FRDG
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FIRE MODELS TRAINING MANUAL FOR FSO'S

VOLUME 2: ARGOS

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 ARGOS which the reader will need access to. ARGOS is a zone-type model (see section 3) produced by the Danish Institute of Fire Technology (DIFT). Copies of ARGOS may be obtained from:-

Danish Institute of Fire Technology
Datavej 48,
DK 3460 Birkeroed
DENMARK
Tel: 45 45 82 00 99
Fax: 45 45 82 24 99

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 FASTLITE and HAZARD-I, both of which are 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 <u>pyrolysis</u>. Secondly, the vapour produced mixes with the air and undergoes an exothermic (heat producing) chemical reaction with the oxygen present, a process known as <u>combustion</u>.

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 in a <u>plume</u>. 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

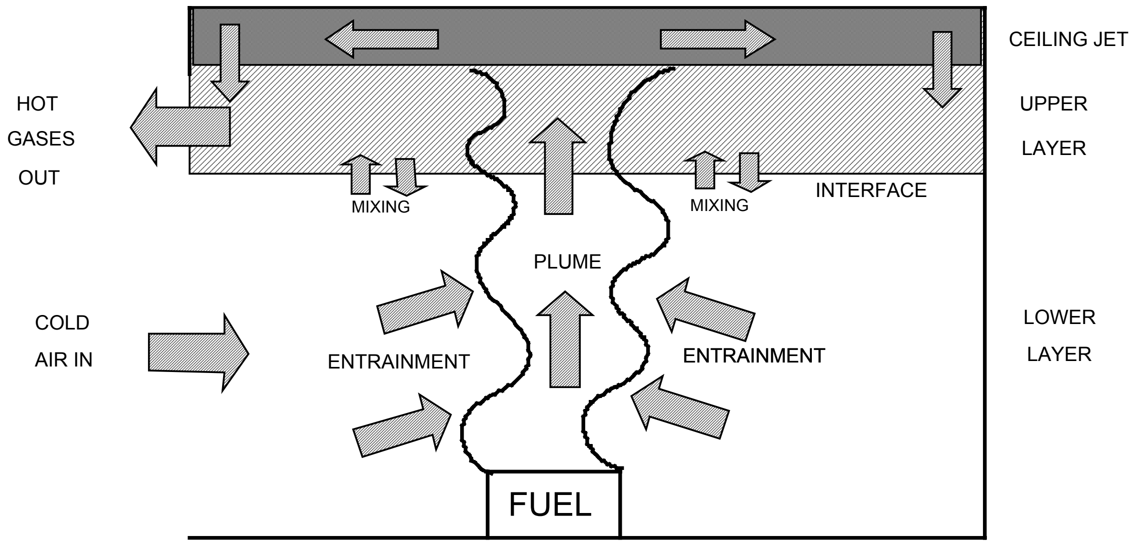

Figure 1 The Physical Processes of a Fire

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 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.

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

(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. In most cases, ARGOS takes only a few minutes on a PC with a 486 or Pentium processor. As the simulation proceeds, the results are displayed on the screen. A print-out is also produced if this has been requested. At the end of the simulation, graphs of the results may be viewed on the screen.

(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 temperatures
- smoke obscuration
- oxygen concentrations

The results may be analysed from the tables and graphs which appear on the screen or from the print-out.

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 which 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 $2.5 kW/m^2$ 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 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 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.

(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. However, ARGOS does not predict the concentration of toxic gases.

(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% will 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. Section 2.3.2 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. As the ARGOS model does not predict escape times, these must be calculated or estimated independently.

7. TYPOGRAPHICAL CONVENTIONS

♦ indicates an action to be taken.

<Return> indicates a key to be pressed.

PART 2: USING ARGOS

1. INSTALLATION

Installation instructions are provided with the ARGOS software. The installation takes only a few minutes to complete. The release notes for ARGOS state that the hardware requirements are an IBM-compatible PC with EGA or VGA graphics, at least 640k RAM and 3 Mbytes of free disc space. This manual is based on ARGOS version 3.01.

2. ACCESSING ARGOS

ARGOS is supplied with a licence key which must be plugged into the parallel port of your PC to allow the software to run.

To access ARGOS from the DOS prompt, change to the directory in which ARGOS was installed, usually C:\ARGOS, and type "ARGOS". This will bring up the main menu.

3. MAIN MENU

The main menu has four options.

Client files. This option allows files of input data to be created and edited prior to running the model.

Calculate. This option allows the model to be run, to simulate a fire based on one of the input data files created using the **Client Files** option.

Database. This option allows the database of fire engineering information to be examined and edited.

System configuration. The following system configuration changes can be made:-

(i) adjustments to the screen set-up
(ii) definition of the directory in which the data is held
(iii) selection of printer type
(iv) changes to the parameters used by ARGOS in the calculations (for expert user only)

♦ From the system configuration menu, select the printer which is most appropriate for your system.

4. CREATING INPUT DATA FILE

This section covers the basics of creating an input data file with ARGOS. Full details about entering data in each input screen are given in part 3, section 2.1.

♦ Invoke ARGOS as described above.

♦ From the main menu, select "Client files" then select "Create new".

♦ When prompted for a file name, enter a name to identify the case to be modelled.

Another menu will appear titled "File *(FILENAME)*" with 9 options, each one allowing a different section of input data to be entered. At the bottom of each input menu is a key to the key strokes that may be used, e.g. F1 = Help, F2 = Save. The keys available vary from one menu to another. When exiting from each input menu, **remember to press F2 to save the data entered**.

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 ARGOS 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 a 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 2 and Table 2.

2.1 Setting up the input data file.

For the basics of getting around ARGOS, see part 2 of this manual.

2.1.1 Opening the input data file.

- ♦ Invoke ARGOS (see part 2 for instructions on how to do this).
- ♦ From the main menu, select “Client files” then select “Create new”.
- ♦ When prompted for a file name enter “HOUSE1” to indicate that this is the first scenario of the House study.

Another menu will appear titled “File (HOUSE1)” with 9 options, each one allowing a different section of input data to be entered. Instructions for entering data for each section are given below.

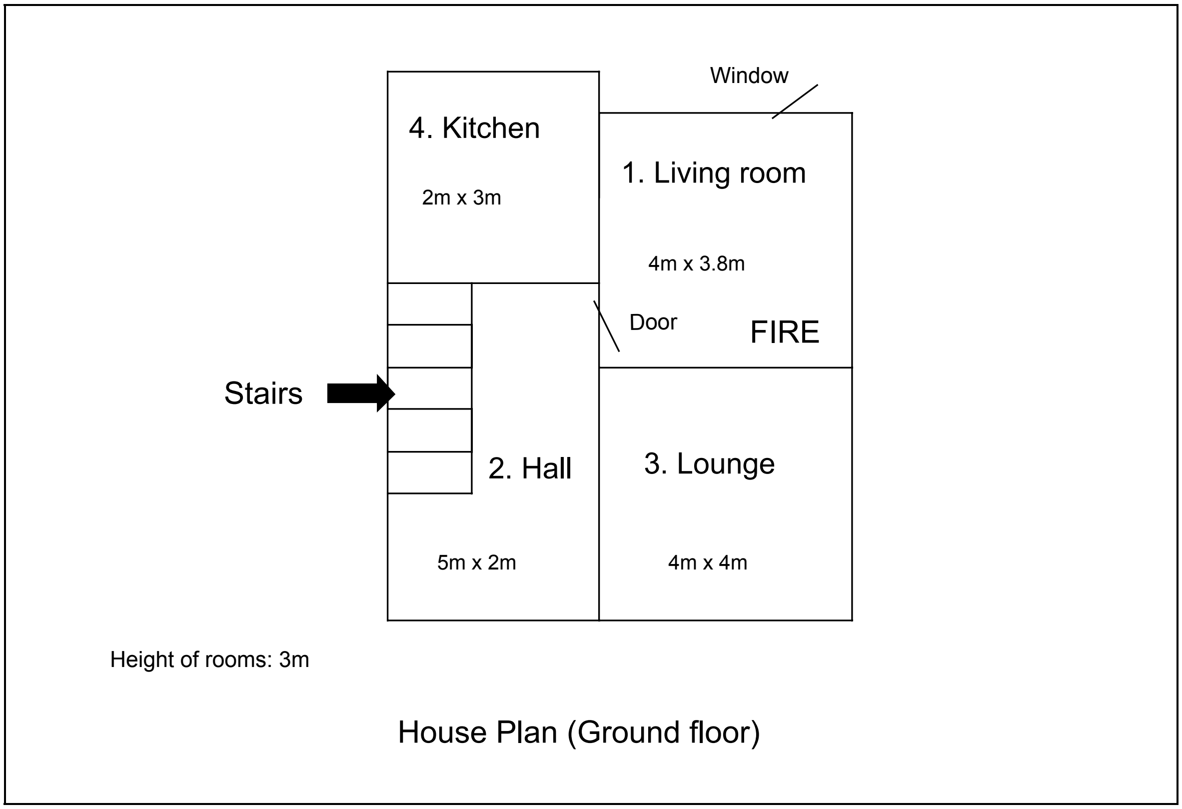

Figure 2. House fire scenario - floor plan.

OPENINGS

Connecting rooms	Type of opening	Dimensions
Living room/hall	Door, open	sill height = 0m soffit height = 2m width = 1m
Living room/outdoors	Window	sill height = 1m soffit height = 2m width = 1m

WALLS, FLOORS AND CEILINGS

Walls	Gypsum board, 13mm thick
Floor	Not defined
Ceiling	Gypsum board, 13mm thick

FIRE

Armchair in living room.

Table 2. House fire scenario - input data.

2.1.2 Input Menu: Basic information

The information entered here helps to identify the case but does not affect the results. Table 3 is an example of a completed menu. The "Company type" and "Basic bldg. constr." are entered by pressing the space bar and selecting from a list. The other information must be typed in.

♦ Complete the information as in Table 3.

File name	HOUSE1
Client	Home Office
Consultant	Brian Hume
Company type	Service, consultant
Basic bldg. constr.	Concrete
Remarks	House fire study
Remarks	Initial scenario
Last updated	1995.08.29
Revision no.	0

Table 3. Input Menu: Basic Information

♦ When all data has been entered, press F2 to save the information to the file.

2.1.3 Input Menu: Fire brigade

This section allows a calculation of the time to arrival of the fire brigade. Since this calculation gives only a very approximate estimate, it will be ignored by setting the distance to the fire station, the response time and the time before manual alarm to high values. To set the maximum value, position the cursor over the chosen parameter and press the PgUp key.

♦ Complete the information as in Table 4.

File name	HOUSE1
City area	**Yes** No
24 hour	**Yes** No
Distance/fire station [km]	50.0
Calculated response time [min]	720
Time before manual alarm [min]	720

Table 4. Input Menu: Fire brigade

2.1.4 Input Menu: Rooms

In this section, dimensions and other details are entered for each room in turn. Data will be entered for the living-room and hall only, as these are the only two rooms involved in the fire. “Room use” and “Floor type” are entered by pressing the space bar and selecting from a list.

- Enter 2 for the number of rooms.

The room may be selected by moving the cursor to “Edit data for room #” and using the left and right arrow keys.

- Select room number 1 (living room)

- Enter data for the living room as in Table 5.

- When all data has been entered, press F2 to save the information to the file.

File name	HOUSE1
No. of rooms	2
Edit data for room #	**<u>1</u>** 2 3 4 5
Room name	Living room
Room use	
Room area [m^2]	15.20
Average height [m]	3.00
Max. length [m]	4.00
Floor type	Timber floor

Table 5. Input Menu: Rooms - Living room

Now select “Rooms” again from the “File” menu and this time select room 2 (hall).

- Enter the data for the hall as in Table 6.

- When all data has been entered, press F2 to save the information to the file.

File name	HOUSE1
No. of rooms	2
Edit data for room #	1 **<u>2</u>** 3 4 5
Room name	Hall
Room use	
Room area [m^2]	10.00
Average height [m]	3.00
Max. length [m]	5.00
Floor type	Timber floor

Table 6. Input Menu: Rooms - Hall

2.1.5 Input Menu: Walls

In this section the walls are specified. This includes internal walls and external walls (i.e. walls between a room and the surroundings). A wall is added or removed by moving the cursor to the relevant box in the table so that the two adjacent rooms are highlighted and pressing the space bar. The wall is marked with an X in the table.

♦ Mark the walls as shown in Table 7.

File name HOUSE1

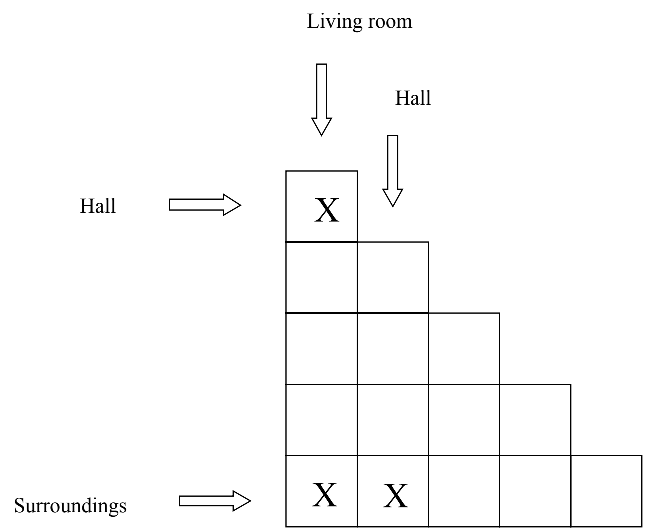

Table 7. Input Menu: Walls

The specifications for each wall are defined by selecting the wall with the cursor and then pressing F5.

♦ Select the wall between the living room and the surroundings and press F5 to define the specifications.

The "Base wall" is entered by pressing the space bar and selecting from a list.

♦ Select the base wall type and enter dimensions as in Table 8.

Other components such as doors or windows may be added. For the wall between the living room and the surroundings a window must be added as follows.

♦ Select Other component # **1**.

♦ Select Category **Windows**.

♦ While the cursor is still on Windows, press the space bar to reveal the selection list and select "Single glass window".

♦ Type in the remaining information about the window as in Table 8.

♦ Press F2 to save this information.

Wall from room: [Living room] to room: [Surroundings]	
Base wall Base wall width [m] Base wall height [m]	Gypsum board, 13mm 11.70 3.00
Other component #	**<u>1</u>** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Walls Doors **<u>Windows</u>** Misc. Single glass window 1 1.00 1.00 1.00
Table 8. Input Menu: Wall construction	

♦ From the first menu of the Wall option, select the wall between the living room and the hall and enter the information in Table 9. This time you need to define a door in the wall.

♦ Press F2 to save this information.

Wall from room: [Living room] to room: [Hall]	
Base wall Base wall width [m] Base wall height [m]	Gypsum board, 13mm 1.00 3.00
Other component #	**<u>1</u>** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Walls **<u>Doors</u>** Windows Misc. Solid wood door, 34mm (open) 1 1.00 2.00 0.00
Table 9. Input Menu: Wall construction	

♦ Now select the wall between the hall and the surroundings and enter the data in Table 10. There are no other components in this wall.

♦ Press F2 to save this information and press F2 again to leave the Walls option.

Wall from room: [Hall] to room: [Surroundings]	
Base wall Base wall width [m] Base wall height [m]	Gypsum board, 13mm 9.49 3.00
Other component #	**1** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Walls Doors Windows Misc. 0 0.00 0.00 0.00
Table 10. Input Menu: Wall construction	

2.1.6 Input Menu: Ceilings

In this section information on the ceilings is entered for each room in turn.

♦ At the top of the menu, select room **1** (living room)

The "Base ceiling" is entered by pressing the space bar and selecting from the list. Other information is typed in. Other components such as skylights and holes may be included in the ceiling but in this case no other components are required.

♦ Complete the information on the living room ceiling as in Table 11.

♦ When finished, press F2 to save the data.

File name: [HOUSE1]	
Edit ceiling of room Selected room, name	**1** 2 3 4 5 Living room
Base ceiling Ceiling area [m^2] Max. height [m]	Gypsum board, 13mm 15.20 3.00
Other component #	**1** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Ceilings Skylights Misc. 0 0.00 0.00 0.00
Table 11. Input Menu: Ceilings	

Now the hall ceiling must be defined.

♦ Select the "Ceilings" option again.

- Select room 2 and enter the information in Table 12. Again no other components are present.

- When finished, press F2 to save the data.

File name: [HOUSE1]	
Edit ceiling of room Selected room, name	1 **2** 3 4 5 Hall
Base ceiling Ceiling area [m^2] Max. height [m]	Gypsum board, 13mm 10.00 3.00
Other component #	**1** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Ceilings Skylights Misc. 0 0.00 0.00 0.00
Table 12. Input Menu: Ceilings	

2.1.7 Input Menu: Stocks

In this section stocks may be entered to allow a calculation of property loss and total fire load. However, this does not affect the calculated fire conditions. In this example we are concerned with life safety only and so this section will be ignored.

2.1.8 Input Menu: Machines

In this section machines may be entered to allow a calculation of property loss and fire frequency. In this example we are concerned with life safety only and so this section will be ignored.

2.1.9 Input Menu: Fire installations

In this section smoke venting systems, sprinklers and fire detectors may be added. In this example no fire installations will be added.

2.1.10 Input Menu: Fire start (room/type)

In this section the fire itself is defined. In this example the fire is an armchair in the living room.

- Select Fire start in room 1.

The fire may be defined from one of six different types of fire.

- Select fire start type 1, solid material.

- While the cursor is still on the fire start type, press the space bar and select Armchair from the list.

- Set the time limit to 5 minutes.

- When the menu is complete as in Table 13, press F2 to save the information.

File name: [HOUSE1]	
Fire start in room # Selected room, name	**1** 2 3 4 5 Living room
Fire start, type # Fire start, type	**1** 2 3 4 5 6 Solid Material
Fire start, name	Armchair
Time limit [min]	5

Table 13. Input Menu: Fire start

2.1.11 Quitting the Input Program

Now that all data has been entered and saved, quit the “File” menu by selecting “Previous menu”.

2.2 Running the Fire Model

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.

- If this is the first time you have tried printing from ARGOS, go to the main menu, select “System Configuration”, “Printers” and select the printer which is closest to the one you will be using.

- From the “Client files” menu, select “Print”, then select HOUSE1 from the list of files displayed.

- Compare your file with the one in APPENDIX B. If any changes to the file need to be made, select “Display/edit” from the “Client files” menu and select the file HOUSE1. Then look at the input menus and check that your data is the same as in section 2.1.

When you are satisfied that your input data file is correct, you can proceed to run the model:-

- From the main menu, select “Calculate”.

- Select HOUSE1 from the list of files.

The “Calculate client file” menu will now appear.

- Select “Print-outs” and set a print-out interval of **10** seconds for the pre-flashover period.

- Leave the print-out interval for the post-flashover period at **0** seconds as a print-out is not required here.

♦ Set “Print damage report” to **No** as this is not required for a life safety calculation.

♦ Set “Stop at critical points” to **Yes**.

♦ Press **<F2>** to accept this information.

The other options on the calculation menu allow changes to be made to the fire scenario before beginning the simulation. These changes only affect the current simulation and the data in the input file is not changed. For instance, the option “Doors open/closed” allows the user to change the status of a door from the status defined in the input file. A further option, “Wind load”, is included in more recent versions of ARGOS. This option defines the external wind, the default value being +5 metres per second for the fire start room and zero for other rooms. Five metres per second is equivalent to a gentle breeze and the plus sign indicates that the room is on the windward side of the building. Leave these values unchanged.

♦ No other information needs to be entered from this menu so select “Start calculation” and the calculations will proceed.

♦ When critical points are reached, the calculation will stop. Press the return key to continue.

The results will be printed out as the calculations proceed.

2.3 Analysing the Results

2.3.1 Viewing the Graphs

When the calculation has finished, press the F6 key to view the graphs. You can display different graphs by pressing different keys as indicated at the bottom of the screen.

N.B. Graphs can be printed using the Print option but make sure you have a graphics printer connected first, otherwise you may have problems with your printer.

By examining the graphs, answer the following questions:

Q1. What is the peak heat release rate reached by the fire?

Q2. At what time does the smoke layer reach the floor in the living room and in the hall?

Q3. What are the peak smoke densities reached in the smoke layers in the living room and in the hall?

Now exit from the “Calculate” option by pressing the “Escape” key until you return to the main menu. Select the “Database” option and look up the heat release rate data for the armchair. (From the “Main menu”, select “Database”, “Fires”, “Solid Materials”, “Display/Edit”, then select the armchair at the bottom of the list and press F6 to display the graph of heat release rate.)

Q4. 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?

2.3.2 Assessment of Hazard to Life

In this section it will be shown how to assess the hazard to life using the print-out of results. 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.

ARGOS calculates the following quantities which may be used in the hazard analysis:

1. Heat radiation from the upper layer
2. Upper layer temperature
3. Upper layer smoke
4. Lower layer smoke
5. Upper layer oxygen concentration

ARGOS does not predict the concentration of toxic gases produced by the fire and so the toxic gas hazard cannot be considered.

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.

♦ <u>Box A.</u> Fill in the scenario name "HOUSE1".

♦ <u>Box B.</u> Fill in a description of the scenario as a reminder of the main conditions.

♦ <u>Box C.</u> Fill in the room "Living room".

♦ <u>Box D.</u> 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.

♦ <u>Box E.</u> The output interval is the interval selected for your print-out which 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.

♦ <u>Box F.</u> Find the time when the interface reaches head height. From the "Living room" section of the print-out, follow down the column "Floor layer" which gives the height of the interface between the upper and lower layers, and note the point at which this height descends to the head height (1.5 metres). The nearest value to 1.5 metres occurs in the third row at 30 seconds after ignition. Therefore, enter 30 seconds in the form at box F.

♦ Column 2. For each variable in column 1 of the table, follow down each column of the print-out to find the peak value reached and enter the value in column 2. The heat release rate is listed in the column headed “Fire” on the third page of the print-out. The upper-layer smoke in the living room is listed in the column headed “Smoke, layer” on the fourth page of the print-out and the lower-layer smoke is listed in the column headed “Smoke, room”. When the interface reaches the floor, any further values of lower-layer smoke should be ignored as they are not meaningful. The oxygen concentration is not given on the print-out so you will need to read it from the graph on the screen. For oxygen, the minimum value reached 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 layer temperature 100°C, upper layer smoke 2 dB/m, lower layer smoke 2dB/m, oxygen concentration 10% or less.

♦ Column 4. Follow down each column of the print-out 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 the variables “upper-layer temperature”, “upper-layer smoke” 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, look up the interface height corresponding to the time given in column 4 and enter this height in column 5.

♦ Column 6. Compare the height in column 5 with the height in box D and enter Yes or No accordingly.

♦ Column 7. If you entered Yes in column 6, the upper layer was below head height when the hazard criterion was reached and you should enter the contents of column 4 in column 7.

If you entered No in column 6, 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 7.

If column 6 did not apply (i.e. for heat radiation and lower layer smoke) copy the contents of column 4 to column 7.

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 30 seconds after ignition due to smoke in the upper layer. The next hazard to occur was at 40 seconds after ignition due to the temperature of the upper layer.

- Now repeat the hazard analysis for the hall using the same process as described above. All the information should be taken from the sheet of output data for the hall except for the fire heat release rate which is taken from the third sheet of the print-out.

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 smoke. The onset of hazard in the hall occurred at 50 seconds due to upper-layer smoke and at 1 minute 20 seconds due to upper-layer temperature.

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 50 seconds from the time of ignition in which to escape before the hall is obscured with smoke. However, in the case of a house fire it may be thought that the occupant would be sufficiently familiar with the escape route that he would find his way out without much delay even when smoke obscures his view. In this case one could consider the next hazard in the hall which is due to the upper-layer temperature and occurs at 1 minute 20 seconds after ignition.

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. DIFFERENT ARMCHAIR FIRE (HOUSE2)

In this scenario, the fire will be changed. Instead of the standard armchair fire supplied in the ARGOS database, you will define your own armchair fire. To do this, you will need to add the fire to the ARGOS database.

- ♦ From the main menu, select “Database”.
- ♦ From the Database menu, select “Fires”.
- ♦ From the Fires menu select “Data Points”. This will allow the fire to be defined as a series of data points of heat release rate against time.
- ♦ From the “Data Points” menu, select “Create New” and call the file MY_ARMCHAIR
- ♦ Enter the data shown in Table 14.

Name: [MY_ARMCHAIR]		
Data points	t (sec)	Q(t) [MW]
#1	0	0.001
#2	200	0.058
#3	420	0.830
#4	550	0.450
#5	1000	0.120
Smoke pot. [dB/m]		400.0
CO-potential		0.0
CO2-potential		0.0
Other tox. potential		0.0
Y-value		0.0

Table 14. Input menu: Fire, data points

- ♦ When you have finished entering data press F6 to view the graph of heat release rate of MY_ARMCHAIR.
- ♦ Save the data by pressing F2.
- ♦ Compare this data with the data used in the previous scenario. (To view the data for the fire used in the previous scenario, select Database, Fires, Solid material, Display/edit, Armchair and press F6 to view the graph of the heat release rate.) Although they are both armchair fires, “MY_ARMCHAIR” reaches a peak 7 minutes after ignition compared with just over 1 minute after ignition for the armchair fire used in the previous scenario. Therefore, it might be expected that the onset of hazard would occur later in this scenario.

Now you need to make a copy of the input file used for HOUSE1 and edit it to select the MY_ARMCHAIR fire from the database.

- From the main menu, select "Client files".
- From the Client files menu select Copy and copy the file "HOUSE1" to a new file "HOUSE2"
- Now select Display/edit and select the file "HOUSE2".
- From the File menu, select "Fire Start (room/type)"
- On the "Fire Start" input menu select room 1, the living room. Then select fire start no. 6, "Data points".
- While the cursor is still on fire type 6, press the space bar to show a list of fire types in the database. Select MY_ARMCHAIR
- Still in the Fire Start screen, change the time limit to 20 minutes so that the simulation continues until the fuel is burnt out.
- Press F2 to save this data.
- Now run the model again by selecting "Calculate" from the main menu and choosing the file HOUSE2. Remember to select a print-out interval as no print-out is produced if the print-out interval is left as zero.
- Complete a hazard analysis form (Appendix A) for the living room for the HOUSE2 scenario.
- Compare your hazard analysis with the completed form in Appendix C (Table C3).

Q5. How does the peak heat release rate calculated by ARGOS compare with the peak heat release rate in the input data? What do you conclude?

Q6. What is the initial hazard predicted by ARGOS in the living room and when does it occur?

Q7. How does the predicted hazard from the lower-layer smoke compare between the HOUSE1 and HOUSE2 scenarios? Can you explain the difference?

Q8. How does the onset of hazard due to upper layer temperature and upper layer smoke compare between the HOUSE1 and HOUSE2 scenarios? How do you explain the difference?

- Now complete a hazard analysis form for the hall for the HOUSE2 scenario.
- Compare your hazard analysis with the completed form in Appendix C (Table C4).

Q9. How does the hazard in the hall compare between the HOUSE1 and HOUSE2 scenarios?

4. HALF-OPEN WINDOW (HOUSE3)

In the previous two scenarios, a window was present in the wall connecting the living room with the surroundings. But was the window open or shut? To find out, you need to look in the ARGOS database where the window is defined.

♦ Select the Database from the main menu, then select “Building Components”, then select “Windows”.

♦ Select “Display/edit”, then select “Single glass window”.

The specifications for the window are displayed. One of the factors listed is “imperviousness” which is set to 99% as the default. If you press F1 for Help, the help screen states that the imperviousness is defined as the percentage of area which is blocked. Therefore, the window defined here is closed but there is a 1% leakage area.

♦ Press **<Esc>** to exit from the Window/Edit menu.

In this scenario we wish to model a half-open window with an imperviousness of 50%. To do this, a new window must first be defined in the database.

♦ From the “Windows” menu select “Create new”.

♦ Press F3 to copy the specifications from an existing window and then select the single glass window from the list.

♦ Enter the name “Half Open Window”.

♦ Change the imperviousness to 50% and press F2 to save the change.

Now a new input file must be created in which the half-open window will be selected.

♦ Come out of the Database option and from “Client files”, copy the HOUSE2 file to HOUSE3.

♦ Edit HOUSE3 and change the window selected in the living room/surroundings wall to the half-open window.

♦ Press F2 to save the change.

♦ Now run ARGOS with the input file HOUSE3.

♦ From the output data, complete a hazard analysis form for the hall and compare it with Table C5 in Appendix C.

Q10. How does the peak heat release rate calculated by ARGOS compare with the peak heat release rate in the input data? What do you conclude?

Q11. What is the time to the initial hazard in the hall and how does this compare with the HOUSE2 scenario?

5. LIVING-ROOM DOOR CLOSED (HOUSE4)

In this scenario the door connecting the living-room to the hall will be closed which should improve conditions in the hall. The living-room window will also be closed so that it might be expected that the fire would be constrained by lack of an air supply to the room.

In the HOUSE2 scenario, the living-room window was already closed so we can use this file.

♦ From the "Client files" menu, copy the HOUSE2 file to HOUSE4.

♦ Now edit the HOUSE4 file and close the door connecting the living-room to the hall. (For more instructions, see note 1 in the section "Additional Instructions".)

♦ Now run ARGOS with the input file HOUSE4.

♦ Complete a hazard analysis form for the hall and compare your results Table C6 in Appendix C.

Q12. How does the peak heat release rate calculated by ARGOS compare the peak heat release rate in the input data? What has been the effect of closing the living-room door?

Q13. How have the conditions in the hall changed from the HOUSE2 scenario?

Q14. What is the width of the door crack?

Q15. In the HOUSE4 scenario, the living-room door was closed.   What effect has this had on the time available for escape?

An alternative way to open and close doors is from the "Calculate" menu:-

♦ Select the "Calculate" menu from the main menu and select HOUSE4.

♦ Now select "Doors open/closed" and change the status of the living-room/hall door by selecting "Yes" or "No" in the "Open" column.

6. SMOKE DETECTOR IN THE HALL (LIVING-ROOM DOOR OPEN) (HOUSE5)

In this scenario a smoke detector will be added in the hall. This will of course have no effect on the fire or the conditions in the house but will show, from the time at which the alarm goes off, how much time is available for escape. The living-room window will be closed and the living-room/hall door will be open.

♦ From the “Client files” menu, copy the HOUSE2 file to HOUSE5.

♦ Now select “Display/edit” and select HOUSE5.

♦ Select “Fire Installations”, then move the cursor to Room 2 and AFA, smoke detector.

♦ Press the space bar to add a smoke detector and then press F5 to add the specifications.

At this point ARGOS warns that smoke detectors are not suitable for rooms lower than 4 metres, but ignore this message. You will still be able to add a smoke detector.

♦ In the smoke detector name field, select “Smoke detector”.

The next two parameters are properties of the smoke detector selected and are supplied from the database:

(i) smoke sensitivity = 0.3 dB/m

(ii) y-value = 0

♦ Set the distance between heads to 10 metres so that only one detector is present in the hall.

♦ Press F2 to save the data.

♦ Now run ARGOS with the HOUSE5 input file.

You should find that the results are identical to the HOUSE2 example except for the additional information about the smoke detector.

Q16. What time did the smoke detector activate?

Q17. What is the time available for escape after the activation of the smoke detector?

7. SMOKE DETECTOR IN THE HALL (LIVING-ROOM DOOR CLOSED) (HOUSE6)

In this example, a smoke detector is added in the hall 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 scenario HOUSE4) 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.

♦ Copy the HOUSE4 file to HOUSE6.

♦ As for HOUSE5, add a smoke detector in the hall.

♦ Run ARGOS with HOUSE6.

You should find that the results are identical to those for HOUSE4 except for the smoke detector activation time.

Q18. What time did the smoke detector activate?

Q19. What is the time available for escape after the activation of the smoke detector and how does this compare with the HOUSE5 case?

These results seem to indicate that shutting the living-room/hall door may increase the time available for escape when a smoke detector is present in the hall. However, one should not give too much weight to these results. They depend, for instance, on the assumed door crack size which is critical to the amount of heat and smoke passing into the hall and on the smoke movement in the hall, which will affect the activation time of the smoke detector.

Another factor which needs to be considered here is whether the smoke alarm will be loud enough to alert the occupants. This will depend on the sound level of the alarm, whether the occupants are awake or asleep and whether the bedroom doors are open or closed. The point to bear in mind is that the smoke alarm may not always alert the occupants and even if it does they may not decide to escape immediately.

8. OTHER EXERCISES WITH THE HOUSE SCENARIO

Below are some further exercise with the house scenario which you may like to try.

8.1 Smoke detector in the living-room

In previous examples a smoke detector was added in the hall. Still using the "MY_ARMCHAIR" fire defined for the HOUSE2 scenario, try adding a smoke detector in the living-room, the room of origin of the fire, to see how much sooner the detector activates.

Q20. At what time does the smoke detector in the living-room activate?

8.2 Smoke detector sensitivity level

Now try changing the sensitivity level of the smoke detector to see what effect this has on activation time. The default sensitivity level used in previous scenarios was 0.3dB/m. Try changing this to 0.5dB/m and 0.8dB/m. Both of these values are quoted in BS5446 part 1: 1990 as maximum permissible levels for smoke detector activation for different fire tests.

Q21. What are the activation times of the smoke detector in the hall and the living room for these new sensitivity levels?

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 15.

OPENINGS		
Connecting rooms	Type of opening	Dimensions
Sales floor/surroundings	Door, closed	sill height = 0m soffit height = 3m width = 1m
WALLS, FLOORS AND CEILINGS		
Walls	Cavity wall, insulated, 30cm	
Floor	Concrete	
Ceiling	Gypsum/mineral-wool/concrete	
FIRE		
Material	Dimensions	
Polyurethane foam furniture	6m long x 0.8m wide x 1m high	

Table 15. Shop fire scenario - input data.

For instructions on using ARGOS, see part 2 of this manual.

- Set up an input file called "SHOP1" in the same way as for the House Fire Study (see part 3 section 2.1 of this manual). Your input menus should appear as in Appendix D. Note that no input is required for Stocks, Machines and Fire Installations.

- ♦ Once you have completed your data input, run ARGOS in the same way as for the House fire study (see part 3, section 2.2). Select the print-out interval to 10 seconds.

- ♦ From the output data, complete a hazard analysis form for the shop fire. Assume the head height to be 1.5 metres. Compare your completed form with Table E1 in Appendix E. The hazard criteria are taken from Part 1, Section 5 of this manual. You will see that in Table E1, a hazard criteria of 0.65dB/m has been set for upper and lower layer smoke as the occupants are likely to be unfamiliar with the building.

Q22. What is the initial hazard predicted by ARGOS 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.

- ♦ Complete another hazard analysis form but this time assume head height to be 2.0 metres.

Q23. What is the initial hazard predicted by ARGOS and how has it changed?

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.

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

♦ Edit the SHOP2 file and, from the Fire Start menu, change the fire start name to “PS foam in cartons”.

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

Q24. How does the peak heat release rate of the fire compare with the SHOP1 case?

Q25. What is the initial hazard predicted by ARGOS for the SHOP2 case and when does it occur?

Table E2 is a completed hazard analysis for the SHOP2 case. You can see that although the time to hazard is only slightly less with the larger fire, there are now additional hazards due to heat radiation and upper-layer oxygen concentration.

4. POLYSTYRENE FOAM FIRE WITH SPRINKLERS (SHOP3)

In this scenario, sprinklers will be added to the compartment to see if this reduces the hazard. First, you need to define a sprinkler with the characteristics shown in Table 16.

- To define a sprinkler, select "Database" from the main menu. The sprinkler operates on heat detection, so define the sprinkler as a heat detector by selecting "Fire detectors", "Heat detector" and "Create new". Enter the detector name "Standard sprinkler" and enter the activation temperature and RTI (response time index) as in Table 16. Press **<F2>** to save this data.

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

- Edit the SHOP3 fire and from the "Fire Installations" menu select "Sprinklers". (To do this, select "Sprinklers" with the cursor and press the space bar to mark with an "X".) Press **<F5>** to define the specifications and select "Standard Sprinkler" as the detector name. Set the distance between heads to 3 metres. The table should then look like Table 16.

File name:	SHOP3
Name of room:	Sales floor
Detector name	Standard sprinkler
Activation temperature (°C)	70
RTI (m.sec)^0.5	200
Distance between heads (m)	3.0

Table 16. Input menu: Sprinkler

- Press **<F2>** to save your data and return to the main menu.

- Now run ARGOS for the SHOP3 case and complete a hazard analysis form.

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

Q26. What effect have the sprinklers had on the fire?

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

Q28. What effect have the sprinklers had on the hazard in the compartment?

5. POLYSTYRENE FOAM FIRE WITH NATURAL SMOKE VENTING (SHOP4)

In this scenario, the effect of natural smoke venting will be considered.

♦ Make a copy of the SHOP2 data file and call the copy SHOP4.

♦ Edit file SHOP4 and select the "Fire Installations" menu. Select "Smoke venting, heat detector" and enter the specifications as in Table 17.

File name:	SHOP4
Name of room:	Sales floor
Thermo detector name	grade 1
Activation temperature (°C)	58
RTI (m.sec)^0.5	10
Distance between detectors (m)	4.0
Total opening area (m^2)	27.0
Mechanical extract (m^3/s)	0.0
Average height above floor (m)	3.0

Table 17. Input menu: Smoke venting, heat detector

♦ Now run ARGOS for the SHOP4 case and complete a hazard analysis form.

Table E4 is a completed hazard analysis for the SHOP4 case.

Q29. How has the addition of natural smoke venting affected the conditions in the compartment?

6. POLYSTYRENE FOAM FIRE WITH NATURAL SMOKE VENTING AND OPEN DOOR (SHOP5)

In the SHOP4 case, an opening was created in the compartment to allow smoke out by natural convection. However, no opening was created to let clean air in to replace the smoke. A door was defined in the compartment but it was left closed. In this scenario, an open door will be defined to see if this improves the flow of smoke out of the compartment and improves the situation.

♦ Make a copy of the SHOP2 data file and call the copy SHOP5.

♦ Edit the SHOP5 file and examine the definition of the door.

> To do this, select “Walls”, and press **<F5>** (Wall construction). The door is defined as an “Other Component” in the wall. Move the cursor down to “Other component”, select no.1 and notice that a “Roll-up door” has been selected. Move the cursor down the screen to highlight “Category” and press the space bar to display the list of alternatives. You will see that there is only one selection for a roll-up door and this is not marked open. You can only open this door from the “Calculation” screen.

♦ Set the dimensions of the door to 6 metres wide by 2 metres high and zero height above floor. This should give a sufficient area for an inlet vent (12 square metres compared with 27 square metres for the outlet vent). Press **<F2>** to save the changes.

♦ Now set the door to open from the calculation screen.

> To do this, press **<Esc>** until you reach the main menu and then select “Calculate” and select the SHOP5 file. Now, before starting the calculation, select “Doors open/closed”, move the cursor down to select “Roll-up door” and set the door to open by selecting “Yes” in the column headed “Open” using the left and right arrow keys. Then press **<F2>** to accept this change.

♦ If “Wind load” is present on the calculation screen (not available in earlier versions of ARGOS), set this to zero. In this case we will assume there is no wind. Remember to press **<F2>** to accept the change.

Note that when you make a setting from the “Calculation” screen, it only applies to the current calculation and does not alter the data in the input file. This means that next time you carry out a calculation with the same input file, you must select the settings again.

♦ Now run ARGOS for the SHOP5 case and complete a hazard analysis form.

Table E5 is a completed hazard analysis for the SHOP5 case.

Q30. How has the addition of an inlet vent affected the time to hazard?

You may like to try changing the inlet vent area and the wind speed to investigate how these parameters affect the conditions 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.

2. “HAZARD-I Fire Hazard Assessment Method”, Building and Fire Research Laboratory, National Institute of Standards and Technology, USA.

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.

ANSWERS TO EXERCISES

Q1. 0.6 megawatts

Q2. 1.8 minutes in both rooms. (Press F4 for "Floor to layers" graph.)

Q3. 77dB/m (decibels per metre) in the living room and 86dB/m in the hall.

Q4. The two heat release rate curves are identical. Therefore, the heat release rate entered as input data has not been modified by ARGOS during the calculation, which indicates that there is sufficient oxygen in the room for complete combustion of the armchair.

Q5. The peak heat release rate calculated by ARGOS is 747kW compared with 830kW in the input data i.e. the data entered in the database for "MY_ARMCHAIR". This indicates that the fire has been constrained due to lack of oxygen. Examination of the graph of oxygen concentration will confirm that the oxygen concentration in the living room has fallen to 3% at the end of the simulation.

Q6. Onset of hazard in the living-room occurs at 1 minute 20 seconds due to smoke in the lower layer.

Q7. By comparison, in scenario HOUSE1 the lower-layer smoke did not reach the hazard criterion. The reason for this is that the heat output rate of the fire in HOUSE2 remained at a lower level for longer. In this early period of the fire before the upper layer has formed, ARGOS assumes that all smoke produced will go into the lower layer. You can see from the graphs displayed by ARGOS at the end of the HOUSE2 simulation that once the upper layer starts to form, the smoke density in the lower layer stops rising.

Q8. The onset of hazard due to upper layer temperature and upper layer smoke occurs later in the HOUSE1 scenario than in the HOUSE2 scenario. This is to be expected as the fire used in HOUSE2 grows more slowly than the HOUSE1 fire.

Q9. The onset of hazard in the hall in HOUSE2 is due to the lower layer smoke and occurs at 3 minutes 40 seconds after ignition. This compares with the onset of hazard at 50 seconds after ignition due to upper layer smoke in HOUSE1. Therefore, changing the armchair fire has made a significant difference to the time to hazard. In the HOUSE2 scenario, providing that the occupants become aware of the fire early they have a reasonable chance of escaping before the hall becomes blocked with smoke.

Q10. The peak heat release rate is now 830kW, the same as in the input data so that opening the window has allowed the fire to burn without restriction. By comparison, in the HOUSE2 scenario with the window closed, the peak heat release rate was only 747kW with the same fire.

Q11. The time to the initial hazard in the hall is the same as calculated for the HOUSE2 scenario. Therefore it can be concluded that opening the living room window has had little effect on the hazard in the hall.

Q12. The fire peak heat release rate was constrained to 584kW compared with the peak of 830kW in the input data. In the HOUSE2 scenario the peak was 747kW so that closing the living-room door has further constrained the fire.

Q13. No upper layer is predicted in the hall. This is to be expected when the intervening door is closed, preventing the smoke and hot gases from reaching the hall. However, smoke is predicted in the lower layer, which will in this case extend from floor to ceiling. This can be explained by cold smoke emanating from the door crack.

Q14. If you examine the specifications for doors in the database you will see that for closed doors the imperviousness is set to 99%. This means that 99% of the area of the door is blocked to the passage of gases. From the remaining 1% area which is unblocked, the crack width can be calculated to be 3mm.

[Total door area = 1 metre x 2 metres = 2 m^2
Unblocked area = 1% of 2 m^2 = 0.02 m^2

Crack width = unblocked area $\div$ perimeter of door
Perimeter of door = 2 x (2m + 1m) = 6m
$\therefore$ Crack width = 0.02 m^2 $\div$ 6m = 0.003m = 3mm.]

Q15. The onset of hazard in the hall occurs at 5 minutes 20 seconds after ignition due to hazardous smoke levels in the lower layer. Comparing the results with HOUSE2, it can be seen that shutting the living-room/hall door has given an extra 1 minute 40 seconds for escape before the onset of hazard in the hall.

Q16. The smoke detector activated at 3 minutes 18 seconds.

Q17. The onset of hazard in the hall occurred at 3 minutes 40 seconds due to smoke (see hazard analysis form for HOUSE2). The time between the activation of the smoke alarm and the onset of hazard in the hall may be taken as the time available for escape which is, in this case, 22 seconds.

Q18. The smoke detector activates at 4 minutes 12 seconds.

Q19. The onset of hazard in the hall occurs at 5 minutes 20 seconds due to smoke in the lower layer (see hazard analysis form for scenario HOUSE4). This allows 1 minute 8 seconds for escape, an improvement on the HOUSE5 case.

Q20. The smoke detector in the living-room activates at 26 seconds. This compares with 3 minutes 18 seconds for the smoke detector in the hall.

Q21. The activation times are as follows:-

Smoke detector location	Sensitivity level		
	0.3dB/m	0.5dB/m	0.8dB/m
Living room	26 seconds	34 seconds	44 seconds
Hall	3 min 18 sec	3 min 20 sec	3 min 24 sec

Q22. The initial hazard for SHOP1 occurs at 3 minutes 50 seconds due to the temperature and smoke density of the upper layer.

Q23. The initial hazard now occurs at 2 minutes 40 seconds, again due to the temperature and smoke density of the upper layer. The time to hazard has been reduced by 1 minute 10 seconds by changing the assumed head height from 1.5 metres to 2.0 metres.

Q24. The peak heat release rate for SHOP2 is 15.4 MW compared to 4.1 MW for SHOP1, an increase of almost a factor of 4.

Q25. The initial hazard occurs at 3 minutes 10 seconds due to temperature and smoke in the upper layer.

Q26. By viewing the graph of heat release rate following the calculation for SHOP3, it can be seen that the sprinklers have prevented the fire growing once it reached 2,818kW (compared to a peak of 15.4MW without sprinklers). The fire was then extinguished by 3.5 minutes.

Q27. The calculation used by ARGOS for the effect of sprinklers on the fire is described in the ARGOS Theory Manual. The calculations assume that once the sprinkler operates, the heat release rate will remain constant for 30 seconds and then decline at a rate of 33kW per second. The same assumptions are made for any fire.

Q28. None of the hazard criteria were reached and so the sprinklers have prevented the occurrence of hazardous conditions.

Q29. Comparing the results of SHOP2 and SHOP4, the addition of smoke venting has increased the time to hazard by 30 seconds, to 3 minutes 40 seconds. On the basis of this figure the difference is not great. However, bigger effects are seen if other parameters are considered. For instance, the peak value of the upper layer smoke density has been reduced from 150 to 66 dB/m and the minimum oxygen concentration reached is 12% instead of 4%. This illustrates the point that the conclusions drawn from a fire modelling study depend on which figures from the results are selected.

Q30. The time to hazard has increased from 3:40 to 4:30, due to heat radiation. The hazards due to upper layer temperature and smoke have been removed as the upper layer no longer descends to head height.

ADDITIONAL INSTRUCTIONS

Note 1.

- From the “Client files” menu select “Display/edit”, then select HOUSE4.
- Select “Walls” and then highlight the Living-room/Hall wall with the cursor.
- Press F5 to edit the wall construction, highlight “Category” with the cursor and press the space bar to bring up the list of doors.
- Select “Solid wood door 34mm” but <u>not</u> the open one and press return.
- Press F2 to save the change

APPENDIX A

HAZARD ANALYSIS FORM

Hazard Analysis of Results of ARGOS 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)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)						
Heat radiation (kW/m^2)						
Upper-layer temperature (°C)						@
Upper-layer smoke (dB/m)						@
Lower-layer smoke (dB/m)						
Upper-layer oxygen (%)						@
Comments:						
KEY: N/R = Hazard not reached						
Note for column (7). For parameters of the upper layer only, which are marked with a “@”: If column (6) = Yes, enter contents of column (4) If column (6) = No, enter contents of box (F)						

APPENDIX B

PRINT-OUTS FROM ARGOS FOR HOUSE1

APPENDIX C

HOUSE FIRE STUDY: HAZARD ANALYSIS FORMS

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *HOUSE1*

B) Scenario description: *Initial scenario. Living-room and hall. 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): *0:30*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*600*					
Heat radiation (kW/m^2)	*4.17*	*2.5*	*1:20*			*1:20*
Upper-layer temperature (°C)	*262*	*100*	*0:40*	*1.19*	*Yes*	*@ 0:40*
Upper-layer smoke (dB/m)	*77*	*2*	*before 0:20*	*greater than 2.33*	*No*	*@ 0:30*
Lower-layer smoke (dB/m)	*1.67*	*2*	*N/R*			*N/R*
Upper-layer oxygen (%)	*14 (minimum reached)*	*10 or less*	*N/R*	N/R	N/R	*N/R*

Comments: *Onset of hazard occurs 30 seconds after ignition due to smoke in the upper layer. A further hazard occurs at 40 seconds due to the temperature of the upper layer.*

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table C1. HOUSE1 Hazard Analysis - Living-room

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *HOUSE1*

B) Scenario description:. *Initial scenario. Living-room and hall. 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): 0:50

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*600 in living room*					
Heat radiation (kW/m^2)	*1.54*	*2.5*	*N/R*			*N/R*
Upper-layer temperature (°C)	*144*	*100*	*1:20*	*0.2*	*Yes*	*@ 1:20*
Upper-layer smoke (dB/m)	*83.3*	*2*	*less than 0:40*	*more than 2.59*	*No*	*@ 0:50*
Lower-layer smoke (dB/m)	*1.77*	*2*	*N/R*			*N/R*
Upper-layer oxygen (%)	*15 (minimum reached)*	*10 or less*	*N/R*	N/R	N/R	*N/R*

Comments: *Onset of hazard occurs 50 seconds after ignition due to smoke in the upper layer. A further hazard occurs at 1:20 due to the temperature of the upper layer.*

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table C2. HOUSE1 Hazard Analysis - Hall

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *HOUSE2*

B) Scenario description:. *Different armchair fire. Otherwise as HOUSE1.*

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): 3:20

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*747*					
Heat radiation (kW/m^2)	*6.12*	*2.5*	*5:30*			*5:30*
Upper-layer temperature (°C)	*315*	*100*	*4:10*	*1.13*	*Yes*	*@ 4:10*
Upper-layer smoke (dB/m)	*252*	*2*	*less than 3:10*	*more than 1.96*	*No*	*@ 3:20*
Lower-layer smoke (dB/m)	*15.9*	*2*	*1:20*			*1:20*
Upper-layer oxygen (%)	*3 (minimum reached)*	*10 or less*	*6:40*	0	Yes	*6:40*

Comments: *The onset of hazard in the living-room occurs at 1 minute 20 seconds due to smoke in the lower layer.*

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table C3. HOUSE2 Hazard Analysis - Living-room

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *HOUSE2*

B) Scenario description:. *Different armchair fire. Otherwise as HOUSE1.*

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): *4:20*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*747 in living room*					
Heat radiation (kW/m^2)	*2.04*	*2.5*	*N/R*			*N/R*
Upper-layer temperature (°C)	*174*	*100*	*5:30*	*0.01*	*Yes*	*@ 5:30*
Upper-layer smoke (dB/m)	*271*	*2*	*less than 4:00*	*more than 2.95*	*No*	*@ 4:20*
Lower-layer smoke (dB/m)	*9.37*	*2*	*3:40*			*3:40*
Upper-layer oxygen (%)	*3 (minimum reached)*	*10 or less*	*7:10*	*0*	*Yes*	*7:10*

Comments: *The onset of hazard in the hall occurs at 3 minutes 40 seconds due to the lower-layer smoke.*

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table C4. HOUSE2 Hazard Analysis - Hall

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *HOUSE3*

B) Scenario description:. *Half-open window in living-room. Otherwise same as HOUSE2.*

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): *4:20*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*830 in living room*					
Heat radiation (kW/m^2)	*2.05*	*2.5*	*N/R*			*N/R*
Upper-layer temperature (°C)	*175*	*100*	*5:30*	*0.01*	*Yes*	*@ 5:30*
Upper-layer smoke (dB/m)	*150*	*2*	*less than 4:10*	*more than 1.97*	*No*	*@ 4:20*
Lower-layer smoke (dB/m)	*11.7*	*2*	*3:40*			*3:40*
Upper-layer oxygen (%)	*9 (minimum reached)*	*10 or less*	*8:00*	*0*	*Yes*	*8:00*

Comments: *The onset of hazard in the hall occurs at 3 minutes 40 seconds due to the lower-layer smoke, the same as for HOUSE2. Opening the living-room window has had little effect on the hazard in the hall.*

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table C5. HOUSE3 Hazard Analysis - Hall

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *HOUSE4*

B) Scenario description: *Living-room door closed, otherwise as HOUSE2.*

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): *No upper layer present.*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*584 in living room*					
Heat radiation (kW/m^2)	*0*	*2.5*	*N/R*			*N/R*
Upper-layer temperature (°C)	*No upper layer*	*100*	*N/R*	*N/R*	*N/R*	*@ N/R*
Upper-layer smoke (dB/m)	*No upper layer*	*2*	*N/R*	*N/R*	*N/R*	*@ N/R*
Lower-layer smoke (dB/m)	*75*	*2*	*5:20*			*5:20*
Upper-layer oxygen (%)	*No upper layer*	*10 or less*	*N/R*	*N/R*	*N/R*	*N/R*

Comments: *No upper layer is predicted in the hall as the living-room door is closed. However, the onset of hazard occurs in the hall at 5 minutes 20 seconds due to smoke in the lower layer.*

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table C6. HOUSE4 Hazard Analysis - Hall

APPENDIX D

SHOP FIRE STUDY: INPUT MENUS

File name	SHOP1
Client	Home Office
Consultant	Brian Hume
Company type	Service, trade
Basic bldg. constr.	Brick wall/concrete roof
Remarks	Shop study
Remarks	Initial scenario
Last updated	1995.09.06
Revision no.	7

Table D1. Input Menu: Basic Information

File name	SHOP1
City area	**Yes** No
24 hour	**Yes** No
Distance/fire station [km]	50.0
Calculated response time [min]	720
Time before manual alarm [min]	720

Table D2. Input Menu: Fire brigade

File name	SHOP1
No. of rooms	1
Edit data for room #	**1** 2 3 4 5
Room name	Sales floor
Room use	Office/administration
Room area [m^2]	900.00
Average height [m]	3.00
Max. length [m]	30.00
Floor type	Concrete floor

Table D3. Input Menu: Rooms - Sales floor

File name SHOP1

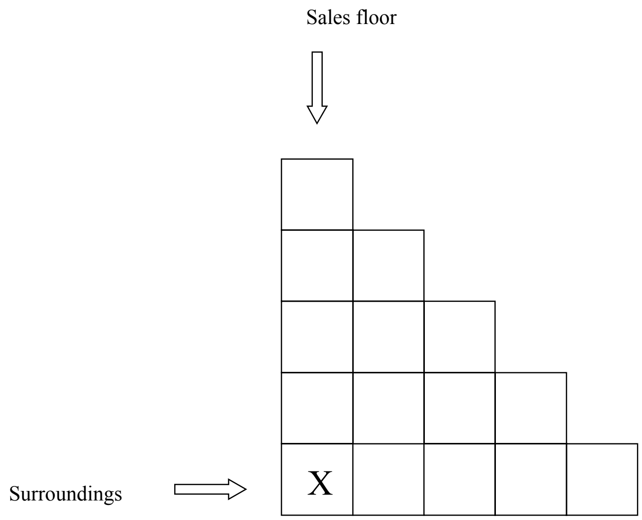

Table D4. Input Menu: Walls

Wall from room: [Sales floor] to room: [Surroundings]	
Base wall Base wall width [m] Base wall height [m]	Cavity wall, insulated, 30cm 120.00 3.00
Other component #	**1** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Walls **Doors** Windows Misc. Roll-up door 1 1.00 3.00 0.00

Table D5. Input Menu: Wall construction

File name: [SHOP1]	
Edit ceiling of room Selected room, name	**1** 2 3 4 5 Sales floor
Base ceiling Ceiling area [m^2] Max. height [m]	Gypsum/mineral wool/concrete 900.00 3.00
Other component #	**1** 2 3 4 5 6 7 8 9 10
Category Name of component No. of Width [m] Height [m] Ht. above floor [m]	Ceilings Skylights Misc. 0 0.00 0.00 0.00
Table D6. Input Menu: Ceilings	

File name: [SHOP1]	
Fire start in room # Selected room, name	**1** 2 3 4 5 Sales floor
Fire start, type # Fire start, type	**1** 2 3 4 5 6 Solid Material
Fire start, name	PUR foam furniture
Time limit [min]	20
Table D7. Input Menu: Fire start	

APPENDIX E: SHOP FIRE STUDY - HAZARD ANALYSIS FORMS

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *SHOP1*

B) Scenario description:. *Initial scenario. Sales floor of shop, dimensions 30m x 30m x 3m high. PU foam-filled furniture fire. Entrance door closed.*

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): 3:50

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*4,063.5*					
Heat radiation (kW/m^2)	*1.45*	*2.5*	*N/R*			*N/R*
Upper-layer temperature (°C)	*138*	*100*	*1:50*	*2.49*	*No*	@ *3:50*
Upper-layer smoke (dB/m)	*53*	*0.65*	*before 0:50*	*more than 2.95*	*No*	@ *3:50*
Lower-layer smoke (dB/m)	*0.19*	*0.65*	*N/R*			*N/R*
Upper-layer oxygen (%)	*17.5 (minimum reached)*	*10 or less*	*N/R*	N/R	N/R	@ *N/R*

Comments:

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table E1. SHOP1 Hazard Analysis

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *SHOP2*

B) Scenario description: *Fire load: polystyrene foam in cartons*

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): *3:10*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*15,360*					
Heat radiation (kW/m^2)	*7.18*	*2.5*	*3:40*			*3:40*
Upper-layer temperature (°C)	*339*	*100*	*1:40*	*2.61*	*No*	@ *3:10*
Upper-layer smoke (dB/m)	*150*	*0.65*	*before 0:50*	*more than 2.97*	*No*	@ *3:10*
Lower-layer smoke (dB/m)	*0.17*	*0.65*	*N/R*			*N/R*
Upper-layer oxygen (%)	*4 (minimum reached)*	*10 or less*	*7:00*	*0*	*Yes*	@ *7:00*

Comments:

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table E2. SHOP2 Hazard Analysis

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *SHOP3*

B) Scenario description: *Fire load: Polystyrene foam in cartons. Standard sprinklers.*

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): *N/R*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*2,818*					
Heat radiation (kW/m^2)	*1.01*	*2.5*	*N/R*			*N/R*
Upper-layer temperature (°C)	*104*	*100*	*1:50*	*2.53*	*No*	@ *N/R*
Upper-layer smoke (dB/m)	*28.6*	*0.65*	*before 0:50*	*more than 2.97*	*No*	@ *N/R*
Lower-layer smoke (dB/m)	*0.17*	*0.65*	*N/R*			*N/R*
Upper-layer oxygen (%)	*18 (minimum reached)*	*10 or less*	*N/R*	*N/R*	*N/R*	@ *N/R*

Comments:

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table E3. SHOP3 Hazard Analysis

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *SHOP4*

B) Scenario description: *Polystyrene foam fire (as SHOP2) but with smoke venting (natural only)*

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): *3:40*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*15,360*					
Heat radiation (kW/m^2)	*5.98*	*2.5*	*4:30*			*4:30*
Upper-layer temperature (°C)	*312*	*100*	*1:50*	*2.62*	*No*	@ *3:40*
Upper-layer smoke (dB/m)	*66*	*0.65*	*before 0:50*	*more than 2.99*	*No*	@ *3:40*
Lower-layer smoke (dB/m)	*0.17*	*0.65*	*N/R*			*N/R*
Upper-layer oxygen (%)	*12 (minimum reached)*	*10 or less*	*N/R*	*N/R*	*N/R*	@ *N/R*

Comments:

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table E4. SHOP4 Hazard Analysis

Hazard Analysis of Results of ARGOS Fire Simulation

A) Scenario name: *SHOP5*

B) Scenario description: *As SHOP4 (polystyrene foam fire, natural venting) but roll-up door, open, 6 metres wide x 2 metres high*

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): *N/R*

(1)	Peak value (2)	Hazard criterion (3)	Time to Reach Hazard Criterion (min:sec) (4)	Interface height at this time (metres) (5)	Upper layer below head height? (6)	Time to Hazard (min:sec) See note below (7)
Heat release rate (kW)	*15,360*					
Heat radiation (kW/m^2)	*3.84*	*2.5*	*4:30*			*4:30*
Upper-layer temperature (°C)	*253*	*100*	*1:50*	*2.84*	*N/R*	@ *N/R*
Upper-layer smoke (dB/m)	*31*	*0.65*	*before 1:00*	*more than 2.97*	*N/R*	@ *N/R*
Lower-layer smoke (dB/m)	*0.18*	*0.65*	*N/R*			*N/R*
Upper-layer oxygen (%)	*17 (minimum reached)*	*10 or less*	*N/R*	*N/R*	*N/R*	@ *N/R*

Comments:

KEY: N/R = Hazard not reached

Note for column (7). For parameters of the upper layer only, which are marked with a "@":

If column (6) = Yes, enter contents of column (4)
If column (6) = No, enter contents of box (F)

Table E5. SHOP5 Hazard Analysis