An appraisal

of the

ODPM - BRE Report

"*Effectiveness of sprinklers in residential premises*"

EXECUTIVE SUMMARY

The FSA congratulates the ODPM, sponsors of this Research Project, for commissioning the work, which provides UK derived data to support statistics from the USA and elsewhere on the effectiveness of residential sprinklers. The report took 3 years to complete and the FSA has had just 3 months to evaluate its findings. It has not therefore always been possible to bottom out all of the issues raised in this appraisal and doubtless other matters will emerge from the 700+ pages of the report in the months to come.

Whilst the FSA broadly welcomes the findings of this report, in that it demonstrates that residential sprinklers are reliable, effective and cost beneficial, we feel the report is flawed in several respects. A number of important areas were not

Therefore properties with systems being installed but not yet operational, those with systems being removed, those disconnected for whatever reason, or those with no water supply connected, were all included as properties with sprinkler systems. As a result the Rohr report inaccurately suggests there are many fatalities in sprinkler-protected properties each year.

Page 13 of the Pilot Study suggests the saving of every fire death is unrealistic, but that is in fact what happens in real life and this is substantiated by the other reports quoted, such as those from Scottsdale and Vancouver. Indeed in the years from 1985 Operation Life Safety (a US Fire Administration/Fire Industry joint body) tracked residential sprinkler activations. They documented over 600 activations in the following years with no fatalities.

Benchmarking - BS DD252

This British Standards Draft for Development, largely based on the Underwriters Laboratories (UL) and Factory Mutual (FM) tests protocols developed in the United States over the past 30 years, has yet to be used, although it is called up in DD251:2000 *Sprinkler systems for residential and domestic occupancies – Code of practice.*

The fire test commonly used to evaluate residential sprinklers was developed from a specification originally written by Rolf Jensen in 1972 and subsequently tested and improved by the US Fire Administration, FM, and NFPA through the 1970s. This became Underwriters Laboratories' standard UL1626, which was again improved in 2002. The basis of the testing procedure is to simulate a standardised severe domestic fire scenario, which can be easily and reliably repeated, and which the fire sprinklers must control sufficiently so that occupants of the test room would survive the fire.

To this extent we would have assumed that DD252 would follow established procedures, but using UK sourced and dimensioned materials. It would seem to us to be pointless to develop a UK standard that deviates substantially from test procedures that have been established for over 25 years, unless some very good reason became apparent. Such a deviation would make it impossible to compare results from UK tests with existing data from elsewhere. All residential sprinklers currently used have been tested and approved using UL1626 and it is highly unlikely that manufacturers would produce special residential sprinklers for the UK market (in the unlikely event that this was deemed necessary) until such time as a viable market has been established in this country.

The second part of the ODPM research brief was therefore to prove the validity of DD252 and if necessary make recommendations for improvements.

We are therefore surprised that in performing the tests the research team chose to remove the lintels specified in DD252, which should have been over the doors of the test chamber. This in our view would substantially change the characteristics of the test chamber and thus invalidate the tests.

We are also surprised to see that the third (or dummy) sprinkler was located outside the doorway, whereas UL1626 clearly puts it inside. The operation of this dummy sprinkler (with a lintel in place) would indicate that the sprinklers being tested were not controlling the fire and that flashover might be imminent.

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Furthermore the research team chose to conduct some of the tests at flow rates below the minimum requirement of 60 l/min set in DD252. The 'K' factor of Sprinkler 1 was 80 and this would have required a flow rate of about 75 l/min to comply with its UL approval and the manufacturer's recommendations. Therefore this sprinkler was already being used at a flow rate substantially below its specification and, although of passing interest, we can see no validity in reducing the flow rate even further – in this case to about 60% of its approved design flow.

In addition, the multiple sprinkler flow rate in DD252 (42 l/min each) has been superseded and UL1626 now generally requires the same flow rates as for individual operation. Therefore all the tests in which more than one head operated are invalid.

Nevertheless the residential sprinklers performed well in the benchmark tests and demonstrated their ability to maintain a survivable environment despite these anomalies. This demonstrates the resilience of residential sprinklers to abuse and shows clearly their ability to control fires even when their water supply has been compromised.

Experimental program - House Fires

The house fires used in these tests were all of a slow growing type that produced a lot of smoke but limited heat. Because sprinklers depend on heat to activate these fires posed a severe challenge to the sprinklers and clearly demonstrate the value of always combining smoke alarms with residential sprinkler systems.

Nevertheless the tests demonstrated that residential sprinklers will successfully prevent the death of all persons in the house, either by eliminating the risk or by providing substantially longer period in which to escape or be rescued.

Cost Benefit Analysis

In general the FSA is in agreement with the methodology used in evaluating the Cost Benefit of installing residential sprinklers in various types of property, but would question the need to further complicate the computation by then applying uncertainty factors. The addition of these factors merely confuses the results and one is tempted to surmise that the purpose for the research has been largely lost in the mathematics.

The Cost Benefit analysis essentially compares the cost of installation and maintenance to the saving in lives, injuries and property damage, all taken over the expected life of the system. It is our view that the analysis is severely flawed by the data it employs to evaluate the benefits of installing sprinklers. For instance the savings in lives, injuries and property damage are derived from UK commercial sprinkler data and experience from other countries has been largely ignored. The cities of Scottsdale, Arizona, USA and Vancouver, British Columbia, Canada have both adopted legislation requiring sprinklers to be fitted to all new building, whether commercial or residential. Scottsdale now has nearly 20 years data available and Vancouver nearly 15, yet this is not used in the calculation.

There is also a basic fallacy in the assumption used in the report that there is a direct relationship between fire size and the likelihood of death or injury. The relationship is plainly more complicated, especially at the lower end. Small fires do not in themselves necessarily pose a threat to life and it is not until they reach a certain size that sufficient smoke, toxic fumes and/or heat is produced to cause death or injury. There is therefore a threshold size, below which a fire is not a danger, but this is not reflected in this report, which assumes that there is a linear relationship throughout the range of fire sizes.

Both Scottsdale and Vancouver have yet to record a single death in a sprinkler-protected property. Indeed it is now some 140 years since fire sprinklers (as we know them) first appeared and there are many, many millions of sprinkler-protected buildings around the world. Yet in all that time and in all those places there have been no more than a handful of deaths recorded, most of which were caused by structural collapse or explosions.

Yet the report concluded that residential sprinkler would only be 70% effective in preventing death, 30% in preventing injury and 50% in preventing property damage. By comparison both Scottsdale and Vancouver quote sprinklers as being 100% effective in preventing death, 85% in preventing injury and 90% in reducing property damage.

Using these revised figures alone substantially alters the Cost Benefit ratios and shows there would be a positive benefit to installing residential sprinklers in many more properties.

The report also assumes that residential sprinklers would be used in addition to all existing fire safety measures. Not only does this seem illogical and unnecessary, there is already a considerable amount of case history where Building Control officers have relaxed some requirements for other fire safety methods (not smoke alarms) where residential sprinklers have been used. Therefore the cost of installation of the fire sprinkler system should be offset by savings elsewhere.

If these saving were also included it is likely that the case for requiring residential sprinklers in all multi-occupancy and high-rise accommodation would be overwhelming.

The FSA has always recognised that the case for residential sprinklers on pure cost grounds can only be successfully argued for these higher risk properties. Nevertheless the cost of installing residential sprinklers in new homes is trivial (around 1%) compared to the cost of construction.

It is interesting to note that the Government recently introduced Approved Document "E" which increases noise insulation in new homes. The Government's own calculation showed this would increase new home prices by an average of £2,000 – a sum that would cover the installation of a sprinkler system.

This begs the question – *which is more important – life or noise?*

OVERVIEW

This research project, funded by the ODPM, took some three years to complete and is one of the most exhaustive projects of its kind in recent years. The aim of the project was 'to determine the benefits and effectiveness of sprinklers in residential accommodation'. It follows some 30 years of application of residential sprinklers in the USA, where over 4 million residential sprinkler heads are currently installed each year.

The report, which runs to over 700 pages in length, is seriously flawed by misunderstandings of the use of residential sprinklers, and errors in the conduct of some of the experiments. It consists of four main sections, namely a pilot study, so called 'benchmark' tests of sprinklers against the sprinkler head test standard DD252, experimental fire tests and a cost benefit analysis. Fundamentally, these lead to a lack of clarity in the conclusions, and could result in the real fire protection benefits from the use of residential sprinklers being missed. This appraisal therefore seeks to identify the problems, without overstating the case for sprinklers, or ignoring lessons, which can be used to improve their performance, and the applicable standards.

The publication in 2000 of BS DD 251 *'Sprinkler systems for residential and domestic occupancies — Code of practice'* for the installation of domestic and residential sprinkler systems in the UK, and its companion standard BS DD252 *'Components for residential sprinkler systems – Specification and test methods for residential sprinklers'*, for the sprinkler heads themselves, gave a sound basis for this research project. Since it was published in 2000 some thousands of installations have been made in the UK in accordance with DD 251. Since no sprinklers have been tested to DD 252, all the sprinklers installed in the UK have been approved to the equivalent US standard, UL 1626 '*Standard for Residential Sprinklers*'.

The basic objective of residential sprinkler protection is not defined in the BRE report, but could be stated as '*aiming to save the life of any person in the room of fire origin, and to save the lives of all other people in the occupancy*'. Thus the objective of the system is to control the fire to such a degree as to allow escape or rescue of occupants. DD251 indicates a rescue period of 10 minutes for domestic and 30 minutes for residential occupancies. The water supplies for domestic systems (single family dwellings) must be designed to provide for up to 2 sprinklers operating simultaneously, and for residential systems (multi-occupancy dwellings), up to 4 sprinklers simultaneously. Both systems require internal and external alarms to be initiated upon sprinkler operation.

The US approach to approval of suitable sprinklers is to examine their performance in a room fire test, operating at a specified minimum flow rate. The test relates to the containment of fires in the room of origin, and the sprinklers have to prove that they meet a variety of performance requirements in the standard. The UK specification has a simple fixed flow rate requirement, following the historical, prescriptive, approach of the UK fire sprinkler industry as typified in BS 5306pt 2.

The project involved three sets of experiments:

1. Evaluation of the so far unused fire test procedure in BS DD252 and corresponding assessment of sprinklers
2. House fires. Simulated 'real' fires in a domestic house, situated in a standard lounge and an open plan lounge, with a sprinkler installation complying with BS DD251.
3. Compartment fires. A range of 5 typical fire types in a test facility simulating fires in lounge, bedroom and kitchen, again with a sprinkler system to DD251.

The report included a section reviewing prior research work and statistical information mainly from the USA and New Zealand. This is in the Pilot Study section of the report. Unfortunately, some of the US statistical information used is flawed, and this has led to a less positive view of the performance of residential sprinklers by the project team than should be the case. This is typified by the obviously incorrect figure for the effectiveness of detectors and we are surprised this did not cause the team to be more circumspect in the use of those statistics (see table 3.15 of the BRE report).

The report also included cost benefit analyses for a wide range of occupancies, where the costs of installation, water supplies etc were estimated against the benefits of reduced life loss and injury, and property damage. These analyses are flawed by doubtful data and false deductions made in the Pilot Study (see below), and did not take account of any reduction in costs where existing fire protection measures could be reduced where sprinklers are installed.

PILOT STUDY

The pilot study covers a review of available statistical and other information, mainly from overseas application of residential sprinklers. The underlying concept expressed early on that 'information from other countries may not be directly applicable to the UK situation, due to cultural and technical differences, and in particular is not appropriate for use in any future regulatory assessment' is a questionable statement. Much of the material of the pilot study is used in the cost benefit analysis later on, and is commented upon elsewhere in this appraisal.

The data used depends heavily on reports by Rohr 2002 and Ruegg & Fuller 1984. In 1984 there was very little experience of residential sprinklers anywhere in the world and, since the first residential sprinkler had only been approved in 1981, Ruegg & Fullers findings would have been largely based on the use of conventional sprinklers and therefore not valid in this context. The Rohr report contains data that suggests that a number of people die each year in sprinkler-protected properties in the USA, whereas in fact this does not happen.

Enquiries to NFPA, who commissioned the Rohr report, reveal that the report makes no attempt to determine whether properties claimed to have sprinkler systems fitted did in fact have them and/or that they were operational at the time of the fire. As a result the Rohr report inaccurately suggests there are many fatalities in sprinkler-protected properties each year. Reports from Scottsdale and Vancouver are more accurate but were dismissed.

The pilot study includes an assessment of the risks in residential premises in the UK, and evaluates the risk factor per building by taking the number of deaths and dividing by the number of building in that building class. It also attempts to assess the effect of building height on the risk of death, and although conclusions are drawn, clearly there is a problem in this area of analysis. Inconsistencies in the figure relating to deaths in relation to building height (Figure 3.1 of the report) need addressing.

Lastly the authors of the pilot study briefly consider the suitability of BS DD 251 and BS DD 252 as a basis for UK residential standards. A discussion in the report on problems in the Underwriters Laboratory standard (UL 1626) tests against which all residential sprinkler used in the UK are Listed, have been superseded by events, and all sprinklers since July 2002 have been re tested and listed to a revised UL 1626 in which the problems raised have been dealt with.

BENCHMARKING - EVALUATION OF BS DD252.

DD252 is based upon standards published by Underwriters Laboratories and Factory Mutual in the USA, and the LPC Technical Bulletin 14. It has been carefully drafted to take account of specific UK requirements. All sprinklers suitable for use in the UK standard for domestic and residential occupancies are currently 'listed' (US equivalent to UK 'approved') to the current version of UL 1626 '*Standard for Residential Sprinklers*' July 2002. DD252 is similar to this standard, but has a fixed sprinkler area/water flow rate and inflexible area coverage. Also fuel materials have been re-specified into materials readily obtainable in Europe. Prior to this project, no sprinklers had been tested against DD252.

The performance of four residential sprinklers was compared against DD252 requirements whilst experience was gained in testing to the standard. It is important to note at this point that UK thinking regarding best sprinkler performance is prescriptive, aiming at uniform water distribution at fixed density levels, and following the approach used for industrial/commercial installations. For the past 30+ years the US approach to testing sprinklers has been performance based; manufacturers having to demonstrate fire control with specified water densities, and distribution patterns appropriate to achieve this. Residential type sprinklers in both UK and US require wall wetting up to 0.7m from ceiling level.

Criteria

The pass/ fail criteria are similar. DD252 acceptance criteria are shown in Table 4.4 in the BRE report, basically:

a) that temperatures at 4 positions within the chamber should not exceed set limits in the first 10 minutes of the test, and that

b) a sprinkler (not fed with water) situated just outside the door of the test room (with a lintel), should not operate in the 10 minute period.

Deviations from DD252

It should be noted that in the UL tests this "dummy" sprinkler is situated just inside the door. Also both DD252 and UL1626 require a lintel above both doorways, but this was removed form most of the BRE tests. The results are summarised in Table A below.

We are therefore concerned that the DD252 fire test was not properly conducted in all of the tests. Table 4.5 in the BRE report suggests that there were some failures of the sprinklers to meet DD252 pass criteria, with regard to 3rd (dummy) sprinkler operation. However, two of the tests listed as 'fail', 17 and 18, were invalid both with regard to the absence of the lintel and the correct water flow rate being applied. The relevance of the last column on Table 4.5 of the report, relating to the criteria of the FM test, is inappropriate and misleading.

Table A. Temperatures reached in Benchmark tests.

Test	Sprinkler used & (k) factor	Sprinkler B1 secs	Sprinkler B2 secs	Max temp @75 mm °C	Max temp @1.6 m °C	Applied density mm/min	Lintel	Time over 55 °C	Dummy sprinkler operate	Was DD252 test valid?
1				< 320	< 95	4	No	<120	No	
2	3 (62)	82	No op	100	50	4	No	Nil	No	Yes
3	4 (43)	73	No op	90	48	4	No	Nil	No	Yes
4	2 (56)	67	No op	65	40	4	No	Nil	No	Yes
5 (a)	1 (80)	79	No op	95	43	4	No	Nil	No	Yes
6 (a)	3 (62)	122	126	98	72	4	No	60	135	No
7 (a)	4 (43)	123	127	160	68	4	No	<60	No	No
8 (a)	2 (56)	112	114	155	62	4	No	<30	No	No
9 (a)	3 (62)	111	131	150	63	4	No	<30	122	No
10 (a)	3 (62)	57	131	115	43	4	No	Nil	127	No
11 (b)	3 (62)	63	No op	95	50	4	Yes	Nil	No	Yes
12(a,b)	3 (62)	107	133	n/a	n/a	4	Yes	n/a	No	No
13(a,b)	3 (62)	98	103	160	78	4	Yes	<60	No	No
14	4 (43)	71	No op	70	42	4	No	Nil	No	Yes
15 (c)	3 (62)	68	No op	138	50	3	No	Nil	148	No
16 (c)	3 (63)	78	No op	145	48	3	No	Nil	168	No
17(a,c)	2 (56)	66	104	148	47	3	No	Nil	100	No
18 (a)	2 (56)	66	134	130	42	4	No	Nil	138	No

Note: (a) Water flow less than current manufacturers requirements
(b) Only tests with lintel. DD252 requires a lintel for all tests
(c) 15,16 &17 tests with lower density
Test 1 is not included. It was invalid due to late application of water.

Results of tests

However, despite problems in the details, we feel the tests are of great value. Summing up:

- The temperature criteria were met in all cases.
- The sprinklers performed well in the benchmark tests, which indicates that sprinklers meeting the requirements of UL 1626 are likely to satisfy the requirements of DD252 if properly applied.
- There was little difference in temperatures reached when lower application rates were used in tests 15, 16 and 17.

It must be noted that:

- The flow rates used when 2 sprinklers operated were lower than the manufactures recommended flow.
- A lintel should have been in place in all tests
- The dummy sprinkler should have been inside the room
- The area coverage was 16m^2, rather than the 15m^2 maximum in DD251.

Deficiencies of testing

Only one area coverage was examined. The sprinklers listed to UL 1626 are each listed for a range of areas of coverage, giving more flexible and cost effective installation.

Also, neither concealed nor sidewall sprinklers were examined. This was especially disappointing since concealed sprinklers form a substantial percentage of residential sprinklers currently being installed in the UK.

Since the DD252 fire test specification requires much further development, and does not cover concealed, recessed or sidewall sprinklers, it may be more appropriate to adopt the ISO standard, currently in draft form ISO/DIS 6182-10 *Fire Protection-automatic Sprinkler systems, Part 10 'Requirements and test methods for domestic sprinklers'*.

EXPERIMENTAL PROGRAM - HOUSE FIRE AND OPEN PLAN TESTS.

Eight lounge-fires were conducted in a two-story house with a loft conversion; three tests without sprinklers, and five with. The fire test posed was one that examines the performance of sprinklers against a slow burning, very smoky type of fire - a 'worst case' situation for sprinklers. Comparison tests with a more typical faster fire growth would have been valuable in demonstrating a more normal sprinkler response. The test facility was well instrumented and measurements were made of temperatures, visibility levels and toxicity levels throughout each fire.

The results are graphically shown in the report in Figure 5.7. They demonstrate clearly the value of sprinklers over other forms of fire protection. In these fires, they would have saved people elsewhere in the house, as well as those in the room of fire origin. Without sprinklers, a person unable to leave the room of fire origin would die within 20 minutes, and with open doors others in the house shortly afterwards.

The house fire tests examine fires in what would be a Domestic occupancy as defined in BS DD 251. It should be noted that it is unlikely that a smoke detector would currently be found in the lounge of domestic dwellings. The time advantage of the alarm raised by the smoke detector on the landing compared to the alarm raised by the operation of the sprinkler was about 2 minutes in 3 cases. In one case the landing detector did not operate. The results are illustrated in Table B.

Table B. House fires.

Standard Lounge arrangement							
Test No	**Lounge Door**	**Water flow rate L/min**	**Sprinkler operating time min:s**	**Lounge Death secs**	**Bedroom death**	**Loft door open death**	**Loft door closed death**
1	Open	Nil	n/a	16min40s	yes	yes	no
2	Open	60	7:10	no	No	no	no
3	Closed	Nil	n/a	18min20s	yes	yes	no
4	Closed	60	6:02	no	No	no	no
5	Open	60	7:08	no	No	no	no
Open plan lounge arrangement							
6	N/a	nil	n/a	14min	yes	yes	no
7	N/a	84(1)	8:24,nr(2)	no	No	no	no
8	N/a	84(1)	6:56,7:04	no	No	no	no

Notes. (1). Sprinkler pressure less than 0.5bar, thus test not complying with DD251.
(2). 2nd sprinkler operating time not recorded

The house fire tests demonstrate

- The high likelihood of death resulting from such fires in unsprinklered risks

- The effectiveness of sprinklers in saving the life of the person in the room of origin, either allowing escape, or rescue in the case of an incapacitated person
- That sprinklers provide protection of people in all other areas of the house.
- That open plan lounge arrangements can be equally well protected, allowing safe use of open plan living arrangements.

Compartment fires

Sprinkler performance was assessed against five fire types, three in the lounge, one in the bedroom and one in the kitchen. The test facility was well instrumented, and similar measurements were made to those made in the house fire tests.

For reasons not explained the sprinkler flows were limited in many cases to 42

Kitchen fire

A simulated chip pan fire using a standard 350mm diameter pan of oil was heated with a gas burner. The resulting fire was small in relation to the room size, and there were no curtains or other materials in close by. The sprinklers dealt with the fire.

The results of the fires where sprinkler were installed are shown in Table C.

Table C -Experimental fires with sprinklers

Sprinkler tests	Alarm in room min s	External alarm min s	Sprinkler activation min s	Time to Unconscious min s	Time to death min s	Rescue time before death alarm in room min s	external alarm min s	sprinkler alarm min s	Possible death in room
TV fire									
8	3m 17s	3m 47s	8m 20s	no	no				no
7		13m 31s	23m 11s	20m 24s	25m 4s		11m 33s	1m 53s	yes
28	1m 24s		7m 11s	no	No				no
20		7m 10s	9m 14s	no	No				no
19	3m 17s	4m 27s	11m 53s	no	No				no
Table fires									
12	1m 2s	1m 47s	6m 36s	6m 53s	9m 10s	8m 8s	8m 13s	2m 34s	yes
14	34s	1m 52s	2m 59s	5m 56s	8m 49s	8m 15s	6m 57s	5m 50s	yes
17	37s	1m 15s	1m 58s	6m 58s	11m 10s	10m 30s	9m 52s	9m 9s	yes
22	22s		2m 25s	9m 46s	14m 38s	14m 16s	13m 36s	12m 13s	yes
24	57s		1m 35s	7m 49s	11m 30s	10m 33s	11m 1s	9m 55s	yes
Sofa fires									
9		12m 29s	no op	no	no				no
10		12m 18s	14m 26s	21m 37s	no				no
Bed fires									
15		3m 10s	5m 3s	no	no				no
13			2m 36s	no	no				no
Oil pan fires									
27	7m 29s		20m 2s	no	no				no
29	18s		22m 16s	no	no				no

Summing up, as would be expected and despite in some cases being supplied with less than the specified flow of water, the sprinklers dealt extremely well with the sofa fires and the bed fire. There was also no problem with the chip-pan fire, except that it was rather a small fire in a large room, and it was some time before it created enough heat to operate the sprinkler.

- The table fires, with a substantial fire load under the table obscured from the sprinkler discharge, proved a severe challenge.
- The sprinkler discharge stopped the fire spreading beyond the table area, and therefore beyond the room of origin.
- Toxic smoke build up was such in each sprinklered fire that occupants unable to escape themselves would need to be rescued in 2½ minutes to 12 minutes after the sprinkler alarm sounded. As in the TV fires, this demonstrated that smoke alarms should still be specified to give the optimum level of protection.

Looking at the 4 TV fires, in three cases the sprinklers would have prevent the death of occupants unable to evacuate the room. In the fourth case a rescue would have needed to be effected within 2 min from the time of sprinkler alarm, although this was some 11 minutes after the external smoke detector operated.

The table and TV fires scenarios suggest the need to use the most sensitive sprinklers available. Those used in the tests were fast response type but rated at 68°C. These tests suggest that a lower temperature sprinkler, perhaps 57°C, may have operated earlier.

COST BENEFIT ANALYSIS

Apart obviously from establishing that residential sprinklers can actually do what is claimed, the FSA recognises that many readers of this report may be more concerned with cost implications of any future legislation requiring sprinklers, and will therefore view the Cost Benefit analysis as the most important part of the project. We therefore feel that it is essential that the analysis is fair and draws on robust data for its calculations.

The FSA has identified 5 main areas of concern:

1. the value of a life used in the calculations
2. the average cost of fire injuries
3. the estimations of sprinkler effectiveness
4. the loss of the effect of building height
5. the absence of "trade offs"

General

In general we have no argument with the methodology used in evaluating the cost benefit of residential sprinklers. Although the effect of fire is felt right through the community, the major financial costs and savings are concentrated in a limited number of areas. Other costs and savings are of comparative insignificance, although it is sometime difficult to know where to draw the line.

Whilst it is obvious that the major costs are centred around installation and maintenance, and the major savings are in the reduction of deaths, injuries and property damage, we are concerned that no allowance has been made in cost of installation for trade-offs (we see these as trade-ups) and design freedoms under revised Building Regulations, which we would expect to be substantial.

Value of a life

Whilst the FSA agrees that the figure used for the value of a life is to an extent subjective and may be impossible to evaluate accurately, we feel that this report should at least have been consistent with previous fire-related Cost Benefit analyses – in particular that performed for Smoke Alarms in 1996. In that report (Spearpoint 1996) a value of £960,000 was used, (which as the BRE report states is the same used by the United Nations Intergovernmental Committee on Climate Change). Allowing for inflation at today's prices this would equate to £1,530,094.

Cost of injuries

Moving on to the cost of injuries, it appeared that the analysis has based costs of injuries largely on those of road traffic accidents, although there is reference to a Home Office study of 1999. Nevertheless, the figures used would seem to significantly underplay the cost of fire injuries, which are well known to be the most difficult, time consuming and costly injuries to treat and therefore likely to be considerably more expensive to treat than road traffic injuries.

For instance, at a seminar held by Merseyside Fire Brigade several years ago, a burns specialist from Liverpool Royal Infirmary gave treatment costs as varying from £6k for a minor burn to £6million for serious burns – and occasionally very substantially more. This would suggest that the average cost used in the Cost Benefit analysis may have been substantially underestimated.

Relationship between risk of death and injury and fire size

In 6.1 the BRE report states that the pilot study found that a direct estimate of sprinkler effectiveness was not possible due to a scarcity of UK data. Instead an indirect method was used based on the assumption that sprinklers would restrict the ultimate fire size and, as a consequence, correspondingly reduce the risk of death and injury. The report therefore assumes that if sprinklers were to reduce fire size by, say, 70% then the numbers of deaths would correspondingly be reduced by 70%.

However, given that a fire must develop to a sufficient size before it poses any risk to life this linear relationship is flawed. By reducing fire size by 70% the sprinkler system can reduce the risk of death to zero. Moreover since the fire must produce sufficient heat to operate a sprinkler, the attenuation of fire size can never reach the 100% required in order to correspond to the actual recorded number of deaths in a sprinkler protected building in the UK - namely none.

As shown earlier in the appraisal, the BRE report depends heavily on data derived from Rohr 2002 and Ruegg & Fuller 1984. In 1984 there was very little experience of residential sprinklers anywhere in the world and, since the first residential sprinkler had only been approved in 1981, Ruegg & Fullers findings would have been largely based on the use of conventional sprinklers and therefore not valid in this context.

The Rohr report contains data that suggests that a number of people die each year in sprinkler-protected properties in the USA, whereas in fact this does not happen. As is reported elsewhere in this response, it is now some 140 years since fire sprinklers first appeared and there are many, many millions of sprinkler-protected buildings around the world. Yet in all that time and in all those places there have been no more than a handful of deaths recorded, most of which were caused by structural collapse or explosions.

Enquiries to NFPA, who commissioned the Rohr report, reveal that the report makes no attempt to determine whether properties claimed to have sprinkler systems fitted did in fact have them and/or that they were operational at the time of the fire. Therefore properties with systems being installed but not yet operational, those with systems being removed, those disconnected for whatever reason, or those with no water supply connected, were all included as properties with sprinkler systems. As a result the Rohr report inaccurately suggests there are many fatalities in sprinkler-protected properties each year – which is simply not true.

Effectiveness of residential sprinklers

Rather than use international data the research team therefore preferred to deduce the effectiveness of residential sprinklers from the expected reduction in fire size calculated from data derived using commercial sprinklers. There are 3 serious problems with this approach. Firstly, residential sprinkler systems work quite differently to commercial system, especially the pattern of spray produced and density of water applied. Secondly, residential fires are quite different to commercial fires both in the

Effect of building height

The ENTEC report also states that HMO's of 3 or more storeys show a fourfold increase in risk of fatalities. In addition it shows a similar increase for HMO's for vulnerable people and for those that house large numbers of people, irrespective of number of storeys. This is not reflected in the BRE report although the figures are tabled in Appendix 6 of the report.

Appendix 6A gives details for single occupancy houses, multiple occupancy houses, purpose built flats, converted flats, and care homes. These calculations include saving of deaths, injuries and property damage based on the estimates deduced in the Pilot Study.

Appendix 6B is taken from the ENTEC report and provided calculations for bed-sits, shared houses, lodgings, purpose-built HMOs, various categories of flats, rest homes, hostels and single occupancy houses.

However the ENTEC calculations only take into account savings on deaths and ignore injuries and property damage. The BRE report suggests that the ENTEC figures might be increased by between 1.5 and 2 to take into account savings due to reductions in injuries and property damage.

Fig 2. Revised Annex 6B

Type of Dwelling	Deaths/000,000 units	BRE CB	Revised CB
Bedsits 3+ storeys	67	0.68	1.38
Shared houses 3+ storeys	33	0.21	0.43
Lodgings 3+ storeys	32	0.20	0.41
Purpose built HMOs 3+ storeys	122	0.54	1.10
Flat, self cont. 3+ storeys	79	0.70	1.42
Flat, purpose built 3+ storeys	50	0.49	1.00
OAP rest home, purpose built	747	2.43	4.93
Hostel	210	0.93	1.89

Fortunately both the ENTEC report and the BRE report have calculated cost benefits for Purpose Built Flats. On the assumption that these are similar properties the relative CBs are 0.33 and 0.67, giving a ratio of 1:2.03, which agrees well with the estimate in the BRE report as shown above.

Figure 2 above illustrates the effect this would have on the figures in the ENTEC report to reflect saving due to reductions in injuries and property damage.

As can be seen, these revised figures show clear cost benefits for many more properties, especially those over 3 floors in height, and these are highlighted in yellow.

Appendix 6C provides calculations for bungalows, and houses and flats of various heights. These calculations include savings of deaths, injuries and property damage with saving, again based on the estimates deduced in the Pilot Study.

These calculations clearly show positive benefits for higher properties, especially those over 3 floors.

Summarising all the above factors the following table (Fig. 3) reveals a somewhat different picture to the BRE report, especially for properties over 3 floors in height.

Fig. 3. Revised Cost Benefit calculation

Type of property	Original CB	Revised CB	Ratio Increase
Bungalow	0.22	0.41	1.86
Single occupancy house	0.18	0.38	2.11
House 3 floors	0.30	0.58	1.93
House >4 floors	1.32	2.65	2.01
HMO all	0.27	0.53	1.96
HMO < 3 floors #	0.26	0.49	1.86
HMO > 3 floors #	1.10	2.04	1.86
Flat purpose built	0.67	1.37	2.04
Flat 1-2 floors	0.52	1.06	2.04
Flat 3-5 floors	0.81	1.66	2.05
Flat 6-10 floors	1.06	2.06	1.94
Flat 11+ floors	2.12	4.29	2.02
Bedsit all #	0.51	0.95	1.86
Bedsit < 3 floors #	0.30	0.57	1.86
Bedsit > 3 floors #	1.38	2.57	1.86
Care home old person	2.21	4.28	1.94
Care home children	4.85	9.85	2.03
Care home disabled	1.22	2.39	1.96

Note: BRE cost benefits for property types marked with # do not include savings for injuries or property damage.

Fire statistics have always shown such high-rise properties to have much higher than average casualty rates and the FSA has consistently emphasised that it is these types of property – together with properties that house the young and old and those with disabilities - that would most benefit from residential sprinklers.

Design freedoms

The BRE report makes no allowance for design freedoms where sprinklers are used or trade-offs against other types of fire protection measures if sprinklers are installed. The DETR report states clearly that such trade-offs should be considered.

The FSA believes that resulting cost savings would be significant and would substantially increase the cost benefit ratios still further. In fact it is now common in the United States for building to be cheaper to construct using fire sprinklers than conventional fire safety measures. This failure to take account of trade offs is a serious omission in the BRE cost benefit analysis.

Number of lives that could be saved by residential sprinklers

By using flawed data the Cost Benefit analysis in the BRE report suggests that only care homes and high-rise blocks would present positive financial benefits for the fitting of residential sprinklers. Ignoring the recent and tragic care home fires in Scotland and elsewhere, fire casualties in these types properties are not normally very high and therefore present limited opportunities to reduce casualties. In contrast the report erroneously concludes that those types of accommodation that have the greatest number of fire casualties are not cost effective for the installation of sprinklers.

If the current recommendations in the report are followed this would result in the saving of very few lives each year. If on the other hand a more realistic view of the cost benefits is taken, this would extend the recommendations to include dwellings of more than 3 floors and would significantly increase the number of lives saved, injuries prevented and property preserved.

A Home Office report ("the economic cost of fire"- Home Office research study 229 by Mark Weiner) states that the most significant cost in a domestic fire is that of casualties, in terms of healthcare costs, lost output and pain and suffering of the victims, and represents almost half of the average cost of a fire. The annual cost of casualties is put at more than £1bn in total, with domestic fires representing almost over 70% of the total. Fire sprinklers and smoke alarms together (rather than smoke alarms alone) can make massive reductions in these costs and can save hundreds of lives and thousand of injuries each year.

Summary of Cost Benefit analysis

In summary the FSA believes that the -

cost of installation is overstated because

- trade-offs and design freedoms have not been allowed

savings are understated because

- casualty rate and property damage reductions are too low
- value of a life saved is too low
- cost of injuries is too low
- effect of building height and occupancy has been down-played

Proper evaluation of these factors would radically alter the cost benefit ratios and show that sprinklers are cost effective in many more applications.

We would therefore suggest that the Cost Benefits be re-evaluated using more realistic data, especially in terms of reductions in deaths, injuries and property damage and "trade-ups". This would bring the finding more into line with evaluations done elsewhere.

OVERALL CONCLUSIONS

The experimental programme demonstrated that sprinklers installed to a standard such as DD251 have the potential to save almost every life in a domestic/residential fire situation. For those not able to escape the fire scene, sprinklers in almost every situation offer the reasonable possibility of rescue by the fire service. Obviously injuries would be reduced significantly, together with the trauma associated with fire. Property loss and dislocation would also be significantly reduced.

The cost benefit analysis was made before the results of the experimental programme were known, and did not fully reflect the outcome of the research.

The cost benefit analysis did not take into account the reduction in cost of other fire protection measures, which would not be necessary, if sprinklers were installed. The obvious inconsistency in relation to other figures for fire frequency in high HMOs casts doubts on the other cost benefit findings.

The less obvious benefits, such as the freedom of movement in residential occupancies due to reduction in need of fire doors and self-closers in corridors etc. are not taken into account.

Despite these and other deficiencies the report found that -

1. Sprinklers offer a level of life safety protection unobtainable by any other currently available means of fire protection and without the problem of false alarms.

2. BS DD251 provides a sound basis for the uniform installation of sprinkler systems in domestic and residential occupancies.

3. The research programme largely validated the development of residential sprinklers over the past 30 years, to the point that they should be seriously considered as the prime means of fire protection in residential and domestic properties.

4. That smoke detectors should still be installed to give early warning of fire, but if not installed the sprinkler will still result in the great majority of lives being saved in sprinkler occupancies.

5. That the temperature setting of sprinklers used needs to be reassessed to give quicker operation in slow, smoky fires, and 57^{o}C is probably the best choice of available sprinkler temperature rating for most situations in the UK. The development of sprinkler with a temperature rating of say 50^{o}C would be beneficial.

6. That DD252, whilst being an adequate standard a far as it goes, would be better replaced by the ISO standard, rather than being further developed.

7. That sprinklers can be justified not just on a life safety basis, but also on a cost benefit approach, for a wide variety of risks

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