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EXITT - A Simulation Model of Occupant Decisions and Actions in Residential Fires: Users Guide and Program Description

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Fires: Users Guide and Program Description

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ABSTRACT

EXITT is a computer model that simulates the decisions and actions of
occupants in a residence. This model can be used to determine the locations
of the occupants during the progress of a given fire. The rules for the
action choices of the occupants are based largely on studies of residential
fires and to a lesser extent on relevant controlled experiments. These rules
involve consideration of the smoke conditions, and the characteristics,
capabilities and locations of the occupants. EXITT can be run on a personal
computer and does not require user training--the user controls the model by
answering simple questions that appear on the screen. It can be run with pre-
selected scenarios and, also, with buildings, fires and occupants selected by
the user.

1. INTRODUCTION

The EXITT model simulates occupant decisions and actions in fire emergencies
in small residential buildings. In assigning decisions to an occupant, the
computer considers such factors as: age of occupant; sex; whether occupant is
asleep; smoke conditions; whether smoke detector is sounding and how loud it
sounds; whether occupant needs help in moving; and location, capabilities,
condition and status of the occupants. This version of the model does not
consider the heat or toxic components of the smoke. The permitted actions
include: investigate the fire; alert others; awake others; rescue others; and
evacuate/escape. Actions not permitted in the current version include:
telephoning fire department from within the building; fighting the fire; and
re-entering the building to make a second rescue.

The simulation is currently being developed as a series of progressively more
sophisticated models. This report describes an early interactive version of
the model.

The next Chapter of this report describes the EXITT model, with emphasis on
the rules used in determining the simulated decisions and actions of the
occupants. The casual user, who is familiar with personal computers, may

wish to read only the first two chapters of this report. The remaining
chapters are designed to be reference material plus some guidance for the
computer novice to help him get started (see Section 3.2).

Chapters 3 and 4 of this report serve as a users manual and computer program
documentation, respectively. The program is written to be sufficiently user
friendly that it should not be necessary to read the users manual in Chapter
3. Chapter 4 also contains details about the program that are not in the
general description of Chapter 2.

This simulation program is designed to run on the IBM-PC computer (and similar
microcomputers using the MS-DOS operating system) using the BASICA programming
language.[1] To run the model the user must load BASICA into the computer and
run the program EXITT. The program is sufficiently user friendly that the
user can run and understand the program from the comments, questions and
information appearing on the screen. Descriptions of the full set of the
various options given to the user are provided in Section 3.3.

The necessary input data for running the model are: a description of the
building, the smoke characteristics of the fire, and the characteristics of
the occupants. The user can provide his own input data or select from three
buildings, nine fires and eight occupant sets "stored" in the computer
program. While the layout of a building stored in the program will be
displayed on the screen, the user may find it important to have a copy of the
building layout available in hard copy. See Figures 1a-1d for copies of the
layouts of the three buildings used.

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[1] The use of company names or trade names within this paper is made only
for the purpose of identifying those computer hardware or software products
with which the compatibility of the programs of EXITT has been tested. Such
use does not constitute any endorsement of those products by the National
Bureau of Standards.

. DESCRIPTION OF THE MODEL

2.1 Introduction.

The EXITT model simulates occupant decisions and actions during fire
emergencies in small residential buildings. Buildings are represented in the
model as nodes that represent rooms, exits and secondary locations within
rooms; and links or distances between adjacent nodes. The occupants move from
node to node at a speed that is a function of their assigned normal travel
speed, the smoke conditions, and whether or not they are assisting another
occupant.

The user controls the model through the keyboard by answering simple questions
that appear on the screen. (A "batch" version of the model, that does not
require or permit user interaction during the running of the model, is also
available in the FORTRAN programming language: the decision rules in this
paper apply also to the batch version.) The decisions of the occupants are
reported on the screen and on the printer. The movements of the occupants are
displayed graphically on the screen, reported on the printer, and stored in a
data file. The user can suppress outputs on the printer and on the screen.

All the decision rules programmed in the computer model are designed to make
the decisions as similar as possible to those that building occupants would
make. The decision rules are based on: 1. a limited number of controlled
experiments; 2. case studies of occupant actions in residential fires; and 3.
the judgment of the author. Whenever the rules are based directly on data in
the literature or specific case studies, reference is made to such data.
Otherwise, the rules are based on the author's judgment.

Imbedded in the decisions rules are parameters that can be easily changed.
Developing improved values for these parameters is a major part of the future
development of the model.

The fires, buildings and occupants that are modelled can come from three
sources: 1. three buildings--each with two or more fires and two or more sets
of occupants--are stored in the computer programs and associated data files;
2. the user can substitute a new building, fire and/or set of occupants by
answering a large number of simple questions appearing on the screen; 3. the
user can substitute a new building, fire, and/or set of occupants by changing
the program and/or providing a new data file using the guidance provided in
Chapter 6.

2.2. Input Variables and Parameters.

2.2.1. Building. The building is represented within the computer by nodes
that represent rooms, exits and secondary locations within rooms; and by links
or distances between adjacent nodes. The major data used to define a building
are: the number of rooms, nodes and exits; the height of each room; the room
location of each node; nature of each exit (door or window); and the distances
between adjacent nodes. Windows that cannot or would not be used in a fire

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are not entered into the computer as exits, e.g., those with a window air conditioner installed.

2.2.2. Smoke. The program is designed to use the output of the FAST model--or any other similar model--for distributing smoke throughout the building over time [Jones, 1984].[2] EXITT assumes a two layer smoke model. However, it is assumed that a small proportion of the smoke in the upper layer gets into the lower layer so that there is an odor of smoke in the lower layer. Exitt accepts as input the smoke density in the upper layer and the depth or height of the two layers in each room at the beginning of each time period, e.g., every five seconds.

The measure of optical density for which the model is being calibrated is the one used by Jin in his studies of human behavior in smoke.

$$OD = \ln (L_0 / L)$$

where L_0 is the initial light intensity which reduced to a value of L over a path of one meter. This measure is consistent with the well recognized fact that when people perceive a physical stimulus, the perceived intensity tends to vary directly with the log of the physical intensity of the stimulus.

One important factor in making action choices in a residential fire is the properties of the smoke in the occupant's room. A measure of the psychological impact of smoke is determined as follows:

$S = 2 * OD * D / H$ where,

      S is the psychological impact of the smoke.
      OD is the optical density of the smoke in the upper layer,
      D is the depth of the upper layer, and
      H is the height of the room.

This expression is based on the assumption that the impact varies directly with the optical density (i.e., the log of the amount of smoke in the upper layer) and with the depth of the upper layer relative to the height of the room. The formula is an arbitrary representation of this assumption.

Some of the decision rules and definitions that involve S include:

> Sometimes the response to smoke is largely a function of the height of the lower layer, which can be presumed to be relatively clear. For example, occupants will escape through a room containing any density of smoke provided there is sufficient clear space for crawling, say, 1.2 meters.

> Occupants will not move to a node where S>0.5 unless the depth of the lower layer (H-D) is at least 1.2 meters.

> Occupants will not move to a room where S>0.4 unless the depth of the lower layer is at least 1.2 meters.

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[2] Items in brackets refer to references at end of report.

Occupants will increase their travel speed by 30% after encountering a room where S>0.1.

Occupants will terminate an investigation if they are in a room where S>0.05. They will terminate their investigation before entering a room where S>0.1.

Once an occupant is in a room where S>0.1, the decision rules are modified, e.g., in the text below these changes are referred to as consequences of believing the fire to be serious.

When S>0.4 there are prohibitions and penalties: these are referred to below as consequences of encountering "bad smoke."

Each of the above mentioned thresholds is an input parameter and can be easily changed as we continually improve the calibration of the model, i.e., modify the model to correspond better to behavior in real fire emergencies. Although the values selected are consistent with a conservative interpretation of Jin's data [1976], these values will be reconsidered as part of the further development of the model.

2.2.3. <u>Noise and Alarm</u>. The background noise level in a room affects the ability of an occupant to hear the alarm, both in real fires and in the model. The background noise is preset at 35 decibels. The user can easily override this value, on a room by room basis, by entering a <u>larger</u> value when defining the fire scenario.

Another input, related to a specific fire scenario, is the loudness of each smoke detector in each room, including the room in which it is located--it is a function of distances and of which doors are open. The impact of the alarm is a function of the difference between the signal intensity of the alarm and the background noise.

2.2.4. <u>Characteristics of the Occupants</u>. The user has an opportunity either to define or modify the characteristics of the occupants through the keyboard. The characteristics are: age, sex, normal travel speed, whether or not the occupant needs help in evacuation, whether or not the person is awake, room location, and, if the occupant is asleep, a measure of how difficult it is for the occupant to awaken.

There are a number of additional parameters imbedded in the decision rules which are described below. These include: the age below which a child is considered as a baby, unable to initiate any action; and the times required to perform various actions, such as waking a sleeping adult occupant when the fire does not appear to be serious. Some of these additional parameters are described in Section 2.5, Delays, Pauses and Action Times.

2.3. <u>Decision Rules</u>.

2.3.1. <u>Introduction</u>. There are two types of occupants: those who are fully capable when awake and those who need assistance in moving. The decision rules apply only to those who are capable when awake. Those who need

assistance moving make no decisions and their movements are determined by their "rescuer".

At the beginning of the simulation, all occupants are unaware of the fire and the potential danger. Actions and decisions are assigned, in part, based on the smoke conditions in each room at the beginning of the appropriate time period.

The following paragraphs describe the sequential steps the computer follows in determining the decisions and actions of one occupant for one time period. The computer goes through these steps for each capable occupant for the first time period and then repeats the process for each subsequent time period, in turn, until all the occupants are either out of the building or trapped by the fire. (For each step, the computer considers all occupants before proceeding to the next step.)

2.3.2. Aware of Fire. The first step in determining the actions of an occupant is to determine if and when an occupant is sufficiently aware of the fire cues (i.e., smoke, sound of alarm and visible flame) to undertake an action. If the occupant became aware of the fire cues in a previous time period, he will remain aware of the fire cues for this and all subsequent time periods. An occupant becomes aware of the fire when the fire cues are sufficiently strong. Obviously, stronger cues are needed to awaken and alert a sleeping occupant than to alert an awake occupant. The fire cues are: the sound of the smoke detector; the odor of smoke; and, for awake occupants, visible smoke. (Visible flame can be used, if desired, as input data: if it is used, it will be an additional fire cue.) If the weighted sum of the intensities of the cues reach a prescribed threshold, the occupant will be flagged as being aware of the fire cues. (If the fire cues are of borderline intensity, the occupant will become awake and aware after an assigned delay.) If the fire cues are not sufficiently strong for the occupant to become aware of the fire during the current time period, the consideration of this occupant for the time period is completed.

The following basic equation, for determining if and when an occupant will start to respond to the fire cues, was suggested by the empirical results of Nober et al.[1981]. While Nober studied only the response of the smoke detector alarm, his results were generalized for the odor of smoke, and the sight of smoke.

$$T = 70 - 4(C-20) \qquad \text{and}$$
$$C = (A-N)+X1+X2+X3+X4 \qquad \text{where,}$$

 T is the delay time, in seconds, before the occupant will start his first action;

 C is the sum of the sensory impacts on the occupant;

 A is the sound intensity of the smoke detector as heard by the occupant; N is the background noise;

 X1 is impact of an awake occupant seeing flame. It is set sufficiently high to assure a rapid response whenever an awake occupant is in the

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same room as a visible flame; and set equal to zero if the occupant is asleep or if the location of the flame is not entered into the computer;

X2 is impact of an occupant smelling smoke--it is a function of the smoke density and smoke depth and applies to both sleeping and awake occupants. It varies directly with S, the psychological impact of smoke when the smoke remains above 1.2 meters. However, its value dramatically increases when the upper smoke level gets down to the height of a person in a bed;

X3 is impact of an awake occupant seeing smoke--it is a function of the product of the smoke density and smoke depth in the upper layer and also varies directly with S; and

X4=0 if the (typical) occupant is asleep and X4=15 if the occupant is awake. This reflects the fact that more stimuli are required to awake than to alert an occupant. The value of 15 is based on the data in Nober [Nober et al, 1981]. Occupants who have difficulty waking could be assigned negative values of X4.

Subject to the restrictions:

A-N cannot be less than zero. If N>A let A-N = 0;

If C < 20 then T = infinity (i.e., 99999 in the computer). This restriction is based on Nober's data where occupants usually either responded within 70 seconds or remained asleep for the remainder of the test period;

X1 and X3 equal zero if the occupant is asleep.

The model as described above assumes that the response is a function of the sum of the impacts of different sensory cues. This assumes that the relevant aspects of the perceptual processing of olfactory, visual and auditory cues are similar. There does seem to be a surprisingly consistent perceptual observation (Fechner's Law) that the intensity of a perception varies directly with the log of the physical stimulus. (While Fechner's Law has broad applicability, it is not universal and only approximate [Boring, 1950].) Since our measure of the psychological impact of all the cues are based on the log of a physical measure, the impacts to the three types of cues can be assumed to be roughly comparable. The decision to sum the impacts of the three cues is based on the assumption that simple behavioral rules are better than complicated ones when there is no technical reason to select a complicated one. Furthermore, simple summing is consistent with the results of Fletcher and Munson who found that a tone heard binaurally seems twice as loud as the same tone heard monaurally [Licklider, 1951].

The physical measure of each fire cue is measured in different units and they must be converted to a single measure of sensory impact. The cue most easy to quantify, and the one for which we have the most data, is the sound of the smoke alarm which is measured in decibels. It was decided to use "equivalent decibels" as the single measure of sensory impact. The impacts of the other sensory cues are "converted" to equivalent decibels, i.e., the values of X2 and X3 are transformed to the number of decibels that would approximate an equivalent impact in alerting occupants. (When the flame is visible to an awake occupant, the value of X1 is set sufficiently high to ensure a rapid

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response.) The transformation factors are input parameters: their values will be the subject of future research and analysis.

While occupants respond more quickly to strong fire cues, there is a minimum duration of time required to awaken or become aware of the fire cues, select an action, and perform preparatory actions. These minimum times range from 1 to 10 seconds depending on whether the occupant is asleep and the amount of smoke. (See Section 2.5.5.)

For each occupant, a time to start his actions is computed independently at each time period until the occupant starts his first action: that is, a different time to start his actions will be computed each time period. He will start his action at the earliest time among those computed.

2.3.3. Assigning Actions to Occupants Who Are Aware of Fire. If an occupant has been assigned an action in a previous time period, he will be given an opportunity to complete that action before any consideration is made regarding additional actions.

2.3.4. Investigation Top Priority. The normal first action is to investigate the fire cues to determine the nature of the hazard. However, there are a number of exceptions, i.e., situations that would make investigation either a lower priority or an unreasonable choice. [Levin, 1985] If the computer determines that none of these exceptions applies, the computer assigns the room with the most smoke as the GOAL, labels the occupant as investigating, and assigns him the task of going to the room with the most smoke.

One special situation that would cause investigation to be a low priority arises when an adult female occupant is in the same building as a baby--in a case study provided by Keating and Loftus a mother rescued her baby before determining if it was necessary. [Keating and Loftus, 1984]

Investigation is not permitted: if the occupant has already completed an investigation; if the occupant has been in a room with moderate or bad smoke; or if the occupant has been awakened or alerted by an occupant for whom investigation is not permitted.

If the exceptions do apply, the computer considers the following alternative actions in the order given below.

> Help Occupant in Same Room. The computer determines if there is another occupant in the same room who needs help. If that occupant is fully capable but asleep, he will be awakened. If he needs assistance moving, he will get that assistance. (If more than one occupant qualifies for help, the sleeping occupant is given priority.)

> Help Occupant in Different Room. If there is one or more persons in a different room(s) who needs to be alerted, rescued or awakened, the computer will make two assignments: tentatively assign the fully capable occupant a person to alert, rescue or awaken; and assign the capable occupant the action of going to the room of that person. (Once he arrives at that room, a new action will be assigned based on the fire

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situation at that time and the capabilities of the persons in the room. Exception: if he is going to the room of an awake and capable person who needs to be alerted, he will automatically alert that occupant.) The priority order of these tentative assignments for helping persons in different rooms is: alert capable adult; rescue other occupant; wake other occupant; and alert child.

Occasionally an occupant will go to a room for the purpose of assisting a sleeping or disabled occupant: upon arrival at the room he finds an awake, capable adult unaware of the fire, i.e., not responding to the fire cues. In such a situation, the responding occupant will quickly alert the unaware occupant before addressing the needs of the other occupant.

Investigate. If investigation is still a permitted choice, the occupant is assigned the task of investigating. The computer assigns the room with the most smoke as the GOAL, labels the occupant as investigating, and assigns him the task of going to the room with the most smoke.

Egress. If none of the above alternative assignments apply, the occupant is assigned the action of evacuating.

Every capable occupant is considered for helping an occupant in the same room before any occupant is considered for helping an occupant in a different room.

In this version of the model, an occupant over the age of ten functions as an adult, that is, they follow the priority list presented above for adults.

A child who is 8,9, or 10 will rescue any occupant in the same room and will go to another room to awaken or alert another occupant. However, he will not go to another room for the purpose of rescuing an occupant. Children 7 and younger do not assist others out of the building but will wake or alert other occupants who are older. A child is considered to be a baby if his age is equal to or less than the parameter BABY: babies do not initiate any actions. The tentative value of BABY is 3.

The general rationale for the above priority order is to determine if there is a need for positive action, to assist those known to require help, and then to assist those who might require help. (When it is unknown if a sleeping occupant has awakened, he can be considered as someone who might require help.) If two people are known to require help, provide help to the one needing more limited help, that is, a sleeping but otherwise capable occupant. The rule that supercedes all others is to help someone in the same room before helping an occupant in different room.

2.4. Travel Within the Building.

Occupants move within the building from node to node. The path assigned is determined by finding the shortest path to an exit based on a shortest path algorithm which contains an option for assigning penalties for going through bad smoke and for leaving through windows.

The route to be taken to a designated room, the best exit, or another designated node is determined by a shortest path algorithm. The shortest path algorithm used is described by Levin and Hedetniemi [1963]. Normally when the occupant is investigating or going to assist another occupant, a straightforward shortest distance is determined.

If the occupant wishes to egress or evacuate the building, or if the occupant had encountered too much smoke when going to assist another occupant, then the path with the lowest number of demerits is selected. Each meter of travel is assigned one demerit, leaving by a window is assigned 100 demerits, and going to a node through bad smoke is assigned 200 demerits. If the smoke at a node is intolerable, that node cannot be part of a route. If smoke is blocking all routes to the designated node, the occupant will decide to escape. If the occupant is escaping, the route out of the building with the least demerits is selected. If all escape routes are also blocked, he will be considered trapped. (See section on Smoke in Section 2.2 for decision rules regarding moving or not moving through bad smoke.)

As an occupant attempts to move, whenever he encounters an intolerable amount of smoke based on the criteria in Section 2.2, he will stop moving and the computer will redetermine his best route to his destination, i.e., the route with the fewest demerits. If the shortest path algorithm fails to find an acceptable path, the computer will look for the best route out of the building. If all exit routes are blocked by smoke, the occupant is considered trapped.

2.5. Delays, Pauses, and Action Times.

2.5.1. Introduction.
The time consuming activities of an occupant can be classified into three categories.

Movement from one node to another. He travels the shortest path at the speed defined below.

Delays and pauses. These activities include time to awaken, time to make decisions, and time to prepare for action.

Assisting actions, i.e., waking another occupant and preparing another occupant for egress.

2.5.2. Speed.
The travel speed of each occupant is set at:

1.3 meters per second for normal conditions;

1.69 m/s (30% faster than normal) if an occupant should consider the fire to be serious (e.g., he has been in a room with heavy smoke);

0.65 m/s (50% of normal) if the occupant is assisting another occupant, or 0.845 m/s if the occupant also considers the fire to be serious;

0.78 m/s (60% of normal) if the smoke is bad (i.e., S>0.4) and if the depth of the lower layer is less than 1.5 meters, i.e. if the occupant has to "crawl" under the smoke. (0.52 m/s if the occupant is also assisting another occupant.)

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The normal travel speed and all the modification factors are parameters that can be set by the user. While these values will be reconsidered as part of further model development, they are similar to those reported by Jin [1976].

Whenever an occupant moves, his actions are printed on the screen and on the printer, recorded in a data file, and graphically represented on the screen. (Printing on the screen or on the printer can be suppressed.)

2.5.3. Delay Times. The delay time, the decision time, and the time to perform assisting actions (hereafter, collectively called Delay Times) depend on the occupant characteristics, the fire characteristics and the impact of the fire cues on the occupant. The length of these Delay Times are determined by a set of decision rules as described below. These Delay Times can be changed rather easily and all assigned values should be considered as tentative.

2.5.4. Minimum Response Time. The normal (i.e., smoke is not bad) minimum response (delay) time is 6 seconds for awake occupants: this includes decision and preparation time. The normal minimum response time for sleeping occupants is 10 seconds: this also includes decision and response times. These values are based on the work of Nober [Nober et al, 1981]. The status of sleeping occupants is changed to awake status whenever the remaining response time is 6 seconds or less.

2.5.5. TPAUSE. An occupant is assigned normally a delay time of TPAUSE seconds whenever: he completes his investigation or terminates his movement along a route because of intolerable smoke; or changes his mind about helping another occupant. This delay includes the time required to choose a new action. TPAUSE is tentatively set equal to 3 seconds.

2.5.6. Decrease in Preparation Time Due to Heavy Smoke. When an occupant is subjected to normal fire stimuli, a ten second response Delay Time is assigned to a sleeping occupant and six seconds to an awake occupant. (Note the response time will be greater if the fire stimuli are not sufficiently strong for an immediate response.) However, if the occupant believes the fire to be serious, the maximum Delay Time for the occupant becomes four seconds and if the smoke in the room is bad, the maximum Delay Time becomes 1 second.

2.5.7. Hesitation Due to Not Being Alone. Research by Latane and Darley [Latane and Darley, 1968] has shown that when the fire cues are noticed but not immediately compelling, adults will hesitate in their responses if other capable adults are in the same room. A simple explanation is that there is a failure to respond due to a feeling of shared responsibility. The computer program accounts for this by delaying responses by one time period for each time period where: there is no one that needs to be rescued, alerted, or roused; there is a second capable occupant in the room; the smoke detectors are not sounding; and the sum of the psychological impacts of the fire cues is less than 30, i.e., if C<30 then T=99999, where C and T are defined in Section 2.2. (The threshold for this hesitancy is 30 rather than 20 to reflect that more stimuli or cues than the "minimum for response" are required to prevent the "hesitation due to not being alone.")

2.5.8. <u>Time Required to Alert, Wake or Prepare for Evacuation</u>. Whenever one occupant assists another, time for providing or receiving the service must be assigned. The following times are assigned:

> If Occupant J is alerting a fully capable and awake adult, he moves to the node of the other occupant. Once he arrives at that node, Occupant J starts his next action with no delay or decision time charged. The occupant being alerted is assigned a Delay Time of five seconds or 2.5 seconds depending on whether the alerting occupant believes the fire to be serious.

> There are two types of assistance that an occupant may be flagged as needing: waking; and help moving. If an occupant is asleep and does not need help moving, the delay is five seconds for the occupant doing the waking. For the occupant who is being awakened the delay is ten seconds--5 seconds for waking plus 5 seconds decision and preparation time. However, if the assisting occupant believes the fire to be serious, then his time devoted to waking would be only 2.5 seconds and the total Delay Time for the previously sleeping occupant would be 5 seconds.

> If an occupant needs help moving, the Delay Time (at the time the assisting occupant arrives at the location of the other occupant) is usually 10 seconds if the disabled occupant is awake and 12 seconds if he is asleep. However, if the disabled occupant is a baby, the Delay Time, in seconds, is the baby's age plus 4. (It does not take long to pick up a baby and wrap him or her in a blanket.) In addition, if the capable occupant believes the fire to be serious, the previously determined Delay Time is halved. For example, if the fire is believed to be serious, the Delay Time for helping a 2 year old baby would be 3 seconds ((2+4)/2).

2.6. <u>Smoke Detectors.</u>

The building may have up to three smoke detectors. These smoke detectors are independent and are not interconnected in any way. It is necessary to provide the locations of the smoke detectors and how loud each detector would sound in each room of the building. A smoke detector will sound if the smoke density of the upper layer smoke is at least .015, and the depth of the upper layer is .15 meters or greater.

An option in the program is to consider the smoke detectors as broken. It is, therefore, easy to determine the effect of smoke detectors by running the program twice with the same fire and occupants, once with smoke detectors working and once with them broken.

A third option is for the user to preset the time for each detector to sound.

2.7. <u>Current Limitations and Future Development</u>.

The model as described in this paper is a preliminary version of a model under development. The development, improvement and expansion of the model is a continuing activity. The user should be aware of the limitations of the current model. These limitations include:

1. The model is deterministic. Only typical behavior is modelled: aberrant behavior is not permitted.

2. Improved calibration is required to upgrade its validity. Calibration means changing parameter values in the model based on: a. analyses of data in the technical literature; b. judgments of a panel of experts; c. analyses of in depth interviews of survivors of residential fires; and, d. attempts to simulate behavior in real fire emergencies for which we have information. An intensive effort to improve the calibration of the model, is scheduled for the next year.

3 Some typical actions are not included, especially, fighting the fire, phoning the fire department from within the residence, reentering the building.

4. Occupants respond to smoke conditions but not to heat conditions.

The current development program is designed to overcome and eliminate these limitations. The program can be made probabilistic, and heat will be added as a factor in decision making and route selection,

The model permits the user at the keyboard to override a very limited set of the occupant decisions assigned by the computer. Within the next few months, the user will be given the opportunity to override most, if not all, of these assigned decisions. This will permit the model to be used in studying the effect on safety of alternative decisions by the occupants.

3   USING THE MODEL.

3.1   Introduction.

The program is written in the BASICA programming language for the IBM-PC
computer. Other computers can be used if: they can accept programs written
for the IBM-PC; and there is available a version of BASICA (or BASIC)
compatible with BASICA for the IBM-PC. It is very user friendly in that it
requires very little knowledge about the program--and no knowledge about
programming--to use. It is designed to be sufficiently easy to use that it
should not be necessary to refer to this chapter in order to run the model.
However, this chapter is valuable as the source of information for the
following purposes:

> To assist users to get started if they have no knowledge of the Disk
> Operating System (DOS):

> To obtain a better understanding of the options given the user when
> running the program;

Since much of this chapter is designed to be used as reference material, many
of the sections are written as reference material rather than as descriptive
narrative.

The simulation normally displays the building layout and the location of the
occupants on the monitor screen (i,e., the "TV" screen). This feature
requires the computer to have a "graphics board" that enables the computer to
handle the graphics instructions in programming language BASICA. The computer
will ask if the computer has an IBM graphics board or one that works like it.
If the computer does not have the proper graphics board, answer NO, and the
program will not display the floor layouts and the location of the resident on
the screen.

There are nine fire scenarios available for use in the version being
distributed. (It is possible to add a fire scenario of the users choice but
adding a completely new scenario requires a considerable amount of effort to
input all the data that is needed.) Making changes to the fire
characteristics and to the occupants is relatively easy. Making minor changes
to the characteristics of the building is also easy but some changes require a
working knowledge of the BASIC programming language (but not an expert
knowledge). More information on this will be given later.

While it is not necessary to know anything about programming to use this
simulation, it is, of course, necessary, to know enough about your computer to
start the running of a BASIC program and to understand the limited computer
terminology in this introduction.

The simulation is provided on one floppy disk. This floppy disk contains a
number of different programs and data files. These programs must work
together for the simulation to work properly. If all these programs and data
files remain together in a single disk drive (and directory), the computer

will switch or chain from one program to the other automatically. The user must tell the computer in which disk drive the program is available by answering a question which will appear on the monitor or screen.

The program has a number of options. The user selects the options he wants by answering questions. The number of such options might overwhelm the first time user. One question is "IS THIS YOUR FIRST EXPERIENCE WITH THIS PROGRAM?" A YES answer directs the computer to select a fire scenario and to limit the number of options for the novice.

There are three different building layouts permanently available to the user. (It is possible for the sophisticated user to add a fourth building of his/her own design. Instructions for doing this are in Chapter 6, Describing a New Building, Its Occupants and the Fire.) One option is to load the characteristics of a building of the user's choice through the keyboard by answering a series of questions. When you define a building through the keyboard you lose the option of having a graphical representation of the building layout on the monitor screen. To gain an understanding of the input data that affects the simulation, it is suggested that you enter the characteristics of a very small building, its occupants and a fire, through the keyboard. (Such a small building might be only two rooms and a hallway.) However, use of the stored scenarios and buildings are recommended for use by the novice as he experiments with the model and learns its characteristics.

3.2 How to Start and Run the Program.

To run the simulation model the user must load BASICA into his computer and then load and run the program EXITT. If all the provided programs and data files are available on the default disk drive, no other actions are needed to run the simulation model. However, if you have fancy options on your computer, you may have to program your computer to perform like a standard IBM-PC.

The following describes, for the novice, one way to set up a computer to do this if the simulation is being run as a self contained model. If the simulation is being run in conjunction with other models, such as is done with the Hazard Assessment Methodology [Bukowski, 1987], procedures and instructions that permit the models to work together will supercede the recommendations below.

Whether or not your computer has a hard or fixed disk drive will determine how the program is loaded into the computer. The following discussion is for users with a standard IBM-PC personal computer (or compatible computer) and very limited knowledge of the disk operating system for their computer.

> If your computer has one or two floppy disk drives and no hard disk drives, place a disk with MS DOS (DISK OPERATING SYSTEM) into disk drive A, close the "door" of the disk drive and turn the computer on. (When you turn on the computer, the disk operating system will automatically load into the computer--If you have problems, you probably put the disk in the wrong disk drive.) At the A> prompt--i.e., when A> appears on

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the screen--type BASICA and press the return key. This will load the
BASICA programming language into your computer. (If you do not have an
IBM computer, you may have to replace the MS DOS disk with a disk
containing BASICA before typing BASICA.)

Once the programming language BASICA has been loaded into the computer,
you will receive a prompt, Ok, from the computer. At the Ok prompt,
replace the MS DOS DISK with the disk containing all the programs for
the simulation, close the door, type the expression RUN "EXITT" and
press return. This statement will load the simulation into the computer
and start the program.

If your computer has a hard disk drive and you wish to copy the simulation
onto the hard disk, use the following instructions: (It is assumed that the
computer has the root directory on the hard disk as the available directory.
Unless the computer has been programed to do otherwise, you have this
situation when you turn on the computer.)

Place the disk containing all the programs for the simulation in drive A
and close the door.

At the C> prompt type COPY A:EXITT and press return. (This will load a
program that will make it easier to start the program.)

At the C> prompt, type MD EXIT. (This will make a new directory in
which we will store the simulation programs on your hard disk.)

Type CD\EXIT. (This will tell the hard disk to refer to the EXIT
directory.)

Type COPY A: *.* and press return. (This will copy the contents of the
programs and data files on the simulation disk onto the hard disk.)

Remove the simulation disk from drive A and replace it with the MS DOS
disk. (If you do not have an IBM computer, use whatever disk has your
copy of BASICA.) At the C> prompt, type COPY A:BASICA.* and press
return. (This will copy BASICA onto the hard disk in the simulation
directory.)

Note: This step can be omitted if you can access BASICA from
this directory. You can test for this by typing BASICA and
pressing the return key before starting this step. If
BASICA appears on the screen, you can omit this step. You
can get out of BASICA by typing SYSTEM and pressing the
return key.

To start the program when you are using a hard disk, type EXITT and
press the return key. (You can do this if you are in either the root
directory or the EXIT subdirectory.) This will start a program that
will change to the proper directory; load BASICA; load program EXITT;
and tell the computer to start running the EXITT program.

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To control the running of the program, the user answers the questions posed by the computer on the monitor screen (i.e. the "TV screen"). To answer these questions it is not necessary to have any knowledge of computers, programming or the characteristics of this computer simulation.

Exception: the user should know if his computer has an IBM graphics board (or one that works like one). If the user does not know, he should assume his computer has the proper board. If the program stops running immediately after he answers YES to the question about the graphics board, he can assume he does not have the proper board (or the board in his computer is not currently programmed to act like an IBM graphics board).

3.3   Description of the Options.

The options are presented as questions and are self explanatory. However, some of the effects of the option choices are not obvious. While it is not necessary to know these effects to use the program, they are described below.

DO YOU WANT TO USE YOUR PRINTER? A negative response will suppress all printer output. If your computer does not have a printer, the program may not work unless you give a negative response. If you give an affirmative response, a record of the simulation results will be printed.

IN WHICH DISK DRIVE IS YOUR PROGRAM: A, B, OR C? Since some users may have stored the program on a hard disk (drive C) and others may have the program stored on a floppy disk (drive A or B), this option gives users the flexibility to use any of these disk drives.

DOES YOUR COMPUTER HAVE A COLOR MONITOR (TV SCREEN)? Color displays on the screen often cannot be seen on black and white screens. This option permits the computer to use color displays on color monitors and monochrome displays on monochrome monitors. Type 1 if you have a color monitor or 2 if you have a monochrome monitor. (Note there will be color displays only when you use building 1.)

It is not necessary to ask the user this question when he is using an IBM-PC. Instead he should change the instructions in statement 971 of program EXITT to X=1. When X=1, the program will direct an IBM computer to determine for itself whether it is attached to a monochrome or color monitor.

DO YOU WANT TO DEFINE YOUR OWN BUILDING? The normal mode of running this simulation program is to use one of the available fire scenarios, including scenarios you have "programmed". If you do, the characteristics of the building are preset. If you choose to define your own building, you must also enter the characteristics of the smoke and of the building occupants through the keyboard. Entering the characteristics of the building, smoke spread and occupants is very easy but time consuming because of the amount of data that must be entered.

If you define your own building through the keyboard, the graphics part of the output is suppressed.

ARE YOU IN A HURRY--THAT IS, WOULD YOU LIKE TO BYPASS SOME OF THE REPETITIVE INFORMATION THAT CAN BE PRINTED ON THE SCREEN? This option is self explanatory. It also applies to output from the printer if the printer is working. The most important sets of data that are not displayed, if you respond affirmatively, are the smoke conditions. It is recommended that you answer YES to this question unless you have a special reason to answer NO.

IN THIS SIMULATION THE COMPUTER WILL MAKE DECISIONS FOR THE BUILDING OCCUPANTS SUCH AS WHETHER TO INVESTIGATE THE FIRE OR ESCAPE. DO YOU WANT THE ABILITY TO OVERRULE SOME OF THE OCCUPANT DECISIONS AS GENERATED BY THE COMPUTER? The current version of the program gives the user a limited capability to make changes. Future versions will give the user additional capability. An affirmative answer gives the user an opportunity to change the cycle time if the user is entering the smoke characteristics through the keyboard. An affirmative response gives the user the opportunity to answer the following questions about the smoke detectors.

ARE THE SMOKE DETECTORS BROKEN? The simulation is based on the assumption that there is one, two or three independent single station detectors in the building. The available fire scenarios all include working detectors. This option gives the user the capability of disabling all the defined detectors. If the user defines his own scenario that does not include operating smoke detectors, he must answer yes to this question. (He must also respond YES to the question DO YOU WANT THE ABILITY TO OVERRULE SOME OF THE OCCUPANT DECISIONS AS GENERATED BY THE COMPUTER? in order to get to this option.) If the smoke detectors are not functional, the initial response to the simulated fire may be delayed, just as in real life.

DO YOU WANT TO PRESET WHEN THE SMOKE DETECTOR WILL SOUND? The simulation will normally determine when a smoke detector will sound based on the smoke conditions in the room in which the specific smoke detector is located. If the user chooses to have the ability to overrule some the occupant decisions, he will be presented with this option. If he answers affirmatively, he will be directed to preset the time of sounding for each of the smoke detectors in the building.

DO YOU WANT TO CONTROL THE DENSITY AND THICKNESS OF THE UPPER SMOKE LAYER? If the user is using one of the available fire scenarios, the spread of the smoke is normally controlled by the computer. However, if this question is answered affirmatively, the computer will ask the user to input the smoke conditions each time period. (To minimize the effort required, only changes in the smoke conditions from the previous time period need to be entered.) If you are defining your own building through the keyboard, you must, of course, provide the smoke densities through the keyboard. The computer will give the user an opportunity to change smoke densities, height of upper layer, and whether or not a

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flame is visible at the beginning of each separate time cycle. Note: if the simulation program contains smoke data for X time cycles and the simulations runs for X+1 time cycles, at the X+1 time cycle, the program will switch to this option.

DO YOU WANT TO RUN AN ADVANCED VERSION OF THIS PROGRAM? The "advanced" features relate to the ability to make and store changes in the input data and the program parameters. Specifically, an affirmative response to this question will automatically give the user the opportunity to make changes in the input data and some of the parameter values (unless the user is defining his own building through the keyboard.) If a negative response is chosen, the user will be given the opportunity to make changes only in the characteristics of the occupants.

DO YOU WANT TO SAVE THE INPUT DATA FROM THIS RUNNING OF THIS PROGRAM? An affirmative answer to this question directs the computer to save all the input data and parameter values used in the current running of the program. The purpose of saving these values is to use them in a subsequent running of the model. It should be noted that if no changes are made, the future running of the model will give the same output as the current run. However, the user will have ample opportunity to make changes when he runs the model with the saved data.

DO YOU WANT TO USE THE INPUT DATA FROM A PREVIOUS TIME YOU RAN THIS SIMULATION? An affirmative response permits the user to use the input data saved from a previous run. See comments under previous option.

WE WILL USE THE INPUT DATA AND PARAMETERS IN A COMPUTER FILENAME 'DATA.SAV'. DO YOU WANT TO USE A DIFFERENT FILE? The program contains some error checks when renaming files--however, failure to follow the rules for naming files might cause the running of the program to terminate.

THE RESULTS OF THIS RUN WILL BE STORED IN A COMPUTER FILE NAMED 'DATA.SAV'. DO YOU WANT THE FILE TO HAVE A DIFFERENT FILENAME? These two options permit the saving and reusing of many sets of input data and parameter values.

THE RESULTS OF THIS RUN WILL BE STORED IN A COMPUTER FILE NAMED 'RERUN. EVA'. DO YOU WANT THE FILE TO HAVE A DIFFERENT NAME? The data being saved contains the arrival time of each occupant as he arrives at a node. It is used by Program TENAB which calculates the toxic smoke exposure of each occupant [Bukowski, 1987]. Although the suggested name may differ, the user is always given an opportunity to assign the name he prefers. Therefore, the user can easily save the results of an unlimited number of runs.

DO YOU WANT THE COMPUTER TO PLACE OCCUPANTS IN THE BUILDING? If the user is using one of the available fire scenarios, the location and characteristics of the occupants are normally preset. However, if the user answers this question affirmatively, the computer will ask a series of questions that permits the user to define the characteristics of the

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occupants. In any event, the user is given the opportunity, at a later point in the program, to modify the characteristics of the occupants.

3.4 Description of Input Data.

3.4.1 Introduction. In order to run this model it is necessary to define the characteristics of the building, the building occupants and the fire. These input data can be defined in one of three ways:

The user can enter the characteristics through the keyboard. He does this by answering a very long series of questions. The user activates this option by giving an affirmative respond properly to the question: DO YOU WANT TO DEFINE YOUR OWN BUILDING? (If he answers negatively, the user will be asked to choose among the three buildings stored in the computer programs and data files.)

The characteristics of three buildings, nine fires and eight sets of occupants are stored in subroutines and data files. These subroutines and data files will be automatically called, as needed, if the user responds properly to the questions:

DO YOU WANT TO DEFINE YOUR OWN BUILDING?

DO YOU WANT TO CONTROL THE DENSITY AND THICKNESS OF THE UPPER SMOKE LAYER? and

DO YOU WANT THE COMPUTER TO PLACE OCCUPANTS IN THE BUILDING?

The user will be asked to select among the three buildings, the two or more fires for that building, and the two or more sets of occupants for that building. (It is possible to change these inputs by modifying the appropriate subroutines and data files: information that will assist the user in making these modifications is contained in Chapter 6.) The user will be given an opportunity to change the characteristics of the occupants through the keyboard. He also will be given the opportunity to change the characteristics of the building and the fire by answering affirmatively to the question: DO YOU WANT TO RUN AN ADVANCED VERSION OF THIS PROGRAM?

The characteristics used in a previous run can be used. The user selects these data if he answers affirmatively to the questions: DO YOU WANT TO RUN AN ADVANCED VERSION OF THIS PROGRAM? and DO YOU WANT TO USE THE INPUT DATA FROM A PREVIOUS TIME YOU RAN THIS SIMULATION? Note that if you use the same input data, you will get the same output. Therefore, the user will be given ample opportunity to make changes.

3.4.2 Occupant Characteristics

3.4.2.1 Introduction: The user will always have an opportunity to either define or modify the characteristics of the occupants. The characteristics that can be defined or modified by the user are: age, sex, whether or not the

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occupant needs help in evacuation, whether or not the person is awake, room location, and, if the occupant is asleep, a measure of how difficult it is for the occupant to awaken. These characteristics are used in the decision rules of the simulation.

3.4.2.2 Age. The age of an occupant is most important if the occupant is a child. An infant is defined as being age 0. Very young children will not respond to a fire and should be labeled as needing assistance.

The computer may assign capable children different actions than it assigns adults in the same situation. An occupant over the age of ten functions as an adult. Young children (i.e., seven or younger) respond differently than children eight or older, e.g., young capable children will not be assigned to assist someone out of the building. Younger persons who need assistance are rescued before older persons in the same room.

3.4.2.3 Sex. The sex of the occupant plays a significant role only if the occupant is over twenty and young children are in the building. A male adult may investigate a fire before he attempts to rescue his children, while a female occupant, twenty years of age or older, will always rescue a baby first.

3.4.2.4 Help. Whether or not an occupant needs help in evacuating plays a large role in the simulation. An adult who needs help evacuating cannot investigate a fire and cannot leave unless another occupant over the age of ten can assist him. It is assumed that it does not require much strength to assist an occupant out of the building: e.g. carry a baby, assist an elderly occupant, lead a mentally retarded occupant.

When an occupant is being helped to evacuate, the travel speed of the rescuer is decreased.

An occupant cannot need partial help; he is either capable or incapable of egressing the building. An occupant, over the age of ten, who does not need help evacuating, is assumed to be able to help any other occupant who does need help.

Very young children are automatically defined as needing help. If the age of the child is equal to or less than the assigned value of the parameter BABY, the child is labelled as needing help.

3.4.2.5 Sleep. An occupant who is asleep cannot respond to the fire until after he awakes. The fire cues or stimuli must total at least TH (the response threshold) or the occupant will remain asleep until awaken by another occupant. His state of consciousness (i.e., asleep or awake) is important in determining the total length of time it will take for that occupant to react to a given set of fire cues.

> SELECT A SLEEPING PENALTY FOR PERSON J. The sleeping penalty is an extra amount of fire cues or stimuli needed to awaken a sleeping occupant. A sleeping penalty of zero is normal. The higher the number, the heavier a sleeper the occupant is: a high value may prevent the

occupant from awakening without help. (Entering a negative value for the sleeping penalty will indicate that the person is a light sleeper-- e.g. parent of a baby.) An occupant who is in a relatively deep sleep will have a sleeping penalty of around five to ten and will require a greater intensity of fire stimuli before awakening: an intoxicated occupant may be assigned a much larger sleeping penalty, depending upon how much alcohol he has consumed. A person with a minor hearing loss should normally be assigned a sleeping penalty equal to his hearing loss in decibels.

3.4.2.6 <u>Room.</u> This item is self explanatory. The occupant must be in a room and not at an exit node at the start of the program. His room location is defined when his other characteristics are defined and can be changed whenever the user is given the opportunity to change the characteristics of the occupants. The occupant is automatically placed at the node that is the same as his assigned room number, e.g., if an occupant is placed in room 2, the computer will place him at node 2.

3.4.3 <u>Building Characteristics</u>

3.4.3.1 <u>Introduction</u>. The user will have the opportunity either to define or modify the characteristics of the building if he selects the correct options-- see Section 3.4.1. The characteristics of the building are: number of rooms, number of exits, number of nodes, room location of each node, distances between nodes, background noise in each room, and information about smoke detectors and how loud they sound in each room.

The simulation has three subroutines that each contain the input data that describe one building, giving the user easy access to three different buildings. It is possible to write a fourth subroutine that contains the input for a building of your choice, but it is very time consuming to write. Procedures for creating a fourth building or for changing the stored values of the building characteristics, will be described in Chapter 6. Changes that can be made through the keyboard by answering questions will be discussed in this section. Data for the three buildings includes floor plans based on common layouts.

3.4.3.2 <u>Description of the three buildings.</u>

    <u>Ranch House.</u> This is a three bedroom, two bathroom, one level ranch house. It includes a living/dining room and a kitchen as well. This building layout is the simplest of the three in that there is only one story. See Figure 1a.

    <u>Two-story Townhouse.</u> On the first floor there is a living/dining room off of the kitchen, a foyer, a family room directly off of the kitchen, a bathroom, and a broom closet that houses the hot water heater. The second floor includes three bedrooms and two bathrooms. There is a central hallway on each of the levels. The most important difference between the townhouse and the ranch house is that the townhouse has two stories and, therefore, has a staircase leading to its second floor. See Figure 1b.

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Two-story Detached House. The first floor features a separate living and dining room, family room, kitchen, and bathroom. The second floor has three bedrooms, two bathrooms and an extra room (bedroom, study or office). At the front door is a foyer and a hallway leading to the family area. The rest of the first floor rooms can be separated from adjacent rooms by doors. The second floor has a central hallway that leads to all of the bedrooms and one of the bathrooms. See Figure 1c.

Limitations. This program is limited to 12 rooms and a total of 35 nodes. The program that distributes the smoke throughout the building is limited to a smaller number of rooms. To keep the number of rooms small, in the two story houses, not every room is necessarily treated as aa separate "room". In the town house, the kitchen and family area constitute one room as opposed to two separate rooms: the only bathroom that is counted as a separate room is the one in the master bedroom. In the two-story detached house, none of the bathrooms are treated as a separate room. Although the kitchen has been assigned a node, it is considered to be in the same room as the family area (i.e., the smoke conditions in the entire area are similar). Room five includes the stairs and the second floor hallway, and room three includes the living room and the foyer. Room numbers are assigned to be consistent with the program from which the smoke data is obtained, i.e., FAST.

3.4.3.3 Nodes, Rooms and Exits.

Number of Rooms. This program is limited to 12 rooms.

Number of Exits. Exits include doors to the outside and windows that can and might be used to exit the building. Windows that are not usable (e.g. painted shut or with a window air conditioner) or near a door, would not be considered to be exits.

Number of Nodes. Each room contains at least one node: the node number of the most central node is the same as the corresponding room number. Each exit is considered a node. In addition, additional nodes may be assigned within any room. These extra nodes are usually assigned at choice points along paths between rooms/nodes: for example, in Figure 1a, node 15 is a choice point on all routes starting at room one and ending elsewhere in the building such as the route between node 1 and node 2 and the route between node 1 and node 7.

Distances Between Nodes. If the normal route between two nodes is direct-- i.e., not by way of a third node--then the distance (the length of the link) between the two nodes should be an input variable. It is necessary to define the distance in one direction only--either direction is acceptable. The unit of measure is meters.

3.4.3.4 Background Noise. The background noise level in a room will affect the ability of an occupant to hear the alarm. There is a minimum of 35 decibels of background noise--even if there is no background noise, the computer will consider the background noise to be 35 decibels. The white noise generated by an air conditioner will result in approximately 50 decibels

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of background noise. A loud stereo will result in even more background noise.
If the background noise is louder than the smoke detector (i.e. if the
background noise is greater in decibels than the alarm), the occupant in that
room will not hear the smoke detector. The loudness of the alarm can also be
changed (see below).

3.4.3.5 Input Variables for One Story Buildings. A building is treated as
one story building when the parameter NB1=1. (A building with only one story
could be treated as a two story building but the converse is not true.) In
"one story" buildings there is only one smoke detector and it is defined as
being in the hall. It is necessary to set·the loudness of the detector in the
hall and the door position (open or closed) of the doors between the hall and
the other rooms. The loudness of the alarm in each room is computed using the
following rule: 12 decibels are lost as the sound passes into a room with an
open door and 24 decibels are lost as the sound passes into a room with a
closed door. The minimum background noise is 35 decibels.

Whether or not a door is open or closed will affect two aspects of the
simulation. A closed door will result in a decrease in loudness of the alarm
signal in that room. Secondly, smoke movement will be restricted. For
example, little or no smoke may enter a room with a closed door, depending on
how the leakage through the door is defined. Because of this, the response
time of an occupant in a room with a closed door--other than the room of fire
origin--may be greatly delayed, both in the simulation and in real life.

3.4.3.6 Input Variables for Two Story Buildings. A building is treated as a
multiple story building when parameter NB1=2. (A building with only one story
could be treated as a two story building but the reverse is not true.) In one
story buildings the computer computes, for each room, the loudness or signal
intensity of the one smoke detector. In larger buildings there may be more
than one detector and the geometry of the building is such that it is easier
to enter the loudness of each detector for each room than to enter data that
permits the computer to compute these values. Therefore, the user must enter
the loudness of each detector for each room. (If the loudness is 35 decibels
or less, the value of value 35 should be entered: lower values will be
automatically increased to 35.) It should be noted that in the current
version of the model, whenever the user defines the building through the
keyboard, he is restricted to using a one story building, i.e. NB1=1. (If
NB1=2, there is neither the need nor the opportunity for the user to set the
door positions when running the EXITT model.)

3.4.3.7 Smoke Detectors. There are several opportunities in the program to
alter different aspects of the smoke detectors by answering questions through
the keyboard. Those aspects that can be changed will affect the
responsiveness of an occupant to the fire cues.

Broken Smoke Detectors. The user will get a chance to "break" the smoke
detectors if he answers affirmatively to the question, DO YOU WANT THE
OPPORTUNITY TO OVERRULE SOME OF THE OCCUPANT DECISIONS AS GENERATED BY THE
COMPUTER? A broken smoke detector will never work. It is equivalent to not
having a smoke detector at all--one way to model a building with no smoke
detectors is to define the detector(s) as broken. (Another way is to set the

smoke detectors to activate at a time after all occupants are certain to be safe or dead--see option DO YOU WANT TO PRESET WHEN THE SMOKE DETECTORS WILL SOUND in Section 3.3). Occupants in a building where the smoke detectors do not work are dependent solely upon the other fire cues (e.g., smoke) to determine that there is a fire. This may greatly increase the amount of time necessary to respond to the fire.

Loudness. The loudness or signal intensity of a smoke detector alarm is important in determining if a person will hear the alarm or, if sleeping, if he will awaken. The normal signal intensity for a smoke detectors alarms in the hall of a one story building is 85 decibels, but it can have a range from 75 to 141 decibels when the user defines his own building through the keyboard. Locations more remote from the alarm will have lower signal intensities.

Presetting Smoke Alarm. The smoke detector will sound if the smoke density exceeds a prescribed level, and the depth of the smoke in the upper layer is at least .15 meters. The user will be given the opportunity to override this automatic feature and preset the time when the smoke alarms will sound. Whether the smoke detector activation is controlled by the program or is preset, the alarm will sound only at the beginning of a time period.

(The minimum smoke density that will activate a smoke detector is the parameter TOL(5): it is set equal to .15. The user will get a chance to change this value if he responds affirmatively to the question: DO YOU WANT TO RUN AN ADVANCED VERSION OF THIS PROGRAM?)

3.5 Making Changes in the Program.

Much of the information in the following chapters is designed to permit the user to make changes in the program. The casual user is unlikely to want to make such changes. However, there are some changes that the serious user may want to make. Some examples are:

> The user may want to add an additional building of his own design to the available set of buildings.

> The user may want to change some of the parameter values that cannot be changed through the keyboard for a given run.

> The user may want to change default values of parameters that can be changed through the keyboard for a given run.

The user making such changes should be aware that program DEC3 is too large to run within the 64k bytes of memory available in BASICA. To make it small enough, it has been compressed. The compressed program is called COMP4. To make changes in DEC3, the user must have access to a program to compress the modified version of DEC3 or the user must make the changes directly in program COMP4. (The program used to compress DEC3 is copyrighted and cannot be provided as part of the simulation disk.)

4. DESCRIPTION OF COMPUTER PROGRAM.

4.1 Introduction.

EXITT is programed in the BASICA programming language for an IBM PC computer with 128k bytes of random access memory. It can be run without modification on similar computers of other companies. DOS 2.1 or later is required.

For the most part the program is written in a simple style. Emphasis was given to making the model easy to modify and expand rather than to minimizing computer running time.

This Chapter presents information about the computer program. While the general description of the model in presented in Chapter 2, additional details about the model are included in this chapter.

4.2 Structure of the Program. Because of the characteristics and limitations of the BASICA programming language, the computer instructions are contained in 10 separate programs. One of the programs, DEC3, contains the basic simulation model. Since program DEC3 does not fit into the maximum space permitted by BASICA, it has been compressed and the shorter version is called COMP4. (The difference between the two programs is that COMP4 contains no comment statements and two or more short statements in DEC3 may be combined into one long statement in COMP4.) All the other programs are concerned with: defining the building, fire and occupants; defining the parameters; and input and output. The program switches from one program to another through the CHAIN instruction. These programs are:

EXITT. The EXITT program contains: an alphabetic list and very brief description of all parameters and variables; the dimension statements; and the statements that give the user an opportunity to select some of the options. It chains to program DEC1. (A brief description of all parameters and variables is in Appendix A of this report.)

DEC1. The main function of DEC1 is to control the input of the desired fire scenario, including the characteristics of the building, fire and occupants. Based on options selected by the user, the program will:

> Give the user the opportunity to enter the fire scenario (i.e., the characteristics of the occupants, the building, and the fire) through the keyboard;

> Call other programs (using the CHAIN statement) that will provide the fire scenario;

> Provide an opportunity to modify the fire scenario and many of the program parameters;

> Combinations of the above.

DEC1 also contains additional statements that give the user an opportunity to select options.

There is a package of programs that contains: 1. programs with the characteristics of three buildings; two or more set of occupants for each building; and two or more fires for each building; and 2. a program for saving, retrieving and modifying the input data of a run. DEC1 calls these programs (i.e., CHAINS to them), as needed, to obtain the desired information. These programs are:

OCC1. OCC1 is the program that contains the information about the characteristics of the occupants. This program chains back to the DEC1 program.

BLDG. BLDG1 is the program that contains the information about the characteristics of building 1, a ranch house. (See Figure 1a.) BLDG2 contains the information about building 2, a townhouse. (See Figure 1b.) BLDG3 contains the information about building 3, a two story detached house. (See Figures 1c and 1d.) BLDG4 is reserved for a building designed by the user. These programs chain either to another BLDG program or back to the DEC1 program.

SMOKE9. The smoke characteristics of each fire is stored in a data file with a name containing the word SMOKE followed by one or two digits and the suffix SMK. The first digit indicates the building in which the fire is located. The second digit, if any, is used to distinguish between fires in the same building. (For example, SMOKE11.SMK is the file for one of the fires in building 1.) Program SMOKE9 inputs data from the selected data file. SMOKE9 also contains (and inputs) data for other aspects of the fire scenario such as background noise and the location and characteristics of the smoke detectors. Program SMOKE9 chains to the DEC1 program.

AGAIN. AGAIN is a program that stores the input data from a run so that it can be used again and that retrieves these data in a subsequent run. If the data were used unmodified in a second run, the run would be identical and the results would be identical: therefore, AGAIN provides the user with an opportunity to change one or more of the input datum, including many of the parameter values.

4.3 Description of the Fire.

4.3.1 General Description. The fire characteristics within room I at a given time are fully described by three variables:

> SDUL(I). The simulation model is based on a two zone smoke spread model with a layer of smoke at the top of the room and a lower layer of non defined density. SDUL(I) is the density of the upper layer.
>
> SDLL(I). SDLL(I) is the height of the lower layer. If there is no smoke in a room, then SDLL(I) is defined equal to the height of the room.

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FLAME(I). FLAME(I)=0 if there is no visible flame, FLAME(I)=999 if there is visible flame in room I, and FLAME(I)=1 if there is no visible flame in room I but flame in another room can be seen from room I. It is not necessary to input values of FLAME(I) and little will be lost if, at ignition, no occupant is awake in the room with the flame. The program is normally run without inputting flame characteristics, i.e., FLAME(I)=0 for all rooms. In future versions flame may have a more important role.

4.3.2 HF(I). To decrease the number of rooms in a computer run of a smoke spread model, rooms may be consolidated. A "room" could contain a stairway and a upstairs hallway. The height of the floor at a node in the hallway would be above the height of the bottom of the room, i.e., the bottom of the stairs. This difference is the variable HF(I). It is used in determining the impact of the smoke. If this problem does not arise, ignore this variable, it will be automatically be given the default value of zero and the program will operate correctly. Note: the value of HR(I), the height of the room at node I, will be the distance from the floor to the ceiling at node I.

4.3.3 SMOKE. The impact of smoke is a function of the density of the upper smoke layer and its thickness. The generally used measure of this impact in a room is the variable SMOKE. It is computed in subroutine 3090-3098 of program DEC3. (It is twice the product of SDUL(I) and the ratio of the thickness of the upper layer to the height of the room--see Section 2.2).

4.4 Awareness of Fire.

4.4.1 The Basic Algorithm. The 5000 series of instructions in program DEC3 contains the decision rules for determining if and when an occupant will respond to the fire cues. The basic equation (which is statement 5250 of program DEC3) is:

TRESP(J) = 70 - 4(AWARE(J)-TH), subject to the following restrictions:

TRESP(J) is unchanged if TH>AWARE(J); and

TRESP(J) >= a minimum value based on the smoke conditions and whether the occupant is awake or asleep, where:

AWARE(J) is the sum of the impacts of all the fire cues;

TRESP(J) is the time until occupant J starts his action; and

TH is the threshold for response, i.e., the minimum value of AWARE(J) necessary for a response. Its value is set in statement 1008 of program DEC1 and can be modified through the keyboard in program AGAIN if the appropriate options are selected. It value must be greater than 15 unless instruction 5125 of DEC3 is modified. That is, TH must be greater than X4.

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The basic equation for computing AWARE(J) is:

AWARE(J) = ALEFF + X1 + X2 + X3 + X4, where:

ALEFF is the difference between the loudness of the alarm and the background noise;

X1 is impact of an awake occupant seeing flame;

X2 is impact of an occupant smelling smoke;

X3 is impact of an awake occupant seeing smoke; and

X4 is bonus for being awake or (penalty for being asleep).

4.4.2 <u>Detectors</u>. Detectors sound at a signal intensity of LROOM(I,II) where I is the room number and II is the detector number. The units are decibels. In two story buildings, these values are input variables. In one story buildings, the values are computed using the rule that 12 decibels are lost as the sound enters a room with the door open and 24 decibels are lost as the sound enters a room with the door closed. See instructions 5055, 5155, 5255 or 5355 of program SMOKE9 (and subroutine 4250 of program DEC1 when user is defining his own building and subroutine 5400 of program DEC1 when the user is changing or correcting the door settings from open to closed or vice versa).

The volume of the detector alarm in the room containing the alarm is the parameter LALARM. Its value is set in statements 1400-1428 of program DEC1 when the user defines the building through the keyboard. Otherwise, it is defined in statement 20 of program SMOKE9.

4.4.3 <u>Measures of Fire Cue Impact</u>. Each of the fire cues is measured in different units. The units for the loudness of the smoke alarm is decibels (dB). All the other units are "converted" to decibels, i.e., the values are transformed to the number of decibels that would approximate an equivalent impact in alerting occupants.

<u>Sound</u>. ALEFF is the difference between the loudness of the alarm and the background noise. This is computed in statements 5010 to 5115 of program DEC3. The first step in computing ALEFF is to determine if the smoke detectors are sounding. One of the options is to preset when the detectors will sound. If the detectors are preset, statement 5026 will flag a detector as sounding. If the detectors are not preset, statement 5031 will flag a detector as sounding if there is sufficient smoke in the room/hall containing the detector.

<u>X1</u>. X1 is the impact of an awake occupant seeing flame. It is the product of SLP, CFIRE and FLAME(I). (See statement 5116 of program DEC3.) Since both SLP AND FLAME(I) are either zero or >=1, X1 will be either zero or >=CFIRE.

<u>SLP</u>. If the occupant J is asleep (i.e., if SLEEP(J)=1), then SLP=1. Otherwise, SLP=0. (See instruction 5010.)

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FLAME(I). FLAME(I)=999 or 1 if flame is in or near room I. Otherwise, FLAME(I)=0. Note: the program normally runs well if FLAME=0 throughout the running of the program because the smoke conditions provide sufficient information about the fire.

CFIRE. CFIRE is a parameter that defines the magnitude of the impact of seeing a fire on becoming aware of the fire. Its value is set in statement 1005 of program DEC1 and can be modified through the keyboard in program AGAIN if the appropriate options have been selected (see statement 4325 of program AGAIN).

X2. X2 represents the impact of the odor and irritability of smoke. Its value is the product of SMOKE and COLF where:

SMOKE is a measure of the impact of smoke and is described in Section 4.4.3.

COLF is a parameter that determines the importance of the odor of smoke in alerting an occupant to the fire cues. It is the multiplier used to modify a measure of smoke so that is can be combined with a measure of sound. Its value is set in statement 1005 of program DEC1 and can be modified through the keyboard in program AGAIN if the appropriate options have been selected (see statement 4355 of program AGAIN).

Exception 1. If the occupant is asleep and the lower smoke layer is between 1 and 1.2 meters in depth, then X2=5*(SDUL(I)). (See statement 5119 of program DEC3).

Exception 2. If the occupant is asleep and the lower smoke layer is 1 meter in depth or less, then X2=10*(SDUL(I)). (See statement 5120 of program DEC3.)

X3. X3 represent the impact of seeing smoke. It is the product of SLP, CSMK, and SMOKE where SLP and SMOKE have the properties described above. CSMK is analogous to COLF but relates to the importance of seeing smoke.

Note: if the occupant is sleeping, SLP=0 and, therefore, X3=0.

X4. X4 reflects the phenomenon that awake occupants will require less impacting cues to be alerted. If the occupant is awake, X4=15 (see statement 5125 of program DEC3). If the occupant is asleep, X4=-CSLP(J).

CSLP(J) is a measure of the extra amount of fire cues or stimuli needed to awaken a sleeping occupant who has difficulty waking. It is called a sleeping penalty. A sleeping penalty of zero is normal, i.e., no extra cues are needed. The higher the number, the heavier a sleeper the occupant is: a high value may prevent the occupant from awakening without help. An occupant who is in a relatively deep sleep may have a sleeping penalty of ten or more and will require a greater intensity of fire stimuli before awakening. An intoxicated occupant may be assigned a much larger sleeping penalty, depending upon how much alcohol he has

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consumed. A person with a minor hearing loss should normally be
assigned a sleeping penalty equal to his hearing loss in decibels if it
is expected the fire alarm will sound.

Entering a negative value for the sleeping penalty will indicate that
the person is a light sleeper--e.g., a parent of a baby. If the value
of the sleeping penalty were negative 15, the intensity of the fire cues
necessary for response would be the same as when the occupant is awake--
see value of 15 given X4 in statement 5125 of program DEC1. Therefore,
CSLP(J) should not be given a large negative value.

The values for CSLP(J) are defined in the appropriate subroutine of
program OCC1 (and in statement 5292 of program DEC1 when the
characteristics of the occupants are being entered or modified through
the keyboard).

4.4.4 _Minimum Response Times_. While occupants respond more quickly to strong
fire cues, there is a minimum amount of time required to awaken, if necessary,
select an action, and perform preparatory actions. If the occupant is asleep,
the minimum time is 10 seconds, (see statement 5258 of program DEC3). If the
occupant is awake, the minimum time is 6 seconds, (see statement 5257).

Exception 1. If the smoke is bad (i.e., SMOKE>TOL(3)), the minimum is 4
seconds. (See statement 5263.)

Exception 2. If the smoke is very bad (i.e., SMOKE>TOL(2)), the minimum
is 1 second. (See statement 5265.)

For each occupant a time to start his actions is computed at each time period
until the occupant starts his first action: that is, a different time to start
his actions will be computed each time period. He will start his action at
the earliest time among those computed.

4.5 _Choice of Actions_.

4.5.1 _Permitted Responses._ Once a capable occupant has decided to respond or
has completed an action, he has a choice of responses or actions. Several
common responses are not available in this version of the simulation: phoning
the fire department; fighting the fire; reentering the building, and assisting
or escorting more than one occupant out of the building . The available
responses for capable adults in order of priority are listed below. The order
of items 2-7 is determined by instructions 7800-7806 and 7900-7906 (or 7820-
7829 and 7920-7922 for children). It should be noted that the priority list
of items 2-10 is also followed when an action choice is made upon arrival at a
room.

1. Investigate the fire--there are a number of conditions that will
make this action an unacceptable or lower priority choice. See Section
2.3.4 and statements 7120-7129 of program DEC3.

2. In the unlikely event that there is a capable and awake adult in the same room who is not aware of the fire cues, alert that occupant. See statements 7450-7469.

3. Wake a sleeping but otherwise capable occupant in the same room (see statements 7500-7516 and 7400-7429 of program DEC3).

4. Rescue an occupant in the same room (see statements 7500-7548). Sleeping occupants are considered first in subroutine 7500: if there are no sleeping occupants that need rescue, awake occupants will be considered in subroutine 7530.

5. Go to the room of a capable awake adult (age between 18 and 60) who is unaware that there may be a fire (response delay of more than 10 seconds) and alert him. (See instructions 7700-7708).

6. Go to the room of an occupant needing rescue (see instructions 7560-7574).

7. Go to the room of an occupant who is asleep (see instructions 7580-7599).

8. Alert an awake and capable occupant, whose response delay is greater than 10 seconds, that there is a need to respond or hurry (see instructions 7710-7718).

9. Investigate the fire if investigation is a permitted choice (see instructions 7200-7202).

10. Egress the building (see instruction 7216).

The available responses for competent children (age 10 years or less) are listed below in order of priority. Competent children are those who don't need assistance in evacuating, i.e., ACT(J) is not equal to 1, 11 or 21.

In this version of the model, an occupant over the age of ten functions as an adult, that is, they follow the priority list presented above for adults. (See statements 7142 and 7160 of program DEC3 for the branching statements.) Young children (i.e., seven or younger) respond differently than children eight or older. (See statements 7129 and 7820 of program DEC3.)

1. Investigate the fire--there are a number of conditions that will make this action an unacceptable or lower priority choice as discussed below. In this version of the model, the rules for older children are the same as for adults. Capable children 7 or younger will not investigate (see statement 7129).

2. In the unlikely event that there is a capable and awake adult in the same room who is not aware of the fire cues, alert that occupant. See statements 7450-7469.

3. Wake a sleeping but otherwise capable occupant in the same room. (See statements 7500-7516 of program DEC3 for children eight and older and statements 7400-7429 for younger capable children. See statement 7820 for the statement with the branching instruction).

4. If the child is 8, 9, or 10 years of age, rescue an occupant in the same room. (See statements 7500-7548.)

5. Go to room of an unaware (or sleeping) but capable adult (age between 13 and 70). (See instructions 7720-7728.)

6. Go to room of an unaware (or sleeping) but capable occupant who is older, i.e., a child will awake or alert another child in another room who is older than he is. (See instructions 7480-7499.)

Note that a child who is 8,9, or 10 will rescue any occupant in the same room but will not go to another room for the purpose of rescuing an occupant. Children 7 and younger neither investigate nor assist others out of the building.

4.5.2 <u>Reasons for Investigation Being Low priority or Not Permitted.</u> Investigation is the most likely action or response unless one of the following conditions apply:

1. If the occupant is a female at least 20 years old and there is a baby who has not yet been assigned to a rescuer, then rescue, waking and alerting have a higher priority than investigation for that female occupant (see instructions 7120-7124 of program DEC3). A child is considered to be a baby if his age is equal to or less than the parameter BABY.

2. Investigation is a permitted action for occupant J only when ACT1(J)> equals zero.

4.5.3 <u>Criteria for Setting ACT1(J)=1.</u> Investigation cannot be selected as an action for occupant J whenever ACT1(J)> is one or two. The criteria for setting ACT1(J) equal to two is described below in the section, "Criteria for the Fire to be Considered Serious". In addition ACT1(J) is set equal to one by any of the following instructions in program DEC3. (Note: none of these apply when ACT1(J)=2):

6844. Occupant is in room with a smoke density of TOL(4) or greater.

6971. Occupant was alerted to the fire emergency by another occupant for whom investigation was not a permitted action.

7127. Same as in instruction 6844.

7678. Occupant was awakened or alerted by another occupant for whom investigation was not a permitted action.

4.5.4 Criteria for Fire to be Considered Serious. A fire is considered to be serious by Occupant J if ACT1(J)=2; occupant J being any capable occupant in the building. ACT1(J) can be set equal to two by any of the following instructions:

6845. Occupant is in a room where the smoke density is at TOL(3) or greater, or in a room where flame is visible.

6937. Occupant is in the same room as another occupant who considers the fire to be serious. (In this early version of the model, this statement is reached only under special circumstances.)

6971. Occupant is being alerted to the fire emergency by another occupant who considers the fire to be serious.

7128. Same as in instruction 6845.

7678. Occupant is being awakened by another occupant. If the other occupant considers the fire to be serious, then the occupant being awakened will also consider it to be serious.

8150. Occupant has completed his investigation.

8488. Occupant cannot reach his goal (i.e., cannot successfully complete his action because of heavy smoke).

4.6 Finding Shortest Path.

4.6.1 Shortest Path Algorithm. The shortest path algorithm is adapted from Levin and Hedetniemi [1963]. All routes are considered to be composed of nodes along the route and links between the nodes. The basic approach is to develop a tree of nodes and links representing the shortest routes from the origin node to all other nodes. Each time a shorter route is found to any node, that route is tested to determine if it can be used (or extended) as the first n-1 nodes of an n node route to another node. Much of the computer code is concerned with the bookkeeping: to assure that all routes that should be considered for extension are, in fact, tested; and to record the tentative shortest routes.

4.6.2 Handling Obstacles. There are two versions of the subroutine for finding the shortest path. Statements 6100-6199 comprise a subroutine that is a straightforward application of the shortest path algorithm.

Statements 6200-6399 comprise a subroutine that considers obstacles such as smoke and windows. The approach of the second subroutine is to find the route with the fewest demerits where demerits are assigned as follows:

One demerit is assigned for each meter to be travelled. Fractional demerits are assigned. (See statements 6219 and 6257.)

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One hundred demerits are assigned for leaving by a window. This is a
sufficient penalty to assure that an unobstructed exit path through a
door is considered superior to an exit path through a window. (See
statements 6219 and 6257.)

Two hundred demerits are assigned for reaching a node that is in a room
where the value of SMOKE is between TOL(2) and TOL(1) at the time the
subroutine is being run. (See statements 6232 and 6237.)

A link is considered blocked if:

The destination node of the link is in a room where the value of SMOKE
is TOL(1) or greater. (See statements 6227 and 6236.)

The destination node of the link is in a different room than the origin
node of the link, and the destination node is in a room where the value
of SMOKE is TOL(2) or greater. (See statements 6222 & 6227 and 6260 &
6236.)

Exception. If lower smoke layer has depth of at least 1.2 meters,
The route is considered passible. (See statements 6221 and 6259.)

Note that a link that may be passible, when the shortest path routine is run,
and it may be blocked later, when the occupant attempts to travel the link.

4.6.3 Choice of Exit. When searching for the route out of the building, the
subroutine that considers obstacles is used, i.e., the subroutine starting at
statement 6200. This subroutine finds the route out of the building with the
fewest demerits.

The subroutine uses a two step approach. The routine first finds the best
path to the front door. In running this subroutine the computer finds all
"shortest" paths to other nodes that are "shorter" than the distance to the
front door; that is, all paths that have fewer demerits. (A blocked path is
considered to have an infinite number of demerits.) After the best path to
the front door is found, the computer selects the path out of the building
with the fewest demerits as the best egress route. (See statements 8210-8224.)

4.6.4 Choice of Shortest Path Subroutine. In brief, the straightforward
subroutine is called when the occupant has not had an opportunity to learn
much about the fire. The subroutine that considers smoke is called when the
occupant has learned about the fire or is attempting to leave the building.

When the occupant is investigating the fire cues, the straightforward
subroutine is called. (See instruction 8110.)

When the occupant is leaving the building, the subroutine that considers
smoke and windows is called. (See statement 8209.)

When the occupant is going to another room to alert, awaken or rescue
another occupant, the straightforward subroutine is used. Exception:
if the occupant has just been blocked by smoke in his attempt to go to

a room or to investigate--that is ACT2(J)=93--the subroutine that considers smoke is called. (See statement 8418.)

4.7   Moving the Occupants.

4.7.1 Introduction. Statements 6800-6999 comprise the one set of instructions that moves all occupants along the path selected by the shortest path programs described in Section 4.6.

4.7.2 Speed. SPEED(J) is the normal travel speed of occupant J. SPD is a parameter which is set at 1.3 meters per second (i.e., almost 3 miles per hour) in statement 1006 of program DEC1. SPEED(J) can be set in three ways:

> If the characteristics of the occupants are entered through the keyboard, an occupant's speed is entered in response to a question. · (See 5270-5276 of program DEC1.)

> If the characteristics of the occupants are entered when running program OCC1, the values of SPEED(J) can be defined with the other characteristics.

> If the characteristics of the occupants are entered when running program OCC1, and if the value of any SPEED(J) is not defined with the other characteristics, the value of that SPEED(J) is set equal to SPD. (See statements 1910-1919 of program OCC1.)

The following modifications to the travel speed do not apply to occupants who are investigating.

If an occupant J should consider the fire to be serious, as described in Sections 2.2.2 and 4.5.4--that is, if ACT1(J)=2--then the travel speed would be multiplied by SPD1. SPD1 is set equal to 1.3 in statement 1006 of program DEC1. Therefore, the travel speed of occupant J would be increased by 30% if ACT1(J)=2. (See statements 6809 and 6962 of program DEC3.)

If occupant J is assisting another occupant out of the building, his travel speed usually is cut in half. (See instruction 6808 and 6961.) Note that if he considers the fire to be serious, it is the increased travel speed that is cut in half.

Travel speed to the next node is set as follows when the occupant needs to crawl or bend very low. He is deemed crawling if SMOKE at the next node is at least the average of TOL(2) and TOL(3) and if the depth of the lower smoke layer is less than 1.5 meters. (See statements 6847 and 6848.)

> If he is assisting another occupant out of the building, their speed will be .4(SPEED(J)).

> If he is not assisting another occupant out of the building, his speed will be .6(SPEED(J)). (See statement 6945.)

4.7.3 <u>Available Time</u>. In this model, the computer must know the location of each occupant. It does this by recording the node at which the occupant is located and the time he started his current action. In this context the "action" could be moving or making a decision. If the occupant cannot complete his movement to the next node in the current time period, the movement is deferred to the next time period.

There are three quantities of interest: distance, travel speed and time. To see if an occupant can complete a movement to a node in the time period, it is necessary to either convert the length of the link to a travel time or convert the available travel time to a travel distance. In this version, the program converts the available travel time to a distance that can be traveled in that time. This new variable is called DT. (See statement 6810.) It is then possible to compare DT with the distance between nodes (statement 6825) and to subtract the distance between nodes from DT to get a new value of DT (statement 6950). By cycling back to statement 6815, the new DT can be used to see if the occupant can move to another node in this time period.

4.7.4 <u>Criteria for Branching out of Subroutine</u>. Whenever the distance to the next node exceeds DT, the program branches out of this subroutine. (See statements 6825-6832.) The program also branches out when: 1. SHORT(J)=0, i.e., the shortest path has not yet been determined (see 6805); 2. route is blocked by smoke (see 6868); 3. occupant reached an exit node (see 6919 and 6929); 4. occupant reached goal, i.e., arrived at destination node (see 6976); and 5. occupant terminated his investigation because he encountered heavy smoke (see 6889).

4.7.5 <u>Smoke</u>. An occupant cannot move to the next node if it requires that he pass through intolerable smoke. Also, if he is investigating the fire cues, he will not move through unpleasant smoke. When SMOKE exceeds TOL(2) and the lower smoke layer is less than 1.2 meters in depth, the smoke is too bad to enter that room. When SMOKE exceeds TOL(1) and the lower layer is less than 1.2 meters, the smoke is too bad to go from one node to another in the same room. Note that the smoke is never so bad as to prevent an occupant from leaving a room if the next node is in a location with an acceptable level of smoke. (See instructions 6850-6855)

When an occupant is investigating, he will:

> Terminate (i.e., complete) his investigation when he arrives at a node where SMOKE>=TOL(4) or flame is visible (see especially statements 6844, 6845, 6930, and 6932);

> Terminate (i.e., complete) his investigation without additional movement when the next node on his path is in a room with bad smoke, i.e. SMOKE>=TOL(3) and the lower smoke layer is less than 1.8 meters in depth (see statements 6847 and 6848); and

> Complete his investigation if he arrives at his goal, i.e., node GOALJ(J) (see instruction 6948.)

Whenever an occupant moves, his actions are printed on the screen, may be printed on the printer, and may be graphically represented on the screen. Many of the statements in this subroutine are concerned with printing this information. They are straightforward and obvious and are not described in this report.

4.7.6 <u>Assisting Other Occupants to Escape</u>. When an occupant is assisting another occupant to escape, the following is done whenever the first occupant moves to a different node. The program branches to a set of statements that: 1. describes the action on the screen; 2. prints similar information on the printer; and 3. resets the node location of the disabled occupant. (See statements 6988-6991 and 6920-6929.)

5. PARAMETER VALUES

5.1 <u>Introduction</u>. There are a number of numerical constants, imbedded in the decision rules, that the user might wish to change. The value of each of these constants can be changed by making a simple change in the program itself. To provide the user with greater flexibility and control, some of these constants are described below and information necessary to modify them is provided. Usually, the change is so simple and obvious that a brief description of the function of the constant and the location of the statement assigning the constant its value, is all the information provided.

An attempt has been made to make it easy for the user to change some of these values. These constants are assigned parameter names, and the parameter names, rather than the numerical value, are used in the decision rules. These constants will be called parameters. They can be changed by redefining their values in the computer program. Also, some of them can be changed through the keyboard when the user responds affirmatively to the question DO YOU WANT TO RUN AN ADVANCED VERSION OF THIS PROGRAM?

A number of these constants appear as numerical values in the computer statements that set delay times. These values can be changed only by changing the appropriate program statement.

5.2 <u>Parameters</u>.

<u>BABY</u>. BABY is the upper limit of the age at which a child is considered to be too young to perform productive actions in a fire emergency. It is set equal to 3.0 in instruction 1005 of program DEC1.

<u>CFIRE</u>. CFIRE is the scaling factor for seeing flame when summing the impacts of the fire cues. It is set equal to 100 in statement 1005 of program DEC1. The impact of seeing the fire is equivalent to awake person hearing an alarm of CFIRE decibels. Any assigned value above TH+15 will result in the same rapid response.

<u>COLF</u>. COLF is the scaling factor for smoke odor and irritability when summing the impacts of the fire cues. It is set equal to 50 in statement 1005 of program DEC1.

Obviously, the impact of smoke odor is important for awakening and alerting sleeping occupants. However, it appears to have only a mild effect when the smoke conditions are not severe [Kahn, 1984]. The impact on sleeping occupants depends on: smoke density, the irritability of the smoke components and, the location of the head in relation to the upper smoke layer. This model disregards variations in the irritability of the smoke components. If the sleeping occupant's head is in the upper layer, i.e., the depth of the lower layer is less than 1 meter, the impact is similar to a sound of COLF*10*(SDUL(I)) decibels. (See instructions 5118-5123 of program DEC3).

<u>CSMK</u>. CSMK is the scaling factor for awake occupants noticing smoke when summing the impacts of the fire cues. It is set equal to 1000 in statement

1005 of program DEC1. When the upper and lower smoke level depths are equal, the impact is similar to a alarm of CSMK*SDUL(I) decibels. (More precisely, it is the impact of CSMK*S decibels, where S is defined in Section 2.2.2.) Note that for awake occupants, this factor dominates the impact of smoke odor/irritability.

LALARM. LALARM is the loudness or volume of the smoke detector alarm in the hall of a one floor ranch house. Depending on the options selected, it is assigned a value by the user in response to a question or in statement 1105 of program BLDG1, In this version, LALARM is not used for two story houses.

SPD. In program DEC1, SPD is the normal speed of typical capable occupants as they move through the building. It is set equal to 1.3 meters per second (2.9 miles per hour) in instruction 1006 of program DEC1. As described in Section 4.7.2, the normal travel speed of each individual, SPEED(J), can be set equal to SPD or to a value provided by the user, depending on the options selected by the user. Once the values of SPEED(J) are set for all occupants, SPD can then used in program DEC3 for the actual speed of the current occupant being considered. Occupant J refers to any of the occupants in the building.

SPD1. When occupant J considers the fire to be serious (i.e., ACT1(J)=2), he increases his travel speed. This increase is accomplished by multiplying his normal speed by the parameter SPD1. It is set equal to 1.3 in instruction 1006 of program DEC1. This value of SPD1 increases travel speed by 30%.

TCYCLE. TCYCLE is the number of seconds in one time period. It is set equal to 5.0 in statement 1050 of program DEC1 and this value can be superceded through the keyboard if the appropriate options are selected after choosing to use an "advanced" features of the program. If the fire is loaded into the computer by running program SMOKE9, TCYCLE could be assigned a value by a statement in the SMOKE9 program: this would supercede the value assigned in statement 1050 of program DEC1 but not the value assigned through the keyboard.

TH. TH is the threshold for an occupant to respond. The sum of the impact of all fire cues or fire stimuli must equal TH units for any occupant to respond: otherwise he will ignore the fire stimuli. The value of TH is set equal to 20.0 in instruction 1008 of program DEC1.

> Awake occupants are given an extra 15 units when computing the sum of the impacts of the fire cues. This is mathematically equivalent to decreasing TH by 15 for awake occupants. These 15 extra units are given in instruction 5125 of program DEC3: it is the value assigned to X4. The value assigned TH in statement 1008 of program DEC1 must be greater than the value assigned to X4 in statement 5125 of program DEC3.

TOL(I). There are five levels of smoke tolerance used in this simulation. Their values are set in instruction 1007 of program DEC1. In applying four of these parameters, TOL(1) through TOL(4), the measure of the impact of the smoke is called SMOKE. SMOKE is twice the product of two factors: 1. the optical density of the smoke and 2. the ratio of the depth of the upper smoke layer to the height of the room. That is, it is the optical density of the

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smoke in the upper layer (SDUL(I)) if the room is half filled with smoke. (See discussion of S in Section 2.2.2 and instruction 3095 of program DEC3.)

TOL(1) is the threshold for stopping action. It is set equal to 0.5. If an occupant tries to reach a node with this level of smoke, he will cease all action, unless the lower layer of cleaner air is greater than 1.2 meters (3.9 feet) in depth; that is, he will stop movement unless he can crawl under the smoke.

TOL(2) is the threshold for not entering a room. It should be noted that an occupant will not be assigned a route that involves entering a room with smoke density greater than TOL(2) unless the lower layer of cleaner air is greater than 1.2 meters. It is set equal to 0.4.

TOL(3) is the threshold for quickening the pace of an occupant's actions. It is set equal to 0.1. If Occupant J encounters this much smoke, ACT1(J) is set equal to two. When ACT1(J)=2, travel speed is increased by 30% and some response (delay) times are less (See Section 4.3. Delays and Pauses, and the above description of SPD in this section).

TOL(4) is the threshold for terminating an investigation or deciding an investigation is not necessary. When SMOKE>=TOL(4), there is enough smoke for an occupant to realize that egress is necessary. It is set equal to 0.05.

TOL(5) is the threshold for activating a smoke detector. If the upper or smoke layer has optical density greater than or equal to TOL(5) and if the depth of the smoke layer is greater than .15 meters, a smoke detector will sound. TOL(5) is set at 0.015 per meter. The depth of .15 meters is set in instruction 5031 of program DEC3.

TPAUSE. TPAUSE is the time allotted for an occupant to spend between completion of an action and the start of the next action. It basically accounts for decision time. TPAUSE is set equal to 3.0 in instruction 1009 of program DEC1. It is used after completing an investigation and after finding that a path is blocked by smoke.

5.3 Delays and Action Times.

5.3.1 Introduction. The time consuming activities of an occupant can be classified into three categories.

Movement from one node to another. (This section is not concerned with these actions.)

Delays and pauses. These activities include time to awaken, time to make decisions, and time to prepare for action.

Assisting actions.These activities include awaking another occupant and preparing another occupant for egress.

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The delay time, the decision time, and time to perform the assisting actions (hereafter called Delay Times) depend on the fire characteristics and the impact of the fire cues on the occupant. In this section, the times assigned to these actions will be presented and, also, information will be provided that will permit the user to change these assigned times by making changes to statements in program DEC3. (The time to move from one node to another and the time to become aware of the fire cues will not be discussed in this section: those times are treated differently and they have been amply discussed in earlier sections.)

The numerical value of most Delay Times is specified in a program statement as a number rather than as a parameter. Therefore, to change its value, i.e., the time duration, the number in the statement must be changed. To permit the user to change these Delay Times, the relevant statement is identified. One exception is the decision time after completing some of the actions: see discussion of TPAUSE in Sections 5.2 and 5.3.2.

The normal (i.e., smoke is not bad) minimum response (delay) time is 6 seconds for awake occupants. This includes decision and preparation time. It is based on the work of Nober [Nober et al, 1981]. It is set in statement 5257 of program DEC3. A new value can be selected by substituting the new value for the number 6 both times it appears. If the smoke is bad, this can drop to 4 seconds (if SMOKE>=TOL(3)) or to 1 second (if SMOKE>=TOL(2). (See statements 5263 and 5265 where TRESP(J) is the response time for occupant J.)

5.3.2 <u>TPAUSE</u>. When an occupant completes his action (e.g., reaches his goal) or terminates his action (e.g. blocked by smoke), he is assigned a delay time of TPAUSE seconds. (See TPAUSE in Section 4.2 for the assigned value of TPAUSE.) This delay includes the time required to choose a new action. There are times, however, when the usual delay time is not assigned.

    Exception 1. There is no Delay Time assigned when the completed action is to alert an able and awake adult to the fire emergency.

    Exception 2. There is no Delay Time assigned when the occupant arrives at the room of someone needing assistance.

    Exception 3. When the action is to wake a sleeping occupant, the rules in Section 5.3.5 apply.

There are currently four cases where the Delay Time of TPAUSE seconds is assigned.

    Suppose an occupant is moving towards another occupant in order to alert, awaken, or assist that person. If for some reason the second person awakens, becomes alerted to the fire, or is being actively assisted by a third occupant before the first occupant arrives, the first occupant will change his action, i.e., change his decision in mid-route and be assigned a Delay Time of TPAUSE (decision time for choosing another course of action). See statement 2134 of program DEC3..

If the chosen route is found to be blocked by smoke, the occupant will stop and select another route or action. The time taken to decide on another course of action will be accounted for in the assigned Delay Time of TPAUSE. See statement 6868.

After seeing sufficient smoke or fire to stop the investigation, the occupant will decide on another course of action. After a Delay Time of TPAUSE, he will start his next action. See statement 6886.

After arriving at the end point of the investigation--the room with the most smoke or with visible flame--the occupant will decide on another course of action and be assigned a Delay Time of TPAUSE accordingly. The occupant will then start his next action after the Delay Time has elapsed. See statement 6973.

5.3.3 <u>Decrease in Preparation Time Due to Heavy Smoke</u>. When an occupant is subjected to normal fire stimuli, a ten second response delay time is assigned to a sleeping occupant and six seconds to an awake occupant. (See instructions 5257-5258.) (Note the response time will be greater if the fire stimuli are not sufficiently strong for a timely response--See Section 4.5.1.)

Exception. If the fire cues are sufficiently strong or long lasting such that the occupant is scheduled to respond within 10 seconds, the maximum remaining delay time of the occupant is: four seconds if SMOKE=>TOL(4); or one second if SMOKE=>TOL(3). These delay times can be changed by changing the values related to TRESP(J) in instructions 5263 and 5265. (Note the need for two changes in each instruction.)

5.3.4 <u>Hesitation Due to Not Being Alone</u>. Research by Latane and Darley [Latane and Darley, 1968] has shown that when the fire cues are noticed but not immediately compelling, adults will hesitate in their responses if other capable adults are in the same room. A simple explanation is that there is a failure to respond due to a feeling of shared responsibility. The computer program accounts for this by delaying responses by one time period for each time period when <u>all</u> of the following conditions apply:

1. There is no one that needs to be rescued, alerted, or roused (see instruction 7225 of program DEC3);

2. There is another fully capable adult occupant in the same room (see instructions 7332-7344);

3. None of the smoke detectors is sounding (see instructions 7345-7347);

4. There is no visible flame (see instruction 7348);

5. The fire cues are noticed but are not taken very seriously by the occupant(s) i.e., AWARE(J)>=TH <u>and</u> AWARE(J)<TH+10--see instruction 7350.

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5.3.5 Time Required to Alert, Wake or Prepare for Evacuation. Whenever one occupant assists another, time for providing or receiving the service must be assigned. The following times are assigned:

If Occupant J is alerting a fully capable and awake adult, he moves to the node of the other occupant. Once he arrives at that node, Occupant J starts his next action with no delay or decision time charged. The occupant being alerted is assigned a Delay Time of five seconds or 2.5 seconds depending on whether the alerting occupant believes the fire to be serious (i.e., ACT1(J)=2). These delay times can be altered by changing values of TRESP(JK) in statement 6971. (See Section 4.6.4, Criterion for Fire to be Considered Serious.)

There are two types of assistance that an occupant may be flagged as needing: waking; and help moving. If an occupant is asleep and does not need help moving, the delay is five seconds for the occupant doing the waking. (See value of ZZZ in statement 7642 for assigned waking time. See statement 7676 for the adjustment of TCR(J)--time remaining in the time period. In statement 7676, Y is the time, if any, required to travel within the room to the node of the occupant needing assistance--see statements 7636-7639.) For the occupant who is being awakened, the delay is ten seconds. His remaining time in the time period is the amount assigned the person waking him plus 5 seconds-- i.e., plus ZZZ seconds--decision and preparation time. (See statement 7684.)

Exception: if the assisting occupant believes the fire to be serious (i.e., ACT(J)=2) the value of ZZZ would be halved (see instruction 7670). Therefore, his time devoted to waking would be only 2.5 seconds and the total delay time for the previously sleeping occupant would be 5 seconds . (See Section 3.6.4, Criteria for Fire to be Considered Serious.)

If an occupant needs help moving, the Delay Time (starting at the time the assisting occupant arrives at the location of the other occupant) is 10 seconds if the disabled occupant is awake and 12 seconds if he is asleep. (See value of ZZZ in statement 7643.)

Exception 1. If the disabled occupant is a baby (i.e., AGE(JK)<=BABY), the Time Delay in seconds is the baby's age plus 4. (See value of ZZZ in statement 7646.)

Exception 2. If the capable occupant believes the fire to be serious (i.e. ACT(J)=2), the previously determined Delay Time is halved. (See value of ZZZ in statement 7647.)

Note: if you wish to make a change in the Delay Time in statements 7642 or 7643, change the values of ZZZ but do not change the values of Z.

6.0 DESCRIBING A NEW BUILDING, ITS OCCUPANTS AND THE FIRE

6.1 Introduction.

There are three ways of entering input data when running the simulation:

Enter input data through the keyboard by answering questions;

Enter input data saved from a previous run;

Enter input data by chaining to programs that contain data in DATA statements and LET statements and that call data files. These programs will be called INPUT PROGRAMS.

In this chapter we will discuss; the structure of the INPUT PROGRAMS; the format of the data files; and the structure of the subroutines in programs DEC1 and DEC3 that draw the building layout.

This section is written for a user who is familiar with the BASICA programming language. It is recommended that you not attempt to make alterations in the input programs unless you have a knowledge of BASICA.

Warning!! Do not make changes in the program before you have made copies of the original disk.

The set of computer programs and data files comprising this simulation contains the characteristics of three buildings, nine fires and eight different sets of occupants. The information is stored in the form of computer instructions in a number of separate programs and data files.

There are three programs that contain the characteristics of the three buildings, one program for each building. They are called BLDG1, BLDG2 and BLDG3.

There are nine data files that contain the characteristics of the nine fires, each containing the characteristics of one fire. They are called SMOKE1.SMK, SMOKE2.SMK, etc. One program, called SMOKE9, contains information about the loudness of the smoke detectors and about the position of the bedroom doors in the one story building. Program SMOKE9 also calls the appropriate data file containing information about smoke conditions.

One program, called OCC1, contains the characteristics of all eight sets of occupants.

One additional program, BLDG4, is also provided. It is only half written and can be completed by the user as he defines a building of his own selection. Together with additions to programs DEC1, DEC3/COMP4, SMOKE9 and OCC1, the user can add another building of the user's choice.

In this section, we will discuss how to add an additional building, fire and set of occupants. This discussion will also provide sufficient information to permit the user to modify the characteristics of the other buildings, occupants, and fires, although the focus of the discussion will be on adding a completely new building, fire, and set of occupants.

If the user wishes to add a second new building after defining the first one, it is recommended that he add it on a separate disk, starting with the original set of programs and using BLDG4. Similarly, if the user changes the characteristics of a building, he should do it on a separate disk and save the original disk.

If the user adds a new building, he must also add: 1. new occupants by modifying or expanding program OCC1, and 2. new fire data by modifying program SMOKE9 and providing a new data file for smoke characteristics.

6.2 Describing the Building.

6.2.1 Introduction. The characteristics of the new building will be contained in program BLDG4. A substantial part of program BLDG4 is devoted to locating nodes and occupants on the building layout on the screen. That part of the program is discussed below in Section 6.5, Layout of New Building.

Note in program BLDG1, most of the input data is in the 1000 series of statements; in BLDG2, the 2000 series; in BLDG3, the 3000 series; and BLDG4, the 4000 series: but the last three digits of the statement numbers are comparable for similar instructions in the four programs. Similarly, different series of instructions are used in the different programs that contain the smoke characteristics and within the program that contains the occupant characteristics.

6.2.2 Number of Nodes, Rooms, and Exits. The number of nodes, rooms and exits are entered as variables into the program in the form of LET statements. The number of nodes is variable NN, the number of rooms is NR, and the number of exits is NE. Statement 4010 of programs BLDG4 is reserved for entering the values of these parameters. Variable NB1 tells the computer what graphics mode to use: it is given the value of 2 in statement 4005 which directs the computer to use high resolution graphics.

6.2.3 Lengths of Links Between Nodes. The distance, in meters, between two nodes is stored in the matrix DIST(I,II). Initial values are defined as 999 meters in subroutine 500. The distance DIST(I,I) is defined equal to .01. because the shortest path routine would not work if it were zero: any positive value could have been assigned to DIST(I,II). When the link between the two nodes, node I and node II, is X meters, the length of the link is entered as a LET statement in the form DIST(I,II)=X. A separate entry is made for each link. The distance from node I to node II is normally the same as the distance from node II to node I: it is necessary to define the link only once, using either direction. Statements 4030 to 4039 of program BLDG4 are reserved for these entries. You may enter more than one DIST parameter per line, if you separate each statement with a colon. For example:

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```
4030 DIST(1,12)=2: DIST(1,15)=3.5: DIST(2,13)=1.5
```

6.2.4 <u>Defining Windows</u>. If an exit node X is a window that can be used as an
exit, set WINDO(X)=1 in instruction 4040. (Do not place a node at a window
unless it can be used as an exit: an unusable window can be shown in the
graphical representation of the building on the screen but it should not
considered as a node and it must not be defined as an exit node.) The values
WINDO(I) should be defined in instruction 4040 of program BLDG4. For example:

```
4041 WINDO(11)=1: WINDO(12)=1: WINDO(18)=1: FRONT=3
```

When determining the desirability of a path, 100*(WINDO(I)) demerits are given
if the egress path involves going out window I. Note that exiting by window
II could be given fewer or greater than 100 demerits by assigning WINDO(II) a
value less or more than one, respectively.

6.2.5 <u>Front Door</u>. The number of the exit node for the front door is entered
in instruction 4040 of program BLDG4 as the value of the variable FRONT. (See
above example.)

6.2.6 <u>Room Location of Nodes</u>. If there are NR rooms, each of the first NR
nodes are assigned to a room of the same number (e.g. node 1 is in room 1).
This assignment is made automatically by statements 4064-4068 of program
BLDG4. The exit nodes are not considered to be in any room. If there are
additional nodes, it is necessary to inform the computer in which room they
are located. This information is stored in parameter RMNOD(I). If node Y is
in room X, then RMNOD(Y)=X. This information is entered in instructions 4060-
4063 of program BLDG4. For example:

```
4062 RMNOD(15)=7: RMNOD(16)=4: RMNOD(17)=4
```

6.2.7 <u>Height of Rooms</u>. The heights of all the rooms in the other buildings
is set at 2.4 meters, i.e., as close as we can get to 8 feet using two
significant digits. The heights are set in instructions 4130-4134. The user
can change the heights, if he wishes, by a simple change in these
instructions. Note that parameter HR(I) is the height of room I. If there is
a staircase in your building, and the staircase is a room, double the height
of the room and add the thickness of the floor/ceiling construction. Line
4140 is reserved for this type of modification. Also note that the default or
"no smoke" value of SDLL(I), the height of the lower smoke layer, must be set
equal to the height of the room in this instruction. (The reason for this is
explained in the next section.) For example:

```
4132 HR(I)=2.4: SDLL(I)=HR(I)    '--existing instruction
4132 HR(I)=2.3: SDLL(I)=HR(I)    '--new instruction if we want to change
the room heights
4140 HR(4)=4.7: SDLL(I)=HR(I)    '--room 4 is stairs
```

If a computer model is used to provide the characteristics of the spreading
smoke, it must use the same room heights as the EXITT model.

6.2.8 <u>Combining Rooms</u>. This set of computer programs can model a building with up to 12 rooms. The programs that distribute the smoke (i.e. programs that provide input to the EXITT model) also have limits on the number of rooms that can be modelled. To keep the number of rooms within the prescribed limits, it is sometimes necessary to treat several rooms as a single room.

Normally one would consider the hall or foyer at the bottom of a stairs, the stairs, and the upstairs hallway as three separate rooms. However, it may be desirable to treat the foyer, the stairs, and the upstairs hallway as three (or more) nodes of one room. If this is done, the smoke conditions of the three areas should be treated differently because the psychological and physiological impact of the smoke in the three areas are different. This is handled by treating the combined area as one smoke compartment with different heights of the floors and ceilings for the various nodes in the compartment. The height of the ceiling, i.e., HR(I), in relation to the bottom of the smoke compartment, must be defined for each node.

Similarly, the height of the floor--HF(I)--in relation to the bottom of the smoke compartment must be defined for each node. Since the usual value of HF(I) is zero, and HF(I) is automatically assigned a value of zero, nothing needs to be done unless we combine a stairway with the upstairs hallway. Similarly, the program assigns the same value of HR(I) for all rooms and nodes and nothing needs to be unless we combine the stairway with a portion of the downstairs. The special values of HR(I) and HF(I), if any, can be specified in statement 4145 and 4146

6.3 <u>Smoke Characteristics</u>.

6.3.1 <u>Introduction</u>. Each fire is stored in a separate data file with a name that starts with the word SMOKE. The next character is the building number: an additional digit may be used to distinguish among different fires for the same building. The suffix is .SMK. The data file name reserved for the first fire in the new building, building 4, is SMOKE4.SMK

Statements 5000-5090 in program SMOKE9 contains information about one fire scenario. Each of the eight succeeding blocks of 100 statements contains information about another fire scenario. The block of statements from 5900-5990 is reserved for a new fire scenario. The organization of the data in the nine blocks of statements are similar.

6.3.2 <u>Smoke Characteristics</u>. The current version of this simulation is based on the assumption that there are two layers of air in each room--an upper layer contaminated with smoke particles and a lower layer that is practically clear. The two characteristics of smoke that are used are: 1. the optical density of the upper layer with smoke; and 2. the depth of the lower clear layer (i.e., the distance from the floor to the upper (or smoke) layer). Before a fire takes place, the depth or height of the lower "smoke" layer is equal to the height of the room. This is because there is no smoke in the room. If the room were to become completely filled with smoke, the depth of the lower layer would be equal to zero because there would be no more clear air left in the room.

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The two sets of smoke characteristics for each room for a single time period are stored in the data file whose name is stored in the string XX$. For a fire in the new building, XX$ is defined as SMOKE4.SMK in statement 14118. However, the user will be given the opportunity to change this data file through the keyboard (see subroutine 7000 of program SMOKE9).

In the data file, each data entry is a separate data record. If there are N rooms, there will be (2*N)+1 entries for each time period. The first N entries will be the optical densities of the N rooms in sequential order of the room number (i.e., the smoke density of room one will be first). The second N entries will be the depth or height of the lower clear layer in each room, again in sequential order of room number. The last entry will be 999. The computer will accept any value for the smoke densities and height of the lower layer but will check to see if there are 2*N entries between the 999 entries. The height of the lower layer should not exceed the height of the room (but it may exceed the height of a foyer if the foyer is in the same room as the stairs).

If the data file contains data in a different format, statements 7100-7170 can be modified to accept the new format.

6.3.3 <u>Number of Time Periods</u>. The current version of the program can input from a data file smoke conditions for 102 time periods. (The limit comes from one of the dimensions of the matrix of smoke values.) The actual number of time periods for which smoke data is obtained from a data file is NZ and the value of NZ should be entered in instruction 14116 of program SMOKE9. If the simulation is run for more than NZ time cycles, then smoke conditions for the NZth time period can serve as the smoke conditions for the remainder of the simulation. However, if the simulation is run for more than NZ time periods, the user will have an opportunity to change the smoke conditions in all time periods following the NZth period.

6.3.4 <u>Description of the Fire</u>. Statements 14110-14111 are reserved for a brief description of the fire. The description can be either a comment statement or the part in quotes of a print statement. Remember to put an apostrophe before the comment to avoid a syntax error.

6.3.5 <u>Smoke Detectors</u>. The building may have up to three smoke detectors. (Building 1, i.e., NB=1, can have only one detector. Also, since NB=1 for buildings defined through the keyboard, they also have only one detector.) These smoke detectors are independent and are not interconnected in any way. It is necessary for the user to provide the characteristics of the smoke detectors and how loud each detector would sound in each room of the building for any new fire scenario. Statements 14120-14130 of program SMOKE9 are reserved for these entries. The following parameters should be defined. NSD is the number of smoke detectors. DET(I) is the room (or node) where detector I is located. LROOM(N,I) is how loud (decibels) detector I will sound in room N: all combinations of rooms and detectors should be entered. (Note that detectors usually sound about 85 decibels in the room in which they are located, and they sound about 12-15 decibels less in an adjoining room if the door is open and about 24-30 decibels less if the door is closed.) See statements 5620-5628 for an example.

(If you are using statements 5000-5300 as a guide in making changes in a building stored in the computer, you should note that in building 1 the smoke detectors are treated differently. Because of the simplicity of the building, there would normally be only one smoke detector and it is possible to let the computer compute the loudness of the detector in each room. However, it is necessary to input information about the bedroom doors that are closed-- default position is open. An example of the instructions for doing this are located in statements 5140-5159 of program SMOKE9.)

6.3.6 Background Noise. The background noise in each room is set as 35 decibels in statements 4082-4086 of program BLDG4. If any room has a greater amount of background noise, this information can be entered in statement 4088 of program BLDG4. If the background noise in room I is X decibels, then NOISE(I)=X.

6.4 Occupant Characteristics.

6.4.1 Introduction. The characteristics of all occupants are in program OCC1. The space reserved for the occupants of the new building is the 3000 series of instructions. The OCC1 program will not accept the new set of occupants until statement 400 is changed to read: 400 GOTO 3000

As you enter the characteristics of the occupants, be sure to keep statement 3000 as an instruction or comment statement.

The 3000 series of statements, when constructed as described in this section, will be similar to the nine series of statements starting with statement 2000. They can be used as examples.

6.4.2 Number of Occupants. Set the parameter NP equal to the number of occupants in statement 3005.

6.4.3 Age. Set the parameter AGE(J) equal to the age, in years, of occupant J in statement 3010. A separate LET statement is needed for each occupant: they should be separated by colons.

6.4.4 Disabilities. An occupant either is fully capable when awake or is in need of assistance to evacuate. The actions of capable children are limited solely as a function of age, e.g., they may be too young to rescue others. If ACT(J)=1 or AGE(J)<=BABY, then occupant J is treated as one who needs assistance escaping. Setting ACT(J)=1 is the only way of flagging an occupant of age BABY+1 or older as needing assistance in moving. This should be done in statement 3011. (To avoid careless errors, you may wish to set ACT(J)=0 for the capable occupants.)

6.4.5 Sex. When SEX(J)=1, occupant J is a male. When SEX(J)=0, occupant J is a female. The sex of the occupants should be defined in statement 3015.

6.4.6 Location of Occupants. The parameter RP(J) signifies the room number

in which occupant J is currently located. The initial room locations should be defined in statement 3020.

6.4.7 <u>Sleep</u>. When SLEEP(J)=0, occupant J is asleep. When SLEEP(J)=1, occupant J is awake. The initial sleep status of each occupant should be defined in instruction 3030.

Some occupants are deep sleepers and require more stimuli than the average in order to awaken from sleep. The deviation from the norm is indicated by the value of the parameter CSLP(J). When CSLP(J)=0, occupant J requires the normal amount of stimuli to awaken. As a general guideline in setting the value of CSLP(J), consider the units as additional decibels required to awaken the occupant. Note the parent of an infant is likely to awaken more easily than most people and might be assigned a small (say less than 8) negative value for CSLP(J). Values of CSLP(J) are defined in statement 3035.

6.4.8 <u>Travel Speed</u>. The parameter SPD is the normal travel speed of the occupants. It is set in statement 1006 of program DEC1. In subroutine 1910 of program OCC1, the speed of all occupants is set as SPD. The speed of occupant J is stored in parameter SPEED(J). If you wish to set the normal speed of any occupant to be different than the value of SPD, you can override the speed set in subroutine 1910 by defining a new value for SPEED(J) in statement 3091.

6.5 <u>Output to TENAB</u>.

When this model is being used as part of the Hazard Assessment Methodology, it provides a data file specifying all movements of the occupants. TENAB is a model that determines the physiological impact of the toxic gases and heat on the occupants. It uses as input the data file specifying all movements of the occupants. The name of the data file must have the suffix .EVA. The name of the file for the fire in the new building is given in statement 14105. The user will be given the opportunity to change the name through the keyboard. The name given by the program can also be changed by changing statement 14105.

6.6 <u>Layout of New Building</u>.

6.6.1 <u>Introduction</u>. The simulation is designed for use at the computer with the results being displayed on the screen. It includes displaying the floor layouts, and the movements of the occupants in the building: the layout is displayed on the monitor screen using the computer graphics of BASICA.

The simulation program contains the layouts of three buildings: a ranch house; a townhouse; and a detached house. The model is designed to print the appropriate layout on the monitor screen during the running of the model. The user may add a fourth building of his choice. To add the layout of the new building, it is necessary to develop a set of instructions that will draw the floor layouts and that locates nodes on the layout. While this is relatively easy, it can be very time consuming, especially if you show details of the layout in the graphics.

6.6.2 <u>How to Skip the Graphics</u>.   You can run the program without developing
the instructions that draw the layout by either of the following methods:

1.   Answer the question "DO YOU HAVE AN IBM GRAPHICS BOARD?" negatively
each time you run the simulation with that building; or

2.   In the program SMOKE9, add the instruction: 5 OWN$="Y"

Do not forget to delete this instruction when you want to run the
program with the graphics.

6.6.3 <u>How to Draw the Building.</u> The complete set of instructions for drawing
the new building must be included in both the DEC1 and the DEC3/COMP4
programs.   The first statement must be number 14110 and the last statement
must be less than 14199.   (These restrictions apply to both the DEC1 and
DEC3/COMP4 programs.)

The following instructions are for drawing the building in the high resolution
graphics mode.   The programs are written with the assumption that the layout
for the additional building will be in the high resolution graphics.   High
resolution graphics are used when NB1=2.

The screen is composed of 640 horizontal points and 200 vertical points.
(Numbering starts from the upper left corner of the screen.)   All of the
horizontal range may be used but only some of the vertical range is available:
the remainder of the screen is reserved for text describing the actions and
decisions of the occupants.   The vertical range reserved for the graphical
representation of the building is 61 to 181.

Detailed descriptions of the instructions used for drawing the building can be
found in the IBM BASIC MANUAL.   It explains the use of the PSET and DRAW
functions used in the BASICA language.   It is not necessary to draw the
building in the style (e.g., level of detail) used in drawing the other
buildings stored in this set of computer programs.   It is important, however,
to stay in the vertical range defined above.

The general approach used in drawing the other buildings is to start at line
61 using the PSET instruction.   (The horizontal coordinate should be selected
so that the final drawing is reasonably centered on the screen.)

In drawing the other buildings stored in this set of computer programs, the
simulation used diagonal lines to represent doors and gaps to represent
windows.   In drawing the building the following features of BASIC should be
noted:

1.   The length of a diagonal line is longer than a vertical or
horizontal line of the same number of units,

2.   On typical monitors, five vertical units are the same length on the
screen as twelve horizontal units (high resolution mode).

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3. Retracing a line does not affect its characteristics.

When drawing the buildings, select a scale so that the drawing will be in proportion to the actual dimensions. Two scales should be made: one for the vertical and one for the horizontal dimensions. The reason for two scales is because of feature 2 noted above. Remember that the vertical dimension should not exceed 120 units.

The 12000 and the 13000 series of statements of programs DEC1 and DEC3 are examples.

6.6.4 _Labelling Nodes._ It should be noted that the coordinate system for locating alphanumeric characters on the screen is different from that for locating lines on the screen. In the high resolution graphics there are 80 horizontal positions and 24 vertical ones, again counting from the upper left corner.

In the graphics mode, the LOCATE instruction can be used to place an alphanumeric character on the screen. The LOCATE instruction requires a pair of coordinates to define the desired location on the screen. If you give the computer the coordinates for the location of each node on the floor layout, the computer will show the location of those nodes (and the location of the occupants who are at that node). These coordinates are stored in matrix $G(I,J)$. $G(I,1)$ is the vertical coordinate of node I and $G(I,2)$ is the horizontal coordinate of the same node. Sometimes there will be more than one occupant at a node. The parameters $G(I,3)$ and $G(I,4)$ are for use when more than one occupant is at node I. They tell the computer where to place the second occupant in relation to the first.

When there are two occupants at node I:

1. If occupant 2 is to be shown below occupant 1, then

    $G(I,3)=1$ and $G(I,4)=0$;

2. If occupant 2 is to be shown above occupant 1, then

    $G(I,3)=-1$ and $G(I,4)=0$;

3. If occupant 2 is to be shown to the right of occupant 1, then

    $G(I,3)=0$ and $G(I,4)=1$, etc.

The values of $G(I,J)$ are stored in instructions 4900-4998 of program BLDG4 as DATA statements. It is suggested that instruction 4901 be used for node 1, instruction 4902 for node 2, etc. Each instruction should be a DATA statement with five numbers. The first four numbers should be $G(I,1)$, $G(I,2)$, $G(I,3)$ and $G(I,4)$ respectively. The fifth and last number must be 999. The first data statement will contain the data for node 1, the second for node 2, etc. For example in program BLDG1, the positions of the nodes for the Ranch house are entered as:

    1901 DATA 9,10,1,0,999
    1902 DATA 18,11,1,0,999

```
1903 DATA 18,17,1,0,999
etc.
```

The line number 1901 is the data for node 1, 1902 is the data for node 2, etc.
Using statement numbers starting with 4901, enter the data values that define
the node/occupant locations to suit your own building. (You may wish to use
program DEC1 to print the layout on the monitor screen, interrupt the running
of DEC1, and move the cursor across the layout on the screen to determine the
desired coordinates of the nodes.)

7 OUTPUTS

The program provides outputs in three formats:

1. A description of the decisions and movements of the occupants is printed on the screen as the simulation progresses. There will be frequent pauses to permit the user to read the text on the screen: the user can end each pause and permit the simulation to continue by pressing the RETURN key. The pauses and graphics can be suppressed by selecting the appropriate options.

2. A description of the decisions and movements of the occupants can be printed of the printer. Once the program starts, the first question posed to the user is, "DO YOU WANT TO USE YOUR PRINTER?"

3. A record of the movements of the occupants will be stored on hard disk drive if the program is run from the hard disk. The information recorded on the disk is designed to be used as input to program TENAB which determines the hazard for each occupant according to the room conditions encountered along the escape route. [Bukowski, Chapter 6.] The model provides this output only when the program is in the C disc drive, that is, on the hard disc.

When the movements of the occupants are stored on the hard disc, the information is stored in the following order:

1. Number of rooms, number of exits, total number of nodes, number of occupants, and length of one time cycle in seconds.

2a. Occupant number, initial room location of occupant, time in seconds (i.e., zero if it is the initial location).

2b. Height of floor at node in relation to lowest level in "room".

2c. Node number.

2d. Height of separation between lower and upper smoke layers.

2e. Smoke density of the upper layer.

3. Repeat steps 2a to 2e for each occupant

4. Repeat steps 2a to 2e each time an occupant arrives at a node. (Modify step 2a to reflect that we are not recording an initial location.)

The arrival time is recorded as an integer: it is obtained by dropping the fractional portion of the number. That is, there are no fractional seconds in this output although there are fractional seconds in the other outputs.

The name of the data file used to store these results is defined in program SMOKE9. The file name is a function of the fire scenario and is defined at the time the fire scenario is defined. See statements 5005, 5105, 5205, 5305, etc.

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DEFINITIONS AND DESCRIPTIONS OF PARAMETERS AND VARIABLES

ACT(J) is the current action choice of Occupant J. The choices are:

0. Initial setting. The choice of preferred action has not yet been addressed by the simulation.
1. Needs rescue. This is the choice if Occupant J has been classified as needing help in evacuation (see, for example, instruction 5266 of program DEC1).
3. Go to occupant (in other room) who needs rescue.
4. Investigate. Go towards room with greatest smoke.
5. Escape. Egress without helping others.
7. Go to occupant (in other room) who needs waking or alerting.
11. Rescuer assigned. This assignment is made to Occupant JJ--an occupant who needs assistance. This assignment is made when Occupant J makes the choice of going to rescue Occupant JJ.
13. Take someone out of building. This choice is permitted only if Occupant J and an occupant needing rescue are in the same room. (Use choice 7 if in different rooms.)
21. Rescuer has started assisting this occupant.
50. Awaiting new choice. This assignment is made when Occupant J has completed the actions required by his most recent choice of action, e.g. occupant completed investigation by arriving at room with visible flame.
100. Actions completed. This assignment is made when Occupant J has left the building. Note that in this version occupants do not reenter the building.

ACT1(J) is a flag to indicate if investigation is a permitted choice for Occupant J. Investigation is not a permitted choice for an occupant who has already completed an investigation or who has been awakened by an occupant who has completed an investigation.

0. Investigation is a priority choice.
1. Investigation is not a priority choice. See Section 4.5.3, Criteria for Setting ACT(J)=1.
2. Investigation is not a permitted choice. See Section 4.5.4, Criteria for Fire to be Considered Serious.

ACT2(J) indicates the status of Occupant J in accomplishing the goal of his most recent action choice.

0. Initial status including sleeping.
90. Successfully completed action or terminated investigation due to seeing flame or moderate smoke--accomplished goal.
93. Cannot reach GOAL using current shortest path--shortest path blocked by smoke.
95. Cannot reach GOAL--cannot find route using subroutine 6200.
98. Trapped--cannot find route to outside of building using subroutine 6200.
99. Waiting at a window for help in evacuating disabled occupant--all routes to exit doors are through bad smoke. Completed final action.

100. Completed final action--outside building.
    101. Needs assistance--that is, ACT(J) = 1, 11, or 21.

ADJ is an adjustment to TCR(J) that permits subroutines to be called at
different times in relationship to instruction 2158 of Program DEC3.

ADJ1 is an adjustment to TCR(J) that permits subroutines to be called at
different times in relationship to instruction 2158 of Program DEC3.

ADV(I) are switches for using or by-passing "advanced" features. Default
values are zero.
    ADV(1)=0. Bypass all "advanced" features.
    ADV(1)=1. Can use "advanced" features.
    ADV(2)=0. Will not store input data for future run.
    ADV(2)=1. Will store input data in file on disk.
    ADV(3)=0. Will not rerun simulation using input data from previous run.
    ADV(3)=1. Will rerun simulation using input data stored during a
         previous run where ADV(2)=1.
    ADV(4)=0 or 1. Progress of the simulation can be followed on the
         monitor screen.
    ADV(4)=2. Graphic presentations on monitor are suppressed and pauses
         that permit reading of the screen also are suppressed.

AGE(J) is the age of Occupant J. Children who have not reached their first
birthday are considered to be 0 years old. The maximum age permitted to be
entered through the keyboard is 110 (See instruction 5254 of Program DEC1).

ALARM(I) is a flag to indicate if there is sufficient smoke to activate smoke
detector I if it is working.
    0.   Not sufficient smoke to activate a detector.
    1.   Sufficient smoke (but detector may be broken and not sound.)

ALEFF is the difference between the loudness of the smoke detector alarm and
the background noise. It is used in the subroutine for calculating the
awareness index which starts with instruction 5000.

ALERT(J) is a flag indicating that someone is coming to alert occupant J.
    0.   Default value--no one is coming.
    1.   An occupant is coming.

ALONE(J) indicates if Occupant J is the only one in the room.
    0.   Occupant is alone.
    1.   Other occupants are also in the room.

AWARE(J) is the sum of the impacts of all the fire cues. It is described in
Section 4.4, Awareness of Fire.

B$ indicates if the smoke detectors are broken.
    "N". All smoke detectors are working properly.
    "Y". All smoke detectors are broken.

BABY is upper limit of the age of children who will not make rational
decisions.

C indicates if the monitor is color.
    1. Color.
    2. Monochromatic.

CFIRE is the scaling factor for seeing fire when determining how quickly an occupant will respond to the fire cues. See Section 3.5.3, Measures of Fire Cue Impact.

COLF is the scaling factor for smoke odor (olfactory sense) when determining how quickly an occupant will respond to the fire cues. See Section 4.4.3, Measures of Fire Cue Impact.

CLSP(J) is a sleeping penalty for occupants who have difficulty waking, such as occupants who have hearing loss and young children. Occupants who awake more easily than most, such as mothers of infants, can be assigned a negative penalty. The units are additional decibels. When entering the value through the keyboard, permitted values are -15 to 50.

CSMK is the scaling factor for seeing smoke when determining how quickly an occupant will respond to the fire cues. See Section 4.4.3, Measures of Fire Cue Impact.

DET(I) indicates the room location of detector I.

DIST(K,KK) is the distance from node K to node KK in meters. The distance from a node to itself is defined to be 1 cm. so that the shortest path algorithm will operate more efficiently. The distance from K to KK is defined to be equal to the distance from KK to K in this version. A distance of 999 meters or greater indicates there is no link between the two nodes.

DOPEN(I) indicates if the door to room I is open or closed. When entering a building's characteristics through the keyboard and when using the Ranch House, the room with the smoke detector is the corridor and it is considered to have no doors. This variable is not used when modelling two story buildings.
     0. open.
     1. closed.

DT is the distance, in meters, to be travelled by the occupant in this time period (or in the remaining time of this time period).

E is a flag that warns that an input value is not within the permitted range.
     0.   Value is within the prescribed range or the string is an acceptable string of alpha characters.
     1.   Value is not within the prescribed range or the string is not an acceptable string of alpha characters.
E has a second use. When screen is not in the graphics mode, pressing E, after a pause, will terminate the run. (See instructions 3165 of program DEC1 and 3162 of program DEC3.)

F is a count of the number of times the examples of the smoke densities have been printed. After 5 printings, the printing is suppressed. (See instruction 3651 of programs DEC1 and DEC3).

FAST indicates if the user will provide the smoke data through the keyboard.
     0. Provide smoke data through the keyboard.
     1. Use smoke data in data statements or input file.

FF indicates if this is the first or second series of passes through subroutine 7000 of Program DEC3. (See statements 2144 and 7140.)

FFF indicates if all occupants are either outside the building or are trapped. When this is true, FFF=0 and the simulation will end (see instruction 2948 of Program DEC3).

FIRST$ indicates if the user calls himself a first time user.
     "Y". Yes.
     "N". No.

FLAME(I) indicates the location of flame visible from room I.
     0.   No visible flame.
     1.   Flame in another room is visible from room I.
     999. Flame is in room I.

FRONT is the number of the exit node representing the front door (see, for example, instructions 1144-1148 of program DEC1).

G(K,II) is a matrix of information about the location on the screen of node K. (See Section 5.5.4, Labelling Nodes.)

G1 is a variable for the LOCATE instruction in locating an occupant on the screen. (See Section 5.5.4, Labelling Nodes and statement 11410 of programs DEC1 and DEC.)

G2 is a variable for the LOCATE instruction in locating an occupant on the screen. (See Section 5.5.4, Labelling Nodes and statement 11415 of programs DEC1 and DEC3.)

GOAL is the number of the node toward which the movement of an occupant is directed.

GOALJ(J) is the number of the node toward which movement of Occupant J is directed.

H$ indicates if some displays on the screen are to be bypassed because information is redundant and user is in a hurry.
     "Y". Yes.
     "N". No.

H(J) indicates the next time to print on screen the status of occupant J, if his status does not change earlier. Only has meaning if H$="Y".

HELP$ is a temporary variable indicating if an occupant needs assistance in evacuating. Y=Yes, N=No

HF(I) is the height of the floor at a node compared to the height at the bottom of a stairs. Applies only when there is more than one node in a room and the different node are at different heights, e.g., bottom of stairs & hallway at top of stairs, or room & balcony.

HR(I) is the height of room I in meters.

HUE indicates if the location of the occupants will be displayed on the screen. it is used in setting the color on the screen.
     0. Use colors for showing occupant locations.
     1. Use colors for showing only node locations.

I is the number of the room under consideration. It also is used as a general index number.

IFLAG is a flag that warns that an input value is not within the permitted range.
        0.   Value is within the prescribed range or the string is an acceptable string of alpha-numeric characters.
        1.   Value is not within the prescribed range or the string is not an acceptable string of alpha-numeric characters.

II is the number of a room or node. It is used when determining in which room a node is located.

III indicates the character position in a string.

J is the number of the occupant under consideration.

J9 is used to temporarily store the value of J.

JJ is the number of an occupant--usually an occupant who needs assistance of some sort (e.g. waking, evacuating).

JK is the number of an occupant--usually an occupant who needs assistance of some sort (e.g. waking, evacuating). There is no logical difference between JJ and JK.

K is the number of a node--often the node at the end of a path.

KK is the number of a node other than the one at the end of a path.

KK1 indicates the character position in a string.

KKK is the sequence number of a node on a route. It is used in recording the route to node J in PATH(J,KKK). PATH(J,KKK)=0 when KKK is greater than the number of nodes in the route.

LALARM is a measure of the loudness or signal intensity of all smoke detector alarms.   The measure used is decibels as heard by a person in the same room as the detector. (The possibility that the sound might vary within a room is ignored.)

LP is switch for sending output to the printer. This switch is part of each statement that sends output to the printer.
        0. Send output to the printer.
        1. Do not send output to the printer.

LROOM(I) is the loudness or signal intensity of the smoke detector alarm in room I. The units are decibels.

M$ indicates on which disk drive the program is stored.

MATCH1$ is a temporary string variable used in checking keyboard input.

MATCH2$ is a temporary string variable used in checking keyboard input.

MMM is an alpha-numeric character in ASCII code.

MN$ is string for use in the CHAIN command.

N is the number of a room or node--often a room being considered for entry and which needs to be evaluated for safety.

NE is the number of exits--doors and qualifying windows.

NELSON(I,J) is a array of variables that stores the values of input variables that change during a simulation run so that the run can be "repeated" using the same input data.

    NELSON(1,J)=ACT(J)
    NELSON(2,J)=RP(J)
    NELSON(3,J)=SLEEP(J)
    NELSON(4,J)=SPEED(J)

NLEN indicates the length of a string.

NN is the total number of nodes including exits.

N1 is a local variable.

NB is the building number of the building stored in programs BLDG1, BLDG2, BLDG3, and BLDG4.

NB1 indicates the screen resolution used in the graphics for the different buildings.
    1. medium resolution--used for one story buildings.
    2. high resolution--used for two story buildings.

NOISE(I) is the background noise in room I. The units are decibels. If NOISE(I)<35, it is treated as if it were 35 (see statement 5111 of program DEC3).

NP is the number of occupants.

NPATH(J) is the number of nodes in the route from the location of occupant J to his desired goal.

NR is the number of rooms.

NSD is the number of smoke detectors.

NT is the maximum number of time periods or time cycles to be simulated.

NZ is the number of time periods.

NZZ is the maximum number of time periods for which smoke conditions can be stored, i.e., DIM SDU(12,NZZ) and DIM SDL(12,NZZ).

OWN$ indicates if the computer operator is to define the building or if the computer will use a pre-defined building. After the building characteristics are entered, it is used to bypass the graphical representation.
    "N". User will not define own building and graphical representation of the building layout, and occupant locations will be shown on the screen.
    "Y". User will define own building and graphical representations will be bypassed.

P$ indicates if the user or the computer will place occupants in the building
    "N". User places occupants in the building by answering questions through the keyboard.
    "Y". Computer places occupants in the building from stored information.

PATH(K,KKK) contains the sequence of nodes in the path to each node K (i.e. the Kth row of the matrix defines the path to node K). Zeros indicate that the path to node K was fully described by previous (more to the left) cells in row K.

PATHJ(J,KKK) indicates the sequence of nodes (path) in Occupant J's route to his goal. Zeros indicate that the path to node K is fully described by previous (more to the left) cells in row K.

PPATH(J) indicates where on his route Occupant J is located. If PATH(J)=KKK, then occupant J is located at node PATH(J,KKK).

Q$ is a switch that indicates if the computer operator will be given the opportunity to override or change some of the decisions made by the computer for the occupants.
>   "N". No, computer operator cannot override decisions.
>   "Y". Yes, computer operator will have an opportunity to override some of the decision.

QUICK indicates if there are any occupants who need assistance in waking or evacuating.
>   0. No occupants need help.
>   1. At least one occupant needs help.

R(XP) indicates the number of occupants found so far to be located at node XP. Used to prevent locating two occupants at the same precise location on the screen when they are at the same node (i.e. avoid erasing one occupant when locating another).

RMNOD(K) indicates the room in which node K is located.

RP(J) indicates the room in which Occupant J is located.

RR indicates the number of occupants already located on the screen at node XP. Used to prevent locating two occupants at the precise location on the screen even though they are at the same node. Note in instruction 11400 RR=R(XP)-1.

S(I) is used to define a block of times and rooms where the smoke conditions will be changed. That is, S(I) is used to define a block of rows and columns in matrices SDU(II,NZ) and SDL(II,NZ).
>   I=1. First time period
>   I=2. Last time period
>   I=3. First room in block.
>   I=4. Last room in block.

S1(K) is used in the shortest path algorithms (subroutines starting at instructions 6100 and 6200) to indicate the length (distance in meters or demerits, see Section 3.7.2, Handling Obstacles) of the shortest path found so far from node START to node K. S1(K) also is used to indicate changes that will be made in the input data, if the input data is entered into the computer using program AGAIN, i.e. if input data from a previous run is being used. Default values are zero.
>   S1(1)=0 or 1. No changes in occupants.
>   S1(1)=2. User will have opportunity to change characteristics of occupants through the keyboard..

S1(1)=3. User will be required to provide characteristics of new set of
          occupants through the keyboard.
S1(2)=0 or 1. No changes in building characteristics.
S1(2)=2. User will have an opportunity to change characteristics of the
          building.
S1(3)=0 or 1. No changes to fire/smoke conditions.
S1(3)=2. User will have opportunity to change some of the smoke
          characteristics.
S1(3)=3. User will enter the smoke characteristics as the simulation
          progresses.

S2(K) is used in the shortest path algorithms (subroutines starting at
instructions 6100 and 6200) to indicate if the path to K should be tested as
the first n-1 nodes of a path (with n nodes) to each of the other nodes.
    0.   The path to node K either has already been tested or it is not a
          promising candidate.
    1.   The path to node K needs to be tested to determine if it can be
          extended to form a shorter route to other nodes.

S4 is a flag in the shortest route algorithms (subroutines starting at
instructions 6100 and 6200) to indicate if any S2(K) has been set equal to 1
since the last check of the flag.
    0.   No value of S2(K) has been set equal to 1 since the last time S4
          was set equal to 0.
    1.   At least one S2(K) has been set equal to 1 since the last time S4
          was set equal to 0.

S5 is the length of a trial route in the shortest route algorithms
(subroutines starting at instructions 6100 and 6200). The units are meters or
demerits (see Section 4.6.2, Handling Obstacles).

S6(K) contains the numbers of nodes in the current shortest path from node
START to the other nodes. The origin node, START, and the destination node,
GOAL, are both counted.

SAV(J) indicates the occupant number of the occupant that Occupant J is
assigned to assist. If SAV(J) is 0, then Occupant J is not currently assigned
another occupant to awaken or rescue.

SDL(I,NZ) a matrix containing the values of SDLL(I) for all time periods.

SDLL(I) is the height of the top of the lower layer of smoke (i.e. the top of
the clear layer at the bottom) of room I for the current time period. The
units are meters.

SDU(I,NZ) a matrix containing the values of SDUL(I) for all time periods.

SDUL(I) is the smoke density in the upper layer of room I for the current time
period.

SETAL(I) indicates when detector I will sound.
    0. Will sound when sufficient smoke reaches the detector.
    1 or greater. Detector will sound at (SETAL-1) seconds. (Note the
          sound of the detector affects the decisions and actions of the
          occupants only if it sounds at the beginning of the time period.)

SEX(J) indicates the gender of Occupant J.
        0. Female.
        1. Male.

SHORT(J) indicates if a shortest path for occupant J from node START(J) to
node GOAL is stored in the Jth row of PATHJ(J,KKK).

SLEEP(J) indicates if occupant J is asleep.
        0. Asleep.
        1. Awake.

SLP indicates if an occupant is asleep, i.e., current value of SLEEP(J).

SMOKE is a measure of the impact of the smoke in a room (or at a node). See
instructions 3090-3098 of program DEC3.

SPD is the current travel speed for Occupant J in meters per second in program
DEC3. Before DEC3 is run, SPD is the normal speed of typical occupants.

SPD1 is a parameter (multiplier) for increasing the travel speed of an
occupant who considers the fire to be serious.

SPEED(J) indicates the normal travel speed of Occupant J. The unit of speed
is meters per second. If occupant characteristics are not entered through the
keyboard, SPEED(J)=SPD.

START is the number of the first node in a route.
        0. Shortest path not stored.
        1. Shortest path is stored.

SX indicates if screen is in the graphics mode.
        0. In graphics mode.
        1. Not in graphics mode.

TCR(J) indicates the time remaining for movement of Occupant J in the current
time period of time cycle. It is also the unused time at the end of the time
period. TCR(J) is often greater than the length of one time period because at
first it includes the length of the current time period plus the unused time
of the previous period.

TCYCLE is the number of seconds in one time cycle or time period.

TH is the threshold for awareness of fire cues in terms of loudness or volume
of sound, i.e. units of decibels. Measures of odor and visibility are scaled
to "equivalent" units of decibels.

TLENGTH indicates the approximate maximum length of the run in seconds. It is
defined in statement 1066 of program DEC1. The program will also stop
whenever each occupant is either out of the building or awaiting rescue at a
window. Periodically (every 10 time cycles as currently set in instructions
2911-12 of program DEC3) the computer operator has the option of stopping the
simulation.

TNOW indicates the number of the current time cycle or time period. TNOW = 1
for the time period beginning at time 0.

TOL(I) are parameters related to response to smoke. See Section 4.2,
Parameters.

TPAUSE is the time, in seconds, between completion of one action and the start of the next--decision time.

TRESP(J) is a delay time (in seconds) before occupant(J) will respond. Its initial value (set in instructions 4215 and 5251 of program DEC1) is 9999 or 999 which corresponds to infinity. Once an occupant decides to perform an action (e.g. investigate, evacuate) the value of TRESP(J) represents a response time that includes time for preparatory actions. Ten seconds is frequently used. Sometimes it includes time to wake up which can be up to 70 seconds.

W(J) indicates if occupant J has started moving toward his current or soon to be assigned GOAL.
 0. Has not yet started.
 1. Has started.

WINDO(K) indicates if an exit is a window. If an exit is not a window, it is assumed to be a door.
 0. Exit is a door.
 1. Exit is a window.

X is a local variable. It is often used as the temporary storage location of an input parameter while the computer checks if the input parameter value is within a defined range.

X$ is a local string variable.

X1 is a local variable. It indicates: 1, the location (node number) of an occupant in the graphics subroutine; 2, the first node of a link in the subroutine that moves occupants (starting at instruction 6800 of program DEC3); 3, the contribution of seeing the fire in the subroutine for computing the awareness index starting at instruction 5000 of program DEC3.

X2 is a local variable. It indicates the second node of a link and, also, the contribution of the odor of smoke in the subroutine for computing the awareness index starting at instruction 5000 of program DEC3.

X3 is a local variable. It indicates the contribution of seeing smoke in the subroutine for computing the awareness index starting at instruction 5000 of program DEC3.

X4 is a local variable. It indicates the contribution of being awake in the subroutine for computing the awareness index starting at instruction 5000 of program DEC3.

X5 is a local variable.

XHIGH indicates--for an input variable--at what magnitude a value is so high that the computer operator should review the input value before the computer accepts it.

XLL indicates the lowest value of an input parameter that the computer will accept.

XLOW indicates--for an input variable--at what magnitude the input is so low that the computer operator should review the input value before the computer accepts it.

XP is the node at which Occupant JJ is located. It is used in graphics only.

XT$ is a dummy variable used in examining structure of user's response.

XUL indicates the largest value of an input parameter that the computer will accept.

XX is a local variable.

Y is a local variable.

Y$ is a string variable used in checking to see if an input string is "Y" or "y" for a yes answer. See subroutine 3660-3669 of programs DEC1 and DEC3.

YY is a local variable.

Z is a local variable.

Z$ is a local string variable used in entering input from the keyboard.

ZZ is a local variable.

ZZ$ is local string variable.

ZZZ is a local variable.

ZZZ$ is a local string variable.
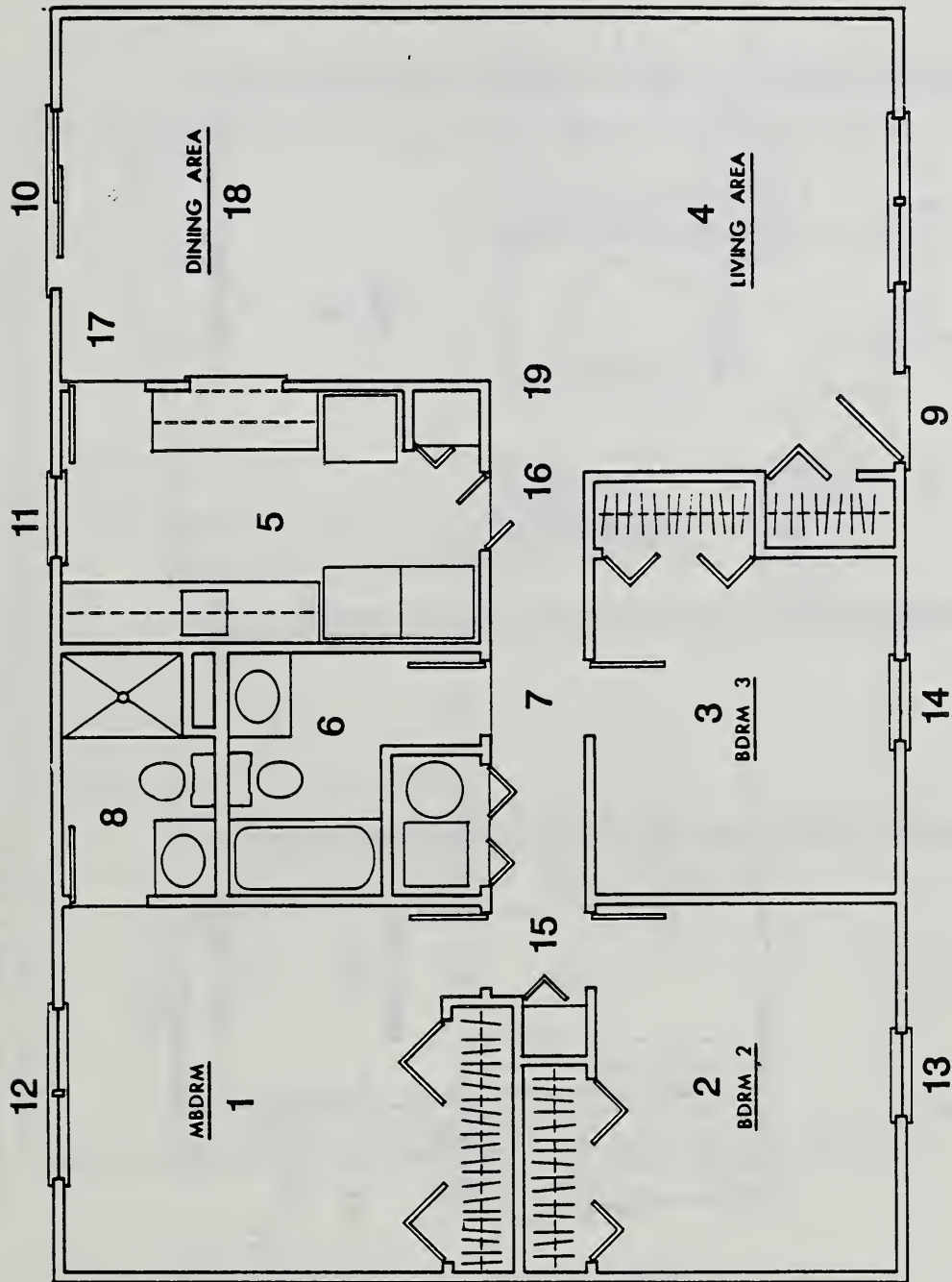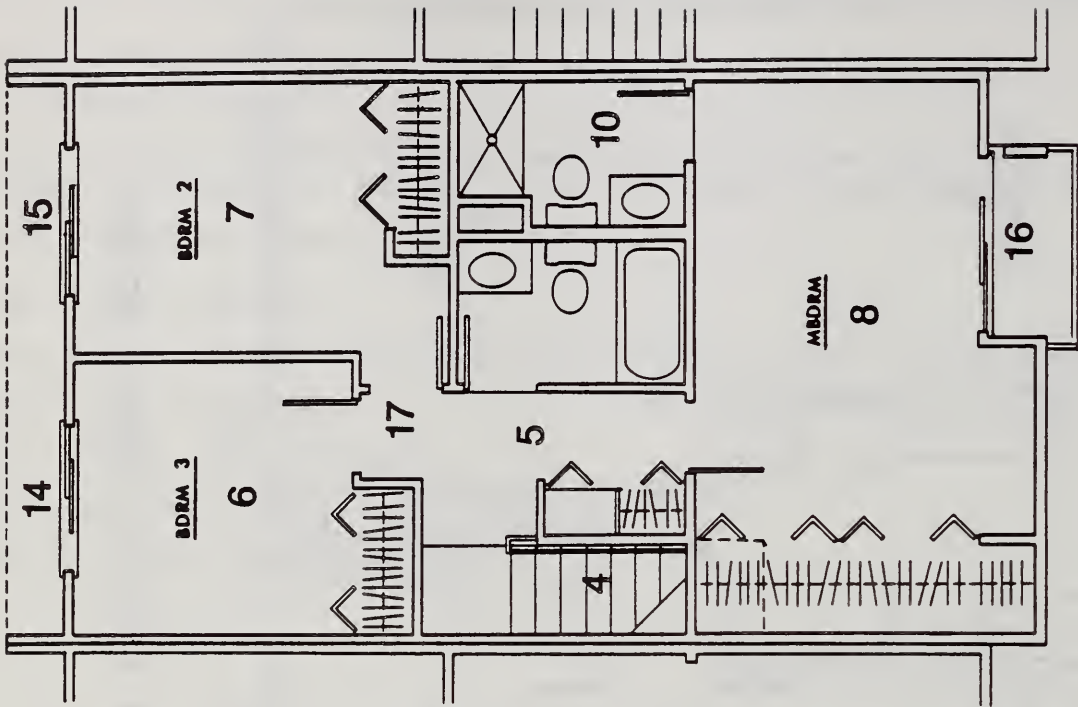
Figure 1a. FLOOR PLAN OF A TYPICAL RANCH HOUSE
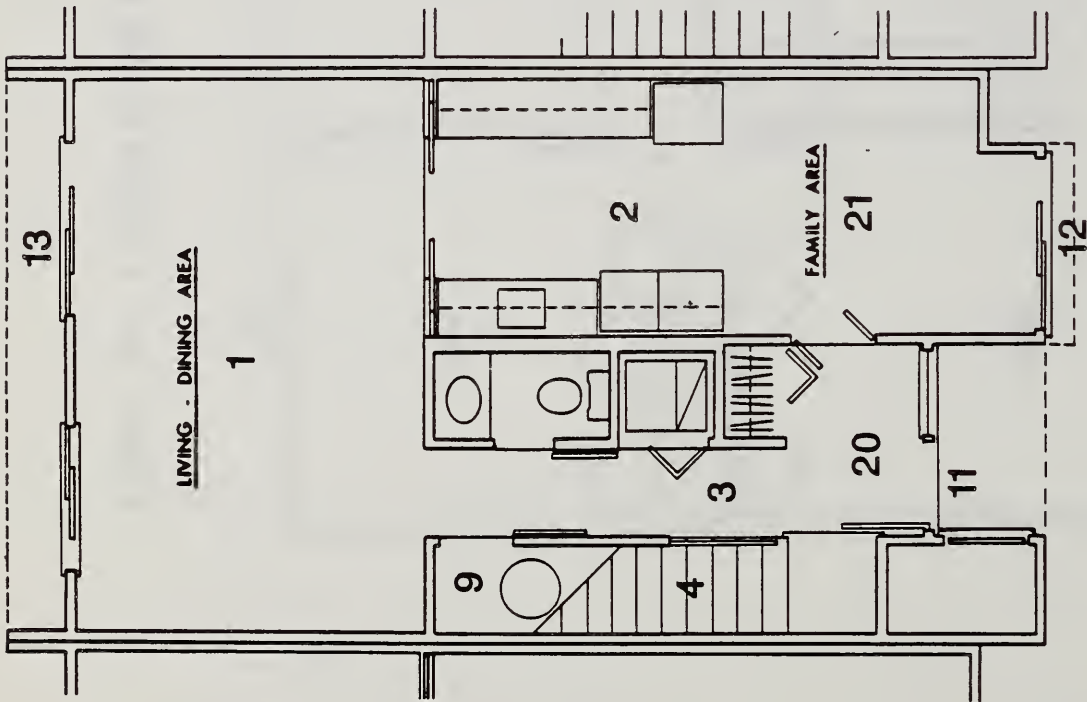
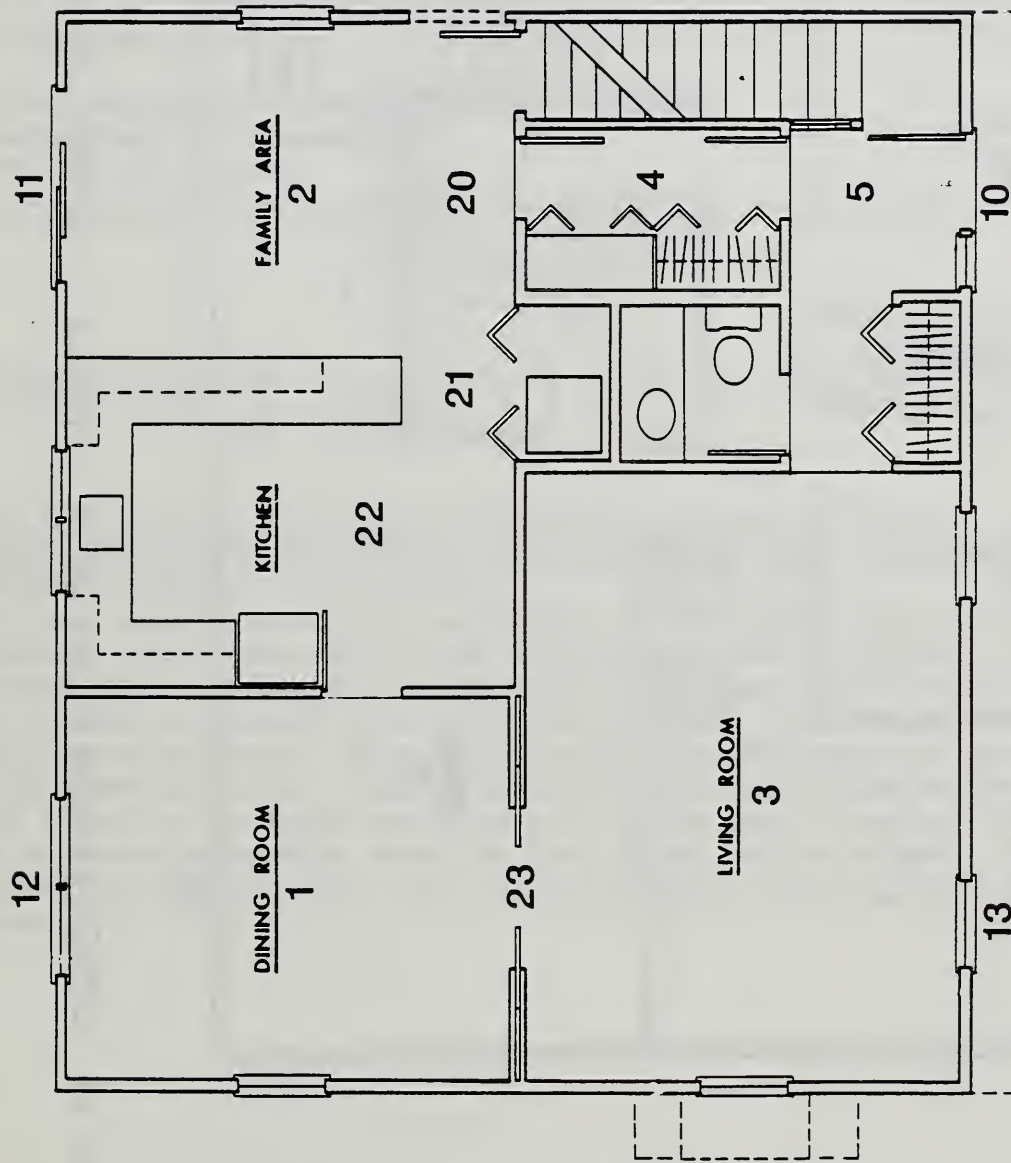Figure 1b. FLOOR PLAN OF TOWNHOUSE

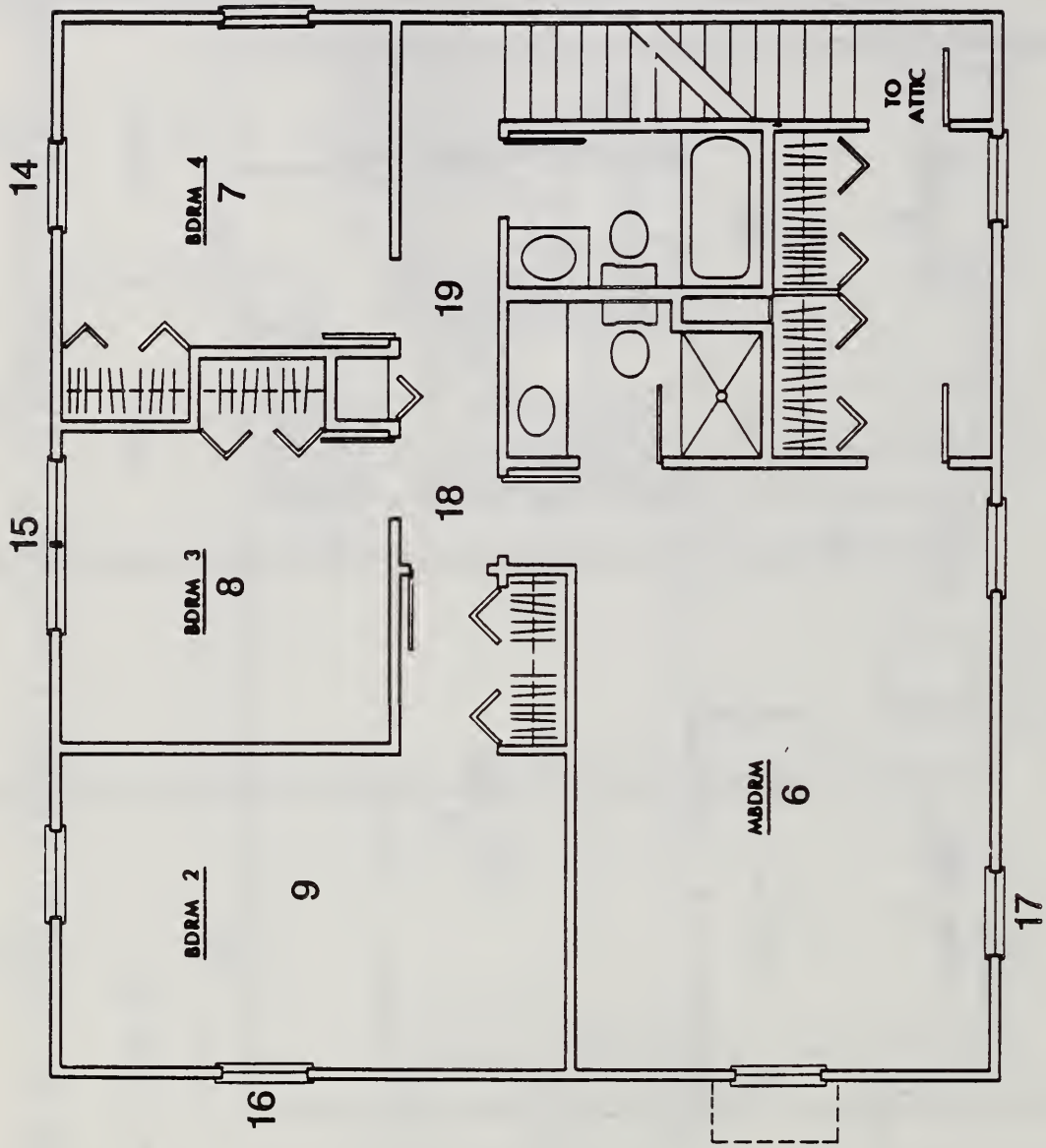Figure 1c.   LOWER FLOOR PLAN OF A TYPICAL 2-STORY HOUSE

Figure 1d. UPPER FLOOR PLAN OF A TYPICAL 2-STORY HOUSE

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4. TITLE AND SUBTITLE

EXITT - A SIMULATION MODEL OF OCCUPANT DECISIONS AND ACTIONS IN RESIDENTIAL
     FIRES: USERS GUIDE AND PROGRAM DESCRIPTION

5. AUTHOR(S)

Bernard M. Levin

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10. SUPPLEMENTARY NOTES

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

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

EXITT is a computer model that simulates the decisions and actions of occupants in a residence. This model can be used to determine the locations of the occupants during the progress of a given fire. The rules for the action choices of the occupants are based largely on studies of residential fires and to a lesser extent on relevant controlled experiments. These rules involve consideration of the smoke conditions, and the characteristics, capabilities and locations of the occupants. EXITT can be run on a personal computer and does not require user training-- the user controls the model by answering simple questions that appear on the screen. It can be run with pre-selected scenarios and, also, with buildings, fires and occupants selected by the user.

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

behavior models; building fires; computer models; decisions making; egress; escape; fire; human response; people movement; psychology; simulation

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