bre

DCLG Final Research Report

Effectiveness of sprinklers in residential premises – an evaluation of concealed and recessed pattern sprinkler products

Section 1: Summary Report

C Williams and K Annable

218113

March 2006

Summary Report

This Summary Report describes the Project "The effectiveness of sprinklers in residential premises – an evaluation of concealed and recessed pattern sprinkler products" commissioned by the Buildings Division of the Office of the Deputy Prime Minister (ODPM) and carried out by BRE. Full details of this study and its findings are given in BRE project report number 218113.

The background to this study is as follows. The majority of fire casualties in the UK each year occur in residential and domestic accommodation. Residential sprinklers continue to be the subject of much debate in the UK because they offer a potential means of saving lives, preventing injuries and reducing property damage, if they are installed in domestic and residential properties to complement other fire protection measures.

This study is related to a previous study carried out by BRE on behalf of the ODPM on the effectiveness of residential sprinklers. The previous study[1] concentrated on pendent type residential sprinklers.

Recessed and concealed sprinklers, where the building structure is integral to their installation, are in common use in residential and domestic premises rather than pendent type sprinklers, mainly for aesthetic reasons. However, their fire performance in the UK is unproven. Concern has been expressed about these sprinkler types as there are a number of potential problems with their use, especially if used for life safety applications.

British Standard BS 9251 (systems)[2] and British Standard Draft for Development, DD 252 (components)[3] have been published but some aspects of assessing the performance of recessed and concealed sprinkler product are not addressed.

The overall aim of this current project was to investigate the suitability of concealed and recessed pattern sprinklers for use in residential premises, particularly concerning their effectiveness and maintainability. The specific objectives of this project were to:

a) Carry out an experimental programme of realistic/stylised fires to assess the effectiveness of concealed and recessed pattern sprinklers in fire suppression, in particular in respect of life safety in the room of fire origin

b) Develop and evaluate a robust, reliable and credible UK test method for rating thermal sensitivity for these types of products and

c) Review maintainability issues for these types of products.

To achieve these objectives, four main Tasks were carried out: Task 1 Steering Group, Task 2 Selection of products, experimental programme and review of maintainability issues, Task 3 Develop and evaluate new thermal sensitivity test and Task 4 Dissemination of findings.

---

[1] C Williams, J Fraser-Mitchell, S Campbell, R Harrison. Effectiveness of sprinklers in residential premises, BRE Project Report number 204505, February 2004.

[2] British Standards Institution. BS 9251 Sprinkler systems for residential and domestic occupancies – Code of Practice, January 2005.

[3] British Standards Institution. DD 252 Components for Residential Sprinkler systems – Specification and Test Methods for Residential Sprinklers, July 2002.

The results will provide input to the development of UK standards and will also provide the Regulators with sound engineering-based results that they can use for any Regulatory decisions. In the short term, the results from this project will be available to assist and support those working in the fire arena.

Steering Group

The Steering Group was established at the start of the Project and met twice during the course of the work programme. The members included representatives from government regulators, the residential sprinkler industry, the housing industry and the fire service. They provided general advice and review on all aspects of the project methodology and specific advice and information about residential sprinkler products. Wider industry contribution was sought through a seminar.

Selection of products and experimental programme - Stylised fires

Two British Standards BS 9251 (systems) and BS DD 252 (components) have been published.

Concealed and recessed sprinkler products were selected and their performance evaluated by carrying out stylised fires inside a suitable compartment facility to assess their effectiveness in fire suppression, in a similar way to the previous ODPM study.

This previous work included a series of eighteen stylised and seven calorimetry fires, which established a suitable benchmark fire test for UK conditions to support the further development of BS DD 252 and assessed the performance of pendent residential sprinklers in fire test conditions.

It should be noted that the fire performance test using stylised fires is one of a large number of tests that a residential sprinkler head is subjected to when being assessed against DD 252. Other tests include horizontal and vertical water distribution, thermal sensitivity, mechanical and ageing tests.

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 a suitable, installed sprinkler system. The room contains two sprinkler heads of the same type spaced 4 m apart. There are two open doorways and outside the opening of one doorway is a third dummy sprinkler head which is not connected to the water supply. Lintels were not installed in this study because their influence was not considered to be a significant aspect of this work.

The sprinkler system performance is determined by its ability to control the fire for a period of time after sprinkler operation, defined by the gas temperatures being limited to specified values and the dummy sprinkler head not operating.

The fuel package in DD 252 consists of two non flame retardant polyether foam sheets, each attached to a stand, a wall lining of four non flame retardant plywood sheets and an ignition package. The ignition package consists of a wood crib consisting of eight layers of wood sticks placed on top of a steel tray containing commercial grade heptane.

Residential concealed and recessed sprinkler models that have been approved in the USA and that are available in the UK market were identified from manufacturer's/ supplier's website literature and information from the residential sprinkler industry members of the project Steering Group. These residential sprinkler models were reviewed and those considered most appropriate for further examination were selected. The sprinklers were obtained for the experimental programme from the manufacturers/suppliers via the residential sprinkler industry members of the project Steering Group.

Six residential sprinkler models, one pendent, one recessed and four concealed, were selected for the stylised fires. The concealed sprinklers comprised: flat and domed concealer plates, vented and non vented recess cups, solder and glass bulb thermal elements, drop down and static deflectors. One of the sprinklers was chosen because it is allegedly the most commonly used in the UK. Single selected sprinklers were characterised using horizontal, floor level water distribution measurements.

A series of twelve stylised fires was conducted, based on the procedures and acceptance criteria of the fire test for pendent residential sprinklers given in DD 252, recommendations given in BS 9251 and findings of the previous ODPM study, to examine the effect of varying parameters on the performance of pendent, recessed and concealed residential sprinklers. The parameters investigated were: sprinkler model, location of fuel package within the sprinkler spray (wall and corner configurations), the effect of frame arm/deflector attachment pins shadow (parallel to the long axis of the test room and pointing towards the fire) and recess distance (manufacturer's recommended maximum and minimum).

The main conclusions of the stylised fires, for the conditions studied, are:

- The sprinklers examined met all the acceptance criteria of the DD 252 fire test, with two exceptions, as follows.
- The recessed sprinkler in the corner test at maximum recess distance exceeded one of the temperature criteria just after sprinkler operation but subsequently controlled the fire.
- One of the concealed sprinklers, at maximum recess distance, with unfavourable frame orientation, did not meet the acceptance criteria of DD 252. The test was prematurely terminated to protect the experimental facility. This failure was due to a combination of maximum recess distance and the alignment of the frame arms and concealer plate retainer lug which caused a detrimental effect on water distribution in the location of the fire.
- Some maintainability features of concealed residential sprinklers were observed which could detrimentally affect sprinkler performance.
- If the performances of recessed and concealed residential sprinklers are to be assessed against DD 252, parameters that influence water distribution and fire performance characteristics need to be considered and specified in DD 252, e.g. recess depth, frame arm/deflector attachment pins shadow, blocked/unblocked vent holes.

Selection of products and experimental programme – Realistic fires

Concealed and recessed sprinkler products were selected and their performance was assessed against realistic fires inside a suitable compartment facility.

The previous ODPM project investigated the effectiveness of pendent residential sprinklers, in particular to life safety in the room of fire origin. The same approach was adopted for this current work.

Sprinklers installed to BS 9251 are not necessarily designed to extinguish the fires but to control them. The effectiveness of the residential sprinklers was primarily assessed, particularly in the room of origin, by their ability to control toxicity, temperature effects and visibility effects in a period of 30 minutes from ignition. Fractional effective dose (FED) calculations were performed using the results of each test in order to assess the tenability, primarily in the room of fire origin and connected spaces. The calculations were based on carbon monoxide, carbon dioxide and oxygen concentrations (at 1.0 and 1.6 m above the floor), gas temperatures (at various heights) and optical density per metre (at 1.0 m and 1.6 m above floor level).

A series of ten fires, using realistic fuel arrays representative of domestic and residential premises, was conducted inside a compartmented experimental facility. The facility essentially comprised residential rooms with a timber structure supporting plasterboard walls and a calcium silicate board ceiling. The facility was configured to provide alternative fire rooms at either end each measuring 4 m by 4 m, connected to a middle room measuring 3.8 m by 4 m by open internal doorways. The internal heights of the rooms were 2.5 m. The effective enclosure volume was approximately 118 m^3.

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

Two fire scenarios were conducted, with sprinklers and with the door of the room of fire origin open. Two types of lounge fire were investigated, each with nominally the same fuel arrangement but with different items used for the primary ignition source, as follows:

- Lounge, ignition by nightlight under front corner of television (television fire)
- Lounge, ignition by crumpled newspapers underneath a magazine rack under the table directly beneath sprinkler (table fire).

The television fires were relatively slowly-growing, smoky, shielded, fires and the table fires were rapidly-growing flaming, shielded fires, with the table placed directly beneath the sprinkler.

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

One pendent and three concealed residential sprinkler models were examined. In addition to sprinkler model and fire scenario, the other parameter investigated was recess distance (manufacturer's specified maximum and minimum).

The water flow rate of the single operating sprinkler was either 60 l/min or the manufacturer's recommended minimum if greater than 60 l/min, as in the previous ODPM study.

The main general conclusions for the room of origin in the realistic fires and using results from the previous study, for the conditions studied, for a duration of 30 minutes from ignition, are:

- Concealed and pendent sprinklers significantly reduced the effect of convected heat from the fire. However, these sprinklers did not observably improve visibility.
- Television fires. Concealed and pendent sprinklers generally greatly improved conditions in the room of fire origin, maintained tenable conditions in terms of toxic effects, reduced the effects of convected heat but produced no observed improvement in visibility.
- Table fires. For all the pendent and concealed sprinklered and unsprinklered fires the conditions became unsurvivable in terms of toxic effects. Concealed and pendent sprinklers greatly reduced the effects of convected heat but had no observed improvement in visibility.
- However, in one of the television fires in the previous study, conditions became unsurvivable in one slower growing fire where a lot of smoke was produced prior to operation of a pendent sprinkler.
- For all the unsprinklered fires in the previous study, the conditions became unsurvivable/lethal.
- For all the unsprinklered fires in the previous study, the first tenability criteria to be reached was visibility, followed by convected heat, then toxicity effects.
- The life safety benefit of fitting smoke alarms was clearly demonstrated. Smoke alarms, fitted in the room of fire origin, responded in 31% to 57% of the time required by sprinklers and well before conditions had become life threatening. Smoke alarms, fitted in adjacent spaces, responded in 43% to 77% of the time required by sprinklers and well before conditions had become life threatening.

Thermal sensitivity

The purpose of this stage of the project was to establish a suitable UK thermal sensitivity test for concealed and recessed residential sprinklers.

The thermal sensitivity test in DD 252 is not suitable for evaluating concealed and recessed sprinklers. As a consequence of this, there is a recommendation in DD 252 appended with a note stating “For sprinklers which do not fit into the wind tunnel, equivalence of sensitivity is determined by a fire test (not yet standardised)”.

During this project, a new test has been specified and developed. The design has been based on DD 252 and previous experimental work by Factory Mutual Research Corporation, USA and utilises a modified mounting plate and frame with appropriate instrumentation. An experimental matrix was devised and tests were conducted to investigate the effect on the thermal response of sprinkler model, frame arm/deflector attachment pins orientation, recess distance, concealer plate retainer orientation (i.e. lug position), wind tunnel air temperature, wind tunnel air velocity and the pressure difference between the wind tunnel and the plenum box. Tests were also conducted that demonstrated the influence of some plausible maintainability scenarios on the thermal sensitivity of concealed sprinklers. Tests were initially carried out on one concealed sprinkler model. One pendent, one recessed and five concealed sprinkler models were used.

The thermal sensitivity (Conductivity factor, C and Response Time Index, RTI) and resulting classification of category were calculated in accordance with the specifications of DD 252 and EN 12259-1. In EN 12259-1, there are four categories of thermal response of sprinklers: quick, special, standard response A and standard response B. BS 9251 and DD 252 specify 'quick response' in terms of thermal sensitivity rating for residential sprinklers.

The main conclusions for the thermal sensitivity work, for the conditions studied, are as follows:

- A suitable thermal sensitivity test for evaluation of concealed sprinklers has been established for provision to the relevant British Standards committee for consideration in the development of residential sprinkler standards. Improvements, modifications and required specifications have been identified.
- Higher pressure differentials between the tunnel and the plenum box were found to be beneficial in terms of concealed sprinkler thermal sensitivity.
- The pendent sprinkler resulted in a thermal sensitivity rating of quick response under favourable conditions.
- The recessed sprinkler resulted in a thermal sensitivity rating of quick response under favourable conditions and resulted in special response for unfavourable conditions.
- None of the concealed sprinklers achieved a thermal sensitivity rating of quick response, even in the most favourable conditions.
- The thermal sensitivity ratings of the concealed sprinklers were found to be special response, standard response A, standard response B and 'off scale', under favourable conditions.
- The thermal sensitivity ratings of the concealed sprinklers were found to be standard response A, standard response B and 'off scale' under less favourable conditions.
- Unfavourable frame arm/deflector attachment pins orientation, maximum recess distance and unfavourable concealer plate retainer position had a detrimental effect on the thermal sensitivity of the concealed sprinklers.
- Water in the concealer plate, blocked vent holes and glued concealer plates resulted in a significantly delayed thermal response.
- The issue of whether the thermal sensitivity ratings determined in this study for concealed and recessed residential sprinklers are suitable for life safety applications could be considered by the relevant British Standards committee.

Design, installation and maintenance

The purpose of this part of the project was to review maintainability issues with concealed residential sprinkler product that might detrimentally affect the performance of concealed and recessed pattern sprinklers.

This involved identifying, gathering and reviewing information on design, installation and maintenance. The information was gathered from BS 9251, anecdotal experience with this type of product installed in real

buildings, other studies, visual examination and the experience of the BRE project team members obtained during the course of the experimental fires and wind tunnel work in this study.

It should be realised that there may be additional issues of this nature that have not yet been identified.

The main conclusions of the review of maintainability issues are:

- There are a number of potential problems relating to the design, installation and maintenance of concealed sprinklers.
- For example, unfavourable frame arm orientation, maximum recess distance and unfavourable concealer plate position and a combination of these can delay the thermal response of concealed sprinklers.
- For example, maximum recess distance, alignment of the concealer plate retainer lugs, and frame arm/deflector attachment pins orientation, proximity to high level obstructions and a combination of these can be detrimental to the water distribution of the concealed sprinkler.
- For example, water in the concealer plate, blocked vent holes, glued and painted concealer plates can delay the thermal response of concealed sprinklers.
- These potential problems are avoidable through awareness and improved installation practices. As an aid, a simple checklist of the potential problems identified during this project has been prepared.