(1'0,1X,'TIME',8X,'Q/QO',7X,'LAYER THICKNESS INTERFACE EL
2EVA TION 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
2EVA TION LAYER TEMPERATURE',7X,'RATE OF RISE',10X,'CONCENTRATION'
3/(SECS)',8X,'KW',5X,'(FT)',6X,'(M)',8X,'(FT)',6X,'(M)',8X,'(F)',6
4X,'(C)',9X,'(F/MIN) (C/MIN) DETECTABLE HAZARDOUS'/1H ,111X,'P
50C',8X,'POC')
380 FORMAT(1H0,17X,'RATE OF LAYER LAYER',13X,'DETECTABLE HAZARDOUS
2S'/2X,'TIME TEMP. RISE THICKNESS ELEVAT. Q/QO',7X,'POC')
SUBROUTINE

3,8X,'POC'/56X,'CONCEN.',CONCEN.+2X,'SEC DEG F DEGF/M
4FT',7X,'FT'/9X,'(DEGC/M) (M) (M))
300 FORMAT(1H0,17X,'RATE OF LAYER LAYER',13X,'DETECTABLE HAZARDOUS
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,'(DEGC/M) (M) (M))
400 FORMAT(1H0,15,5X,'F8.2,4(5X,F7.2,2X,F7.2),5X,E9.4+2X,E9.4)
410 FORMAT(1H0,1X,15,4(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'
2.1X,'HAZARDOUS'/4X,'AREA TIME TEMP. THICKNESS RISE',
36X,'Q/Q0 CONCEN. TIME TEMP. ELEVATION Q'.5X,'5X,4
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 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/73X,'(M**2),12X,'(DEGC/M) (M) (DEGC/M)',33X,'(DEGC)
* (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,'5X,4
4CONCEN. AVAILABLE'/14X,'AT',7X,'AT',8X,'AT',9X,'AT',8X,'AT',9X,'A
5T',8X,'AT',7X,'AT',8X,'AT',9X,'AT',6X,'EGRESS'/10X,'DETECT
6ION 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,'S
9FT',10X,'KW',18X,'SEC/3X,'(M**2),12X,'(DEGC/M) (M) (DEGC/*
*M)',33X,'(DEGC) (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,'4
4CONCEN. CONCEN.+8X,'(DEGC/M) (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,'(DEGC/M) (M) (DEGC/M)
5')
460 FORMAT('OPRESS CARRIAGE RETURN TO CONTINUE.**
470 FORMAT('****DETECTION CHARACTERISTICS****)
480 FORMAT('****HAZARD CHARACTERISTICS****)
490 FORMAT('****SAFE AVAILABLE EGRESS TIME = ',15,' SECONDS****)
C END
SUBROUTINE INTGR

C THIS IS EGRESS*ASET.INTGR. ITRequires 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
******************************************************************************
DIMENSION WK(1),X0(1)
INTEGER ZXR,LH,LJ
LOGICAL LD,LH,LJ
DATA E5,.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 TO 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))
SUBROUTINE INTGR

100  GO TO 130
    T=3.*0
    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
        IWKO=N+J
        X0(J)=WK(IWK0)
150  CONTINUE
160  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
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(XO,T,XP)
C
******************************************************************************
COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRO(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,DPRDT0,
4 DPRHTO,Q0,LNORM
DIMENSION XO(4),XP(4)
EXTERNAL QDQ0
EXTERNAL PRODPRO
EXTERNAL PRHPRO
LOGICAL LINTER,LNORM
IF (T.GT.O.O) GO TO 10
XP(1)=-C1-C2*(ZETO**(5./3.))
XP(2)=(C1/C2)**(1./6.)*(2.*DQDTO-5.*XP(1))/(ZETO**(8./3.))
XP(3)=((5.*C1*C3D)/(6.*C2*(ZETO**(8./3.))))*(1.+C1/ZETO*DPRDT0)/C1
2.*C1-ZETO*DQDTO/(5.*C1)+C2*(ZETO*(5./3.))/C1
XP(4)=((E.*C1*C3H)/(6.*C2*(ZETO**(8./3.))))*(1.+C1/ZETO*DPRHT0)/C1
2.*C1-ZETO*DQDTO/(5.*C1)+C2*(ZETO**(5./3.))/C1
GO TO 40
10 IF (XO(1).LE.0.0) GO TO 20
XP(1)=XP(1)-C2*(QDQ0(T)**(1./3.))*(XO(1)**(5./3.))
XP(2)=(XO(2)**2.*C1*QDQ0(T)+1.-1./XO(2))**XP(1))/(ZETO-XO(1))
XP(3)=XO(2)**C3D*PRODPRO(T)-XO(3)*C2*(QDQ0(T)**(1./3.))*(XO(1)**(5./3.))
2./3.))/ZETO-XO(1))
XP(4)=XO(2)**C3H*PRHPRO(T)-XO(4)**C2*(QDQ0(T)**(1./3.))*(XO(1)**(5./3.))
2./3.))/ZETO-XO(1))
GO TO 40
20 IF (XO(1).LE.-DELTA) GO TO 30
XP(1)=-C1*QDQ0(T)
XP(2)=(XO(2)*C1*QDQ0(T))/(ZETO-XO(1))
XP(3)=(XO(2)*C3D*PRODPRO(T))/(ZETO-XO(1))
XP(4)=(XO(2)*C3H*PRHPRO(T))/(ZETO-XO(1))
GO TO 40
30 XP(1)=0.0
XP(2)=(XO(2)**(1.0)+C1*QDQ0(T))/(ZETO+DELTA)
XP(3)=(XO(2)**C3D*PRDPRO(T))/(ZETO+DELTA)
XP(4)=(XO(2)**C3H*PRHPRO(T))/(ZETO+DELTA)
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 NSEG,O,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZET0,FIRE,
PRODD,PRODH,LIMIT,DPHI,TAILIM,LINTER,DELTA,DQDTO,DPRDTO,
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)

COMMON NSEGQ,NSEGPD,NSEGPH,TAUQ(100),TAUPRD(100),TAUPRH(100),
Q(100),PRD(100),PRH(100),AKAP(100),C1,C2,C3D,C3H,ZETO,FIRE,
PROD,PRODH,LIMIT,DPHI,TAULIM,LINTER,DELTA,DQDTO,DPRT0,
LOGICAL LINTER,LNORM
DIMENSION TAUVAR(100),RATVAR(100)
CHARACTER L,ICHECK

10 IF (ITYPE.EQ.1) WRITE (6,40)
   IF (ITYPE.NE.1) WRITE (6,50)
   READ (5,60) ICHECK
   IF (ICHECK.EQ.1) 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

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
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Figure 2. Computer output from batch run of Example 1
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| 135 | 1320.00 | 2.27 | 7.03 | 2.36 | 336.67 | 170.37 | 23.67 | 13.15 | 0.0000 | 2649-001 |
| 140 | 1320.00 | 2.34 | 7.06 | 2.33 | 340.65 | 171.47 | 23.77 | 13.21 | 0.0000 | 2659-001 |
| 145 | 1320.00 | 2.41 | 7.09 | 2.31 | 342.63 | 172.57 | 23.87 | 13.26 | 0.0000 | 2668-001 |
| 150 | 1320.00 | 2.48 | 7.02 | 2.29 | 344.62 | 173.68 | 23.97 | 13.32 | 0.0000 | 2708-001 |
| 155 | 1320.00 | 2.55 | 7.05 | 2.27 | 346.63 | 174.79 | 24.07 | 13.38 | 0.0000 | 2728-001 |
| 160 | 1320.00 | 2.62 | 7.38 | 2.28 | 348.64 | 175.91 | 24.17 | 13.43 | 0.0000 | 2747-001 |
| 165 | 1320.00 | 2.69 | 7.31 | 2.23 | 350.66 | 177.03 | 24.27 | 13.48 | 0.0000 | 2767-001 |
| 170 | 1320.00 | 2.76 | 7.24 | 2.21 | 352.68 | 178.16 | 24.37 | 13.54 | 0.0000 | 2787-001 |
| 175 | 1320.00 | 2.83 | 7.17 | 2.19 | 354.72 | 179.29 | 24.47 | 13.60 | 0.0000 | 2807-001 |
| 180 | 1320.00 | 2.90 | 7.10 | 2.17 | 356.76 | 180.42 | 24.57 | 13.66 | 0.0000 | 2828-001 |
| 185 | 1320.00 | 2.96 | 7.04 | 2.14 | 358.81 | 181.56 | 24.67 | 13.72 | 0.0000 | 2848-001 |
| 190 | 1320.00 | 3.03 | 6.97 | 2.12 | 360.87 | 182.71 | 24.78 | 13.77 | 0.0000 | 2858-001 |
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**Figure 2. continued**
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## Flashover Potential

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Figure 4. Computer output from batch run of Example 3
---THE UPPER LIMIT OF THE DIGITAL DATA HAS BEEN EXCEEDED.
CONTINUE WITH THE NEXT COMPARTMENT HEIGHT OR SPECIFIED
DETECTION CRITERIA.---
### Flashover Potential

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<th>Q at Detection (KW)</th>
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---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.
### TITLE AND SUBTITLE

**CALCULATING AVAILABLE SAFE EGRESS TIME (ASET) - A COMPUTER PROGRAM AND USER'S GUIDE**

### AUTHOR(S)

Leonard Y. Cooper and David W. Stroup

### PERFORMING ORGANIZATION

**NATIONAL BUREAU OF STANDARDS**  
**DEPARTMENT OF COMMERCE**  
**WASHINGTON, D.C. 20234**

### 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.

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