Communities and Local Government

Sprinkler effectiveness in care homes

Final Research Report: BD 2546

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EXECUTIVE SUMMARY

This is the report for the Department for Communities and Local Government Buildings Division project entitled Sprinkler Effectiveness in Care Homes. The Department for Communities and Local Government Contract reference CI 71/5/33 BD2546. This project was commissioned under the Department for Communities and Local Government Fire Safety Framework Agreement with the BRE.

A recent review of fire statistics had indicated that most fatalities in care homes arise from occupants accidentally setting fire to bedclothes, nightclothes etc whilst they are in bed.

There was no available information to determine whether the severity of such a fire at the time the sprinkler operates would be invariably fatal to the person involved or whether there would be a good chance that they would survive. The most recent research only generally considered people in the room of origin - it did not differentiate between people in intimate contact with the fire and those remote from it.

There was also a need to collect more information and evidence to ensure that current assumptions in respect of the life-saving benefits of residential sprinklers stand up to scrutiny. In the earlier study it was assumed that people involved in a clothing/bedding fire would not survive, so there is very little change to the estimate of sprinkler effectiveness previously established. Whether sprinklers in care homes are cost-effective or not is determined by the installation costs; the findings from this research do not affect this conclusion.

The overall aim of the project has been to gather information on the nature of fire injuries and fatalities in care homes in the context of the life-safety benefits of sprinklers fitted in the room of fire origin. This information will be used to further inform the Approved Document B (Fire safety) (AD B) consultation and revision process.

There are many fires each year involving elderly people where clothing or bed coverings have ignited. Such fires are often fatal, or cause serious burns. Many are a result of smokers' materials.

Where a fire has occurred involving either the nightwear or bed clothes of an occupant of a bed, the fire experiments have indicated that sprinklers alone are unlikely to operate quickly enough to prevent the occupant of a bed being fatally injured or suffering very serious injuries from flames and/or heat.

In most situations where a sprinkler operates, other occupants within the room should survive, since the heat and toxic gases within the room are kept within tenability limits by the sprinkler system.

A smoke alarm fitted in the room will provide early warning of a fire and should alert the occupant and nursing staff to the problem. If the smoke alarm is linked to the sprinkler system, early suppression of the fire is also possible. In such a case, all occupants of the room, including any person in the affected bed, should survive. However, such a system would be far more complex (and expensive) than a 'normal' sprinkler system, and there would be a possibility of frequent false operations, which could cause distress (and possibly harm) to elderly residents.

This report is concerned with care homes for the elderly. However, many of the findings are relevant to other types of care home.

CONTENTS

1 Introduction and objectives

This is the report for the Department for Communities and Local Government Buildings Division project entitled Sprinkler Effectiveness in Care Homes, the Department for Communities and Local Government Contract reference CI 71/5/33 BD2546. This project was commissioned under the Department for Communities and Local Government Fire Safety Framework Agreement with the BRE.

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The overall aim of the project has been to gather information on the nature of fire injuries and fatalities in care homes in the context of the life-safety benefits of sprinklers in the room of fire origin. This information will be used to further inform the Approved Document B (Fire safety) (AD B) consultation and revision process.

2 Programme of work

The programme and method was developed to meet the required objectives and the time scale of the AD B consultation and revision.

The project involved a search and review of existing information, supplemented with an important small but focussed experimental element.

The programme comprised the following activities:

Literature review.

- Search and review existing information on sprinkler effectiveness in protecting life in the room of origin

- Gather more detailed information on room of origin fire injuries and fatalities in care homes, particularly on those in intimate contact with the fire.

Experimental study

- Determine the severity (heat release) of bed fires required to activate a sprinkler (or sprinklers).

- Measure the toxicity and fractional effective dose (FED), based on CO, CO_2 and O_2 measurements

- Seek to determine the likely survivability of a bed occupant exposed to such a fire; as far as possible, taking account of potential generic age and health effects.

Analysis.

- Re-assess the overall effectiveness of sprinklers in care homes (in relation to that previously assumed in DCLG research (Ref. 1)

- Re-determine the cost benefit analysis for sprinklers in care homes.

TASK 1: LITERATURE REVIEW

The objectives of this task were to review existing information on sprinkler effectiveness in protecting life in the room of origin and to gather more detailed information on fire injuries and fatalities in care homes, (i.e. those arising from burns, smoke inhalation, or other causes such as heart attacks) particularly for those in intimate contact with the fire.

TASK 2: EXPERIMENTAL STUDY

The objectives of this task were to determine the severity (heat release) of bed fires required to activate a sprinkler (or sprinklers) and to seek to determine the associated likely survivability of a bed occupant exposed to such a fire.

TASK 3: ANALYSIS

The analysis examined the findings from tasks 1 and 2 to determine the likely survivability within the defined scenarios with sprinkler operation. The criteria applied to the data to assess sprinkler effectiveness and survivability was determined enabling the cost benefit analysis for sprinklers in care homes to be updated.

TASK 4: REPORT

A short publishable research report describing the project, the findings, analysis method, analysis and conclusions, and addressing the objectives of the research, would be prepared (this Report).

3 Findings

TASK 1: LITERATURE REVIEW

A literature review of available published work, information from electronic searches (e.g. web searches) and searches involving personal professional contacts was carried out. Relevant existing data and analysis from this search and the previous sprinkler projects and other relevant projects was reviewed against the project objectives. Previous experimental research was reviewed to seek to provide a base-line of fire severity against time to sprinkler operation.

US RESEARCH

Research from the USA (Ref. 2) shows that (in the US) 'Nearly 50% of older people who die in fires are intimately involved with the source of fire that kills them (e.g. their clothing or bedding has ignited). Approximately 40% are asleep and 20% are bed-ridden at the time the fire is ignited'.

This report goes on to say that '... since older adults have a diminished sensation of pain, they may sometimes delay getting treatment for burn injuries. The mortality from burns for individuals over age 65 increases five-fold when treatment is delayed from 2 to 5 hours.'

Smoking is given as the cause of fire in 29% of fatalities involving older adults.

DTI INFORMATION

Some useful information regarding clothing fires is available from the DTI, see Appendix B. This shows that clothing fires are a particular problem for the elderly.

The information nicely describes the problems with clothing fires. It is evident that elderly people are at particular risk from fires involving their clothing, but most fires where the person is in bed are a result of smoking or smoker's materials.

NOTICE TO IAAI AND NASHICS

A notice was prepared with the assistance of DCLG, to be circulated to the IAAI UK (UK Branch of the International Association of Arson Investigators) and separately to NASHICS (the National Association for Safety and Health in Care Services), as follows:

Dear colleague

DCLG Buildings Division has just commissioned BRE to carry out a project in response to a recent review of fire statistics which indicated that most fatalities in care homes arise from occupants accidentally setting fire to bedclothes, nightclothes etc whilst they are in bed.

Most research we are aware of only considers people in the room of origin generally and does not differentiate between people in intimate contact with the fire and those remote from it. We are therefore seeking to gather more detailed information on fire injuries and fatalities in care homes (i.e. those arising from burns, smoke, or other causes such as heart attacks), particularly on those in intimate contact with the fire. We are also seeking information on the effectiveness of sprinklers in such circumstances.

We would be pleased to hear from anyone with information, including case studies, that might assist us.

With thanks

Martin Shipp

This request was circulated to IAAI members on 31st March 2006 and to NASHICS members on 18th April 2006.

A number of useful and interesting case studies were provided (see Appendix C).

These incidents again demonstrate smoking as the main cause of relevant fires, and identify the need for good, responsive, management in care homes. The particular fire problems related to oxygen therapy are highlighted.

WEB SEARCHES FOR CASE STUDIES

A number of incidents involving bed clothes or bedding have been located and reviewed; see Appendix C.

There are many cases of fires involving clothing or bedding, mostly involving children or elderly people. Many such fires are fatal, although not invariably, but where survived they often result in very bad burns. People not in the bed may also die from the smoke from bedding fires elsewhere in the room.

Smoking is again identified as a significant cause, as are candles. The fire problems related to oxygen therapy are again mentioned.

DCLG SPRINKLER RESEARCH

The earlier work by Williams et al for DCLG (Ref. 1) has been reviewed in relation to the current project. The findings show that sprinklers in a bedroom should respond to a bed fire within a few minutes from ignition, at heat release rates as low as 100kW with ceiling temperatures around 100 to 150°C. See Appendix E.

The work showed that loss of visibility (from smoke) was the first factor to put lives at risk, and could be a problem even if a sprinkler operated. The operation of a sprinkler had a significant effect on survivability from the effects of toxic smoke.

OTHER EXPERIMENTAL WORK

1992, unpublished, work by the (then) FRS for the (then) Home Office (Ref. 3) gives heat release results for a number of bedding composite combinations, as follows:

A

- CM foam mattress with 100% nylon cover
- 100% polyester sheets
- 100% polyester blanket
- 100% cotton counterpane.

	Test 1	**Test 2**
Peak heat release:	17.4kW	16.9kW
Time to peak:	3:20	3:15 (Minutes:seconds)

B

- CM foam mattress with 100% nylon cover
- 100% cotton sheets
- 100% cotton blanket
- 100% polyester counterpane.

	Test 1	**Test 2**
Peak heat release:	25.5kW	15.8kW
Time to peak:	29:25	3:40

C

- Three layers of BP Grade cotton wool
- 100% cotton sheets
- 60% wool, 40% modacrylic blanket
- Quilted bedspread.

	Test 1	**Test 2**
Peak heat release:	29.3kW	24.9kW
Time to peak:	15:2	17:30

D

- Three layers of BP Grade cotton wool
- 50% cotton, 50% polyester sheets
- Continental quilt.

	Test 1	Test 2
Peak heat release:	201.6kW	133.6kW
Time to peak:	7:25	7:25

It is evident that bedding fires need not be particular severe with regard to heat release rate.

Fairly recent work carried out by BRE on behalf of HM Prison Service examined the effectiveness of sprinklers in prison cells. A room was constructed of a steel frame with two layers of calcium silicate board, to represent a prison cell of dimensions 2.4 high, 2.2m wide and 3.3m in length, with a 0.8m x 1.9m door in a short side wall.

The fire load comprised a prison bed with prison issue mattress, sheet, pillow and pillow case, blankets, an item of MDF furniture, a bag of clothing and items of food, papers, books and toiletries. Two ignition scenarios were used; one near the door, the other under the bed. A thermocouple tree was located near the centre of the cell. (The effectiveness of the sprinkler system was not relevant to the current research.)

In the tests involving a sprinkler, the sprinkler operated at a 'ceiling' air temperature as follows:

Test 2: 'Ceiling' air temperature - 145°C., time of operation – 5 minutes.

Test 4: 'Ceiling' air temperature - 115°C., time of operation – 4 minutes.

Test 6: 'Ceiling' air temperature - 135°C., time of operation – 5 minutes.

At the time of sprinkler operation air temperatures at low level (190 mm from the floor) were around 30 to 50°C.

TASK 2: EXPERIMENTAL STUDY

As stated earlier, the objectives of this Task were to determine the severity (heat release) of bed fires required to activate a sprinkler (or sprinklers) and to seek to determine the associated likely survivability of a bed occupant exposed to such a fire.

Six experiments were undertaken to determine the severity of a typical fire likely to occur in the room of an occupant in a care home. Information was obtained on the operation of a residential sprinkler system located in the room of fire origin and the associated survivability of the occupant exposed to such a fire. The extent to which the door was open or closed was also considered.

For each test a fire was started in the specified location. The two selected locations were:

1. On the top of the bedcovering.

2. On the clothed 'chest' of the target, at the edge of the bed covering.

For each location two tests were carried out.

In addition, one of these test locations was selected and a calibration test carried out without the sprinkler system operating but with a dummy sprinkler to determine potential actuation time.

A further test considered the effect of a sprinkler that operated on actuation of a smoke detector, i.e. very rapidly.

ASSUMPTIONS AND TEST PARAMETERS

Body target.

It was agreed at the start of the programme that it would be of value to obtain some direct indication of the extent of skin burns (if any) that might be experienced by a person who had set light to their nightwear or bed covers in the agreed scenarios. For a programme of this scale it was considered that the use of a 'thermal test dummy', as used by protective clothing manufacturers and others (firefighter clothing manufacturers, for example), was not appropriate (for reasons of both cost and lead-time). It was therefore agreed with DCLG that an appropriate body target could be formed from a large piece of pork, since the skin and flesh has thermal characteristics similar to human, and that any skin or flesh heat damage could be interpreted for equivalent human injury.

Clothing

The care home industry (via the National Association for Safety and Health in Care Services) was consulted regarding 'typical' nightwear in care homes. Nightwear will usually be provided by the resident, and so cheap, common and readily available poly-cotton men's pyjamas were selected for these tests.

Bed coverings

The care home industry (via the National Association for Safety and Health in Care Services) was consulted regarding 'typical' bed coverings in care homes. We were informed that, in most homes, bed covering will be provided by the home. Duvets and pillows are mostly poly-cotton, with polyester fillings, and duvet covers and pillowcases are cotton. Duvet covers and pillowcases will mostly start out with fire-retardant treatment, but often re-treatment is not carried out, despite frequent laundering. For the purposes of these tests, it was therefore agreed to use un-treated coverings.

TEST SET-UP

The ISO test room attached to the BRE 3m calorimeter was equipped with an operational sprinkler system to an appropriate and agreed specification for residential sprinklers (see below). The calorimeter was operated for Tests 2 to 6 to measure heat release rate (HRR).

The room has dimensions 3.6m long, 2.4m wide and 2.4m high. See Appendix F.

The room was fitted out with bed, mattress, bedcovers and pillows and instrumented with six thermocouples at various heights (a thermocouple tree) and a thermocouple near the sprinkler head.

For each test a 'body target' was constructed from a large portion or side of pork, with skin, approximately 1m long, 0.4m wide and 0.2m thick.

The 'body target' was fitted with two thermocouples (one beneath the skin on the 'upper chest' (i.e. the 'neck'), the other on the surface of the skin of the 'lower chest', beneath the duvet), a heat-flux meter and gas sampling tube for carbon monoxide, carbon dioxide and oxygen analysis, located around the location of the face of the target. The instruments were located to enable an assessment of physiological damage to the target.

The target was 'clothed' appropriately and located in the bed under the duvet. A fresh target was used for each test.

In addition, to establish conditions should a fire occur on a chair or another bed in the room remote from the bed occupant, a further 'secondary' measurement target, away from the fire location, was also fitted with a heat flux meter and gas sampling tube for carbon monoxide, carbon dioxide and oxygen analysis. Temperatures in this location were taken from the thermocouple tree.

Ventilation conditions within the room were considered to be significant and a 'typical' ventilation setting (i.e. door opening width) was agreed with DCLG of 25% door width. For one test the door was closed after ignition and for one test the door was fully open.

A single sprinkler head was located in the centre of the room ceiling. The sprinkler criteria were as follows:

- Type: Viking Freedom VK430, Residential Pendant Sprinkler (4.3 K-Factor)
- Pressure: 0.5 bar to 1.0 bar
- Flowrate: 60 l/min
- Nominal operating temperature: 68°C.

The tests were carried out at BRE during the weeks beginning 10th April 2006 and 17th April 2006.

Results are given in Appendix F.

Initial test

Before the main tests were carried out, a pyjama jacket was ignited, to ensure that it would burn. A single match was applied to the jacket, which burned vigorously. See Appendix G.

TEST 1 - IGNITION OF NIGHTWEAR

- Ignition of nightwear (collar)
- Sprinkler activation dependent on fire size.
- Room door 75% closed.

The sprinkler operated at 177 seconds (i.e. ~3 minutes); ceiling temperature at the time of sprinkler actuation was 88°C.

At this time the body target 'neck' temperature was 22°C. and the skin temperature under the duvet was 44°C.

Over the duration of the test, the peak body target 'neck' temperature was 25 °C and the skin temperature under the duvet was 53°C. Peak temperatures in the room reached 88°C.

Peak heat flux on the target was 58 kW/m^2.

Peak gas concentrations were as follows for the target:

- CO = 0.21%
- CO_2 = 2.6%
- O_2 = 17.7%

Peak gas concentrations at the other location were as follows:

- CO = 0.13%
- CO_2 = 0.44%
- O_2 = 20.6%

The bed occupant almost certainly would not have survived, or at best would have been very severely injured. Other occupants of the room may have survived.

TEST 2 - IGNITION OF BEDCLOTHES

- Ignition of bedclothes (duvet)
- Sprinkler activation dependent on fire size.
- Room door 75% closed.

The sprinkler operated at 114 seconds (~2 min) when the ceiling temperature was 96.2°C. At this time the body target 'neck' temperature was 10.5°C. and the skin temperature under the duvet was 98°C.

The peak HRR was around 50kW.

Peak temperatures in the room reached 96°C. Over the duration of the test, the peak body target 'neck' temperature was 11.5°C. and the skin temperature under the duvet was 138°C.

Peak heat flux on the target was 15 kW/m^2.

Peak gas concentrations were as follows for the target:

- CO = 0.02%
- CO_2 = 0.56%
- O_2 = 20.1%.

Peak gas concentrations at the other location were as follows:

- CO = 0.02%
- CO_2 = 0.6%
- O_2 = 20.4%.

The bed occupant almost certainly would not have survived, or at best would have been very severely injured. Other occupants of the room may have survived.

TEST 3 - IGNITION OF NIGHTWEAR

- Ignition of nightwear (collar)
- Sprinkler activation dependent on fire size
- Room door 75% closed.

The sprinkler operated at 928 seconds (~15 min) when the ceiling temperature was 74°C.

The fire was extensive but flame lengths were comparatively short, with a HRR around 40kW for some time and a peak HRR around 75 kW. Peak temperatures in the room reached 76°C. There was significant smoke from the polyurethane mattress.

At the time the sprinkler operated the body target 'neck' temperature was 74°C. and the skin temperature under the duvet was 86°C.

Over the duration of the test, the peak body target 'neck' temperature was 83°C. and the skin temperature under the duvet was 506°C. (probably due to flame contact).

Peak heat flux on the target was 8.1 kW/m2.

Peak gas concentrations were as follows for the target:

- CO = 0.4%
- CO_2 = 2.0%
- O_2 = 18.9%.

Peak gas concentrations at the other location were as follows:

- CO = 0.35%
- CO_2 = 1.2%
- O_2 = 19.6%.

The bed occupant would not have survived, with the 'body target' suffering extensive burning to the neck and chest. The duvet and much of the mattress were destroyed. Other occupants of the room may have survived.

TEST 4 - IGNITION OF BEDCLOTHES

- Ignition of bedclothes (duvet)
- Sprinkler activation dependent on fire size
- Room door closed.

The sprinkler operated at 153 seconds (~2.5 minutes) when the ceiling temperature was 75°C. At this time the body target 'neck' temperature was 35°C and the skin temperature under the duvet was 8°C.

The fire size was limited as a result of the closed door, and HRR measurements were also restricted due to the closed door; the peak HRR over the test was 6 kW (9kW after the door was opened). The peak temperatures in the room reached 75°C. The 'body target' temperature reached a peak of 45°C on the area of the chest.

Peak heat flux on the target was 3.85 kW/m2.

Peak gas concentrations were as follows for the target:

- CO = 0.06%
- CO_2 = 0.64%
- O_2 = 20.2%.

Peak gas concentrations at the other location were as follows:

- CO = 0.03%
- CO_2 = 0.4%
- O_2 = 20.2%.

It is likely that the bed occupant would not have survived or at best would have suffered severe injuries.

Other occupants of the room are likely to have survived.

TEST 5 - IGNITION OF NIGHTWEAR

- Ignition of nightwear (collar)
- Sprinkler activation five seconds after smoke alarm sounds
- Room door 100 % open.

This test involved a sprinkler which was operated manually on actuation of a smoke detector, to test the potential effectiveness of a rapidly responding sprinkler.

The fitted smoke alarm in the room detected the fire 33 seconds after ignition and the sprinklers were operated manually 5 seconds after the sounder activated, when the ceiling temperature was 17°C. At this time the body target 'neck' temperature was 16°C and the skin temperature under the duvet was 16°C.

Peak temperatures in the room reached 18°C. Over the duration of the test, the peak body target 'neck' temperature was 17°C and the skin temperature under the duvet was 16°C.

Peak heat flux on the target was 0.1 kW/m2.

Gas concentrations did not exceed ambient levels and no heat release data was recorded (measurements were below recording threshold).

Both the bed occupant and the other occupants of the room are very likely to have survived, with only minor injuries sustained.

TEST 6 - IGNITION OF NIGHTWEAR

- Ignition of nightwear (collar)
- Dry sprinkler pipe, no intervention from the sprinkler
- Room door 75% closed.

This was a calibration test carried out without the sprinkler system operating but with a dummy sprinkler to determine actuation time. This test was to be terminated manually when peak heat release was passed.

The fitted smoke alarm in the room detected the fire 25 seconds after ignition. The dummy sprinkler head operated 3 min 34 seconds after ignition (the ceiling temperature was 50°C at this time). The fire on the bed grew steadily, reaching a peak of 476kW, with the temperature in the room reaching in excess of 300°C. The mattress, duvet and pillows were all fully consumed.

The peak ceiling temperature was 320°C.

Over the duration of the test, the peak body target 'neck' temperature was 57°C and the skin temperature under the duvet was 754°C (flame contact).

Peak heat flux on the target was 37 kW/m2.

Peak gas concentrations were as follows for the target:

- CO = 0.2%
- CO_2 = 2.9%
- O_2 = 17.5%.

Peak gas concentrations at the other location were as follows:

- CO = 0.03%
- CO_2 = 0.33%
- O_2 = 20.2%.

Any occupants of the room are very unlikely to have survived.

4 Analysis and discussion

TASK 1: LITERATURE REVIEW

A literature review has been carried out.

Duvets are mentioned frequently in the case studies found to date; it is possible that the make-up and materials used in duvets give much more dangerous fire performance than blankets. Alternatively, it may indicate the wider popularity of duvets in modern homes.

Many of the incidents of clothing fires involve young children. However, there are a substantial number of fires where old peoples' nightwear has ignited, and while such fires are not always fatal, they do cause bad burns (and which can then result in fatality later, for example, as a result of septicaemia).

Smoking in bed appears to be a major cause of bed fires. Involvement of the mattress can also be significant in the development of a fire, probably due to its mass.

It is evident that fires involving bedding or clothing need not be invariably fatal. The case studies appear to show that there should be opportunities for sprinklers to make a difference.

TASK 2: EXPERIMENTAL STUDY

The following table summarises the findings.

In general the results from all the tests are consistent, given the differing conditions and random nature of fire spread over the bed; the higher heat flux recorded in Test 1 is due to the proximity of the flames to the heat flux meter.

SUMMARY OF TEST RESULTS

Test	**1**	**2**	**3**	**4**	**5**	**6**
Conditions	Collar	Duvet	Collar	Duvet-Door Closed	Collar – Sprinklers operated	Collar – No sprinkler
Smoke detector operation (Seconds)	n/a	12	20	32	33	25
Sprinkler operation (Minutes)	2	1.9	15	2.5	0.5	3.5 (dummy)
Sprinkler operation (°C)	88	96	74	75	17	50 (dummy)
Peak value Room temp. (°C)	88	96	50	75	18	300
Peak value (under skin) Neck Temp. (°C)	25	11.5	83	35	17	57
Peak value (above skin) Body temp. (°C)	53	138	506	45	16	754
Peak value Heat flux to target (kW/m^2)	58	15	8.1	3.85	0.1	37
Peak value HRR (kW)	-	50	75	9	-	476
Target CO %	0.21	0.02	0.4	0.06	n/a	0.2
Target CO_2 %	2.6	0.56	2.0	0.64	n/a	2.9
Target O_2 %	17.7	20.1	18.9	20.2	n/a	17.5
Other CO %	0.13	0.02	0.35	0.03	n/a	0.03
Other CO_2 %	0.44	0.6	1.2	0.4	n/a	0.33
Other O_2 %	20.6	20.4	19.6	20.2	n/a	20.2

All toxic gas measurements are quite low and considered to be survivable. The highest recorded value of CO was 0.4% (Test 3) but this was late in the test and of limited duration. Test 3 was notable for the very late operation of the sprinkler, and hence large quantity of toxic gases produced.

Typical values for CO exposure are:

- 20,000 ppm.min. Dizziness (2 %.min.)
- 30,000 ppm.min. Collapse (3 %.min.)
- 60,000 ppm.min. Death (6 %.min.).

Over a 20 minute exposure, 20,000 ppm.min. would be inhaled from gases at a concentration of 1000 ppm, i.e. 0.1%. 60,000 ppm.min. would be inhaled from gases at a concentration of 3000 ppm, i.e. 0.3%. In all tests (except Test 6) these concentrations were achieved (if at all) for very short periods of time.

The FED analysis carried out for Test 3 and Test 6 showed predicted blood carboxyhaemoglobin concentrations to be well below the dose needed to cause incapacitation of a person in the bed.

Work by Purser elsewhere (not published) has indicated that otherwise healthy elderly people are not more susceptible to these gases than younger people; however they are more prone to complications which arise from exposure to smoke (e.g. lung complaints). Elderly people are more sensitive to heat exposure and burns. Elderly people with other medical complaints clearly are at greater risk for a number of reasons.

The experimental programme has demonstrated that a sprinkler in the bedroom will not react quickly enough to prevent death, or very severe injury, to the occupant of a bed where the nightwear or bed coverings of the bed have ignited; for Tests 1, 2, 3 and 4, it is likely that the bed occupant would not have survived or at best suffered severe injuries. But other occupants of the room are likely to have survived.

Test 3 demonstrates that, probably in exceptional circumstances, a very slow burning fire can occur on bed coverings, with low temperatures within the room, and consequently very extended sprinkler response times.

From the FED analysis carried out for Test 3 and Test 6 the comparison shows that for a room with a sprinkler:

- For the person in the bed the conditions became untenable very rapidly as the fire entered its rapid growth phase, with death predicted at around five minutes in that location as a result of heat and/or flame contact
- For an occupant of the bedroom elsewhere the conditions do not become untenable.

The comparison shows that for a room without a sprinkler:

- For the person in the bed the conditions became untenable very rapidly as the fire entered its rapid growth phase, with death predicted at around five minutes in that location as a result of heat and/or flame contact

- For an occupant of the bedroom elsewhere the conditions became untenable very rapidly as a result of convected heat.

Where a sprinkler operates in response to a smoke detector, very little damage or injury occurs.

COST BENEFIT ANALYSIS

The experimental results indicate that (for the scenarios examined) sprinklers are unlikely to save an elderly person who is involved in a bedding/clothing fire. We have re-examined the cost benefit analysis (Ref. 1) accordingly.

In most cases in the earlier study it was assumed that people involved in a clothing/bedding fire would not survive, so there is very little change to the previously established estimate of sprinkler effectiveness.

The analysis shows that the slight change to sprinkler effectiveness (as a result of the present study) is not going to change the following conclusions:

- If the costs provided by the Fire Sprinkler Association are correct, sprinklers will be cost effective in care homes (>95% confidence level)

- If the higher costs provided from other sources are correct, sprinklers will not be cost-effective (<80% if trade-off allowed, or <50% confidence level if provided as an additional safety feature).

It has been shown that whether sprinklers in care homes are cost-effective or not is determined by the installation costs; the issues relating to the appropriate sprinkler effectiveness factor do not affect this conclusion.

5 Conclusions

Where a fire has occurred involving either the nightwear or bed clothes of an occupant of a bed, the fire experiments have indicated that sprinklers alone are unlikely to operate soon enough to prevent the occupant of a bed being fatally injured or suffering very serious injuries from flames and/or heat.

However, in most situations where a sprinkler operates, other occupants within the room should survive, since the heat and toxic gases within the room are kept within tenability limits by the sprinkler system.

A smoke alarm fitted in the room will provide early warning of a fire and should alert the occupant and nursing staff to the problem. If the smoke alarm is linked to the sprinkler system, early suppression of the fire is also possible. In such cases all occupants of the room, including any person in the affected bed, should survive. However, such a system would be far more complex (and expensive) than a ‘normal’ sprinkler system, and there would be a possibility of frequent false operations, which could cause distress, and possibly harm, to elderly residents (e.g. from shock or pneumonia).

While this project has been concerned with care homes for the elderly, many of the findings are relevant to other types of care home, in particular those where the residents have only limited ability to respond themselves to a fire involving their clothing (for example children's homes, or homes for those with mobility disabilities).

Note: Since the completion of this programme of work, the authors have been notified of a case of a fire in a New Zealand residential community care home (Ref. 4). In this incident (which is summarised in Appendix C) one occupant of a sprinklered bed room set fire to themselves. The sprinkler system operated but they died of burns. However, the other occupant survived.

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7 Acknowledgements

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At BRE; Kelvin Annable, Paul Rock and Dave Purser.

Appendix A – Summary of the research

DCLG Buildings Division has commissioned BRE to carry out a project entitled Sprinkler Effectiveness in Care Homes.

A recent review of fire statistics had indicated that most fatalities in care homes arise from occupants accidentally setting fire to bedclothes, nightclothes etc whilst they are in bed. There was no available information to determine whether the severity of such a fire at the time the sprinkler operates would be invariably fatal to the person involved or whether there is a good chance they would survive. The most recent research only generally considered people in the room of origin - it did not differentiate between people in intimate contact with the fire and those remote from it.

There was a need to collect more information and evidence to ensure that current assumptions in respect of the life-saving benefits of residential sprinklers stand up to scrutiny. The overall aim of the project has been to gather information on the nature of fire injuries and fatalities in care homes in the context of the life-saving benefits of sprinklers in the room of fire origin. This information is intended to be used to further inform the AD B consultation and revision process.

The project involved a search and review of existing information, supplemented with an important small but focussed experimental element and comprised the following activities:

Literature review.

- Search and review existing information on sprinkler effectiveness in protecting life in the room of origin
- Gather more detailed information on room of origin fire injuries and fatalities in care homes, particularly on those in intimate contact with the fire.

Experimental study

- Determine the severity (heat release) of bed fires required to activate a sprinkler (or sprinklers)
- Measure the toxicity and FED, based on CO, CO_2 and O_2 measurements
- Seek to determine the likely survivability of a bed occupant exposed to such a fire; as far as possible, taking account of potential generic age and health effects.

Analysis.

- Re-assess the overall effectiveness of sprinklers in care homes (in relation to that previously assumed in DCLG research
- Re-determine the cost benefit analysis for sprinklers in care homes.

There are many fires each year involving elderly people where clothing or bed coverings have ignited. Such fires are often fatal, or cause serious burns. Many are a result of smokers' materials.

Where a fire has occurred involving either the nightwear or bed clothes of an occupant of a bed, the fire experiments have indicated that sprinklers alone are unlikely to operate soon enough to prevent the occupant of a bed being fatally injured or suffering very serious injuries from flames and/or heat. However, in most situations where a sprinkler operates, other occupants within the room should survive, since the heat and toxic gases within the room are kept within tenability limits by the sprinkler system.

A smoke alarm fitted in the room will provide early warning of a fire and should alert the occupant and nursing staff to the problem. If the smoke alarm is linked to the sprinkler system, early suppression of the fire is also possible. In such a case all occupants of the room, including any person in the affected bed, should survive. However, such a system would be far more complex (and expensive) than a 'normal' sprinkler system, and there would be a possibility of frequent false operations, which could cause distress, and possibly harm, to elderly residents (e.g. from shock or pneumonia).

While this project has been concerned with care homes for the elderly, many of the findings are relevant to other types of care home, in particular those where the residents have only limited ability to respond themselves to a fire involving their clothing (for example children's homes, or homes for those with mobility disabilities).

Appendix B – DTI information

DTI HOME SAFETY NETWORK

The following information has been selected from the DTI Home Safety Network at: http://www.dti.gov.uk/homesafetynetwork/cf_intro.htm

CLOTHING FIRES

Introduction

The UK has stringent nightwear fire safety laws but it's important that the public remains fully aware of the precautions to take when purchasing and wearing nightwear.

This information provides background on a number of issues including the people most at risk and why; clothes which pose particular risks; sources of ignition; current legislation; accident prevention and current research into flame-retardant textiles.

Who is most at risk and why?

Children and the elderly are at the greatest risk from nightwear fires, and females are more than twice as likely as males to suffer. The reason for the high number of women and girls suffering burns varies according to age, but is most commonly due to the type of nightwear they can wear such as flimsy, free-flowing, nightdresses that can more easily catch light and spread flame more quickly than with tighter-fitting garments.

Ignition sources

The most frequent sources of ignition for clothing fires are: cookers (particularly open flame gas cookers and hobs), gas fires, open fires, matches, cigarette lighters and candles.

Current legislation

The General Product Safety Regulations 2005 place a general overall safety requirement on all clothing and, for nightwear, there are specific national regulations.

The Nightwear (Safety) Regulations 1985 require children's night-dresses, dressing gowns, bath robes and other similar garments to satisfy flammability performance requirements as specified in British Standard 5722. These requirements are expressed as a rate of flame spread and involve following strict testing procedures. Items such as children's pyjamas, babies' garments and adult nightwear do not have to meet these requirements but must carry the specified label according to whether they do or do not. The precise wording of the warning label is specified in the regulations, including the type, colour and size of lettering, along with options for positioning.

Labelling

Manufactures of pyjamas, baby's garments and cotton terry towelling bathrobes who choose to meet the flammability requirements of the Nightwear (Safety) Regulations 1985 must include a label with the wording 'LOW FLAMMABILITY TO BS 5722' or 'KEEP AWAY FROM FIRE'.

Pyjamas, baby's garments and cotton terry towelling bathrobes which are not flame resistant must include a label with the wording, 'KEEP AWAY FROM FIRE'.

Please note, however, that a label which reads 'LOW FLAMMABILITY' does not indicate a completely flameproof garment, i.e. all clothing should be kept away from fire.

You should follow the washing instructions on flame resistant garments, which include not washing them at more than 50°C and checking the suitability of your washing agent.

Enforcement

The Nightwear (Safety) Regulations 1985 are enforced by Trading Standards. Anyone who fails to comply with the Regulations is liable to imprisonment, a fine, or both.

Elderly Feature - The Fatal Risk of Flaming Fabric

The warm glow of an open fire in winter is a sight that we have all welcomed as we come in from the cold - a fire, however, can have tragic consequences if you get too close to the flames or even drop-off sitting in the warm atmosphere.

People over the age of 60 suffer more than 80 per cent of the fatalities caused by clothing catching light according to latest figures. Each year about 80 people in Britain are killed and over 200 seriously injured in the home when their clothing accidentally catches fire.

One such tragedy recently happened to a 68 year old man when he fell asleep in front of his open fire. He was too close for too long and the heat caused his clothes to ignite and he suffered fatal injuries from burns to his legs.

One of the reasons for a high number of deaths in older people, is the inability of an older person's body to cope with the effect of burns. If a person's age plus the percentage of burns exceeds 100, doctors and other medical professionals know that the chances of survival are usually low.

The majority of accidents occur during the winter months. Department of Trade and Industry research shows that just under half of all these fatal accidents involve electric fires and almost four fifths of the fatal accidents caused by cookers involved gas cookers.

General accident data show that the older we are the more accident prone we become. Added to this, evidence from burns units indicate that as we grow older our reactions are slower, we have lower dexterity and therefore find it difficult to put out a fire once alight. Older people are often alone when accidents occur and help is not always at hand.

There are safety regulations which help to reduce the risks of clothing flammability but these can only do so much - it is just not possible to make clothes that will not burn under any conditions. It is often the style of clothes rather than the actual material which poses most fire risks, so take particular care when wearing loose fitting and flowing garments such as dresses, dressing gowns, night-dresses and scarves. High risk items such as nightwear carry warning labels which you should look out for when shopping for clothes.

If you are elderly, living alone, or if you have elderly parents living with you, there are some straightforward common sense precautions which will help guard you against the risk of clothing fire accidents:

TAKE CARE WHEN USING MATCHES AND CIGARETTES
Watch your clothing when lighting a match. Never smoke a cigarette when feeling sleepy, particularly if you are in bed.

WATCH OUT FOR LOOSE CLOTHING
Particularly if you are close to an open fire, around gas cooker hobs or lit candles.

DON'T SIT TOO CLOSE TO A FIRE
Particularly if you feel sleepy and might doze off. Apart from clothing igniting there is also the risk of sparks flying onto your clothes.

CASE STUDY DETAILS TAKEN FROM ACCIDENT STATISTICS

Of the 80 fatal accidents which occur in Britain each year, accidents included:

An 85 year old who suffered fatal burns after her nightdress came in contact with an open gas ring. The old lady suffered 60 per cent burns.

An elderly lady of 84 suffered 80 per cent burns when the scarf she was wearing came into contact with an open fire and ignited.

A 60 year old man was fatally injured when he fell asleep trying to light a cigarette. The match fell on his towelling dressing gown which caught alight.

An 80 year old women was cooking chops on an electric stove when her nylon sweater ignited from the heat. She was fatally injured.

Clothing Flammability Accidents
All clothes burn. Most clothing flammability accidents are caused by carelessness.

There are about 750 clothing flammability accidents each year.

Every year there are about 80 fatal accidents, 225 severe injuries and 445 minor accidents.

The three main causes are cookers (especially gas hobs), fires (gas, coal and electric) and matches.

The group at gravest risk is people over 60 years old, especially women over 70.

Young girls, especially teenage girls aged 12-17, are the highest risk groups for severe injuries, which can involve extensive stays in hospital and plastic surgery.

Loose fitting, 'floaty' garments, especially dresses, nightdresses and dressing gowns, need extra care. This is why young girls and elderly women are at highest risk.

Clothing flammability accidents study

Summary

In the UK, nightwear for children under 13 years old must meet specified flammability performance and labelling requirements. Legislation regarding children's night clothes was also found to be in force in the Netherlands, Eire, the USA, Australia and New Zealand.

There are at least 750 clothing flammability accidents in the UK each year, i.e. 13.3 accidents per million population (pmp). Further cases were identified, but could not be fully verified as 'bona fide' cases within the definition of this study. The number of accidents is stable, but varies about the mean level (i.e. 750 accidents ± 25 %).

An estimated 80 (11 %) clothing flammability accidents are fatal (1.4 pmp). 670 (89%) are non-fatal, of which 225 (30%) involve severe burns requiring in-patient admissions (4 pmp) and 445 (59%) are minor accidents (7.9 pmp).

Overall, burns account for 99% of all injuries. Injuries caused by inhalation of fumes/suffocation are minimal for non-fatal accidents (less than 0.3%), but account for 9% of fatal accidents.

Females account for 55 % of all clothing flammability accidents and males 45 %.

Minor accidents occur in all age groups. Above average levels of minor accidents (UK average is 7.9 pmp) generally occur amongst all children under 18, the highest being boys aged 14-17 (24.5 pmp). The frequency of minor accidents steadily decreases as adults get older.

The proportion of accidents that are severe increases significantly for children under 14 (26% minor 36% severe) and elderly people over 60 (12% minor 25% severe). Fatalities are almost entirely in the over 60 age group (82%), especially the over 70s, and are very low in other age groups.

Above average numbers of severe accidents (of the UK average of 4 pmp) are found amongst girls under 18, i.e. 0-5 years (12 pmp), 6-13 years (9.4 pmp) 14-17 years (12.2 pmp), and women over 70 (9.7 pmp). Above average fatalities (of UK average 1.4 pmp) are found amongst women over 70 (8.8 pmp) and men over 70 (7.7 pmp). Severe/fatal accident levels are insignificant/low in most other age/sex groups.

The reasons for the increased proportion of severe/fatal accidents amongst older people (over 60) are thought to be that older people:

- are less aware that they have caught alight;
- often lack the motive capabilities to extinguish flames;
- are often alone, so continue burning, because nobody is at hand to put out the fire for them;
- suffer the after effects of burns to a far greater extent than younger people.

The other main reason for higher levels of severe/fatal accidents in the high risk female groups is that potentially loose fitting/flowing garments (notably dresses and nightdresses) were involved in 75% to 100% of the accidents in these groups.

The three most frequent causes of clothing flammability accidents are cookers - mainly gas hobs (240 accidents each year), fires - gas, coal and electric (159) and matches (79). Outside/garden fires (45), smoking (38), lighters (29) and candles (14) are the other main causes of accidents.

The most frequent causes of severe injury accidents are fires (37%), followed by cookers (19%), matches (18%) and lighters (7%). The most frequent causes of fatal accidents are fires, especially electric fires (28%), followed by cookers - mostly gas cookers (26%) and smoking (22%).

Naked flames (sources include gas cookers, gas/coal fires, outside fires, candles, matches and lighters) are present in a high proportion (approximately 75% of known causes) of all clothing flammability accidents.

Daywear accounts for 60% of clothing flammability accidents, and nightwear 28%. Shirts/blouses (93 accidents), trousers (85) and dresses (82) are the three daywear garments most frequently involved. Coats/jackets (38), jumpers/cardigans (38), T-shirts (35) and scarves (25) are also significant. Night-dresses (79) and dressing gowns (74), followed by pyjamas (60) are the three nightwear garments most frequently involved.

Loose fitting/flowing garments (especially dresses/skirts and nightdresses) are more frequently mentioned in severe/fatal clothing flammability accidents.

Where the material was mentioned, natural fibres account for about 42% of the accidents, synthetic fibres 42% and natural/synthetic mixed fibres 16%. The most common materials specifically mentioned were cotton (29%), nylon (26%), cotton polyester mix (13%), wool (6%) and 'jeans material' (4%).

OVERALL CONCLUSION

The highest risk groups, i.e. where there are most severe/fatal accidents per million population are - women over 70, girls under 18, and men over 70.

In addition boys aged 14-17 are especially prone to minor accidents, usually due to playing with matches, lighters and outside fires.

Clothing at highest risk is loose fitting, flowing garments (especially dresses, dressing gowns and nightdresses) which are mainly worn by women. No specific type of fibre was identified in this study as being consistently higher risk.

Appendix C - Incident reports

Web results, compiled by Kelvin Annable
The following fire reports (not in date order) have been located from the web and are quoted here verbatim:

MAN DIES AFTER BED CATCHES FIRE

1st January 2006

A man has died from smoke inhalation after his bedding caught fire in the early hours of New Year's Day.

Fire services were called to the detached house in Blackmore End, near Braintree, Essex, after the victim's mother woke after smelling smoke. The elderly woman went to investigate and found her son's bedroom filled with acrid smoke. The man, in his 40s, was pronounced dead at the scene. The small fire was quickly extinguished by firefighters.

A spokesman for Essex Fire and Rescue Service said four smoke detectors had been fitted at the house but they were all found not to be working. He said: 'Unfortunately the installed smoke detectors were not functioning. They may have, if they had been operating, prevented this loss. 'We would urge anyone who has a smoke detector to check it weekly and change the battery annually.'

The cause of the fire is not yet known but it is not being treated as suspicious. An investigation is being carried out by the fire service and the police. Fire investigators are looking into the possibility that the blaze was started by a cigarette. The victim's mother was being cared for by relatives nearby, the spokesman said.

MAN INJURED AS PYJAMAS CATCH FIRE

9th January 2006

An elderly man is being treated in hospital for burns after his pyjamas caught fire at a residential home in Cheshire.

Fire crews were called to Houghton Hall on Greenwood Crescent in the Orford area of Warrington, in the early hours. The fire had been put out before Cheshire fire crews arrived and the man was taken to hospital suffering from burns to his shoulders, arms and chest. An investigation is under way at the home into how the fire started.

ELECTRIC HEATER CAUSES WALTHAM CROSS FIRE

17th March 2006

Cheshunt firefighters are urging people to take extra care this winter after a heater caused a severe fire in a Waltham Cross home.

Firefighters were called to Kenworth Close, at just before 11am yesterday (Monday), to reports of a bedroom fire. On arrival the crews found a first floor bedroom was well alight but luckily the family inside the house had escaped safely.

Station Officer Steve Holton, who is based at Cheshunt Fire Station, said: 'We believe the fire started because an electric fire had been placed too close to a duvet. The duvet caught light and a severe fire took hold. A lot of damage was caused to the bedroom and the rest of the house was smoke logged.'

County Councillor David Lloyd, Executive Member for Community Safety, said: 'Our fire service recently launched its Winter Watch campaign, urging people to take care during winter months. We know people reach for electric blankets and fires when it's cold but we're urging people to be safe. The Service now offers free home fire safety checks and I'd encourage people to make an appointment with their local firefighters.'

WARNING AFTER BLAZE KILLS GRANDFATHER

25th August 2001

Fire service officials have warned of the dangers of smoking in bed after a grandfather died following a blaze in his flat. West Midlands Fire Service said the victim, in his 60s, died in Birmingham's Selly Oak Hospital early on Saturday after being rescued from his bedroom by firefighters.

Assistant Divisional Officer Malcolm Westwood said the tragedy could have been avoided if the man had not been smoking in bed or if the property had been fitted with a smoke alarm.

Fire crews were alerted to the blaze, which is thought to have started when the man's duvet caught fire, at about 3.30BST.

WOMAN 'SET LIGHT TO HUSBAND'S BED'

13th March 2003

A woman from Berkshire has appeared at Reading Crown Court, accused of setting fire to the bed where her husband was asleep. Caroline Barry, 49, of Meadow Close in Thatcham, is charged with one count of arson and one of assault occasioning actual bodily harm.

She was arrested after the duvet under which her husband Michael was asleep, caught fire at the couple's home. Mr Barry escaped serious injury in the fire on 9 January. Mrs Barry was granted unconditional bail and will appear in court again on 24 April.

FAMILY FLEE FROM BEDROOM BLAZE

22nd April 2003

A couple and their daughter had to flee their home when an electric duvet caught on fire. The fire at their home in Church Lane, Witney, left a bedroom badly damaged.

Firefighters from Witney were joined by two Red Cross victim support units at the scene at 11.15pm on Good Friday.

The family were awakened by a smoke alarm which was set off when the electric duvet caught fire. It had been switched on earlier in the evening. The family fled the house and called emergency services. Firefighters managed to contain the fire in the bedroom of the house and said things would have been worse if a properly placed smoke alarm had not woken the family in time.

Station officer John Fathers said: 'Fire crews wore breathing apparatus and quickly prevented the fire from spreading throughout the house. 'The correct positioning of a fully operational smoke detector and quick action of the occupiers and crews undoubtedly ensured the fire didn't have worse consequences.'

Oxfordshire Fire and Rescue Service has warned people who use electric blankets to make sure they are in good working order and that smoke alarms are properly located and installed with working batteries in their homes.

MAN ON DRINKS BINGE RESCUED FROM BLAZE

4th June 2001

A man had a lucky escape after his bed caught fire as he slept off a drinking binge.

A neighbour alerted the fire brigade at about 3.10am on Saturday when he saw smoke coming from a house in High Street West, Coatham, Redcar. Firefighters arrived to find the bed alight and the occupier sound asleep. Station officer Peter Young said: 'It was a young man who had been out drinking. He had left a cigarette on the bed earlier in the day and it had caught fire. He had put the fire out, then fallen asleep, and it had flared up again. The man was very lucky, as he had drunk so much that we had trouble waking him.' He added: 'People should be very careful when smoking.'

MAN BURNS IN HIS BED

30th March 1988

Window cleaner Roy Helm is in hospital with severe burns after his bed caught fire as he slept.

His two flatmates, Kevin Lockyear and Alex Stewart, managed to escape the blaze but Roy, who is in his mid-20s, suffered burns to 15 per cent of his body and serious effects from smoke inhalation. He was taken to the John Radcliffe Hospital in Oxford before being transferred to the burns unit at Stoke Mandeville Hospital in Aylesbury, where his condition was today described as stable.

Ten firefighters tackled the blaze in the first-floor bedroom at the house in Lytton Road, Florence Park, yesterday, which is believed to have started after an electric fire fell on the bed. Labourer Kevin, 24, said he was woken up by his flatmates shouting and thought a burglar had got in. 'I opened the door and this big heat wave just hit me in the face,' he said. 'I phoned for the fire brigade, and the other two were trying to put the fire out. Roy's hands were burned. I was straight out of there - I could see the flames and the window cracking. 'If the fire had gone a bit further up the corridor I would have been done for.' He added: 'One of my worst fears is dying in a fire but at the time I didn't really think about it. I just went for the door.'

Station Officer Richard Bowley, of Oxfordshire Fire Service, said: 'They were very lucky to be able to escape. 'The premises didn't have a smoke detector. If they had had one, it would have given them a much earlier warning.' Fire officers were today still at the scene of the fire to investigate the cause.

LAS VEGAS FIRE & RESCUE - THE YEAR 2005 IN REVIEW

10th September 2005

A woman received second degree burns after her bed caught fire after she fell asleep while smoking in bed in her home in Las Vegas. Damage was estimated at $50,000.

NO TITLE

25th February 2005

A quick-thinking neighbour was praised for helping save the life of a man who slept as his bed caught fire early today.

MAYFAIR MAN DIES IN FIRE

9th April 2003

A Lower Mayfair man who had been accepted into the Philadelphia Fire Department's next firefighter training class died when his bed caught fire in his home on Sunday night. Investigators believe that cigarette smoking caused the blaze.

Patrick Hahn, 27, of the 2700 block of Lardner St. was found dead by his mother, Patricia, shortly after 3:30 p.m. on Monday, according to Sgt. Joe Gindele of the Philadelphia Police Department's Northeast Detectives Division. The victim was in a second-story front bedroom. Neighbours later reported smelling smoke around 10 p.m. on Sunday, but nobody called 911. The fire torched Hahn's bed and mattress but burned out on its own when the oxygen supply in the room expired, official sources said. 'He (likely) fell asleep with a lit cigarette that ignited the bed with the door shut and the air conditioner on low,' Gindele said. 'The fire destroyed the room. But after the oxygen ran out, the fire burnt out.' Fire investigators believe Hahn died of oxygen deprivation and smoke inhalation.

Hahn was expected to start training at the Fire Academy next month, Gindele said, joining his father and a brother in the fire department. The victim's father, John Hahn, is a 37-year veteran firefighter assigned to Engine 71 at Cottman and Loretto avenues. Brother Thomas Hahn is a two-and-a-half-year firefighter assigned to Engine 64 at Rising Sun Avenue and Benner Street. The fire department conducted fire safety demonstrations on the victim's block on Tuesday afternoon.

WOMAN INJURED IN MORNING TRAILER HOME FIRE

17th April 2002

A woman was taken to Trinity Regional Medical Center with burns after a fire consumed her home Tuesday. Her condition was not available Tuesday night.

Gwen Bradt, of 1338 Third Ave. N.W., told assistant fire chief Gene Habben she was smoking in bed when she fell asleep. The fire woke her, he said she told him. The house is on lot No. 6 of the Palace Park Trailer Court. Bradt was the only occupant at the time of the mobile home which she owns. The fire started in the bedroom.

'When we arrived at 10:16 a.m., the back portion of the house was totally involved,' Habben said. 'It had burned through the exterior walls.' Damage was also caused to the house to the north. Habben said its siding was warped from the heat. The fire was out by10:25 a.m., however, the fire department was on the scene for hours to make sure none of the things in the house were smouldering and would reignite.

The fire department was called at 10:11 a.m. by a neighbour who was outside working in a yard when the smoke was spotted. None of the other residents witnessed anything

MAN, 52, DIES IN HOSPITAL FIRE

19thJune 2002

A 52-year-old man died from burns he suffered when his hospital bed caught fire at the Hart County Hospital. The fire forced the evacuation of 34 patients at the hospital. No other related injuries were reported.

The man, who was hospitalized with an upper-respiratory infection and was on oxygen, was apparently trying to light a cigarette when the fire started. Kenneth

Mattox suffered severe burns on his upper body and was transported to the burn center in Augusta, Ga., where he died. Smoking is not allowed anywhere in the hospital building, a spokeswoman said. 'Most of the damage was confined to the room,' hospital spokeswoman Margaret Peterson told WYFF News 4's Kisha Foster. 'There was some smoke in the hallway.'

CLACTON: WOMAN FLEES BLAZING BED IN FLAT

3rd October 2000

A woman fled for her life after her bed caught fire. It is believed the woman - who has not been named - was smoking and dropped the cigarette into the bedding. She realised the danger almost immediately and escaped from her third floor flat in Thoroughgood Road, Clacton.

Fire crews arrived at about 9.45pm last night (Monday). She was taken to Colchester General Hospital suffering from smoke inhalation but released after treatment. A spokesman for the Essex Fire Service said two firefighters using breathing apparatus dealt with the blaze within ten to 15 minutes.

The bed was destroyed and much of the flat was smoke-damaged. 'It appears the woman had been smoking in bed,' the spokesman added.

DUVET FIRE KILLED THREE CHILDREN

2nd December 2002

Three young children died in a house fire after one of them deliberately set light to a duvet, an inquest heard.

The children were alone in the house on the Townsend estate in Bournemouth when the fire broke out at 0900 GMT on 13 April. Neighbours tried in vain to save them and a fourth child was rescued by firefighters. Amanda Gallagher, seven, her brother Ashley, six, and their 22-month-old sister Alesha all died in the fire. Fire investigators say they are almost certain that six-year-old Ashley Gallagher deliberately set fire to his mother's duvet cover. The jury heard that his mother, Tracey Lane, had taken him to a psychiatrist to be assessed for Attention Deficit Hyperactivity Disorder after complaining of behavioural problems including playing with matches.

Coroner Mr Sheriff Payne told the jury they would have to decide if any blame should be attached to Miss Lane as she was out of the house at the time. He said: 'You will have to decide if there was some element of blameworthiness because the mother arrived at the house just before the fire brigade.' The hearing heard that Miss Lane had regular contact with social services during the upbringing of all her children but was considered a good mother. The inquest was adjourned until Wednesday.

OFFICIALS SAY SMOKING CAUSED BLAZE AT HIGH RISE

15th September 2004

Careless smoking is believed to be the cause of a fire that burned a woman living at a housing authority high rise on Alta Drive near Decatur Boulevard this morning, fire officials said.

Firefighters were called to the James H. Downs Towers about 3 a.m. When they arrived flames were blowing out of a window of an apartment on the fourth floor, fire department spokesman Tim Szymanski said. Firefighters found a woman sitting in a wheelchair just inside the door under an activated fire sprinkler. Fire investigators believe the woman was smoking in bed and the mattress caught fire. The woman got into a wheelchair but apparently couldn't get the door open. The woman's cat died in the fire, Szymanski said.

NO TITLE

17th January 2002

A 60-year-old female suffered severe burns over 40% of her body when her mattress caught fire due to an improperly extinguished cigarette. Investigation also showed that the smoke detector had been disabled.

FIREWORKS INCIDENT HOSPITALISES PENSIONER

Grampian Police are investigating a fireworks incident which left an elderly Aberdeenshire woman in hospital.

The sixty nine year old was preparing to go to bed at her home in the village of Drumlithie late last night when a firework smashed through her window. She was taken to hospital suffering from smoke inhalation after her mattress caught fire.

SMOKER DIES IN BED

3rd April 1999

A young man was engulfed in flames after a mattress caught fire when he fell asleep smoking a cigarette.

Tragic Angus McKinsey suffered horrific injuries as he lay on the burning bed in a drunken stupor, an inquest heard. He was plucked from the flames by firefighters, but died in hospital six days later. The 24-year-old clerk, from Crofton Road, Orpington, had been out drinking with pal Thomas Hart on February 5 last year before the pair returned to Hart's home in Avenue Road, Isleworth, Middlesex. They carried on drinking and listening to music in Hart's room until going to bed at about 3am.

Mr McKinsey slept in a spare room at the house and smoked a last cigarette. He fell unconscious before it was stubbed out. The butt ignited the mattress, which smouldered for at least three hours before the entire bed burst into flames.

Westminster Coroner's Court heard that Mr Mckinsey, who had downed at least six pints of lager before hitting the whisky, was so drunk he probably didn't wake up until it was too late. Blaze investigator John Galvin told the hearing that a packet of Marlboro was found on a bedside table in the room and a number of butts were on the floor. There was no ashtray. Recording a verdict of accidental death Dr Paul Knapman said: 'What a tragedy. He died as a result of smoking in bed while under the influence of alcohol.'

FAMILY FLEE BLAZE

6th September 2001

A family was forced to flee from their home last night as a fire swept through a bedroom after a mattress caught fire in a front bedroom at the house in Ramsey Avenue, Farnworth.

A couple and their two children were alerted by smoke alarms and rushed outside to raise the alarm. No one was injured in the blaze but the bedroom was destroyed. A fire brigade spokesman said children are believed to have started the blaze.

LODGER SAVES LANDLADY IN FIRE – ON FIRST NIGHT

29th July 2004

A lodger earned his keep on the first night he moved in . . . by rescuing his new landlady from a burning bedroom. Ian Mellor, 39, moved into the spare room of work colleague Roy Jackson and his wife Lesley in Middleton. By the following morning, he had saved Lesley's life after she was trapped by a fire.

The drama of the first night began when an electrical fault cut power to the house and the residents relied on candles to see what they were doing. At around midnight, when Roy was sitting downstairs and Ian was settling into his new room, a candle set fire to furniture in Lesley's room after she had fallen asleep in bed.

Ian said: 'I was getting ready to go to bed, then I heard Lesley screaming `The bed's on fire'. I ran in and I could just make out where Lesley was trapped and was lying on the floor. 'I tried batting down the fire with my bathrobe but I couldn't get to her so I had to run downstairs and fill some pans with water to try to put it out.' Ian, with Roy's help, dragged the unconscious Lesley to the top of the stairs. The lodger put her over his shoulder and carried her out to safety outside.

Roy closed the bedroom door to contain the fire before joining them. Ian then dialled 999 and a fire crew from Heywood arrived to put out the fire before it could spread. Ian and Lesley were given oxygen and taken to North Manchester

General Hospital, suffering from the effects of smoke. Ian was also treated for minor burns to his foot but both were discharged from the hospital a few hours later.

The damage to the house was confined to Lesley and Roy's bedroom, with minor smoke damage to the upstairs landing. Ian said: 'I just went off instinct, from my days as a security officer. I was coughing and wheezing but with the adrenaline pumping, you just deal with the situation as it comes up. We knew we had to get her out of there, then phone for the fire brigade. Once we got her out of the room, it was plain sailing.' Roy added: 'It was pretty frightening. The first I knew of it was when Ian came in and said `Get out, the bedroom's on fire'. When I saw them both with oxygen masks on, that was very scary too. The fire brigade told us the smoke alarm didn't go off, so it could have been a lot worse.' Lesley said: 'I remember going to bed and I'd left my candle on the bedside cabinet. Then, the next thing I remember was Ian pulling me out, and that's about it. I'm so glad he was here, I don't think I'd have got out without him.'

CIGARETTE IN BED LED TO MAN'S DEATH

21st December 2004

A coroner has warned of the dangers of smoking in bed after a man died in his flat when his bedclothes caught fire.

Club steward Ian Cartledge, 41, died after being overcome with noxious fumes from the fire which started in his bed.

Yesterday Coroner David Hinchliff said the 'most likely' cause of the fire had been a discarded cigarette. The inquest heard Mr Cartledge was renting the flat on Tyersal Crescent, Bradford, after splitting up with his wife Adele and leaving his former home in Undercliffe.

Tests showed that he had been drinking and was about three times over the drink-drive limit at the time of his death.

A neighbour rang the fire service after smelling smoke in her own flat at around midnight on July 15. Crews from Stanningley and Odsal attended the fire and found Mr Cartledge in the living room. He was taken to Bradford Royal Infirmary but later died.

Investigating officer for the West Yorkshire Fire and Rescue Service Keith Robinson said the fire had been 'small and smouldering' and had burnt itself out in the bedroom. But the smouldering bed linen would have given off cyanide fumes which, in addition to the alcohol, would have confused and disorientated Mr Cartledge, Mr Hinchliff concluded. A smoke alarm had been fitted in the flat but the battery had been disconnected.

Recording a verdict of accidental death, the Coroner said the fire could have been started by Mr Cartledge deliberately but he thought it was more likely it had been a 'most unfortunate and tragic accident'.

After the inquest, Mr Cartledge's brother Trevor, of Broughton Avenue, Bradford, said Ian had been a 'happy-go-lucky' man who had been a pub landlord at both the Ring O'Bells in Bolton Road and the Old Crown in Allerton. At the time of his death Mr Cartledge, who had three children and three step-children, was the club steward at the Tyersal Road Club.

Mr Hinchliff said he hoped Mr Cartledge's death would act as a warning to others to get a working smoke alarm. 'Cases like this demonstrate they do save valuable time and that can make all the difference between people surviving or not,' he said.

DEADLY FUMES KILLED FLATMATE

22nd December 2001

A young Borehamwood man died from smoke inhalation when a lit cigarette set his mattress alight a coroner's court heard this week. Jonathan Jacob Townsend, 28, died in his sleep on Friday, December 22, when his bedsit in Borehamwood's Shenley Road filled with smoke. He had been drinking in a pub earlier that evening, celebrating the start of the Christmas weekend.

Coroner Edward Gordon Thomas recorded a verdict of accidental death at St Albans Coroners Court on Monday. He said Jonathan had inhaled the deadly fumes from his smouldering mattress, after falling asleep with a lit cigarette. Jonathan lived in a flat, divided into four bedsits, three of which were lived in. At 11.07pm on December 22, one of his flatmates spotted smoke, and called the fire service on his mobile phone. The flames were confined to Jonathan's room, but the rest of the flat quickly filled with smoke, trapping the two other flatmates in their rooms. Firefighters arrived minutes later, and it took six of them, wearing breathing apparatus, to rescue Jonathan's flatmates. Tragically, Jonathan was already dead.

NO TITLE

13th January 2002

A 60-year-old female suffered severe burns over 40% of her body when her mattress caught fire due to an improperly extinguished cigarette. investigation also showed that the smoke detector had been disabled. A mother has pleaded for smokers to keep cigarette lighters out of the reach of children after her four-year-old daughter died of burns.

NO TITLE

2nd July 2004

Courtney Ord is believed to have been playing with a lighter when her pyjamas caught fire at their flat in Southwick, West Sussex, on 3 June. Mandy Ord said her 13-year-old son Grant had been woken up by his sister who was screaming that she was dying. She died in hospital nine days later after suffering third degree burns. Mrs Ord described Courtney as a 'normal, outgoing, fun loving, caring affectionate little girl'. 'She had the biggest smile in the world,' she said. Mrs Ord, who does not smoke, said it was thought her daughter had been playing with a lighter left accidentally at the house. 'Four-year-old's are very inquisitive - they'll look anywhere and everywhere for anything they shouldn't have,' she said.

GIRL, FIVE, BURNED AS GAS FIRE MELTS PYJAMA TOP

24th November 1997

A young Bolton girl suffered burns when her pyjamas caught fire as she tried to huddle up close to a gas fire. The nylon pyjama top melted on to the five-year-old's body as she screamed in agony at her home in Marld Crescent, Johnson Fold.

Jessica Jackson is thought to have been saved from even more serious burns by her mother, Jennifer, who smothered the flames and ripped the top off her daughter. Paramedics treated Jessica at the scene and firemen were also called to the house.

She was taken to Royal Bolton Hospital and transferred to Booth Hall burns unit, but after treatment was allowed home. The accident happened yesterday at 7am after Jessica had gone downstairs early to watch TV. The gas fire was switched on and, as she sat warming herself, she got too close and the nylon top began to burn. Station Officer Dave Thompson said: 'Nylon melts rather than burns, but it would seem that Jessica's mother managed to smother the fire before we arrived. 'We are warning all parents that children should not put fires on themselves. 'We would also advise parents to make their children let them know if they get up early and plan to go downstairs on their own.'

BOY NARROWLY AVOIDS TRAGEDY AFTER MIDNIGHT FEAST

2nd April 1998

A brave seven-year-old miraculously escaped serious injury when a midnight feast went horrifically wrong. Jason Carter suffered severe burns when he and brother Daniel, aged five, crept downstairs during the early hours of the morning and lit candles using their mum's lighter, taken from her handbag.

The brothers said they wanted to have a party, but the dangerous game took a disastrous turn when Jason's pyjamas caught fire. Flames swept up his arm and scorched the skin from his elbow to his shoulder. It spread to his neck but narrowly missed his face. Mum Cath was sound asleep when her bedroom door burst open. Jason was standing in the doorway screaming for help as his arm was engulfed in flames.

Cath leapt out of bed to put out the fire but the damage had been done. The skin bubbled and blistered and doctors said Jason needed an operation. The brave youngster underwent a three-hour skin graft last Friday (March 20).

Surgeons took a layer of skin from Jason's thigh to repair the burns. Now he has to wear an aeroplane splint for several weeks and a support bandage for a whole year while the wounds heal, though he will be scarred for life.

Stunned Cath said: 'They could have killed us all if the house had caught fire. 'Poor Daniel is very upset. He gave Jason a cuddle and told him he loved him. They've made up - we're a close family. 'They've learned their lesson, and their brothers David and Jonathon certainly won't try the same trick. 'Jay's a bonny lad. I'm just so thankful his face wasn't burned. I'm keeping my lighter well out of reach now, and I urge other parents to keep an eye on theirs. It's been terrible.' The family hopes to welcome young Jason back home on Cedar Road, Ribbleton, Preston, this week.

WOMAN SUES SHOP OVER GARMENT FIRE

Undated, 2000

A woman who suffered scarring after her dressing gown caught fire went to the High Court yesterday to sue the shop she claimed sold the garment as well as the manufacturer of the dressing gown. Mary Larkin, (46) of Lusmagh, Banagher told Mr Justice Nicholas Kearns that her pain was so bad she asked hospital medical staff why they would not leave her alone and let her die.

She is suing Heatons Ltd, of Church Street, Athlone, Co. Westmeath, and C.V. Apparel Ltd, alleged to be manufacturers of the dressing gown with offices at Sutton in Ashfield, Nottinghamshire and Coates Viyella (Insurance) Ltd with registered offices at Wellington Street, Glasgow. Heatons and CV Apparel deny Ms Larkin's claims

UNTITLED

11th October 2004

A woman from Morecambe was badly burnt when her dressing gown caught fire. The 55-year-old woman, from The Coppice, in Bare, Morecambe, was taken to the Royal Lancaster Infirmary where she was treated for severe burns to her left arm and shoulder before being transferred to the Royal Preston Hospital for further treatment. A fireman said: 'She was in a pretty bad state.'

MAN WOKE UP TO FIND PYJAMAS ON FIRE

8th March 1999

An elderly York man was recovering in hospital today after waking up in the night to find his pyjamas on fire. Ex-army officer Ronald Burgess leapt out of his blazing bed and ran into the bathroom at his flat in Coxwold House, Lowther Street, The Groves. When fire crews arrived, they rescued the 75-year-old from the bath, where he had managed to extinguish his pyjama bottoms and socks.

The blaze took hold at dawn yesterday and fire investigators believe it was caused by a combination of a faulty electric blanket and smoker's materials. Mr Burgess's bed was destroyed and parts of his bedroom damaged by the fire, as was the bath. The whole flat, on the ground floor of the council block, was badly affected by smoke.

Pensioner Helen Birnie, who lives upstairs, said: 'I woke up because of the fire engines and when I opened my front door, smoke billowed in.' Mr Burgess was taken to York District Hospital and later transferred to Hull and East Riding Hospital in Hull, where he was kept in after treatment for smoke poisoning.

PENSIONER ACCIDENTALLY SETS PYJAMAS ON FIRE

16th January 2006

An elderly man has been receiving specialist treatment in a hospital burns unit after accidentally setting fire to himself with a lighter. The 79-year-old who is a resident at Houghton Hall residential home was trying to burn a thread off his pyjamas using a lighter when his clothing caught fire just before 5am on Monday morning.

He managed to put the fire out himself in his bathroom, but staff raised the alarm after smelling smoke. The gentleman's room at the residential home on Greenwood Crescent, Orford, was fitted with working smoke alarms but the fire had not generated enough smoke to set them off and the pensioner had not thought to alert staff.

The man is now being treated in the burns unit of Whiston Hospital and is believed to have burned his shoulders, arms and chest. A spokesman for CLS Care Services Group, which operates the home, said: 'Two members of staff were dealing with a call to another room, they smelt some smoke and called the fire brigade. Both the smoke alarm in his room and outside his door were working fine but the fire didn't generate enough smoke to set them off. 'He has been a resident at the care home for almost two years and we are concerned for him.'

FIRE SPRINKLERS SAVE REDMOND HOUSING PROJECT AGAIN

8th June 2005

The fire sprinkler system installed at a Redmond housing project activated tonight extinguishing a bedroom fire, protecting residents, and significantly limiting damage to the residence, adjacent units, and the complex. This is the second sprinkler save at this complex in just four months.

At 9:05 p.m. on Wednesday, June 8, 2005, the Eastside Communications Center received a call from an occupant on the third floor reporting a mattress on fire inside his apartment. Dispatchers heard the fire alarm sounding in the background and advised him to evacuate the building. Two minutes later the fire alarm company called to reporting the multiple activations of the building fire alarm system at The Village at Overlake Station, a 308 unit, King County Housing Authority, multi-family project located in the 2500 block of 152 AVE NE, in Redmond's Overlake neighbourhood. The alarm company operator advised the alarm system was indicating water flowing from the sprinkler system. This housing project consists of three large four or five story residential buildings atop a two story parking garage, one level of which serves as a Park and Ride lot. A multi-family structure fire response was dispatched.

The resident advised he had been smoking in bed prior to falling asleep. He was awakened, possibly by the local smoke detector in the bedroom, and found the mattresses and bedding on fire in the bedroom. He exited the bedroom closing the door behind, which confined the fire to the bedroom of origin. A single, fire sprinkler activated in the bedroom containing the fire until firefighters arrived. The activation of the sprinkler head caused the building fire alarm to sound as the resident was calling 911.

Two fire engines, a ladder truck, an aid car, a Battalion Chief, and a paramedic supervisor from the Redmond Fire Department and two fire engines, and a ladder truck from the Bellevue Fire Department were dispatched. Firefighters arrived to find the building evacuated with light smoke in the third floor hallway. They entered the apartment of origin and found smoke to the floor in one bedroom. Firefighters determined the fire was controlled by the fire sprinkler system. They utilized a 1-3/4' hoseline to enter the unit and confirm extinguishment. Fire damage was contained to the mattresses, carpeting, and a scorched wall in the bedroom of origin. Smoke damage was confined to the bedroom. Moderate water damage occurred in the unit of origin on the third floor, and minor water damage in two, second floor units and one, first floor unit.

Prior to fire department personnel leaving the premises, onsite management personnel had a restoration company removing the water from the carpeting and a sprinkler technician had restored the fire sprinkler system to operation. Fire Investigators have determined the fire to be accidental- the result of smoking in bed. The preliminary loss estimate for damage to the unit and contents, and water damage in the lower units is $3,100.00. This is significantly less than the damage resulting from a typical bedroom fire that must be extinguished by fire fighters using only fire hoses. The unit of origin will be uninhabitable for a minimum of one night to permit necessary minor repairs. No other residents of the 308 apartments in the complex were displaced as a result of this incident. No civilians or firefighters were injured. No adjacent living units were damaged by smoke or flame.

Fire codes in Redmond require the installation of fire sprinklers in all large, multi-family, residential buildings. This incident points to the value of fire sprinklers in protecting residents and limiting damage from hostile fires. The outcome of this evening's incident would have been significantly different, had this structure not been equipped with fire sprinklers. Fire doubles in size every 30 seconds and can quickly consume entire rooms or buildings. Lacking sprinklers and prompt notification from both the resident and the alarm monitoring company, today's fire would have threatened the entire structure and hundreds of residents. This is the second save by fire sprinklers at this complex in four months. The first occurred on February 20, 2005 when an unattended candle in a bathroom fell and ignited nearby combustibles.

Damage in that instance was limited to $1,100.00. The February fire was confined to the room of origin and was limited to scorched paint on the bathroom wall, a burned wicker garbage can, and wet carpeting. Only one resident was displaced while wet carpeting was dried. No adjacent units were affected. In both instances lives and property were protected by the presence of fire sprinklers.

FIRE ALARM DETECTS FIRE CAUSED BY CANDLE

25th September 2005

The Temple Terrace Fire Department responded to a fire alarm at College Court Apartments, 5610 Graduate Circle, at approximately 4:32 p.m. on Sunday, September 25, 2005.

Upon arrival to the complex, firefighters found a fire that had been extinguished by the activation of a single sprinkler head. The fire was located in a bedroom and was caused by a candle that was left burning in a bedroom by the occupant who had left the apartment. The candle caught the night stand and part of a mattress on fire.

The fire alarm and sprinkler system in this building was instrumental in the notification of the occupants and fire department as a result of this fire. The Fire Department operation primarily involved extinguishment, ventilation, salvage, and overhaul. The Temple Terrace Fire Department is working closely with the property owner and the City Building Department to allow the occupants to return to their residence. The cause of the fire was an unattended candle. No injuries were sustained by firefighters or occupants.

Injury update: a Report to Oklahoma Injury Surveillance Participants, September 24, 2004. Burn Injuries Due To Cigarette-Related Residential Fires, Oklahoma, 1988-2002. Prepared by: Miriam McGaugh, M.S. Injury Prevention Service

CASE BRIEFS (UNDATED)

A 64-year old man suffered burns on 100% of his body when he was smoking in bed while on oxygen and his bed caught on fire. He tried to put the fire out with water but was unable and was found in the living room by the fire department.

A 25-year old male died in a mobile home fire after a cigarette caught a seat cushion on the sofa on fire. The cigarette had fallen on the cushion earlier in the day, and residents of the mobile home had poured water on it. They thought it was out, but the cigarette continued to smolder and the cushion re-ignited later. During the fire, the decedent was apparently disoriented and could not find a way out of the home.

A 76-year old woman was burned in an apartment fire when she was smoking in bed while on oxygen. The oxygen concentrator on her tank exploded, catching her bed on fire. She was hospitalized in a burn center with 3.5% total body surface area burns and died 34 days later.

CASE STUDIES REPORTED DIRECTLY TO BRE

NASHICS Case 1

'We had a fire some years ago in one of our EPH's where 2 elderly residents smoked sneakily. We provide smoking rooms and one to one smoking when necessary. Basically one of these 2 was ill in bed, the fellow resident carried many tissues etc. on lighting the ciggie, tissue caught light flared, fell onto bedding etc. They did not press call system for help immediately because they knew what they were doing was wrong and the result was very nasty burns to the resident in bed. Damage of course also to bedding etc.'

NASHICS Case 2

'Fire Incident at a residential care home, 2005. A lightning strike caused an unused BT connection box located on the window sill of a residents bedroom to catch fire. The force of the strike caused damage to the plastic window frame and blackening of the area adjacent. The curtains immediately adjacent were fire retardant and therefore prevented any possibility of fire developing. Nevertheless a quantity of black smoke was produced which set off the smoke alarm. This incident occurred at approx 3.30 in the afternoon at which point the resident was sitting in her bedroom.

The fire alarm activated automatically closing all compartment doors and bedroom doors, ALL staff went to the reception where the fire panel is located at which point the Fire service were called. The Team Manager instructed all staff to remain at reception and there they waited for the Fire Service to arrive.

The Fire Service arrived after approx 10 mins and went to investigate, due to the addressable fire panel they were able to go directly to the affected room in which they found the resident suffering from smoke inhalation. They also found other residents wandering about in the fire compartment.

The affected resident was removed to hospital but was released later in the day.

The salient points of the above incident are :

- the emergency plan for this premise expects 'the manager' to make investigations in to the nature and extent of the fire emergency
- following this evaluation the manager should determine whether it is appropriate to commence lateral evacuation to the next fire compartment.
- the manager has received training in respect of evaluation and lateral evacuation,
- practice in this care home re fire drills has been for all staff to report to reception and for there to be no simulated investigation or practice lateral evacuation.

As a result of this incident and the apparent reluctance on the part of the manager to effect an investigation into the nature of the incident it has been decided to implement a programme of simulated fire emergencies using a smoke generator. This will hopefully provide managers with some hands-on experience of dealing with the presenting factors that may arise from a real fire.'

'Note: regarding whether the training programme include 'hands on' use of fire extinguishers: only for selected staff, typically supervisory, as opposed to all. All staff would however receive information, via video, relating to use of extinguishers.'

IAAI Case 1

'An elderly lady on oxygen therapy decided to have a smoke, not a wise move, the oxygen turned into a blow lamp up her nose!!! (Harpenden) An elderly lady sitting in her chair. Chair ignited due to smoking (I sure?), she died about 14 days afterwards. Both incidents happened within last 10 years.'

'Note: The lady in Harpenden died directly as a result of flames up the nasal passage from the ignited gases. The second lady died as a result of direct burns to her legs. Cause of death I believe was septicaemia.'

IAAI Case 2

'Just before I retired I dealt with a fire in a care home started in a residents bedroom started by a trapped electric cable underneath the leg of the bed. The resident was bed bound so could not escape unaided and the staff, on hearing the alarm and being confronted with smoke in the corridor decided to leave everyone in their rooms and wait for the fire & rescue service.'

IAAI Case 3

'In a trawl of all 24 accidental residential fatal fires directly investigated by myself since 1996 I believe that residential sprinklers would have probably saved 10, possibly saved 7 and would definitely not have saved 7.'

IAAI Case 4

'We have had two incidents that may interest you.

1. This involved a fire at a council managed care home in Cardiff. A resident was allowed to have a final cigarette in the resident's smoking room whilst the staff ensured that the remaining residents were safely in bed. Whilst doing that, the fire alarm actuated. The staff went to the front of the building where the smoking room was and discovered that the door was closed. (This happened as a result of the electro-magnetic door holding devices actuating on the sounding of the alarm.) They could hear the resident inside shouting for help. The staff had received fire training from a third party, and had been instructed that if there was a fire in a room, that they should not enter. The Fire and Rescue Service was already on its way, and a 999 call from the home confirmed a fire with persons reported. The fire was caused by the resident setting fire to his own clothing by careless use of smoking materials and he died as a result of exposure to fire.

2. The second incident involved a male patient in a hospital who was being treated for alcohol dependency. During the evening, his behaviour became extremely erratic and he absconded from the ward. He was accosted by hospital staff and he informed them that he had set his room on fire. The staff discovered a small fire in his room and extinguished it using a 9L water

extinguisher. They decided to evacuate the ward in accordance with their procedures and during this evacuation, another elderly and frail patient went into cardiac arrest. She subsequently died. The erratic behaviour is thought to have been caused by a relative / visitor bringing alcohol into the patient disguised as a milk drink, when in actual fact, it was vodka and orange. That case is still on-going.'

'Note: The patient died from exposure to fire; from burns rather than smoke.

I doubt that sprinklers would have made a difference. In the care home fire [the first fire], the casualty was the fire and he was only wearing pyjamas and a dressing gown. I don't think he would have produced sufficient heat to actuate a sprinkler, particularly as he was moving around the room whilst on fire.

In the hospital incident [the second fire], the same applies in that the fire loading was so low, there was barely any smoke damage.'

HOSPITAL PATIENT DIES LIGHTING CIGARETTE AS SKIN GEL CATCHES FIRE

Riazat Butt Wednesday April 19, 2006 The Guardian

An investigation was launched yesterday into the case of a hospital patient being treated with a flammable gel for a skin condition who died after being engulfed in flames as he lit a cigarette. The 60-year-old man, who has not been named, was being treated at Doncaster Royal Infirmary when the incident happened on Monday evening.

It is thought he left his ward and went to a fire escape to have a cigarette. He was taken to Northern general hospital in Sheffield with serious burns, but died from his injuries.

It is understood the patient knew the gel was flammable and that his understanding of its properties was documented. The hospital knew he was a smoker.

A spokesman for Doncaster Royal Infirmary said: 'A patient raised the alarm and nurses went to the patient's aid, following all the procedures for putting out a fire. The patient was taken to Northern general 25 miles away because there isn't a burns unit at Doncaster Royal Infirmary.

'Whenever we have an untoward incident we set up an investigation to find out what happened, what procedures were followed and what lessons can be learned.

'The Health and Safety Executive are involved, because it's a reportable incident, as are the police and the fire brigade. Smoke alarms across the hospital are linked directly to the fire brigade and they would have attended the scene automatically. The practice is to notify the next of kin as soon as something untoward happens in a patient's treatment process. Counselling will be made available to staff, patients and family members if required.'

Nigel Clifton, chief executive of Doncaster and Bassetlaw Hospitals NHS Foundation Trust, said: ‘This is a most tragic event. Our hearts go out to his family.’

The trust said it would not release further details about the incident. South Yorkshire police said it was not treating the death as suspicious and a report would be prepared for the coroner.

Fire Protection Association New Zealand, FPANZ Newsletter, Issue 119 October 2006. What is the Successful Outcome of a Sprinkler Operation? Author John Davidson, Macdonald Barnett Partners

This article describes a fire in a small residential community care building. The building comprised two bedrooms, a bathroom and lounge. It was protected with a sprinkler system to the New Zealand standard NZS4517:2003.

The two occupants secured themselves in one bedroom. One poured accelerant over them self and ignited it; this occupant suffered 88% burns and died 12 hours later. The other occupant escaped with no injuries.

The fire was evidently severe enough to damage ceiling paint and melt a plastic light shade. It is estimated that the sprinkler operated within 30 seconds of ignition. The room was sooted but had little other damage.

Appendix D – Statistics: fires in care homes for the elderly, 1994 – 2002

ESTIMATES OF SPRINKLER EFFECTIVENESS IN REDUCING RISK OF DEATH

From J Fraser-Mitchell

As the UK fire statistics do not permit a direct estimate of sprinkler effectiveness, an indirect method was used in earlier work for DCLG, exploiting a correlation between fire size (area burned) and risk of death per fire. By assuming that sprinklers will prevent fires becoming larger than some critical size, the risk is reduced because the potentially large fires now have the same (lower) risk as those of the critical size. The critical fire size at sprinkler activation was estimated to be between <1 sq.m and 1~2 sq.m. [Williams et al 2004, Fraser-Mitchell 2004].

Results for care homes have large uncertainties due to the scarcity of fatal fires, so in the DCLG work it was assumed that residential sprinklers had a similar effectiveness in all property types, reducing deaths by about 70% ± 15% (two standard deviations). However, a more detailed method of estimating the effectiveness suggested that this assumption from the earlier work is incorrect, at least for fires in care homes for the elderly.

The alternative method is simply to examine the individual circumstances of every fatality in care homes for the elderly over the years 1994-2002. This was feasible as only 34 fatalities occurred during that period. A subjective judgement was made as to whether or not sprinklers, had they been present, might have prevented the fatality. This judgement was expressed as a probability, in the hopes of increasing accuracy somewhat.

The reason that sprinklers are likely to be less effective in care homes for the elderly than elsewhere lies in the nature of the fatal fires. Many are caused by careless smokers, who set light to their clothes or bedding. We have assumed that it would not be likely for sprinklers to save lives in these cases. By the time the first sprinkler activated, the heat release rate of the fire would be approximately 500kW. In addition to the heat, the victim would be in the immediate vicinity of the undiluted toxic fire products.

Summary

The costs of installing sprinklers are very uncertain. Based on data from the Fire Sprinkler Association (FSA), an average value of £5,600 can be derived for a 26-bed care home. Based on other sources, the figure is £16,700.

As a consequence, it may be concluded that sprinklers can be justified on cost grounds as an additional measure if the FSA cost data is correct, but not if the cost data from other sources is more realistic.

As the confidence level of the cost-effectiveness of sprinklers is very dependent on the installation costs (which have high levels of uncertainty), the analysis has also been 'turned around' to estimate the maximum costs that would result in at least a break-even approach. For 95% confidence, this maximum cost was £7,800 for a 26-bed care home.

Details of the fatalities in fires in care homes for the elderly, 1994 – 2002

Time	Fire Locn	Details	Fire area	Age	Sex	Cas Locn	Died	Injury
1994								
?	corridor	smoker, set clothes on fire	<1 sq.m	90	M	fire room	in fire	other, specified
4pm	lounge	matches, ignited textiles (not clothes)	<1 sq. m	90	M	fire room	in fire	burns
5pm	bedroom	smoker, set clothes on fire	<1 sq. m	77	M	fire room	in fire	burns
3pm	kitchen	cooker too close to other combustibles	<1 sq. m	94	F	fire room	in fire	shock
1995								
11pm	bedroom	smoker, set bedding on fire	1-2 sq.m	83	F	fire room	in fire	burns
7am	common room	smoker, set clothes on fire	<1 sq.m	77	M	same floor	in fire	burns
7pm	common room	smoker, ignited furniture	1-2 sq.m	87	F	fire room	in fire	burns & smoke
4am	bedroom	incandescent light ignited bedclothes	5-9 sq. m	83	M	fire room	in fire	shock
7pm	bedroom	smoker, ignited textiles (not clothes)	10-19 sq. m	92	F	fire room	in fire	burns
1996								
8pm	bedroom	matches, set waste on fire	<1 sq. m	80	F	fire room	in fire	smoke
11pm	common room	smoker, set clothes on fire	1-2 sq. m	93	M	fire room	in fire	burns
8pm	bedroom	unknown	3-4 sq. m	75	F	fire room	in fire	burns & smoke
1997								
11am	common room	smoker, set clothes on fire	<1 sq.m	78	M	fire room	in fire	burns
3pm	cloakroom	smoker, set clothes on fire	<1 sq.m	74	M	fire room	in fire	burns
1998								
6pm	bedroom	smoker, set clothes on fire	<1 sq.m	95	M	fire room	fatality	burns
10pm	bedroom	smoker, set clothes on fire	<1 sq.m	78	M	other	fatality	burns
5pm	kitchen	chip pan, unattended	1-2 sq.m	85	M	firefighting	fatality	burns
1999								
10pm	bedroom	incandescent light ignited bedclothes		91	M	fire room	in fire	burns
5pm	common room	lighter, ignited textiles (not clothes)		87	M	fire room	in fire	burns
9pm	bedroom	matches, material ignited unknown		92	M	fire room	in fire	
11pm	bedsit	cooker hotplate, set clothes on fire		79	F	same floor	later	burns
11pm	bedroom	smoker, set clothes on fire		73	M	fire room	in fire	burns
9am	common room	smoker, set clothes on fire		73	M	fire room	later	burns
5pm	bedroom	smoker, set furniture on fire		78	M	fire room	later	burns
11pm	bedroom	electric blanket, set furniture on fire		84	F*	fire room	later	smoke
				85	F*	1 floor up	later	smoke
					** one of these two died*			
2000								
There were no fatalities in 2000								
2001								
6pm	bedroom	matches, set waste on fire		79	F	fire room	in fire	burns
7pm	bedsit	smoker, set clothes on fire		86	M	fire room	in fire	burns & smoke
10pm	lounge	smoker, set clothes on fire		82	F	fire room	in fire	burns
3am	bedroom	smoker, set clothes on fire		88	F	fire room	in fire	burns
10pm	common room	unknown		75	M	same floor	later	precaution check
10pm	bedsit	smoker, set clothes on fire		83	M	fire room	in fire	burns
2002								
11am	corridor	smoker, set clothes on fire		76	F	fire room	in fire	burns
2am	bedroom	smoker, set clothes on fire		71	F	fire room	in fire	burns

Summary of fires in care homes for the elderly – fires and casualties (fatalities, injuries and rescues) 1994 to 2002, by year.

Sum of fires

	room									
Year	**bedroom**	**corridor**	**dining**	**kitchen**	**laundry**	**lounge**	**other access**	**stair**	**#N/A**	**Grand Total**
1994	64	35	2	459	115	14	1		229	919
1995	120	31	5	393	106	39	3	3	289	989
1996	132	45	23	553	100	37	1	19	279	1190
1997	97	33	9	525	132	35	5	5	256	1097
1998	105	38	51	505	87	45	5	3	206	1044
1999	94	43	24	608	150	42	9	4	232	1206
2000	100	30	13	486	118	18	7		177	948
2001	144	26	11	382	94	29		5	197	888
2002	56	42	21	367	110	49		5	192	842
Grand Total	**912**	**323**	**159**	**4278**	**1012**	**307**	**31**	**44**	**2056**	**9122**

Sum of casualites

	room									
Year	**bedroom**	**corridor**	**dining**	**kitchen**	**laundry**	**lounge**	**other access**	**stair**	**#N/A**	**Grand Total**
1994	28	8	1	28	38	5	1		33	142
1995	49	0	0	23	7	8	0	0	58	145
1996	64	2	0	29	0	11	1	0	19	126
1997	9	0	0	30	18	5	0	0	95	157
1998	20	0	0	33	4	4	0	0	7	68
1999	41	3	0	27	18	11	0	0	23	123
2000	11	7	0	19	45	4	0		28	114
2001	33	0	0	26	1	4		0	27	91
2002	27	4	0	32	4	5		0	97	169
Grand Total	**282**	**24**	**1**	**247**	**135**	**57**	**2**	**0**	**387**	**1135**

Summary of fires in care homes for the elderly – fires and casualties, 1994 to 2002, by time of day.

Sum of fires										
					room					
Time of day	**bedroom**	**corridor**	**dining**	**kitchen**	**laundry**	**lounge**	**other access**	**stair**	**#N/A**	**Grand Total**
00~02h	43	3	7	90	67	7			98	315
02~04h	42	20	42	35	7			5	81	231
04~06h	29	21	2	51	26	3		1	54	187
06~08h	71	45	5	218	41	6		1	128	516
08~10h	77	9	72	891	110	45	4	12	267	1488
10~12h	105	38	7	600	179	31	7	5	209	1180
12~14h	71	29	2	608	123	11		1	172	1016
14~16h	64	16	2	304	91	22		4	182	686
16~18h	83	48	31	596	40	48	12	4	256	1118
18~20h	130	37	20	489	97	42	2	5	236	1058
20~22h	128	33	2	276	102	52	5	5	253	856
22~24h	68	24	9	115	101	33	1	1	120	473
Grand Total	**912**	**323**	**159**	**4278**	**1012**	**307**	**31**	**44**	**2056**	**9122**

Sum of casualites										
					room					
Time of day	**bedroom**	**corridor**	**dining**	**kitchen**	**laundry**	**lounge**	**other access**	**stair**	**#N/A**	**Grand Total**
00~02h	33	4	0	9	10	9			19	84
02~04h	20	0	3	0	2			0	30	55
04~06h	12	0	0	3	1	5		0	11	32
06~08h	9	6	0	7	42	2		0	13	79
08~10h	18	0	0	8	8	2	0	0	22	58
10~12h	11	4	0	51	4	3	0	0	9	82
12~14h	14	2	0	46	37	1		0	16	116
14~16h	10	0	0	24	4	8		0	60	106
16~18h	19	3	0	37	4	2	1	0	96	162
18~20h	30	0	0	31	17	3	0	0	64	145
20~22h	52	0	1	19	6	8	1	0	10	97
22~24h	54	5	0	9	2	12	0	0	37	119
Grand Total	**282**	**24**	**1**	**247**	**135**	**57**	**2**	**0**	**387**	**1135**

It should be noted that the statistics do not identify fires which started elsewhere (e.g. in a bedroom) and were brought or carried into the identified location (e.g. a corridor). Very few casualties are associated with the fires on corridors, other access or stairs.

Appendix E – Review of DCLG sprinkler research

An examination of the earlier DCLG sprinkler research (Williams C, Fraser-Mitchell J, Campbell S & Harrison R, Effectiveness of sprinklers in residential premises, BRE Report 204505, Feb 2004) has been carried out with regard to the bed fires that formed just part of the much larger project.

Some results for the bed fire test are reproduced here (Figures D1 to D7). (Sprinklered and unsprinklered).

Two tests were carried out using sprinklers: Test 13 and Test 15.

For Test 13, the sprinklers operated at a ceiling temperature of around 150°C (after around 2.6 minutes from ignition), where the room door was closed, see Figure D2.

For Test 15, the sprinklers operated at a ceiling temperature of around 102°C (after around 5 minutes from ignition), but for this test the room door was open, see Figure D4.

Where the bed was burned under the BRE calorimeter, at a time between 2.5 minutes and 2.75 minutes the heat release rate was between 100 to 120kW, see Figure D7.

These data indicate that a bedroom sprinkler could operate at a heat release rate as low as 100kW. Conclusions for the bed fires, for the room of fire origin, were:

- The bed fires were found to have consistent ignition and burning characteristics
- For the unsprinklered cases, the first tenability criteria to be reached were visibility, then convected heat rather than toxic effects
- For the unsprinklered cases, the conditions rapidly became unsurvivable.
- For the sprinklered tests, the conditions remained tenable in terms of FEDAG
- Sprinklers helped to significantly reduce the effect of convected heat from the fire
- Visibility became untenable in the sprinklered door open case but remained tenable in the door closed sprinklered case.

See the full report for complete details.

Test No.	Set-up	Wet or dry	Room of origin	Alarm activation time						Sprinkler activation		OD Limit reached (OD/m >0.5)		FED$_{AG}$ limit @ 1.6m reached (room of origin)		FED^{H} limit reached		
				R1		MR		R2		Time	Temp	R1	R2	Uncon	Death	R1	MR	R2
				ion (s)	opt (s)	ion (s)	opt (s)	ion (s)	opt (s)	(s)	(C)	(s)	(s)	(s)	(s)	(s)	(s)	(s)
Bed Fires																		
2	Standard	dry	2	–	–	118	136	70	107	n/a	n/a	215	159	764	1011	300	620	300
15	Standard	wet	2	–	–	190	–	132	–	303	102	(364)	295					
6	Door closed	dry	1	59	–	1186	–	–	–	n/a	n/a	144	(0.07)	938	(1.34)	603		
13	Door closed	wet	2	–	–	dna	–	87	156	105		133						

(Note: 303 seconds = 5.05 minutes, 156 seconds = 2.6 minutes)

30 s (½ minute) | 60 s (1 minute) | 90 s (1½ minutes)

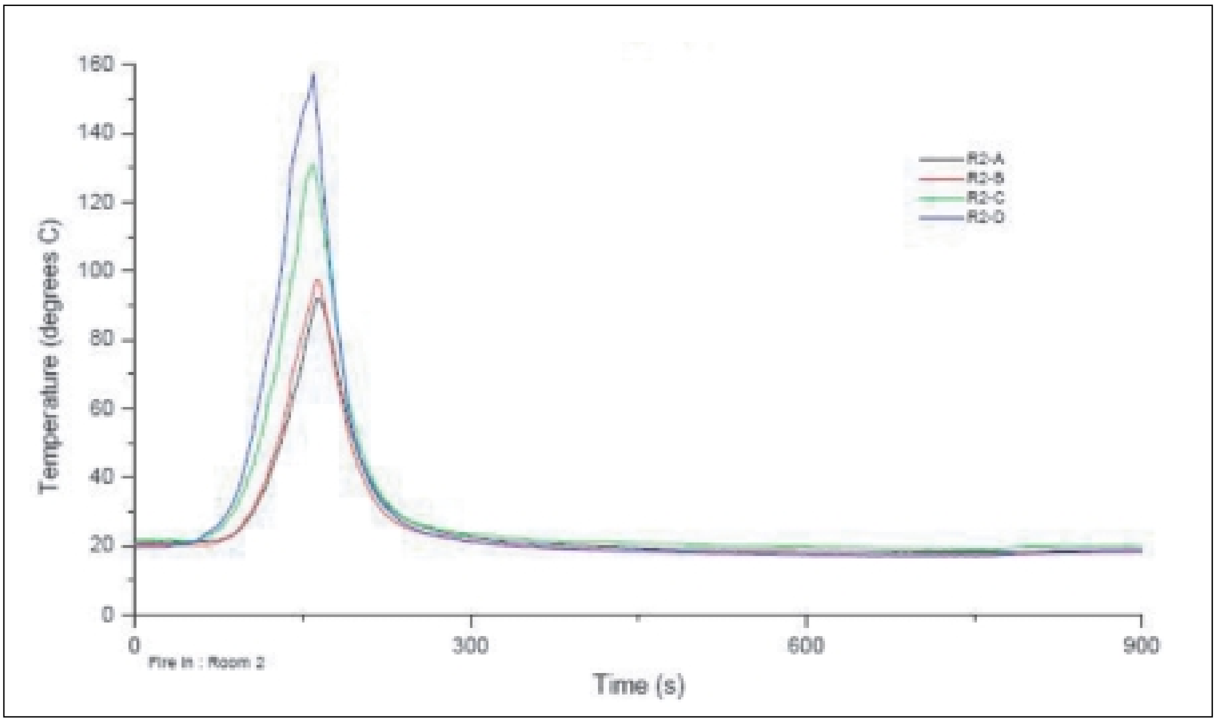
120 s (2 minutes) | 150 s (2½ minute) | 180 s (3 minutes)

240 s (4 minutes) | 330 s (5½ minute)

Photographs taken before, during and after bed calorimetry fire

Figure D1

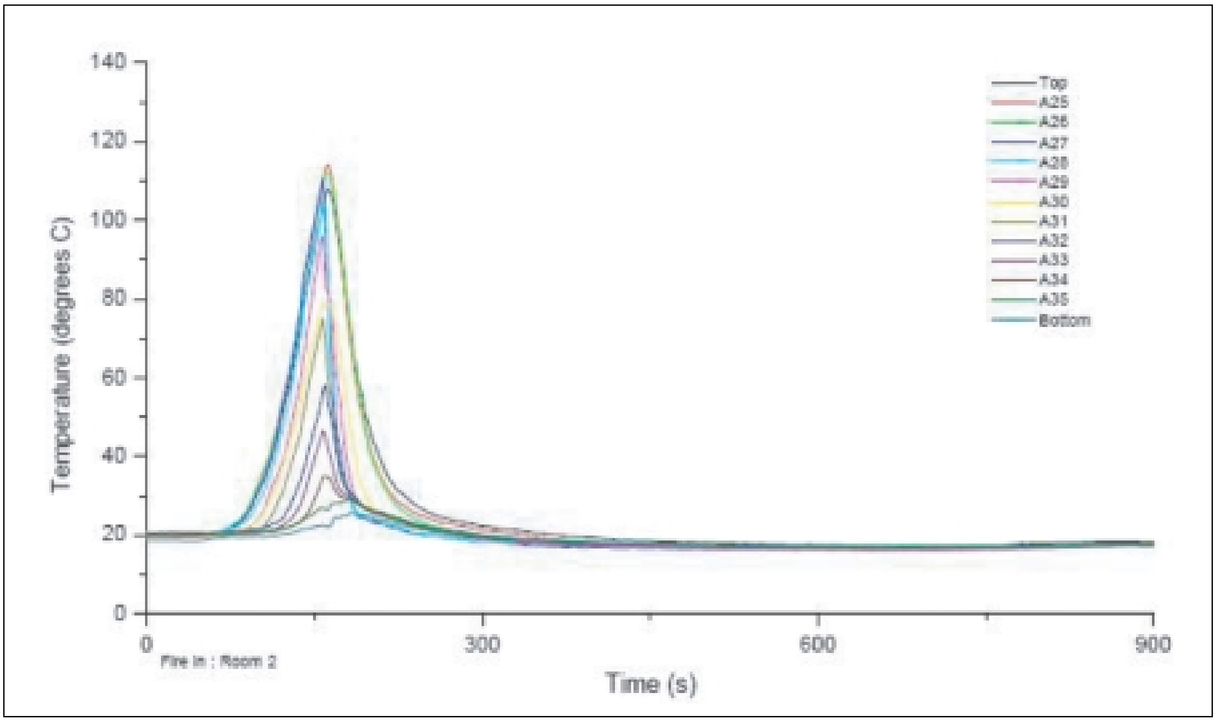
Residential sprinklers project: Compartment fire tests
Test 13 – Bed fire, sprinklered, door closed
Room 2 Ceiling temperatures



(b) Compartment 2 – room of origin

Figure D2

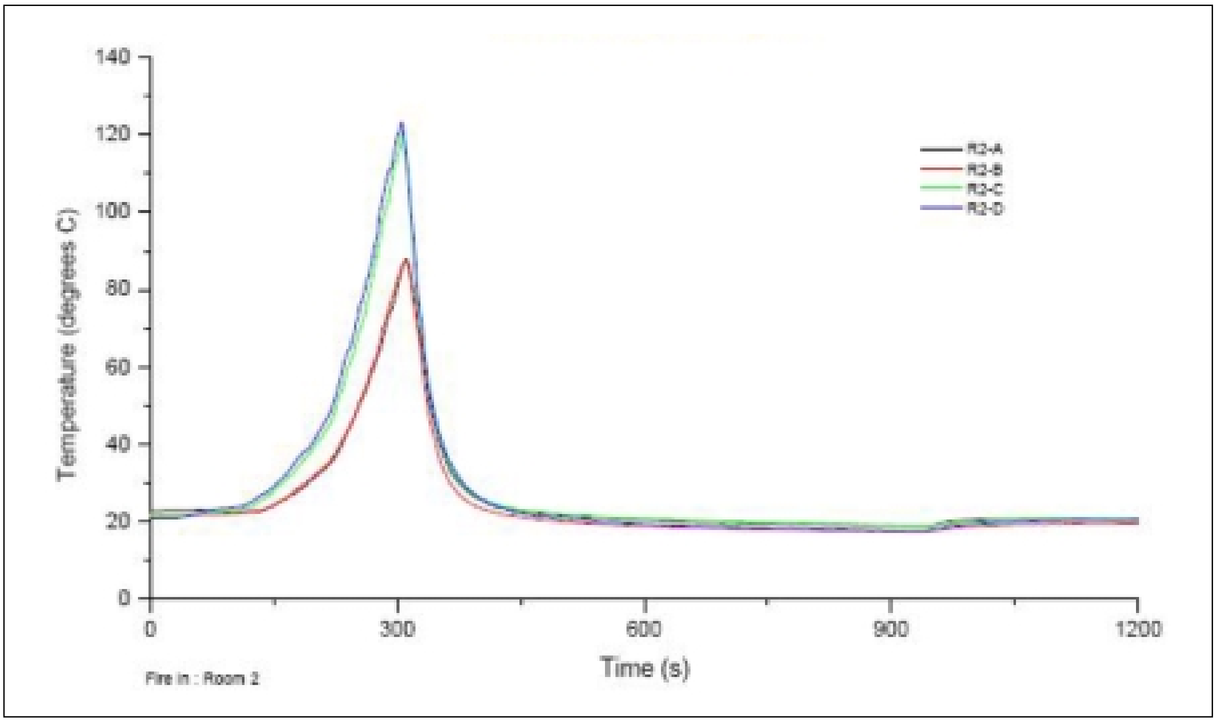
Residential sprinklers project: Compartment fire tests
Test 13 – Bed fire, sprinklered, door closed
Room 2 Thermocouple column



(b) Compartment 2 – room of origin

Figure D3

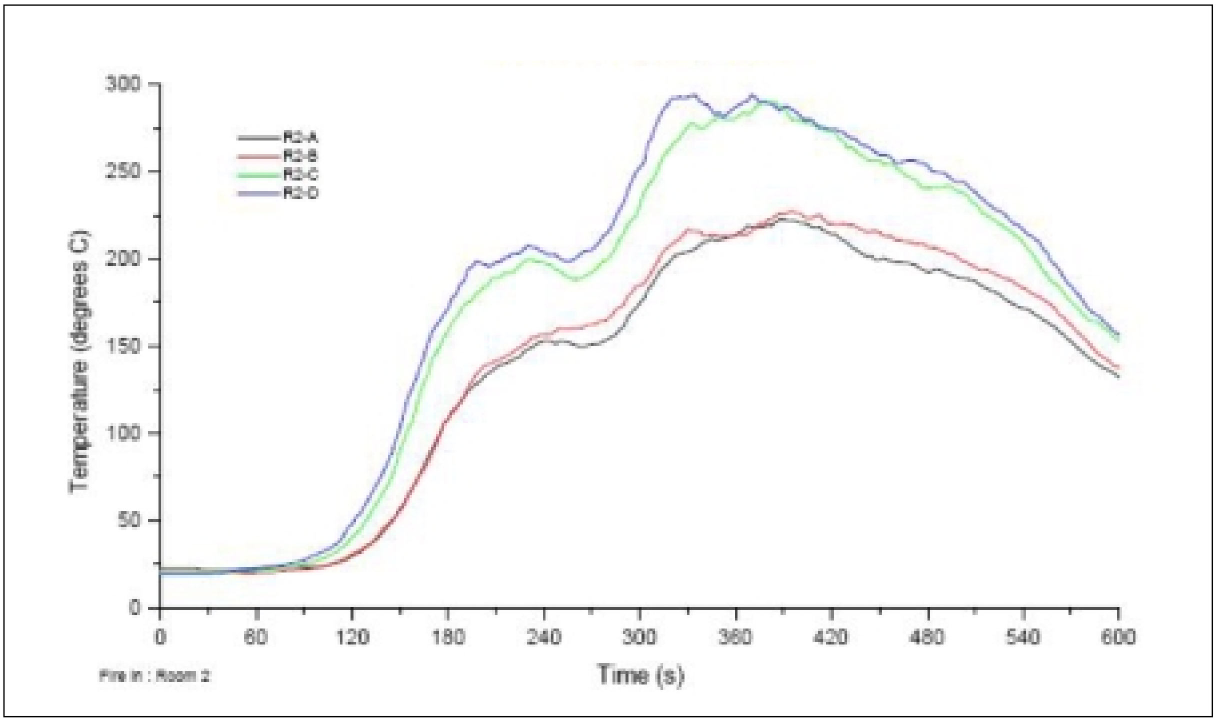
Residential sprinklers project: Compartment fire tests
Test 15 – Bed fire, door open, sprinklered
Room 2 Ceiling temperatures



(b) Compartment 2 – room of origin

Figure D4

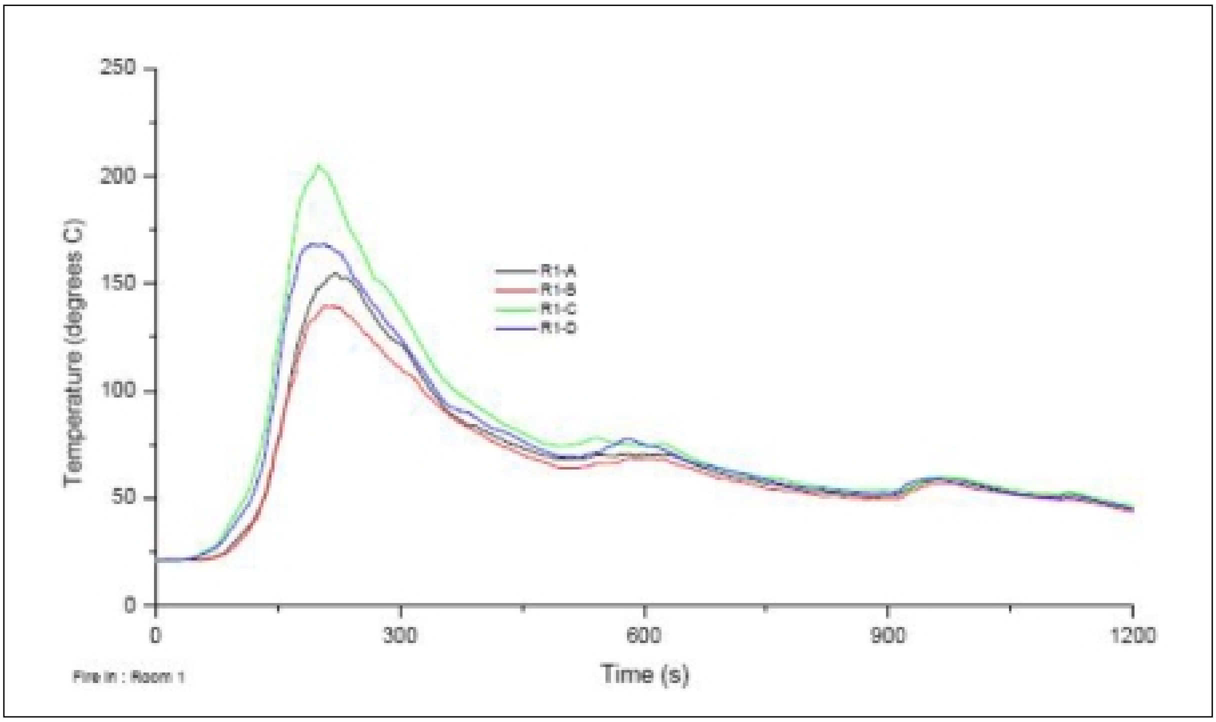
Residential sprinklers project: Compartment fire tests
Test 2 – Bed fire, unsprinklered, door open
Room 2 Ceiling temperatures



(b) Compartment 2 – room of origin

Figure D5

Residential sprinklers project: Compartment fire tests
Test 6 – Bed fire, unsprinklered, door closed
Room 1 Ceiling temperatures



(a) Compartment 1 – room of origin

Figure D6

Bed fire calorimetry test

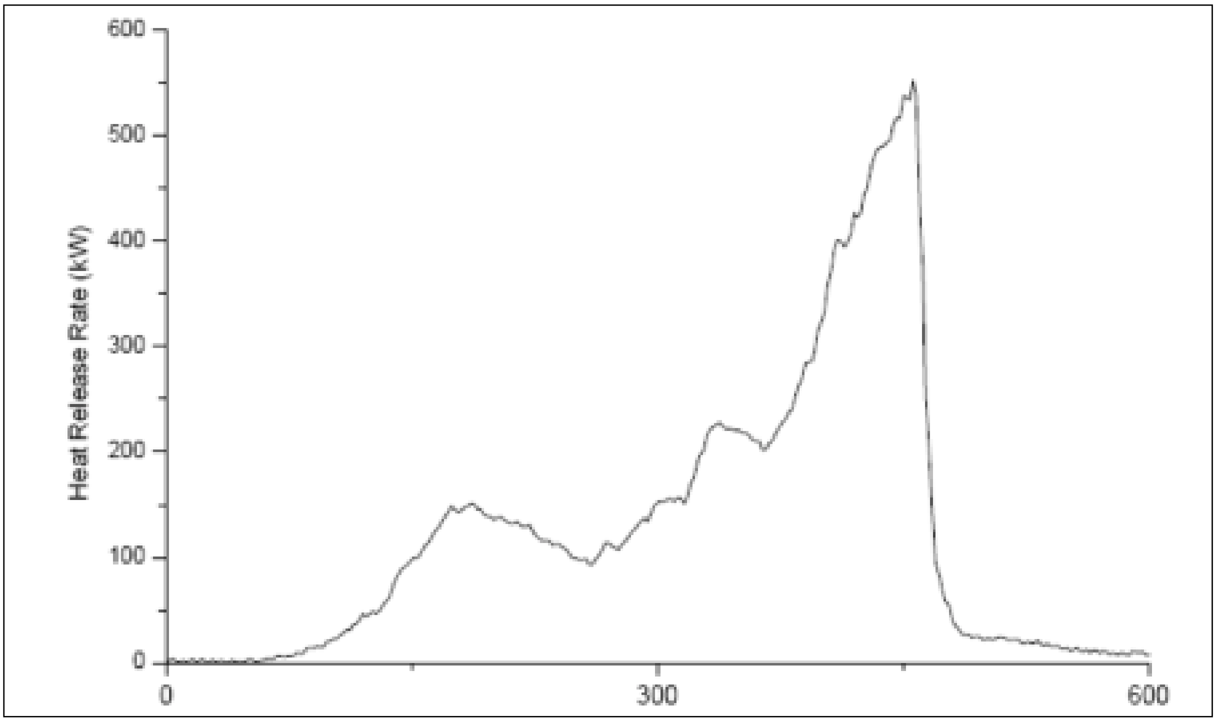


Figure D7

Appendix F – Experimental results

Rig size: 2.4m high, 2.4m wide (with doorway in one side), 3.6m long. Width of door 0.8m wide, 2.0m high.

Target: Joint of pork, approximately 25kg, portion of neck, leg and ribs (i.e. upper quarter without head), with skin. Approximately 35-40cm wide, 1m long, max 20cm thick at shoulder.

Nightwear: For all tests: Marks and Spencer 'easycare' pyjamas with cotton. 65% Polyester, 35% Cotton. Jacket only used.

Bed coverings: For all tests:
Duvet: Ikea Mysa Sno. 4.5 Tog. Fabric; 65% Polyester, 35% Cotton. Filling; Polyester.
Pillows: Ikea Gosa Sott. Fabric; 65% Polyester, 35% Cotton. Filling; Polyester.
Duvet cover and pillowcases: Ikea Thisted Rand Design Helle Vilen. 100% Cotton.
Undersheet: Ikea Slumra. 52% Polyester, 48% Cotton.

Mattress: Spring mattress Ikea Sultan Högbo; Bonell spring unit/ Cross spring: Steel. Comfort material: Polyester wadding, Polyurethane foam 25kg/cu.m., Felt liner. Ticking: 76% cotton, 24% polyester. Length: 200 cm, Width: 90 cm, Thickness: 20 cm.

Bed frame: IKEA Day-bed Meldal: Head/footboard/ Bedside: Steel, Pigmented epoxy/polyester powder coating. Length: 208 cm, Width: 95 cm, Height: 96 cm, Mattress length: 200 cm, Mattress width: 90 cm.

INSTRUMENT LOCATIONS

A = Gas sample point

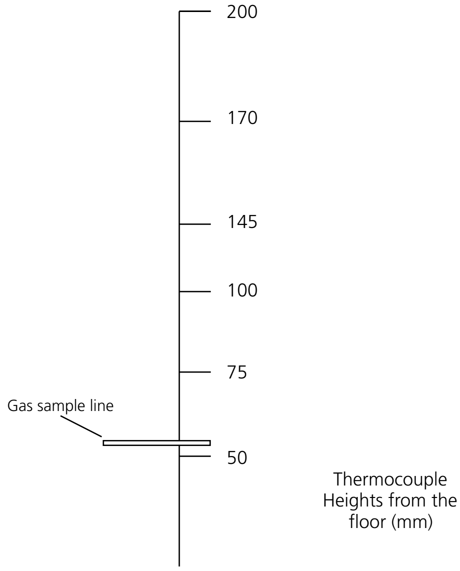
B = Gas sample point

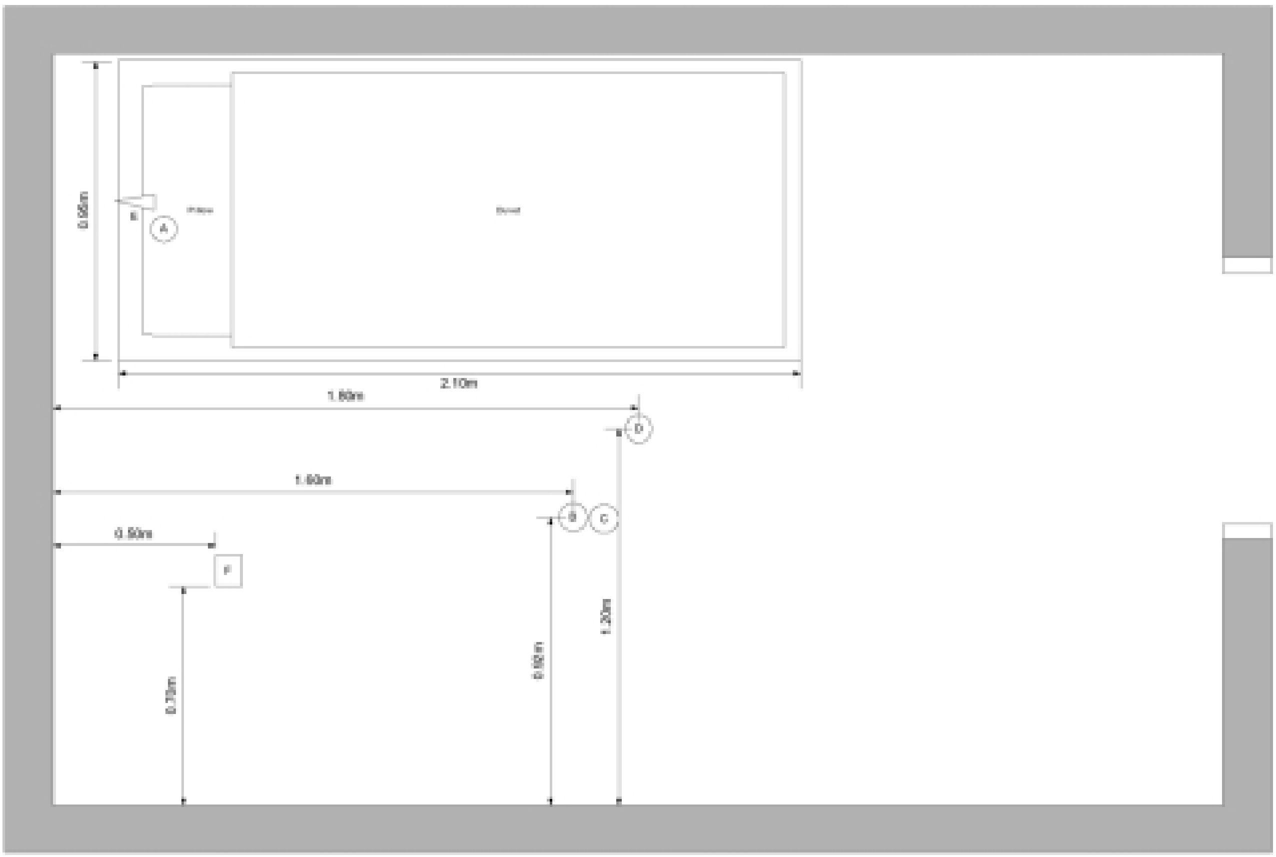
C = Thermocouple tree

D = Heat flux meter (vertical view)

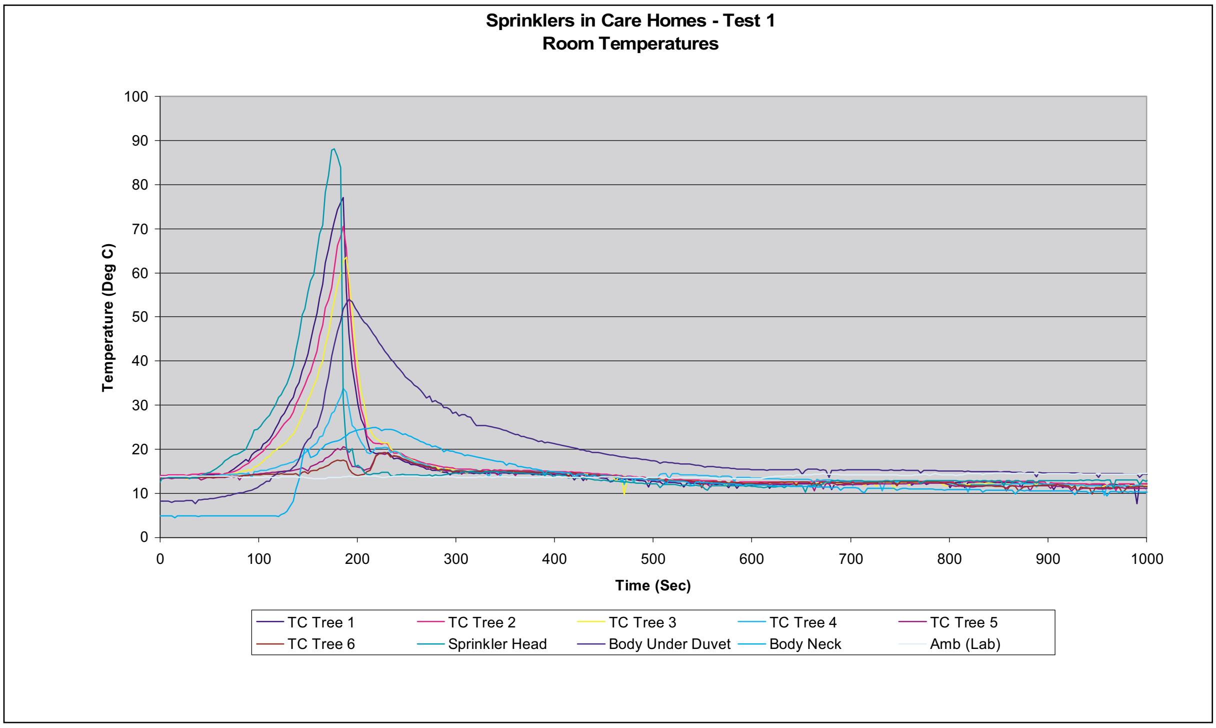
E = Heat flux meter (horizontal view)

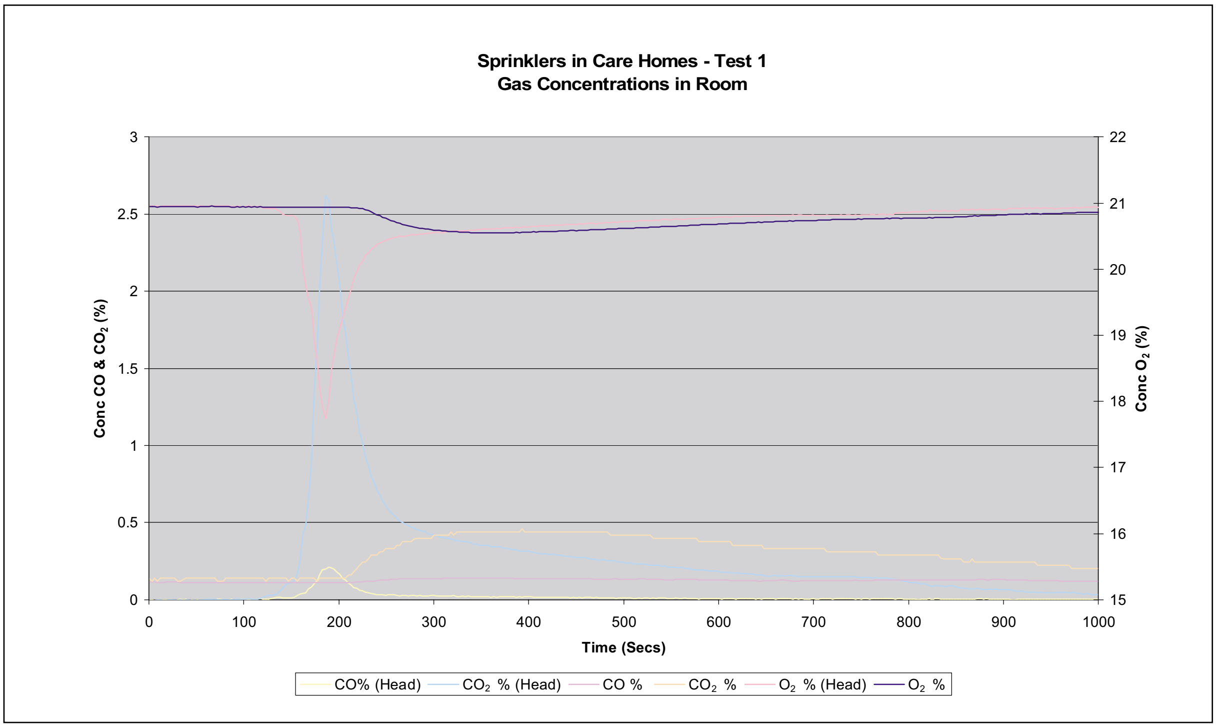
F = Smoke Detector (ionization type)





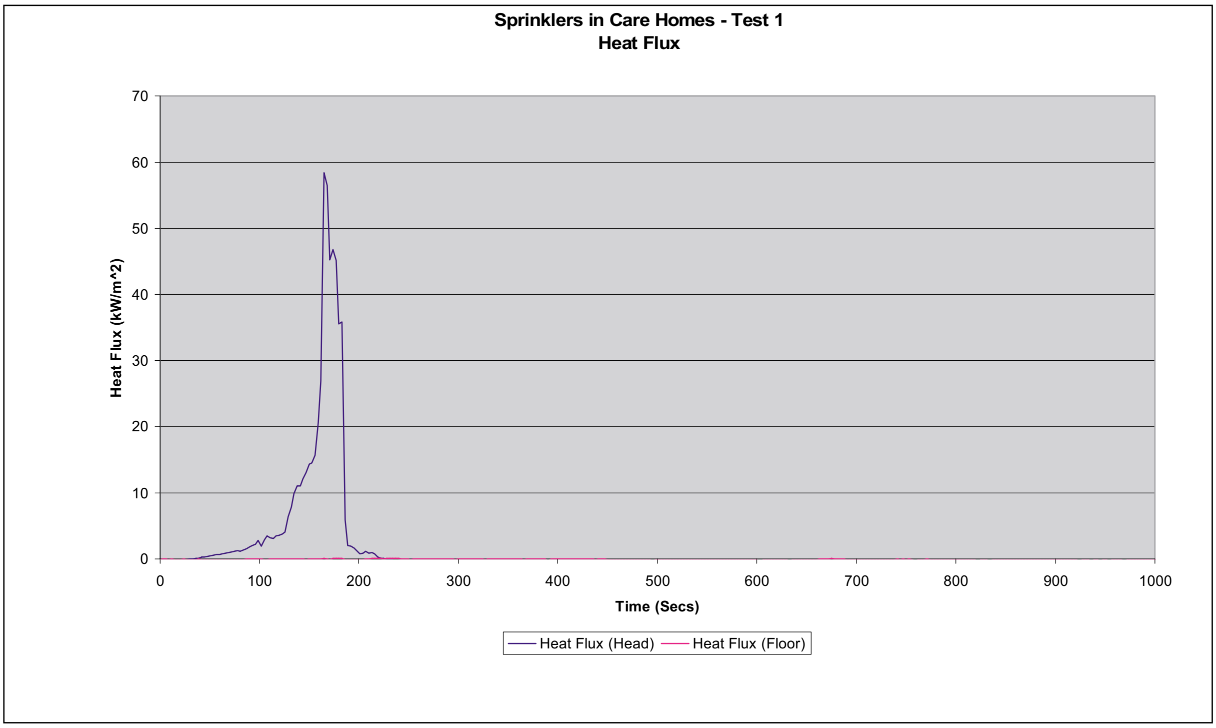
Test 1





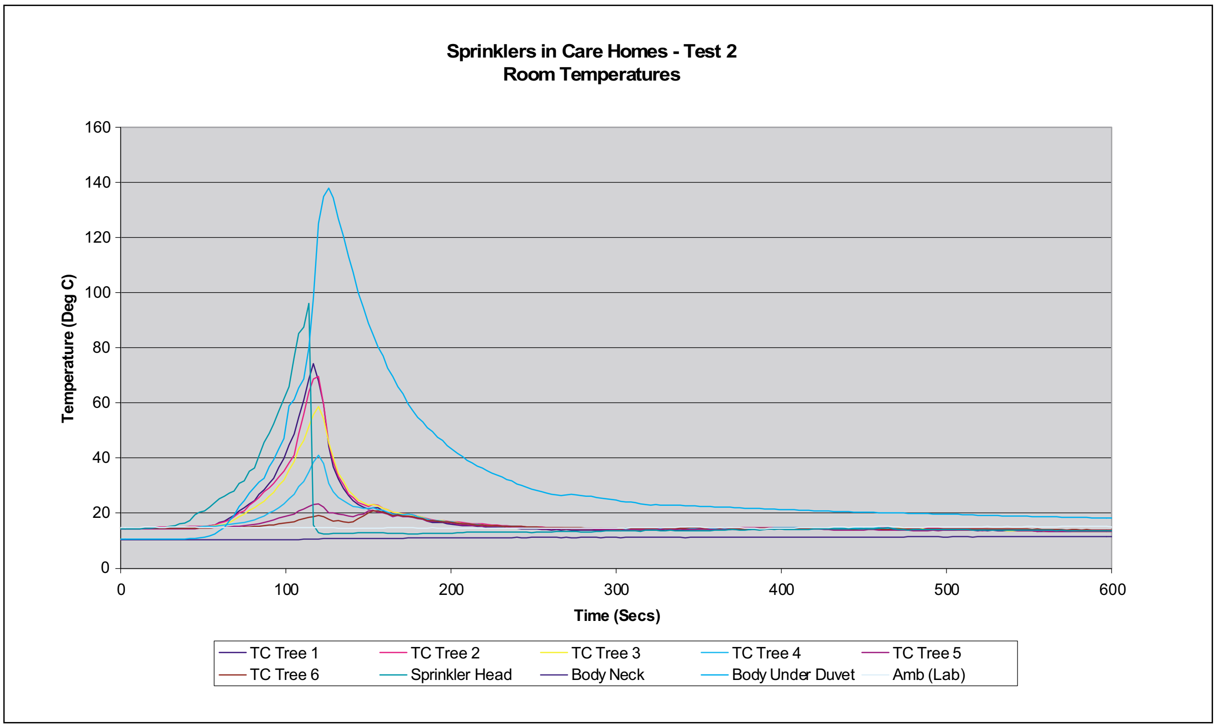
Note: No heat release rate measurements were carried out in Test 1.

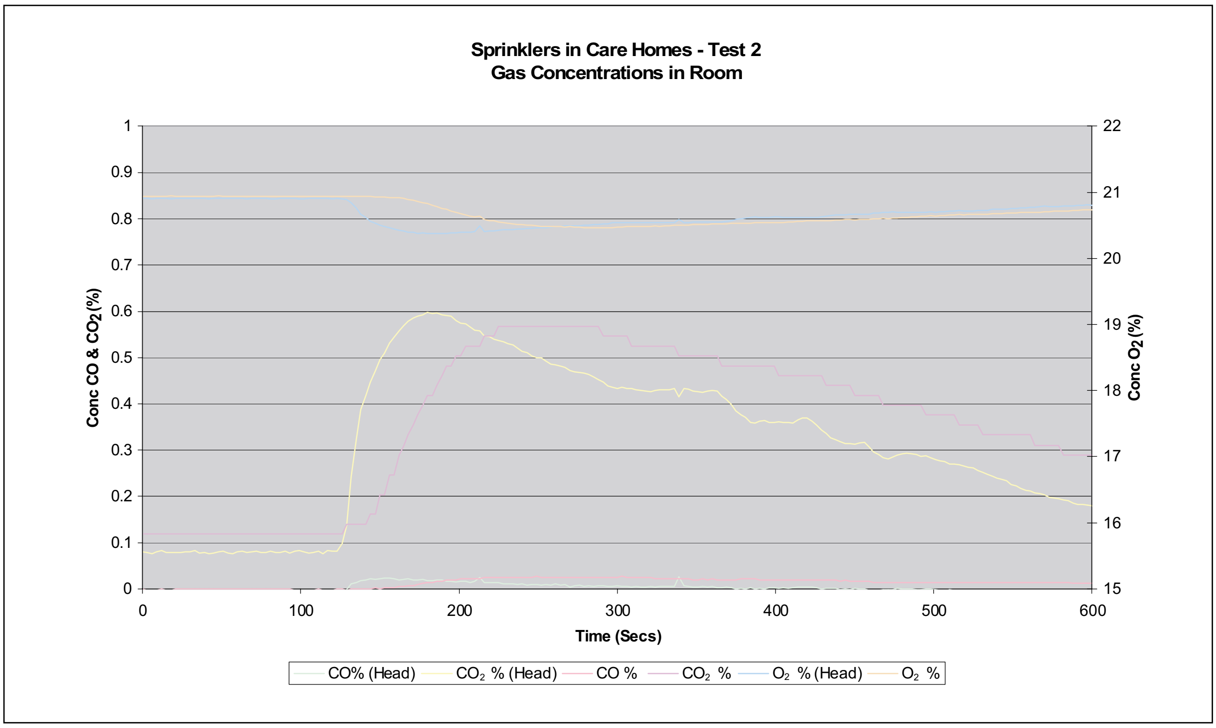
Test 1



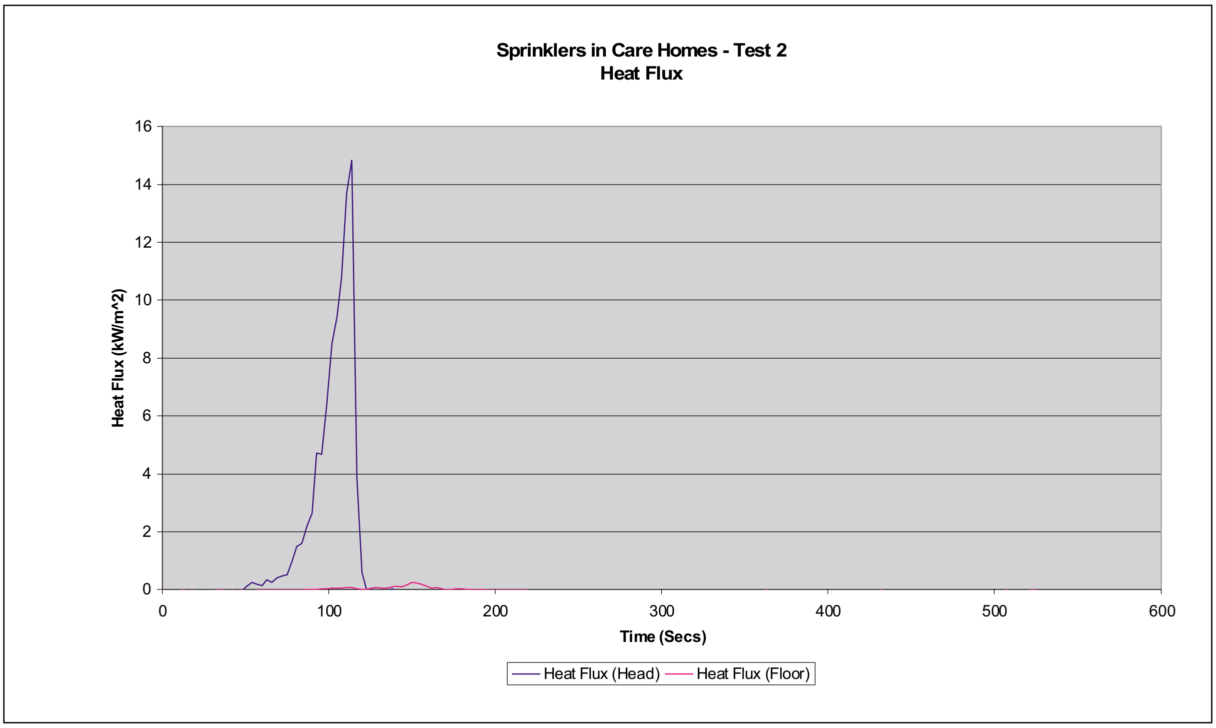
Note: No heat release rate measurements were carried out in Test 1.

Test 2

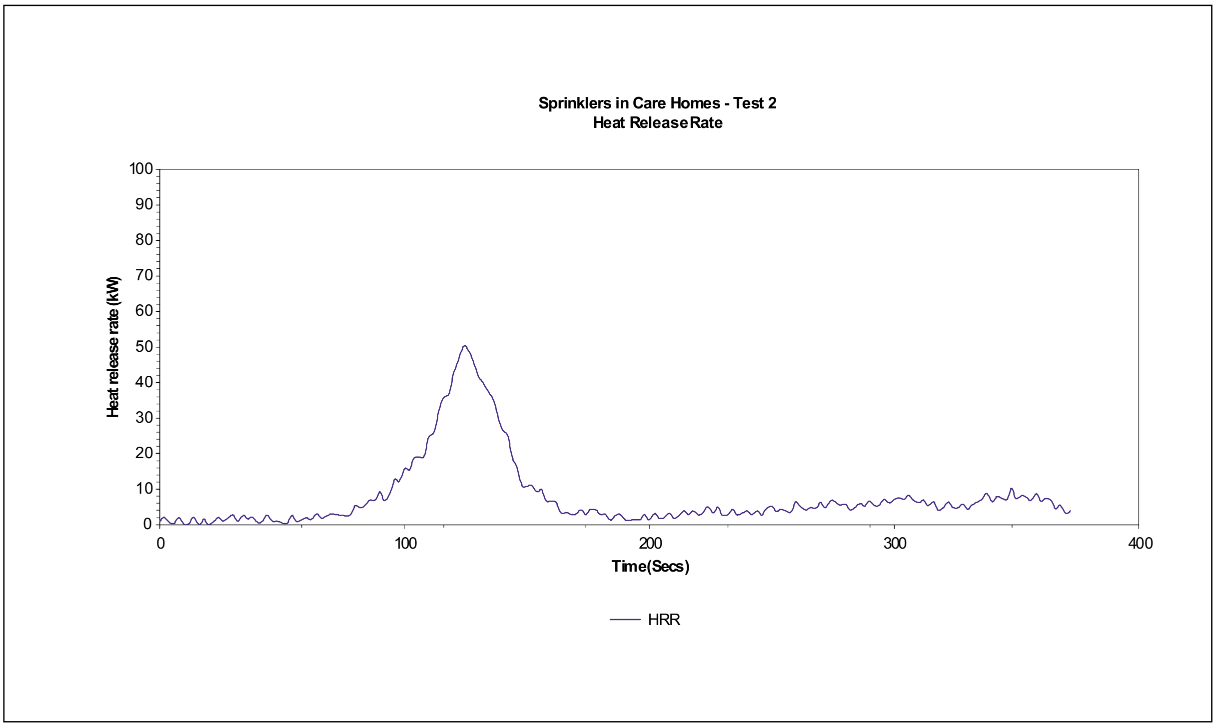

Sprinklers in Care Homes - Test 2
Room Temperatures
Temperature (Deg C)
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
Time (Secs)
TC Tree 1
TC Tree 2
TC Tree 3
TC Tree 4
TC Tree 5
TC Tree 6
Sprinkler Head
Body Neck
Body Under Duvet
Amb (Lab)


Sprinklers in Care Homes - Test 2
Gas Concentrations in Room
Conc CO & CO2 (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Conc O2 (%)
22
21
20
19
18
17
16
15
0
100
200
300
400
500
600
Time (Secs)
CO% (Head)
CO2 % (Head)
CO %
CO2 %
O2 % (Head)
O2 %

Test 2

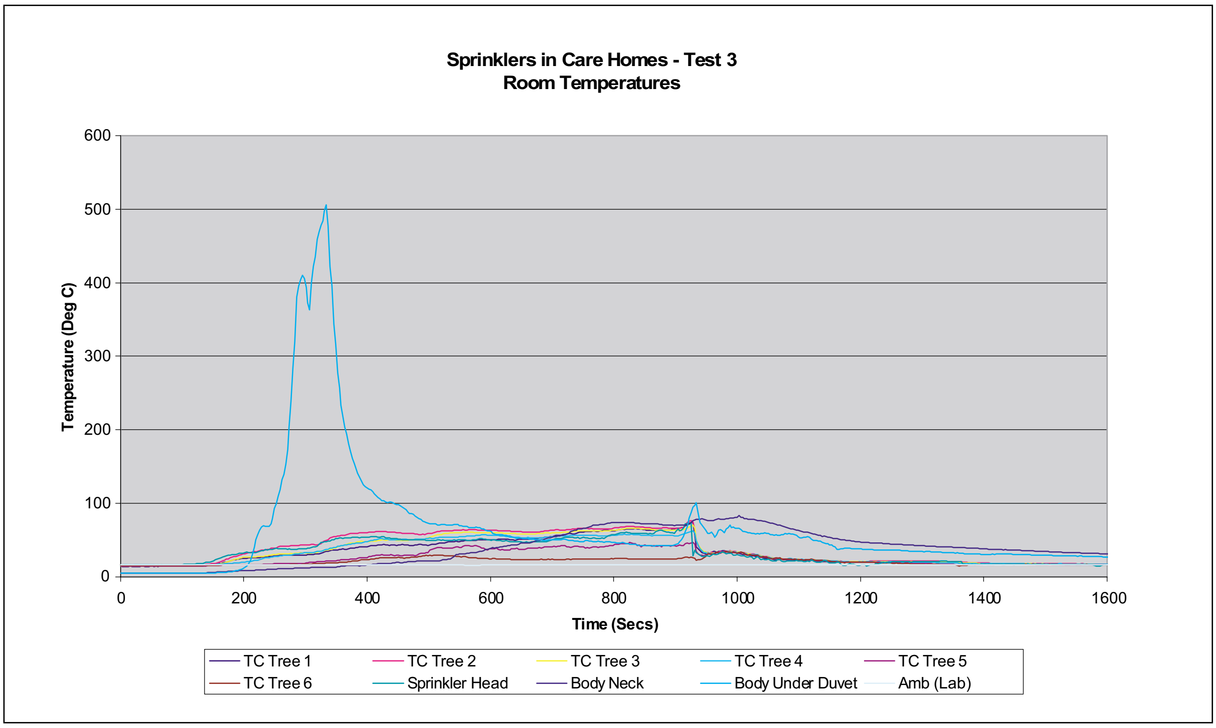


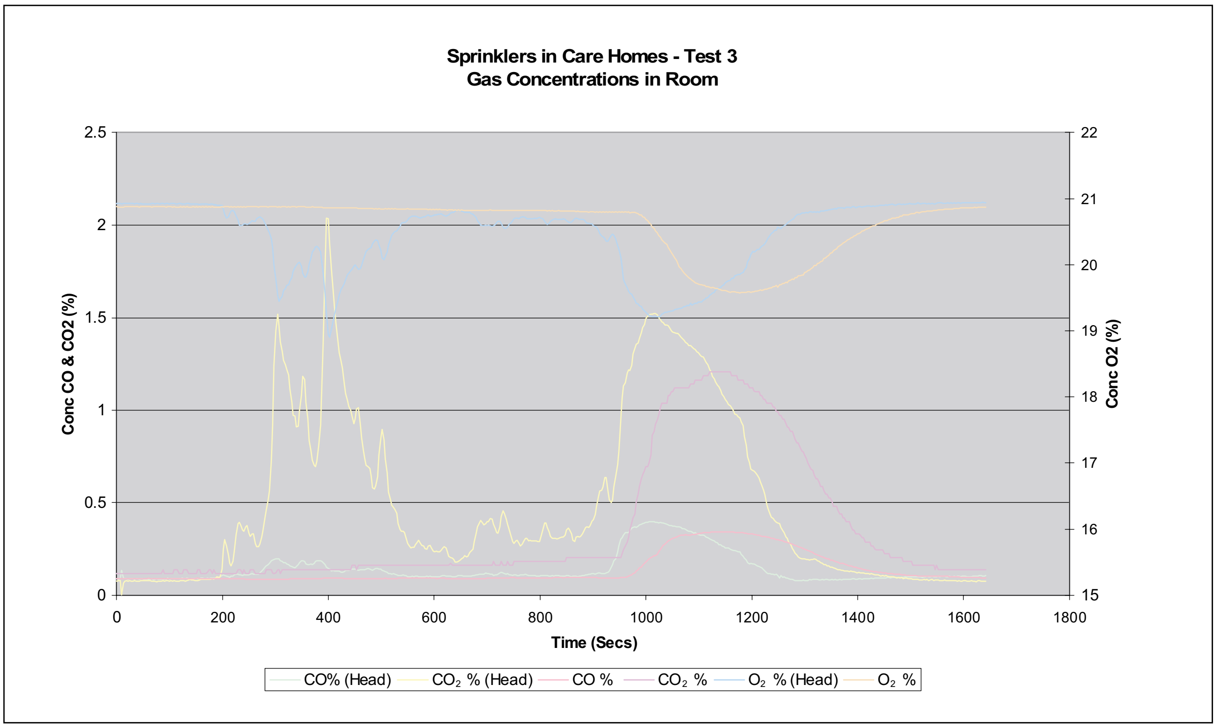
Sprinklers in Care Homes - Test 2
Heat Flux
Heat Flux (kW/m^2)
0
2
4
6
8
10
12
14
16
0
100
200
300
400
500
600
Time (Secs)
Heat Flux (Head)
Heat Flux (Floor)



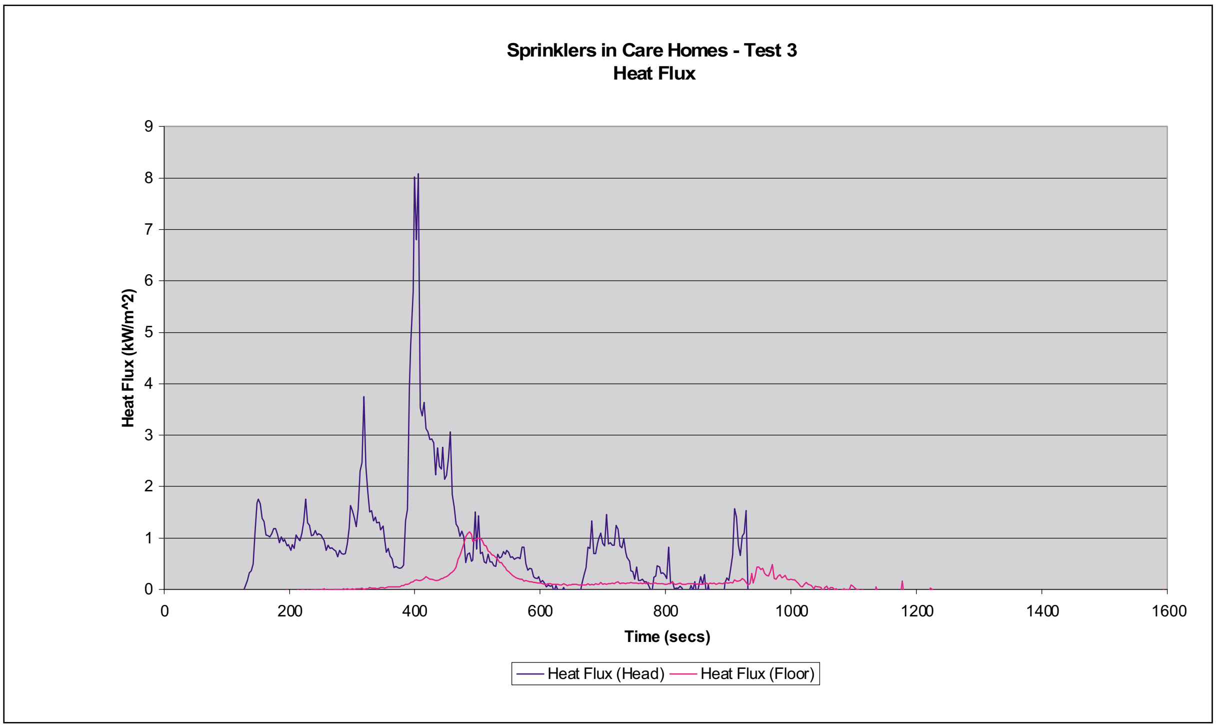
Sprinklers in Care Homes - Test 2
Heat Release Rate
Heat release rate (kW)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
Time(Secs)
HRR

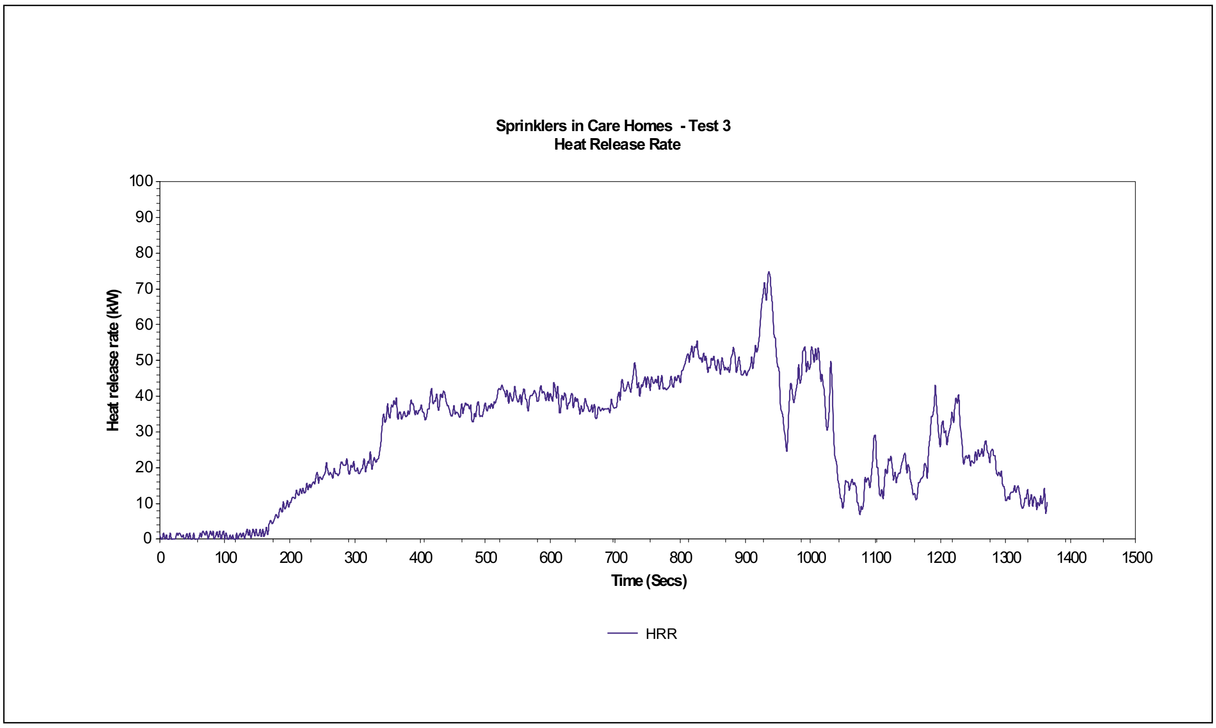
Test 3


Sprinklers in Care Homes - Test 3
Room Temperatures
Temperature (Deg C)
0
100
200
300
400
500
600
0
200
400
600
800
1000
1200
1400
1600
Time (Secs)
TC Tree 1
TC Tree 2
TC Tree 3
TC Tree 4
TC Tree 5
TC Tree 6
Sprinkler Head
Body Neck
Body Under Duvet
Amb (Lab)

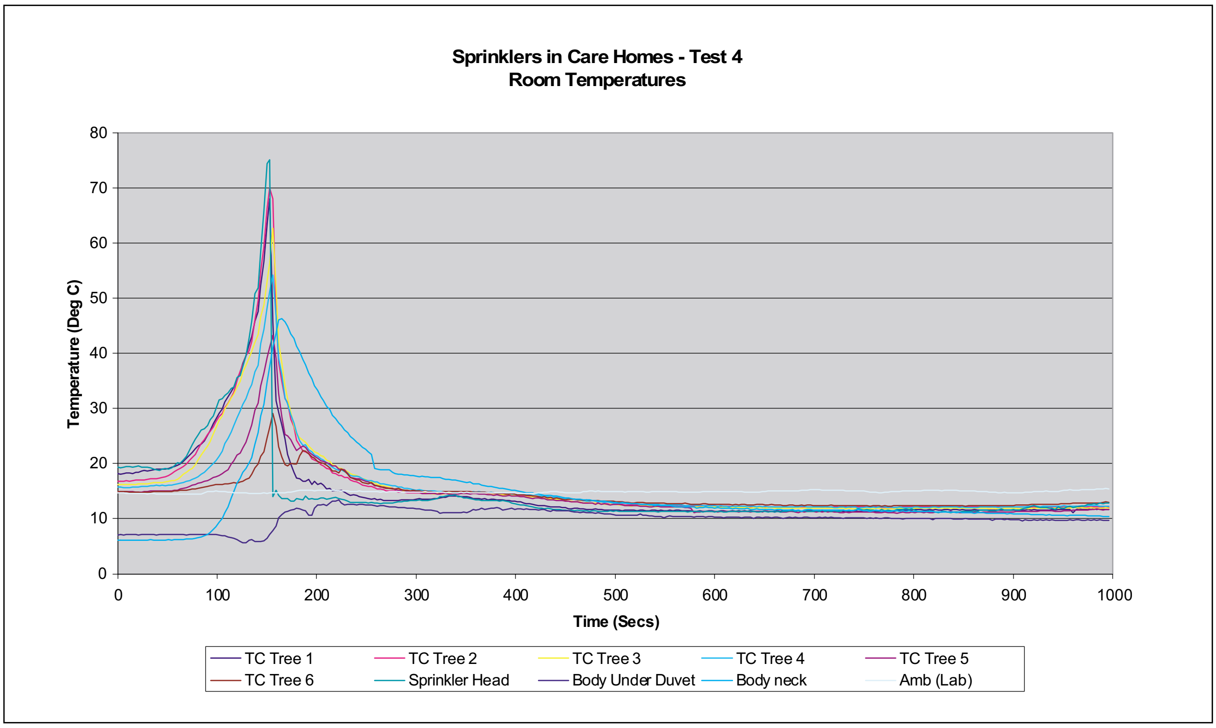

Sprinklers in Care Homes - Test 3
Gas Concentrations in Room
Conc CO & CO2 (%)
0
0.5
1
1.5
2
2.5
Conc O2 (%)
15
16
17
18
19
20
21
22
0
200
400
600
800
1000
1200
1400
1600
1800
Time (Secs)
CO% (Head)
CO_2 % (Head)
CO %
CO_2 %
O_2 % (Head)
O_2 %

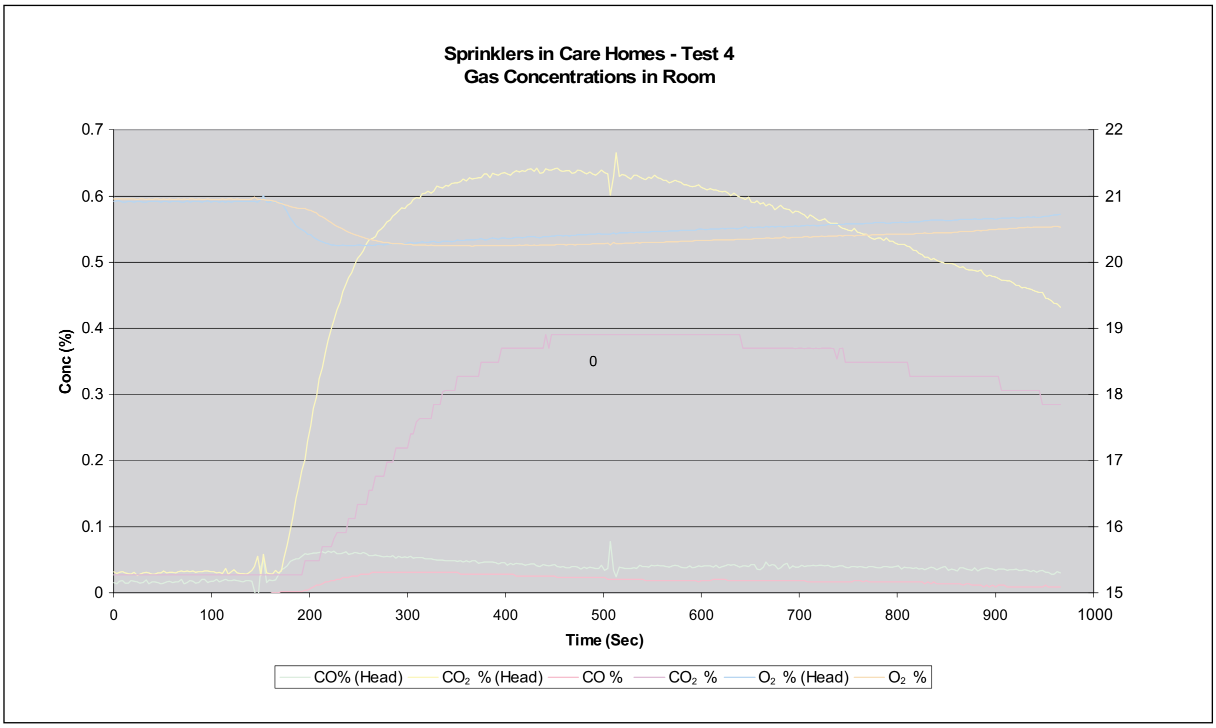
Test 3


Sprinklers in Care Homes - Test 3
Heat Flux
Heat Flux (kW/m^2)
0
1
2
3
4
5
6
7
8
9
0
200
400
600
800
1000
1200
1400
1600
Time (secs)
Heat Flux (Head)
Heat Flux (Floor)

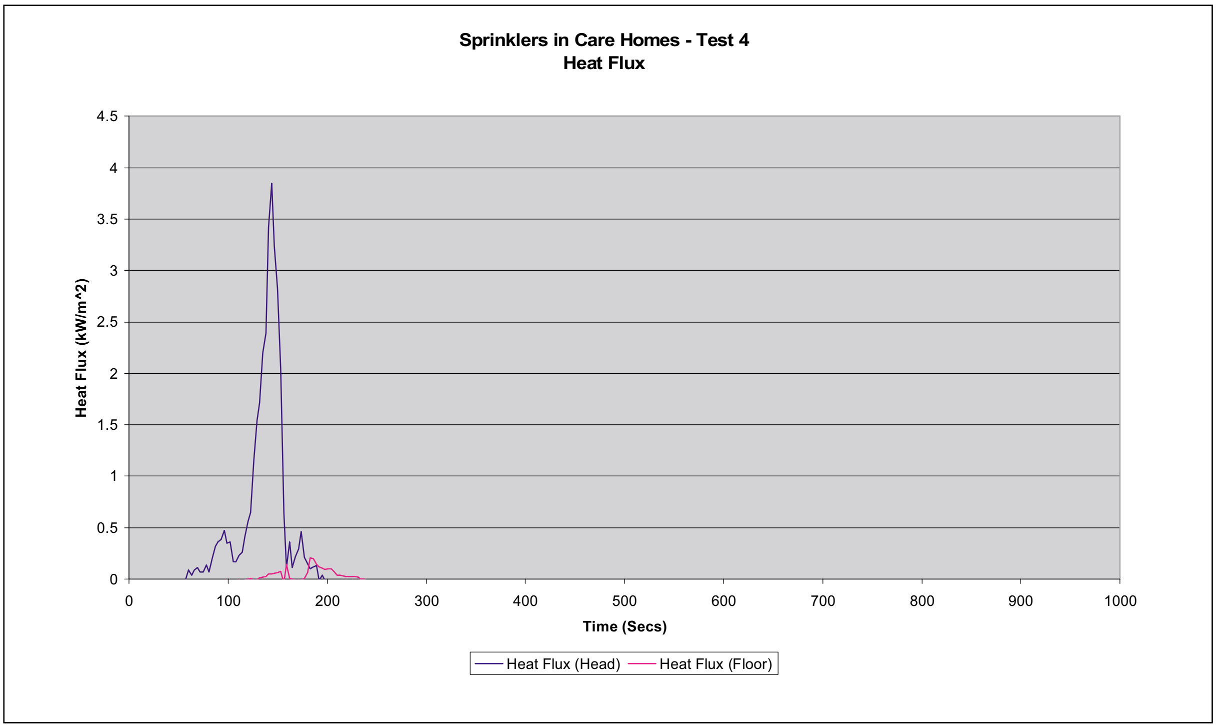

Sprinklers in Care Homes - Test 3
Heat Release Rate
Heat release rate (kW)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Time (Secs)
HRR

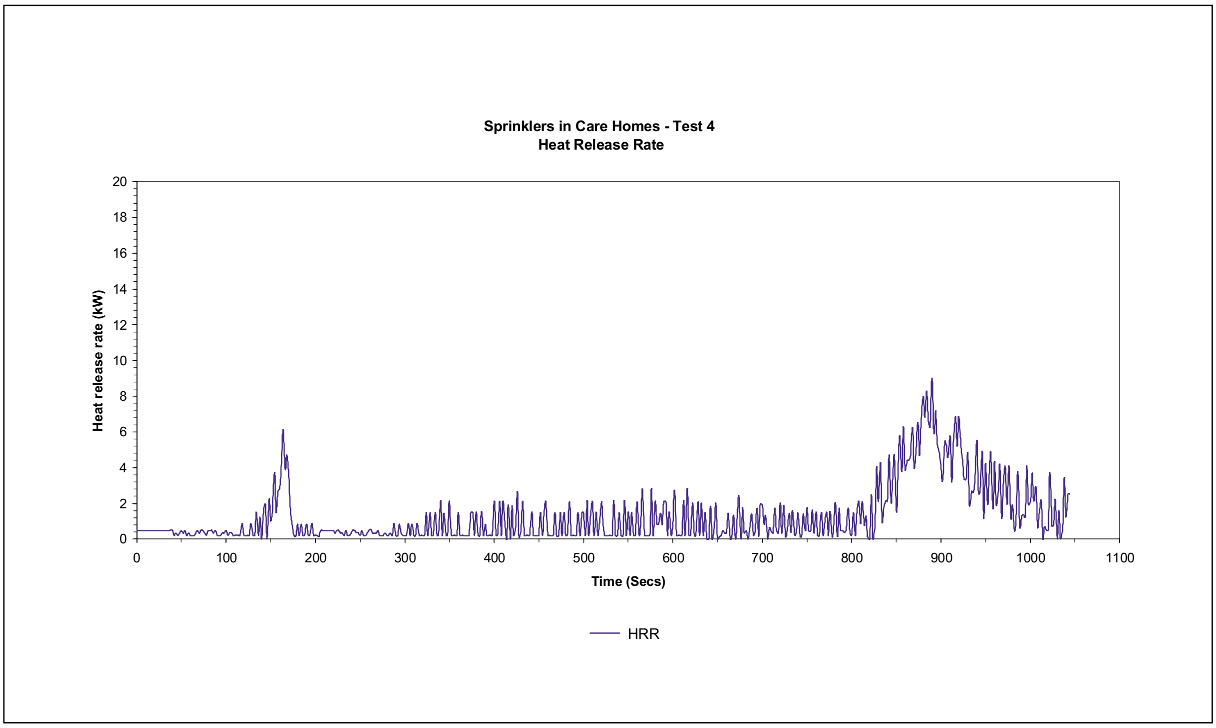
Test 4


Sprinklers in Care Homes - Test 4
Room Temperatures
Temperature (Deg C)
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900
1000
Time (Secs)
TC Tree 1
TC Tree 2
TC Tree 3
TC Tree 4
TC Tree 5
TC Tree 6
Sprinkler Head
Body Under Duvet
Body neck
Amb (Lab)

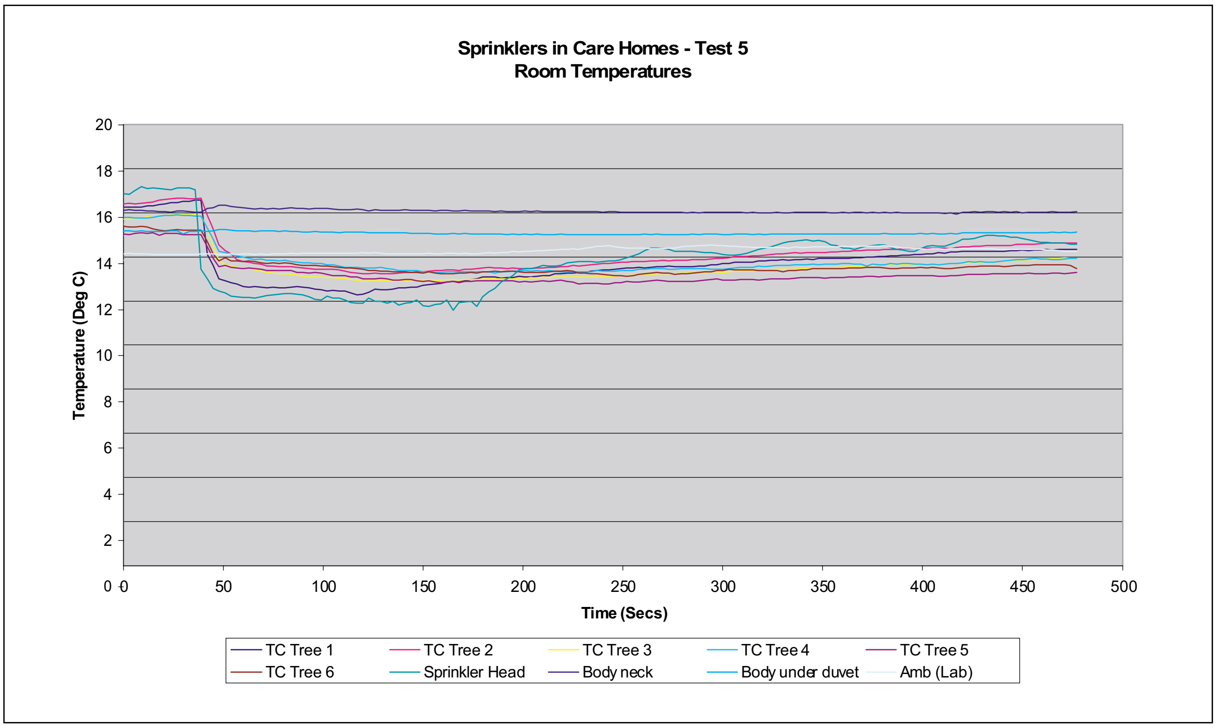

Sprinklers in Care Homes - Test 4
Gas Concentrations in Room
Conc (%)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
15
16
17
18
19
20
21
22
0
0
100
200
300
400
500
600
700
800
900
1000
Time (Sec)
CO% (Head)
CO_2 % (Head)
CO %
CO_2 %
O_2 % (Head)
O_2 %

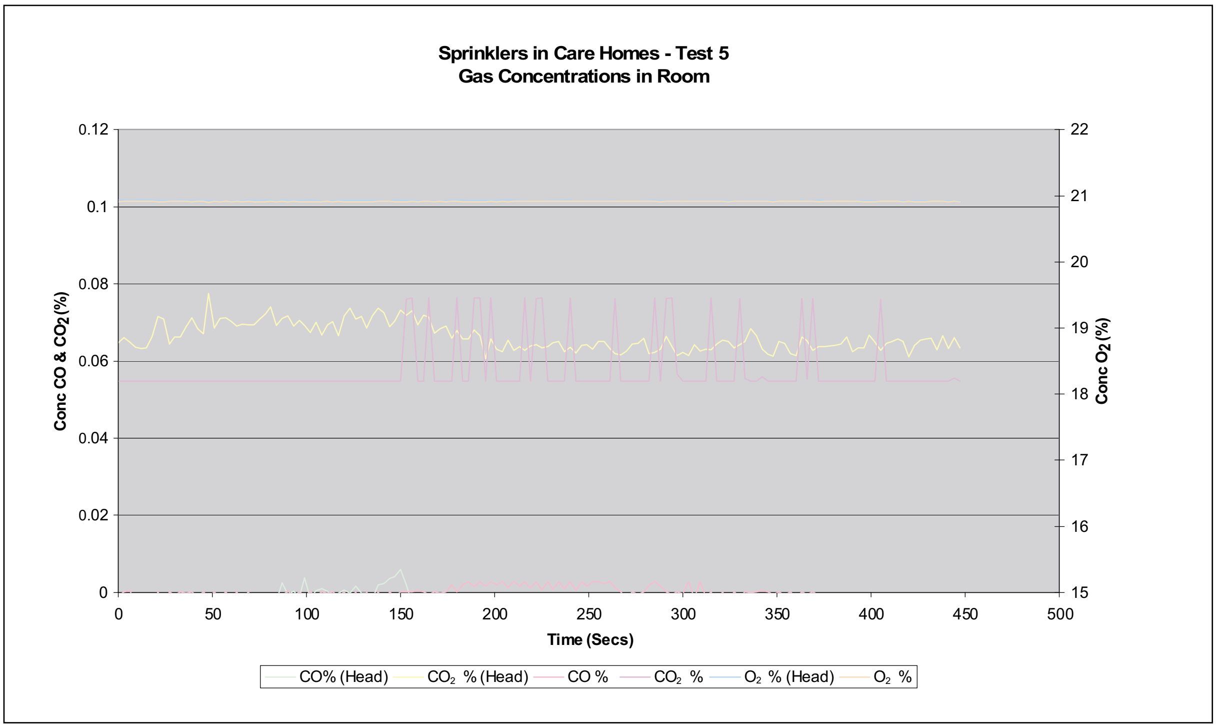
Test 4


Sprinklers in Care Homes - Test 4
Heat Flux
Heat Flux (kW/m^2)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
800
900
1000
Time (Secs)
Heat Flux (Head)
Heat Flux (Floor)

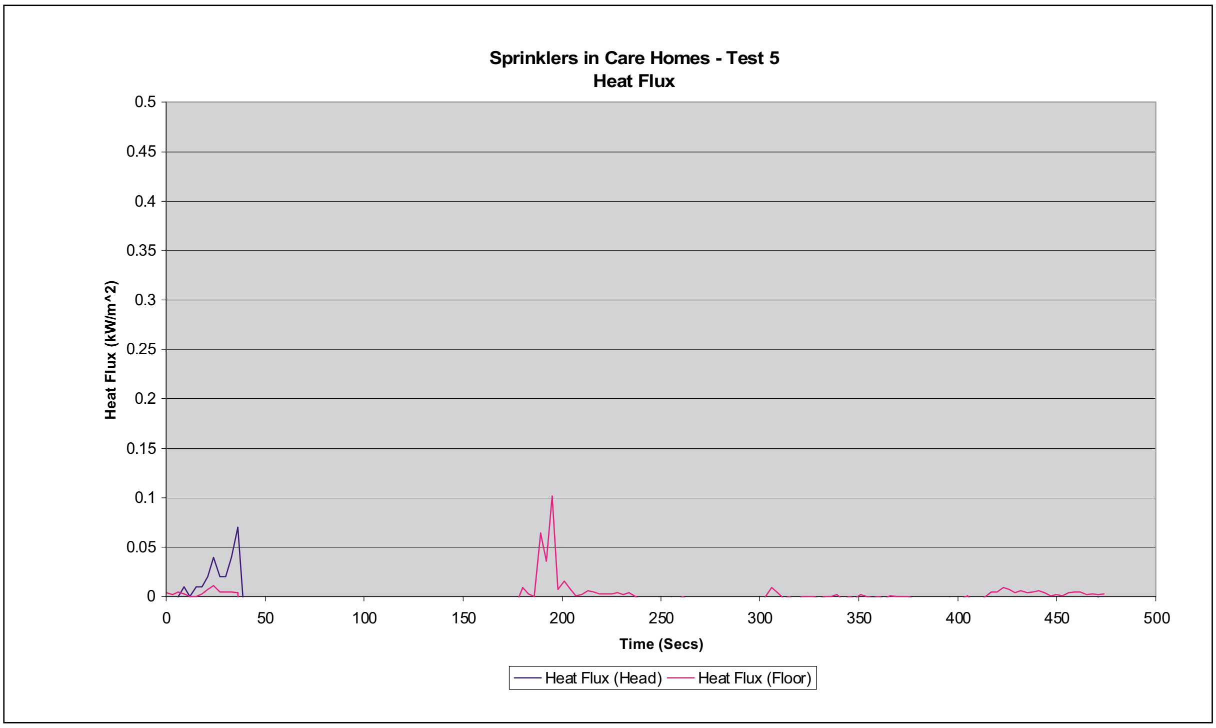

Sprinklers in Care Homes - Test 4
Heat Release Rate
Heat release rate (kW)
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
1100
Time (Secs)
HRR

Test 5


Sprinklers in Care Homes - Test 5
Room Temperatures
Temperature (Deg C)
Time (Secs)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
300
350
400
450
500
TC Tree 1
TC Tree 2
TC Tree 3
TC Tree 4
TC Tree 5
TC Tree 6
Sprinkler Head
Body neck
Body under duvet
Amb (Lab)

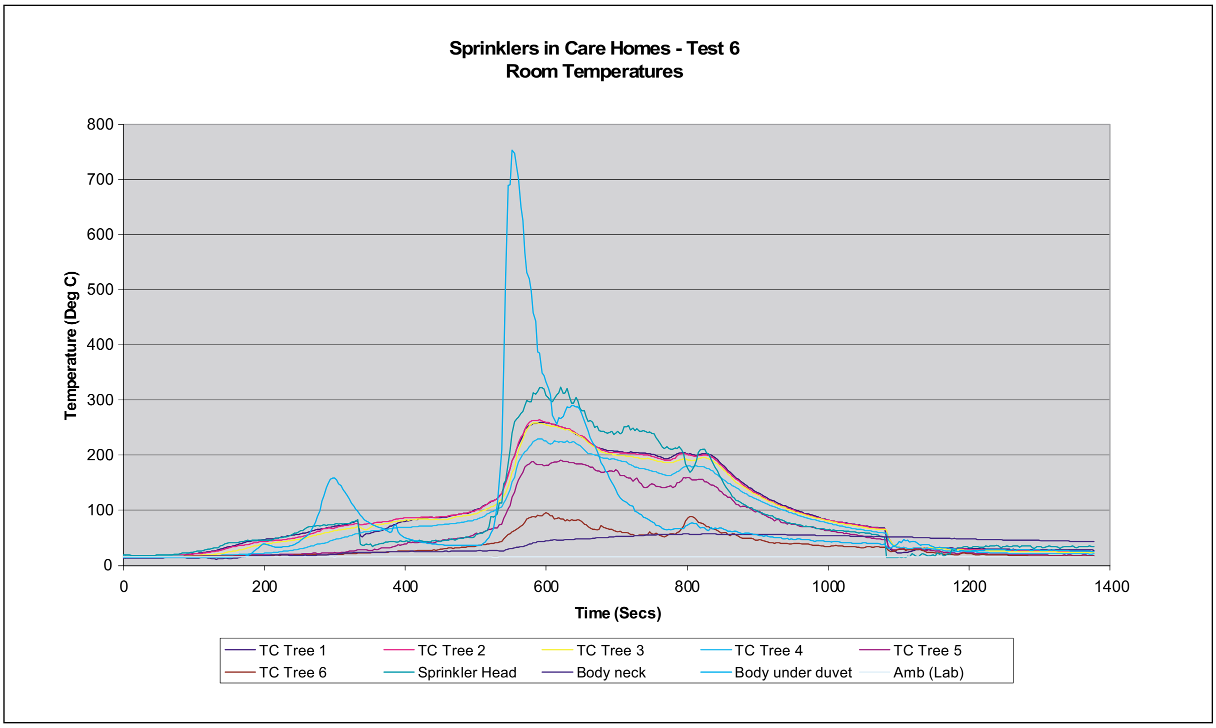

Sprinklers in Care Homes - Test 5
Gas Concentrations in Room
Conc CO & CO2 (%)
Conc O2 (%)
Time (Secs)
0
0.02
0.04
0.06
0.08
0.1
0.12
15
16
17
18
19
20
21
22
0
50
100
150
200
250
300
350
400
450
500
CO% (Head)
CO_2 % (Head)
CO %
CO_2 %
O_2 % (Head)
O_2 %

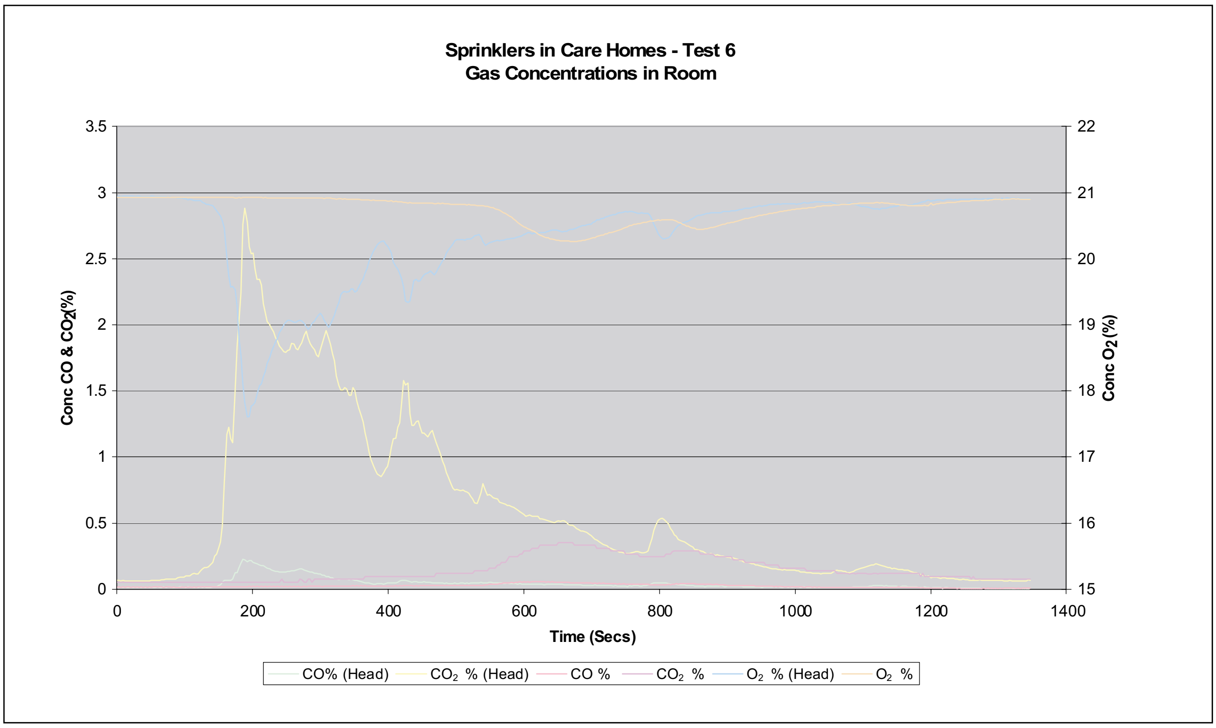
Test 5



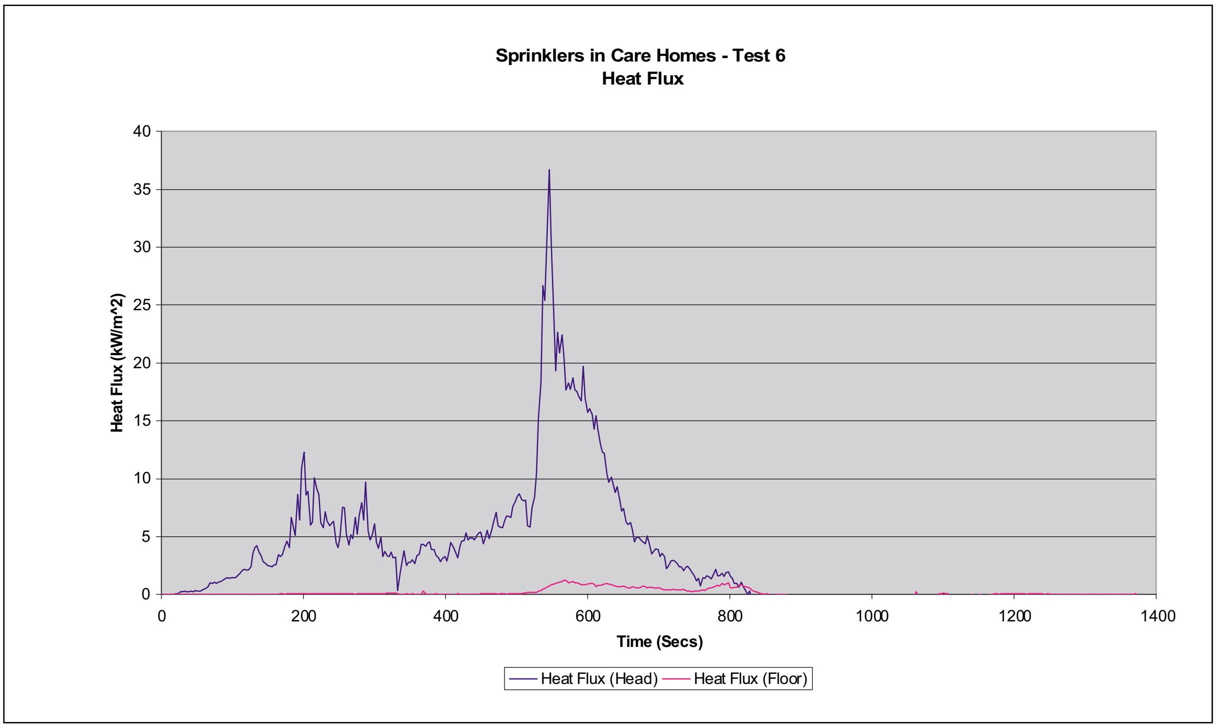
Note: No heat release rate measurements were carried out in Test 5.

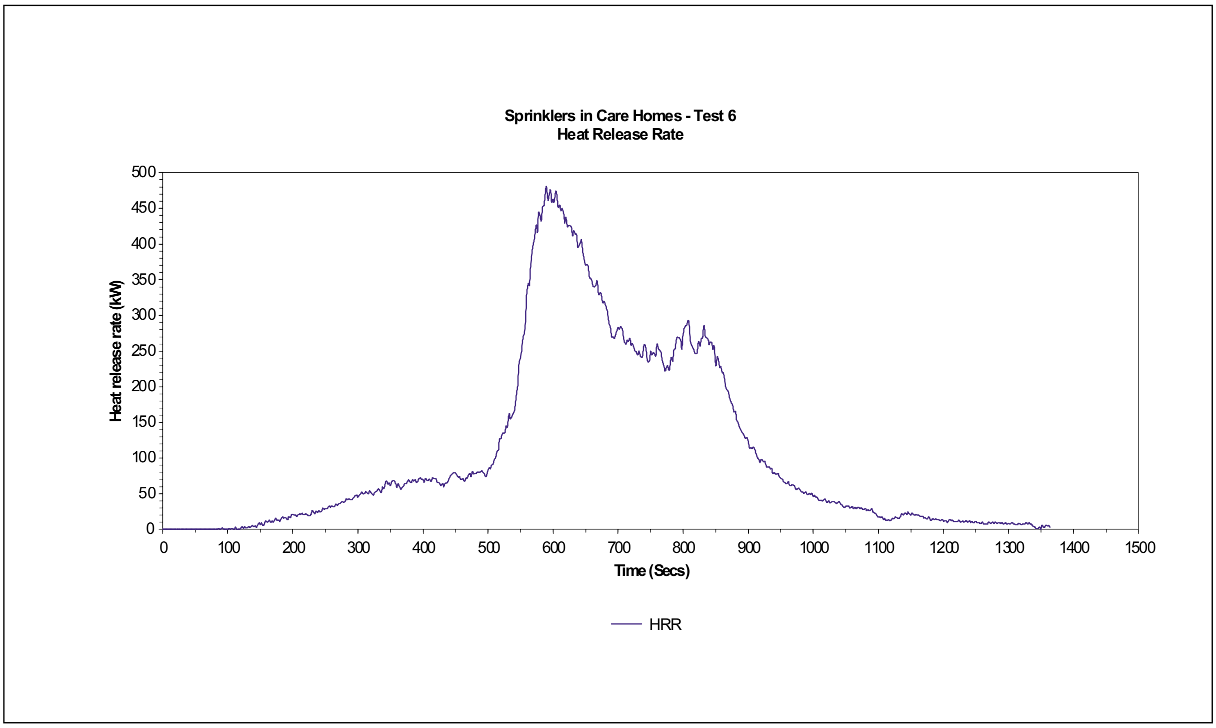
Test 6


Sprinklers in Care Homes - Test 6
Room Temperatures
Temperature (Deg C)
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
1400
Time (Secs)
TC Tree 1
TC Tree 2
TC Tree 3
TC Tree 4
TC Tree 5
TC Tree 6
Sprinkler Head
Body neck
Body under duvet
Amb (Lab)


Sprinklers in Care Homes - Test 6
Gas Concentrations in Room
Conc CO & CO2(%)
3.5
3
2.5
2
1.5
1
0.5
0
22
21
20
19
18
17
16
15
Conc O2(%)
0
200
400
600
800
1000
1200
1400
Time (Secs)
CO% (Head)
CO_2 % (Head)
CO %
CO_2 %
O_2 % (Head)
O_2 %

Test 6


Sprinklers in Care Homes - Test 6
Heat Flux
Heat Flux (kW/m^2)
40
35
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
Time (Secs)
Heat Flux (Head)
Heat Flux (Floor)


Sprinklers in Care Homes - Test 6
Heat Release Rate
Heat release rate (kW)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Time (Secs)
HRR

Appendix G – Photographs

Set up and initial test

Gas analysis equipment

Sprinkler flow-rate meter

Initial test – pyjamas

Test 1 (nightwear)

Target in bed

Ignition

Fire developing

Fire developing

Test 1 (nightwear)

Fire developing

After test

Duvet removed

Target after test

Test 2 (bedclothes)

Target in bed

Ignition

Fire developing

Fire developing

Fire developing

Fire developing

Test 2 (bedclothes)

After test

Duvet removed

Target after test

Test 3 (nightwear)

Target in bed – ignition

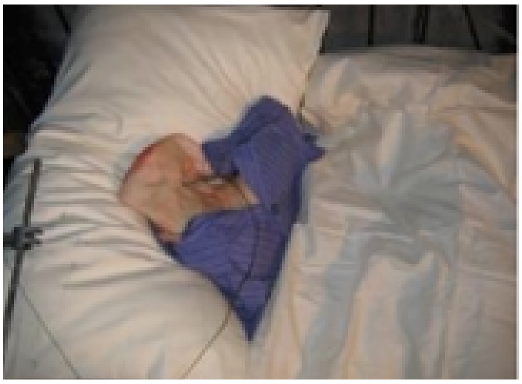
Fire developing

After test

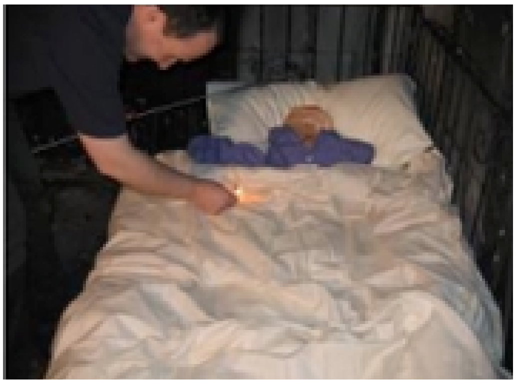
Target after test

Target from Tests 1, 2 and 3

Test 4 (bedclothes – door closed)



Target in bed



Ignition

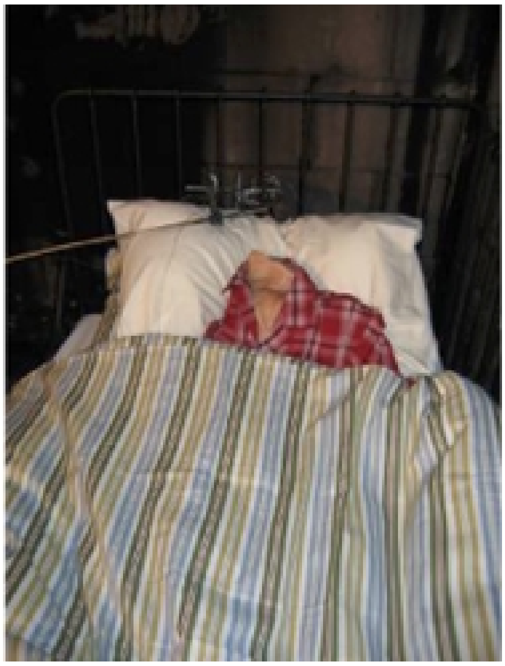
After test

Duvet removed

Target after test

Test 5 (nightwear – sprinkler responds on smoke alarm)

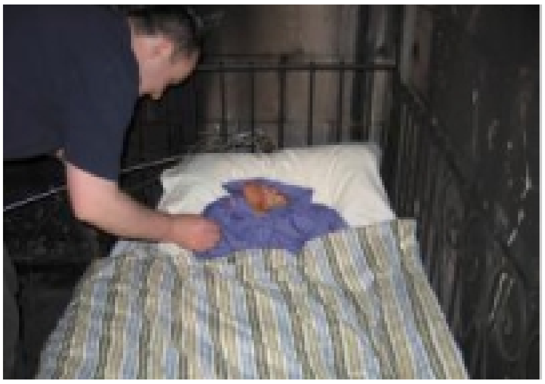
Target in bed



Target in bed

Target after test (no damage)

Test 6 (nightwear – no sprinkler)



Target in bed

Ignition

Fire developing

After test

Target after test

Appendix H – Toxic hazard analysis

By D Purser

METHOD FOR TOXIC HAZARD ANALYSIS

The hazards from exposure to asphyxiant toxic gases and from heat (hazard from convection due to contact with hot fire gases) have been analysed for a location at nose height standing within the bedroom in the test room during two of the fire tests. The asphyxiants considered are carbon monoxide (CO), carbon dioxide (CO_2) and low oxygen hypoxia. The combined effects of these gases have been estimated according to the method of Purser[1,2] .

The method uses a fractional effective dose (FED) approach. For each unit of time during the fire, the exposure dose of an asphyxiant gas (such as CO) in ppm x minutes is expressed as a fraction of an exposure dose for that gas required to cause incapacitation (loss of consciousness). The FED for CO is them summed with time throughout the fire until the fraction reaches unity, at which time incapacitation is predicted.

Where mixtures of gases are present, the fractional doses each unit of time are estimated on the basis that the presence of CO_2 increases the rate of uptake of CO by causing hyperventilation. The effects of low oxygen hypoxia are also considered to be additive with those of the other asphyxiants according to the following general equation:

$$FEDin = (FED_{CO}) \times VCO_2 + FED_{hypoxia}$$

Where:

FED_{in} = total fractional asphyxiant dose

FED_{CO} = FED carbon monoxide

VCO_2 = hyperventilatory factor due to carbon dioxide

$FED_{hypoxia}$ = asphyxiant effect of low oxygen hypoxia

Death due to asphyxiation is predicted at an FED of approximately 2-3.

The percentage carboxyhaemoglobin (%COHb) for a subject in each location has been estimated according to the linear uptake model of Stewart[3]. This provides a good prediction for adults when the carbon monoxide concentration is well in excess of the air/blood equilibrium concentration.

For these calculations a resting base ventilation (VE) of 8 litres/minute has been assumed. This is then increased according to the carbon dioxide concentration.

The time to incapacitation due to skin pain or hyperthermia for exposure to convected heat has been derived empirically (see Ref 1) and is given by:

$$t_{IHEAT} = 5 \times 10^7 \times T^{-3.4}$$

where T = temperature ^oC

and

t_{IHEAT} = time to incapacitation, minutes

The fractional dose of heat acquired per minute is the reciprocal of the time to incapacitation. The fractional heat doses each unit of time are summed until the FED for heat reaches unity at which time incapacitation due to pain is predicted.

The tenability limit for exposure of skin to radiant heat is approximately 2.5 kW/m^2 below which exposure can be tolerated for at least several minutes. Radiant heat at this level and above causes skin pain followed by burns within a few seconds, but lower fluxes can be tolerated for more than five minutes. For situations where occupants are required to pass under a hot smoke layer in order to escape, this radiant flux corresponds approximately to a hot layer temperature of 200^{o}C. Above this threshold, time (minutes) to incapacitation due to radiant heat tIrad, at a radiant flux of q kW/m^2 is given by the equation below[1].

$$t_{Irad} = \frac{80}{q^{1.33}} \quad (8) \qquad (3)$$

Where q = heat flux kW/m^2.

Based upon the work of report of Hockey and Rew[7], the threshold for pain occurs at approximately 1.333-1.667 $(kW.m^{-2})^{1.33}$ .min, second degree burns at 4-12.17 (kW.m-2)1.33 .min and third degree burns at approximately 16.667 $(kW.m^{-2})^{1.33}$.min (Figure 3). For infrared radiation it is also proposed that 10 $(kW.m^{-2})^{1.33}$ min represents a fatal level for a vulnerable population (over 65 years of age) or a 1% fatality level for the average population, while 16.667 $(kW.m^{-2})^{1.33}$.min represents a 50% probability lethal level for the average population. Thus:

1.33 $(kW.m^{-2})^{1.33}$ .min = pain/first degree burns

10 $(kW.m^{-2})^{1.33}$ .min = serious injury from second degree burns to 50% exposed population (pain heat dose x 7.5)

16.667$(kW.m^{-2})^{1.33}$ .min = fatal third degree burns to 50% of the exposed population (pain heat dose x 12)

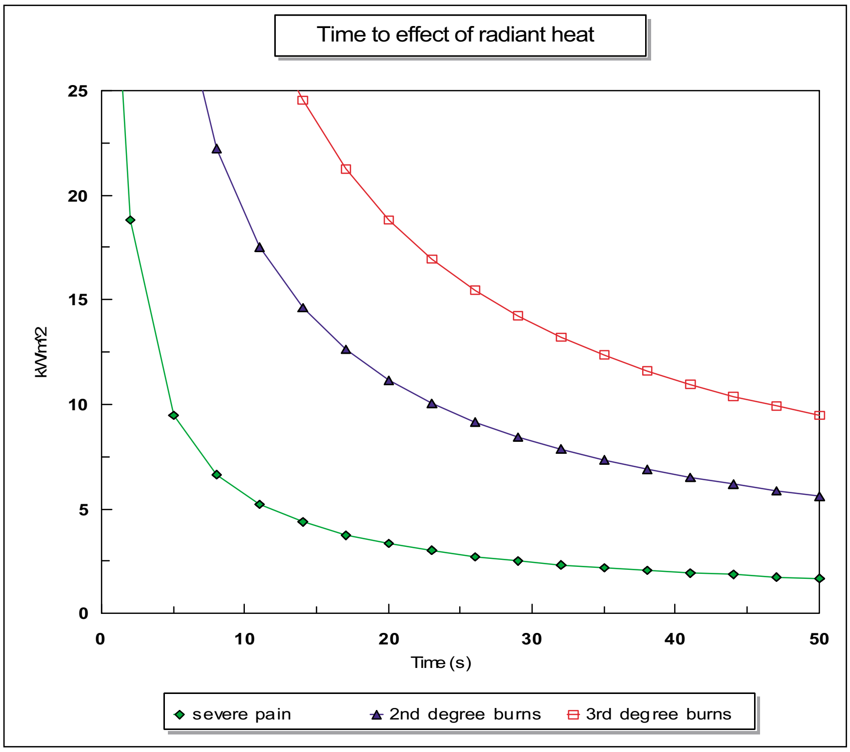


Figure H1. Calculated relationship between incident heat flux and exposure time for pain, 2nd degree burns and 3rd degree burns

For an exposure to a heated atmosphere in room during a fire, the main source of exposure is likely to be the sum of the convected and radiant heat. For this reason a method has been developed for expressing the effects of convected heat in terms of heat flux rather than temperature.

The incident heat flux to a surface due to radiation and convection is given by:

$$Q = \varepsilon\sigma \, (T_i^4 - T_m^4) + h(T_i - T_m) \quad (4)$$

Where:

Q = heat flux W/m²
T_i = heat source temperature K
T_m = material surface temperature K
ε = emissivity (0.05 for a gas to 1 for a black body, perhaps 0.25-0.5 for pyroclastic flow dust, 0.9 for smoke)
σ = Stefan Bolzmann constant (5.67 x 10-8 Wm-2K-4)
h = convective heat transfer factor. For air this depends upon the flow rate past the object. It will be approximately 5-8 for slow moving air but as much as 80 for a pyroclastic flow at 145 km/hr

(The configuration factor is assumed to be 1).

The second term in the equation represents the convective component of heat flux. Using this equation it is therefore possible to calculate heat flux from the smoke temperature. The radiative component is relatively small at low temperatures. For smoke the emissivity is likely to be around 0.4 so that at higher temperatures both components should be considered to calculate the total heat flux to the skin.

This method has therefore been used to calculate the total heat flux for a subject in the fire room exposed to hot smoke. An FED analysis has then been carried out to predict the time at which a dose of heat flux capable of causing fatal third degree burns would have been received.

METHODS USED FOR OBTAINING A FULL DATA SET FOR FED ANALYSIS

The FED hazard analysis has been carried out for the effects of heat and asphyxiant gases (CO, CO_2 and low O_2) in the specified location for the fire test. In order to carry out the FED analysis, a full continuous data set was required.

RANGE OF LETHAL CARBOXYHAEMOGLOBIN CONCENTRATIONS

The percentage blood carboxyhaemoglobin concentrations (%COHb) provide a valuable source of information, especially when considered in conjunction with the pathology reports. In general, all fires produce some carbon monoxide([1]). The longer an occupant survives during an incident the higher the %COHb. Carbon monoxide is also the major toxic fire gas and a major cause of death from exposure to toxic fire effluent([1,4]). An examination of the %COHb in a decedent therefore enables estimates to be made of how long the exposure continued before death, the extent to which death can be attributed to inhalation of toxic fire effluent and the extent to which death resulted from physical trauma, or heat and burns.

Figure 1 shows the % frequency distribution of deaths at different post-mortem %COHb levels in a large sample of fire and non-fire deaths in the United States studied by Nelson([5]). The non-fire deaths consist mainly of accidental CO exposures resulting from faulty space heaters or suicides (mostly in young men and often by inhalation of vehicle exhaust fumes). The fire deaths are for decedents dying from exposure to fire effluent in the absence of significant burn injuries.

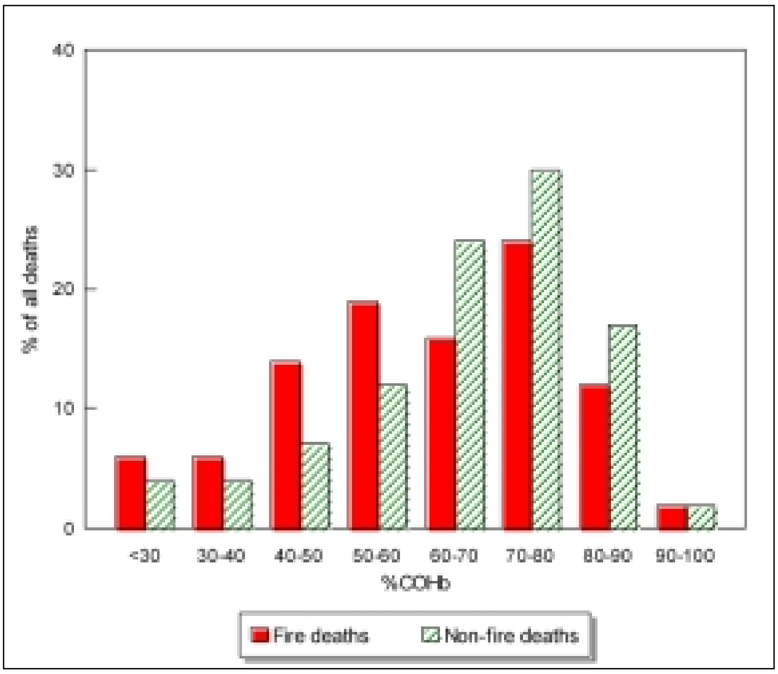


Figure H2. Frequency distribution of fire and non-fire deaths at different %COHb concentrations (after Nelson(5))

The basic findings from this and from other data, including experimental data on humans and other primates([1,5]) are that incapacitation resulting from acute CO poisoning typically occurs at 30-40% COHb as intoxication followed by loss of consciousness([6]). It is rare for people dying from CO poisoning to have less than 30% COHb in their blood, although this can occur occasionally, particularly if there is some pre-existing medical condition such as heart disease. As Figure H2 shows, the mode for %COHb in fatal CO poisoning is 70-80% COHb and levels of up to 90% are quite common. It is considered that a typical fatal blood concentration is around 50% COHb, in that subjects rescued alive at this level may not survive even if given prompt treatment. The data for fire fatalities shows similar but somewhat lower blood concentrations to those from CO poisoning incidents. The higher incidence of fatalities with 30-60% COHb may reflect the added effects to CO poisoning of other toxic products in fire effluent (hydrogen cyanide, smoke particulates and irritants). It is considered that for death to be attributable solely to the inhalation of toxic fire effluent in an otherwise healthy subject the % COHB would be expected to be in excess of 30% COHb and most likely in excess of 50% COHb.

RESULTS OF HAZARD ANALYSIS

A review of the measurements from the six tests show that neither the person in the bed, nor a person elsewhere in the room would be likely to die as a result of the inhalation of toxic gases.

The critical parameter is heat; convected heat from the hot gases and thermal radiation from the flames.

The heat flux on the head of the bed occupant for the six tests is as follows:

Test 1 – 58kW/m^2

Test 2 – 15kW/m^2

Test 3 – 8.1kW/m^2

Test 4 – 3.85kW/m^2

Test 5 – 0.1kW/m^2

Test 6 – 37kW/m^2

The critical value of 2.5 kW/m^2 over 20 seconds for pain and around 4 kW/m^2 over more than one minute for burns is exceeded in all cases except Test 5 (where very rapid sprinkler operation occurred).

In addition, the burn damage to the skin of the body target (which would have experienced greater heat fluxes than those seen by the radiometer) was excessive in all tests except Test 5.

For the purposes of the FED analysis, the two 'worst' sets of results have been assessed; these are Test 3 (where the sprinkler took nearly 20 minutes to operate) and Test 6 (where there was no sprinkler system).

The results of the hazard analysis are illustrated in the Figures presented below.

The figures show the developing hazards with time represented as Fractional Effective Dose (FED) and predicted blood carboxyhaemoglobin concentration in exposed subjects calculated from the gases and temperature curves. For the FED curve, the data represents the accumulated 'dose' with time expressed.

'FED asphyxia no HCN' represents the fractional dose of asphyxiant gases (mainly carbon monoxide) required to cause collapse and loss of consciousness. 'Heat' represents the point where exposure to hot gases is predicted to cause skin pain followed by burns at approximately a 'Heat' value of 3.

The predicted results of an exposure in this room are:

- For the occupant of the bed; pain from heat exposure and extensive third degree burns at around seven minutes (Test 3) and five minutes (Test 6). This would lead to death within a minute or so

- For another seated occupant of the room; pain from heat exposure and extensive third degree burns at around 12 minutes (Test 6). (Test 3 was survivable).

In no case does %COHb exceed 6% (well below the critical value of 30%). Consequently, incapacitation and death due to asphyxia is not predicted for either the occupant of the bed or anyone else seated or lying in the room.

SUMMARY

The results show the calculated times to incapacitation and death in the specified location. In general, where hazards are high and times are a few minutes the accuracy of the predictions of time to incapacitation and death are considered to be high (i.e. + or – approximately 0.5 minutes). Where predicted times are long (approximately 1 hour or more) the predictions are more uncertain due to variations in individual susceptibility and the need to extrapolate the test data. For these data the uncertainty on either side of the predicted time is considered to be approximately one minute.

The comparison shows that for a room with a sprinkler:

- For the person in the bed the conditions became untenable very rapidly as the fire entered its rapid growth phase, with death predicted at around five or so minutes in that location as a result of heat and/or flame contact

- For an occupant of the bedroom elsewhere the conditions do not become untenable.

The comparison shows that for a room without a sprinkler:

- For the person in the bed the conditions became untenable very rapidly as the fire entered its rapid growth phase, with death predicted at around five or so minutes in that location as a result of heat and/or flame contact

- For an occupant of the bedroom elsewhere the conditions became untenable very rapidly as a result of convected heat.

Appendix H References

1. Purser, D.A. ‘ Toxicity Assessment of Combustion Products.’ *The SFPE Handbook of Fire Protection Engineering 3rd ed)*,.DiNenno P.J (ed.), National Fire Protection Association, Quincy, MA 02269, 2002, pp. 2/83 – 2/171.

2. Purser, D.A. (1996) *Behavioural impairment in smoke environments. Toxicology*, 115, 25-40.

3. Stewart, R. D. Peterson, J. E., Fisher, T. N. , Hosko, M. J., Baretta, E. D. , Dodd, H. C. and Hermann, A. A. *Experimental human exposure to high concentrations of carbon monoxide*. Arch. Environ. Hlth. 26, 1, 1973.

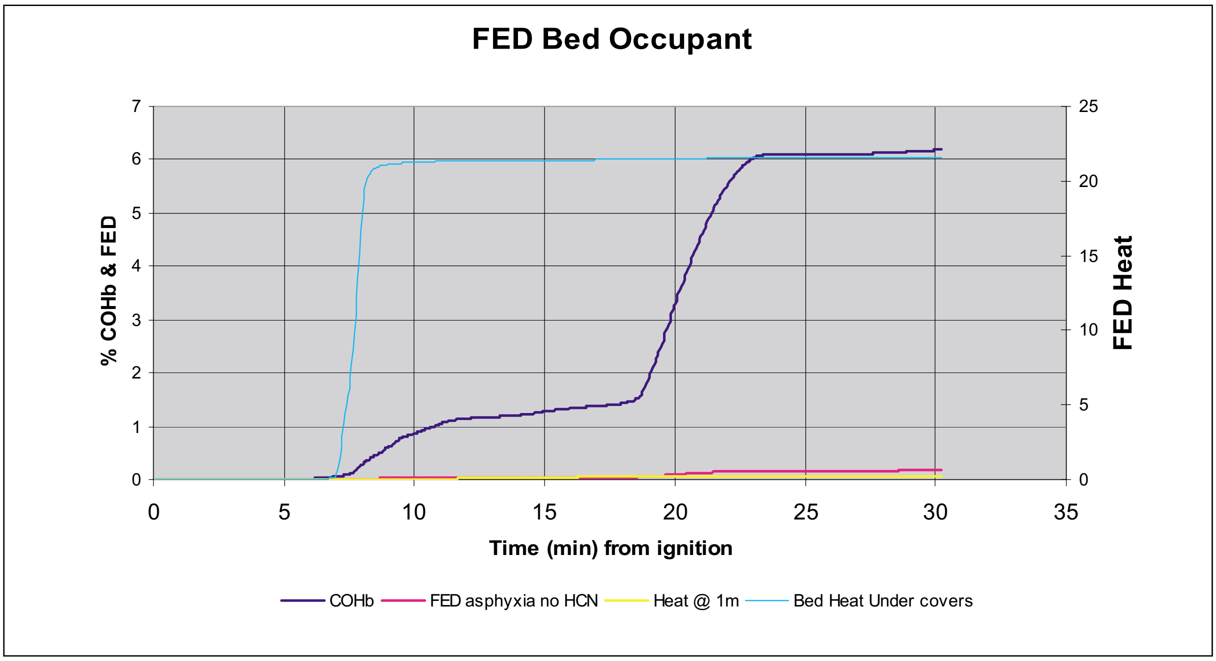
4. Purser, D.A. *‘Interactions among Carbon Monoxide, Hydrogen Cyanide, Low Oxygen Hypoxia, Carbon Dioxide and Inhaled Irritant Gases. In: Carbon Monoxide Toxicity.* David G. Pennery Ed. CRC Press, Boca Raton. pp. 157-191, 2000.

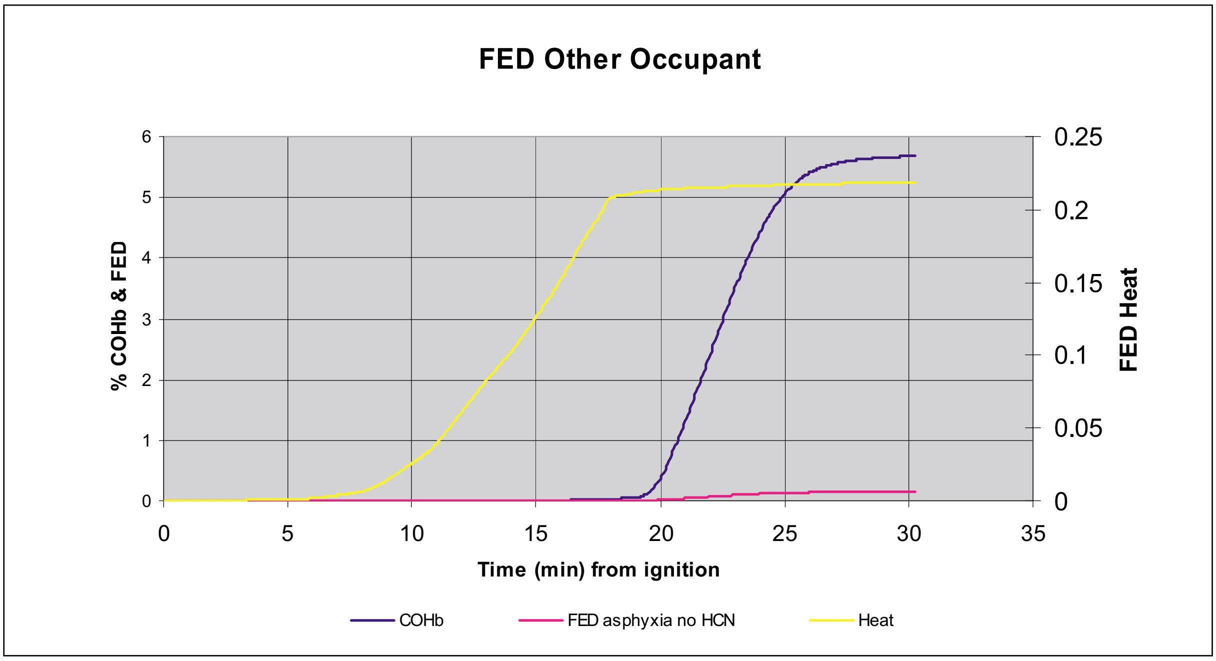
5. Nelson, G.L., *Carbon Monoxide and Fire Toxicity: a Review and Analysis of Recent Work*. Fire Technol. 34, 39-57, 1998.

6. Purser, D.A. and K.R. Berrill, K.R. (1983) Effects of carbon monoxide on behaviour in monkeys in relation to human fire hazard. Arch. Environ. Hlth. 39, 308-315.

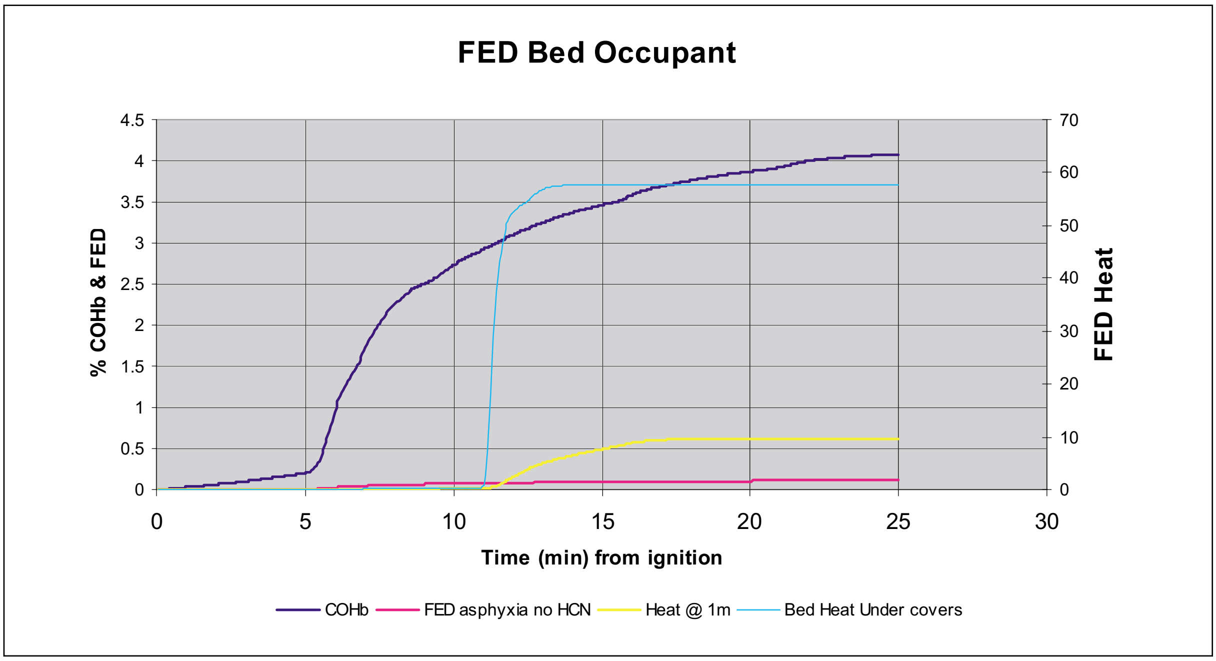
7. Hockey, S.M. and Rew, P.J. *Review of Human Response to Thermal Radiation*. HSE Contract Research Report No. 97/1996. HMSO ISBN 0 7176 1083 7.

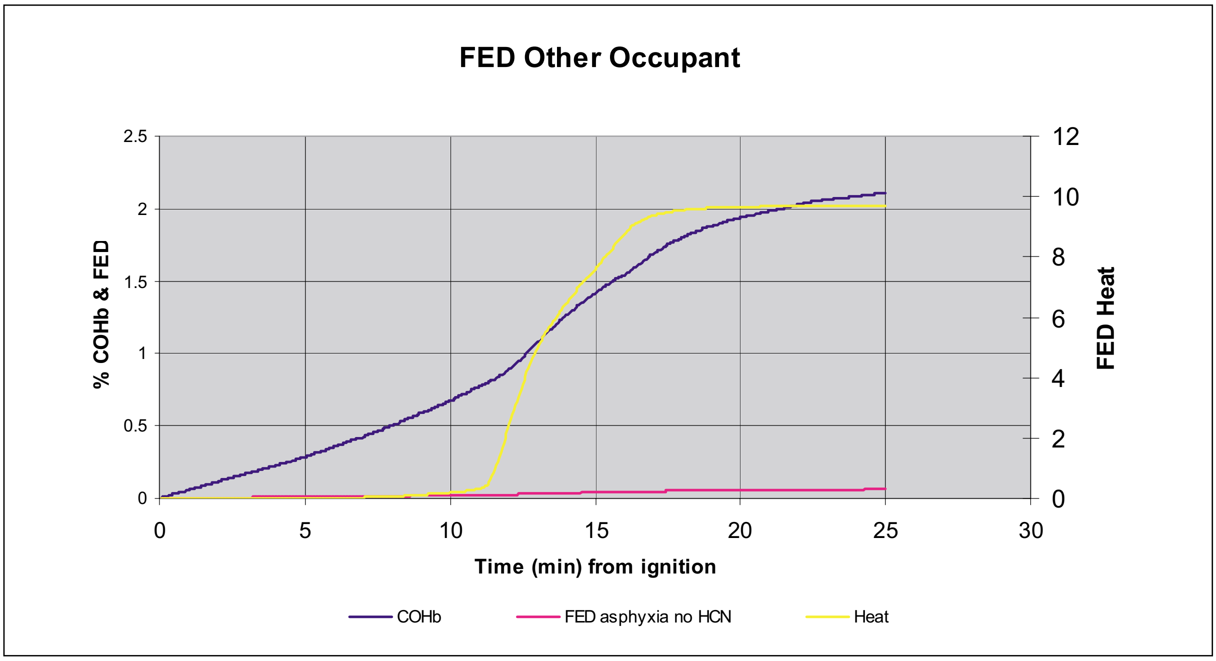
Test 3


FED Bed Occupant
% COHb & FED
FED Heat
Time (min) from ignition
0 5 10 15 20 25 30 35
0 1 2 3 4 5 6 7
0 5 10 15 20 25
COHb
FED asphyxia no HCN
Heat @ 1m
Bed Heat Under covers


FED Other Occupant
% COHb & FED
FED Heat
Time (min) from ignition
0 5 10 15 20 25 30 35
0 1 2 3 4 5 6
0 0.05 0.1 0.15 0.2 0.25
COHb
FED asphyxia no HCN
Heat

Test 6


FED Bed Occupant
% COHb & FED
FED Heat
Time (min) from ignition
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
COHb
FED asphyxia no HCN
Heat @ 1m
Bed Heat Under covers


FED Other Occupant
% COHb & FED
FED Heat
Time (min) from ignition
2.5
2
1.5
1
0.5
0
12
10
8
6
4
2
0
0
5
10
15
20
25
30
COHb
FED asphyxia no HCN
Heat