ArupFire

British Automatic Fire Sprinkler Association (BAFSA)

Sprinklers for Safer Living

The Benefits of Automatic Fire Suppression Systems in Residential Care Premise

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Contents

		Page
1	Executive Summary	1
2	Introduction	2
3	Fire safety risks in residential care premises	2
3.1	Occupancy Characteristics	3
3.2	Building Characteristics	5
3.3	Challenges facing care providers/staff	10
4	Human behaviour in fire	11
5	Consequences of fire in residential care premises	12
5.1	Direct consequences	12
5.2	Indirect consequences of fire	16
6	Review of Current Fire Safety Guidance Documents	18
6.1	England and Wales (Approved Document B)	18
6.2	England and Wales - Regulatory Reform (Fire Safety) Order 2005 (RRO)	21
6.3	BS 9999: 2008	23
6.4	Scotland - Scottish Technical Handbook	24
6.5	Scotland – Fire Scotland Act 2005	25
6.6	Northern Ireland	25
6.7	United States of America – NFPA 5000 and NFPA 101	27
6.8	United States of America - International Building Code	27
6.9	Hong Kong – Code of practice for residential care homes	28
6.10	Australia – Building Code of Australia	28
6.11	Fire Safety Guidance Review	29
7	Automatic fire suppression systems	30
7.1	Residential Sprinkler Systems	30
8	Fire Safety Research on Residential Sprinklers	31
8.1	Sprinkler Effectiveness in Care Homes	31
8.2	Effectiveness of Sprinkler Systems in Residential Premises	32
8.3	NHBC Foundation Study into Open Flat Layouts	37
9	Quantifying the Impact of Sprinklers	37
9.1	Fire and Smoke Modelling Conclusions	40
10	Other options/considerations	41
10.1	Design considerations	41
10.2	Management Considerations	43
11	Conclusions	44
12	References	46

Appendices

Appendix A

Fire Incidents

Appendix B

Fire and Smoke Modelling

Appendix C

Review of Experimental Study in BRE Report 204505, Effectiveness of sprinklers in residential premises

1 Executive Summary

Residential care premises present a series of unique challenges with respect to fire safety. The needs of the occupants and the resources required to undertake an evacuation in these types of premises require careful consideration both in the design and ongoing operation of such buildings, to ensure that an appropriate level of fire safety is provided.

The primary purpose of this study is to identify the key life safety, property protection and business continuity risks associated with fires in these premises and assist in the decision-making process on whether or not the incorporation of automatic fire suppression systems in residential care premises is beneficial both in terms of the design of such premises and the requirements of the end user (i.e. the care provider).

To this end the study reviews the following key aspects:

- the identification of the risks associated with residential care premises;
- the direct and indirect consequences of a fire in residential care premises;
- the recommendations within current fire safety guidance documents in the UK and internationally;
- automatic fire suppression;
- alternative solutions;
- a fire modelling study to quantify the benefits that automatic fire suppression provides in residential care premises.

The following points summarise the key findings of this report:

- residential care premises present unique challenges in relation to fire safety, largely because many residents need help to escape. Currently fire safety guidance in England and Wales does not address this fully;
- where residents require assistance it is likely that the evacuation process will take longer and sprinklers provide significant benefits to address this risk;
- England and Wales are among the few countries where the official fire safety design guidance does not recommend automatic fire suppression in residential care premises. The fire safety guidance documents for Scotland, USA, Hong Kong and Australia all recommend automatic fire suppression and recognise the benefits in terms of life safety and property protection;
- research undertaken in the USA [31] concludes that sprinklers are considered to be the single most effective fire protection feature and it notes that there has never been a multiple-death fire in a fully sprinklered nursing home;
- fire and smoke modelling was undertaken and showed that the temperatures within the corridors and all rooms beyond the room of fire origin were survivable where sprinklers were provided. The visibility in all rooms beyond the room of fire origin also remained survivable, where sprinklers were provided; this was clearly not be the case where they were not provided. It is therefore considered that automatic fire suppression would provide significant benefit particularly beyond the room of fire origin;
- if fire suppression systems are provided in a residential care premises, they can assist in reducing the risks from fire, particular if other fire safety measures (for example, passive fire protection) fail to act as intended;
- the adoption of an automatic fire suppression system within residential care premises is considered a cost effective means of providing an improved level of safety and can be used to compensate for other areas of the design when all relevant factors are considered;

2 Introduction

Arup Fire has been commissioned by the British Automatic Sprinkler Association (BAFSA) to undertake a study to evaluate the potential benefits of automatic fire suppression systems in residential care premises. The nature of the occupants, the complexity of evacuation and the resources required to undertake an evacuation in these types of premises present challenges that are often unique to these types of premises which many consider to be inadequately addressed within current fire safety guidance documents.

The need for residential care premises for the elderly throughout the UK continues to grow as the average age of the population in the UK increases. According to the UK government statistics the proportion of people aged 65 and over is projected to increase from 16 per cent of the population in 2006 to 22 per cent by 2031[1], meaning that more care premises are likely to be required in the coming years, whether these be new building facilities or conversions of existing buildings. Therefore it is vitally important that provisions are put in place to ensure that a reasonable level of fire safety be provided to the increasing number of people who reside in such premises.

The risk in these types of premises is evident from the large number of serious fires in residential care premises worldwide that result in multiple deaths. Each year in the UK there are between 800 to 900 fires in residential care premises and over the past 10 years more than 45 people have died as a result of these fires (Source: Annual fire statistics CLG/ODPM [2]). This is above the national average when compared to other types of buildings and the risk in these premises and the relatively high proportion of fatalities/number of fires can be attributed to a number of factors, many of which result from the profile of the occupants who reside in such premises and their ability to escape in the event of a fire.

This study aims to identify the key life safety, property protection and business continuity risks associated with fires in these types of premises and, by reviewing international guidance documents and current research on fire safety and human behaviour, consider ways that these risks can be reduced to an acceptable level.

3 Fire safety risks in residential care premises

Residential care premises often present a unique series of risks in relation to fire safety, not least these associated with the means of escape in an emergency.

Within the UK, the requirement to provide an adequate level of life safety within buildings is primarily covered by the Building Regulations 2000 [3] with Part B of Schedule 1 of those Regulations dealing with fire safety. There are no specific requirements within UK legislation for the protection of property, business continuity and the social impact of a fire in such premises (i.e. the emotional impact a fire would have on the residents within the building since the building is the resident's home).

The Building Regulations 2000 states (Schedule 1, Part B, Paragraph B1):

"The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire, and appropriate means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times."

Due to the occupant profile in residential care premises this may be difficult to achieve due to the problems that some of the residents have in evacuating. Therefore in order to develop robust fire protection strategies it is important to have a full understanding of the risks involved. The following Sections discuss this further.

3.1 Occupancy Characteristics

When it comes to the evacuating a premises in the event of a fire, the main difference between residential care premises and other types of buildings is the profile of the occupants who reside in the former. In a large number of cases the residents who live in these buildings are no longer completely independent and often need additional support during their day-to-day activities. Clearly the level of support required varies depending on the resident in question with some residents needing more support than others.

The elderly are more likely to suffer from reduced sensory abilities such as smell, touch, vision and hearing, as well as mental and physical impairment (e.g. memory loss and arthritis). Such impairments can have the following effects:

I. inability to escape unaided;

II. increased reaction times;

III. reduced movement speeds;

IV. greater likelihood of accidental ignition caused by occupants.

The first three factors will likely result in increased evacuation times and a reduced ability to escape during the early stages of fire development while the last factor may result in an increased likelihood that the occupants will be close to the source of a fire. This is supported by the guidance within PD7974-6:2004 [4] which gives a pre-movement time in the region of 30-40 minutes for an occupancy such as a residential care premises.

The level of vulnerability of the occupants is therefore significantly higher within residential care premises than in most other types of buildings.

The following table reinforces the point by showing the number of casualties (fatal and non fatal) caused by fires in residential care premises.

Year	Elderly persons homes, children's homes and homes for the disabled or handicapped		
	Reported number of fires	Fatalities	Injuries
2000	1452	0	77
2001	1261	5	113
2002	1344	4	120
2003	1323	2	121
2004	1342	20	126
2005	1092	4	99
2006	1013	3	100
2007	998	3	127

Source: Annual fire statistics CLG/ODPM [3]

Table 1: Fires in residential care premises

The above table shows the high number of injuries and fatalities in residential care premises as a proportion of the number of fires.

Residential care premises do not only provide residential accommodation for the elderly and can provide accommodation for the following:

a. persons suffering from mental/physical disabilities;

b. children and young persons;

c. persons receiving care (for example home health and hospice care).

Residents with disabilities and residents receiving care present different and in some cases additional risks in terms of fire safety and it is considered that the support the residents need day to day can be linked to the level of assistance that they would require to evacuate in the event of a fire.

Where occupants require a large amount of assistance to evacuate (e.g. some occupants may be confined to their bed through illness) then this can require a significant number of staff to undertake the evacuation of just a single resident. If there are a number of residents who require assistance to evacuate then, due to the number of staff available within the building, this can potentially lead to extended evacuation times. Therefore in the event of a fire it will be important for the staff to prioritise the evacuation process, with those considered to be at greatest risk being evacuated first.

This may result in significantly extended evacuation times and it is important that sufficient measures be in place to reduce the risks to the building occupants and ensure that the occupants within the building can wait in an area safe from the effects of fire until they are evacuated.

Although fire safety guidance documents, building codes, fire risk assessments, and trained staff serve to mitigate this risk, larger occupant numbers will inevitably make evacuation and fire safety management more challenging (especially where occupants are reliant on staff assistance).

The following section considers the different resident profiles and the underlying causes that result in the associated increase in the risk to life safety.

3.1.1 Resident profile

The residents of these buildings are more vulnerable in the event of a fire than the majority of the general population due to a combination of factors, including:

- physical frailties. The elderly tend to have physical disabilities that hinder their mobility with approximately 32 per cent [5] of fire-related deaths occurring in the course of escape. There may also be residents who are bedridden and are therefore completely dependent on assistance to escape. According to US statistics [5] on fire incidents in residential care premises, 48 percent of fatalities occur within the bedroom (Figure 1).

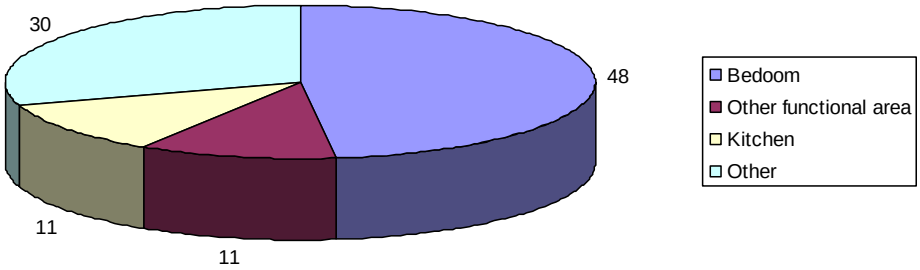

Figure 1: Location of fire fatalities

- vision impairment. Deteriorating vision not only makes things look blurred and indistinct but higher levels of lighting are required in order for older persons to be able to see objects clearly in comparison to younger adults. This can be problematic during the night, when limited lighting levels exist, and it would be further

exacerbated by smoke. This effect is made worse if residents awaken to an unexpected situation during the night; this may create difficulty in undertaking basic actions such as putting on glasses or getting dressed.

- hearing impairment. Difficulties with hearing can also significantly extend the time taken to respond to a fire alarm and subsequently increase the time it takes to escape. In extreme cases a person might not hear the fire alarm at all and be unaware of the risk.
- mental health. The ageing process increases the potential of a person to suffer from mental health diseases. Memory loss, Alzheimer's disease and dementia are just a few of the different afflictions that occupants may suffer from. These afflictions could have a significant influence on the response time and behaviour in emergency situations since persons that are suffering from these illnesses may require significant support through the evacuation process.
- touch. The elderly have a decreased ability to feel heat and warmth when touching objects. This may extend the response time taken to react when directly exposed to heat and may lead to an increased severity of pain and burns.
- prescribed medication, drugs and alcohol. Medication and drugs or mixtures of drugs with alcohol may affect logical thought processes and affect situation judgement. This may be a factor in residential care premises other than just elderly care facilities.

Lessened senses increase the risk from fire; and when two or more senses are diminished, the risk from fire for the individual increases dramatically. The diminished senses that result from the ageing process may ultimately result in the occupants of residential care premises having a slower reaction time to raise an alarm, and due to the residents' reduced physical capabilities, a slower response time to an alarm, which may result in an increased evacuation time. All of the above-mentioned factors combine to increase the risk of injury or fatality in a fire.

3.2 Building Characteristics

3.2.1 Main causes of fires in residential care premises

There is a large amount of readily available fire incident data and fire statistics in both the UK and the USA. A review of the US and UK fire statistics [2] [6] was undertaken to establish the primary causes of fire within residential care premises and according to the statistics the primary causes are:

- cigarettes/smoking;
- faulty electrical equipment or wiring;
- cooking;
- malicious ignition/fire setting.

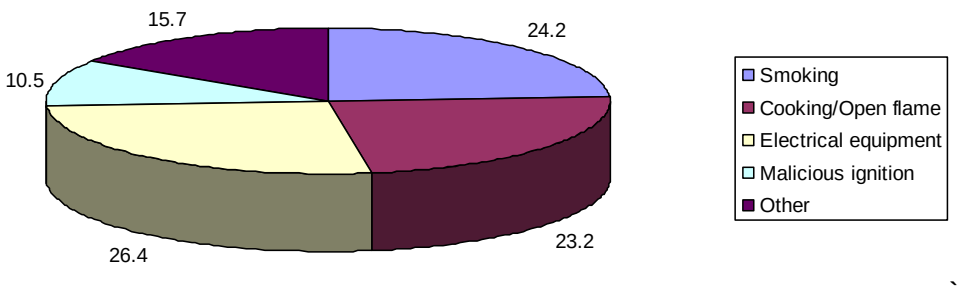

Figure 2: Causes of adult fire casualties

According to US statistical data [6] 50 per cent of older people who die in a fire are in close proximity to the source of the fire and 29 per cent of deaths are the result of smoking. The

above findings are also supported by data obtained from the fire damage reports for South Yorkshire Fire and Rescue Service between 01/01/2004 to 31/12/2008 [7] in that 64 per cent of fires were caused by adults (aged 18 and over) suggesting that they were in close proximity to the cause of the fire and 35 per cent of fires had other causes, such as electrical faults.

Most of the fires which are listed within Table 2 occurred during the night when most of the residents were in bed. This correlation was also found when reviewing fires in residential care premises within the USA [5]. This study also found that fires occurring within residential care premises were very similar to domestic fires, in terms of ignition source and ignited agent, and that smoking was the most prominent ignition source.

This conclusion was also drawn in BD2546, "ODPM Final Research Report on Sprinkler effectiveness in care homes" [8], in that the main causes of fires within residential care premises is residents igniting their clothes/bedding by smoking (see Section 8.1).

The following table presents a number of recent fire incidents that have occurred in the UK.

Time/Date/ Year	Location	Fire origin	Extent of fire/smoke damage	Provision of sprinklers	Fatalities
04:37 31 January 2004	Rosepark, Scotland	Electrical fault within store cupboard	Large volumes of smoke produced	No	10 died at the home due to smoke inhalation 4 later died in hospital
Early morning 1 February 2004	Old Refectory Care Home, Gumfreston	Electrical fault in electrical cupboard	Significant	No	2 died; one at the scene, one in hospital. Others treated for smoke inhalation
23 February 2004	Paxton Hall, Cambridgeshire	N/A	Contained in room with extensive smoke damage throughout	No	2 deaths and 3 treated for smoke inhalation
05:00 20 August 2004	St David's Nursing Home, Redcar	Resident room	Considerable damage to a number of rooms and the roof space	No	1 death
Early morning 20 August 2004	Redcar, UK	Electrical fault in extractor fan	Fire spread to the roof	No	1 died at the home
04:00 17 August 2006	Llanelli, UK	Electrical fault in cupboard	Smoke-logged to 1st floor	No	none; 1 taken to hospital for smoke inhalation

Time/Date/ Year	Location	Fire origin	Extent of fire/smoke damage	Provision of sprinklers	Fatalities
9th July 2006	Arson by carer, Victoria Mews Nursing Home, West Midlands	Room of victim and an additional seat of fire which didn't take hold	Significant amount of smoke damage	No	1 death
Evening 9 October 2006	Shannon Court, Bolton, Greater Manchester	N/A	N/A	No	none; 1 taken to hospital for smoke inhalation
22 November 2006	Priory Grange, Potters Bar	4th floor apartment	Considerable damage	No	1 death, 24 treated for smoke inhalation
08:30 20 December 2006	Monica Wills House, Bedminster	Car park below	24 cars in car park. Windows to façade broken	Yes in the residential areas. None in the car park	One resident located in the car park later died in hospital. None in residential area.
Early morning 2 October 2007	Care home on Sanderstead Road, Croydon	N/A	Heavy smoke logging throughout the building	No	Five people treated for smoke inhalation
29 December 2007	Cartrefle nursing home in Llanrwst	N/A	Confined to one bedroom causing severe smoke damage	No	All 23 residents evacuated
23 May 2008	Manor Gardens, Gateshead	N/A	N/A	No	1 death, plus others treated for smoke inhalation
23:00 6 July 2008	The Hockeridge, Westgate-on-Sea	N/A	Significant damage	No	1 death
17 August 2008	Clayton Manor Care Home, Congleton, Cheshire	Arson	N/A	No	1 death brought on by smoke inhalation and burns
03:00	Dell Road, Cotteridge,	N/A	N/A	No	1 resident died after being

Time/Date/ Year	Location	Fire origin	Extent of fire/smoke damage	Provision of sprinklers	Fatalities
11 January 2009	Birmingham				found overcome by smoke after the fire was put out
1 February 2009	Ancaster Court Home, Bexhill, Sussex	Arson	N/A	No	1 death
11th May 2009	Oldfield Bank Care Home, Highgate Road, Altrincham, Trafford	Bedroom	Smoke logging to the top floor	No	3 people treated for smoke inhalation
03:00 20th May 2009	Benore Care Home, Benarty	Arson	Extension of the care home, under construction at the day of the fire	No	None of the occupants of the existing section of the care home needed to be evacuated
21st September 2009	Aashna House, Streatham	Arson	N/A	No	1 death, plus seven others treated for smoke inhalation
12th November 2009	Care home in Henfield	Oven	N/A	No	Building cleared before fire-fighters arrived

Table 2: Selection of UK fire incidents

Further details of the above fire incidents together with some additional fire incidents are provided in Appendix A.

The primary causes of ignition are discussed in the following sections.

3.2.1.1 Cigarettes/smoking

In some residential care premises, smoking may be permitted within the residents individual apartments/bedrooms to provide comfort to the residents. If smoking is permitted then residents with diminished senses place themselves at an increased risk due to the increased potential for ignition due to the smoking materials. It is also likely that if a fire occurred as a result of smoking materials then the resident is very likely to be in close proximity to the fire, which can create additional likelihood of injury or death.

Therefore, where smoking is permitted within the individual apartment/bedroom of a residential care premises it is considered that the risk of ignition is much greater than that which would be present in a non-smoking premises.

3.2.1.2 Faulty electrical equipment/wiring

Electrical equipment is a major cause of fire within buildings, particularly older buildings that are unlikely to meet current electrical safety standards. There is a whole range of causes of electrical fires and these include:

- overloading of electrical sockets;
- poor connections and arcing;
- damaged cables;
- overloaded cabling;
- incorrect protection devices installed (e.g. fuses)
- poor testing and maintenance;
- faulty electrical equipment;
- combustible materials being stored in the proximity of heat-emitting devices (light bulbs etc).

3.2.1.3 Cooking

In residential care premises such as 'extra care' facilities[1], where residents live in their own individual apartments to enable the residents to live as independent a life as possible, with staff on hand to support the residents as required there is an increased likelihood that the residents will be cooking for themselves.

Where residents cook for themselves then the risk of ignition is increased and the fire is more likely to be in close proximity to the residents.

Where residential care premises have more commercial type kitchens, in which staff provide meals for the residents, then it is likely that these rooms will be fully separated from the rest of the accommodation through fire-resisting construction. In addition, the staff within the kitchen probably will not suffer the same mental and physical disabilities as the residents within the care premises and therefore the potential for first aid firefighting through the use of appropriate portable fire extinguishers and/or fire blankets should be greater.

3.2.1.4 Malicious ignition/fire setting

Malicious ignition/fire setting is another of the main causes of fire within residential care premises. This is highlighted in 'Fire Safety Risk Assessment: Residential care premises, Department for Communities and Local Government which states '*Recent studies indicate that, over 2,100 serious deliberately set fires, resulting in two deaths and 55 injuries, occur every week"* (It should be noted that this refers to all fire-setting and not just residential care premises).

Fires that occur as a result of such actions can be particularly hazardous as there can be multiple seats of fire and/or the fires will be located on escape routes (corridors, base of stairs etc) to maximise the impact of the fire. The fire safety design of these premises often does not cater for multiple seats of fire but there are recommendations in place for the protection of escape routes to reduce this risk (controls on wall linings, cross-corridor doors etc).

Arsonists may also use accelerants, which will cause the fire to develop significantly faster than would otherwise be the case. This can create additional difficulties and all efforts should be made to design the building to reduce the risk as far as possible. Section 10.2.5 includes a number of design and management considerations that relate to arson prevention.

It should not be assumed that malicious ignition or fire setting is entirely the work of the residents as there have also been a number of recent instances where the fire setter is a member of staff working for the care provider. For example:

- Victoria Mews, Coventry – Carer set fire to resident's bed: single fatality [9];

[1] 'extra care' housing is used to describe developments that comprise self-contained homes with design features and support services available to enable self- care and independent living. Extra care housing is popular with people whose disabilities, frailty or health needs make ordinary housing unsuitable but who do not need or want to move to long term care.

- Paxton Hall, Cambridge – Carer started fire in resident's bedroom – two fatalities [10];
- Shannon Court, Bolton – Suspended carer set fire in the basement of the home – no fatalities

While such cases involving staff are relatively few, they demonstrate the unpredictability and the real risk presented by such events, and the potential impact these events could have on residents.

Appendix A includes information on a number of fire incidents where it has been determined that they have been caused deliberately.

3.2.2 A comfortable living environment and an acceptable level of fire safety

The need to provide a comfortable living environment and a high level of care to residents can sometimes conflict with the measures required to provide an acceptable level of fire safety. The following factors point to areas where the fire safety design provisions are often in conflict with the operational and functional needs:

- the provision of soft furnishings and decorations within the common circulation areas;
- the provision of fire doors which can be difficult to open for frail residents;
- during the night time some residents prefer the bedroom doors to be left ajar to allow a small amount of light into their room. This is also preferred by the care staff since it allows the staff to look in on a resident without having to turn the door handle, which may wake the resident;
- wherever possible, carers will provide their residents with as much independence as possible. While this undoubtedly improves the quality of life of residents it may introduce the risks of ignition outlined in section 3.2 above.

Such conflicting interests should not be seen to create unduly onerous conditions within residential care premises but they do present risks that need to be addressed to ensure the residential care premises is fit for purpose and provides a comfortable living environment while still maintaining a good fire safety regime.

3.3 Challenges facing care providers/staff

3.3.1 Staffing levels (England)

The national minimum level of care that a care provider needs to achieve in England is covered under the Care Standards Act 2000 [11]. The guidance document to the Care Homes Regulations 2001 is *"Care Homes for Older People"* [12].

That document does not outline detailed specifications for staffing to address each and every situation but sets out baseline standards that should be utilised to determine the minimum staffing level in all premises. Each residential care premise should then determine the number and skills of the staff that need to be on duty at any one time to meet the needs of its residents.

In order to meet the minimum levels, the staffing levels within residential care premises are generally higher during the day due to the day-to-day requirements of the residents (assistance with activities, providing medication etc.), with additional staff being on duty at peak times of activity during the day. Therefore the number of staff employed during the evening and night time hours is generally less than the number which would be present during the day.

Under the Regulatory Reform (Fire Safety) Order 2005 it is the duty of the 'responsible person' to ensure that the occupants of the building can be evacuated safely and it is usually the responsibility of the staff within the building to undertake/assist with the evacuation of residents.

In reviewing the fire incidents in Table 2 above it is clear that in a large number of instances where fatalities occurred, the fire occurred during the evening and night time hours when there is potentially a reduced staffing level.

3.3.2 Assisted evacuation

The increased number of fatalities may be attributable to difficulties in evacuating residents during this period. In many instances a number of staff would be required to evacuate a single resident if the person is significantly disabled. If there are a number of residents who require assistance to evacuate then the reduced numbers of night-time staff on duty (as low as two persons in small residential care premises) would individually need to evacuate the occupants.

This could result in significant delays and extended evacuation periods compared to those indicated in current fire safety guidance documents and the fire safety measures put in place will need to take account of such factors. Sections 7 and 9 discuss this further.

Difficulties may also arise where residents suffer from diseases such as dementia as the residents may need monitoring once they have left the building and reached a place of safety.

4 Human behaviour in fire

The behaviour of persons in a fire in residential care premises varies significantly and each person will interpret and react to the fire differently [13]. Conclusions taken from behavioural research related to occupants who are exposed to a fire suggest that physical fire protection measures are considered to be the most important attribute in determining the level of safety and that the occupant response is not always dependable.

From a number of investigations carried out within the USA [14] the general behavioural sequences of elderly persons during a fire are dependent on a number of factors, in particular the physical and psychological conditions of residents and the social interactions between staff and residents.

US statistical data [6] states that at least 75 per cent of residents within residential care premises need some assistance to escape and 63 per cent of the residents use wheelchairs for general circulation. Therefore one of the key risks in residential care premises is the resident's ability to evacuate and in many residential care premises it is likely that a large proportion of the occupants will need physical assistance in evacuating.

Therefore the speed of the evacuation process will be largely dependent on the staffing levels within the residential care premise.

In the study by Eldeman et al [14] the fire alarm and 'indications from others' served as cues detected by respondents although the 'indications from others' were the most effective in motivating escape behaviour. This, therefore, reinforces the fact that in such evacuations residents will invariably be looking to staff for guidance and confirmation for the need to escape as well as assistance to escape. The study also highlighted that many of the residents used the primary circulation routes to evacuate and they did not use the less familiar escape routes (stairs which are purely used for escape and not circulation) which highlights the need for improved fire emergency training for both staff and residents to ensure that less familiar escape routes are utilised.

This is backed up by a study of Human Behaviour in Fires Summary Report [15] which concludes that there is a strong correlation between the normal routes of circulation and those used in evacuation. As the residents will use the primary circulation routes to escape, the fire protection measures provided within the building should aim to ensure that these routes remain tenable throughout the evacuation period.

This study also determined that *"the most important 'exit choice' decision was that at the doorway of the rooms after an investigation of opening the door onto the corridor".* People are obviously reluctant to escape through thick smoke and therefore the conditions within

the corridor together with well trained staff can be seen to be critical in determining whether or not the residents would move towards an escape route. To assist this, the strategy should be to ensure that tenable conditions are provided within the escape routes.

Automatic fire suppression provides a means of ensuring that the escape routes remain tenable for escape. Section 8.1 presents the key findings of the study undertaken by the BRE in their report titled Sprinkler Effectiveness in Care Homes. This concluded that a sprinkler installation provided effective protection to the occupants outside the room of origin and those within the room of origin not directly involved in the fire (the occupants could be in the room but remote from the flame). This is supported by the results of the quantitative analysis undertaken as part of this study which showed that conditions remained survivable beyond the room of origin in terms of temperature (see Section 9 for more details).

5 Consequences of fire in residential care premises

Where the risk of fire is not reduced to a sufficiently low level and a fire occurs the consequences can be significant. Section 3 considered the potential causes of fires within residential care premises, the risks associated with the persons who reside there and the challenges faced by care providers and staff in residential care premises.

The following section reviews the potentially significant consequences that can occur in the event of a fire. This includes the impact on:

- the building (property protection/business continuity);
- the residents;
- staff;
- relations of the residents.

5.1 Direct consequences

5.1.1 Area of fire damage

Most fires in residential care premises are either located within a resident's apartment/bedroom (typically caused by cooking/smoking materials) or are due to an electrical fault or arson (see Section 3.2.1 for further information).

The extent of fire damage within the building can be linked to the life safety risk to the residents within a building since a larger fire is more likely to impact on a greater number of residents (due to the spread of combustion products). The extent of fire damage can also have a significant business and social impact for the following reasons:

- a larger fire is likely to cause more damage in terms of overall monetary cost of a fire;
- a larger fire is likely to take longer to recover from since the work required to repair and refurbish the building after the fire incident will be greater;
- a larger fire will potentially have structural implications for the building and it may require the residents to be relocated for a period of time.

In order to determine the extent of fire damage within residential care premises in the UK a review has been undertaken on data collected from the FDR1 database of the London Fire Brigade [16]. Form FDR1 is a document completed by the fire and rescue services following their attendance at a fire and the database contains basic information on the nature and possible cause of the fire.

The data presented in Table 3 presents a summary of fires which occurred between 2005 and 2008 within residential care premises in London where the Fire Brigade had attended. This data does not cover other incidents where the fire had been extinguished by a member of staff or other persons.

Description of fire spread	Financial year (1st April – 31st March)		
	2005/2006	2006/2007	2007/2008
Confined to compartment of origin	154	149	133
Spread beyond compartment	8	3	6
Total	**162**	**152**	**139**

Table 3: Number of fires confined to and spread beyond the compartment of origin

It can be seen in Table 3 that the majority of the fires were confined within the compartment of fire origin.

The fire data presented within Table 3 can be further broken down to determine the extent of:

- damage caused by the fire itself. The information recorded is limited to single items of furniture (see Table 4);
- overall damage caused by the fire and the products of combustion. This consists of the damage made by the smoke and heat radiation. These assessments are made separately and do not impact on each other (see Table 5).

Estimated Area Damaged by Burning	Year/% area damaged						Totals	
	2005/06	%	2006/07	%	2007/08	%	Area	%
None recorded	6		7		15		28	
<1m²	124	95	121	99	104	88	349	92
1-2m²	19		14		13		46	
3-4m²	5		5		4		14	
5-9m²	2		1		-		3	
10-19m²	4		1		2		7	
20-49m²	-	<1	2	2	1	<1	3	1
50-99m²	1		-		-		1	
100-199m²	1		1		-		2	
>200m²	-		-		-		-	
Total	162		152		139		453	

Table 4: Damage caused solely by fire in residential care premises in the UK

Table 4 has been divided into two zones based on the area of damage consumed by the fire itself. The estimated fire damage areas with an area up to 20m² (highlighted in red) are considered to be limited to the room of origin based on the area involved in the fire. This is based on information provided within *Care Homes for Older People* [12]; the national minimum standards recommend a minimum 12m² of usable floor space for a single resident's room and 16m² for shared rooms. It is assumed for areas greater than 20m² that

the fire has spread beyond the room of origin or that it started in a relatively large room or a circulation space.

From Table 4 it can be seen that over 90 per cent of all fires in the years between 2005 and 2008 were relatively small (less than 20m²). Less than 3 per cent of all examined fires developed to a size which could be regarded as larger than the room of origin. This is reasonable when it is considered that the information collected is limited to single items of furniture but it does not consider spread of products of combustion and the impact this has on occupants outside the room of fire origin who suffer death or injury through exposure to products of combustion resulting in untenable conditions.

There may be a number of different reasons for the large number of fires that were controlled to less than 20m², these being:

- the fire did not have sufficient energy to spread beyond the item first ignited;
- the fire was extinguished by a member of staff or a resident;
- the fire-resisting compartmentation within the building limited the fire size;
- there was insufficient ventilation to maintain combustion.

Table 5 presents the overall extent of areas damaged by fires in residential care premises in the UK between 2005 and 2008. The data in the table below refers to damage by the fire itself and also damage caused by products of combustion.

Estimated area damaged by fire heat and smoke	Year/% area damaged						Totals	
	2005/06	%	2006/07	%	2007/08	%	Area	%
<1m²	33	77	29	79	27	78	89	78
1-2m²	16		23		12		51	
3-4m²	25		19		22		66	
5-9m²	27		18		25		70	
10-19m²	24		31		23		78	
20-49m²	20	23	20	21	14	22	54	22
50-99m²	12		7		12		31	
100-199m²	3		3		1		7	
>200m²	2		2		3		7	
Total	162		152		139		453	

Table 5: Damage made by fire smoke and heat in fires in residential care premises in UK

From studying Table 5 it can be concluded that the area of a building affected by all products of combustion (i.e. smoke, heat etc) is significantly larger than the damage which results directly from burning.

Approximately 22 per cent of all fires damaged an area greater than 20m² (this would equate to the area covered by 2 sprinkler heads if they were provided). This is a significant increase in comparison to the area damaged by the fire only (around 10 per cent from Table 4). Therefore it can be concluded that while in the majority of incidents the fire itself is

restricted to the room of origin, in a significant proportion of the fires smoke has not been contained to the room of fire origin and has spread to adjacent rooms or circulation spaces. It can therefore be concluded that in a number of cases the persons beyond the room of fire origin are at risk.

This is supported by data where a number of residents have died due to smoke inhalation in multiple fatality incidents (refer to Table 2). In reviewing the incidents in Table 2 it can be seen that, in a number of the fires, products of combustion significantly affected the area beyond the room of fire origin and in many cases the entire storey in which the room of fire origin was located.

5.1.2 Effectiveness of passive fire protection

5.1.2.1 Current fire safety recommendations

The guidance within Approved Document B for residential care premises relies heavily on passive fire protection (i.e. fire-resisting construction). In following the recommendations within the guidance the building will be subdivided into small compartments that are separated from the other parts of the building through fire-resisting construction. The recommendations in Approved Document B are:

- every resident's room requires fire-resisting doors equipped with a self-closing mechanism;
- each bedroom should be enclosed in fire-resisting construction;
- every corridor serving these rooms should be a protected corridor (i.e. fire-resistant).

The above provisions assist in preventing fire spread beyond the compartment of fire origin. But from fire incident data obtained (Table 2 and Table 3) there are a number of fires which do spread beyond the room of fire origin. This may be attributed to the severity of the fire or breakdown of the passive fire protection (in particular the non-functioning of the self-closing fire doors).

In reviewing Table 2 it can be seen that a number of fatalities occur beyond the room of origin and therefore the protection to these areas is equally important.

5.1.2.2 Review of recommendations

The guidance in PD 7974-7 [4] provides an insight into the likely effectiveness of self closing fire doors and compartment walls and floors and the reliability of these items in achieving their intended level of fire resistance. It is stated in this published document to the British Standard that recent studies have indicated that 23 per cent of fire doors are rendered ineffective. No further information on the origin of this figure is given, and it is therefore assumed that this mainly applies to fire doors in public / commercial buildings as opposed to those in dwellings. Additionally, it is stated that 20 per cent of the fire doors that are not rendered ineffective by the building occupants (propped open etc), fail to close properly, resulting in nearly a 40 per cent failure rate for fire doors in general. It is also concluded from recent studies that 40 per cent of fire doors fail to act as intended in premises where systematic maintenance is possible.

For residential care premises in particular, self-closing doors present a challenge for day-to-day movement in and out of a room, for frail residents, people using walking frames and people in wheelchairs. Thus some doors may be more likely to be wedged open, increasing the likelihood of the doors failing to close. Therefore in reviewing the above it is considered that the likelihood of fire doors failing to perform as intended will be at least 40 per cent.

The guidance in PD 7974-7 also states that the probability that walls will not achieve 75 per cent of their designated standard is:

- masonry walls – 0.75;
- partition walls – 0.65;

- glazing - 0.40.

5.1.2.3 Conclusions

In considering the reliability information above together with the fire spread data it is considered that while passive fire protection does provide significant benefit in preventing fire spread if installed, maintained and managed correctly, in reality this is not always the case and the 'human factor' can sometimes undermine this provision through factors such as fire-doors being wedged open or damaged and not maintained ,and penetrations passing through compartment walls not being appropriately fire stopped.

The human element and the maintenance/installation of any type of fire-protection measures are crucial to their reliability to perform as intended in the event of a fire but in reviewing the figures above it is clear that this is not always undertaken as well as it should. In reviewing the risks associated with the occupants who reside in residential care premises, extended evacuation periods may be required to get all of the residents to a place of relative safety. It is therefore vital that the escape routes be maintained for evacuation during this extended period and the provision of automatic fire suppression to supplement passive fire protection can help to reduce the risks in care home premises;

5.2 Indirect consequences of fire

5.2.1 Disruption

In the event of a serious fire the resulting disruption can be significant and, depending on the spread of the fire throughout the building and the impact this has on the building structure, it may not be possible for the residential care premises to continue to function effectively in the short term.

In serious cases the building may need to close completely whilst the building undergoes repairs and refurbishment.

This could have the following effects:

- **residents** would need to be re-located. The residents get comfort from the familiarity and awareness of their surroundings and relocating them could exacerbate the trauma that they may suffer since they will need to be moved to premises that are unfamiliar. This is particularly relevant where the resident suffers from diseases such as Alzheimer's or dementia;
- **staff** would either need to move to the alternative new residential care premises to support the residents when they are relocated or may need to find interim employment. If the new place of work is a significant distance away there are associated cost issues with the staff needing to travel to work;
- **financial implications** on the residential care premises while it is closed are significant. Their funding is based on the number of residents they are caring for. During the interim period the funding would be reduced as the residents are being cared for elsewhere leading to loss of revenue and business interruption which may not always be met by insurance. The family of the resident may also choose to move the resident to another home in the interim period;

5.2.2 Sustainability

The indirect consequences of a fire often need careful consideration and are frequently overlooked, particularly those associated with social, human and sustainability aspects.

Fires by their very nature are harmful to the environment. The types of products discharged into the environment during a building fire are largely dependent on the types of materials that are burning within the fire. Many buildings contain a range of different materials including a number of different types of plastics which can lead to significant amounts of

toxic gases being discharged into the atmosphere in the event of a fire. All building fires discharge the following combustion products:

- carbon monoxide (CO);
- carbon dioxide (CO_2);
- hydrogen chloride (HCl);
- hydrogen Cyanide (HCN).

The provision of automatic fire suppression may not only provide benefits in terms of life safety and the protection of property but may also be used to mitigate the impact the building fire has in relation to environmental issues. This is discussed further in Section 8.2.3.2.

5.2.3 Trauma

Post-fire trauma can have a significant impact on the resident's wellbeing. This is not always a major consideration since the effects are sometimes not apparent immediately after the incident and therefore they sometimes go unreported.

In the article *Management of post-incident trauma: a fire service perspective* [17] it states that trauma has specific features relating both to the incident and symptoms it produces. Reactive symptoms occur in most people in the immediate after-period but rising or persisting anxiety towards the end of the first week indicates a risk of a serious disorder developing.

The article cited recommends that management of trauma should start immediately after the event in a three-stage process:

- immediate management after the fire involving de-briefing and peer group support of the participants in the incident;
- for those who continue to experience rising or persisting anxiety after the first week, referral to occupational health advisers, welfare/counsellors or general practitioners is necessary;
- if symptoms persist or recur, tertiary referral to specialist advisers such as psychologists or psychiatrists may be required.

Post incident trauma can be directly linked to the exposure of residents, staff and management to injury, death and damage resulting from fire and therefore it is considered that the primary objective in reducing trauma should be to reduce the impact of a fire (by reducing the size of the fire and resultant damage).

5.2.4 Impact on a Resident's family

The impact a fire can have on a resident's family can be significant. In the event of a fire, the family of the resident can often be primarily affected emotionally (through their concern for their relation and in the case of a fatality the family will need to deal with the loss of a relation).

In the event of a serious fire within a residential care premises particularly one where a fatality has occurred, there is usually an inquest or some form of investigation into the cause of the fire. This often looks at whether or not the level of fire safety management and the fire protection measures within the building were sufficient. The inquests and investigations can take a significant period of time and may extend the period the family members suffer. To deal with their suffering some family members may require counselling.

In addition to the emotional impact there is also the potential monetary impact to the resident's family due to the potential relocation of the residents and the associated travel costs their friends and family may incur visiting them.

6 Review of Current Fire Safety Guidance Documents

The following sections review the recommendations within current fire safety guidance documents for residential care premises in the UK and discuss their ability to address the fire risks associated with residential care premises. A review has also been undertaken on a selection of international fire safety guidance documents to identify international best practice.

6.1 England and Wales (Approved Document B)

The recommendations on the minimum level of fire safety measures that need to be provided to meet the requirements of the Building Regulations in England and Wales are covered in the 2006 edition of Approved Document B: Fire Safety [18].

Volume 2 of Approved Document B *Buildings other than dwelling houses*, provides recommendations for residential care premises.

The guidance within this document provides two alternative evacuation strategies, one whereby a simultaneous evacuation strategy is adopted and one where a progressive horizontal evacuation is to be adopted. A judgement on the most appropriate strategy should be made early on in the design development, both for new build developments or where existing buildings are being converted to residential care premises.

6.1.1 Simultaneous evacuation

If a simultaneous evacuation strategy is adopted all the occupants within the building would need to evacuate upon activation of the fire alarm.

There is no limit on number of bedrooms within a protected area (compartment separated via fire-resisting construction) when a simultaneous evacuation strategy is adopted.

6.1.2 Progressive horizontal evacuation

The fundamental premise of a progressive horizontal evacuation strategy is that the building should be sufficiently subdivided through fire-resisting compartmentation to enable occupants to escape through a line of fire resisting compartmentation to reach a 'place of relative safety' (see Figure 3).

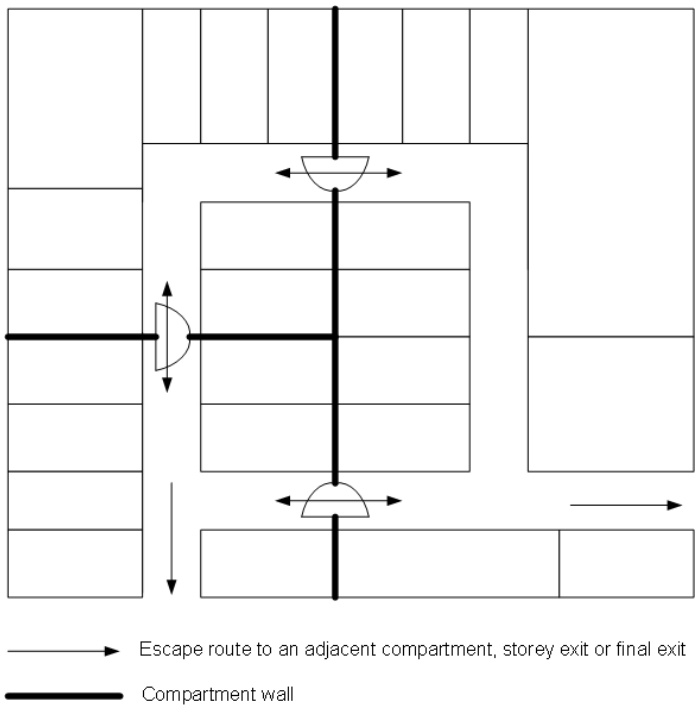

Figure 3: Progressive horizontal evacuation in residential care premises

Approved Document B recommends that this strategy should be adopted where a reasonable number of residents will need to be assisted by staff in order to evacuate.

The key benefit of this strategy is that by evacuating the residents through a line of fire-resisting construction they are assumed to be in a place of relative safety, safe from the immediate effects of fire. Providing this place of relative safety relieves the time in managing further evacuation of all affected residents. Additionally, this approach reduces the immediate reliance on staircases for escape (which can be difficult to negotiate by the elderly) in the early stages of a fire.

The number of residents accommodated within a protected area should be established based on an assessment of the number of staff likely to be available and the level of assistance that residents may require in evacuating. The recommendations of Approved Document B suggest that the maximum number of occupants/beds in any one protected area should not exceed ten residents/beds. This recommendation is intended to limit the number of residents who would need to be initially evacuated. Therefore in adopting this strategy it is feasible that up to ten residents who may require assistance in evacuating to a place of relative safety could be located within a single fire compartment.

6.1.3 Fire detection and alarm

In England and Wales most fire detection and alarm systems are designed in accordance with BS 5839: Fire detection and alarm systems: Part 1: Code of practice for system design, installation, commissioning and maintenance. Part 1 lists six categories of life safety installations. These are:

Category of System	Extent of areas covered
M	No automatic detection, manual call points only
L5	Extent of coverage is determined by a risk assessment.
L4	All areas that form part of the common escape route including escape stairs and corridors
L3	The same coverage as for the L4 system plus all rooms that open onto the escape routes except rooms that are less than 4m deep and are separated via fire resisting construction
L2	The same coverage as for the L3 system plus rooms where the fire risk is high enough to warrant individual protection
L1	All rooms and areas of the building, but the following areas need not be protected if they are of low risk: - toilets, shower rooms and bathrooms; - stairway lobbies and toilet lobbies - small cupboards (<1m²) - some shallow voids (<800mm in depth)

Table 6: Extent of detection

Systems in residential care premises should be category L1, intended for the protection of life, and this system provides fire detection coverage throughout the building.

6.1.4 Fire resisting construction

In accordance with the recommendations of Approved Document B where a progressive horizontal evacuation strategy is the choice of the management then every bedroom should be enclosed with fire resisting construction. The corridors serving the bedrooms should be constructed as fire-protected corridors and all doors opening onto the corridor should be fire doors fitted with self-closing devices and with the same level of fire resistance as the walls in which they are fitted.

Where a simultaneous evacuation strategy is adopted only the corridor itself would need to be a fire-protected corridor and there is no recommendation for the walls between the bedrooms to be comprised of fire-resisting construction.

Every floor within a residential care premises should be a compartment floor in both evacuation strategies.

6.1.5 Sprinkler systems

Approved Document B considers a number of alternative approaches which may provide significant benefits in terms of the design of a residential care premises, by providing sprinklers as part of the design. These include:

- bedroom fire doors need not be fitted with closing devices;
- protected areas (when a progressive horizontal evacuation strategy is adopted) may contain more than 10 beds;
- bedrooms may contain more than 1 bed.

This recognises the significant benefits provided by sprinklers particularly in the areas beyond the room of fire origin, since the above relaxations are considered to show that there is a reduced risk of fire spreading from the room of origin.

6.1.6 Review of guidance

It is clear that in any use of Approved Document B the type of accommodation and the needs of the resident will need to be considered carefully.

In terms of evacuation strategy, Approved Document B proffers two potential solutions, simultaneous and progressive horizontal evacuation.

- in order for a simultaneous evacuation to be effective a large number of the residents within the building would need to be ambulant and be able to evacuate without assistance. Otherwise the staffing levels required to undertake the evacuation process would be unrealistically high.
- a progressive horizontal evacuation strategy may also be very staff intensive if a large number of the residents within the building need assistance to evacuate. It is acceptable for up to ten bedrooms to be located within a single fire-resisting compartment and therefore if a fire occurred in a compartment it is feasible that the staff may have to evacuate up to ten residents initially. Progressive horizontal evacuation would be preferable to simultaneous evacuation if a large number of the residents require assistance to escape due to the difficulties associated with evacuating residents down stairs (particularly if the residents are wheelchair bound). However if all of these residents required assistance to evacuate then it is highly unlikely that the compartment in which a fire is located would be able to be evacuated in the 2.5 minutes flow time on which the exit widths in Approved Document B are based.

The guidance within Approved Document B goes some way to address this by recommending that all bedrooms should be enclosed in fire-resisting construction and every corridor serving the bedrooms is a protected corridor. However, the extent of fire and smoke damage discussed in Section 5.1.1 and the potential means of failure of compartmentation (refer to Section 5.1.2), suggests that fire protection using compartmentation alone is not always effective. This is particularly relevant in older premises that may have been designed to previous versions of Approved Document B or via local byelaws before 1965. Automatic fire suppression would provide an effective means of controlling the fire and reduce the risk that the escape routes become compromised throughout the extended evacuation process.

6.1.7 Welsh Assembly Legislative Competence Order – Residential Sprinklers

It should also be noted that at the time of writing the Welsh Assembly have voted in favour of the Legislative Competence Order which if enacted would require the installation of sprinklers in all new dwellings.

6.2 England and Wales - Regulatory Reform (Fire Safety) Order 2005 (RRO)

The Regulatory Reform (Fire Safety) Order 2005 [19] (from this point referred to as the Order) replaces previous fire safety legislation such as the Fire Precautions Act 1971 [20]. The Order places a general duty of fire safety care on employers, occupiers and owners of the residential care premise and requires them to provide and maintain adequate fire precautions.

Responsibility for complying with the Fire Safety Order rests with the 'responsible person'. In a residential care premises this will usually be the person or people who are responsible for the control of the premises (e.g. the owner or occupier).

The responsible person has a duty to carry out a fire risk assessment which must focus on the safety of all 'relevant persons' in the event of a fire. To assist the responsible person in meeting their duties under the Order, HM Government produced the document "*Fire Safety Risk Assessment – Residential care premises"* (from this point referred to as FSRA) [21] which provides advice on what the responsible person needs to do to satisfy their legal requirements under the Order.

FSRA primarily provides guidance on how to prevent fires and how to ensure people's safety in the event of a fire.

FSRA applies to England and Wales only and makes reference to other standards and guidance documents that may be useful in assessing fire precautions in residential care home premises, as well as for the fire safety management of the premises.

The document consists of two parts:

- Part 1 – explains what a fire risk assessment is and how it should be conducted;
- Part 2 – provides further guidance on fire precautions in residential care premises.

Specific guidance from that document is provided in the sections below.

6.2.1 Evacuation strategy

FSRA guidance identifies three different types of evacuations: single-stage evacuation, progressive horizontal evacuation and delayed evacuation.

6.2.1.1 Single-stage evacuation

This evacuation strategy is generally recommended for buildings where it may be expected that all the occupants inside the building are able to evacuate quickly to outside the building to a place of safety. This would only be possible where the residents within the building would generally be able to evacuate without assistance

6.2.1.2 Progressive horizontal evacuation

FSRA recommends that all care premises other than small buildings should develop a strategy of progressive horizontal evacuation. The process of horizontal evacuation relies on the parts of the building that are used for sleeping accommodation being separated into smaller sub-compartments called protected areas.

If a fire occurs, residents can be moved away from the affected area to the adjoining protected area, where they are able to remain for a time in reasonable safety.

6.2.1.3 Delayed evacuation

In some residential care premises where it is difficult to get all semi-ambulant and non-ambulant residents into an adjoining protected area or to a refuge (a place of reasonable safety in which a disabled person or others who may need assistance may rest or wait for

assistance before reaching a place of total safety) during the initial stage of the evacuation, a delayed evacuation may be applied.

In this situation, the FSRA recommends that an individual bedroom may provide a temporary refuge to protect the occupant from a fire elsewhere in the building until they can be taken to a place of safety, or danger has passed. If this strategy is adopted the FSRA recommends that the bedroom should be of 60 minutes fire-resisting construction and the doors should be fitted with a self-closing device. In addition the escape route from the bedroom(s) to the adjoining protected area, refuge or final exit (including stairs) will also require an increased level of fire protection.

6.2.2 Fire detection and alarm

In accordance with FSRA, all residential care premises should have automatic fire detection, which actuates the fire alarm system. FSRA recommends smoke detectors as the most appropriate because they provide the quickest response to a fire.

The extent of the fire detection and alarm system within the building will depend on the size of the building and nature of the residents within the premises. In small residential care premises (i.e. with no more than one floor above ground) accommodating residents who do not need assistance to escape, a basic system based on mains powered interlinked smoke alarms with battery back-up may provide suitable protection. In larger premises the guidance recommends the relevant system designed in accordance with BS 5839-1 [22]:

- a category L2 system in premises where all the residents are capable of evacuating themselves – detectors in all the escape routes, in any room opening onto any escape route and in any other areas of high risk;
- a category L1 system in premises where a significant proportion of the residents are dependent upon staff assistance to escape – detectors covering all areas of the building.

See Section 6.1.3 for further information.

6.2.3 Fire resisting construction

In accordance with the guidance in FSRA, all floors in care premises should be compartment floors, i.e. of fire-resisting construction. In general a rating of 30 minutes fire resistance is acceptable although a 60 minute rating may be more appropriate where delayed evacuation is necessary (it is likely that if the building was new build then the floors would need to achieve 60 minutes following the recommendations within Approved Document B).

All corridors that serve sleeping accommodation should be of 30 minutes fire-resisting standard and doors therein should be fitted with self-closing devices and appropriately certificated door furniture. If the corridor is longer than 30m, it should be subdivided with fire doors.

6.2.4 Sprinkler system

The FSRA guidance does not specifically state whether or not sprinklers should be provided in residential care premises since the document is intended to support the responsible person in undertaking their risk assessment. It does recognise, however, that there may be worthwhile safety and financial benefits in providing a sprinkler system and suggests the following benefits:

- reduction in the amount of portable firefighting equipment;
- relaxation of restrictions in the design of buildings (including the lengths of escape routes, the provision of fire-resisting barriers or the provision of some self-closing fire doors);
- favourable consideration from fire insurers in setting premiums;
- reduction in the risk of major business interruption.

6.2.5 Review of Guidance

The Regulatory Reform (Fire Safety) Order describes three potential evacuation strategies, simultaneous, phased and delayed. It also states that evacuation of all occupants from a compartment should be within 2.5 minutes.

While it is appreciated that the 2.5 minutes evacuation time is only guidance, in reviewing this figure against results of evacuation drills in residential care premises [23] it is clear that in a large number of instances it is unlikely that evacuation can take place within this period. The evacuation drills referenced above showed that evacuation of a single person can take up to 3 minutes with six members of staff and therefore due to the extended evacuation periods the responsible person will need to address as part of their risk assessment the extent of fire protection provided to the residents during the evacuation period.

The three evacuation strategies also have potential drawbacks. A review of the simultaneous and the progressive horizontal evacuation is discussed in Section 6.1.6 above while the guidance on delayed evacuation within the FSRA document requires a carer to stay with a resident while they are waiting to be evacuated. The adoption of this guidance may not be possible in some residential care premises since there may be an insufficient number of staff to carry out the evacuation process while others wait with residents.

The adoption of a delayed evacuation strategy would also require some compartments to have enhanced fire resisting construction. This is very similar to private residential building fire strategy (e.g. an apartment building) whereby occupants are considered to be in a place of relative safety within their bedroom/apartment. However the level of fire protection provided in following the recommendations (of the FRSA document) for delayed evacuation are not considered to provide a level of protection commensurate with that provided if the guidance of Approved Document B were followed for apartment buildings. For instance there is no recommendation within the FSRA document to provide smoke ventilation to the corridors or stairs.

6.3 BS 9999: 2008

BS 9999: Code of practice for the fire safety in the design, management and use of buildings, 2008 [24] is a guidance document that is based on fire safety engineering principles, although it is not intended as a guide to fire safety engineering. The concept behind the document is that it provides a risk based approach to prescribing the fire safety precautions in the design of buildings, and provides an alternative to following Approved Document B. BS 9999 therefore provides a middle ground in terms of design flexibility, sitting between the basic guidance of Approved Document B and the fully fire engineered approach of BS 7974: Application of fire safety engineering principles to the design of buildings, Code of practice, 2001.

The guidance within BS 9999 states that residential care premises could potentially fall under two different occupancy characteristics.

Occupancy characteristic	Description
Cii	Occupants receiving medical care
D	Long-term managed occupancy

Table 7: Occupancy characteristics

While occupancy characteristic D falls outside the scope of BS 9999; the guidance within BS 9999 for occupancy characteristic Cii could be followed in developing the fire safety design for residential care premises.

In assessing the risk profile it is considered than an unsprinklered residential care building would typically have a risk profile of C2 (occupants who are likely to be asleep and a medium fire growth rate) in accordance with Table 4 of BS 9999.

For this type of premises a brief summary of the recommendations is provided below:

- management level 1; staffing level appropriate to building, management systems in place;
- simultaneous evacuation should be adopted;
- alarm and detection – L2 system, based on risk profile.

6.3.1 Sprinkler systems

If sprinklers were provided within the building then in following the recommendations of BS 9999 it is acceptable to reduce the fire growth rate by one level to that of C1 (occupants who are likely to be asleep with a slow fire growth rate).

In reducing the fire growth rate by a single level, BS 9999 allows the following benefits (assuming the minimum fire protection measures are provided):

- the management level can be reduced from Management Level 1 to Management Level 2 (refer to Section 8.3 of BS 9999 for further details);
- travel distances can increase from 18m where escape is possible in more than one direction and 9m where escape is only possible in a single direction to 27m where escape is possible in more than one direction and 13m where escape is only possible in a single direction;
- the minimum door width per person can reduce from 4.1mm per person to 3.6mm per person (assuming the overall minimum door widths are achieved);
- the stair widths can reduce in accordance with Table 15 of BS 9999 (assuming the overall minimum stair widths are achieved);
- the fire resistance periods for elements of structure may be reduced in accordance with Table 25 of BS 9999.

In addition to the above, if automatic fire suppression is provided the separation distance between buildings or the extent of fire-resisting façade can increase due to the reduced risk of external fire spread.

6.4 Scotland - Scottish Technical Handbook

Scotland was the first area in the UK to introduce the recommendations for residential sprinklers within its Building Regulations guidance (refer to Section 6.4.4) for residential care premises.

Recommendations on the minimum fire safety measures to satisfy the requirements of the Building (Scotland) Regulations are provided within the Scottish Technical Handbook [25].

Specific recommendations on residential care premises are provided within Appendix 2A of the Scottish Technical Handbook.

6.4.1 Evacuation strategy

The recommended evacuation strategy in residential care buildings is a progressive horizontal strategy where occupants may need to be evacuated into an adjoining compartment. It recommends that the each compartment should be capable of holding the occupancy capacity of the compartment and the occupancy of the largest adjoining compartment (i.e. a single compartment should be large enough to accommodate all of the persons present within two adjacent compartments).

6.4.2 Fire Detection and alarm

Automatic fire detection and alarm systems should be of a L1 type in accordance with BS 5839 Part 1. For a building designated to accommodate not more than 10 residents, an L2 type alarm system may be utilised.

See section 6.1.3 for a summary of BS 5839 Part 1 installation categories.

6.4.3 Fire-resisting construction

The maximum size of a single compartment in a care home building should not exceed 1500m². Every floor of such a building should be constructed as a compartment floor. In addition to the limits on a maximum fire compartment size, each compartment should be subdivided into at least two sub-compartments each not exceeding 750m². Sub-compartment walls may be constructed of a material having 'short fire resistance duration' (30 minute fire resistance period).

6.4.4 Sprinkler systems

According to the recommendations of Scottish Technical Handbook, sprinkler systems in residential care premises should be designed and installed in accordance with the recommendations of DD 251 [26] (the document refers to DD 251:2000 however this standard has been superseded by BS 9251: 2005 [27]).

6.5 Scotland – Fire Scotland Act 2005

Scotland has its own fire regulations which govern how fire safety is to be managed in regulated premises. The Fire (Scotland) Act 2005 [28] replaces the previous fire safety regime and the system of fire certificates. The new fire safety regime is based on the principles of risk assessment and the requirement to take steps to prevent fire and mitigate the detrimental effects of a fire on the premises to ensure the safety of persons. Such a risk-based approach centred on fire risk assessment, introduces more flexibility in satisfying the regulations, with the Technical Annexes (contained in the Scottish Government's Sector Specific Guides) intended to be used in a non-prescriptive manner. This is of benefit to existing buildings where it may not always be possible to meet current recommendations to the letter.

The Fire (Scotland) Regulations 2006 [29] ('the 2006 Regulations') are made under the 2005 Act and contain provisions which are part of the fire safety regime. The 2006 Regulations cannot be looked at in isolation; the fire safety regime in Scotland is split into primary and secondary legislation and duty holders have obligations under both. In some respects the primary legislation (the 2005 Act) contains a broad-brush approach to fire safety measures while the 2006 Regulations, the secondary legislation, contain more detailed provisions.

To support the Part 3 of the Fire (Scotland) Act 2005 and the 2006 Regulations made thereunder, in more detail a series of occupancy-specific guides have been published by the Scottish Government. The Guides do not offer prescriptive guidance, solutions are offered but do not have to be adopted if the outcomes of a fire risk assessment can be met in some other way.

One of these Guides provides specific guidance on care homes. That guide notes that sprinklers can be designed to protect life and/or property and may be regarded as a cost-effective solution for reducing the risks created by fire. It also suggests that as an automatic life safety fire suppression system can be very effective in controlling a fire. It may limit fire growth and extend the time taken for untenable conditions to develop outside the room involved in fire giving more time to evacuate residents, particularly in cases where the standard of fire compartmentation, structural fire protection, fire spread on internal linings or travel distance may be a concern.

It should also be noted that in residential care buildings (as defined in regulation 2 of the Building (Scotland) Regulations 2004) where building warrant approval was granted after 1 May 2005 in respect of new or altered premises, automatic life safety fire suppression systems are required to comply with Building Regulations.

6.6 Northern Ireland

The recommended level of fire safety in Northern Ireland for residential care premises is covered in the Northern Ireland Firecode, Health Technical Memorandum 84 – *Fire Safety in*

Residential Care Premises [30] which has been produced for the Health and Personal Social Services Management Executive (HPSS ME).

The guidance in that document is appropriate for buildings up to three storeys above ground level that are intended for residents' bedrooms.

The document serves three main purposes:

- to provide guidance in the design of new residential care premises (or where there is a changed in use to residential care);
- to set acceptable levels of fire safety in the existing premises;
- to provide a form of fire risk assessment in residential care premises.

The recommendations within the document are largely dependent on the size of the care home in question and the document uses the following designation:

- small premises – 1-3 residents;
- medium premises – 4-9 residents; and
- large premises – 10 or more residents.

Based on the size of the premises, more or less stringent recommendations are made to achieve the minimum recommended level of fire safety. These include:

- separation of fire hazard rooms (such as plant rooms, kitchens, laundry rooms, store rooms and large day rooms);
- types of surface finishes;
- emergency signage;
- required fire alarm and detection system;
- compartmentation.

6.6.1 Fire detection and alarm

The minimum level of fire detection and alarm system in small and medium (existing and new) premises is an L3 system in accordance with BS 5839 - Part 1. Alternatively a suitable number of self-contained fire alarms should be installed.

In large, new-build premises an L1 system in accordance with BS 5839 – Part 1 should be provided.

In a large, existing building, the existing alarm and detection system should be acceptable on the basis that it was in accordance with the appropriate British Standard at the time of installation and on the proviso that it has been properly maintained. When the system needs to be replaced, an L1 system should be installed in accordance with BS 5839 - Part 1.

6.6.2 Fire-resisting construction

All elements of structure should achieve a minimum fire resistance of 30 minutes, except for a building with three or more storeys or with basement storeys where structural fire resistance should be increased to 60 minutes.

Every floor in medium and large premises should be constructed as a compartment floor.

Staff and resident's bedrooms should be enclosed with 30 minutes fire-resisting construction.

6.6.3 Sprinkler systems

There are no specific recommendations in relation to the provision of an automatic sprinkler system within the document. It does however suggest that the provision of a sprinkler system may be adopted as part of an alternative fire engineering strategy approach for a particular building.

6.7 United States of America – NFPA 5000 and NFPA 101

In accordance with NFPA standards (NFPA 5000 [31] and NFPA 101[32]), nursing and residential care premises fall under the *'health care occupancy'* category, which is defined as

"an occupancy used for purposes of medical or other treatment or care of four or more persons where such occupants are mostly incapable of self-preservation due to age, physical or mental disability, or because of security measures not under the occupants' control".

The NFPA codes suggest that occupants within health care occupancies may have difficulties in using the available exits due to their physical condition and there may also be difficulties relocating them to different parts of the buildings and ultimately evacuating the building since the occupants may be confined to their beds, immobile, debilitated or disabled.

Therefore the standard code approach is based on a 'defend-in-place' strategy. The concept of such an approach is to provide a sufficient package of fire safety measures to enable the occupants to survive a fire while remaining in the building

The package of fire safety measures may include:

- fire-rated building construction and compartmentation;
- provision of a sprinkler installation;
- provision of fire detection and alarm system;
- utilisation of horizontal evacuation with appropriate staff training.

6.7.1 Sprinkler provisions

The 2009 edition of NFPA 101 (Life Safety Code) requires automatic sprinkler protection to be provided to all new health care occupancies and many existing ones.

6.7.2 Background

The recommendations in relation to sprinklers within the NFPA guidance documents are based on the United State Government Accountability Office Report, *Nursing Home Fire Safety – Recent Fires Highlight Weaknesses in Federal Standards and Oversight* [33]

The report followed on from fires in 2003 where 31 residents died in unsprinklered nursing homes fires in Hartford, Connecticut and Nashville, Tennessee. The report states that sprinklers are considered to be the single most effective fire protection feature and it notes that there has never been a multiple death fire in a fully sprinklered nursing home fire. While sprinklers were already in new build residential care premises the US Government document reviewed the need for sprinklers to be retrofitted in existing accommodation.

6.8 United States of America - International Building Code

The 2009 edition of the International Building Code (IBC) [34] was issued by the International Code Council, Inc.

The intention of the IBC is to meet '*the need for up-to date building code addressing the design and installation of building systems through requirements emphasizing performance'.*

The design approach presented within the document is based on both prescriptive and performance-related solutions and the recommendations of this code may be adopted and used by appropriate jurisdictions internationally.

The primary objective of this code is to provide recommendations for new buildings; however, one section of the code contains recommendations for existing buildings, although the provisions of that section should only apply where alteration, repair or change of occupancy has taken place in existing premises.

The code distinguishes between a number of different Institutional Group occupancies based on physical, psychological and other health limitations as well occupants whose liberty is restricted due to penal or correctional reasons.

According to the Group designation, care home premises and nursing homes fall into Group I-2 occupancy. This group includes '*buildings and structures used for medical, surgical, psychiatric, nursing or custodial care on 24-hour basis for more than five persons who are not capable of self- preservation'.*

6.8.1 Sprinkler provisions

Sprinkler protection should be provided throughout the Group I buildings as indicated in Section 903.2.6 of the code.

6.9 Hong Kong – Code of practice for residential care homes

Guidance on the minimum level of fire protection measures for residential care homes in Hong Kong is covered in '*Code of Practice for Residential Care Homes – Elderly Persons*' [35] produced by the Social Welfare Department.

The guidance gives the following requirements for residential care homes with a floor area less than 230m²:

- a fire detection system should be provided for the whole home with smoke detection within the bedrooms;
- a manual fire alarm system should be provided with manual call points;
- automatic fire extinguishers should be provided;
- all exits should be provided with appropriate exit signage;
- emergency lighting should be provided throughout the entire home;

In the Code of Practice for Residential Care Homes – Elderly Persons, the following requirements for residential care homes where the floor area is greater than 230m² should be met:

- an automatic sprinkler system should be provided for the entire home premises;
- a smoke detection system should be provided within the areas of sleeping accommodation;
- a hose reel system should be provided such that all parts of the home are within 30m of the hose reel;
- a manual fire alarm system should be provided with manual call points;
- automatic fire extinguishers should be provided;
- all exits should be provided with appropriate exit signage;
- emergency lighting should be provided throughout the entire home.

6.9.1 Sprinkler provisions

The 'Code of Practice for Residential Care Homes – Elderly Persons' recommends sprinklers should be provided in residential care premises greater than 230m².

6.10 Australia – Building Code of Australia

In accordance with Building Code of Australia (BCA) [36] the following building classes of residential accommodation can be identified:

- Class 3 – a residential building, other than a building of Class 1 or 2, which is a common place of long term or transient living for a number of unrelated persons, including … accommodation for the aged, children or people with disabilities …;

- Class 9a – a building of a public nature … a health care building: health care building means a building whose occupants or patients undergoing medical treatment need physical assistance to evacuate the building during an emergency and includes:
    - a public or private hospital; or
    - a nursing home or similar facility for sick or disabled persons needing full-time care; or
    - a clinic, day surgery or procedure unit where the effects of the predominant treatment administered involve patients becoming non-ambulatory and requiring supervised medical care on the premises for some time after the treatment.
- Class 9c – a building of a public nature … an aged care building; aged care building means a building for residential accommodation of aged persons who, due to varying degrees of incapacity associated with the aging process, are provided with personal care services and 24 hour staff assistance to evacuate the building during an emergency;

6.10.1 Sprinkler provision

Under the BCA, the provision of a sprinkler system is determined by a building's use, height, fire hazard and size of the fire compartment. The following is a brief overview of the Deemed-to-Satisfy (DtS) provisions as they apply to the provision of sprinklers to residential care buildings:

- Class 3 and Class 9c buildings - DtS provisions provide concessions to fire-resistance levels of the structural elements if an automatic sprinkler system is installed. In Class 9c buildings a number of rooms can be located within a single compartment negating the need for fire doors;
- Class 3 buildings used for accommodation for the aged, children or people with disabilities require a sprinkler system when the building exceeds 25m in effective height (It should be noted that all classes of building over 25m require sprinklers);
- Class 9c aged care buildings require an automatic sprinkler system to be installed throughout the building and any fire compartment containing a Class 9c part should also be sprinklered in a building that contains other classifications.

Class 9c provisions arose from a study of aged care accommodation and the desire to design to allow 'aging in place'. Class 3 (hotels etc) and Class 9a (hospitals) were not really appropriate for aged care homes, and the code designs did not allow for the correct functionality and safety. Aged care premises in Australia are generally designed to Class 9c.

Class 9c uses smoke compartmentation (500m^2) and fire compartmentation (3,000m^2) along with sprinklers and fire separation of hazardous areas like kitchens, store rooms and laundries to give more flexible and functional layouts for aged care homes.

The recommendations within the BCA for Class 9c result from a study which was undertaken following a serious fire at Kew Cottages which resulted in nine fatalities (see Appendix A for further details).

6.11 Fire Safety Guidance Review

In reviewing the various guidance documents above it can be seen that England and Wales are among the few places where official fire safety design guidance does not recommend sprinklers within residential care premises.

The fire safety guidance documents for Scotland, USA, Hong Kong and Australia all recommend automatic fire suppression within residential care premises since it is recognised that sprinklers are effective in both reducing the number of fatalities and injuries

within buildings and reducing the extent of property damage and the subsequent business interruption. It should also be noted that sprinklers are required in new care homes in Canada and New Zealand, and in Finland in existing care homes following a risk assessment.

6.11.1 Consultation document to the 2006 edition of Approved Document B

The consultation document to the most recent edition of Approved Document (the proposed new edition of Approved Document B: *Fire Safety,* Volume 2: *Buildings Other than Dwellings*, A consultation document July 2005) included the following statement:

Whilst the ODPM is minded to introduce a provision for sprinklers in all residential care homes, this will be dependent on the final Regulatory Impact Assessment showing that it would be justified. Consultees' views on this matter and whether it should be applied to all homes, only new homes or just those designed with progressive horizontal evacuation are particularly sought.

It is therefore clear that the provision of residential sprinklers within residential care premises was considered but following the final Regulatory Impact Assessment residential sprinklers were not specifically recommended within the 2006 edition of Approved Document B although it did recognise the benefits of residential sprinklers by allowing a number of variations to the guidance (see 6.2.4).

The Regulatory Impact Assessment was based on the cost benefit study undertaken in the BRE Report *Effectiveness of sprinklers in residential premises* but even though this document concluded that residential sprinklers are probably cost effective for residential care premises the finally issued document did not include this recommendation. The findings and limitations of this review are discussed in Section 8.2, together with additional factors that may further support the case for installing sprinklers.

It should also be noted that the similar review in Scotland based on the same research concluded that sprinkler were cost effective.

7 Automatic fire suppression systems

7.1 Residential Sprinkler Systems

The Scottish Technical Handbook (non domestic) recommends the provision of automatic fire suppression systems within residential care premises (see Section 6.4). This resulted from a number of serious fires and the findings of the BRE report (see Section 8.2).

Approved Document B (2006 edition) also recognised the value of sprinklers by allowing a number of trade offs in terms of fire protection measures (see Section 6.1). Where these trade offs occur the sprinkler system should satisfy BS 9251: 2005 for a life safety system.

BS 9251: 2005 gives recommendations on the design and installation of fire sprinkler systems in residential and domestic occupancies. The intention of the document was to provide a more building-specific and cost-effective sprinkler solution for residential premises.

Residential care premises such as aged persons' homes, nursing homes and residential rehabilitation accommodation are considered to fall under the scope of this document.

7.1.1 BAFSA Technical Guidance Note Number 1

In 2008 BAFSA issued a Technical Guidance Note to BS 9251 [37] with the aim of providing clarification and guidance to BAFSA members on a number of clauses within the document that have given rise to different interpretations.

In this document it clarifies that BS 9251: 2005 is a Code of Practice and therefore the guidance within this document should be seen as a series of recommendations rather than specific requirements. However, where the sprinkler design deviates from the

recommendations of BS 9251 it is recommended that such deviations be brought to the attention of the authority having jurisdiction for approval.

Some of the clarifications are considered still to be appropriate in terms of residential care premises and these include:

- it was considered that if only one or two flats were sprinklered, and no corridors or common spaces, then domestic requirements (as opposed to residential requirements) would be appropriate. It is also recommended that if more than four flats are protected in a block, then the residential requirements should be met. Common areas should also follow residential requirements;
- rooms larger than 40m² can be protected by residential sprinklers;
- bathrooms, shower rooms and toilets less than 5m² can be provided with sprinklers;
- concealed sprinkler heads may be used for life safety purposes.

All of the above points should be agreed with the authority having jurisdiction.

8 Fire Safety Research on Residential Sprinklers

8.1 Sprinkler Effectiveness in Care Homes

In 2006, the Building Research Establishment Ltd (BRE), commissioned by the Office of the Deputy Prime Minister (ODPM), produced a report titled Sprinkler Effectiveness in Care Homes [8].

The research was undertaken under the ODPM Fire Safety Framework Agreement with the BRE and followed a review of fire statistics that indicated that a large number of fatalities in residential care premises were the result of occupants accidentally setting fire to nightclothes, bedclothes etc while they were in bed.

The main purpose of the report was to gather information on fires in residential care premises with regards to the life-safety benefits of sprinklers in the rooms of fire origin (in this case fires within the resident's bedrooms were investigated).

Other experimental data, examples and findings from similar research undertaken by third-party companies were also included in the report for reviewing purposes.

In order to examine the effectiveness of sprinkler installations in the room of origin, six different experimental fire tests were conducted which simulated conditions similar to those in a typical care home resident room.

A primary objective of these tests was to examine the severity (the amount of heat released) of a bed fire required to operate a sprinkler and to determine the likelihood of an occupant within a bed surviving such a fire. In addition to the fire conditions recorded for the bed of fire origin (temperature, concentration of toxic gases etc), each test also included information on the likely survivability of other persons within the room during a fire.

The main findings from the report were as follows:

- where sprinklers were provided in the room, in the case of a fire involving the bed it is very unlikely for a person in the bed not to receive fatal injuries or suffer from very serious injuries from the flames or heat;
- fire tests have shown that a sprinkler installation provides effective protection for the other people in the room of fire origin. This is based on the assumption that the sprinkler system will control the fire and effectively limit the amount of heat transfer and smoke production;

- in the case of a fire in a room without sprinklers the conditions within the room became untenable for both the person in the bed and occupants elsewhere in the bedroom;
- a smoke alarm installed within the room is likely to provide early warning of a fire and alert both the occupants of the room and staff members. A smoke alarm linked with the sprinkler system would allow early fire suppression, essentially resulting in relatively few injuries for all occupants in the room of fire origin (however this arrangement was deemed to be far more complex and expensive compared to a standard sprinkler system, and presents a risk of unnecessary water discharge as a result of a false alarm or very minor incident.

In reviewing the above findings it is considered that residential sprinklers provide significant benefit in terms of reducing the risk of fatalities. In the sprinkler protected room only the occupant in the bed which was ignited was considered to experience life threatening conditions with all other occupants within the room being able to survive since untenable conditions are unlikely prevail. The fact that untenable conditions are reached for the person in the bed is understandable since the person would be directly involved with the fire and would be in contact with heat and/or flames and smoke.

8.2 Effectiveness of Sprinkler Systems in Residential Premises

8.2.1 BRE/FRS Experimental Study

The Fire Research Station (FRS) of the BRE were commissioned to carry out a study on behalf of the Building Division of the Office of the Deputy Prime Minister (ODPM) into the effectiveness of sprinklers in residential premises.

Full details of the study and the key findings can be found in BRE Report No 2048505 *Effectiveness of sprinklers in residential premises* [38].

The purpose of the study was to ascertain whether or not sprinkler systems could provide an adequate fire control to allow escape/rescue at a reasonable cost.

The objectives of the study were:

- to analyse statistical information to determine how effective sprinklers had been in reducing life loss and property damage;
- to make a risk-based assessment to determine the potential benefits for the UK housing sector, including houses in multiple occupation (HMO), flats and maisonettes of varying heights;
- to collect data on the benefit and costs of residential sprinklers;
- to establish benchmark tests for UK conditions to support the further development of DD 251 and DD 252;
- to carry out an experimental programme to examine and quantify the effectiveness in fire suppression of residential sprinklers, in particular with regards to the room of fire origin.

The experimental study, among other research activities, comprised 8 simulated domestic dwelling lounge fires and 29 compartment fires. The effectiveness of sprinklers was assessed by the ability to control toxicity, temperature and visibility.

The overall findings of the research included the following:

- for the majority of fires, a sprinkler installation proved effective, possibly reducing casualties in the room of origin;
- sprinkler protection were not particularly effective for slow developing and shielded fires;

- smoke alarms installed in the fire test rooms responded in approximately half the time required by the sprinklers and well before conditions become untenable;
- residential sprinkler installation is probably cost effective for residential care premises (Section 8.2.2 below discusses the cost benefit analysis in more detail).

The purpose of the experimental programme within BRE Report 204505 was to examine and quantify the effectiveness of residential sprinklers particularly in relation to life safety in the room of fire origin. Following on from the issue of the final report a large amount of attention has been focussed on the results of the shielded fire tests and in particular the finding that conditions became unsurvivable in both the sprinklered and unsprinklered fires.

The table fire tests (Tests 11-12, 14, 16-17, 22-24) are considered to represent a true 'worst case' due to the shielding of the developing fire, which prevented effective sprinkler operation. While this arrangement is unlikely to occur in practice, even in this extreme scenario sprinklers could be expected to provide benefit in terms of reducing the likelihood of fire spread to other parts of the room since once the fire breaks out beyond the shielding (assuming sufficient fuel load exists) it is likely that the sprinklers would control the fire and prevent it spreading. It was also considered that the sprinklers would provide benefit in reducing the risk that flashover conditions would develop within the room of origin. Hence, even in that simulation, it was considered that there would a safety benefit associated with the provision of sprinklers.

A more detailed review of the experimental study is provided in Appendix C.

8.2.2 Cost benefit Study

Section 6 of BRE Research report 204505 undertook a cost benefit analysis of the expected impact of residential sprinklers to determine whether there was a cost benefit in providing them for a range of residential type buildings, one of which was residential care premises. This BRE cost benefit analysis utilised a statistical value for each life saved of £1,243,000 and a statistical value of each injury prevented of £58,300.

The above values for lives saved and injuries prevented is based on the figure utilised by the Department of Transport for the basis of its cost/benefit assessments on the investment required to prevent road crash fatalities. The same approach has been used in making Regulatory Impact Assessments for the DCLG (Department for Communities and Local Government).

The applicability of this figure as the basis of the assessment in this case is open to debate since the risks associated with building safety are very different from that of road safety. Indeed there have been a number of cost benefit studies that have been undertaken based on Willingness to Pay that have a range of very different values.

The assessment considered the following factors in its cost benefit analysis:

Factors considered	
Costs	**Benefits**
Installation	Lives saved
Water supplies	Injuries prevented
Maintenance and testing	Property loss savings

Table 8: Factors considered as part of cost benefit analysis of sprinkler installation

The following factors do not appear to have been considered as part of the BRE/FRS assessment as the data was considered to either be unavailable or too hard to quantify with any accuracy:

Factors not considered	
Costs	**Benefits**
Accidental water discharge	Environmental impact reduction
	Insurance premium reductions
	Fire brigade cost savings
	Design/construction trade offs

Table 9: Factors not considered as part of cost benefit analysis

In assessing the factors in Table 6 the cost benefit study concluded that sprinklers would probably be cost effective in residential care premises. This study was utilised as part of the Regulatory Impact Assessment both in England and Wales and in Scotland. However the final results in the published fire safety guidance were different between England/Wales and Scotland. While Scotland considered residential sprinklers to be cost beneficial in residential care premises and included the recommendation for residential sprinklers in residential care premises, this was not the case in England and Wales and there was no similar recommendation within Approved Document B.

8.2.3 Factors not considered in the study

The decision not to recommend sprinklers within residential care premises has been questioned by many in the fire safety community, especially when the conclusion of the BRE study was that sprinklers would probably be cost effective in residential care premises.

The conclusion that sprinklers would probably be cost effective in residential care premises was made even though the factors within Table 7 were not considered. The following sections discuss these additional factors and while not providing any specific monetary values aim to provide a greater understanding in terms of the cost and benefits that residential sprinklers may bring.

8.2.3.1 Cost – Accidental water discharge

The concept here is that the sprinkler system is prone to unwanted activation leading to water damage. Such activation may be caused by accidental or malicious breaking of a sprinkler head or by the leaking of the water supply system. Statistics establish that the likelihood of a sprinkler head operating spuriously is 1 in 500,000 (Source: Loss Prevention Council). The accidental operation due to mechanical damage is statistically low and can be mitigated against by the provision of sprinkler head guards (or concealed heads) in those areas where heads may be exposed to potential damage.

Therefore the additional cost associated with accidental water discharge is considered to be negligible.

8.2.3.2 Benefit – Environmental impact reduction

The provision of sprinklers may not only provide benefits it terms of life safety and the protection of property but may also be used to mitigate the impact the building has in relation to environmental issues either limiting the combustion products that enter the environment by controlling/extinguishing the fire but also by rationalising the passive fire protection measures. This may include;

- reducing the extent of fire resisting partitions and walls and the embodied energy within those materials;
- removing the need to move residents to temporary and permanent accommodation by preventing large destructive fires;
- reducing the extent of refurbishment and repair to buildings post fire;
- reducing the extent of fire resisting glazing;
- facilitating the use of existing buildings;
- reducing the exposure to harmful materials and substances that may be released in large fires;
- reduced risk of polluting ground, air and water courses.

8.2.3.3 Benefit – Improved insurability

The provision of sprinklers within residential care premises will reduce the risk of loss or damage to the contents and fabric of the building by controlling the growth of the fire. The improvement in the level of insurability of sprinkler-protected premises compared to a similar but unsprinklered building is a benefit which can help fund the sprinkler installation.

8.2.3.4 Benefit - Fire brigade cost savings

Fire brigade cost savings are difficult to quantify in terms of the benefits that sprinklers would bring. However it is considered that sprinklers in residential care premises could provide the following benefits:

- a reduced number of fire service pumps could be sent to an incident;
- upon attendance of the fire service the attendance period may be reduced as the fire service would be able to deal with a smaller fire more quickly;
- in the event of small fires the fire may be extinguished by the time the fire service has responded to the call;

8.2.3.5 Benefit - Design and construction trade offs

The potential for providing alternative solutions through the use of sprinklers is considered to be a key factor in determining whether or not the provision of sprinklers within residential care premises are cost effective and it is considered that these should have been accounted for in the decision made by the Regulatory Impact Assessment.

Residential sprinklers may be utilised to achieve significant cost savings in other areas while still maintaining an appropriate degree of fire safety. In accordance with the recommendations of Approved Document B and BS 9999 (refer to Sections 6.1 and 6.3) for new buildings and the guidance within FSRA (refer to Section 6.2) for existing buildings there are a number ‘trade offs’ that are allowed within the recommendations of these documents when residential sprinklers are being considered for residential care premises.

In addition to the trade offs recommended in the fire safety guidance documents there may be a number of additional trade offs that may or may not be appropriate depending on the details of the proposed design.

Table 8 presents a summary of the fire protection options available with and without sprinklers for a 3 storey residential care home in England with a floor-to-floor height of approximately 3m (i.e. the finished floor level of the uppermost floor is approximately 6m).

Recommendations without sprinklers	*Recommendations with sprinklers*
Bedrooms should have no more than one bed	Rooms are permitted to have more than one bed
Protected areas should have a maximum of 10 bedrooms	Protected areas may have more than 10 bedrooms
Free swing door closers to be used on bedroom doors, with circulation routes also provided with door closers	Bedroom doors need not be provided with door closing devices
Bedrooms should not contain more than one bed (this includes a double bed)	Bedrooms may contain more than one bed
Additional areas where sprinklers can be utilised as part of the justification for the rationalisation of fire safety measures	
L1 alarm and detection system	Possible rationalisation to an L2 system
60 minute period of structural fire resistance	Possible rationalisation to 30 minutes
Travel distances limited to those in Table 2 of AD B	Potential extension of travel distances

Table 10: Potential alternative solutions using residential sprinklers

The trade offs that are not within the prescriptive fire safety guidance would need approval from the approval authorities and it is therefore advisable to consult a fire engineer/consultant if an alternative approach is to be adopted.

The BRE study concluded that sprinklers were probably cost effective in residential care premises even without the above factors being considered. In reviewing the additional factors it is considered that the case for automatic fire suppression is even stronger.

8.2.4 Case study – Residential care premises in Dinnington and Rawmarsh

The following residential care premises owned and operated by Rotherham Metropolitan Borough Council further demonstrates the benefits that residential sprinklers can bring to a building design. The building has 90 residents and was handed over in October 2008 (see Figure 4).

Figure 4: Residential care premises in Dinnington and Rawmarsh, Rotherham

The building was provided with a residential sprinkler system in accordance with the recommendations of BS 9251, the presence of which led to the following departures from the recommendations of Approved Document B:

- extended travel distances within the building;
- flats opening onto balconies that overlook atria;
- firefighting access for a vehicle exceeded 45m from all points within the flats meaning there was no requirements for dry rising fire mains in the building;
- inlet breeching was installed as a secondary supply to a mains-fed water supply.

8.3 NHBC Foundation Study into Open Flat Layouts

The NHBC study [39] recently undertook a study into open plan flat layouts and assessing life safety in the event of a fire. One of the main conclusions of the study was that the provision of a residential sprinkler system in connection with increased detection (LD1) provides a level of protection that is at least as good as the equivalent AD B compliant case where the building is less than 30m (an apartment with a protected entrance hall.

Although the study was aimed at residential flats rather than residential care premises it does show the benefits that sprinklers can bring in improving the level of safety to residential occupants when they are considered as part of an overall package of fire protection measures.

9 Quantifying the Impact of Sprinklers

In order to gain a better understanding of the benefits that automatic fire suppression would provide in terms of the conditions within a typical residential care building, a fire and smoke modelling study was undertaken. This assessed the likely conditions in terms of visibility and smoke temperature for both a sprinkler-controlled fire and an unsprinklered fire.

The overall aim of the fire and smoke modelling was to undertake a quantified comparative assessment to evaluate the level of protection provided to escaping occupants within a typical residential care premises for the following cases:

- residential care premises without sprinklers;
- residential care premises with sprinklers (controlled fire);
- residential care premises with sprinklers (extinguished fire).

In the three cases the conditions within the room of fire origin, the corridor, the stair and the adjacent bedrooms were assessed.

The fire and smoke modelling was undertaken using the Fire Dynamic Simulator developed by NIST (National Institute of Standards and Technology). Full details of the assessment are provided in Appendix B.

Images from the models are shown in Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9.

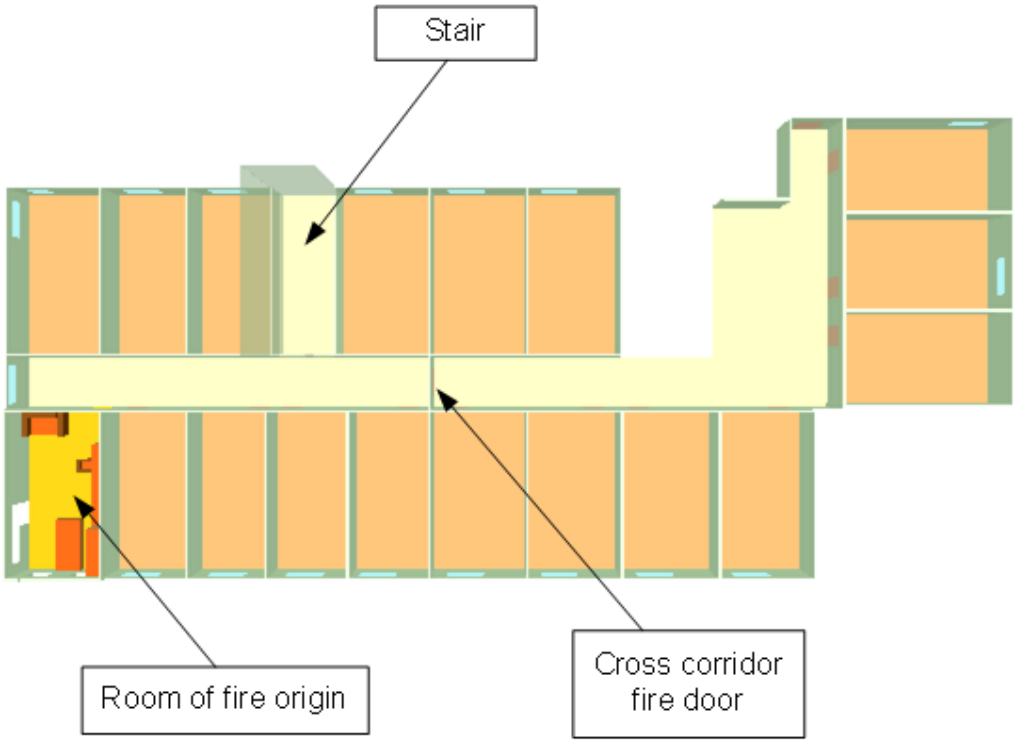

Figure 5: General layout of the model (for both sprinklered and unsprinklered cases

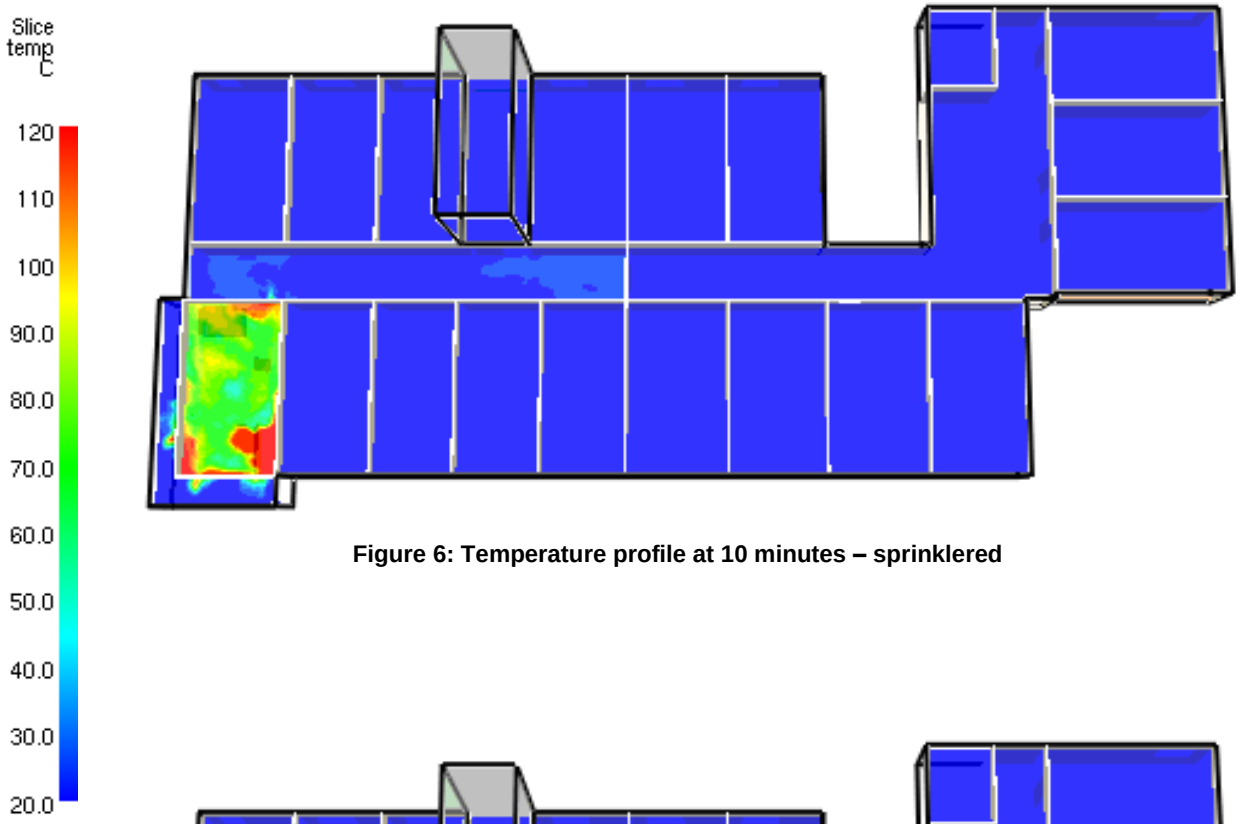

Figure 6: Temperature profile at 10 minutes – sprinklered

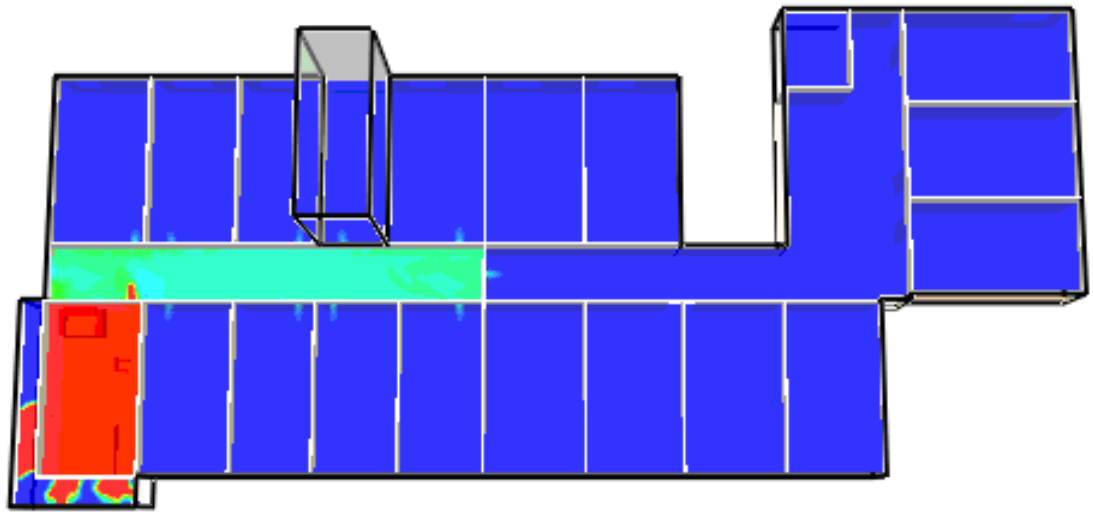

Figure 7: Temperature profile at 10 minutes – unsprinklered

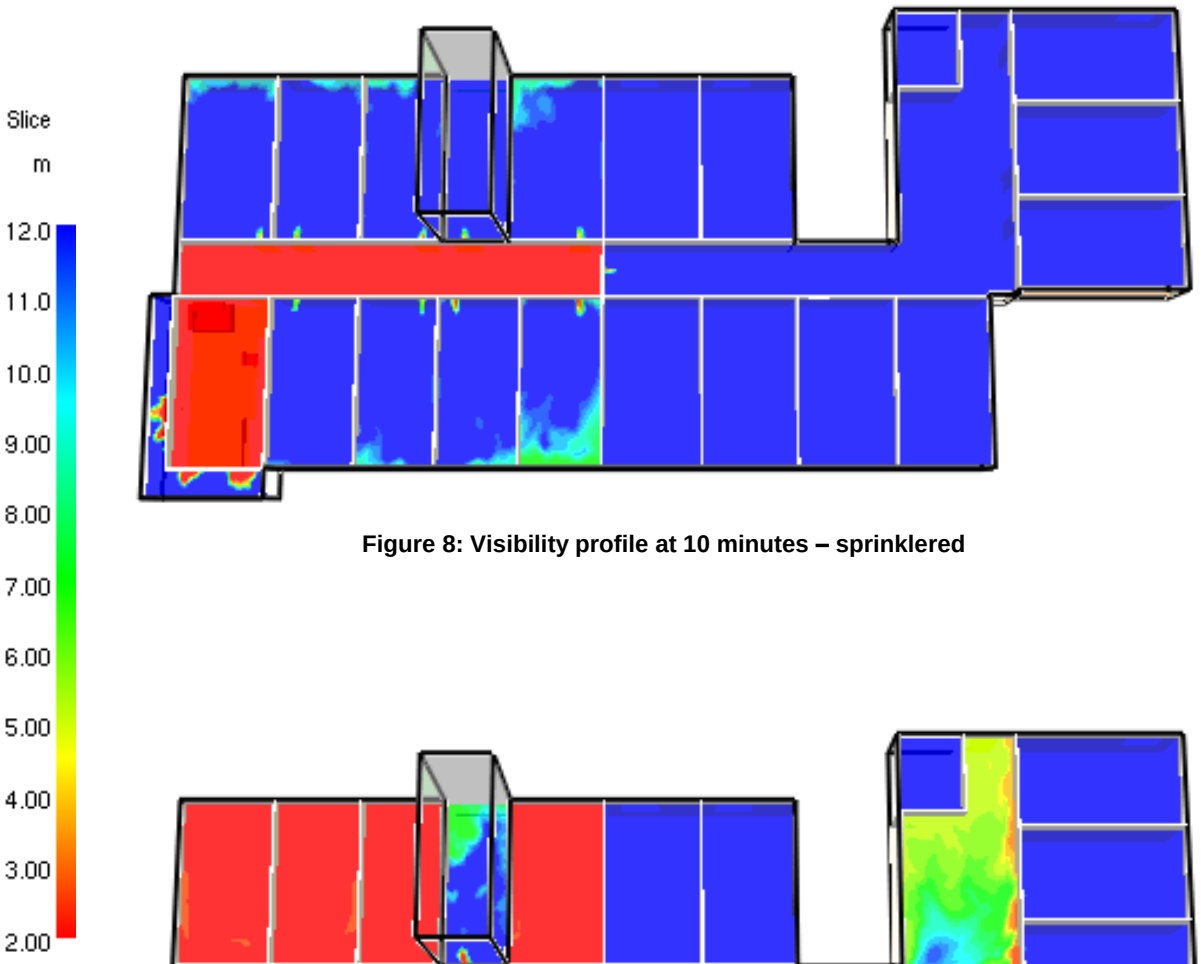

Figure 8: Visibility profile at 10 minutes – sprinklered

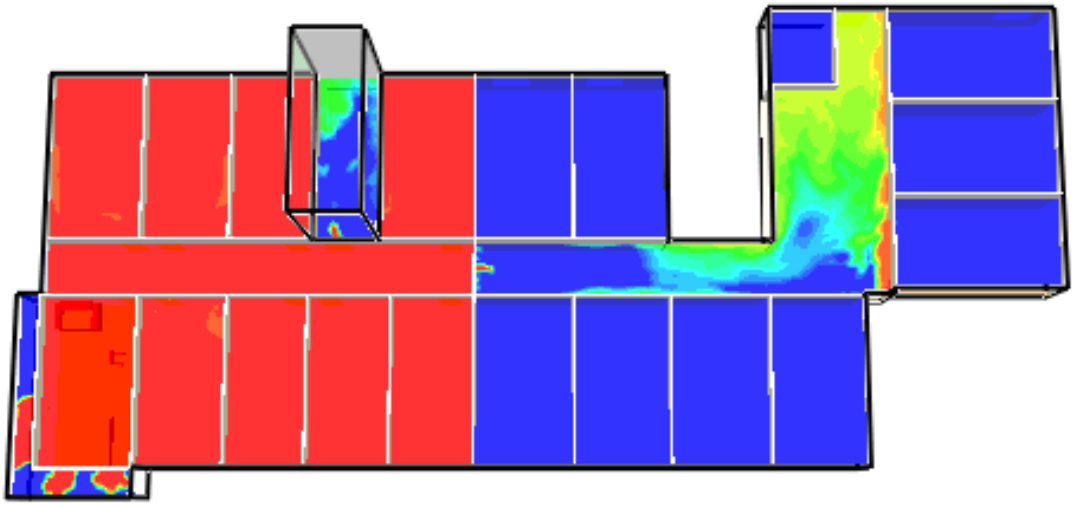

Figure 9: Visibility profile at 10 minutes – unsprinklered

9.1 Fire and Smoke Modelling Conclusions

The sprinklered case was found to have lowered temperatures within the corridors and all rooms beyond the room of origin to within life tenable levels. It was also found to provide tenable conditions in terms of visibility within all of the adjacent rooms within the fire compartment and in the adjacent compartments. This compared favourably to the non-sprinklered case, in which conditions within the corridor and nearby bedrooms were significantly worse.

Based on the study it is considered that sprinklers provide significant benefit in terms of the likely conditions that would be present in the event of a fire, particularly outside of the room of fire origin.

10 Other options/considerations

10.1 Design considerations

The following options are not intended to provide specific recommendations for the design of residential care premises but rather indicate a number of different alternative solutions that may be considered in developing a design to ensure that an informed decision can be made. These will need to be considered on a case-by-case basis and should be discussed with all relevant parties to ensure the proposed designs are fit for purpose.

10.1.1 Compartmentation between rooms

Approved Document B recommends that the common corridor serving the bedrooms/apartments be a protected corridor (the enclosure of the corridor is of at least 30 minutes fire-resisting construction with 30 minute fire doors). In addition, where progressive horizontal evacuation is adopted the rooms themselves should be enclosed in fire-resisting construction.

In increasing the level of fire resistance between adjacent rooms and between the rooms and the bedrooms; the risk of fire and smoke breaking out of the rooms would be reduced.

10.1.2 Ventilation to corridors

Residential apartment buildings (Purpose group 1a in Approved Document B) within the UK adopt a strategy whereby simultaneous evacuation of the building is unlikely to be necessary and in the event of a fire only the occupants within the flat 'on fire' would evacuate initially with remaining occupants of the building being relatively safe within their flat.

This is considered to be acceptable due to the high level of fire-resisting compartmentation and therefore the low probability of fire spread beyond the flat of origin.

In order to reduce the likelihood that conditions in the common corridor would be compromised due to smoke; Approved Document B recommends that ventilation be provided to common corridors. Where two directions of escape are available this is simply done by providing a cross-corridor fire-resisting door between the two storey exits to prevent a fire in an apartment affecting both sections of corridor. In addition to the subdivision of the corridor, manually openable vents should be provided within the corridor to assist the fire service during their operations.

Where escape is only possible in a single direction within a corridor then the corridor should be provided with automatic opening vents which would be linked to smoke detection within the corridor. The purpose of this is to vent smoke that may enter the corridor and to protect the escape stairs within the building.

In developing the fire protection measures for residential care premises it may be worthwhile considering a similar approach to improve the conditions within the escape routes.

10.1.3 Subdivision of corridors

In following a progressive horizontal evacuation strategy then the maximum number of bedrooms recommended in a single compartment is 10 bedrooms in accordance with Approved Document B. Where a large number of residents require assistance to evacuate then the provision of additional cross-corridor doors would reduce the number of bedrooms/apartments within a single compartment and subsequently the number of residents in the compartment of 'fire origin'. Once outside the fire compartment occupants should be in a place of relative safety assuming that the fire-resisting construction performs as intended and therefore the urgency to evacuate these occupants should be reduced.

10.1.4 Evacuation lifts

Evacuation out of the building will be required in both simultaneous evacuation and progressive horizontal evacuation strategies if the fire is deemed to be serious enough to warrant this. The benefit of progressive horizontal evacuation is that occupants can be

moved through a compartment line where they are considered to be in a place of relative safety and thus the time pressure to evacuate these residents is reduced. However in multi-storey buildings, if a fire continues to develop, it may become necessary to evacuate people down stairs.

Evacuation lifts may provide an alternative solution and ease the difficulty of evacuating persons via the stairs through carry down procedures. The benefit is that it would require fewer staff (only a single trained member of staff would be needed to operate the lift whereas carry down procedures usually require at least three persons).

Section G.2 of BS 9999 provides guidance on the design of evacuation lifts.

10.1.5 Refuges designed into the buildings

The general guidance within Approved Document B for non domestic buildings is that a refuge space should be provided for each protected stair affording egress from each storey. This need not necessarily be within the stair enclosure itself but should enable direct access to the stair.

This may be an enclosure such as a compartment, protected lobby, protected corridor or a protected stair. In designing residential care premises the designer should be mindful that there is likely to be a higher proportion of wheelchair users in these types of buildings and the need to provide suitable refuge points that cater for the end user should be considered. It may be that specific rooms located near to the stair together with compartmentation associated with a progressive horizontal strategy could provide a suitable solution.

10.1.6 Water mist suppression

Water mist systems are similar to sprinkler systems in that they have a water supply, a distribution network, a means of detecting the fire and a mechanism for discharging the water (mist in the case of water mist systems and spray in the case of sprinkler systems).

Water mist systems have been adopted in a number of residential care premises in the UK as an alternative to sprinklers. At present there are no British or European standards for water mist systems within residential buildings and there are concerns that the differing designs of some of the systems and whether or not some of the domestic systems will perform as intended in a fire situation.

It is likely that with the appearance of authoritative standards, approved equipment and components together with further development and independent testing, water mist systems could provide a suitable alternative form of automatic fire suppression in residential care premises. At the time of writing the British Standards committee FSH18/2 responsible for fixed fire suppression systems have invited one of the most active UK water mist companies to draft a standard for the design and installation of water mist systems in dwellings. Any draft for development and eventual British Standard will, however, have to demonstrate that such water mist systems will provide and equivalent level of protection to a BS9251 sprinkler system.

At the time of writing both BS DD8489 Water mist fire suppression systems for industrial and commercial premises [40] and BS DD8458 Water mist fire suppression systems for residential and domestic occupancies [41] have been submitted to the BSi group for initial review. Until a new British Standard is issued, care should be taken in the specification of water mist systems for residential care premises. Where such systems are used as a form of alternative compliance in respect of the measures recommended in Approved Document B (or the Scottish Technical Handbooks)), care should be taken to ensure the system is capable of achieving the required level of protection.

10.2 Management Considerations

The following sections are intended to provide specific recommendations for the management of residential care premises and measures that could be put in place to reduce the risk of fire in their premises.

10.2.1 Fire safety management

The relevant management personnel need to manage fire safety in the same way as they manage other health and safety issues, by implementing the policies agreed and monitoring those policies to ensure they are carried out effectively.

Under the Regulatory Reform (Fire Safety) Order 2005 (see section 6.2) it is the 'responsible persons' duty to undertake a fire risk assessment to ensure that the risks within their premises are as low as reasonably practical.

The main duties of the fire safety management will be to:

- carry out hazard and risk assessments with particular reference to the most vulnerable residents;
- be responsible for fire safety training;
- produce an emergency plan and put up fire safety notices;
- conduct fire evacuation drills;
- check the adequacy of fire fighting apparatus and its maintenance;
- consult with and implement recommendations of the local fire brigade;
- conduct fire safety inspections, preferably every month;
- make interim informal checks to confirm that the fire safety rules (determined by the fire risk assessment) are being followed;
- ensure fire escape routes and fire exit doors/passageways are unobstructed and doors operate correctly;
- check that fire detection and protection systems are inspected, maintained and tested and keep records of such work;

10.2.2 Maintenance

All fire protection measures within a premises should be maintained to ensure that they are in good working order and are fit for purpose. It is recommended that all fire protection installations and equipment be serviced in line with the manufacturer's recommendation and the relevant British Standards but as a minimum they should be serviced annually.

10.2.3 Portable Appliance Testing

Portable Appliance Testing (PAT) testing can reduce the risk of fires from electrical appliances by ensuring that they are properly maintained. It is recognised that controls on portable appliances used by residents cannot always be achieved (for example CD players brought in as gifts etc.). However, by adopting an ongoing testing programme (annually) the risk of untested appliances is reduced.

10.2.4 Personal Evacuation Plan

The residents within the residential care premise will all have differing levels of ability and therefore it important to address these needs. A personal evacuation plan would allow the management/staff of the residential care premise to identify the needs of the residents in the event of a fire and put measures in place whereby an efficient evacuation process can ensue.

10.2.5 Arson Prevention

The Fire Safety Risk Assessment Document produced by HM Government for Residential Care Premises states '*Recent studies indicate that, over 2,100 serious deliberately set fires,*

resulting in two deaths and 55 injuries, occur every week". While this figure relates to all building types and not just residential care premises it clearly represents a significant risk particularly with regards to residential care premises and the risks associated with these types of premises. Automatic fire suppression would provide significant benefit in this regard in that the fire should be controlled by the systems, particularly if the fire is located within the protected escape route. Management should consider a number of arson prevention measures:

- Deter unauthorised entry onto the site or into the building;
- Coats, papers and other combustibles should not be kept in corridors or escape routes;
- Stores containing waste or chemicals in or around the building should be kept clean and locked;
- Bins should be stored away from buildings;
- All fires, no matter how small, should be reported to the fire brigade;
- Make sure automatic fire detection systems are fitted and are operational;
- Check that smoke detectors have batteries that are working;
- Ensure that fire escapes are clear and there is no evidence of hidden or small fires on a daily basis.

11 Conclusions

The foregoing report has reviewed the risks associated with residential care premises within the UK and has considered the impact that a fire can have on the residents, the building fabric, staff and resident's family. It identifies the need to provide appropriate fire protection measures within these types of premises that suitably reduce the perceived risks.

A review has been undertaken of the guidance within current fire safety documents in the UK and the research that was undertaken to support the development of these documents. The guidance has also been compared against a selection of international fire safety guidance that exists to determine international best practice and to determine whether or not the current fire safety recommendations within the UK would be sufficient to address the risks associated with these types of premises.

The review of automatic fire suppression systems undertaken concludes that they are effective in controlling a fire and will provide improved conditions to the residents of the building, particularly beyond the room of fire origin.

The following points present the key findings of this report:

- residential care premises present unique challenges in relation to fire safety, largely due to the increased assistance often required by residents to escape. Current fire safety guidance in England and Wales does not address this fully;
- where residents require assistance it is likely that the evacuation process will take longer and sprinklers provide significant benefits to address this risk;
- England and Wales are among the few countries where the fire safety design guidance does not recommend automatic fire suppression in residential care premises. The fire safety guidance documents for Scotland, USA, Hong Kong and Australia all recommend automatic fire suppression and recognises the benefits in terms of life safety and property protection;
- research undertaken in the USA concludes that sprinklers are considered to be the single most effective fire protection feature and it notes that there has never been a multiple death fire in a fully sprinklered nursing home fire;

- fire and smoke modelling was undertaken and showed that the temperatures within the corridors and all rooms beyond the room of fire origin remained life tenable and the visibility in all rooms beyond the room of fire origin also remained tenable, where sprinklers are provided. This was clearly not the case where they were not provided. It is therefore considered that automatic fire suppression would provide significant benefit, particularly beyond the room of fire origin;
- if fire suppression systems are provided in a residential care premises, they can assist in reducing the risks from fire, particular if other fire safety measures (for example, passive fire protection) fail to act as intended;
- the adoption of an automatic fire suppression system within the building is considered a cost effective means of providing an adequate level of safety and can be used to compensate for other areas of the design when all relevant factors are considered;

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Appendix A

Fire Incidents

The following Appendix provides details of fire incidents that have occurred within residential care premises both in the UK and internationally. The details are taken from both fire incident reports and press reports.

A1.1 Fire incidents in the UK

A1.1.1 Rosepark Nursing Home, Uddingston

The Rosepark Nursing Home provided accommodation for 40 residents at the time of the fire which occurred on 31 January 2004. Fourteen residents died as a result of a fire which started in an electrical cupboard. Most deaths were linked to the large amount of smoke produced, which killed people relatively remote from the fire due to a number of fire doors being left open.

The building was not provided with sprinklers. An investigation is currently under way.

Source: The Independent, "11 pensioners dead as fire sweeps care home", Saturday, 31 January 2004

The Observer, "Care home fire leaves Scotland in mourning", Sunday, 1February 2004

A1.1.2 Old Refectory Care Home, Gumfreston

The Old Refectory Home in Gumfreston, Pembrokeshire, provides accommodation for 19 residents in a large Victorian house.

On 1 February 2004 there was a fire in the early hours of the morning to which the fire and rescue service was called.

Two residents died following the fire; one at the scene and the other shortly after in hospital. Two others were treated for smoke inhalation.

The owners pleaded guilty to four breaches of the care standards which were related to staffing issues and fire procedures and were fined £5,500 and £1,500 in costs.

The cause of the fire was believed to be an electrical fault in a first floor distribution cupboard. Sprinklers are not thought to have been provided in the building.

Source: http://news.bbc.co.uk/1/hi/wales/4103231.stm

A1.1.3 Paxton Hall, Cambridgeshire

Paxton Hall in Little Paxton, Cambridgeshire, was a residential care home which was built in the Georgian period. It provided accommodation for approximately 30 residents and employed 10 carers. The fire occurred on Monday, 23 February 2004. Two female occupants died and three were taken to hospital with symptoms of smoke inhalation. The cause of the fire was not established but it was thought to have been contained to the room of fire origin, with extensive smoke damage occurring outside of the room of fire origin.

It is unknown whether automatic fire suppression was provided to this building at the time of the fire.

Source: http://news.bbc.co.uk/1/hi/england/cambridgeshire/3515813.stm

A1.1.4 Unnamed Care Home, Llanedeyrn, Wales

Firefighters were called out to the fire at 23:00 on 8 April 2004. The firefighters evacuated an 81 year old man who later died in hospital. It is believed that the individual was rescued from the home's smoking room, indicating the cause of the fire may have been due to a resident falling asleep while smoking.

The rest of the building was not evacuated; the occupants of the fire affected zone were relocated to adjacent safe zones in accordance with the evacuation plan.

It is unknown whether the building was provided with sprinklers; however in response to a question the care home owner said they have 'the latest fire detection systems and staff are fully trained in fire procedures'.

Source: http://news.bbc.co.uk/1/hi/wales/south_east/3613621.stm

A1.1.5 St David's Nursing Home, Redcar

This care home provided accommodation for up to 55 residents. An automatic alarm sounded at just after 05:00 on 20 August 2004 and triggered an evacuation of 40 residents. One of the residents was taken to hospital and died later.

The fire spread from an accommodation area into a roof space. A subsequent investigation revealed that the compartmentation in the building was 'faulty' and had penetrations which promoted the spread of fire. It was also found that the fire barriers were not taken to the underside of the roof as per the Building Regulations recommendations in Approved Document B.

Automatic fire suppression was not provided to this building.

Source: http://news.bbc.co.uk/1/hi/england/tees/3586134.stm

A1.1.6 Tegfan Care Home, Ammanford

The Tegfan residential care home in Ammanford, Wales provides accommodation for up to 49 residents.

The fire and rescue service was called out at 01:30 on Saturday, 2 April 2005 and assisted in evacuating all occupants. No deaths or serious injuries were caused.

No automatic fire suppression was provided. The cause of the fire was stated as 'unknown'.

Source: http://news.bbc.co.uk/1/hi/wales/4403349.stm

A1.1.7 Westlands Care Home, Cookstown

The Westlands Home provides accommodation for approximately 30 residents. At 01:45 on Friday, 26 August 2005 a fire broke out in the rear yard of the building. An investigation revealed the fire was maliciously started by igniting two propane gas bottles. The fire spread inside and involved two rooms. Occupants were evacuated safely to adjacent accommodation. It is understood that automatic fire suppression was not provided within this building.

Source: http://news.bbc.co.uk/1/hi/northern_ireland/4186414.stm

A1.1.8 Arson by carer, Victoria Mews Nursing Home, West Midlands

Victoria Mews is a care home providing accommodation for 30 residents, all in ground floor ensuite single rooms of a modern building.

The fire on 9 July 2006 occurred as a result of an act of arson by a carer who deliberately ignited the bed-sheets of a resident in a successful attempt to kill her. The carer then also tried to set another fire in the bin of another resident which did not take hold but produced a significant amount of smoke.

The fire service was called by the arsonist and they rescued the victim but she later died in hospital. The fire did not spread to involve other parts of the building and it is understood that automatic fire suppression was not provided in the building.

Source:
http://news.bbc.co.uk/1/hi/england/coventry_warwickshire/6978317.stm

A1.1.9 Shannon Court, Bolton, Greater Manchester

A fire occurred in the evening of 9th October 2006 in which a 29-year-old man suffered serious burns and was taken to Wythenshawe Hospital.

A further 3 elderly residents of the care home needed treatment for the effects of smoke inhalation and a small number of residents were also moved to a new wing of the home until the fire was brought under control.

The fire was caused by an arson attack.

Source: http://news.bbc.co.uk/1/hi/england/manchester/6036229.stm

A1.1.10 Unnamed Nursing Home, Bournemouth

The fire occurred in one of the bedrooms and the occupants of the home had to be evacuated by the emergency services. No deaths occurred in this nursing home fire which happened on 11 November 2006.

Automatic fire suppression was not provided to this building.

http://news.bbc.co.uk/1/hi/england/dorset/6141334.stm

A1.1.11 Priory Grange, Potters Bar

The Hadley Unit of the Priory Grange Residential Care home provides accommodation for up to 70 residents in a specialist facility built in a refurbished period building.

A fire occurred on 22 November 2006 in which a male resident perished. Seventy other occupants were evacuated safely and 24 of these were taken to hospital for smoke inhalation symptoms.

The fire started in a 4th floor apartment and the fire was brought under control within an hour of calling the fire brigade. The cause of the fire was not identified and the building did not have sprinklers.

Source:
http://news.bbc.co.uk/1/hi/england/beds/bucks/herts/6173270.stm

A1.1.12 Unnamed Care Home. Shepton Mallet

A fire occurred in this residential care home on 24 November 2006. The cause was identified as a faulty oil filled radiator. The building was provided with sprinklers and on arrival the fire brigade noted that they had activated and had managed to contain the fire to the room of origin. No one was injured during the fire.

Source: National Fire Sprinkler Network

A1.1.13 Reverend Bill Baker Court, Sutton-on-Sea

This complex of 36 one and two bedroom flats suffered a fire on 21 April 2007. Eight people required the assistance of fire brigade personnel to evacuate with one person requiring hospital treatment for smoke inhalation.

The cause of the fire was identified as one of the charging units for the mobility scooters. Direct fire damage was caused to three scooters, the charging room, dining room and the foyer. Smoke damage was identified in 14 other rooms. Residents were unable to return to the home for over a week.

Automatic fire suppression was not provided to this building.

Source: http://news.bbc.co.uk/1/hi/england/lincolnshire/6581027.stm

A1.1.14 Douglas View Care Centre, Lanarkshire

The Douglas View Care Centre provides residential care for approximately 100 people in a modern purpose built two storey complex; 15 staff are employed at the centre.

On 2 May 2007 a fire occurred in the early hours, trapping in their rooms a large number of residents who had to be rescued by emergency service personnel. The cause of the fire is unknown but it is understood the fire spread from the room of fire origin. No deaths occurred in this incident.

It is understood that automatic fire suppression was not provided.

Source:
http://news.bbc.co.uk/1/hi/scotland/glasgow_and_west/6615201.stm

A1.1.15 Unnamed care Home, Strathclyde

A fire occurred on 11 August 2007 at 18:01 at a residential care home for elderly persons. The fire involved an electrical appliance and the staff did not actuate the alarm or attempt to fight the fire. Sprinklers were provided and a single sprinkler head operated controlling the fire leaving only minor damage to the room of fire origin. The provision of care was uninterrupted (see Figure).

Source: Strathclyde Fire & Rescue Service

A1.1.16 Allingham Court, Surrey

The Allingham Court care complex provided accommodation to over 50 residents in flat and bungalow buildings; the majority of them being housed in the main 3 storey building.

On 11 September 2007 a fire occurred which required the attendance of approximately 40 firefighters.

The cause of the fire was unknown but was thought to have started in one of the resident's rooms. The fire spread to involve a number of other rooms and the extensive ceiling void. The affected part of the building then remained unoccupied for a significant period of time. Automatic fire suppression was not provided in this building.

Source: http://news.bbc.co.uk/1/hi/england/surrey/6990164.stm

A1.1.17 Old Rectory Residential Home for the Elderly, Acle

The Old Rectory was home to approximately 33 residents who had to be evacuated during a fire on 17 November 2007. Six of these had to be treated at hospital for smoke inhalation. The building was uninhabitable following the fire and alternative arrangements had to be made for all residents.

Fire damage was limited to a relatively small area while smoke damage was extensive.

Automatic fire suppression was not provided and the cause is unknown.

Source: http://news.bbc.co.uk/1/hi/england/norfolk/7100510.stm

A1.1.18 Bearehill Home, Brechin, Angus

The Bearehill Home is situated in a part historic and part new-build facility. The home accommodates approximately 53 residents with a range of needs.

On 31 January 2008 in the afternoon a fire broke out, and the fire service was called; on arrival fire fighters found that the fire had spread to involve timbers underneath the external guttering and outside of the first floor.

After the event the fire service had praised the effectiveness of the staff in evacuating the residents. Automatic fire suppression was not provided in the building.

Source:
http://news.bbc.co.uk/1/hi/scotland/tayside_and_central/7220742.stm

A1.1.19 Manor Gardens, Gateshead

This residential care home provides accommodation for up to 40 residents in self contained flats.

A fire occurred on 23 May 2008 to which the fire brigade was called. A number of residents were rescued and taken to hospital, one of whom died from her injuries.

It is thought the premised was not provided with sprinklers. The cause is unknown.

Source: http://news.bbc.co.uk/1/hi/england/tyne/7418562.stm

A1.1.20 The Hockeridge, Westgate-on-Sea

The Hockeridge is a three storey residential care home in Margate providing accommodation for 26 residents; one of whom perished in a fire which occurred at around 23:00 on Sunday, 6 July 2008.

The rest of the residents were evacuated safely. The fire brigade fought the fire for a number of hours before it was brought under control; it caused severe damage.

Automatic fire suppression was not provided in this building.

Source: http://news.bbc.co.uk/1/hi/england/kent/7492860.stm

A1.1.21 Kalyran Ashran Home, Birmingham

The Kalyran Ashran home provides sheltered accommodation for South Asian people over the age of 65. The building consists of approximately 20 single and 4 double ensuite rooms situated in a converted church building.

On Tuesday, 5 August 2008 a fire broke out in a first floor flat which required the intervention of firefighting personnel to evacuate 5 people. It was reported that the fire was contained within the room of fire origin but a significant portion of the first floor had become smoke logged. One resident was treated for smoke inhalation.

The building was not provided with sprinklers.

Source: http://news.bbc.co.uk/1/hi/england/west_midlands/7545180.stm

A1.1.22 Clayton Manor Care Home, Congleton, Cheshire

A care assistant set fire to the bed of an elderly patient suffering from dementia at a Cheshire care home. He was convicted of murder and arson with intent to endanger life.

A post-mortem examination found the cause of death was bronchial pneumonia brought on by smoke inhalation and burns.

Source: http://news.bbc.co.uk/1/hi/england/8027960.stm

A1.1.23 Dell Road, Cotteridge, Birmingham

The fire brigade were called to a fire at this nursing home at 03:00 on Sunday, 11 January 2009. After fully extinguishing the fire they came across a resident who had perished in the smoke of the fire.

The cause of the fire was unknown. Automatic fire suppression was not provided, although the home's alarm system could be heard operating during the fire.

Source: http://news.bbc.co.uk/1/hi/england/west_midlands/7822848.stm

A1.1.24 Ancaster Court Home, Bexhill, Sussex

The Ancaster Court Home is situated in two converted Victorian houses which provide accommodation for approximately 51 residents.

A fire occurred on 1 February 2009 and was believed to have been an arson attack; witnesses stated someone entered the victim's room to start the fire. Fire services rescued the victim who died from smoke inhalation. No other residents were injured.

Sprinklers are not thought to be provided to this building.

Source: http://news.bbc.co.uk/1/hi/england/sussex/7874100.stm

A1.2 International Fire Incidents

A1.2.1 Kew Cottages, Australia

Kew Cottages, later named Kew Residential Services, was a large multi-unit residential campus for people with intellectual disabilities located in Melbourne. The building in which the fire occurred was built in 1960 and accommodated 600 residents most of whom required medium to high levels of support. Building 37 in which the fire occurred was occupied by 46 residents and two carers.

The fire started on the night of 8 April 1996 and was caused by a resident who used a cigarette lighter to set fire to his bedding. According to the fire report, the fire alarm activated at 22:56 and the first fire appliance arrived five minutes later, but by that time the fire engulfed the unit in Building 37. As a result of the fire, nine residents of the unit were killed and one survived.

At the time of the fire a sprinkler system was in the process of being installed in the area affected by the fire but was not operational. Other factors that were considered to play a major part in the shortcomings were inadequate maintenance and weaknesses in emergency staff training, evacuation procedures, and communication and safety protocols.

A1.2.2 Hartford, Connecticut

A fire broke out in the early morning on Wednesday, 26 February 2003 in a patient room at a nursing home in Hartford, Connecticut. At the time of the fire there were 148 residents within the building and the fire resulted in 16 fatalities and dozens injured. Investigators concluded the fire was caused when a patient ignited her bedding with a lighter. The NFPA report stated "*a lack of automatic sprinkler protection has been noted in previous nursing home fire losses. Given issues of staff training and response noted in this fire and other factors that may have impeded suppression of the fire and smoke spread, as well as rescue of occupants, this fire calls for careful reconsideration of the need for more widespread use of automatic sprinkler protection in nursing facilities".*

Source: *Fire Investigation Summary, Nursing Home, Hartford, CT. National Fire Protection Association*

A1.2.3 Tempe Nursing Home, Westchester Care Center, Arizona

A fire in sprinklered nursing home has been reported on the 21st January 2008. It is believed that the fire has been started by an 82-year-old man when he was smoking in his bed. Due to severe burns to his legs and smoke inhalation he was transported to the hospital to receive treatment.

The fire activated a sprinkler system in the room which kept fire under control until firefighters put out the blaze.

As a result of the fire approximately 60 residents of the nursing home have been evacuated but were able to return later that night.

Source: http://www.azcentral.com/community/tempe/articles/0121abrk-nursinghome0121.html

A1.2.4 Culpepper Place Senior Living Facility, Branson, Missouri, USA

The fire in a bedroom has alarmed residents of an assisted living facility in Branson, MO, USA. The fire started before 03:00 on 19th December 2008 on a residents' couch and it was quickly extinguished by a sprinkler system in the room.

No one was hurt as a result of the fire and the woman in the affected bedroom has been found asleep and moved to another room.

Source: http://www.bafsa.org.uk/sprinkler-stops.php

A1.2.5 Riverview Individual Residential Alternative, Wells, New York State

A fire broke out at 05:30 on Saturday, 21 March 2009 at the Riverview Individual Residential Alternative, in Wells, N.Y. The fire resulted in four fatalities. A fifth resident was injured in the blaze, and two staff members were injured as they tried to evacuate the group home.

The blaze appeared to have started as an electrical fire and the sprinkler system did function as intended. This may be due to the system installed being a type NFPA 13D system rather than a type NFPA 13R system and the fire spread through the roof space which was not covered by sprinklers.

A type NFPA 13D is a sprinkler system standard suitable for one- and two-family dwellings and manufactured homes where as a type 13R sprinkler system is suitable for residential occupancies up to and including four stories in height.

Source: http://www.nytimes.com/2009/03/22/nyregion/22fire.html

A1.2.6 Care Home in Melle, Belgium

A fire broke out at 20:00 (local time) on 6 August 2009 at the Kanunnik Triest home in the Belgian town of Melle. The home houses approximately 90 residents and the fire resulted in nine fatalities. The fire was caused by an overheating fan on the first floor.

Source: http://news.bbc.co.uk/1/hi/world/europe/8188760.stm

Arup**Fire**

Appendix B

Fire and Smoke Modelling

B1 Introduction

Appendix B provides details on the fire and smoke modelling approach that was utilised to assess the likely conditions that would be present in the event of a fire. The overall aim of the fire and smoke modelling is to undertake quantified comparative assessment to evaluate the level of protection provided to escaping occupants within a typical residential care premises for the following cases:

- residential care premises without sprinklers;
- residential care premises with sprinklers (controlled fire);
- residential care premises with sprinklers (extinguished fire).

In the three cases the conditions within the room of fire origin, the corridor, the stair and the adjacent bedrooms were assessed.

The fire and smoke modelling was undertaken using the Fire Dynamic Simulator developed by NIST.

B2 Description of models

B2.1 General layout of the building modelled

The area modelled is that of a common corridor on a single floor with a number of bedrooms leading off the corridor (shown in Figure 10). The room of fire origin is located at the end of the corridor. The stair is located directly off the corridor and a cross-corridor fire door is provided to limit the number of bedrooms within the protected zone to less than ten, in line with current AD B design guidance.

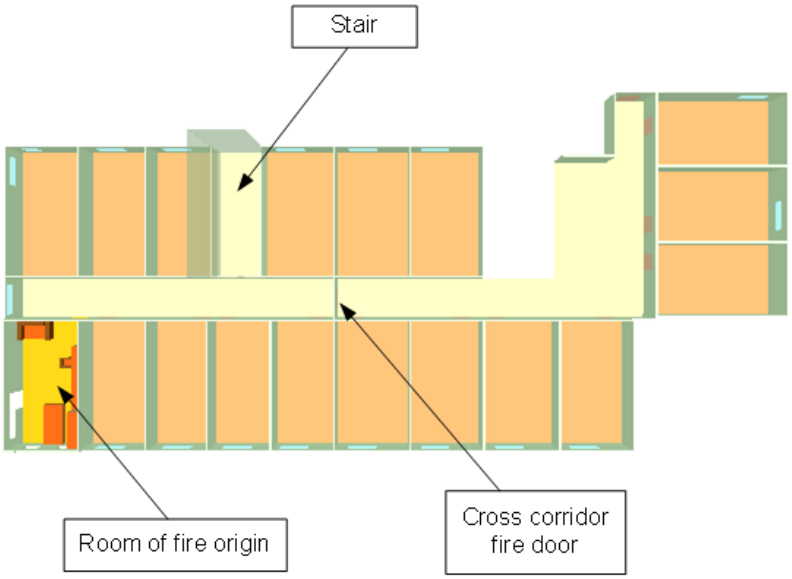

Figure 10: General layout of the model (for both the sprinklered and unsprinklered cases)

B2.2 Unsprinklered case

The unsprinklered case assumes a fast growing fire within a bedroom only limited by the combustible contents of the room and the ventilation area provided (ventilation/fuel bed controlled fires).

The maximum fire size within the bedroom has been calculated to be 5700kW based on the floor area of the bedroom (23m²) and a fire load density of 249kW/m² (typical for a hotel

room – refer to Table 10.3 in CIBSE Guide E). There is sufficient ventilation via the windows to allow the fire to grow)

An illustration of the fire growth modelled in the unsprinklered case is presented in Figure 11.

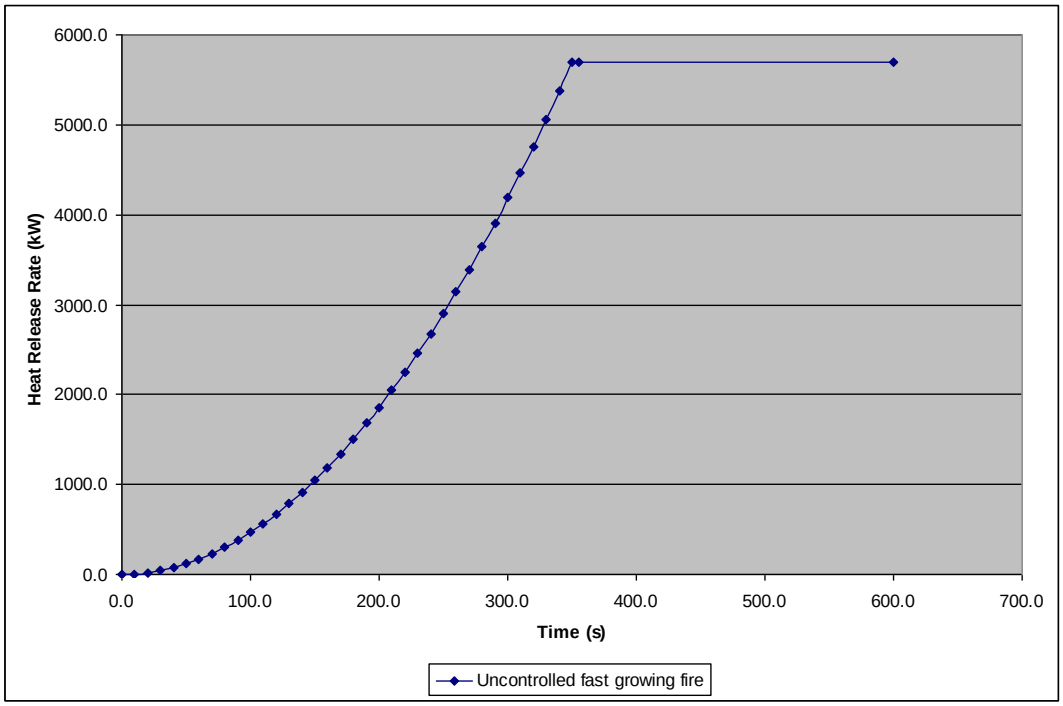

Figure 11: Illustration of uncontrolled fast growing fire modelled in unsprinklered case

B2.3 Sprinklered cases

The assumption for the sprinklered cases is that the fire grows with a fast fire growth rate until the point at which the sprinkler head activates, after which the fire size will remain at steady state in the 'sprinkler controlled' case and will reduce in the 'sprinkler extinguished' case.

The controlled case follows the guidance within CIBSE Guide E Section 10.6.4:

'*In a room equipped with sprinklers, fire may grow until the heat of the plume sets off the first sprinkler heads; the effect of sprinklers on the design fire size can be taken into account by assuming that the fire stops growing when the sprinklers are activated. The design fire is then estimated as the size the fire has grown to at the moment of sprinkler activation unless there is a reason to suspect that the fire will continue to spread after the sprinklers have been activated.'*

That description applies to a sprinkler system designed for fire control, but in a large number of instances, activation of the suppression system would result in the fire being extinguished (see Section B2.3.1) and this scenario has also been modelled.

The time of sprinkler activation was calculated at 85 seconds and was established using FPE (Fire Protection Engineering) tool developed by NIST.

This was based on the following parameters:

- sprinkler Response Time Index (RTI) = 50 $(m/s)^{1/2}$;
- sprinkler activation temperature = 57C;
- ambient temperature = 20C;
- horizontal distance of sprinkler head from centre of fire = 2m;
- vertical distances of the fire above the plume = 2m (assumes a fire on the bed);

- fire growth rate = fast.

At the time of sprinkler activation the fire size was calculated to be 337kW.

An illustration of fires modelled in the sprinklered case is presented in Figure 12.

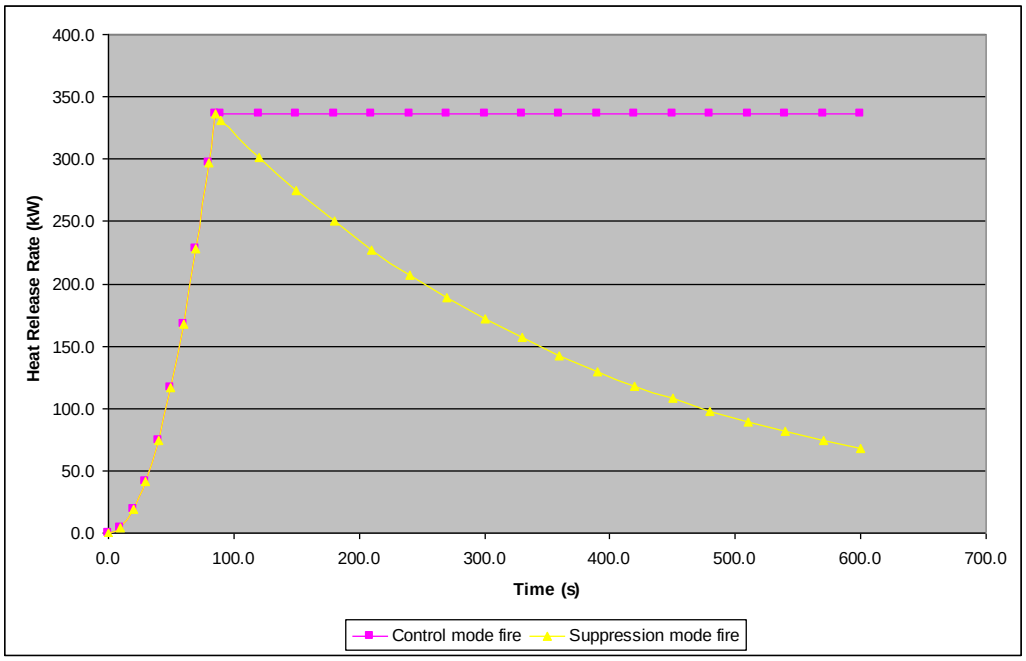

Figure 12: Illustration of fast growing fires modelled in sprinklered case

B2.3.1 Fire decay after sprinkler activation

As stated previously in Section B2.3; the Computational Fluid Dynamics (CFD) analysis for the sprinklered case assumes two cases; in both cases the fire grows with a fast fire growth rate until the point at which the sprinkler head activates after which the fire is assumed to either remain at steady state (control mode) or be extinguished by the sprinkler (suppression mode).

The controlled case is considered to be a conservative assumption since in reality the fire size would reduce in the majority of instances and therefore a separate analysis has been undertaken for comparison to account for the suppression effect on a fire by activation of a sprinkler system.

Based on the guidance of PD 7974-4:2003 the effectiveness of sprinkler systems in reducing the heat release rate of furnishing fires can be determined from the following equation:

$$Q_{(t-t_{act})} = Q_{t_{act}} \cdot e^{-(t-t_{act})/3.0(w'')^{-1.85}}$$, where:

Q is the heat release rate (kW);

t is any time following t_{act} of the sprinklers (s);

w" is the water spray density (mm/s).

Following the equation a suppression mode fire has been modelled where the fire grows with a fast fire growth rate until the point at which the sprinkler head activates after which the heat release rate is being reduced in line with the equation. This is shown as the lower curve in Figure 12.

B2.4 Common assumptions

The following assumptions are common to both of the modelled cases:

- the bedroom doors and the cross-corridor doors have a leakage area of 0.04m² which is intended to address the risk that the doors may have suffered some wear and tear or that the doors are slightly ajar at the time of the fire.
- in both cases the bedroom door opens after 160s and closes after 220s. This is intended to model the evacuation process of a resident within the room.
- the windows break in both models. This is undertaken to permit sufficient ventilation to enable the fire to grow to its determined size (the results within the Fire Dynamics Simulator are only accurate for well-ventilated fires). This is considered to be acceptable on the basis that the relatively small floor area of the individual bedrooms would mean that flame impingement on the glazing is likely.

it is assumed that the fire would not spread beyond the room of fire origin due to the assumed extent of fire-resisting construction within the building and the presence of sprinklers. This is considered to be a conservative assumption particularly when considering the failure rate of passive fire protection (see 5.1.2).

B3 Results

The following images present the results of the fire and smoke modelling for both temperature and visibility at 2m above finished floor level.

The section also presents the results of the suppression effect of sprinkler activation as described in Section B2.3.1.

B3.1 Temperature at 2, 4, 6, 8 and 10 minutes

B3.1.1 Sprinkler controlled fire

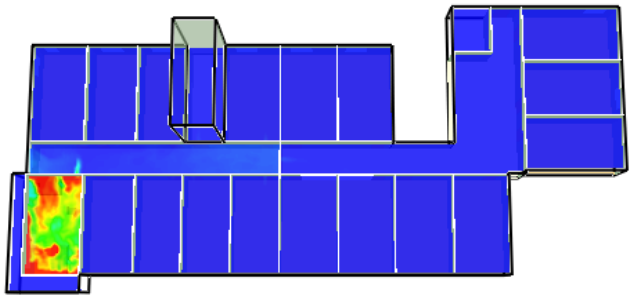

Figure 13: Temperature profile at 2 minutes – sprinkler controlled

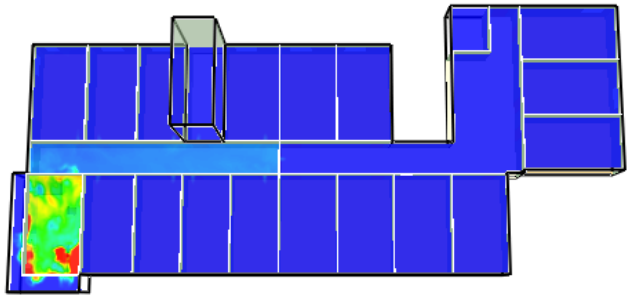

Figure 14: Temperature profile at 4 minutes – sprinkler controlled

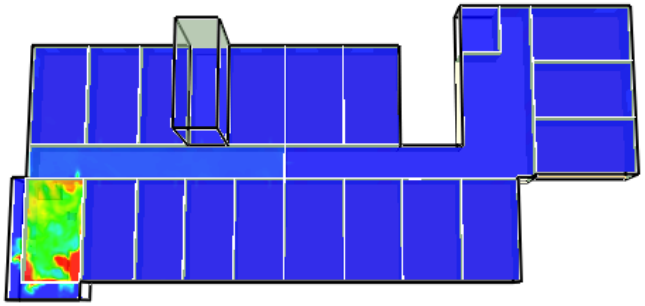

Figure 15: Temperature profile at 6 minutes – sprinkler controlled

B3.1.2 Unsprinklered fire

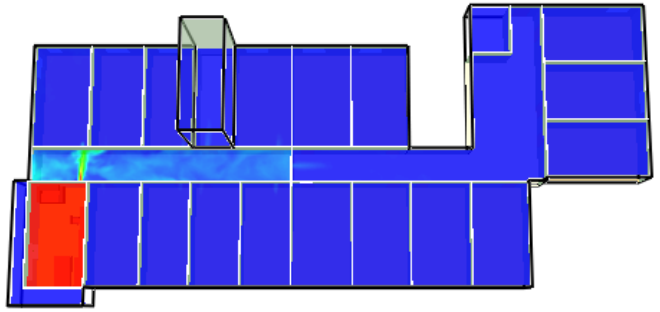

Figure 16: Temperature profile at 2 minutes - unsprinklered

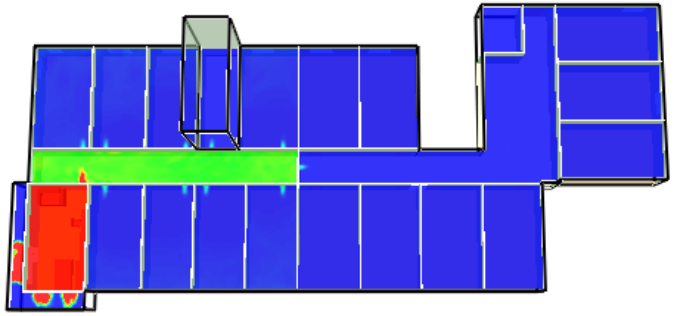

Figure 17: Temperature profile at 4 minutes - unsprinklered

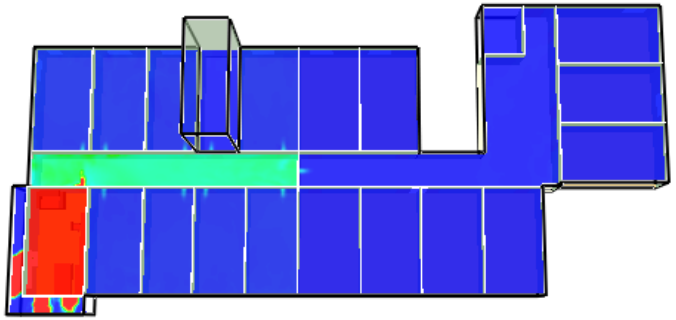

Figure 18: Temperature profile at 6 minutes - unsprinklered

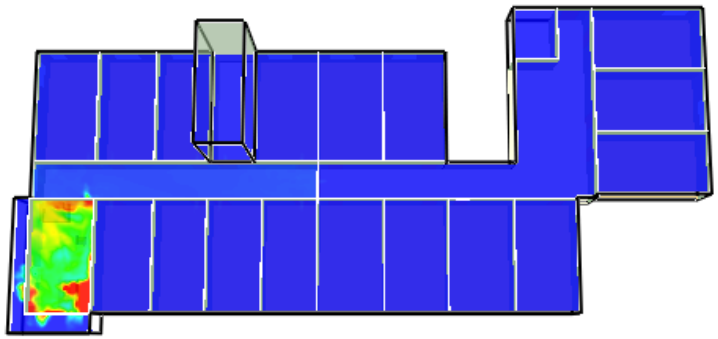

Figure 19: Temperature profile at 8 minutes – sprinkler controlled

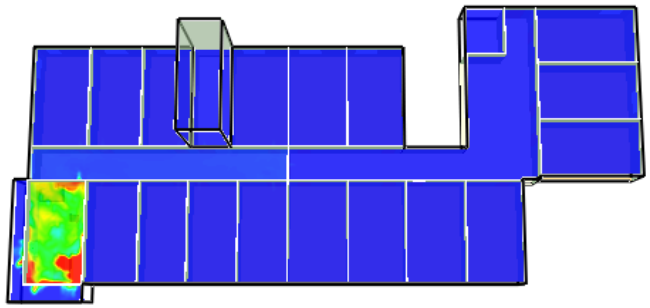

Figure 20: Temperature profile at 10 minutes – sprinkler controlled

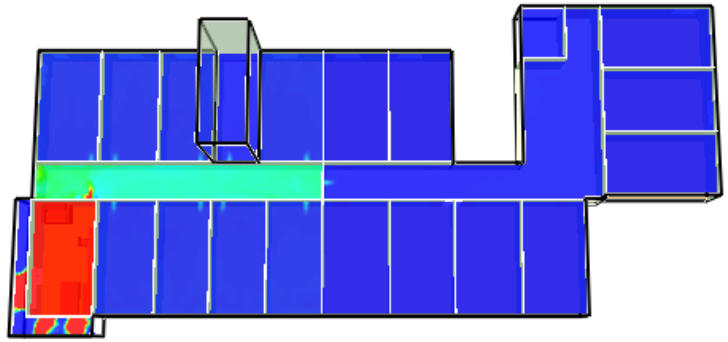

Figure 21: Temperature profile at 8 minutes - unsprinklered

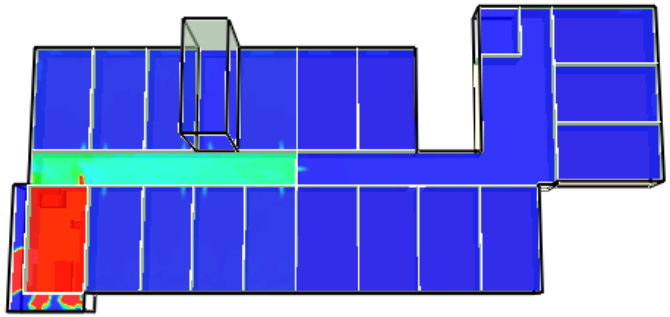

Figure 22: Temperature profile at 10 minutes - unsprinklered

B3.2 Visibility at 2, 4, 6, 8 and 10 minutes

B3.2.1 Sprinkler controlled fire

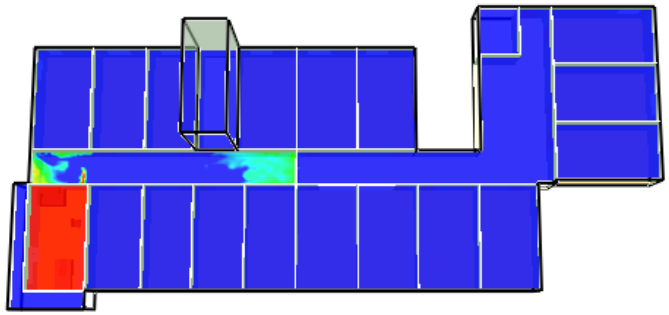

Figure 23: Visibility profile at 2 minutes – sprinkler controlled

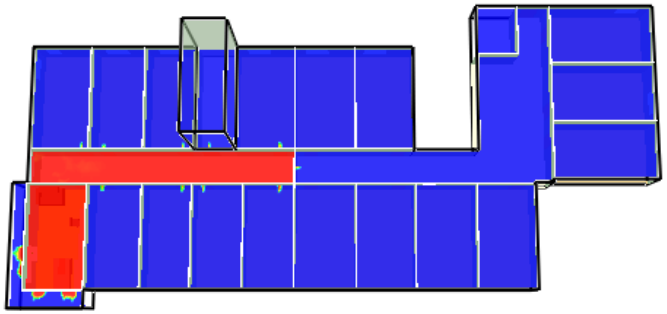

Figure 24: Visibility profile at 4 minutes – sprinkler controlled

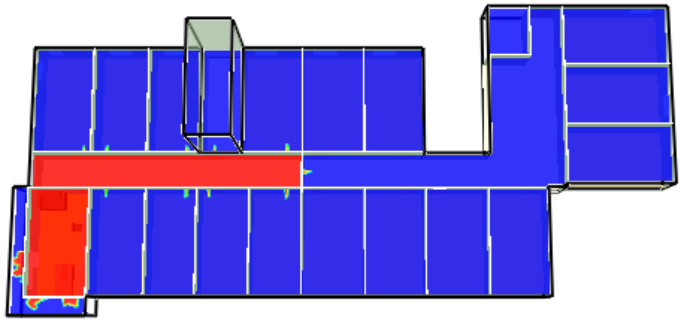

Figure 25: Visibility profile at 6 minutes – sprinkler controlled

B3.2.2 Unsprinklered fire

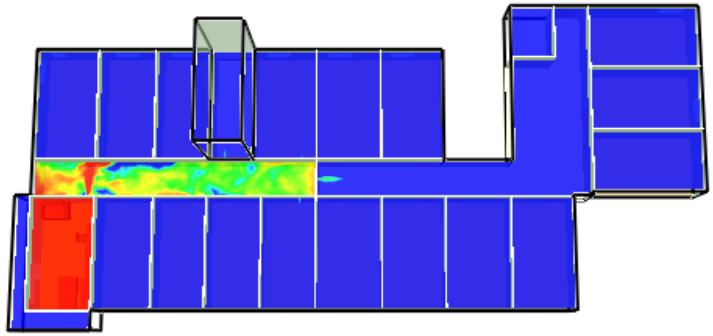

Figure 26: Visibility profile at 2 minutes - unsprinklered

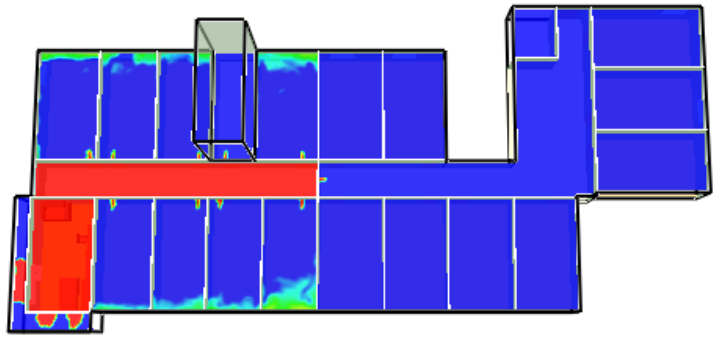

Figure 27: Visibility profile at 4 minutes - unsprinklered

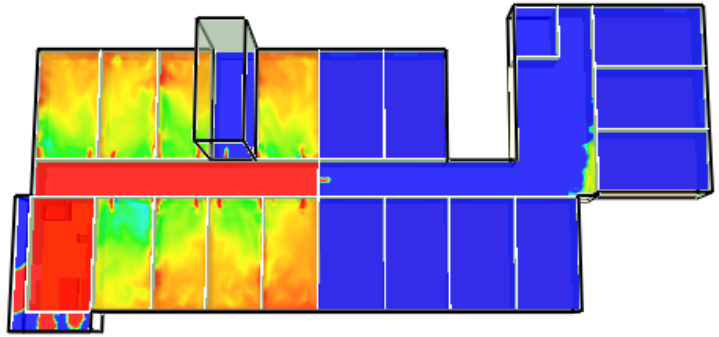

Figure 28: Visibility profile at 6 minutes - unsprinklered

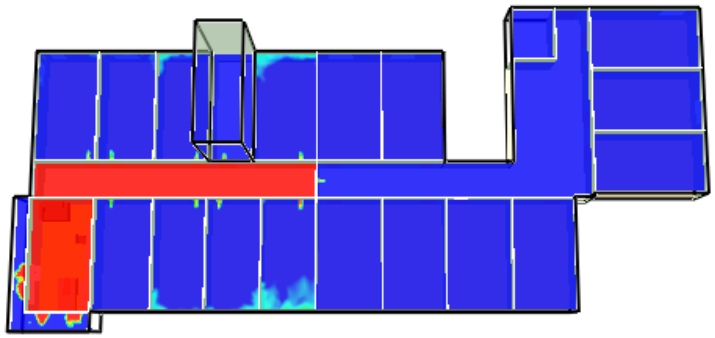

Figure 29: Visibility profile at 8 minutes – sprinkler controlled

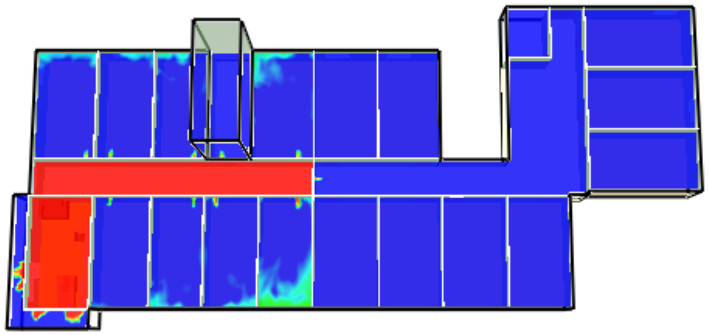

Figure 30: Visibility profile at 10 minutes – sprinkler controlled

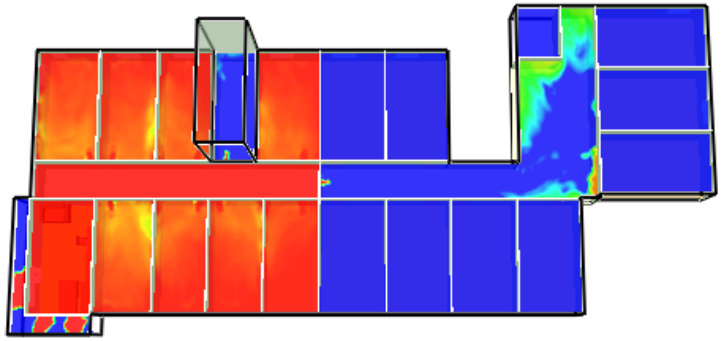

Figure 31: Visibility profile at 8 minutes - unsprinklered

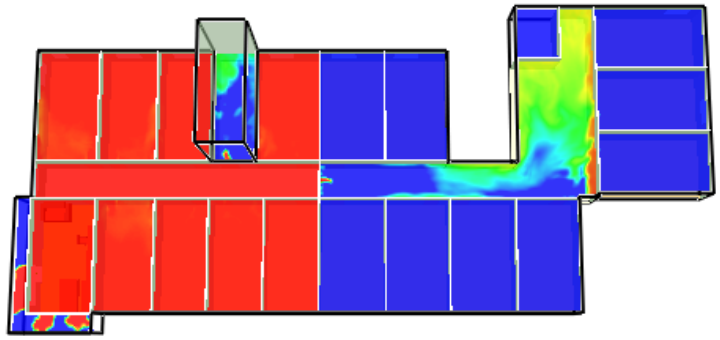

Figure 32: Visibility profile at 10 minutes - unsprinklered

B3.3 Results of suppression mode sprinklered fire

B3.3.1 Temperature through fire at 2, 4, 6, 8 and 10 minutes

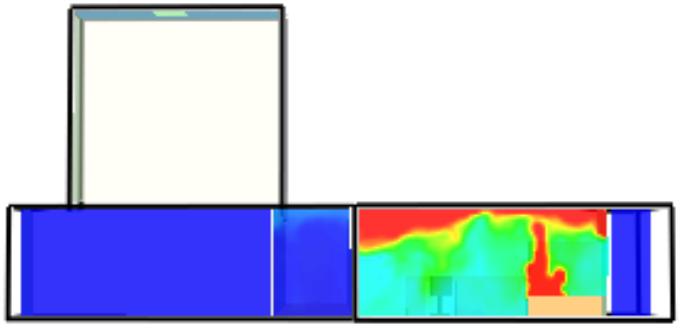

Figure 33: Temperature profile through fire at 2 minutes – sprinkler decay

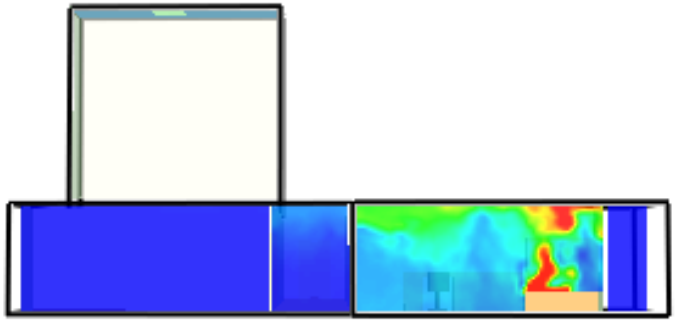

Figure 34: Temperature profile through fire at 4 minutes – sprinkler decay

B3.3.2 Temperature 2m above ground level at 2, 4, 6, 8 and 10 minutes

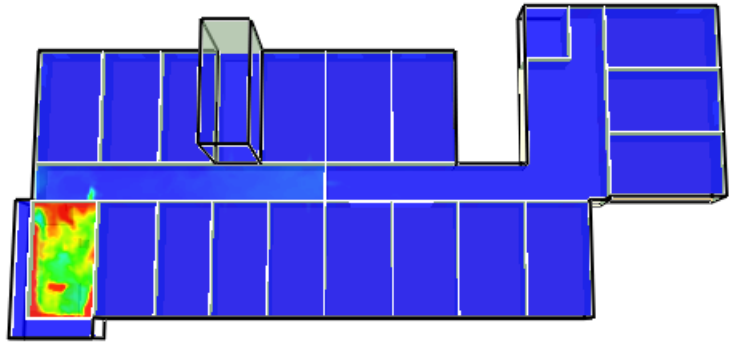

Figure 35: Temperature profile 2m above ground level at 2 minutes – sprinkler decay

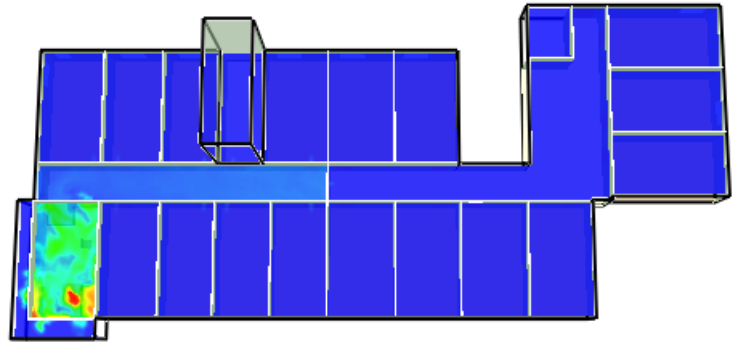

Figure 36: Temperature profile 2m above ground level at 4 minutes – sprinkler decay

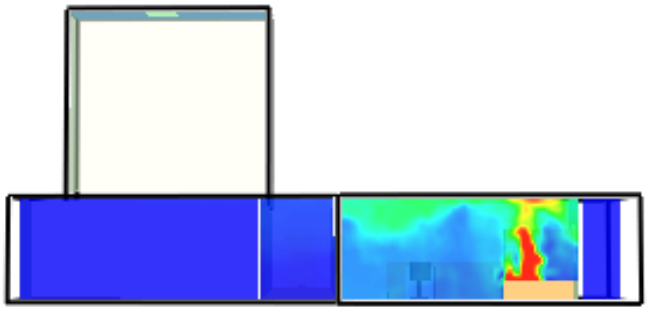

Figure 37: Temperature profile through fire at 6 minutes – sprinkler decay

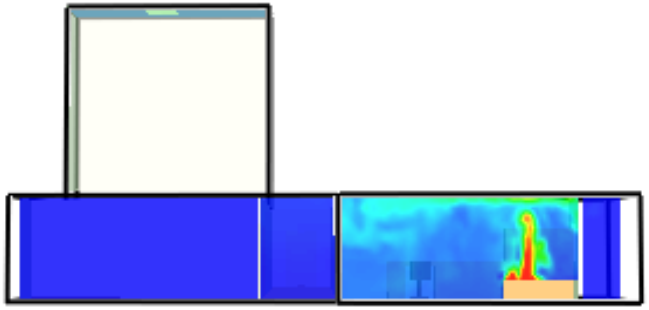

Figure 38: Temperature profile through fire at 8 minutes – sprinkler decay

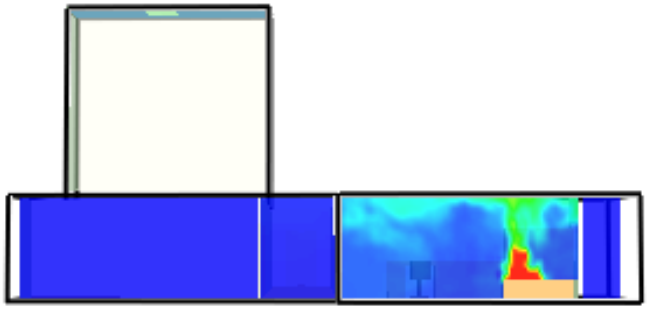

Figure 39: Temperature profile through fire at 10 minutes – sprinkler decay

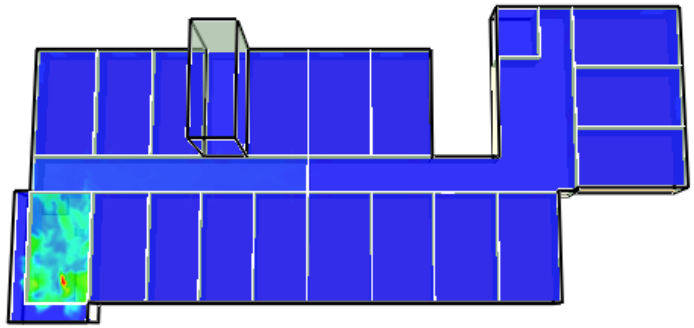

Figure 40: Temperature profile 2m above ground level at 6 minutes – sprinkler decay

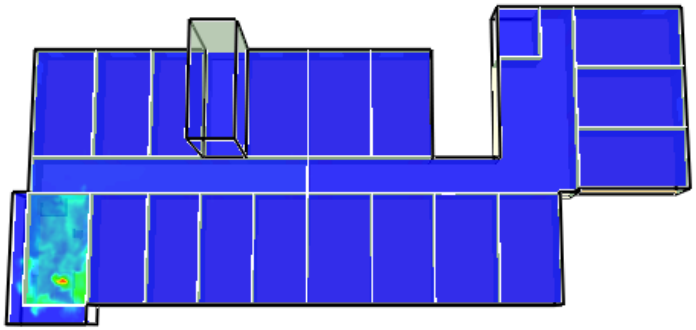

Figure 41: Temperature profile 2m above ground level at 8 minutes – sprinkler decay

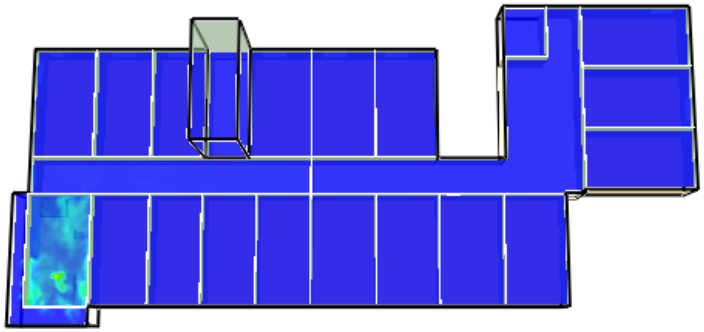

Figure 42: Temperature profile 2m above ground level at 10 minutes – sprinkler decay

B3.3.3 Visibility through fire at 2, 4, 6, 8 and 10 minutes

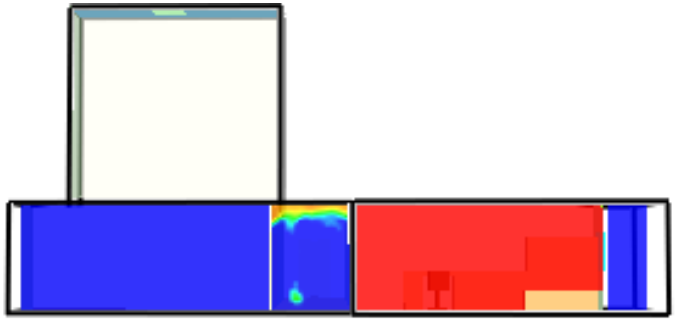

Figure 43: Visibility profile through fire at 2 minutes – sprinkler decay

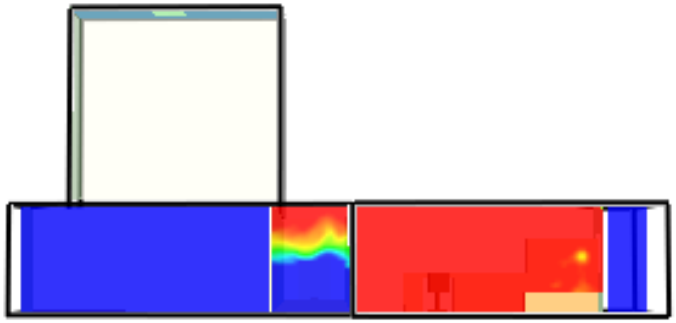

Figure 44: Visibility profile through fire at 4 minutes – sprinkler decay

B3.3.4 Visibility 2m above ground level at 2, 4, 6,8 and 10 minutes

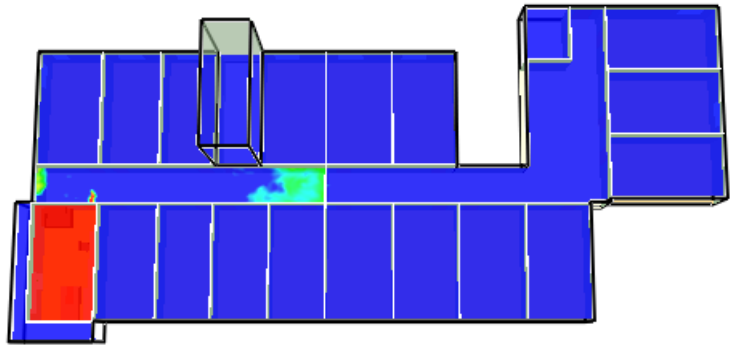

Figure 45: Visibility profile 2m above ground level at 2 minutes – sprinkler decay

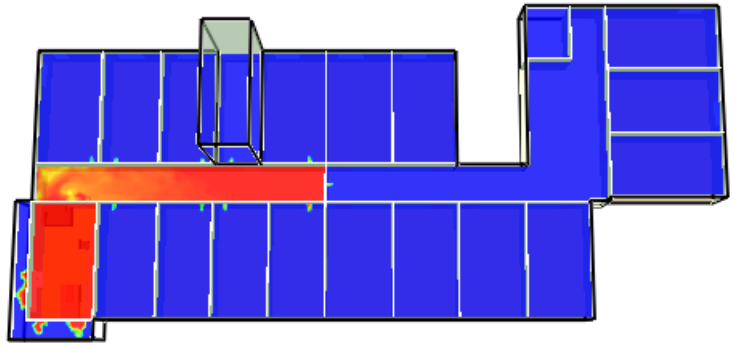

Figure 46: Visibility profile 2m above ground level at 4 minutes – sprinkler decay

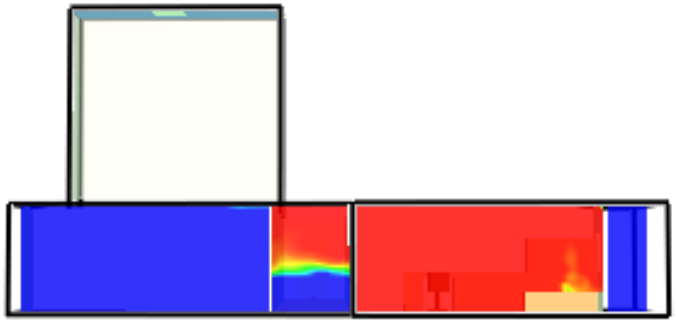

Figure 47: Visibility profile through fire at 6 minutes – sprinkler decay

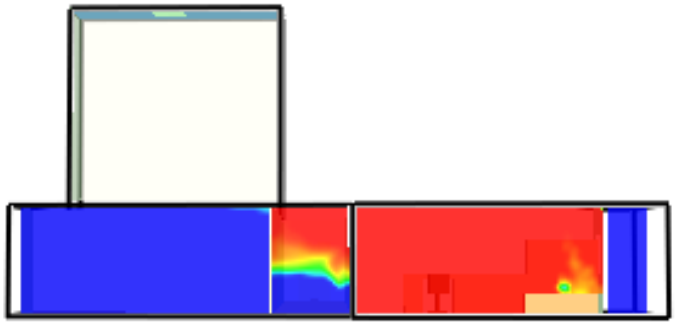

Figure 48: Visibility profile through fire at 8 minutes – sprinkler decay

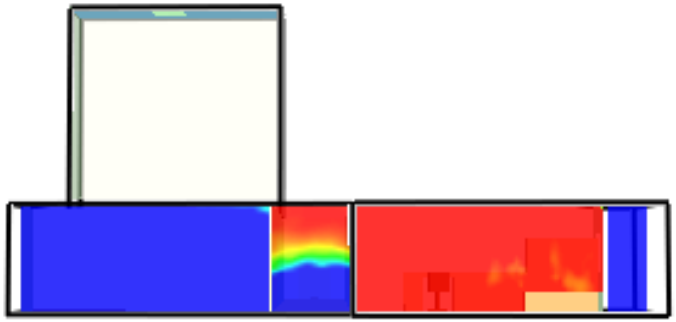

Figure 49: Visibility profile through fire at 10 minutes – sprinkler decay

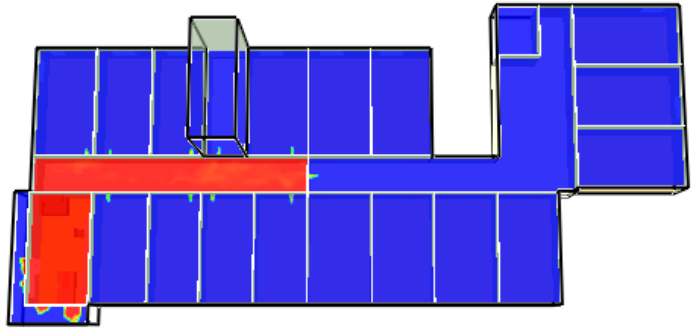

Figure 50: Visibility profile 2m above ground level at 6 minutes – sprinkler decay

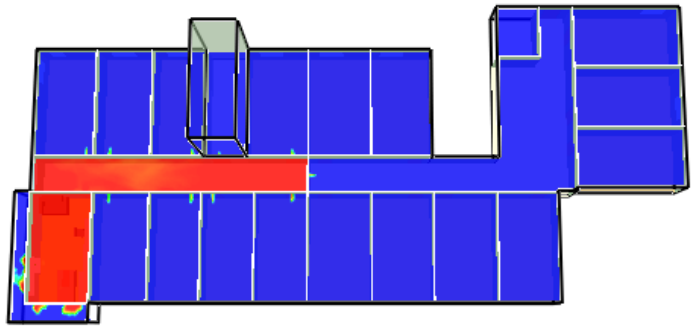

Figure 51: Visibility profile 2m above ground level at 8 minutes – sprinkler decay

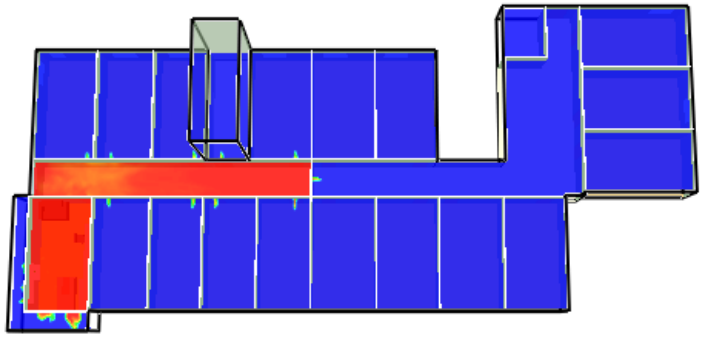

Figure 52: Visibility profile 2m above ground level at 10 minutes – sprinkler decay

B4 Discussion

The illustrations in Section B3 present the temperature and visibility profiles for the sprinklered and unsprinklered cases. In reviewing the results it is clear that the conditions present within the sprinkler controlled models are significantly better than the conditions present in the unsprinklered case. This is discussed further in the following sections.

B4.1 Temperatures

The temperatures within the room of fire origin exceed 120C within two minutes for the unsprinklered case. In comparison the sprinkler controlled fire has a temperature in the region of 70C-80C throughout the model (ten minutes) and in the suppression mode sprinklered fire the temperatures drop below 60C after approximately 8 minutes. This reduction in temperature demonstrates a reduced impact on the building enclosure for the sprinklered cases (which may allow a reduction in the fire resistance periods of the elements of structure and compartmentation).

The sprinklers provide significantly better conditions in respect to temperature within the bedroom and in the sprinkler extinguished case it is considered that the conditions within the bedroom would provide tenable conditions with respect to temperature. In the sprinklered controlled and unsprinklered cases the conditions are considered to be untenable in both instances even though the sprinklers significantly improve the conditions and this can be attributed to the relatively small volume of the rooms within the model itself.

It is the conditions present outside the room of fire origin where there is significant benefit due to the provision of sprinklers. Within the corridors the temperature do not appear to exceed 35°C throughout the duration of the model for the sprinklered case and therefore it can be considered that the corridor would remain tenable with respect to temperature. In the unsprinklered case the conditions appear to range between 60°C and 80°C. The tenability criteria for temperature given in NFPA 130 are 60C for a few seconds and 50C for up to 6 minutes (this may be significantly lower when considering the physical disabilities and respiratory conditions that some of the residents may suffer from) and therefore it is considered that for the unsprinklered case the conditions within the corridor would be untenable, especially when considering the potential for extended evacuation times that may be present due to the diminished ability of the residents to escape.

B4.2 Visibility

The visibility within the room of fire origin drops to less than 2m (at 2m above ground) for both the sprinklered and unsprinklered cases. However this can be attributed to a number of factors:

- the fire modelled had a fast growth rate and no incubation period was modelled. In reality the fire would have a period of incubation and this should result in less smoke being produced during the early stages of the fire during which it is hoped the occupant of the room would be evacuated;
- the sprinkler system is only assumed to control the fire rather than extinguish the fire. In reality it is considered that in most scenarios the sprinklers would extinguish the fire [42] but this approach has been assumed for conservatism and assumes that the fire is shielded in some way (presents a worst case).
- when the door opens into the corridor the fire has grown to a size where the conditions within the room of fire origin are untenable. This is a conservative assumption and results in a large amount of smoke flowing into the corridor during the 60 seconds the door is assumed to be open. In reality the occupants should have evacuated prior to this with the door closing behind them. Therefore the amount of smoke that flows into the corridor would be reduced.

In the common areas in the models (i.e. the corridors) the visibility is tenable for a period of 2 minutes for the sprinklered case but the conditions become untenable at the 4 minute point. In the unsprinklered case the conditions are untenable within 2 minutes.

In the rooms that open onto the corridor the conditions remain tenable for the duration of the model for the sprinklered cases, meaning that occupants would be relatively safe waiting in their bedrooms if assisted evacuation was required. In the unsprinklered case smoke starts to penetrate into the other apartments between 4 and 6 minutes and the conditions within those apartments are considered to be untenable after 6 minutes, reinforcing the potential for extensive smoke spread and untenable conditions beyond the room of fire origin.

In addition, in the unsprinklered cases smoke also appears to begin to affect the section of corridor within the adjacent compartment towards the end of the model duration.

B5 Conclusion

In reviewing the results of the smoke modelling it is clear that sprinklers provide significant benefit in relation to the conditions beyond the room of fire origin and the models show that tenable conditions are maintained in all of the rooms beyond the room of fire origin in the sprinklered cases although this is not the case where sprinklers are not provided. The clear benefit is that the conditions that residents and staff encounter when trying to evacuate in the event of a fire will be significantly improved as a result of sprinklers and this can only ease the evacuation process.

The sprinklered case shows temperatures within the corridors and all other rooms reduced to tenable levels. It also provides tenable conditions in terms of visibility within all of the adjacent rooms within the fire compartment and in the adjacent compartments. The only area where sprinklers do meet the required visibility levels is in the common corridor although this can be attributed to a number of reasons.

- the fire modelled had a fast growth rate and no incubation period was modelled. In reality the fire would have a period of incubation and this should result in less smoke being produced during the early stages of the fire during which it is hoped the occupant of the room would be evacuated;
- the sprinkler system is only assumed to control the fire rather than extinguish the fire. In reality it is considered that in most scenarios the sprinklers would extinguish the fire [42] but this approach has been assumed for conservatism and assumes that the fire is shielded in some way.
- the model has relatively large leakage paths to replicate ill-fitting fire doors. Assuming that the fire compartmentation and fire doors are maintained it is unlikely that this amount of smoke would spread into the corridor.

It is therefore considered that sprinklers provide significant benefit in terms of the likely conditions that would be present in the event of a fire, particularly outside of the room of fire origin. This appears to be in line with the BRE Report 2546 which concludes that the conditions outside the room of fire origin should remain tenable in most situations where a sprinkler operates.

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Appendix C

Review of Experimental Study in BRE Report 204505, Effectiveness of sprinklers in residential premises

C1 Review of Experimental Study

The purpose of the experimental programme within BRE Report 204505 was to examine and quantify the effectiveness of residential sprinklers in particular with respect to life safety in the room of fire origin. Following on from the issue of the final report a large amount of attention has been focussed on the results of the shielded fire tests and in particular the finding that conditions became unsurvivable in both the sprinklered and unsprinklered fires.

The experiments that considered the sprinklered television and bed fires generally showed greatly improved conditions in the room of fire origin by maintaining tenable conditions in terms of toxic effects and reduced effects of convected heat, but showed no observed improvement in terms of visibility (this corresponds with the results of the smoke modelling study in Appendix B).

The results of the table fires experiments (where the fire was shielded by the table) showed that for all of the experiments, in both the sprinklered and unsprinklered fires, the conditions became unsurvivable.

The shielded table fire experiment assumed the ignition of combustible materials stored below a mock up of a coffee table that was located directly below the sprinkler head. This resulted in the fire being completely shielded by the table and subsequently the sprinkler was ineffective in this case.

In reviewing the complete test results and the appropriateness of the findings in relation to residential care premises it is important to consider whether or not the fire scenarios are realistic and represent a credible worst case in a residential care premises. Consideration should also be given to the potential benefits beyond the immediate fire vicinity.

The table fire scenario is considered to represent a true worst case due to the shielding of the developing fire, which prevented effective sprinkler operation. While this arrangement is unlikely to occur in practice, even in this extreme scenario sprinklers could be expected to provide benefit in terms of reducing the likelihood of fire spread to other parts of the room, since once the fire breaks out beyond the shielding (assuming sufficient fuel load exists) it is likely that the sprinklers would control the fire and prevent it spreading. It is also considered that the sprinklers would provide benefit in reducing the risk that flashover conditions would develop within the room of origin. Hence, even in this scenario, it is considered that there would a safety benefit associated with the provision of sprinklers.