Effectiveness of sprinklers in residential premises:

Section 2: Description of the Project

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Contents

2 Description of the Project

Residential sprinklers are the subject of much debate (in the UK) because they offer a potential means of saving lives in domestic/residential properties. The key question is: can a sprinkler system provide adequate fire control to allow escape/rescue at a reasonable cost? The publication of British Standard Drafts for Development DD251[1] and DD252[2] provides a basis on which an examination of both effectiveness and cost can be examined. There was a lack of information at the start of this Project regarding the overall effectiveness of residential sprinklers. Also, firm and transparent guidance is needed regarding the design parameters for these systems.

FRS was commissioned by ODPM to carry out a two and a half-year study on the effectiveness of sprinklers in residential premises. The overall aim of the Project was to determine the benefits and effectiveness of sprinklers in residential accommodation. The specific objectives of this Project were:

a) To analyse statistical information to determine how effective they have been in reducing life loss and property damage

b) To make a risk-based assessment to determine potential benefits for the UK housing sector, including Houses in Multiple Occupation (HMOs), flats and maisonettes of varying heights

c) To collect data on the benefits and costs of residential sprinklers

d) To establish benchmark tests for UK conditions to support the further development of DD251 and DD252, and

e) To carry out an experimental programme to examine and quantify the effectiveness in fire suppression of residential sprinklers, in particular with regards to life safety in the room of origin.

To achieve these objectives, six main Tasks were carried out: Task 1 Steering Group, Task 2 Pilot study, Task 3 Cost benefit analysis, Task 4 Benchmark tests, Task 5 Experimental programme and Task 6 Dissemination of findings.

Initial dissemination of the emerging results of this study was via a seminar which was held in December 2003.

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[1] British Standards Institution, DD 251 Sprinkler systems for residential and domestic occupancies – Code of Practice, April 2000

[2] British Standards Institution, DD 252 Components for residential sprinkler systems - Specification and test methods for residential sprinklers, July 2002

The results from this project will provide input into the development of full UK design standards and will also provide the Regulators with sound engineering-based results that they can use for Regulatory decisions. In the short term, this will undoubtedly assist those working within the fire arena, offering them the potential to consider informed alternative approaches to the current guidance contained in Approved Document B (Fire safety).

2.1 Steering Group

Industry contribution has been an integral part of the Project and has been co-ordinated/ focussed via a Steering Group. The Steering Group was established at the outset of the Project and comprised, representatives of Regulators, Fire Service, House Builders, residential sprinkler industry and the water industry. The Group has been active and enthusiastic and has met six times. A smaller experimental Working Group particularly focussed on reviewing the details of the experimental work. Table 2.1 details the individual Steering Group members and the organisations they represented during the course of the Project.

The purpose of the Steering Group was to inform the Project, to review and comment on the FRS work programme, to provide relevant data/information and to discuss relevant issues and initiatives. Issues discussed by the Steering Group include:

- FRS work programme
- Residential sprinkler systems costs data
- Progress of British Standards activities
- Water supplies initiatives
- Residential sprinkler installation survey [Hardy 2003]
- Proposed Scottish Residential fire sprinklers bill [Matheson 2001]
- Alternative systems e.g. water mist
- Welsh initiatives.

All these topics are covered elsewhere in this Report.

Wider industry contribution has also been provided through a seminar (held on 11 December 2003). 100+ delegates attended, and provided a number of number of comments which have fed into this final report.

2.2 Pilot Study

The Pilot study consisted of the following items:

- Statistical and other information were obtained, reviewed and analysed to determine the effectiveness of sprinklers in reducing life loss and property damage

- A simple assessment was made to look at the risks in residential premises and to determine the potential benefits for the UK housing sector including Scotland.

- A consideration of the suitability of DD 251 and DD 252 as the basis for future UK residential sprinkler standards was made by carrying out a critical review of the DDs to identify the technical knowledge gaps and other areas of uncertainty.

The findings of this pilot study were summarised in a progress and project report with recommendations for the onward direction of the Project.

2.3 Benchmark tests

A series of experimental Benchmark tests were carried out to establish a benchmark fire test for UK conditions to support the further development of BS DD251 and 252 and to assess the performance of residential sprinklers in fire test conditions.

The DD 252 fire test essentially involves burning a stylised, representative fuel package of simulated furniture and wall and ceiling linings arranged inside a simulated residential 'room' with door openings and with two installed sprinkler heads. There are two open doorways and near the opening of one doorway is a third dummy sprinkler head. The sprinkler system performance is determined by its performance in controlling the fire for a period of time measured after sprinkler operation, the gas temperatures being limited to specified values and the dummy sprinkler head not operating.

Five pre-selected commercially-available residential sprinkler heads were obtained and these were characterised using vertical and horizontal water distribution measurements. Four were chosen for further study in the fire tests.

Suitable UK materials were obtained for the fuel package given in DD 252. Elements and the whole fuel package arrangement were characterised using seven fires, in free burns without sprinklers, under a calorimeter.

A series of eighteen fire tests was conducted, including repeat tests, based on the procedures given in DD 252 to examine the effect of varying parameters on the performance of residential sprinklers. The parameters investigated were: sprinkler model (four 15 mm pendent types), location of fuel package within sprinkler spray (wall, corner and directly beneath sprinkler configurations), the effect of the presence of 0.3 m lintels (with and without), sprinkler water flow rate (3 and 4 mm/min).

2.4 Experimental programme

The purpose of the Experimental programme was to examine and quantify the effectiveness of residential sprinklers, in particular to life safety in the room of fire origin. This programme was divided into two main parts: house, and compartment and fires. Calorimetry fires were also performed to characterise the fire scenarios in terms of heat release rate, etc.

Sprinklers installed to in DD251 are not necessarily designed to extinguish the fires, but to control them to allow escape or rescue. The effectiveness of the residential sprinklers in the house and compartment fires was primarily assessed, particularly in the room of origin, by measuring their ability to control toxicity, temperature effects and visibility effects. In addition, the amount of fuel burnt by area, with and without sprinklers, was also measured.

Fractional Effective Dose calculations were performed using the results of each test in order to assess the tenability, both of the fire room and connected spaces. These calculations were based on carbon monoxide, carbon dioxide and oxygen concentrations at head height, head height gas temperatures, and optical density per metre.

2.4.1 House fires

Eight sprinklered and unsprinklered lounge fires using realistic fuel arrays were conducted inside the FRS house which was a two-storey detached house of traditional design, with a loft conversion The ground floor comprised a lounge (4 m by 3.5 m by 2.4 m), a kitchen, a dining room and a hallway. The ground floor could be converted into open plan by removing the lounge/hall wall. The first floor comprised two bedrooms and a bathroom area. There was a straight flight of conventional tread stairs up to the loft room which had a fire-resisting cut off door.

The lounge, main bedroom and loft windows were double glazed and were closed for the tests. Inside the lounge, there was a chimney, two low level air bricks. The door of the main bedroom was partially open, the door of the loft room and bathroom were closed, the dining room/kitchen, back bedroom/landing and kitchen/hallway doors were closed and sealed.

Five fire tests were performed in a standard lounge arrangement, and three in an open plan lounge arrangement.

The effect of lounge/hallway door (open/closed), water flow rate, sprinkler orientation and sprinkler model (two 15 mm pendent types) were studied. The sprinkler water flow rates were 60 l/min for a single sprinkler for standard lounge arrangement, and 60 l/min for a single sprinkler or 84 l/min for two sprinklers operating, for the open plan lounge arrangement.

2.4.2 Compartment fires

Twenty-nine fires using realistic fuel arrays representative of residential premises were conducted inside a compartment experimental facility.

The compartment facility essentially comprised residential ‘rooms’ with a timber structure supporting plasterboard walls and a ceramic fibre board ceiling. The facility was configured to provide alternative fire rooms at either end, each measuring 4 m by 4 m by 2.5 m high, connected to a middle room measuring 3.8 m by 4 m by 2.5 m high. With the fire room door open the effective enclosure volume was approximately 118 m^3, reduced to 40 m^3 with the fire room door closed. Some of the fire tests involved a larger room size of 8 m by 4 m by 2.5 m high.

Smoke alarms were located inside the room of fire origin and its adjacent room and were replaced after every fire.

Initially, sixteen fires comprising four main fire scenarios were conducted, each with and without sprinklers and with the door of the room of fire origin open and closed. The scenarios were, as follows:

- Lounge, nightlight and television fire, shielded fire
- Lounge, fire under table directly beneath sprinkler, shielded fire
- Bedroom scenario, fire on duvet, unshielded fire.
- Lounge, fire on sofa (compliant with 1988 Furniture Regulations), unshielded fire.

The fuel was conditioned prior to each test and the house was allowed to dry out between tests.

Following these initial fires, the television and table fires were chosen for further study of the effect of compartment size (either 4m by 4 m or 8 m by 4m by 2.5 m high 2.5m), sprinkler model (one of two 15mm pendent models), sprinkler orientation (parallel or perpendicular to axis of facility) and water flow rate. The sprinkler water flow rates were 60 l/min or 42l/min for a single sprinkler for standard compartment, and 60 l/min for a single sprinkler or 84 l/min for two sprinklers operating, for the large compartment.

A kitchen scenario was examined, an unshielded oil pan fire, with or without sprinklers (two 15 mm pendent models).

2.5 Cost benefit analysis

Cost benefit analyses have been performed for a range of domestic and residential building types, including houses, flats, various types of houses of multiple occupation (HMOs), and residential care homes. Further analyses were performed for different building heights, within certain of the broad categories listed above, in order to focus on properties that would be expected to have higher than average risks from fire.

The benefits of sprinklers include the prevention of deaths and injuries, and the reduction of property damage. The estimated effectiveness of sprinklers, in terms of the percentage reduction of deaths and injuries, was based on a correlation between fire size and risk of death and/or injury. Full details of this method are described in the section covering the Pilot study. The other benefit considered was the reduction in property damage. Rather than assume the cost of the fire was directly proportional to the area damaged by the fire (which would neglect the larger area damaged by smoke), the estimated effectiveness from the USA statistics was used.

Residential sprinkler systems costs include installation; provision of water supplies; annual maintenance. Estimates of these costs have been provided by members of the UK sprinkler and water industries. Government guidance was followed in assigning monetary values to the numbers of deaths and injuries prevented, the average cost of property damage per fire, and the interest rate to use when calculating the capital recovery factor to convert initial costs into annual terms.

The costs and benefits all have uncertain values. An uncertainty analysis has been performed to estimate the degree of confidence that the monetary benefits from providing sprinklers are significantly greater than the costs[3], for all the cases of building type examined.

2.6 Dissemination

Dissemination of the emerging results of this study was initially via

- a seminar which was held on 11th December 2003. This was attended by about 100 delegates. A number of useful comments were received in feedback from this event, and have helped us to clarify aspects of the report.
- the Final Report which was provided to ODPM by December 2003, circulated to the Project Steering Group for comments and feedback and published in February 2004.

Further dissemination is ongoing.

2.7 Acknowledgements

The authors would like to thank the Steering Group and the Experimental Working Group for their enthusiasm, helpful comments and feedback during the course of this project.

They would also like to acknowledge the contributions of the teams, as follows:

Cost benefit analysis: Jeremy Fraser-Mitchell

Additional advice and feedback on cost benefit analysis: Scott Dennison and Sophie Cruickshank (ODPM) and Richard Hartless (BRE)

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[3] a rough guideline is that if the calculated benefit-to-cost ratio exceeds 1.00 by more than the estimated uncertainty (2 standard deviations) in the benefit-to-cost ratio, then we can say with 95% confidence that sprinklers will be cost-effective.

Benchmark tests: Roger Harrison, Dave Smit, Peter Walker, Corinne Williams

Additional advice for Benchmark tests: John Stephens

House fires: Stuart Campbell, Corinne Williams, Peter Walker, Frans Hofsteede,

Compartment fires: Stuart Campbell, Rajesh Parbat, Corinne Williams

Also, Peter Walker, John Stephens, Christian Nielson for assistance in some of the fires, Phil Clark for preparation of some of the graphs and photographs and Kelvin Annable for help with preparation of two project reports

Advice on toxicity aspects and fractional effective dose modelling for house and compartment fires: Professor David Purser

Advice on smoke alarms aspects: Nigel Smithies

Tom Cray and assistants for building and altering experimental facilities.

The Final Report is part of a contract placed by the Office of the Deputy Prime Minister (ODPM). Any views expressed in it are not necessarily those of the ODPM.

2.8 References

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Matheson M, Consultation document for proposed residential fire sprinklers bill, The Scottish Parliament web site, http://www.scottish.parliament.uk, September 2001.

Appendix 2A - Steering Group members

Member	Organisation represented
Williams, Corinne	Chairman and Co-ordinator, FRS, BRE
Campbell, Stuart	FRS, BRE
Fraser-Mitchell, Jeremy	FRS, BRE
Harrison, Roger	FRS, BRE
Stephens, John	FRS, BRE
Baker, David	House Builders Federation
Bond, Allan	Welsh Assembly Government
Burd, Anthony	Buildings Division, ODPM
Carvell, Tony	Fire Brigades Union
Cornthwaite, Lea	Fire Policy Unit, ODPM
Eady, Mick	HM Fire Service Inspectorate, ODPM
Evans, Glyn	Fire Brigades Union
Hartless, Richard	Energy Technology Centre, BRE
Heaviside, Leslie	Wormald (Ansul) UK Ltd
Hird, Colin	Buildings Standards Division, Scottish Executive
Hobbs, Darren	Buildings Division, ODPM
Kidd, Stewart	British Automatic Sprinkler Association
Reed, Mike	Fire Policy Unit, ODPM
Seaber, CFO Steve	CACFOA
Stollard, Paul	Buildings Standards Division, Scottish Executive
Tucker, Mike	NHBC Ltd
Whittaker, Ian	Water UK
Wilson, Tony	AEA Technology Environment
Young, Roy	Fire Sprinkler Association (formerly Residential Sprinkler Association)

