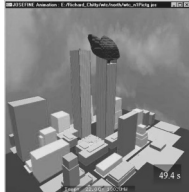


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### How long does structural performance need to be maintained for life safety?

This depends upon two main aspects:

- The size (especially the height and compartmentation) of the building
- The nature of the occupancy



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### How long does structural performance need to be maintained for life safety?

Single storey, single enclosure uncomparted building:

- Examples: "Portacabin", office, workshop, warehouse, supermarket, DIY store, assembly hall, school, (hospital?), dormitory.
- Simultaneous evacuation is feasible in fires. Time required for escape depends upon the occupancy type, fire safety management strategy, detection and alarm system, occupant numbers and characteristics: may only be a few minutes. The time required for structural integrity to be maintained is the time required for escape (plus a margin or safety).



Cambridge Arts Theatre



Harvey Centre Shopping Mall

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### How long does structural performance need to be maintained for life safety?

Single storey, multi-enclosure, multi-compartment building:

- Examples: As previous but several enclosures, could include airports or single-storey shopping malls, multi-screen cinema complexes
- Requirements as for previous category, but there is a danger of a fire growing within undetected in one enclosure or compartment with sudden break out and rapid spread though large and heavily occupied spaces
- Passive fire containment is required for a longer period to protect occupants in enclosure or compartments other than the fire enclosure and to enable safe escape
- The time required for structural integrity to be maintained is the time required for escape (plus a margin or safety).
- (The fire resistance properties of the structure may also depend upon the anticipated fire severity)

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### How long does structural performance need to be maintained for life safety?

Multi storey, multi-enclosure, multi-compartment building:

- Examples: Most large buildings, including stores, hotels, apartment blocks, office blocks, factories, hospitals, schools.
- Rapid evacuation may not be feasible due to the nature of the occupancy coupled with the size (especially the height) and design of the building.

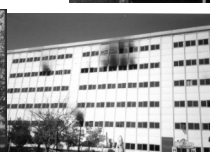


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### Cases where a long period of maintained structural performance is required

- Any sleeping risk (residential domestic, institutional or other [e.g. hotel or HMO]), health care.
- For hotels and hostels an immediate simultaneous evacuation strategy may be used, but long periods are needed and some occupants may not evacuate. Each room or suite then needs to be a compartment, at least in relation to the common escape routes
- For apartment blocks of flats or maisonettes the main strategy is to defend in place. Only the affected unit and adjacent threatened areas are evacuated. The structure thus needs to withstand burnout of any particular unit



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### Cases where a long period of maintained structural performance is required

- For other occupancies, such as high rise office blocks or stores with several stories a phased evacuation strategy may be used
- Immediate evacuation is carried out for the fire floor and at least the floor above
- Other floors are evacuated only if the fire becomes severe or especially if there is a danger of fire or fire effluent spreading beyond the compartment of origin
- This process, involving several phases and the eventual evacuation of large numbers of people from large buildings, requires a relatively long period to accomplish
- Where stair capacity is designed for a phased evacuation the flow capacity is low, so that a total building evacuation is slow.

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Hotel fire - external cladding



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Hotel fire - external cladding



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Hotel fire - external cladding



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Fire



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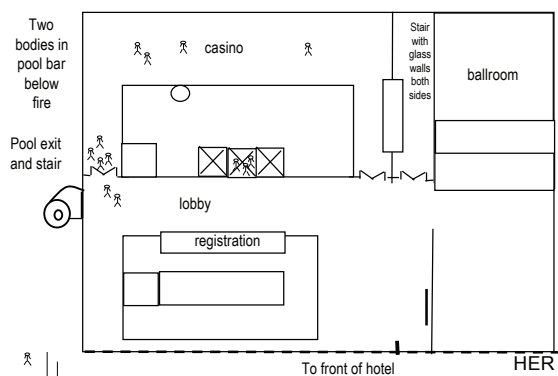
Fire



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DuPont Plaza

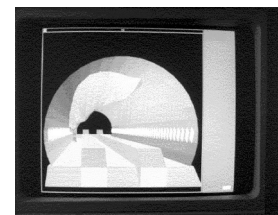


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Fires and slow action - examples

**Dusseldorf airport:** fire between roadway and ceiling know about for many minutes before evacuation alarms given

**Kings Cross:** Frequent fires of fluff/lubricant mixtures under wooden escalators. On the day the fire was ignored for some time, then the staff could not find the extinguishers which were hidden behind a workmans' screen. Police did not know the station layout and misdirected occupant evacuation. Trench effects aided fire spread. Failures of fire safety management



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## Investigations carried out by BRE Fire and Risk Sciences

Main aspects studied are:

- initial fire growth and spread in early stages
- subsequent spread,
- involvement of building structure
- how building occupants first became aware of the fire
- subsequent experiences and behaviour as they attempted to deal with the situation and escape

- Caravan

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## Basic points of fire investigation procedures

### 1. INITIAL IMPRESSIONS AND IDENTIFICATION OF FIRE SEAT

- On arrival the initial impression is often one of chaos, particularly if the fire was large.
- Take time to obtain general impression and discuss with fire officers and witnesses
- Every fire has unique aspects, as well as features common to other cases
- Identify where the fire started, follow the signs of its progression from that point, by examining the pattern of fire spread and damage.
- Sometimes special clues exist. For example it may be possible to examine which electrical circuit breakers have tripped. Or black shattered glass may indicate fire before explosion

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## Basic points of fire investigation procedures

Key points:

- Clear single point of ignition (fire seat) or multiple seats. Latter tends to point to possible deliberate ignition, but sometimes a fire can jump at the early stages to give the appearance of multiple seats.
- Use of accelerants. Smell of petrol or paraffin at the ignition site even after a destructive fire can be confirmed by suitable forensic tests
- Identify item first ignited, such as an item of furniture, and how the fire developed.
- Development depends on ventilation, so that the position of doors and windows at the time of the fire is important (often get changed during the course of the fire, particularly when the fire brigade arrive), often possible to establish which doors were open and at what stage by examination of charring around the lintels, the position of smoke staining and heat damage.

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## Basic points of fire investigation procedures

### 2. MECHANISM OF FIRE SPREAD

- may be by lateral spread to adjacent items (of furniture for example)
- or from secondary ignition from radiation from a hot plume (post flashover fire),
- or from ignition of a fuel rich plume (flashback).

Easy to see how densely furnished rooms may become completely involved, but:

concern where fire sterilized areas such as corridors and stairwells become involved, due to ability of fire to spread along the painted surfaces of corridors and stairwells in some building, particularly when several layers of paint have been applied. (e.g. case of furniture fire in corridor of council block, Palmira Drive Hove fire, Anti-graffiti paint at King's Cross).

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## Basic points of fire investigation procedures

### 3. PATTERNS OF HEAT AND STRUCTURAL DAMAGE, EXTENT OF SMOKE SPREAD

It may be possible to determine the severity of the conditions by the amount and quality of the soot, the effects on surfaces (damage, colour, spalling etc).

- Modes of structural failure important: eg pinned roofing units
- Spread through unstopped cavities and hidden voids
- failure of ceilings or walls - sandwich panels
- unstopped penetrations and vents, spread through HVAC systems
- Façades

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## Basic points of fire investigation procedures

### 4. HUMAN FACTORS

Obtain statements from as many witnesses as possible, to understand:

- how and when occupants and other parties first became aware of the fire
- how they reacted to the situation
- how they escaped or were injured

When deaths occur the blood carboxyhaemoglobin concentration is a very good indication of exposure, together with any burning of the skin or respiratory tract and soot deposits in the lungs.

The carboxyhaemoglobin concentration can also be used as an indication of the conditions in the fire itself. If the duration of exposure is known, it is even possible to estimate the carbon monoxide concentrations in the fire.

It may also be possible by analysing soot deposits in the victims or in the building to identify what materials were involved in the fire. For example certain fatty acids can be used to identify that paint has burned. Hydrocarbon accelerants can also be detected in lungs.

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### Findings of fire investigations

#### Fires in Larger Buildings

- Chesterfield - Clothing on racks
- Supermarket fires - rapid fire spread along displays of goods, and findings that sprinklers do not easily extinguish them when upper shelving shields lower parts from the spray.

#### Toxic hazard in fires in rooms

Toxic hazard depends on rate of fire growth and yield of toxic products. Toxicity depends upon materials and ventilation  
Low toxicity - Little wood's  
Cotton and coconut fibre sofa Moderns furniture - Wales case, Car interior

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### Findings of fire investigations

#### FIRE SPREAD WITHIN AND BEYOND THE ROOM OF ORIGIN

- Rapid spread through goods in stores and supermarkets
- Warlingham Park Hospital
- Stardust Disco
- Bradford City Stadium
- Stair carpets
- Paint - council flats cases, King's Cross - paint and trench
- Electronics factory

#### FIRE SPREAD BETWEEN ENCLOSURES

Design requirement is for fire resisting construction to limit spread to within enclosure or compartment of ignition long enough to allow occupants to escape, and to prevent spread to neighbouring properties. Main reasons are faults in construction and actions by occupants.

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### Fires in multi-enclosure, multi-compartment buildings – domestic and hotels

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Residential Home - Kirton Lincs.



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Palmira Drive - Hove



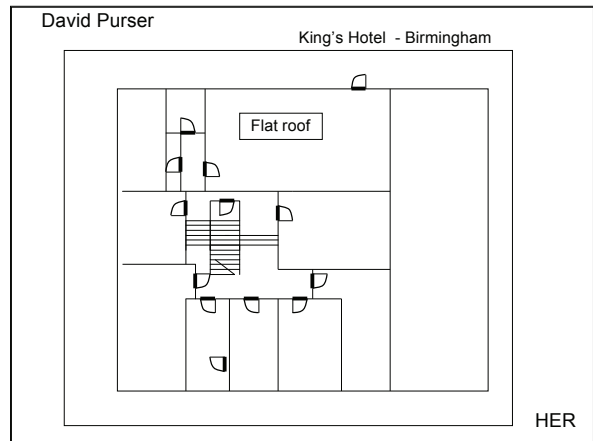
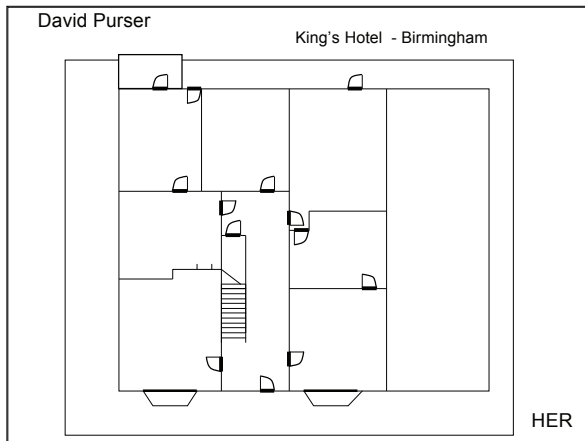
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King's Hotel - Birmingham



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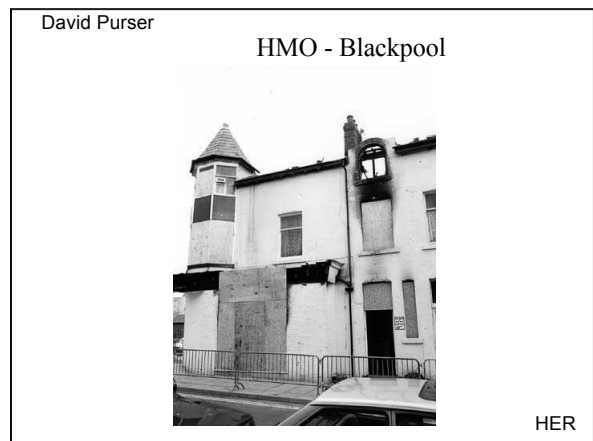
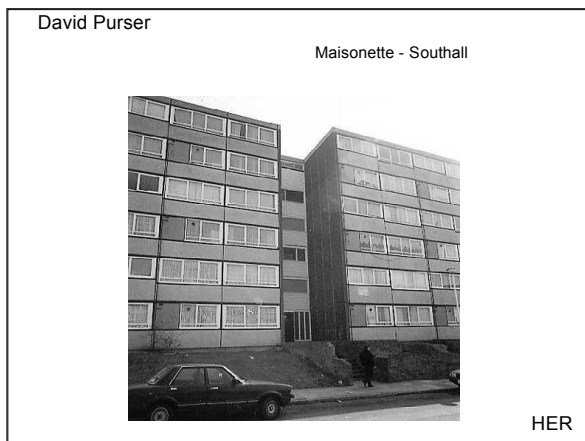
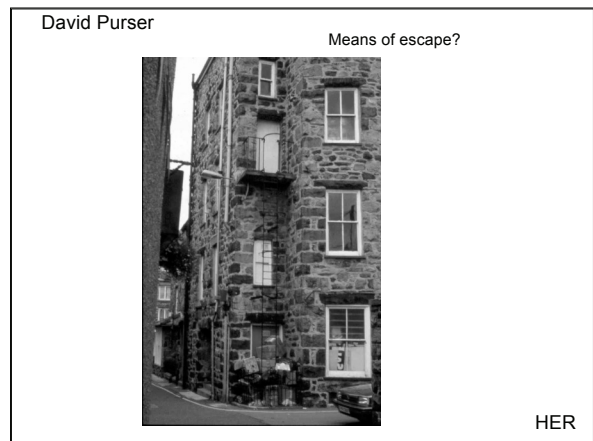
### Findings of fire investigations

**FIRE SPREAD AIDED BY OCCUPANTS**

**Fire Safety Management**

- leaving combustible material in stairwells, careless practice with ignition sources, failure to maintain detectors, switching off sprinklers, hot work.
- Failure to close doors and windows at night, Fire in St. Neots, common family bedroom fire scenarios, children, Blackpool (Self extinguishing fires - Cardington tests) Fire brigade and neighbours
- Wedging open fire doors - (hold open devices)
- Kings Hotel, Residential home

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### Findings of fire investigations

- There is a tendency for architects and designers to expect the occupants to fit into the building rather than to design the building to fit the needs of the occupants - at least as far as fire safety design is concerned. When disasters occur the occupants tend to be blamed for failure to respond or for carrying out inappropriate actions - such as panic.
- There is a need to understand how occupants use buildings and how they respond to emergency cues and situations - and to design the buildings and systems to accommodate these needs. A safe system is one where a large proportion of the fire safety is built in. An unsafe system is one which relies for safety on the constant vigilance and actions of the occupants.

Pre-fire behaviour and fire safety management

- Use of building and safety features, alarms, fire doors
- Emergency plan and regular fire drills

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### Findings of fire investigations

#### FIRE SPREAD AIDED BY OCCUPANTS

##### Fire Safety Management

- leaving combustible material in stairwells, careless practice with ignition sources, failure to maintain detectors, switching off sprinklers, hot work.
- Failure to close doors and windows at night, Fire in St. Neots, common family bedroom fire scenarios, children, Blackpool (Self extinguishing fires - Cardington tests) Fire brigade and neighbours
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### Findings of fire investigations

#### Behaviour during emergencies

- Occupants do not evacuate as soon as cues or alarms received - ambiguous cues, office, hotel 4 am
- Pre-movement time:

#### Recognition Response

- Exit choice and wayfinding, signage
- Egress flow capacities, travel distances,

#### Toxic hazards

- Smoke, Irritants, Asphyxiants -
- psychological and physiological
- - Residential home - Decision in room and corridor
- - San Juan, Croupier, Receptionist, Gambler, pool bar
- - Manchester - food
- - Chesterfield - stairs etc, fire fighting
- - Friendly fires, groups and relatives, authority figures

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### Fire investigation Access database

ID	No.	Action	Status	Comment	Perception	Thoughts
1	1	Help	All right	Fetches inhaler for roommate	Grey/black	Get everyone out
1	2	Alert	All right	Went round waking up residents and staff	Thick smoke coming up stairs, flames	
1	3	Escape	All right	Escape blocked by fire	Thick smoke/flames	
1	4	Escape	All right	Instructed by staff to assemble in hall		

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### Fire investigation database

- Detailed examination of 98 fires in terms of building, fire and occupants.
- Majority of non-cooking fires caused by electrical malfunctions in wiring and appliances.
- Smoke detectors alerted occupants in only a very small number of cases.
- Once alerted occupants carried out six or more actions before escaping. These delayed escape while fires grew.
- Actions included investigating, warning others, mitigating actions (shutting doors, fighting fires, turning off heat), calling for help, being passive.

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### Key aspects of occupant behaviour during fire emergencies

- Commitment to original activities
- Slow recognition of ambiguous cues
- Friendly fire syndrome
- Role and responsibility
- Responses other than egress (family, belongings, theft etc.)
- Fighting fire
- Exit choice and wayfinding
- Reactions to smoke and heat

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How occupants were alerted

Alerted	Frequency
Told by others	37
Heard noise	16
Saw smoke	12
Saw flames	9
Saw sparks/flash	4
Saw flames and smoke	4
Smelt smoke/burning/fumes	23
Heard alarm	10
Woke up coughing	2
Felt heat	1
Saw Fire Brigade	1
TV went off	1
SUM	124

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How alerted occupants in and not in fire room

Alerted	Frequency	Alerted	Frequency
Saw flames	5	Told by others	33
Heard noise	4	Heard noise	11
Told by others	2	Saw smoke	10
Smelt something	2	Smelt smoke	8
Saw smoke	2	Smelt burning	8
Saw flames & smoke	2	Heard alarm	7
Heard alarm	2	Saw flames	4
Woke up coughing	1	Saw flames & smoke	2
Smelt smoke	1	Saw sparks	2
Smelt burning	1	Woke up coughing	1
Saw sparks	1	Smelt fumes	1
Not known	1	Smelt something	1
Heard screaming	1	Saw FB	1
Felt heat	1	Remembered chip pan	1
SUM	26	TV went off	1
		Heard FB	1
		Saw flash	1
		SUM	93

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## Effectiveness of smoke detectors

Frequency	Median	Mean	Mode	Skewness
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low
Very Low	Very Low	Very Low	Very Low	Very Low
None	None	None	None	None

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Number of times actions reported  
houses/flats and all fires

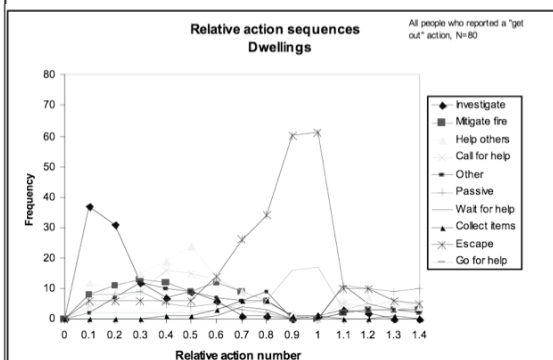
Action category	Frequency	Action category	Frequency
Mitigate fire	124	Help others	224
Investigate	109	Investigate	194
Help others	108	Mitigate fire	176
Call for help	85	Other	170
Escape	84	Escape	145
Other	79	Passive	122
Passive	59	Call for help	110
Wait for help	48	Wait for help	74
Go for help	33	Re-enter building	43
Re-enter building	30	After fire	39
After fire	19	Collect items	35
Collect items	18	Go for help	34
SUM	796	SUM	1366

1366  
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## Action sequences



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### Smoke effects during exposure

Smoke: main effects during exposure	
Frequency	Effects
54	Coughing/violent coughing
13	Couldn't breathe/chest tight
13	Choking
2	Throat/lungs
1	Sore eyes and throat
9	Eyes watering/painful/burning
4	Could not see
2	Eyes painful
2	Nausea
2	Felt Dizz/oxygen deprivation
1	Fatal
5	Fear
5	Can't remember
50	None
156	SUM

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