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FIRE MODELS TRAINING MANUAL FOR FSO'S

VOLUME 1: FASTLITE

by

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PART 1 : INTRODUCTORY NOTES

1. ABOUT THIS MANUAL.

The purpose of this manual is to provide training to Fire Safety Officer's (and other fire brigade staff) in the use of fire models to predict fire spread in a building and its consequences. The training is intended to familiarise FSO's with fire modelling through practical experience so that they can use fire models in connection with their work on assessment of the fire safety aspects of building designs. **However, it should be stressed that the predictions made by fire models should not be assumed to have any great accuracy but only serve to provide an indication of the likely outcome of the fire.**

This manual includes exercises in fire modelling which require the use of the model FASTLITE which the reader will need access to. FASTLITE is a zone-type model (see Part 1, Section 3) produced by the National Institute of Standards and Technology (NIST), USA. Copies of FASTLITE may be obtained from:-

National Fire Protection Association
One Stop Data Shop
1 Batterymarch Park
Quincy, MA
U.S.A.
Tel: 617-984-7450
Fax: 617-984-7060

Alternatively, FASTLITE can be obtained from the Internet at: www.bfrl.nist.gov/fire/fastlite.html.

This manual is one of a series available from the Fire Research and Development Group. The other volumes have a similar content but are based on the models ARGOS produced by the Danish Institute of Fire Technology and HAZARD-I, produced by the National Institute of Standards and Technology, USA.

2. BASIC REVIEW OF FIRE DEVELOPMENT

Fire models are based on an understanding of the physical processes involved in a fire. The following is a description of these processes which are illustrated in Figure 1.

Here we are concerned exclusively with fires which occur in buildings. The fire normally begins at a single location in one room (although this is not always so, particularly in the case of arson).

The burning of a solid item involves two main processes. Firstly, the material is heated to the point where it vaporises, a process known as pyrolysis. Secondly, the vapour produced mixes with the air and undergoes an exothermic (heat producing) chemical reaction with the oxygen present, a process known as combustion.

From the ignition point on the surface of the burning item, the flames spread, increasing the burning area. The combustion process releases heat, smoke and gases which rise from the burning material

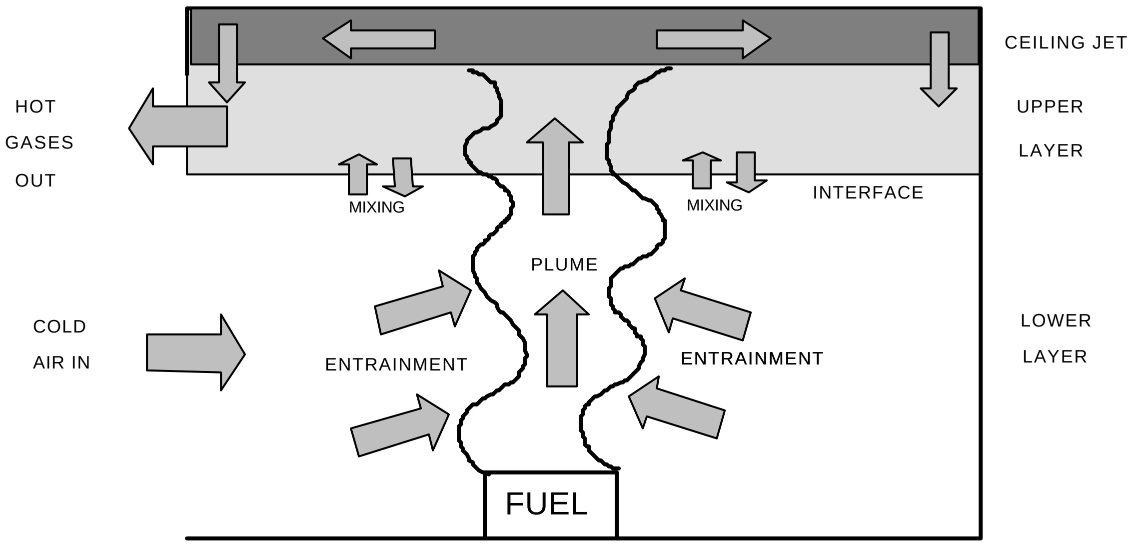

Figure 1 The Physical Processes of a Fire

in a plume. The gases produced typically include Carbon Dioxide, Carbon Monoxide, Hydrogen Cyanide and steam. Soot particles are produced from the incomplete combustion of the material, and these particles form smoke. On the other hand, oxygen is consumed by the fire which will cause the concentration of oxygen in the room to fall below the normal level which is 21% by volume.

The radiation from the fire heats the surfaces of further items in the room, causing further pyrolysis, and if the ignition temperature is reached, these items ignite and add to the fire. This process is called secondary ignition.

As the fire continues to grow, there may come a point where the radiation level in the room is high enough to cause a general ignition of all items, producing a sudden jump in the severity of the fire and the heat release rate. This process is known as flashover.

While the fire is burning, a plume of hot gases and smoke will rise from the fire. As the hot gases rise, driven by their buoyancy, further air is drawn into the plume from the surrounding space, a process known as entrainment. Usually, this plume reaches the ceiling, although this is not always the case if the fire is in a compartment of large height where a warmer air layer has already developed under the ceiling. When the plume reaches the ceiling, the hot gases delivered spread out under the ceiling in a layer called the ceiling jet. Fed by the ceiling jet, a layer of hot, smoky gases gradually builds up under the ceiling. This layer is usually referred to in fire modelling as the upper layer.

The air in the room can be regarded as divided into two main volumes: the upper layer of hot smoky gases and the relatively clear lower layer, with an interface between. However, in a real fire, mixing between the two layers occurs so that the interface is not distinct. As the fire proceeds, more gases are produced which are fed via the plume into the hot upper layer. The upper layer gets thicker and so the interface gradually descends towards the floor.

Openings to the fire room such as open doors or windows allow the fire products in the upper layer to spread to neighbouring rooms. These openings will also allow fresh air into the fire room which provide the fire with more oxygen and maintain combustion as long as there is fuel available.

If there are no openings to the fire room, the oxygen in the room is gradually consumed by the fire until the concentration has fallen to a level which can no longer support combustion when the fire stops burning.

Heat is transmitted around the fire compartment by three mechanisms.

(i) Heat is carried around by the currents of hot gases such as the plume. This is known as convection.
(ii) Heat is transmitted through materials by conduction. In the fire compartment heat is conducted into the walls, floor and ceiling where they are in contact with the hot gases.
(iii) Heat is transmitted through space by radiation. In the fire compartment heat is radiated from the fire and from the hot upper layer, to the surroundings.

3. WHAT IS A FIRE MODEL?

Although there are other ways of modelling fire, this manual is concerned with the use of computer models which predict the spread of the fire and combustion products using mathematical calculations carried out by the computer.

There are two types of computer fire model in common use: zone models and field models.

The zone model is a more simple representation than the field model; it divides the fire compartment up into a few large sections called zones such as the plume of hot gases rising from the fire and the hot smoky gas layer which builds up under the ceiling, and relies on well established but empirical relationships for the transfer of heat and smoke between these zones.

A field model divides the compartment into a large number of cubes, and calculates heat and fluid flow between each cube and its neighbours using the fundamental equations of physics. For this reason, field models are likely to be more accurate but require more computing power and so are more expensive to use.

4. CARRYING OUT A FIRE MODELLING STUDY.

The steps involved in a fire modelling study are as follows:-

- define the fire scenario(s)
- set up the input data
- run the model
- analyse the results

(i) **Definition of the Fire Scenario**. Once you have decided what you want to find out, the first step in the fire modelling study is to define the fire scenario of interest. This will include deciding where the fire will start, what materials are involved, whether doors and windows are open or closed, where the occupants of the building are located and whether any fire protection systems are present. If an overall hazard assessment of a building design is required, a range of scenarios should be considered, so that the main risks are covered.

(ii) **Setting up the Input Data**. Once the fire scenario has been decided, data is entered into the model to define the scenario. This data will include the following:-

- room dimensions
- locations and dimensions of doors and windows
- ceiling, floor and wall materials
- position of the fire
- heat release rate of the fire
- product generation rates (smoke and toxic gases) of the fire

Care must be taken in deciding on the input data. If the data entered is incorrect, the results will also be incorrect. When all input data has been entered, the data is saved to a file.

The heat release rate entered will typically have a critical effect on the results obtained. Typical heat release rates are given in Table 1. Other sources of data on heat release rate are the SFPE handbook (1) and the databases within the fire models FASTLITE, HAZARD-I (2) and ARGOS. The software packages ‘FPETOOL’ produced by the Building and Fire Research Laboratory, National Institute of Standards and Technology, USA, and ‘ASKFRS’ produced by the UK Fire Research Station both give methods of calculating heat release rates.

(iii) **Running the model**. Once the input data file has been created, the model is set running to calculate the progress of the fire specified. The time taken for the model to complete the fire simulation can vary from a few seconds to a few hours depending on the type of computer equipment used and the complexity of the scenario. The more rooms that are included, the longer the run will take. For some cases, FASTLITE takes only a few minutes to run on a PC with a 486 or Pentium processor but for other cases the run time is considerably longer. As the simulation proceeds, the results are displayed on the screen. At the end of the simulation, tables and graphs of the results may be printed out.

Furniture Item	Peak Rate of Heat Release (kW)
Waste-paper basket containing paper or milk cartons	4 - 18
Armchair	1000 - 2000
Sofa	1500 - 3000
Television	120 - 290
Mattress, twin-size	Up to 2800
Wardrobe, wooden, containing small amount of clothing	3000 - 6400

Table 1. Typical heat release rates of furniture items

(iv) **Analysis of the Results**. The results produced will include the following:-

- the temperature of the upper layer in each room
- upper layer depth in each room
- ceiling, floor and wall temperatures
- gas concentrations
- heat radiation

The results may be analysed from the tables and graphs which appear on the screen, from the print-out or from the output file which may be read by a spreadsheet package.

An important point is that the predictions from a fire model should not be assumed to have any great accuracy as there are many uncertainties in the modelling process. There are uncertainties in the input data, for instance the heat release rate profile of the fire may be different in reality from the profile assumed. Also, many approximations are made in the model which reduce the accuracy of the results, for instance all zone models are based on the assumption that the upper and lower gas layers are of uniform temperature, smoke and gas density throughout their volume and this is not the case in reality.

Because of the limited accuracy of the results, it is often more useful to look at the results comparatively to show the effect of making a change to the fire scenario. For instance the model could be run to predict the effect of an armchair fire and then repeated with a different armchair made of more fire resistant material.

Alternatively, the results from a single run of a model may be considered separately but it should be remembered that the results are only approximate. For this reason, it may be necessary to add a safety factor or margin for error to the results as this will not normally be included in the model.

It may also be useful to carry out a sensitivity analysis of the results to find out how sensitive the results are to variations in the different input parameters. This can be done with any or all of the input parameters to see which ones are more critical. A sensitivity analysis will show the size of the error in the results produced by uncertainty or inaccuracy in the input data.

5. ASSESSMENT OF HAZARD TO LIFE

Fire models may be used to predict the property loss or the hazard to life. It will be assumed here that the interest is in predicting the hazard to life. The prediction of the hazard to life of the occupants of the building is not a simple matter. First of all, hazard criteria need to be set to define the conditions which cause incapacitation or death.

There are a number of ways in which a fire causes a hazard to life to the building occupants. The main hazards are described below together with the criteria for hazard to life.

(i) **Direct contact with the fire**
This is not generally predicted by fire models.

(ii) **Heat radiation from the upper layer of hot gases**.
This is the hazard due to the downward radiation from the upper layer of hot gases when the interface between the upper and lower layers is above head height. A radiation level of 2.5kW/m^2 has been quoted as a threshold for human tenability (4).

Alternatively, an upper layer temperature level may be defined which implies a hazardous level of heat radiation. The hazard criterion quoted by Beard (3) is an upper layer temperature greater than or equal to 183°C (or 456°K).

(iii) **Direct contact with hot gases**.
The hazard due to contact with hot gases, both internal (due to inhalation) and external, occurs when the interface between the upper and lower layers descends below head level. The hazard criterion quoted by Beard (3) is an upper layer temperature greater than or equal to 100°C (or 373°K).

(iv) **Smoke obscuration**.
When the view across the room is obscured by smoke, this will make it more difficult for the occupants to find their way to the exits. Critical values quoted by Beard (3) are when the optical density at head height is greater than or equal to 0.065 per metre (0.65 dB/m) for people unfamiliar with the building and greater than or equal to 0.2 per metre (2.0 dB/m) for people familiar with the building. However, FASTLITE does not predict smoke obscuration levels.

(v) **Inhalation of toxic gases.**
The toxic gases commonly produced by a fire include Carbon Monoxide, Hydrogen Cyanide and Carbon Dioxide which are hazardous if the concentrations are high enough. The critical value quoted by Beard (3) for Carbon Monoxide is a concentration of 3,000ppm or 3% by volume which is thought to cause death within 30 minutes and unconsciousness in a shorter time.

(vi) **Lack of Oxygen.**

> The fire consumes oxygen as it burns, which reduces the concentration of oxygen in the room. Exposure to air with a low oxygen concentration causes incapacitation and death. Purser (5) discusses the effect of exposure to low oxygen levels and based on this work a critical oxygen concentration of 10% may be assumed.

A hazard analysis form has been included in Appendix A which may be used to help assess the hazard using the above criteria. Part 3, Section 2.3.4 explains how to use this form to make a hazard analysis.

6. EVACUATION

To carry out a complete analysis of the fire safety of a building, it is necessary to assess the likelihood of the occupants making a safe escape. This can be done by estimating the time required to escape and comparing this with the conditions in the building as predicted by the fire model. The "Tools" option of FASTLITE includes an estimation of "Egress Time" which may provide some useful information on escape times, but otherwise the escape times must be calculated or estimated independently.

7. TYPOGRAPHICAL CONVENTIONS

♦ indicates an action to be taken.

PART 2: USING FASTLITE

Full details of using FASTLITE are given in the manual which accompanies the software (6). However, an outline will be given here.

1. INSTALLATION

Installation instructions are contained in the manual which comes with the FASTLITE software. FASTLITE is a DOS-based programme. The installation takes only a few minutes to complete. The manual states that the hardware requirements are:

- a 386 or later IBM-compatible PC with at least 2.5 megabytes of free extended memory,
- at least a VGA compatible graphics display,
- mouse driver must be 100% MS-mouse compatible,
- at least 12 megabytes free space on hard disc.

Also, FASTLITE requires a maths coprocessor. This means that FASTLITE runs on a PC with a 486 DX processor but not on a PC with a 486 SX processor.

This manual is based on FASTLITE version 1.0b. Due to a bug fix, the results from this version are significantly different from version 1.0.

2. STARTING FASTLITE

To start FASTLITE from the DOS prompt, change to the directory in which FASTLITE was installed, e.g. from the DOS prompt type:-

C: <Ret>
CD FASTLITE <Ret>
FASTLITE <Ret>

This will bring up the opening menu.

3. OPENING MENU

After displaying the FASTLITE logo window, the opening menu is displayed which has the following options:

File
Run
Tools
Options

Utilities Help

You should be able to select an option by pointing and clicking with the mouse. If your mouse is not working at this point you may not have the correct mouse driver loaded. If necessary, find the file MOUSE.COM on your C:\ drive and run this, e.g. type the following:-

C: <Ret>
CD MOUSE <Ret>
DIR MOUSE.COM <Ret>

...file details of MOUSE.COM displayed on screen

MOUSE.COM <Ret>

... and the MOUSE.COM program runs to install the mouse driver.

"File" is used to create and edit data files to set up the fire scenario and also to run the FASTLITE model.

"Run" is used to run FIREFORM which is a separate set of calculations. Most of these calculations have been duplicated in FASTLITE and are available from the "Tools" option.

"Tools" provides quick calculation tools to determine individual characteristics of the fire such as the occurrence of flashover which can also be accessed from the "Tools" option within FASTLITE. These tools are additional to the main fire model and are not used in this manual. For details on these tools, see Section 5 of the manual which accompanies the Fastlite software (6).

"Options" allows FASTLITE to be customised by specifying measurement display units and licensing information.

"Utilities" allows viewing, copying and printing of files.

"Help" provides an overview of each graphic icon.

4. CREATING INPUT DATA FILE

This section gives an overview of creating an input data file with FASTLITE. Further details about entering data in each input screen are given in Part 3, Section 2.1.

- Start FASTLITE as described above.

- From the opening menu, select "Options", "User Specified Units" and select the units you wish to work in for each parameter, e.g. you may wish to select Celcius rather than Kelvin for temperature. To make a selection, click on the down-arrow symbol and select from the drop-down list. When you have finished, click on the OK button to return to the opening menu.

- From the opening menu, select “Options”, “File Names” to select system file locations. Unless you have any special requirements, leave the default values unchanged. Click on the OK button to return to the opening menu.

- From the opening menu, select “Files” by pointing and clicking with the mouse. Then select “New”.

- From the “Select Type of Structure” menu, select the number of compartments. You can do this either by clicking on of the icons or by entering the number. More compartments may be added later up to a maximum of three.

- Next, the “Select Fire Curve” menu will be displayed. Select a fire curve e.g. slow, medium, fast etc., and click on “OK”. The next menu will specify times to define the fire curve. Click on OK to accept the default and the main input menu will then be displayed.

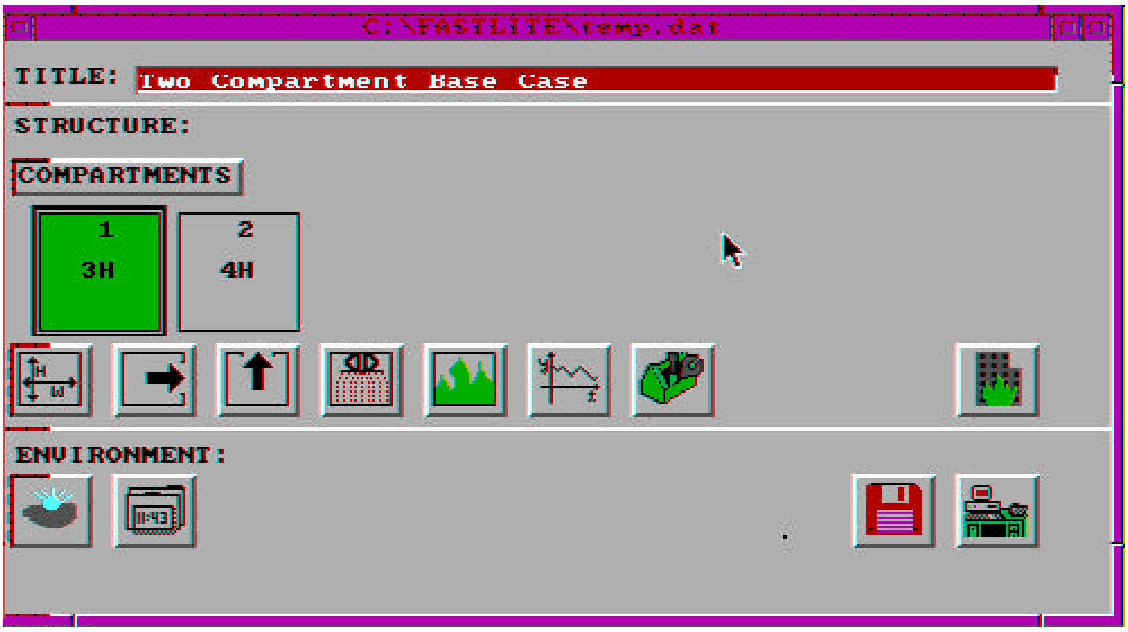

Figure 2. Main Input Menu

Each icon allows different input data to be entered. Most data will apply to a specific compartment so you must select a compartment first before entering data. The compartments are displayed as squares above the main row of icons, and an extra border is displayed around the compartment currently selected. The compartment containing a fire is displayed in red.

From the main input menu the following input data may be entered:

Title:	Enter a title for the case to be modelled
Compartments:	To add or delete compartments

The main row of icons and their functions are shown in Table 2.

Function	Symbol Displayed
Compartment Dimensions	H/W Arrows
Horizontal Vents	Right Arrow
Vertical Vents	Up Arrow
Sprinklers/detectors	Sprinkler Spray
Fire Specification	Flames
Heat Release Rate/Pyrolysis Rate	X-Y Graph
Tools (provides additional calculations if required)	Tool box
Run Simulation	Building on Fire

Table 2. Main Row of Icons

Before using any of the above icons, make sure that the compartment required has been selected first.

The bottom row of icons are shown in Table 3.

Function	Symbol Displayed
Ambient Conditions	Sun and cloud
Input and Output Settings	Digital clock
Save Data File	Floppy disc
Opening Menu	Desktop PC

Table 3. Bottom row of icons

When all data has been entered to define the fire scenario, **remember to save the data using the "Save Data File" option.**

PART 3 : HOUSE FIRE STUDY

1. INTRODUCTION

Part 3 contains a set of exercises for you to perform in which a house fire is modelled. First, an initial scenario is set up by creating an input file and entering data. Then FASTLITE is run for this scenario. Then a series of modifications are made to the scenario and the results are analysed to determine the hazard to life in each case.

2. INITIAL SCENARIO (HOUSE1)

The initial scenario to be considered is of an armchair fire in the living room of a two-storey house. The armchair is assumed to burn with only a brief smouldering phase. The door from the living room to the hall is open and there is an open window in the living room. Doors from the hall to the kitchen and lounge are closed. The floor plan and input data are shown in Figure 3 and Table 4.

2.1 Setting up the input data file.

For an overview on using FASTLITE, see Part 2 of this manual. For more detailed instructions, see the FASTLITE user manual (6).

2.1.1 Opening the input data file.

♦ Start FASTLITE

♦ Select “File”, “New”

♦ Select two compartments by clicking on the two-compartment icon. Then click on “OK” to accept. (Only the living room and hall will be considered as the kitchen and lounge doors are closed and these rooms will be relatively free of hazard.)

♦ From the “Select Fire Curve” menu, select “Pre-Defined Fires”, then from the list displayed select: “Chair, wood frame, California foam, Haitian cotton fabric”. Click on “OK” to accept.

♦ At the main menu, click on the title and enter a suitable name to describe this case, e.g. “House Fire - Initial Case”.

2.1.2 Defining Compartments (Icon: H/W Arrows)

At the main menu, compartment 1 should be displayed in red which indicates the presence of a fire here.

- Click on compartment 1 to select it, then click on the "H/W Arrows" icon to define the compartment dimensions.

- Change the default dimensions displayed to the dimensions of the Living Room given in Figure 3. The depth and width may be entered in either order. Note the display of the permissible range and measurement units at the bottom of the window as the field is selected. Leave the elevation at 0.0. This is the height of the floor of the compartment.

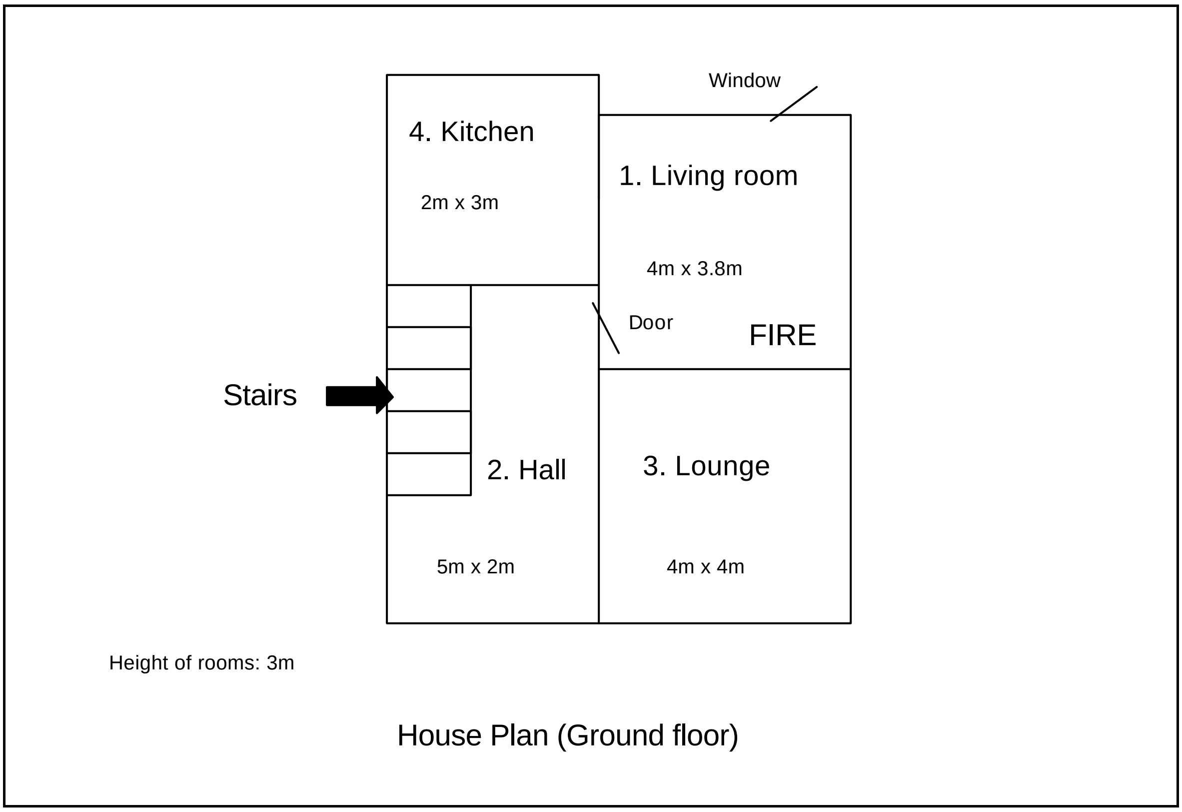

Figure 3. House fire scenario - floor plan.

OPENINGS		
Connecting rooms	Type of opening	Dimensions
Living room/hall	Door, open	sill height = 0m soffit height = 2m width = 1m
Living room/outdoors	Window, open	sill height = 1m soffit height = 2m width = 1m
WALLS, FLOORS AND CEILINGS		
Walls	Gypsum board, 5/8" thick	
Floor	Concrete, 6" thick	
Ceiling	Gypsum board, 5/8" thick	
FIRE		
Armchair in living room.		

Table 4. House fire scenario - input data.

- Click on the down-arrow symbol beside "Ceiling" to select the ceiling material. The material "Gypsum board (5/8")" should already be selected. This is the material required so accept this by clicking on "OK".

- For the "Floor" material select "Concrete normal weight, (6")" and for the Walls select "Gypsum board (5/8")". To display other parts of the list, click on the scroll bar to the right of the list.

The ON/OFF buttons beside Walls, Floor and Ceiling may be used to switch off the heat conduction to the surface if required, to speed up the calculation. These should be left on.

- Click on "OK" to accept the information and return to the main menu.

- Now select compartment 2 (Hall) and click on the "H/W Arrows" icon to enter the dimensions and surface materials defined in Figure 3 and Table 4.

2.1.3 Defining Connections for Horizontal Flow (Icon: Right Arrow)

- Select compartment 1 and click on the "Right Arrow" icon to define the vents for horizontal flow.

In the “Horizontal Flow” menu, a list of compartments adjacent to the one selected is displayed, with the floor and ceiling height and number of connecting vents for each. In this case the adjacent compartments are compartment 2 and the outside of the building.

- Select compartment 2 and click on “Edit”.

One vent is listed, by default, connecting compartments 1 and 2. This will be the door between hall and living room.

- Change the dimensions of the vent connecting compartments 1 and 2 to those given in Table 4, then click “OK” to accept.

- Now select “Outside” to define the vent connecting compartment 1 to the outside and click on “Edit”.

Two vents are displayed by default.

- Press Alt D (hold down the Alt key and press D) to delete one of these vents.

- Enter the dimensions of the living room window for the remaining vent (see Table 4) and click on “OK” to accept.

- Exit from the “Horizontal Flow” Menu.

- Now select compartment 2 and select horizontal flow again by clicking on the “Right Arrow” icon.

- From the list, select compartment 1 and click on “Edit”. This will display the dimensions of the door connecting compartment 1 and compartment 2 which you have already entered. Click on “OK” to accept this.

- From the list, select “Outside” and click on “Edit”. Three vents are displayed by default, connecting compartment 2 to the outside. No vents are required here so press “Alt D” three times to delete these.

- Click on “OK” and “Exit” to exit the “Horizontal Flow” menu.

2.1.4 Defining Connections for Vertical Flow (Icon: Up Arrow)

Vents in the floor and ceiling for vertical flow are entered in the same way as the vents for horizontal flow. However, no floor and ceiling vents are required in this example and you will find that none are defined by default so that no changes are required here.

2.1.5 Adding Sprinklers and Detectors (Icon: Sprinkler Spray)

No sprinklers or detectors are required in this fire scenario and so this option may be disregarded for now.

2.1.6 Defining the Fire (Icon: Flames)

- Click on the "Flames" icon to display the "Main Fire Specification" menu.

The number of the compartment in which the fire originates is displayed at the top of the screen. In this case the compartment should be number 1. If another compartment is indicated, select "Cancel" to exit this menu, select compartment 1 from the main menu, re-enter the "Main Fire Specification" menu and click on "Current Compartment" which will reset the fire location to the currently selected compartment.

Type: The fire type can be unconstrained, constrained or constrained with flashover. If a constrained fire is selected, FASTLITE will estimate the reduction in heat release rate caused by the limited availability of oxygen.

- Select "Constrained" fire.

Position: The position of the fire is specified as the distance from one corner of the compartment. The x and y positions are horizontal dimensions and the z position is the position above the floor. Note that by default the fire is at the centre of the room, on the floor.

- Set both the x and y positions as 1.0 metres so that the fire is positioned in one corner of the room and 1 metre out from both walls. Set the z position as 0.0 metres above floor level.

Lower Oxygen Limit: This is the limit on the ratio of oxygen to other gases below which a flame will not burn and is applicable only to constrained fires.

- The default value is 10%. Leave this value unchanged.

Heat of Combustion: This is the heat of combustion of the fuel which is used to calculate either the heat release rate or the pyrolysis rate from the following formula:

$$\text{Heat of combustion} = \frac{\text{Heat Release Rate}}{\text{Pyrolysis Rate}}$$

A constant value is assumed for the heat of combustion throughout the fire. If the user specifies the heat release rate then the pyrolysis rate is calculated and vice versa. However, if separate time-dependent values of heat release rate and pyrolysis rate are defined by the user then a time-dependent heat of combustion is calculated from these.

- The default value is "1.95E+007" which is 1.95×10^7 J/kg. Leave this value unchanged.

Initial Fuel Temperature: Typically, the initial fuel temperature is the same as the ambient temperature.

- Leave the initial fuel temperature as the default value of 20°C.

Gaseous Ignition Temperature: This is the minimum temperature at which the fuel will ignite and is used to determine ignition as the hot gases flow through a vent into another compartment.

- Leave the gaseous ignition temperature as the default value of 220°C.

Radiative Fraction: The heat released by the fire is transmitted to the surroundings either by convection in the plume or by radiation to the walls and ceiling. The "radiative fraction" is the fraction of heat released by the fire that goes into radiation.

♦ Leave the radiative fraction as the default value of 0.3.

2.1.7 Specifying Time-Dependent Fire Data (Icon: x-y graph)

This icon allows the following time-dependent data to be entered:

- pyrolysis rate
- heat release rate
- toxic combustion products

♦ Click on the "x-y graph" icon and select "heat release rate".

The graph and table displayed show how the heat release rate varies throughout the fire. The table shows the time in the left hand column and the heat release rate in the right hand column with the units displayed at the bottom of the screen. To display other parts of the table, click on the scroll bar to the right of the table or use the arrow keys. The peak heat release rate is 651 kilowatts at 275 seconds. This data relates to the armchair fire selected when you first created the file for the HOUSE1 fire case. Changes may be made to the data at this point if required by editing data in the table.

♦ Use the "Select Curve..." button to select different fire curves and observe how the data displayed on the screen changes. When you have finished, select the fire curve: "Chair, wood frame, California foam, Haitian cotton fabric" which was selected when you opened the file and click on "OK" to leave the "Heat Release Rate" menu.

♦ Now click on the "x-y graph" icon again and this time select "Pyrolysis rate". The pyrolysis rate is the mass loss rate of the fuel as it vaporises prior to combustion. In this case the pyrolysis rate is calculated from the heat release rate by dividing by the heat of combustion supplied earlier. The curve is therefore the same shape as for the heat release rate. Click on "OK" to leave the "Pyrolysis Rate" menu.

♦ Now click on the "x-y graph" icon again and this time select "Toxic Combustion Products".

This option allows the production rate of a toxic product to be specified as a mass ratio of the fuel pyrolysed, i.e. kilograms of toxic product per kilogram of fuel. An example of a toxic product is hydrogen cyanide. Note that the user must specify the production rate by their own judgement and perhaps based on information from fire tests. When the fire simulation is run, the model will calculate the concentration of the toxic product in the different rooms of the building.

♦ No toxic products will be added here so click on "OK" to leave the "Toxic Combustion Products" menu.

2.1.8 Tools (Icon: Toolbox)

This icon displays a menu of estimation tools which may be used to calculate values such as flashover or flow through a vent to provide estimates for input parameters to FASTLITE simulations. These calculations are based on the data already specified for this fire case although further data is also required. These options are not required for this case.

2.1.9 Ambient Conditions (Icon: Sun and Cloud)

This icon allows the following conditions relating to the building environment to be set. The values given in Table 5 are the default values which should be left unchanged in this example.

Parameter	Internal	External
Temperature	20.0°C	20.0°C
Relative Humidity	50.0%	50.0%
Pressure	101300 Pascals	101300 Pascals
Station Elevation	0.0 m	0.0 m

Table 5. Ambient Conditions - Default Values

2.1.10 Model Input/Output (Icon: Digital Clock)

This icon allows the user to control the output from the model.

<u>Simulation</u>. This is the overall duration of the simulation which should be left at 1000 seconds.

<u>Display</u>. The time interval at which results are displayed on the screen during the simulation. This should be left as 20 seconds.

<u>Spreadsheet:</u> The time interval at which results are recorded in a spreadsheet file. If a spreadsheet file is required a filename should be supplied on this screen. In this case enter a time interval of 10 seconds and a filename “HOUSE1.OUT”

2.1.11 Saving the Input Data (Icon: Floppy disc)

Once you have completed your entry of input data to define the fire case, click on the “Floppy disc” icon and select “Save” to save the data to a file. The first time the data is saved you will need to select the “Save as” option and supply a file name. In this case use the name “HOUSE1.DAT”. You can also save your data at any time during data input to prevent loss of data.

2.1.12 Printing Out the Input Data File

Before running the model, print out the input data file you have created to check that it is the same as the one in Appendix B.

♦ Click on the bottom right icon showing a desktop PC. Then select "Utilities", "Print File".

♦ Now click the down arrow to the right of the screen, select HOUSE1.DAT from the list and click on "OK".

♦ Select the correct printer port in the "Print To:" box, e.g. lpt1 for a local printer on the parallel port.

♦ Then click on "Begin" and the file should be printed out, assuming you have a printer connected.

♦ Compare your input data file with the one in Appendix B. If there are any differences you will need to edit your file again to make corrections. To do this, from the initial FASTLITE menu, select "File", "Open" and select the file to edit.

2.2 Running the Fire Model

♦ To run the fire model, click on the "Building on fire" icon at the right-hand end of the main row of icons.

Before beginning the simulation, a further menu of pause times is displayed. These times can be set so that the model will pause at specified times to allow changes to be made to parameters. For instance, a door may be closed to simulate an automatic door closure when a fire detector operates.

♦ In this case no pauses are required, so click on "OK" and the simulation will begin.

♦ While the simulation proceeds, click on the "Graph" button to display graphs of three of these variables.

The changing conditions in the two compartments are displayed on the screen in tables and graphs. Each compartment is represented on the graphs by a different coloured line.

When the simulation is complete, you can use the "Print Graph" and "Print Report" options to print out the results (see Section 2.3.2). These print-outs only include some of the parameters calculated by the model; for a full set of results you will need to look at the spreadsheet file.

♦ Finally click on "Close" to return to the main input menu.

2.3 Analysing the Results

2.3.1 Viewing the Graphs

By examining the graphs, either on the screen or from the print-out, answer the following questions:

Q1. What is the calculated peak heat release rate in the fire compartment?

Q2. How does the calculated heat release rate compare with the heat release rate of the armchair fire used in the input data? What do you conclude?

Q3. What is the peak value of the upper layer temperature in the fire compartment?

Q4. At what time does the smoke layer reach the floor in the living room and in the hall?

2.3.2 Viewing the Print-Out of Results

To obtain a print-out of results, click on the "Print Report" button when the simulation has ended. After reviewing the input data, the print-out lists the following output parameters at each time step for each compartment:-

1. Upper layer temperature
2. Lower layer temperature
3. Interface height, i.e. height above floor of interface between upper and lower layers
4. Pyrolysis rate
5. Fire size, i.e. heat release rate
6. Pressure
7. Ambient target, i.e. heat radiation on a target

2.3.3 Viewing the Spreadsheet File

The spreadsheet file is a data file containing more extensive results than those listed in the print-out. The file is readable by standard spreadsheet packages. The data is arranged with commas separating each column so when opening the file in the spreadsheet package, comma delimitation should be selected. If you are using the MS-Excel spreadsheet package, more detailed instructions are given in Appendix F.

When you have opened the file in the spreadsheet package you will find that each column refers to a separate output parameter and each row a separate time step. You may find it easier to read the data if you convert the format of some of the columns from scientific to numeric to remove the 'E' notation. Otherwise, remember that 'E' refers to power of 10 as follows:

$$1.23\text{ E+03} = 1.23 \times 10^{3} = 1{,}230$$

$$1.23\text{ E-03} = 1.23 \times 10^{-3} = 0.00123$$

The spreadsheet file lists the following additional parameters which are not included in the print-out:

- Ceiling and floor temperature
- Upper and lower wall temperature
- Oxygen, carbon dioxide, carbon monoxide and unburnt hydrocarbon concentrations

Viewing the spreadsheet will show that a large number of variables are included. This may cause confusion in analysing the data and care should be taken to ensure that the correct column is selected. For instance:

"Room 1 UP CO Mass Frac" means the fraction by mass of Carbon Monoxide in Room 1 in the Upper Layer.

Other terms used in the column headings are as follows:-

CO	Carbon Monoxide
UHC	Unburnt Hydrocarbons
O2	Oxygen
CO2	Carbon Dioxide
HRR	Heat Release Rate

2.3.4 Assessment of Hazard to Life

In this section it will be shown how to assess the hazard to life in the building. Some of the information can be found on the print-out of results but for some parameters the spreadsheet file is needed. First, compare your print-out with the one in Appendix B which should be the same.

In Part 1, Section 5, the different types of hazard are described along with the criteria which define whether a hazard exists. For each type of hazard in turn, you need to decided whether the criterion has been reached and if so, at what time after ignition. In Appendix A you will find a "Hazard Analysis Form" which will help you make this assessment. You may wish to photocopy this form for future use.

A separate hazard analysis must be carried out for each room in the building. Therefore, a separate form should be completed for each room. Begin with the living room.

- ♦ Box A. Fill in the scenario name "HOUSE1".

- ♦ Box B. Fill in a description of the scenario as a reminder of the main conditions.

- ♦ Box C. Fill in the room "Living room".

- ♦ Box D. The head height is the height at which gases are inhaled. Opinions differ as to what this height should be. Whatever value you enter will affect the results of the hazard analysis. In this case use 1.5 metres.

- ♦ Box E. The output interval is the interval selected for your results. If using the print-out the output interval was 20 seconds. If using the spreadsheet the interval was 10 seconds. This serves as a reminder of the precision of the results.

The remaining boxes may be filled by examining the print-out or spreadsheet file.

- ♦ Box F. Find the time when the interface reaches head height. The relevant parameter is "Inter. Height" in the print-out or "Layer Height" in the spreadsheet file. Follow the column down to find when the parameter descends to the head height (1.5 metres) in compartment 1. The nearest value to 1.5 metres occurs at 40 seconds after ignition. Therefore, enter 40 seconds in the form at box F.

- ♦ Column 2. For each variable in column 1 of the hazard analysis form, use either the print-out from FASTLITE or the spreadsheet file to find the peak value reached and enter the value in column 2. **Remember that the values required are for compartment 1.** The heat release rate is listed in the column headed “Fire Size” of the print-out or the column headed “HRR” in the spreadsheet. The heat radiation level is “Ambient Target” in the print-out and “Flux to Floor” in the spreadsheet. The units of heat radiation are not given in the spreadsheet but may be checked by comparing the values with the comparative values in the print-out. The values for CO (Carbon Monoxide) and O_2 (Oxygen) are only available in the spreadsheet file. For oxygen, the hazard is due to a lack of oxygen and so in this case the minimum value is required.

- Column 3. The hazard criteria are taken from the values quoted in Part 1 Section 5. Enter the following values: heat radiation: 2.5 kW/m^2, upper and lower layer temperature 100°C, upper and lower layer Carbon Monoxide concentration 3,000 parts per million, Oxygen concentration 10% or less.

- Column 4. Using either the print-out or the spreadsheet file, follow down each column to find the point at which each variable reaches the hazard criterion given in column 3. Enter the time at which this occurs in column 4.

- Column 5. For conditions in the upper layer (temperature, carbon monoxide concentration and oxygen concentration), a hazard is only present when the upper layer has descended below head height. To find out if this is the case, compare the time to reach the hazard criterion (column 4) with the time when the interface reaches head height (Box F). If the value in column 4 is bigger, then the interface reached head height before hazard occurred so enter YES in column 5. Otherwise enter NO in column 5.

- Column 6. If you entered Yes in column 5, the upper layer was below head height when the hazard criterion was reached and you should copy the contents of column 4 to column 6.

  If you entered No in column 5, the upper layer was still above head height when the hazard criterion was reached, and the hazard will only occur when the upper layer reaches head height. Therefore, enter the contents of box F in column 6.

  If column 5 did not apply (i.e. for heat radiation and lower layer conditions) copy the contents of column 4 to column 6.

A completed hazard analysis form for this scenario is shown in Appendix C, Table C1. Now that you have completed the hazard analysis form you can compare the time to hazard for each variable and comment on the hazard level of the scenario that you have simulated. In this case, the onset of hazard occurred at 2 minutes and 30 seconds after ignition due to the temperature of the upper layer. The next hazard to occur was at 3 minutes and 40 seconds after ignition due to the heat radiation level. Another hazard not included in the results from FASTLITE is obscuration by smoke which may hinder escape.

- Now repeat the hazard analysis for the hall (compartment 2) using the same process as described above.

A completed form for the hall is shown in Appendix C, Table C2. This shows that only two of the hazard criteria were reached and the initial hazard, as in the living room, was due to the upper layer temperature. The onset of hazard in the hall occurred at 3 minutes and 30 seconds due to upper-layer smoke and at 8 minute 30 seconds due to upper-layer carbon monoxide concentration.

If we consider the case of an occupant escaping from any part of the house other than the living-room where the fire began, his main escape route is through the hall. He will have only 3 minutes and 30 seconds from the time of ignition in which to escape before the hall becomes hazardous due to the high temperature.

During this time he will need to become aware of the fire, whether by a smoke alarm, by his own observation or from another person, then decide to escape and then make good his escape. Alternatively he may decide to rescue another person in the house which will take up more time.

3. CLOSED WINDOW (HOUSE2)

In the previous scenario (HOUSE1) the window in the living room was open. In this scenario we will look at the effect of closing the window.

- ♦ Make a copy of the input file for the initial house fire scenario (HOUSE1.DAT) and call the new file HOUSE2.DAT. To do this, go to the opening menu of FASTLITE, if necessary closing any file already open. Select the options “Utilities”, “Copy File”, type in the required file names and then click on “Begin”.

- ♦ Once you have successfully copied the file to HOUSE2.DAT, open the new file by selecting “File”, “Open”.

- ♦ Click on the title bar and change the title to describe the new scenario e.g. “HOUSE2 - Armchair fire, Closed Window”

- ♦ Select input and output settings by clicking on the “Digital Clock” icon and change the spreadsheet file name to HOUSE2.OUT. Click “OK” to accept.

In this case the only change to be made to the input data is to close the window in the living-room.

- ♦ Select compartment 1, then select horizontal flow by clicking on the “Right Arrow” icon.

- ♦ In the “horizontal flow” menu, click on “Outside” to select the vent from compartment 1 to the outside. This is the window. Then click on “Edit”.

- ♦ Now change the width of the vent to 1 mm (or 0.001 m). A zero width vent is not accepted by FASTLITE and a width of 1mm represents a crack where the window meets the frame.

- ♦ Once you have made this change click on “OK” to accept and “Exit” to leave the “horizontal flow” menu.

- ♦ Save the change by clicking on the “Floppy Disc” icon and selecting “Save”.

- ♦ Now run this fire case by clicking on the “Building on Fire” icon. No pause times are required so click on “OK” at the pause times menu..

- When the simulation is complete, you can use the “Print Graph” and “Print Report” options to print out the results.

- Finally click on “Close” to return to the main input menu.

Q5. Compare the graphs from HOUSE1 and HOUSE2. How has the heat release rate changed? What is the reason for this change?

- Complete a hazard analysis form for the living-room and another for the hall. This procedure is described in Section 2.3.4.

Q6. What are the first three hazards to occur in the living room and in what order?

Q7. How do the times of onset of hazard in the living room compare with the HOUSE1 case?

Q8. Now assume the head height to be 2 metres above floor level instead of 1.5 metres. What effect does this have on the predicted hazard times? [Hint: no further data is required to answer this].

4. CLOSED WINDOW AND CLOSED LIVING-ROOM DOOR (HOUSE3)

In this example the HOUSE2 case will be modified by closing the door connecting the living-room and the hall. Thus there will be no open vents in the living-room apart from cracks at the window and door. It will be seen how the closed door affects the conditions in the hall.

- Make a copy of the input file for the previous scenario (HOUSE2.DAT) and call the new file HOUSE3.DAT. (From the opening menu, select: “Utilities” and “Copy File”.)

- Once you have successfully copied the file to HOUSE3.DAT, open the new file by selecting “File”, “Open”.

- Click on the title bar and change the title to describe the new scenario e.g. “HOUSE3 - Armchair fire, Closed Window and Door”

- Select input and output settings by clicking on the “Digital Clock” icon and change the spreadsheet file name to HOUSE3.OUT. Click “OK” to accept.

In this case the only change to be made to the input data is to close the door between the living-room and the hall.

- Select compartment 1, then select horizontal flow by clicking on the “Right Arrow” icon.

- In the “horizontal flow” menu, click on the vent connecting compartment 1 to compartment 2. This is the door. Then click on “Edit”.

- Now change the soffit height to 1 mm (or 0.001 m). This will define the vent opening to be a 1mm crack at floor level, i.e. beneath the door.

- Once you have made this change click on “OK” to accept and “Exit” to leave the “horizontal flow” menu.

- Save the change by clicking on the “Floppy Disc” icon and selecting “Save”.

- Now run this fire case by clicking on the “Building on Fire” icon. No pause times are required so click on “OK” at the pause times menu..

- When the simulation is complete, you can use the “Print Graph” and “Print Report” options to print out the results.

- Finally click on “Close” to return to the main input menu.

Q9. From the graphs of results how do the conditions in the hall compare between HOUSE2 and HOUSE3?

- Now complete a hazard analysis form for the hall and compare with the one in Table C5.

Q10. What has been the effect of closing the door on the hazard in the hall, according to the model?

5. CLOSED WINDOW AND SMOKE DETECTOR IN HALL (HOUSE4)

In this example a smoke detector will be added in the hall.

- Make a copy of HOUSE2.DAT and call the new file HOUSE4.DAT.

- Open HOUSE4.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE4.OUT.

- Select compartment 2 (the hall) and then click on the “Sprinkler spray” icon.

- Now click on “Add” to display the “Sprinklers and Detectors” menu where the specifications of the detector or sprinkler are entered.

Compartment number 2 should be displayed as you have already selected this before entering the screen.

- In the box labelled “Typical values” you can select a pre-defined device. (Do this by clicking on the down-arrow symbol to the right of the box.) In this case select the smoke detector.

The default values supplied by FASTLITE will be left unchanged. These are as follows.

<u>The position of the detector in the x, y and z directions</u>. The supplied values are:

X: 2.5 m   Y: 1.0 m   Z: 2.999 m

Thus the device is located centrally in the hall (dimensions 5 m x 2 m) on the ceiling.

The RTI (Response Time Index) and Spray Density. These values are shaded out and only apply if a sprinkler is defined.

The activation temperature is set at 31.111 °C which is approximately 11 °C above ambient temperature. FASTLITE does not predict smoke densities and so it is assumed that the smoke detector will operate as soon as the temperature has risen by 11°C.

The box labelled “Sprinkler” is set to “Off”, indicating that the device is a detector only.

♦ Click on “OK” to accept these values and then click on “Exit” to return to the main input menu.

Compartment 2 should now be coloured in blue to indicate that a sprinkler or detector has been added.

♦ Save the change by clicking on the “Floppy Disc” icon and selecting “Save”.

♦ Now run the HOUSE4 case and, at the “LITE Pause Times” menu, click on “Pause after Detector” to change the box to “Yes”. Leave the time delay at 0.0 seconds, and click on “OK” to start the simulation.

The simulation pauses at 86.6 seconds due to detector activation. At this point you can modify a vent, e.g. to simulate an occupant opening a door to escape in response to the detector alarm, or you can continue the simulation unchanged.

♦ Click on “Stop” to terminate the simulation at this point as the addition of the detector will not change the conditions in the compartments.

Q11. What is the time available for escape after the activation of the smoke detector?

6. CLOSED WINDOW, CLOSED DOOR AND SMOKE DETECTOR IN HALL (HOUSE5)

In this example, a smoke detector is added in the hall as in the previous case but this time with the living-room/hall door closed. The living-room window will remain closed. Shutting the living-room/hall door will reduce movement of heat and smoke into the hall and delay the time to hazard (as found in the HOUSE3 case) but this will also delay the activation of the smoke detector in the hall. It is not therefore clear whether shutting the door reduces or increases the time available for escape when a smoke detector is present in the hall.

♦ Make a copy of HOUSE3.DAT and call the new file HOUSE5.DAT.

- Open HOUSE5.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE5.OUT.

- Select compartment 2 and then click on the “Sprinkler spray” icon.

- Now click on “Add” to display the menu where the specifications of the detector or sprinkler are entered. As for the HOUSE4 case, select the smoke detector and leave the default values unchanged.

- Click on “OK” to accept these values and then click on “Exit” to return to the main input menu.

Compartment 2 should now be coloured in blue to indicate that a sprinkler or detector has been added.

- Save the change by clicking on the “Floppy Disc” icon and selecting “Save”.

- Now run the HOUSE5 case and click on “Pause after Detector” to change the box to “Yes”. Leave the time delay at 0.0 seconds, and click on “OK” to start the simulation.

The simulation pauses at 159.4 seconds due to detector activation.

- Click on “Stop” to terminate the simulation at this point as the addition of the detector will not change the conditions in the compartments.

Q12. Assuming the occupant is not initially in the living-room but will have to escape through the hall, how has the closed living-room/hall door affected the chances of escape?

7. SOFA FIRE, CLOSED WINDOW, CLOSED DOOR (HOUSE6)

A different item of furniture will now be selected for the fire in the living-room, this time a sofa, with a greater heat release rate as measured in free burning conditions, to see whether this produces more severe conditions in the house.

- Make a copy of HOUSE3.DAT and call the new file HOUSE6.DAT.

- Open HOUSE6.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE6.OUT.

- Now change the fire by selecting “Time-Dependent Fire Data” (Icon: x-y graph) and “Heat Release Rate”. Click on “Select Curve...”, “Pre-defined Fires” and click on the last item on the list: “Sofa, wood frame, California foam, polyolefin fabric” and then click on “OK”. Note that the heat release rate now peaks at just over 3 megawatts. Click on “OK” to accept the new data.

- Save the change by clicking on the “Floppy Disc” icon and selecting “Save”.

- Now run the HOUSE6 case. No pause times are required.

Q13. How do the conditions in the house compare with the equivalent case with the armchair fire (HOUSE3)?

Q14. What are the peak values reached in the hall and how do they compare with the HOUSE3 case?

8. SOFA FIRE, ENTRY OF RESCUER (HOUSE7)

In this example, the same sofa fire will be used but a rescuer will enter the house during the fire. The rescuer will enter through the front door, travel through the hall and open the living-room door.

- ♦ Make a copy of HOUSE6.DAT and call the new file HOUSE7.DAT.
- ♦ Open HOUSE7.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE7.OUT.

To simulate entry of the rescuer, the front door and living-room/hall door will be opened during the simulation but first a front door must be defined.

- ♦ Select compartment 2 (the hall).
- ♦ Select the horizontal vent by clicking on the “Right Arrow” icon and select the vent to the outside.
- ♦ Click on “Edit” and enter the dimensions: width 1.0 m; sill 0.0 m; soffit 0.001 m. This defines a closed door with a 1 mm crack at floor level. Click on “OK” and “Exit” to accept this data.
- ♦ Save the changes to the input data before proceeding.
- ♦ Now run the HOUSE7 case and at the “Pause Times” menu click on “Pause at Time” button and select a pause time of 200 seconds. This is the time at which the rescuer will enter the house. **N.B. This case takes about 30 minutes to run with a 486 processor.**

At 200 seconds the simulation pauses as requested. Note that the heat release rate in the living room has fallen to zero indicating that the fire has died out. Before continuing with the simulation you need to open the front door and living-room/hall door to simulate the effect of a rescuer entering. As only one pause time is allowed, both doors will be opened simultaneously although in reality there would obviously be a small time lapse between these two events.

- ♦ Now click on “Modify” and select the vent connecting room 2 to the outside (the front door). Modify this vent by setting the soffit height to 2.0 m. Now select the vent connecting room 1 to room 2 (the living-room/hall door) and again set the soffit height to 2.0 m.
- ♦ Click on “Continue” to allow the simulation to proceed to completion.

The simulation proceeds slowly at this point as the situation has become more complicated and there are more calculations to carry out. Note how the heat release rate in the living-room begins to rise rapidly. The upper layer temperatures in the living-room and hall also begin to rise again. Later, a heat release rate is observed in the hall.

Q15. How do you explain the conditions predicted after the entry of the rescuer?

9. SENSITIVITY ANALYSIS (HOUSE8-11)

As already mentioned, the accuracy of the results of a computer modelling study is always limited. One source of error is the input data supplied by the user. There will always be a degree of uncertainty in the input parameters, for instance in the heat release rate of the fire or the position of the fire. In this exercise different input parameters will be varied from the values used in the HOUSE2 case and the effect on the results noted. This will show the sensitivity of the results to the different input parameters and therefore show which input parameters are more critical.

In the following sensitivity study, input parameters will be varied to see the effect on the following output parameters:

- peak heat release rate
- peak upper-layer temperature in living-room
- peak lower-layer temperature in living-room

The first parameter change will be to change the material of the walls to brick.

♦ Make a copy of HOUSE2.DAT and call the new file HOUSE8.DAT.

♦ Open HOUSE8.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE8.OUT.

♦ Now change the material of the walls in the living-room and in the hall to common brick (3" thick). To do this, click on compartment 1, click on the "H/W Arrows" icon, click on the down arrow symbol beside the walls property, and select the material "COMBRICK" from the list and click on "OK". Repeat for compartment 2.

♦ Save the change by clicking on the "Floppy Disc" icon and selecting "Save".

♦ Now run the HOUSE8 case.

♦ For an approximate comparison, print out the graphs and compare with the HOUSE2 case. For a more accurate comparison you will need to examine the spreadsheet files. It may be easier to do this later when you have obtained files for each parameter change described in this section.

The next parameter change will be to change the fire to an unconstrained fire. This means that the heat release rate data will not be modified by the model to account for any lack of oxygen in the room as oxygen is used up by the fire. In this case the heat release rate data selected was taken from an armchair fire burning with unrestricted ventilation.

♦ Make a copy of HOUSE2.DAT and call the new file HOUSE9.DAT.

♦ Open HOUSE9.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE9.OUT.

- Now change the fire type to “unconstrained”. To do this, click on compartment 1, click on the “Flames” icon, click on the down-arrow symbol next to the fire type box and select “Unconstrained”, then click on “OK” to accept the change.

- Save the change by clicking on the “Floppy Disc” icon and selecting “Save”.

- Now run the HOUSE9 case and compare the results.

The next parameter to change will be the position of the fire. In the HOUSE2 case, the fire was located near one corner of the living-room but will now be moved to the centre of the room.

- Make a copy of HOUSE2.DAT and call the new file HOUSE10.DAT.

- Open HOUSE10.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE10.OUT.

- Click on the “Flames” icon. The position of the fire is indicated by the x, y and z directions, the z direction being the height above the floor and the x and y directions being the two horizontal directions, one along each wall.

- Click on the button “X-Manual” which will automatically set the x position to centrally in the room.

- Click on the button “Y-Manual” to do the same in the y direction.

- Click on “OK” to accept the changes.

- Now save the changes to the file, run the model and compare the results with the HOUSE2 case.

The final parameter change is to change the parameter “Radiative Fraction”. This is the fraction of heat, released by the fire, which is assumed to be radiated out into the room. The remaining heat is assumed to enter the hot gas plume which rises from the fire.

- Make a copy of HOUSE2.DAT and call the new file HOUSE11.DAT.

- Open HOUSE11.DAT and amend the title accordingly. Also, change the spreadsheet file name to HOUSE11.OUT.

- Click on compartment 1 and click on the “Flames” icon.

- In the “Main Fire Specification” window change the radiative fraction value from 0.3 to 0.6.

- Click on “OK” to save the change, run the model and compare the results with the HOUSE2 case.

- Now examine the spreadsheet files for cases HOUSE8 - HOUSE11 and HOUSE2 and compare the peak values as follows:

    - peak heat release rate
    - peak upper-layer temperature in living-room

- peak lower-layer temperature in living-room

Q16. Which input parameters produced the most variation in the results and which produced the least?

PART 4 : SHOP FIRE STUDY

1. INTRODUCTION

Part 4 contains a set of exercises for you to perform in which a shop fire is modelled. In the same way as the house fire study (Part 3), an initial scenario is modelled and then a series of modifications are applied. The results are analysed to determine the hazard to life in each case.

2. INITIAL SCENARIO (SHOP1)

The initial scenario to be considered is of a fire on a large sales floor measuring 30 metres in each direction. The fire load is a display of polyurethane foam furniture. There is a door in the compartment which is assumed to be closed.

The input data are shown in Table 6.

OPENINGS

Connecting rooms	Type of opening	Dimensions
Sales floor/surroundings	Door, closed	sill height = 0m soffit height = 2.13m width = 1m

WALLS, FLOORS AND CEILINGS

Walls	Gypsum
Floor	Concrete
Ceiling	Gypsum

FIRE

Material

Polyurethane foam furniture

Time (min)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0
Heat Release Rate (MW)	0.0	1.0	2.6	2.8	2.6	2.0	0.3	0.0

Table 6. Shop fire scenario - input data.

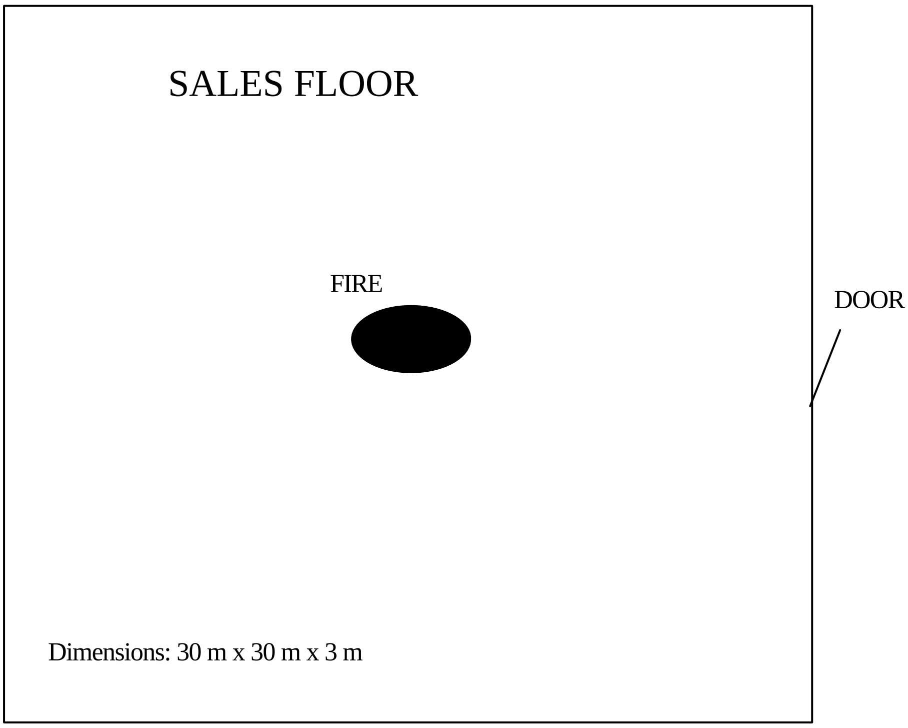

Figure 4. Shop Fire Scenario - Floor Plan

2.1 Setting up the input data file.

For an overview on using FASTLITE, see Part 2 of this manual. For more detailed instructions, see the FASTLITE user manual. In this section there is some repetition of the instructions in Part 3 to cater for readers who have skipped Part 3.

2.1.1 Opening the input data file.

- Start FASTLITE
- Select “File”, “New”
- Select one compartment. This will be the sales floor. Then click on “OK” to display the “Select Fire Curve” menu.
- No pre-defined fire is suitable for this scenario so select “Ultrafast Growth” as this fits best with the heat release rate data required, click on “OK” and then specify the following times:

Level Off Time	120 seconds
Start Decay Time	240 seconds

Click on the “x-y graph” icon and “Heat Release Rate” to display the fire curve you have just defined. The data points follow those in Table 6 reasonably closely. The peak value is 2.7 MW.

- ♦ Click on “OK” to return to the “Main Input Menu”.

- ♦ Now click on the title and enter a suitable name to define the scenario, e.g. “Shop Fire - Initial Case”.

2.1.2 Defining Compartments (Icon: H/W Arrows)

At the main menu, compartment 1 should be displayed in red which indicates the presence of a fire here.

- ♦ Click on the “H/W Arrows” icon to define the compartment dimensions.

- ♦ Change the default dimensions displayed to the dimensions of the sales floor given in Figure 4. Note the display of the permissible range and measurement units at the bottom of the window as the field is selected. Leave the elevation at zero.

- ♦ Click on the down-arrow symbol beside “Ceiling” to select the ceiling material. The material “Gypsum board 5/8” ” should already be selected. This is the material required so accept this by clicking on “OK”.

- ♦ For the “Floor” material select “Concrete normal weight, 6” ” and for the Walls select “Gypsum board 5/8” ”.

The ON/OFF buttons beside Walls, Floor and Ceiling may be used to switch off the heat conduction to the surface if required, to speed up the calculation. These should be left at ON.

- ♦ Click on “OK” to accept the information and return to the main menu.

2.1.3 Defining Connections for Horizontal Flow (Icon: Right Arrow)

- ♦ Click on the “Right Arrow” icon to define the vents for horizontal flow.

A list of compartments adjacent to the one selected is displayed, with the floor and ceiling height and number of connecting vents. In this case the only adjacent compartment is the outside.

- ♦ With the Outside highlighted, click on “Edit”.

Three vents are listed, by default, connecting compartment 1 to the outside. From their dimensions it can be seen that two of these vents are narrow cracks and the other is an open door.

- ♦ Delete the two narrow cracks by selecting each in turn and pressing “Alt-D”.

- ♦ Change the dimensions of the remaining vent to those given in Table 6, only make the width 0.001 metres to represent a closed door with a 1 mm wide crack. Then click on “OK” to accept.

- ♦ Exit from the “Horizontal Flow” Menu.

2.1.4 Defining Connections for Vertical Flow (Icon: Up Arrow)

Vents in the floor and ceiling for vertical flow are entered in the same way as the vents for horizontal flow. However, no vents are required here and you will find that none are defined by default so that no changes are required.

2.1.5 Adding Sprinklers and Detectors (Icon: Sprinkler Spray)

No sprinklers or detectors are required in this case and so this option may be disregarded for now.

2.1.6 Defining the Fire (Icon: Flames)

This icon displays the "Main Fire Specification" menu. Click on this icon and make the following selections.

Type: The fire type can be unconstrained, constrained or constrained with flashover. If a constrained fire is selected, FASTLITE will estimate the reduction in heat release rate caused by the limited availability of oxygen.

- Select "Constrained" fire.

Position: The position of the fire is specified as the distance from one corner of the compartment. The x and y positions are horizontal dimensions and the z position is the position above the floor. Note that by default the fire is at the centre of the room, on the floor.

- Leave the fire position at the default values: x = 15.0 m; y = 15.0 m; z = 0.0 m

The other parameters on this menu are described in Part 3, Section 2.1.6 of this manual. Leave these at the default values as follows:

Lower Oxygen Limit: 10%.

Heat of Combustion: 1.95×10^7 J/kg.

Initial Fuel Temperature: 20°C.

Gaseous Ignition Temperature: 220°C.

Radiative Fraction: 0.3.

2.1.7 Specifying Time-Dependent Fire Data (Icon: x-y graph)

This icon allows the following time-dependent data to be entered:

- pyrolysis rate
- heat release rate
- toxic combustion products

♦ Click on the “x-y graph” icon and select “heat release rate”.

The graph and table displayed show how the heat release rate varies throughout the fire. The table shows the time in the left hand column and the heat release rate in the right hand column with the units displayed at the bottom of the screen. To display other parts of the table, click on the scroll bar to the right of the table or use the arrow keys. The peak heat release rate is 2,701 kilowatts at 120 seconds. This data relates to the ultrafast fire growth curve defined when you first created the file for the SHOP1 fire case. Changes may be made to the data at this point if required by editing data in the table. Click on “Cancel” to leave this data unchanged.

The other two parameters selected from the “x-y graph” icon are pyrolysis rate and toxic combustion products. The pyrolysis rate is defined from by the heat release rate and heat of combustion and no changes are required here. No toxic products will be added so this option may also be ignored.

2.1.8 Tools (Icon: Toolbox)

This option is not required for this case.

2.1.9 Ambient Conditions (Icon: Sun and Cloud)

This icon allows the following conditions relating to the building environment to be set. The values given in Table 7 are the default values which should be left unchanged in this example.

Parameter	**Internal**	**External**
Temperature	20.0°C	20.0°C
Relative Humidity	50.0%	50.0%
Pressure	101300 Pascals	101300 Pascals
Station Elevation	0.0 m	0.0 m

Table 7. Ambient Conditions - Default Values

2.1.10 Model Input/Output (Icon: Digital Clock)

This icon allows the user to control the output from the model.

Simulation. This is the overall duration of the simulation. Set this to 1200 seconds.

Display. The time interval at which results are displayed on the screen during the simulation. Set this to 20 seconds.

Spreadsheet: The time interval at which results are recorded in a spreadsheet file. If a spreadsheet file is required a filename should be supplied on this screen. In this case enter a time interval of 10 seconds and a filename "SHOP1.OUT"

2.1.11 Saving the Input Data (Icon: Floppy disc)

Once you have completed your entry of input data to define the fire case, click on the "Floppy disc" icon and select "Save" to save the data to a file. The first time the data is saved you will need to select the "Save as" option and supply a file name. In this case use the name "SHOP1.DAT".

2.1.12 Printing Out the Input Data File

Before running the model, print out the input data file you have created to check that it is the same as the one in Appendix D.

- Click on the bottom right icon showing a desktop PC. Then select "Utilities", "Print File".
- Now click the down arrow to the right of the screen, select SHOP1.DAT from the list and click on "OK".
- Select the correct printer port in the "Print To:" box, e.g. lpt1 for a local printer on the parallel port.
- Then click on "Begin" and the file should be printed out assuming you have a printer connected.
- Compare your input data file with the one in Appendix D. If there are any differences you will need to edit your file again to make corrections. To do this, from the initial FASTLITE menu, select "File", "Open" and select the file to edit.

2.2 Running the Fire Model

- To run the fire model, click on the "Building on fire" icon at the right-hand end of the main row of icons.
- No pause times are required so click on "OK" at the "Pause Times" menu and the simulation will begin.
- While the simulation is running, click on the "Graph" button to display the graphs of conditions in the compartment on the screen.

2.3 Analysing the Results

By examining the graphs, either on the screen or from the print-out, answer the following questions:

Q17. What is the calculated peak heat release rate in the fire compartment?

Q18. How does the calculated heat release rate compare with the heat release rate of the ultra-fast fire used in the input data? What do you conclude?

Q19. What is the peak value of the upper layer temperature in the fire compartment?

Q20. What is the smallest distance above the floor reached by the smoke layer?

- Now complete a hazard analysis form for the SHOP1 case (this procedure is described in Part 3, Section 2.3.4 of this manual). A completed form is given in Appendix E, Table E1.

Q21. What is the initial hazard predicted by FASTLITE and when does it occur?

The results obtained and the conclusions drawn from fire modelling studies depend, amongst other things, on the assumptions made and the input data supplied by the user. One assumption we made in the SHOP1 case was that the head height was 1.5 metres. As an illustration of the dependence of the results on the assumptions made, try changing the assumed head height to 2.0 metres.

Q22. Assuming head height to be 2.0 metres, what is the initial hazard predicted by FASTLITE and how has it changed? (HINT: the only new information you need to find is the time when the interface reaches 2.0 metres above the floor.)

3. POLYSTYRENE FOAM FIRE (SHOP2)

In this scenario the fire load will be changed to polystyrene foam in cartons. This is a larger fire load than used for SHOP1. The heat release rate of the new fire, taken from an independent source, is shown in Table 8.

Time (min.)	0	2	4	6	8	10	12	14	16
Heat release rate (MW)	0.0	4.4	9.7	14.9	15.4	12.6	6.9	1.8	0.0

Table 8. Heat release rate of polystyrene foam fire

- Make a copy of the SHOP1.DAT data file and call the copy SHOP2.DAT.

- Open SHOP2.DAT by selecting “File”, “Open” from the opening menu and selecting SHOP2.DAT. When you reach the “Main Input Menu”, amend the title accordingly. Then click on the “Digital Clock” icon and change the spreadsheet file name to SHOP2.OUT.

♦ Click on the Time-Dependent Fire Data option (Icon: x-y graph), select "Heat Release Rate". Then click on "Select Curve...", "Ultrafast Growth" and "OK" and enter the following times:

Level Off Time	300 seconds
Start Decay Time	480 seconds

♦ Click on "OK" and the calculated heat release rate curve based on these values will appear.

The data points follow those in the Table 8 reasonably closely. The peak value is 16.9 MW and this compares with a peak of 2.7 MW in the SHOP1 case.

♦ Click on "OK" to return to the "Main Input Menu".

♦ Click on the "Digital Clock" icon and change the simulation time to 1000 seconds so that the fire burns to completion. Then click on "OK".

♦ Click on the "Floppy disc" icon and select "Save" to save the data to the file.

♦ Now run the SHOP2 case and complete a hazard analysis form.

Q23. From the graphs, how do the conditions on the sales floor compare with the SHOP1 case?

Q24. What is the initial hazard predicted by FASTLITE for the SHOP2 case and when does it occur?

Table E2 is a completed hazard analysis for the SHOP2 case. You can see that FASTLITE predicts hazards due to heat radiation, upper-layer temperature, lower-layer temperature, carbon monoxide and lack of oxygen. As expected, the larger fire load has produced a more severe hazard in the compartment.

4. POLYSTYRENE FOAM FIRE WITH SPRINKLERS (SHOP3)

In this scenario, sprinklers will be added to the compartment to see if this reduces the hazard.

♦ Make a copy of the SHOP2 data file and call the copy SHOP3.

♦ Open SHOP3.DAT and amend the title accordingly. Also, change the spreadsheet file name to SHOP3.OUT.

♦ Click on the "Sprinkler Spray" icon. By default no sprinklers are defined

♦ Click on "Add" to add a new device. Then in the "Sprinklers and Detectors" menu, click on "Typical Values" and select "Commercial Sprinkler". This will define the specifications of the sprinkler to a typical commercial sprinkler as in Table 9.

Parameter	Value
Response Time Index (RTI)	100 $m^{0.5}s^{0.5}$
Activation Temperature	73.89°C
Spray Density	7 x 10^{-5} m/s

Table 9. Sprinkler Specifications

The RTI refers to the speed of response of the sprinkler to a change in the temperature of the air surrounding it. A faster sprinkler has a lower RTI. The activation temperature is the temperature that the sprinkler head must reach before activation occurs. The spray density is the rate-of-rise of the water level on the floor due to the sprinkler spray. Leave these values unchanged.

The position of the sprinkler is set at the centre of the compartment by default. However, the fire has already been placed at the centre of the compartment and it is unlikely that a sprinkler will be located directly over the fire. Therefore, a square of four sprinklers will be defined as in Figure 5.

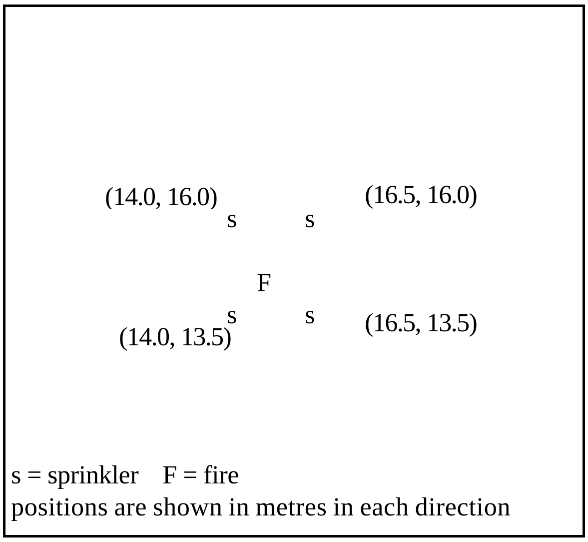

Figure 5. SHOP3, Sprinkler positions on the sales floor.

- Enter the x and y positions of the sprinkler as 14.0 and 13.5 metres. Leave the z position at 2.99 metres, i.e. just below the ceiling. Then click on “OK” to accept.

- Add the other three sprinklers in the positions shown in Figure 5. Select “Commercial Sprinkler” and leave the other specifications as before.

- When four sprinkles have been defined, exit from the Detectors/Sprinklers menu.

- Click on the “Floppy disc” icon and select “Save” to save the data to the file.

- Now run FASTLITE for the SHOP3 case and set a pause at 0.0 seconds after detector/sprinkler activation.

- Complete a hazard analysis form for the SHOP3 case..

A completed hazard analysis form for SHOP3 is shown in Table E3.

Q25. At what times do the sprinklers activate?

Q26. From the graphs, what effect have the sprinklers had on the fire?

Q27. How does FASTLITE calculate the effect of sprinklers on the fire?

Q28. From the hazard analysis form, what effect have the sprinklers had on the hazard in the compartment?

If the sprinklers had responded sooner the fire would have been contained at a smaller size which might have prevented hazardous conditions occurring. Therefore, try repeating the simulation with fast-response sprinklers.

- Select the sprinkler option and edit each sprinkler in turn. Change the RTI value in each case, selecting "Quick Response" which gives an RTI of 50 $m^{0.5}s^{0.5}$.

- Run FASTLITE again with the quick-response sprinklers.

Q29. What are the activation times of the fast-response sprinklers?

Q30. Have the quick-response sprinklers prevented a hazard occurring in the compartment?

REFERENCES

1. "The SFPE Handbook of Fire Protection Engineering", section 2 chapter 1, Society for Fire Protection Engineers, Boston, USA and National Fire Protection Association, Quincy, USA, 1988.

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3. A Beard, "Evaluation of Fire Models: Report 6 - ASET: Quantitative Assessment" (page 26), Unit of Fire Safety Engineering, University of Edinburgh, October 1990, report to the Home Office.

4. L Y Cooper and D W Stroup, "ASET- A Computer Program for Calculating Available Safe Egress Time", Fire Safety Journal, 9 (1985) 29 - 45.

5. D A Purser, "Toxicity Assessment of Combustion Products", SFPE Handbook of Fire Protection Engineering, September 1988.

6. R. W. Portier, R. D. Peacock and P. A. Reneke, "FASTLite: Engineering Tools for Estimating Fire Growth and Smoke Transport", Special Publication 899, National Institute of Standards and Technology, USA.

ANSWERS TO EXERCISES

Q1. 650kW.

Q2. They are almost the same. Therefore there has been negligible constraint of the fire due to ventilation.

Q3. 350°C.

Q4. The upper layer does not reach the floor in the living-room, but in the hall reaches the floor at 3 minutes 20 seconds.

Q5. The heat release rate follows the same curve in both cases until about 310 seconds when the heat release rate for HOUSE2 drops back sharply. This is because the oxygen concentration in the living room has fallen below the minimum level for combustion which was set at 10%. FASTLITE thus modifies the heat release rate supplied in the input data to account for the lack of oxygen. It can also be seen that air temperatures fall at this point as a consequence.

Q6. 1. Upper layer temperature at 2:20;
2. Heat radiation at 3:30;
3. Lower layer temperature at 4:20.
However, from the graph output it can be seen that at 4:20 (260 seconds) the layer in compartment 1 has reached the floor and so the hazard from the lower layer temperature is not relevant. The third hazard is therefore upper layer carbon monoxide concentration at 5 minutes.

Q7. The times are similar. The effect of the closed window in constraining the fire does not take effect until 5 minutes 10 seconds, after the first hazards have been reached.

Q8. The layer interface reaches 1.5 metres at 0:40 in the living-room and will therefore reach 2.0 metres above the floor earlier than this. As all hazards occur later than this time, there will be no effect on the predicted hazard times. For this fire case the assumption of head height is therefore not critical.

Q9. In the HOUSE3 case the upper layer temperature in the hall only rises by about 20°C and the layer interface begins to descend much later, after about 3 minutes.

Q10. FASTLITE predicts that there will be no hazard in the hall. An upper layer is predicted to form due to gases emitted from the door crack, but the temperature and gas concentrations in the layer are not hazardous.

Q11. Assuming the occupant is not in the living-room but they have to travel through the hall to escape, the first hazard occurs in the hall at 3:10 (see HOUSE2). Therefore the time available is 3:10 - 1:26 = 1:44. If the occupant is in the living-room then the time predicted by FASTLITE is 2:20 - 1:26 = 54 seconds although there may be other hazards in the living-room such as direct contact with the fire.

Q12. With the door closed, the smoke detector activated 72.8 seconds later (159.4 - 86.6 = 72.8 seconds), but from the results of the HOUSE3 case there was no hazard in the hall so that the chances of escaping through the hall have improved.

Q13. The peak heat release rate of the sofa is nearly double the value for the armchair selected in HOUSE3. However, the heat release rate is rapidly cut back due to lack of oxygen. The upper layer temperatures are similar to the HOUSE3 case but the peak is much earlier, at about 100 seconds as opposed to 200 seconds in HOUSE3. The layer interface heights also follow similar patterns.

Q14. The peak upper and lower layer temperatures in the hall are significantly higher than in the HOUSE3 case. However, none of the parameters reach the hazard criteria.

Parameter	**HOUSE3 Peak Value**	**HOUSE6 Peak Value**
Heat rad. (kW/m^2)	0.09	0.37
Upper-layer temp. (°C)	35.2	70.7
Lower-layer temp. (°C)	31.5	53.8
Upper-layer CO (ppm)	34	163
Lower-layer CO (ppm)	117	0
Upper-layer O2 (%)	22.7	22.3
Lower-layer O2 (%)	22.4	22.8

Table 10. HOUSE3 and HOUSE6 Peak values

Q15. Before the rescuer arrives, the fire has died out due to a lack of oxygen. When the doors are opened, fresh air is sucked into the living room allowing further combustion. As the hot gases flow into the hall and mix with the fresh air in the hall, they ignite as a "backdraught" which is indicated by the heat release rate in the hall.

Q16. The peak values are shown in Table 11. Significant changes occurred for HOUSE8, HOUSE9 and HOUSE11 so that the results are sensitive to changes in wall properties, fire type (constrained/unconstrained) and radiative fraction. The effect of the fire position in the room (HOUSE10) was small. The biggest change was produced by changing the fire type to unconstrained (HOUSE9) where the peak lower-layer temperature changed from 127°C to 337°C.

Output Parameter	HOUSE2	HOUSE8	HOUSE9	HOUSE10	HOUSE11
Peak heat release rate (kW)	651	651	642	651	651
Peak upper layer temperature (°C)	334	301	373	334	295
Peak lower layer temperature (°C)	127	124	337	140	178

Table 11. Sensitivity Analysis: Peak Values

Q17. 2,700 kilowatts.

Q18. They are the same and therefore the fire as not been constrained by lack of oxygen. This is to be expected in a large compartment.

Q19. 150°C.

Q20. About 1.4 metres.

Q21. The initial hazard occurs at 4 minutes 50 seconds due to the upper-layer temperature.

Q22. The interface reaches 2.0 metres above the floor at 3 minutes and, as the upper-layer temperature has exceeded the hazard criterion at this time, this is the new time to hazard. Changing the assumption about the head height has therefore reduced the time to hazard from 4 minutes 50 seconds to 3 minutes.

Q23. The peak upper-layer temperature is 379°C compared with 147°C in the SHOP1 case. The upper-layer reaches floor level whereas in the SHOP1 case the upper-layer only reached about 1.4 metres above the floor.

Q24. The initial hazard occurs at 3 minutes 20 seconds due to heat radiation. This compares with 4 minutes 50 seconds in the SHOP1 case.

Q25. 123.7, 128.0 and 131.5 seconds. Two sprinklers are equidistant from the fire and so activate at the same time, hence only three activation times are given.

Q26. The sprinklers have limited the growth of the fire so that the peak heat release rate is only 3 megawatts instead of 16.8 megawatts in the SHOP2 case. Also, the upper layer temperature only reaches 140°C compared to 379°C. The interface height remains at just under 1 metre above the floor whereas in the SHOP2 case the interface reached the floor.

Q27. The FASTLITE manual states that the fire suppression calculation is based upon a published experimental correlation. Only the effect of the first sprinkler to activate is taken in to account in the simulation. The calculation assumes that the effect of the sprinkler is to reduce the heat release rate of the fire and any effects on gas temperature or mixing of gas layers are ignored.

Q28. There is still a hazard in the compartment, occurring at 4 minutes 50 seconds due to the upper-layer temperature. However, this is the only hazard and it is much less severe than before. This compares with onset of hazard at 3 minutes 20 seconds in the SHOP2 case and therefore the sprinklers have increased the time available for escape by 1 minute 30 seconds.

Q29. 105.1, 108.6 and 111.0 seconds, i.e. about 20 seconds earlier than the standard sprinklers.

Q30. No. From the graphs, the upper-layer temperature still rises above 100°C which is the hazard criterion.

APPENDIX A

HAZARD ANALYSIS FORM

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name:

B) Scenario description:

C) Room:

D) Head height (metres): (i.e. the height at which gases are inhaled)	E) Time interval of output data (seconds): All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec):

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)					
Heat rad. (kW/m^2)					
Upper-layer temp. (°C)					
Lower-layer temp. (°C)					
Upper-layer CO (ppm)					
Lower-layer CO (ppm)					
Upper-layer O2 (%)					
Lower-layer O2 (%)					

Comments:

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a "@":-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

APPENDIX B

PRINT-OUTS FROM FASTLITE FOR HOUSE1

HOUSE1.DAT

```
VERSN    3HOUSE1 - BASE CASE
#VERSN 3 HOUSE1 - BASE CASE
TIMES   1000     20     10     20     0
ADUMP HOUSE1.OUT
TAMB  293.150        101300. 0.000000
EAMB  293.150        101300. 0.000000
HI/F  0.000000 0.000000
WIDTH  3.80000  2.00000
DEPTH  4.00000  5.00000
HEIGH  3.00000  3.00000
CEILI GYPSUM   GYPSUM
WALLS GYPSUM   GYPSUM
FLOOR CONCRETE CONCRETE
#CEILI GYPSUM   GYPSUM
#WALLS GYPSUM   GYPSUM
#FLOOR CONCRETE CONCRETE
HVENT  1  2  1  1.00000  2.00000 0.000000
CVENT  1  2  1      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000
1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000
HVENT  1  3  1  1.00000  2.00000  1.00000 0.000000
CVENT  1  3  1      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000
1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000
CHEMI  16.0000  50.0000  10.0000 1.95000E+007  293.150  493.150 0.300000
LFBO 1
LFBT 2
CJET ALL
FPOS  1.00000  1.00000 0.000000
FTIME      30.0000      60.0000      90.0000      120.000      150.000      180.000      210.000      240.000      275.000      475.000
533.000      591.000      649.000      707.000      765.000      823.000      881.000      939.000      1000.00
FMASS     0.000000   0.000397488    0.00158995    0.00357740    0.00635979    0.00993723    0.0143096    0.0194769
0.0254392    0.0334001    0.0334001    0.0264279    0.0202710    0.0149294    0.0104031    0.00669215    0.00379643
0.00171602   0.000450908     0.000000
FQDOT     0.000000      7751.02      31004.1      69759.2      124016.      193776.      279037.      379800.      496065.
651301.      651301.      515344.      395284.      291124.      202861.      130497.      74030.3      33462.4      8792.71      0.000000
HCR     0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000
0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000
0.0800000    0.0800000
OD       0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000
CO       0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000
#GRAPHICS ON
DEVICE 1
WINDOW    0.    0. -100. 1280. 1024. 1100.
LABEL  1  970.  960.    0. 1231. 1005.   10. 15 00:00:00 0.00  0.00
GRAPH  1  100.   50.    0.  600.  475.   10. 3 TIME HEIGHT
GRAPH  2  100.  550.    0.  600.  940.   10. 3 TIME CELSIUS
GRAPH  3  720.   50.    0. 1250.  475.   10. 3 TIME FIRE_SIZE(kW)
GRAPH  4  720.  550.    0. 1250.  940.   10. 3 TIME O|D2|O()
HEAT   0 0 0 0 3   1 U
HEAT   0 0 0 0 3   2 U
TEMPE  0 0 0 0 2   1 U
TEMPE  0 0 0 0 2   2 U
INTER  0 0 0 0 1   1 U
INTER  0 0 0 0 1   2 U
O2     0 0 0 0 4   1 U
O2     0 0 0 0 4   2 U
```

APPENDIX C

HOUSE FIRE STUDY: HAZARD ANALYSIS FORMS

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *HOUSE1*

B) Scenario description: *Initial scenario. Living-room and hall. Armchair fire in living-room. Living-room window open. Living-room/hall door open.*

C) Room: *Living room.*

D) Head height (metres): *1.5* (i.e. the height at which gases are inhaled)	E) Time interval of output data (seconds): *10* All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *0:40*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*648*				
Heat rad. (kW/m^2)	*6.94*	*2.5*	*3:40*		*3:40*
Upper-layer temp. (°C)	*327*	*100*	*2:30*	*YES*	@ *2:30*
Lower-layer temp. (°C)	*131*	*100*	*4:20*		*4:20*
Upper-layer CO (ppm)	*3,040*	*3,000*	*7:40*	*YES*	@ *7:40*
Lower-layer CO (ppm)	*834*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*12.9 (min.)*	*10 or less*	*N/R*	---	@ *N/R*
Lower-layer O2 (%)	*20.2 (min.)*	*10 or less*	*N/R*		*N/R*

Comments: *Onset of hazard occurs at 2 minutes and 30 seconds after ignition due to the temperature of the upper layer exceeding 100°C.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a "@":-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table C1. HOUSE1 Hazard Analysis - Living-room

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *HOUSE1*

B) Scenario description: *Initial scenario. Living-room and hall. Armchair fire in living-room. Living-room window open. Living-room/hall door open.*

C) Room: *Hall*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): *10*

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *1:10*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*0*				
Heat rad. (kW/m^2)	*2.11*	*2.5*	*N/R*		*N/R*
Upper-layer temp. (°C)	*186*	*100*	*3:30*	*YES*	@ *3:30*
Lower-layer temp. (°C)	*46*	*100*	*N/R*		*N/R*
Upper-layer CO (ppm)	*3,000*	*3,000*	*8:30*	*YES*	@ *8:30*
Lower-layer CO (ppm)	*1,640*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*13.0 (min.)*	*10 or less*	*N/R*	---	@ *N/R*
Lower-layer O2 (%)	*17.5 (min.)*	*10 or less*	*N/R*		*N/R*

Comments: *Onset of hazard occurs at 3 minutes and 30 seconds after ignition due to the temperature of the upper layer exceeding 100°C.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a “@”:-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table C2. HOUSE1 Hazard Analysis - Hall

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *HOUSE2*

B) Scenario description: *Armchair fire in living-room. Living-room window closed. Living-room/hall door open.*

C) Room: *Living-room*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): *10*

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *0:40*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*651*				
Heat rad. (kW/m^2)	*7.28*	*2.5*	*3:30*		*3:30*
Upper-layer temp. (°C)	*334*	*100*	*2:20*	*YES*	*2:20*
Lower-layer temp. (°C)	*140*	*100*	*4:20*		*4:20*
Upper-layer CO (ppm)	*3,940*	*3,000*	*5:00*	*YES*	*5:00*
Lower-layer CO (ppm)	*3,370*	*3,000*	*6:30*		*6:30*
Upper-layer O2 (%)	*7.2*	*10 or less*	*6:20*	*YES*	*6:20*
Lower-layer O2 (%)	*10.4*	*10 or less*	*N/R*		*N/R*

Comments: *Onset of hazard occurs at 2 minutes 20 seconds due to upper-layer temperature.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a "@":-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table C3. HOUSE2 Hazard Analysis - Living-room

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *HOUSE2*

B) Scenario description: *Armchair fire in living-room. Living-room window closed. Living-room/hall door open.*

C) Room: *Hall*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): *10*

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *1:10*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*0*				
Heat rad. (kW/m^2)	*2.17*	*2.5*	*N/R*		*N/R*
Upper-layer temp. (°C)	*189*	*100*	*3:10*	*YES*	*3:10*
Lower-layer temp. (°C)	*41.5*	*100*	*N/R*		*N/R*
Upper-layer CO (ppm)	*3,930*	*3,000*	*5:40*	*YES*	*5:40*
Lower-layer CO (ppm)	*0*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*7.2*	*10 or less*	*7:10*	*YES*	*7:10*
Lower-layer O2 (%)	*22.8*	*10 or less*	*N/R*		*N/R*

Comments: *Hazard at 3 minutes 10 seconds due to upper-layer temperature.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a "@":-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table C4. HOUSE2 Hazard Analysis - Hall.

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *HOUSE3*

B) Scenario description: *Armchair fire in living-room. Living-room window closed. Living-room/hall door closed.*

C) Room: *Hall*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): 10

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *3 minutes*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*585 in living room*				
Heat rad. (kW/m^2)	*0.09*	*2.5*	*N/R*		*N/R*
Upper-layer temp. (°C)	*35.2*	*100*	*N/R*	---	*N/R*
Lower-layer temp. (°C)	*31.5*	*100*	*N/R*		*N/R*
Upper-layer CO (ppm)	*34*	*3,000*	*N/R*	---	*N/R*
Lower-layer CO (ppm)	*117*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*22.7*	*10 or less*	*N/R*	---	*N/R*
Lower-layer O2 (%)	*22.4*	*10 or less*	*N/R*		*N/R*

Comments: *None of the hazard criteria were exceeded in the hall although the upper layer descended to near floor level.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a "@":-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table C5. HOUSE3 Hazard Analysis - Hall.

APPENDIX D

SHOP FIRE STUDY - INPUT DATA FOR SHOP1

SHOP1.DAT

```
 VERSN    3SHOP FIRE - INITIAL CASE
#VERSN 3 SHOP FIRE - INITIAL CASE
TIMES   1200     20     10     20      0
ADUMP SHOP1.OUT
TAMB  293.150        101300. 0.000000
EAMB  293.150        101300. 0.000000
HI/F  0.000000
WIDTH  30.0000
DEPTH  30.0000
HEIGH  3.00000
CEILI GYPSUM
WALLS GYPSUM
FLOOR CONCRETE
#CEILI GYPSUM
#WALLS GYPSUM
#FLOOR CONCRETE
HVENT  1  2  1 0.00100000  2.13000 0.000000 0.000000
CVENT  1  2  1      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000
1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000
CHEMI  16.0000  50.0000  10.0000 1.95000E+007  293.150  493.150 0.300000
LFBO 1
LFBT 2
CJET ALL
FPOS -1.00000 -1.00000 0.000000
FTIME      13.0000      26.0000      39.0000      52.0000      65.0000      78.0000      91.0000      104.000      120.000      240.000
253.000      266.000      279.000      292.000      305.000      318.000      331.000      344.000      360.000
FMASS     0.000000    0.00162587    0.00650349    0.0146328    0.0260138    0.0406467    0.0585313    0.0796677    0.104055
0.138535     0.138535     0.110145     0.0850067     0.0631200     0.0444852     0.0291021     0.0169706    0.00809087    0.00246285
0.000000
FQDOT     0.000000      31704.4      126818.      285340.      507270.      792610.  1.14136E+006  1.55352E+006  2.02908E+006
2.70144E+006  2.70144E+006  2.14783E+006  1.65763E+006  1.23084E+006      867462.      567490.      330926.      157772.
48025.6      0.000000
HCR      0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000
0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000    0.0800000
0.0800000    0.0800000
OD       0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000
CO       0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000    0.0300000
0.0300000    0.0300000
#GRAPHICS ON
DEVICE 1
WINDOW    0.    0. -100. 1280. 1024. 1100.
LABEL  1  970.  960.    0. 1231. 1005.   10. 15 00:00:00 0.00  0.00
GRAPH  1  100.   50.    0.  600.  475.   10. 3 TIME HEIGHT
GRAPH  2  100.  550.    0.  600.  940.   10. 3 TIME CELSIUS
GRAPH  3  720.   50.    0. 1250.  475.   10. 3 TIME FIRE_SIZE(kW)
GRAPH  4  720.  550.    0. 1250.  940.   10. 3 TIME O|D2|O()
HEAT   0 0 0 0 3   1 U
TEMPE  0 0 0 0 2   1 U
INTER  0 0 0 0 1   1 U
O2     0 0 0 0 4   1 U
```

APPENDIX E

SHOP FIRE STUDY - HAZARD ANALYSIS FORMS

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *SHOP1*

B) Scenario description: *Polyurethane foam furniture fire in centre of sales floor.*

C) Room: *Sales floor*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): *10*

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *4:50*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*2,700*				
Heat rad. (kW/m^2)	*1.34*	*2.5*	*N/R*		*N/R*
Upper-layer temp. (°C)	*147*	*100*	*1:50*	*NO*	*4:50*
Lower-layer temp. (°C)	*36*	*100*	*N/R*		*N/R*
Upper-layer CO (ppm)	*977*	*3,000*	*N/R*	---	*N/R*
Lower-layer CO (ppm)	*2*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*19.6*	*10 or less*	*N/R*	---	*N/R*
Lower-layer O2 (%)	*22.8*	*10 or less*	*N/R*		*N/R*

Comments: *Onset of hazard occurs at 4 minutes 50 seconds when the upper-layer descends to head height. The hazard is due to upper-layer temperature.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a “@”:-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table E1. SHOP1 Hazard Analysis

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *SHOP2*

B) Scenario description: *Polystyrene foam cartons fire in centre of sales floor.*

C) Room: *Sales floor.*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): *10*

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *3:30*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*16,830*				
Heat rad. (kW/m^2)	*9.82*	*2.5*	*3:20*		*3:20*
Upper-layer temp. (°C)	*379*	*100*	*1:45*	*NO*	*3:30*
Lower-layer temp. (°C)	*163*	*100*	*5:40*		*5:40*
Upper-layer CO (ppm)	*3,950*	*3,000*	*6:50*	*YES*	*6:50*
Lower-layer CO (ppm)	*0*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*9.2*	*10 or less*	*8:30*	*YES*	*8:30*
Lower-layer O2 (%)	*22.8*	*10 or less*	*N/R*		*N/R*

Comments: *Onset of hazard occurs at 3 minutes 20 seconds due to heat radiation.*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a “@”:-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table E2. SHOP2 Hazard Analysis

Hazard Analysis of Results of FASTLITE Fire Simulation

A) Scenario name: *SHOP3*

B) Scenario description: *Polystyrene foam cartons fire in centre of sales floor. Sprinklers installed.*

C) Room: *Sales floor.*

D) Head height (metres): *1.5*

(i.e. the height at which gases are inhaled)

E) Time interval of output data (seconds): *10*

All times recorded below are to this level of precision.

F) Time when the interface reaches head height (min:sec): *4:50*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Upper layer below head height? (5)	Time to Hazard (min:sec) See note below (6)
Heat release rate (kW)	*2,813*				
Heat rad. (kW/m^2)	*1.24*	*2.5*	*N/R*		*N/R*
Upper-layer temp. (°C)	*140*	*100*	*1:50*	*NO*	*4:50*
Lower-layer temp. (°C)	*36*	*100*	*N/R*		*N/R*
Upper-layer CO (ppm)	*1,140*	*3,000*	*N/R*	---	*N/R*
Lower-layer CO (ppm)	*9*	*3,000*	*N/R*		*N/R*
Upper-layer O2 (%)	*19.0*	*10 or less*	*N/R*	---	*N/R*
Lower-layer O2 (%)	*22.8*	*10 or less*	*N/R*		*N/R*

Comments: *Onset of hazard occurs at 4 minutes 50 seconds when the upper-layer descends to head height. The hazard is due to upper-layer temperature*

KEY: N/R = Hazard not reached

Note for column (6). For parameters of the upper layer only, which are marked with a “@”:-

If column (5) = Yes, enter contents of column (4)
If column (5) = No, enter contents of box (F)

Table E3. SHOP3 Hazard Analysis

APPENDIX F

INSTRUCTIONS FOR USING MS-EXCEL

Additional instructions for using MS-Excel to analyse data from Fastlite

The section "Viewing the spreadsheet file" in Part 3 Section 2.3.3 of this manual describes how the output data from Fastlite can be read using a spreadsheet package. If you are using the Microsoft Excel spreadsheet package the instructions below provide further details. The instructions are based on MS-Excel version 5.0c.

- Run Fastlite and produce a spreadsheet output file with filename such as HOUSE1.OUT.
- Exit from Fastlite.
- Run MS-Excel.
- Select "File", "Open" and select the file created by Fastlite e.g. C:\FASTLITE\HOUSE1.OUT, and click on "OK".

The "Text Import Wizard Step 1" screen should now appear.

The different variables in the Fastlite file are separated by commas. These variables need to be split into separate columns to be read easily.

- Select "Delimited" to indicate that the data variables in the source file are separated by characters and then click on "Next"
- At the "Text Import Wizard Step 2" screen, select "Comma" as the delimiting character. The data preview window should now show the data separated into columns. Click on "Next".
- At the "Text Import Wizard Step3" screen, no changes are needed so select "Finish".

The data will now be displayed in the spreadsheet. Each column heading indicates the name of the variable in that column. To make the column headings easier to read, you can increase the column width.

- To do this, click on the top left square of the data frame (the square immediately above the "1" and to the right of the "A"). This will select the whole spreadsheet which will now appear highlighted on the screen.
- Now, select "Format", "Column", "Standard Width" and enter a column width e.g. 25. This will cause the data columns to be separated and allow the full variable names to be displayed at the top of the sheet.

Before exiting the spreadsheet, select "File", "Save as" and select the file type "Excel Workbook". The filename will change to e.g. HOUSE1.XLS and this file will save the format changes which you have applied.