AUTOMATIC FIRE SPRINKLER SYSTEMS

A good practice guide

Corinne Williams

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1 INTRODUCTION

This guide provides good practice guidance relating to automatic fire sprinkler systems. Sprinkler systems installed in buildings have a good record of performance and have demonstrated that they can be effective in reducing the risk to life and property damage from fire.

The guide is aimed at project clients, building owners, building managers, specifiers, sprinkler installers and maintenance companies, insurance surveyors, building control practitioners, fire safety officers, risk assessors and fire and rescue service inspectors. It will also be of interest to anyone who needs to consider or deal with automatic sprinkler systems.

Only fixed, automatic sprinkler systems are considered in the guide; it is mainly concerned with sprinklers installed in commercial and industrial buildings, although residential sprinkler systems are briefly referred to.

A range of issues are covered:

- brief background and description
- relevant, current UK standards
- design, installation and maintenance issues
- dealing with existing, new and novel products
- the associated benefits, limitations and potential problems that may occur
- guidance on avoiding these problems so that reliable and effective systems are designed, installed, commissioned and maintained, and fulfil their purpose in the event of a fire.

The guide also suggests where to find further information.

2 BACKGROUND

2.1 CONSEQUENCES OF FIRE

Fires in buildings can result in the loss of lives, injuries, property damage, business interruption and damage to the environment.

UK Fire Statistics[1] record that in 2005 there were 93 100 fires in buildings attended by local authority fire and rescue services, comprising 57 800 in dwellings and 35 300 in other buildings (Fig. 1). In the same year there were 403 fire deaths and 13 000 non-fatal casualties in buildings: this comprised 376 deaths and 11 600 non-fatal casualties in dwellings, 27 deaths and 1400 non-fatal casualties in other buildings (Figs 2 and 3).

An analysis of serious fires in the UK[2] (involving fatalities and/or a loss greater than £100 000) found that the total estimated fire losses reported by insurers was £413 million for 384 building fires in 2005.

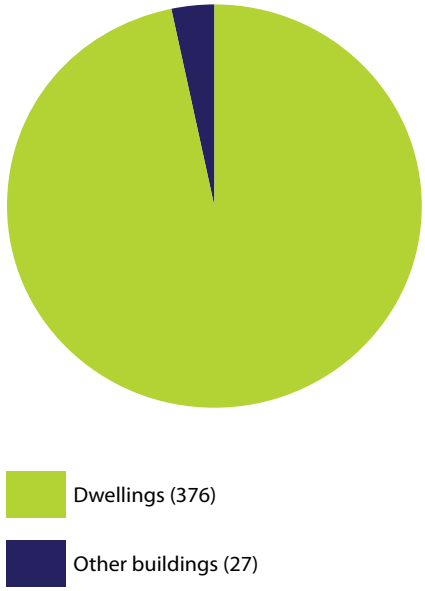

Figure 2: Number of deaths in dwellings and other buildings.*

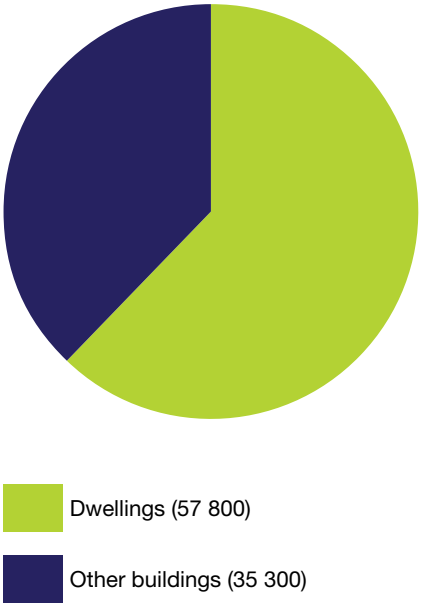

Figure 1: Number of fires in dwellings and other buildings.*

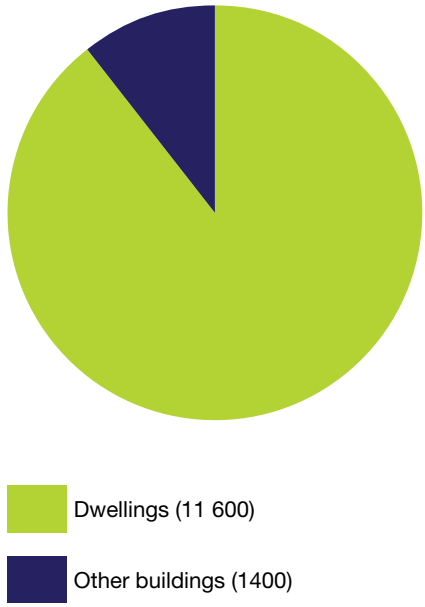

Figure 3: Number of injuries in dwellings and other buildings.*

* *UK Fire Statistics, 2005.*

2.2 REGULATORY BACKGROUND

The statutory requirements for fire protection in the UK relate primarily to the protection of people in or around buildings. They do not regulate for the protection of the building or its contents. Building Regulations cover the construction of new buildings and certain alterations or changes of use. Once the building is occupied, fire safety legislation requires that fire protection systems are maintained and, where the fire risk changes, may require additional measures to be provided.

> The total estimated fire losses reported by insurers was £413 million for 384 building fires in 2005

In England and Wales, the Building Regulations 2000[3] apply. Guidance on ways of complying with these regulations is given in Approved Document B (Fire safety).[4] The provisions for the use of sprinkler protection in Approved Document B have tended to increase over time.

Approved Document B was updated in 2006 and took effect from April 2007. A new, mandatory regulation accompanied these revisions: Regulation 16B Fire safety information, which was introduced through Statutory Instrument 2006 No. 3318.[5] This requires that sufficient information is recorded to assist the eventual owner/occupier/employer to meet their statutory duties under the Regulatory Reform (Fire Safety) Order 2005[6] (the Fire Safety Order) and is specified as "information relating to the design and construction of the building or extension, and the services, fittings and equipment provided in or in connection with the building or extension which will assist the responsible person to operate and maintain the building or extension with reasonable safety". Guidance to achieve this requirement is given in Appendix G of Approved Document B Volume 2,[4] and includes sprinklers.

It should be noted that the Department of Health Firecode consisting of various health technical memoranda (HTMs)[7] should be used for the design of hospitals and similar healthcare premises.

The Department for Children, Schools and Families (DCSF) Building Bulletin 100,[8] and its companion publication Fire safety risk assessment guide: *Standard specifications, layouts and dimensions: Sprinklers in schools*,[9] should be used for the design of schools. Building Bulletin 100 acknowledges the important role of sprinklers. In March 2007, DCSF announced the new policy on sprinklers, that all new schools should have sprinkler systems installed, except in a few low-risk schools.

The Fire Safety Order[6] applies in England and Wales. It covers 'general fire precautions' and other fire safety duties which are needed to protect 'relevant persons' in case of fire in and around most 'premises'. The Fire Safety Order requires fire precautions to be put in place 'where necessary' and to the extent that it is reasonable and practicable in the circumstances of the case.

Responsibility for complying with the Fire Safety Order rests with the 'responsible person'. In a workplace, this is the employer and any other person who may have control of any part of the premises, eg the occupier or owner. In all other premises, the person or people in control of the premises will be responsible. If there is more than one responsible person in any type of premises (eg a complex), all must take reasonable steps to cooperate and coordinate with each other.

The responsible person must carry out a fire risk assessment which must focus on the safety (in case of fire) of all relevant persons. The assessment should pay particular attention to those at special risk, such as disabled people (including mobility or sensory impairment, and learning disability), those who are known to have special needs, and children; it must also include consideration of dangerous substances liable to be on the premises. The fire risk assessment is intended to help identify risks that can be removed or reduced and to decide the nature and extent of the general fire precautions that need to be taken to protect people against the fire risks that remain.

One of the duties of the responsible person is to ensure that the premises and equipment provided in connection with fire fighting, fire detection and warning, or emergency routes and exits are covered by a suitable system of maintenance, and are maintained by a competent person in an efficient state and working order, and in good repair. This duty clearly covers any sprinkler system (or other fire suppression system) in the building.

A series of detailed guides for different occupancies[9] has been produced by Communities and Local Government to assist those preparing fire risk assessments. The benefits of sprinklers are specifically mentioned in the guides, in particular for improving the level of fire safety in a building.

Different, but similar, provisions apply in Scotland and Northern Ireland.[10–15]

In addition to the statutory provisions, fire protection may also be specified by building owners or insurers in order to protect the building or its contents. Many insurers use the Fire Protection Association's *Design guide for the fire protection of buildings*[16] as a basis for providing guidance to the building designer on what they require.

2.3 BRIEF HISTORICAL CONTEXT OF AUTOMATIC SPRINKLER SYSTEMS

Automatic sprinkler systems were originally invented in 1864 for property protection and were part of insurers' requirements. They are now a well established technology and have demonstrated their effectiveness in protecting life and property in industrial and commercial applications over many years. Currently, sprinklers are increasingly being considered and installed in a wide range of building types in the UK, including residential and domestic premises, historic buildings and schools.

2.4 BUILDING TYPES AND HAZARDS

Automatic sprinkler systems are installed in many different types of buildings, including commercial (eg offices and shops), industrial (eg factories and warehouses), institutional (eg schools), places of assembly and recreation, residential (blocks of flats and care homes) and domestic.

Sprinkler systems are designed to provide an appropriate level of protection for a particular type of building and the hazards it contains.

2.5 SPRINKLERS AND OTHER FIRE PRECAUTION MEASURES

Automatic sprinkler systems are part of the overall package of fire safety measures in a building and should not be considered in isolation. For example, there would generally be a fire detection and alarm system installed and passive fire protection measures in place. A complex building may also have a smoke and heat exhaust ventilation system.

2.6 LIFE SAFETY AND PROPERTY PROTECTION SPRINKLER SYSTEMS

Sprinkler systems are designed and installed with a specified objective: to protect property, save life or both. The specifier should decide which purpose they are to serve and specify this at an early stage in the project development. The purpose should be clarified early with the relevant jurisdictional authorities.

Property protection sprinkler systems are used to meet insurers' requirements. More than 100 years of experience with property protection sprinkler systems has shown that they also protect life. Nevertheless, in recent years, additional features for life safety have been introduced, for example for systems installed in large public buildings such as retail stores. These systems are known as life safety sprinkler systems and are used to meet the requirements of the Building Regulations or to satisfy the Fire Safety Order.[6]

The additional features mainly include: the continuity of water supplies, additional valves and limiting the size of zones into which the sprinkler system is divided and which can be closed off for maintenance.

These are intended to increase the reliability of the system and its ongoing availability. In some cases, an insurer may require similar additional measures for property protection.

Residential sprinkler systems for domestic and residential premises are designed to different standards and should not be confused with life safety systems.

2.7 REASONS FOR INSTALLING SPRINKLER SYSTEMS

Sprinklers can therefore be installed in buildings for several reasons, including:

- life safety recommendations intended to meet the Building Regulations
- life safety, as an alternative solution to satisfy recommendations, intended to meet the Building Regulations
- life safety, additional to the Building Regulations, eg a requirement of the fire and rescue service
- property/asset protection to meet insurers' requirements
- property/asset protection as part of a business continuity strategy.

2.8 COST BENEFIT CONSIDERATIONS

Consideration of the costs of a sprinkler system in a cost benefit analysis does not simply include the costs of installation and provision of water supplies, but also includes the costs of inspection, testing and ongoing system maintenance.

The benefits of sprinklers in a cost benefit analysis include:

- a reduced insurance premium.

  And in the event of a fire:
- reduced risk of deaths and injuries
- reduced property damage
- reduced business interruption
- reduced environmental and social impact
- reduced fire and rescue service costs.

If a sprinkler system is being proposed as a compensatory feature, there may also be indirect cost reductions due to building design changes.

3 WHAT IS AN AUTOMATIC SPRINKLER SYSTEM?

3.1 KEY COMPONENTS

A typical sprinkler system consists of a water supply, control valves, an alarm and an array of pipework fitted with individual sprinkler heads (Fig. 4). The sprinkler heads are mounted at specific, appropriate locations, eg beneath a roof or ceiling or within a racking system.

3.2 TYPES OF SYSTEM

Sprinkler systems are divided into three main types: 'wet', 'dry' and 'alternate' systems (including pre-action systems).

In wet systems the pipework is permanently filled with water. Wet systems should be designed with adequate frost protection measures in place to ensure there is no risk of water freezing in the pipework. Life safety systems, and residential and domestic systems should be wet systems.

In dry systems, the pipework is charged with air or inert gas under pressure. In alternate systems, the pipework is selectively charged with water or air or inert gas according to ambient temperature conditions. Additionally, pre-action systems are systems in which the alarm valve can be opened by an independent fire detection system in the protected area and apply to dry systems or alternate systems in the dry mode.

3.3 TYPES OF WATER SUPPLY

There are many different types of water supply that can be used for sprinkler systems. These include:

- town mains
- storage tanks (pump suction tanks, gravity tanks, reservoirs)
- inexhaustible sources (eg rivers or lakes)
- pressure tanks.

Some of these options are used in conjunction with pumps and some may require booster pumps.

3.4 OPERATION AND PERFORMANCE OF SPRINKLER SYSTEMS IN FIRE

Automatic sprinkler systems are used to detect the fire, to operate and provide water to suppress and control, and in some cases extinguish, the fire.

The sprinkler system detects the fire if there is a fire in the vicinity of a sprinkler head. Each sprinkler head has a heat-sensitive device, usually a fluid-filled glass bulb or a fusible link, holding a sprinkler sealing assembly closed against the installation water pressure (Fig. 5). The heat-sensitive device will operate when the liquid in the

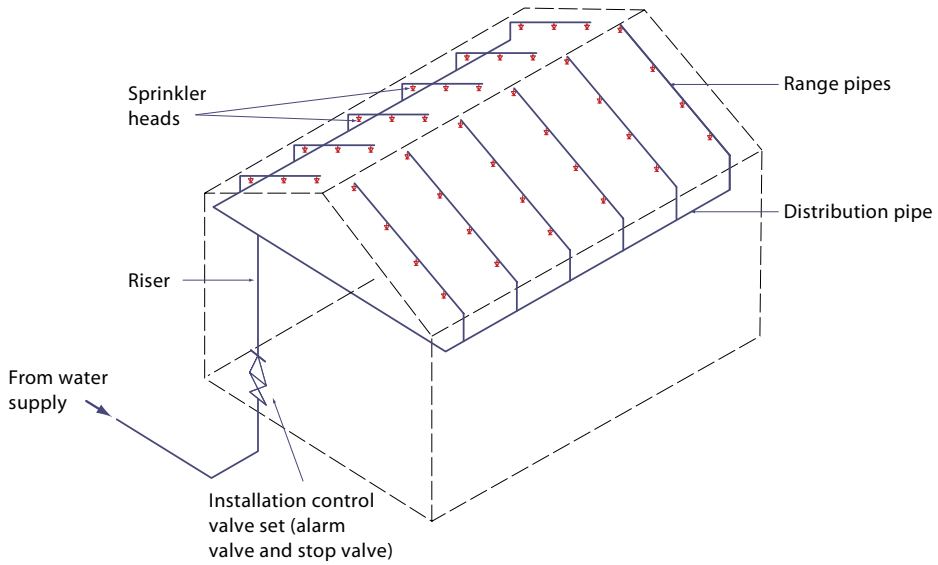

Figure 4: Components of a typical sprinkler system.

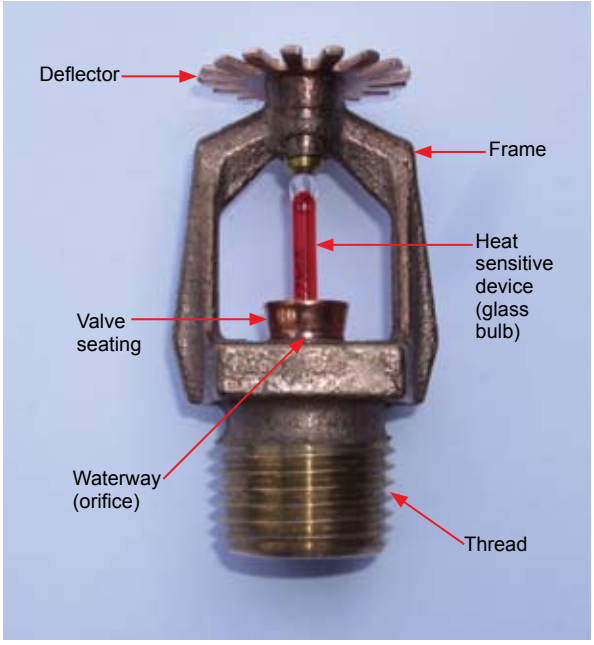

Figure 5: Different parts of a sprinkler head.

glass bulb or the solder reaches a predetermined nominal operating temperature when heated by the fire gases.

The thermal response characteristics of the sprinkler head will determine when and under what conditions the sprinkler will operate. These characteristics are the sprinkler thermal response rating (classified as 'quick', 'special' and 'standard response A') and the nominal operating temperature.

Sprinklers operate when the sprinkler sealing assembly is released, either due to the glass bulb shattering because of the expansion of the liquid or when the solder link has melted. This releases a flow of water and a water spray is discharged onto the fire; the flow of water initiates an alarm which is sounded. The number of sprinklers that operate in a fire will depend on a variety of factors, such as where the fire occurs, the nature of the burning materials and the severity of the fire. Sprinkler systems are designed so that only sprinkler heads in the vicinity of the fire are intended to operate (Fig. 6).

The sprinkler water spray is designed to reduce the intensity and size of the fire and suppress and control it. In some cases, the fire may be extinguished. The characteristics of the water spray, combined with the sprinkler positioning and spacing, have been proved to suppress fires. The water spray inside a room will:

- be directly involved in suppressing and controlling the fire
- wet surrounding combustible materials so they do not ignite
- wet surfaces to cool the building structure
- cool the smoky gases
- reduce the likelihood of flashover.

Also, under some circumstances, sprinkler sprays can cause a downward flow of smoke known as 'sprinkler downdrag', and 'smoke logging'.[17]

The sprinkler spray characteristics are created by the design of the sprinkler head (Fig. 5) (the shape of the frame and deflector plate), the water flow rate, the orifice size and the location of the head relative to the ceiling and other structures. Several suppliers provide sprinkler head products, each with their own range(s) of models.

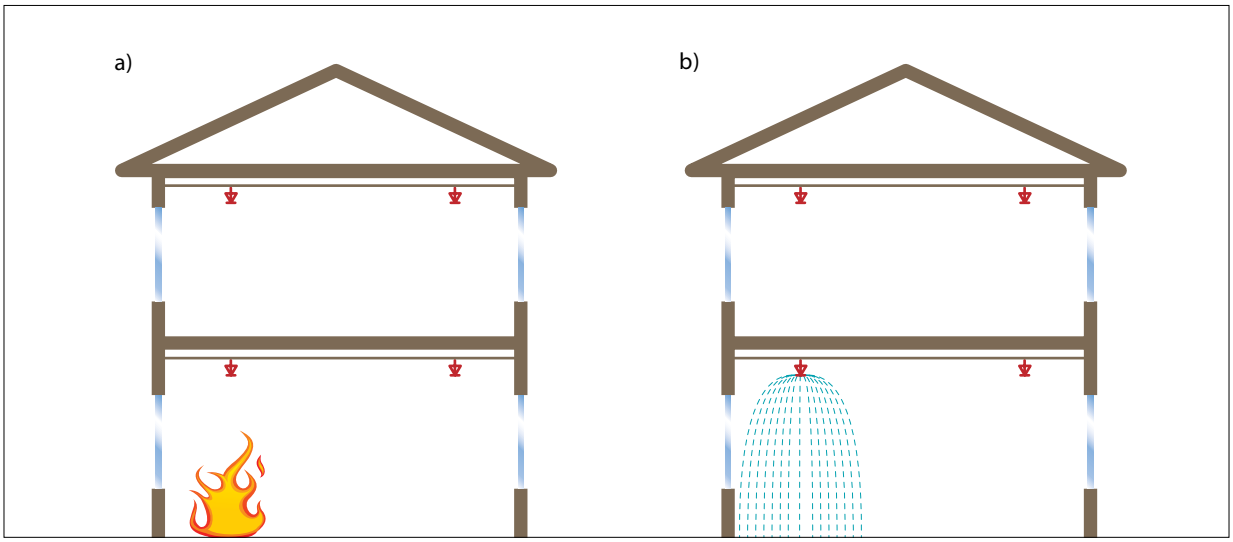

Figure 6: Sprinkler system operating to control the fire a) before operation, b) after operation.

4 BENEFITS OF AUTOMATIC SPRINKLER SYSTEMS

4.1 BENEFITS

The installation of automatic sprinkler protection in buildings results in a wide range of benefits. These include:

- saving lives of, and preventing injuries to, occupants and fire fighters
- preventing fire spread
- reducing property damage
- reducing business interruption
- reducing environmental impact
- reducing water damage compared with water used during fire-fighting activities
- reducing social impact, eg loss of community facilities, loss of employment
- disincentive to arsonists
- reducing financial losses.

In the UK, the British Automatic Fire Sprinkler Association (BAFSA) has published a report on the benefits and uses of incorporating sprinklers in buildings and structures.[18]

4.2 INTERNATIONAL EXPERIENCE

The National Fire Protection Association (NFPA)[19] has published a paper based on the analysis of US Fire Statistics data of fires reported to the US fire departments from 2002 to 2004. This paper concluded that in most property classes:

- the fire death rate per 1000 reported that structure fires are lowered by 57% or more where sprinklers are installed
- the average property loss per fire is lowered by 34% to 68% compared with fires where sprinklers are not present.

However, these figures exclude structures under construction and cases where there was a lack of sprinklers in the fire area.

The paper also showed that sprinklers had an operational reliability of 93% (ie did it operate?) and effectiveness reliability of 97% (ie was it effective, given that it was operational?) where the fire was large enough to activate the systems and where the system was present in the fire area.

One hundred years of experience of automatic sprinkler systems (from 1886 to 1986) in Australia and New Zealand[20] has shown that sprinklers controlled or extinguished 99.46% (8973 fires) and failed to control 0.54% (49 fires) of fires where sprinklers were present. The factors identified which were important in the performance of automatic sprinkler systems in Australia and New Zealand were concerned particularly with:

- good water pressures, and therefore high densities of application of water
- the universal use of alarm connections from sprinkler systems to fire and rescue services
- a high standard of installation, service maintenance and regular testing carried out with the support of fire protection engineers, architects, insurers and government authorities.

5 STANDARDS

Sprinkler systems should be designed, installed and maintained to a recognised standard to ensure the effective performance of the system in the event of a fire and to satisfy insurers and/or approving authorities.

5.1 STANDARDS FOR DESIGN, INSTALLATION AND MAINTENANCE

In the UK, the current recognised principal standards relevant to the design, installation and maintenance of sprinklers in buildings are:

- BS EN 12845: *Fixed firefighting systems – automatic sprinkler systems – Design, installation and maintenance*[21]
- The LPC *Rules for automatic sprinkler installations incorporating BS EN 12845*.[22] These rules are for property protection purposes and contain the text of BS EN 12845 and a series of technical bulletins, which amplify the requirements of the standard or cover additional requirements for insurers
- BS 9251: *Sprinkler systems for residential and domestic occupancies, Code of practice*.[23] It should be noted that residential sprinkler systems designed to BS 9251 are primarily for the protection of life and not intended for the protection of property.

Previous sprinkler standards include BS 5306 Part 2: *Specification for sprinkler systems*[24] published in 1990 which became obsolescent in August 2007. This standard replaced the Fire Offices' Committee *Rules for automatic sprinkler installations*.[25]

5.2 STANDARDS FOR COMPONENTS

In the UK, the recognised principal standards that cover requirements for components of sprinkler systems in buildings are:

- BS EN 12259: *Fixed firefighting systems, Components for sprinkler and water spray systems*.[26] This is a companion standard to BS EN 12845.
- British Standard draft for development DD 252 *Components for residential sprinkler systems. Specification and test methods for residential sprinklers*[27] (under revision) is a companion draft standard to BS 9251 which covers requirements for residential sprinkler heads.

Other countries have their own relevant national systems and components standards.

6 STAGES IN THE LIFECYCLE OF AUTOMATIC SPRINKLER SYSTEMS

6.1 LIFECYCLE STAGES OF THE SYSTEM

Fire protection and sprinklers need to be considered at an early stage of the building design process, so that the impact of different design choices on the design of fire protection/sprinkler systems can be considered.

There are a number of important stages in the lifecycle of the sprinkler system. These are:

- planning
- specification
- design
- installation
- commissioning
- installed system:
  - ongoing maintenance
  - extension or modification, if required
  - operation, in a fire event.
- re-instatement/re-commissioning – following a fire event
- de-commissioning – at the end of its service life.

6.2 STAKEHOLDER ENGAGEMENT

To avoid problems, it is important that key stakeholders are involved at an early stage when considering a sprinkler system, or when altering an existing sprinkler system in a building. Stakeholders may include:

- end client/developer (design stage)
- project manager/architect/fire safety engineer (design and specification stage)
- sprinkler system specifier (if not one of the above) (design and specification stage)
- specialist sprinkler contractor(s) to design, install, commission and maintain the system (design, installation and commissioning stages and the installed system)
- responsible person, building owner, building manager(s), building occupier(s) (the installed system)
- jurisdictional authorities:
  - water supplier
  - building control practitioner
  - local authority fire safety officer
  - insurer(s) of the building, contents and business.

The details of the design brief should be confirmed at the planning stage (eg the purpose of the system, the extent of sprinkler protection, including any exceptions, and the sprinkler fire hazard assessment) with the relevant jurisdictional authorities.

A suitable specialist sprinkler contractor will be appointed to carry out the design, installation, commissioning and maintenance of the system including alterations or extensions to the system. The contractor will base the system design on the detailed information provided in the tender documentation by the specifier.

6.3 KEY ELEMENTS OF THE SYSTEM

The key elements that need to be considered for the design, installation and maintenance of sprinkler systems are:

- documentation
- extent of sprinkler protection, including permitted exceptions
- classification of occupancies and fire hazards, including protection of special hazards
- hydraulic design criteria, including design density and area of operation
- water supply and type
- pumps
- installation type and size
- spacing and location of sprinklers
- pipe sizing and layout
- sprinkler design characteristics and uses
- valves
- alarms and alarm devices
- pipework
- signs, notices and information
- commissioning and acceptance tests, periodic inspection
- regular maintenance
- special requirements for property protection systems or life safety systems.

6.4 SPRINKLER PROTECTION AND HAZARD CLASSIFICATION

Sprinkler protection should be provided throughout the building apart from optional permitted exceptions, so that if a fire starts at any location in the building it is suppressed and controlled and/or extinguished quickly and efficiently, preventing fire spread to other parts of the building. All exceptions to sprinkler protection should be agreed with the relevant jurisdictional authorities.

Sprinkler systems are designed to provide an appropriate level of protection for the occupancy and the hazard. In BS EN 12845[21] occupancies are classified in hazard groups, 'Light' (LH), 'Ordinary' (OH) and 'High' (HH). OH and HH are further subdivided into groups, eg OH is divided into OH1, OH2, OH3 and OH4. In BS 9251[23] occupancies are categorised as 'domestic' or 'residential'. The hazard classification takes into account the properties, dimensions, arrangements, quantities and locations of combustible materials that are likely to be found in the building, and the expected rate of growth of the fire in the early stages. The appropriate hazard classification for the design is determined from a fire hazard review carried out by a suitably qualified person.

6.5 SPRINKLER SYSTEM DESIGN

There are a number of factors that are taken into account in the design of sprinkler systems which influence their performance. Specified criteria that need to be achieved in the design, include:

- minimum and maximum spacing between sprinkler heads
- location of sprinklers relative to building construction:
  - minimum and maximum distance of sprinkler deflector to the ceiling
  - maximum distance between any sprinkler and wall or partition
  - sprinkler locations relative to any ceiling obstructions, eg beams or joists, or other obstructions
  - sprinkler locations relative to racking and goods.
- maximum area protected by each sprinkler, related to occupancy and hazard
- maximum number of sprinklers in each zone
- minimum density of water discharge, related to occupancy and hazard
- minimum sprinkler operating pressure, related to occupancy and hazard
- sprinkler orifice size, related to what is known as the 'k factor'
- sprinkler nominal operating temperature
- thermal response characteristics of the sprinkler head, classified as 'quick', 'special' and 'standard response A'
- minimum duration of water supplies.

Sprinkler model and type are other factors which influence the performance of the sprinkler system. There are many different sprinkler patterns and arrangements. Examples of sprinkler types include: spray, conventional, ceiling, flush, recessed, concealed, sidewall and flat spray (Fig. 7). Examples of specialised types are: ESFR (early suppression fast response), EPEC (enhanced protection extended coverage), extended coverage horizontal sidewall, ELO (extra large orifice) and residential sprinklers.

For fully calculated systems, hydraulic calculations are carried out using computer programs to determine suitable pipe bore sizes and the water supply pressures and flows required to meet the specified performance criteria. For pre-calculated systems, a combination of calculations and pre-calculated tables are used to determine suitable pipe bore sizes and the water supply pressures and flows required to meet the specified performance criteria. Factors including pipe material, eg friction losses, configurations, bends and the height of the highest sprinkler are taken into account.

The sprinkler contractor specifies suitable sprinkler components for the system including suitable pipe, fitting and fixings, sprinkler heads, valves, alarms and hardware needed for the system. The contractor will select and design suitable, adequate water supplies for the system and ensure that the minimum water supply characteristics are capable of providing the required pressure and flow to all parts of the sprinkler system, and that the criterion of the minimum duration of the water supplies is achieved. The contractor will specify the water supply hardware, eg pumps and tanks.

The contractor will also prepare a documented programme of inspections and checks and a test, service and maintenance schedule to the agreed standard.

Note that a sprinkler system installed as part of a fire safety engineered design, eg to BS 7974,[28] may not conform to other existing guidelines. However, full details of the design of the system must be provided or made available.

Figure 7: Different sprinkler types.

7 LIMITATIONS OF AUTOMATIC SPRINKLER SYSTEMS

Automatic sprinkler systems, like other fire protection systems, have limitations. Sprinkler systems are designed to protect a particular hazard and therefore will not be suitable for protecting special hazards that are not allowed for in the design, for example:

- greater hazards than the system is designed for
- saving people in contact with flames
- unprotected areas in a building, ie areas with no sprinkler protection
- fires with a great degree of shielding
- compartments with very tall ceilings
- electrical fires
- explosions
- exposure fires with rapid fire spread (fires originating externally to the sprinkler protected building)
- extreme events resulting in mechanical damage, eg earthquakes and impacts
- small fires, producing insufficient heat generated by the fire to operate a sprinkler head and that can be extinguished promptly by other means.

Any fire safety system is likely to fail if the real hazard exceeds the design hazard; no system can be designed and installed to cope with all eventualities. This is true for any fire protection system (both active and passive).

Contrary to some statements, there have been a few cases where people have died in sprinklered buildings. (However, the following cases should not be regarded as sprinkler failures as the fire scenarios were outside the scope of the sprinkler system design. Nevertheless, they are worthy of consideration.):

- In December 2006 a person died following a fire in a sprinklered block of sheltered flats in Bristol. The fire originated outside the sprinkler protected area in a car inside an unsprinklered open-sided basement car park (Fig. 8).[29, 30]
- In May 2007 in Dorset a person died in a fire in a sprinklered apartment and was thought to be in contact with the flames.[31] Sprinkler systems are not expected to save people in contact with flames (although they have done so).

Figure 8: Fire damage to sprinklered block of flats where fire originated in unsprinklered open-sided basement car park below (by kind permission of Avon Fire & Rescue Service).

8 POTENTIAL PROBLEMS WITH AUTOMATIC SPRINKLER SYSTEMS

The benefits of an installed sprinkler system, and of any fire safety measure, depend on how effective and reliable it is. If a system is designed for the correct hazard, and installed and maintained properly, then the risk of failure in a fire event due to malfunction of the system should be very low. However, failure rates are higher in actual fire incidents due to a variety of reasons.

Analysis of the UK Fire Statistics data from 1994 to 2005[1] provides information about the successes and failures of automatic sprinkler systems. The data are based on fire and rescue service report forms completed after a fire has been attended and reveal problems that can occur with installed automatic sprinkler systems in a fire event.

The following sections outline potential problems with installed automatic sprinkler systems that could occur either in a fire event or without a fire being present.

8.1 POTENTIAL PROBLEMS IN A FIRE EVENT

The following are potential problems:

- sprinkler system did not operate in a fire event
- sprinkler system operated in a fire event, but did not perform effectively, ie did not control the fire.

A sprinkler system that did not operate in a fire, or a sprinkler system that operated in a fire event but did not perform effectively, can result in devastating consequences.

8.1.1 Non-operation of sprinkler system

Possible reasons why a sprinkler system may not operate in the event of a fire (taken from the UK Fire Statistics coding categories) include:

- system shut off by someone to prevent excessive water damage by system
- system shut off for other reasons prior to fire, eg maintenance, repairs
- system frozen
- system defective, including damaged pipework, lack of maintenance, heads painted over
- faulty sprinkler heads (this reason would have been based upon observation by the fire and rescue service – it should be noted that expert testing may be required to determine whether faulty sprinklers were actually present)
- heat/smoke deflected away from heads
- fire flashed into inaccessible area
- system overwhelmed due to a very rapid build-up of heat due to nature of fire load
- system out of commission, obsolete or no longer considered to be required
- small fire, extinguished promptly by other means (including insufficient heat generated by the fire to operate a sprinkler head)
- fire contained within machinery, gutter, trunking etc
- fire above sprinkler heads
- fire in area not covered by sprinkler system, eg cavities.

The last five reasons are not counted as sprinkler failures since they lie outside the design specification, see section *7 Limitations of automatic sprinkler systems*.

8.1.2 Non-effective performance of the sprinkler system

There are reasons why a sprinkler system may operate but not contain/control the fire. The following reasons have been taken from the UK Fire Statistics coding categories:

- sprinkler system shut off after it has operated to prevent excessive water damage by system
- fire larger than that designed for
- not enough water discharged to control fire
- water discharged but could not reach fire
- low mains pressure or water supply failed
- system defective, including damaged pipework, lack of maintenance, sprinkler heads painted over
- faulty sprinkler heads
- change of use for instance where sprinkler design is for lower hazard category and the system is not upgraded.

8.2 REAL FIRE INCIDENTS

Further analysis of the UK Fire Statistics data reveals the following information relating to real fire incidents. The Appendix provides more detail relating to the UK Fire Statistics data[32] and analysis.[33]

There is an unknown selection bias in this statistical data. There is a possibility that sprinkler failures are over-represented and that some sprinkler successes may not be reported in the statistics. This is because if the sprinklers are successful in extinguishing or controlling the fire, it is less likely that the fire and rescue service will attend and therefore the fire will not be recorded in the fire statistics.

In this guide, success is defined as when a system operated and controlled the fire; failure is defined as when a sprinkler system did not operate in the event of a fire or that it operated but did not control the fire. Cases of small fires, extinguished promptly by other means, cases where the fire is in an area not covered by the sprinkler system, and cases where there was an installed system which was out of commission, obsolete or no longer considered to be required, are not included. These total 5417 cases.

Over the 11-year period of the UK Fire Statistics examined, it is recorded that sprinklers were successful in 4024 cases and unsuccessful in 1012 cases (Fig. 9 and Table 1). Of the unsuccessful cases, it is recorded that there were 731 cases where sprinklers did not operate and 281 where they operated, but did not control the fire. There were 1 323 000 reported fires in buildings during the period. Sprinklers were present in a small number of these fires (10 458). Therefore, sprinklers were successful in 80% of cases where they would be expected to operate and unsuccessful, in terms of not controlling the fire, in 20% of cases.

Figure 10 shows the reasons for sprinkler system failure (in descending order) when the fire was large enough to operate the sprinkler system and the system was present in the area of the fire. There were no recorded cases where the system was frozen, or there was a change of use where the sprinkler design was for a lower hazard category and the system was not upgraded.

In cases where the sprinklers extinguished the fire, an average of two sprinklers operated. In cases where the sprinklers controlled the fire, an average of three and a half sprinklers operated. The type of building in which most sprinkler failures and successes occur is 'industrial premises', followed by 'purpose built flats'. The types of business in which most sprinkler failures and successes happen are 'no business', 'retail trade' and 'manufacture of pulp, paper and paper products'. The type of room where the fire originates, in which most sprinkler failures and successes occur, is 'other factory production rooms

Table 1: **Operation of sprinkler systems**

	Did the sprinkler system operate?			
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate
Number of cases	1259	2765	281	731

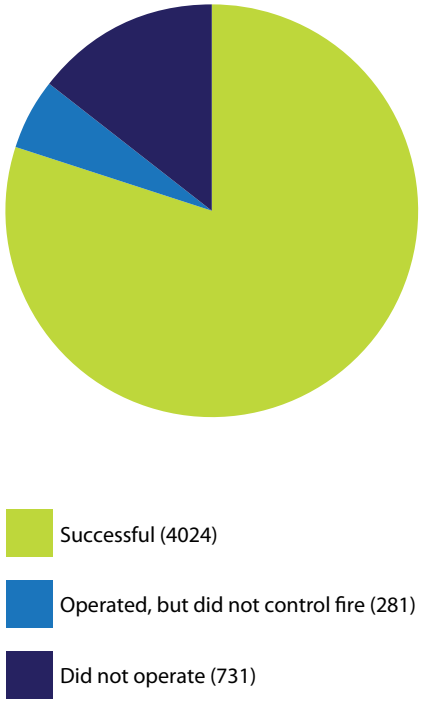

Figure 9: Sprinkler successes and failures (UK Fire Statistics, 2005).

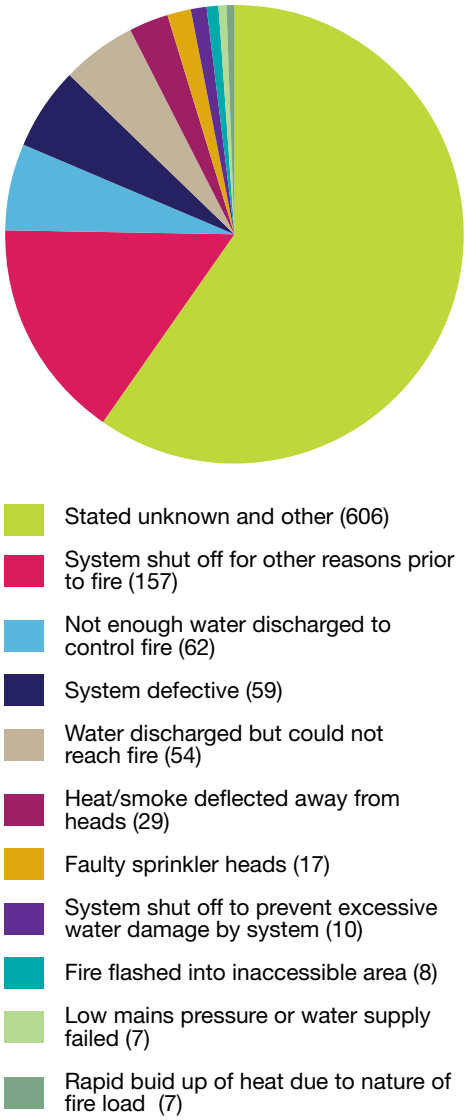

Figure 10: Reasons for sprinkler failures (UK Fire Statistics, 2005) (see section 8.1 *Potential problems in a fire event* for a more comprehensive description).

including workshops', followed by 'refuse including incinerator room', followed by 'store room including stockroom, warehouse'.

Examples of fires where there were problems with sprinkler systems in real premises are shown in Box 1. In these fires, it can be clearly seen that the problems with the sprinkler systems mainly relate to problems with water supplies and are a failure of the management and maintenance of the systems.

8.3 PROBLEMS WITHOUT A FIRE PRESENT

Problems that could be identified with installed automatic sprinkler systems, without a fire present, come under the following categories:

- incorrect design for hazard, eg resulting from change of use of a building, and hazard protected without reference to the design of the installed automatic sprinkler system
- sprinkler component failure
- unwanted sprinkler system operation (false activations).

Incorrect design or sprinkler component failure can result in an ineffective or inoperable sprinkler system when a fire does occur. The inappropriate discharge of a sprinkler system or sprinkler component failure, if severe, could result in water damage that could destroy stock and equipment.

Box 1: **Problems with sprinkler systems in fires in real premises**

March 1990, an office block fire in Hampshire[34] which had a sprinkler system and automatic fire detection system fitted. The fire spread rapidly through the timber joisted roof void which contained sprinklers, resulting in the collapse of the roof and a substantial loss. During the fire, the pumps had been switched off by the fire and rescue service and some stones were found to be present in some of the pipework close to where the fire started.

July 2005, a warehouse fire[35] **in Kent**, involving stacked white goods. Information to date indicates that an automatic sprinkler system was fitted but the pump was turned off. It was reported that no one was injured but the warehouse was left burned out with its metal frame twisted.

November 2005, a clothing high bay storage and distribution warehouse fire in Leicestershire.[36, 37] An automatic sprinkler system was fitted but not working properly due to problems with the water supply. The warehouse and its contents were destroyed but there were no reported injuries. The fire investigation concluded[38] that there was damage to a pipe in the supply ring main resulting in a leak, so the water supply was turned off prior to the fire occurring.

July 2006, a six-storey paper records storage warehouse fire in London.[39] A ceiling mounted and in-rack sprinkler system and addressable automatic fire detection system were fitted. This fire resulted in total destruction of the warehouse and contents but no one was hurt. Both switches to the sprinkler pumps were (discovered by the fire and rescue service on attendance) turned off.

8.3.1 System design

Even though suitably qualified and experienced sprinkler contractors are involved in the design of a sprinkler system, they can be faced with issues which could result in an inappropriate, but properly designed system, as follows:

- the specification/brief may be unclear, eg purpose of system, incorrect hazard classification and sprinklers omitted in some areas
- the specification/brief may not be adequate
- the insurers and other relevant jurisdictional authorities are involved too late
- in the lifetime of the building, there is a change to the fire hazard resulting in an increased fire hazard classification but the sprinkler system is not redesigned and upgraded.

8.3.2 Sprinkler components and unwanted sprinkler operation

Component failures that could occur with installed automatic sprinkler systems include the following:

- water storage/supply – insufficient or no water (eg tank not full or water in tank frozen), insufficient mains pressure, tank leaked, empty, corroded
- sprinkler pump(s) – failure of pump engine/motor, drive, control logic and circuitry, fuel/electricity, corroded, blocked
- main valves – shut off manually, stuck shut, frozen, corroded, broken
- delivery system of pipework – disconnected, burst, broken, blocked, corroded, damaged, eg by forklift trucks colliding with pipework, water in pipe frozen, damaged by fire
- sprinkler heads – damaged, painted, obscured, corroded, blocked, fouled
- concealed sprinkler heads[40] – damaged, painted, taped, wallpapered over, air gap filled/covered up with paint, glue, mastic or painter's caulk, concealer plates disconnected from the rest of the ceiling assembly, positive pressure voids above sprinklers
- sprinkler assemblies inside concrete cups.

In addition to the above:

- in dry, alternate and pre-action systems, the main valve could fail to open because air is replenished quicker than it can be expelled through an open sprinkler head
- in dry systems, water hammer could damage pipe joints
- in alternate systems, incorrect practice during change of alternate valve from wet to dry mode could cause delay in system operation
- in pre-action systems, the use of detectors could increase the chances of false alarms.

The Loss Prevention Certification Board (LPCB) operates a range of certification schemes for sprinkler installers and sprinkler components, see sections 9.3 and 9.4. Any complaints received for LPCB-approved sprinkler installers and sprinkler components are investigated by LPCB and resolved. This process may involve testing of

components to assist in the analysis and assessment of the problem.

The following are examples of complaints/recorded problems that have happened with sprinkler systems and components without a fire present:

Installer scheme

- use of incorrect mechanical coupling
- use of incorrect piping material in pump test assembly
- approved sprinkler contractor working outside its scope of approval.

Component schemes

- butterfly valve failure
- sprinkler heads leaking and forming calcium deposit inside a store. Investigations indicated that the leaks were due to chemical attack on O-rings and not water contamination
- retrospective pump engine modification to correct no re-start condition
- sprinkler tank corroded in approximately 20 years – installation considered to be poor workmanship. The scheme only approved tanks for 15 years, so further maintenance should have been carried out but it was not
- false operation of sprinkler heads in a property, although extensively investigated, no problem was found with the approved product
- permitted sprinkler configuration is unclear in the scheme standard and in the listing for a particular model of sidewall horizontal extended coverage sprinkler.

An example of major damage due to a problem with a sprinkler system (with no fire present) is an office building in London. A non-standard 'detector-operated' sprinkler system using wall-mounted sprinklers to protect the atrium base, accidentally operated due to a false alarm and caused extensive water damage.[41]

9 HOW TO AVOID POTENTIAL PROBLEMS WITH AUTOMATIC SPRINKLER SYSTEMS

This section discusses how to avoid potential problems and offers good practice guidance.

9.1 PROJECT PLANNING AND SPECIFICATION

The insurers and other relevant jurisdictional authorities (building control bodies, water supply company, local authority fire and rescue services, etc) should be consulted as early as possible.

Details of the sprinkler system that need to be provided by the specifier in the tender documentation to the sprinkler contractor (so they can prepare the sprinkler system design proposal) include the following:

- Details of the building
  - internal layouts of rooms, corridors and doors
  - number of storeys
  - dimensions of rooms, corridors, other spaces and doors
  - dimensions and details of concealed spaces
  - details of fire-resisting elements of construction
  - details of ceiling penetrations/obstructions.
- Purpose of system (life safety and/or property protection)
- Role of sprinklers in fire safety design
- Details of hazards and risks to be protected and any anticipated future changes
- Details of sprinkler standard to be used
- Provision and route of water supply
- Details of electrical supply
- Any special requirements for sprinkler head types or other sprinkler products.

The details of the design brief should be confirmed with the relevant jurisdictional authorities, eg the purpose of the system, the extent of sprinkler protection including any exceptions and the sprinkler fire hazard assessment.

The sprinkler fire hazard classification is the specifier's responsibility to develop the sprinkler system tender documentation. This classification should be carried out by a suitably qualified person.

9.2 DESIGN, INSTALLATION AND COMMISSIONING OF THE SYSTEM

Sprinkler systems for buildings should be correctly designed, installed and commissioned. These tasks should be carried out in accordance with the standards by suitably qualified and experienced sprinkler contractors. Also, components of sprinkler systems should be fit for purpose and in accordance with the standards, where available.

9.3 THIRD PARTY CERTIFIED COMPONENTS

Third party sprinkler product certification schemes provide a means of identifying sprinkler products which have demonstrated that they have the requisite performance in fire and also provide confidence that the products actually supplied are provided to the same specification as that tested/assessed.

Insurers usually require sprinkler products which are approved and listed to a recognised and appropriate third party certification scheme and comply with appropriate British/European standards, where available, for the purposes of property protection. Building control bodies may accept the certification of sprinkler products as evidence of compliance with the relevant British/European standards, where available. Nonetheless, a building control body will wish to establish, in advance of the work, that the scheme is adequate for the purposes of the Building Regulations.

In the UK, the LPCB operates various certification schemes for sprinkler products. Certificated sprinkler products are listed in the LPCB *List of approved fire and security products and services*, known as the Red Book.[42]

Certification schemes for sprinkler products reduce the likelihood of problems occurring but cannot completely prevent them. However, if problems do occur and are reported, they can be investigated and dealt with.

9.4 THIRD PARTY CERTIFIED SPRINKLER CONTRACTORS

Using third party certified installers of sprinkler systems provides a means of ensuring that installations have been designed, installed and commissioned by suitably qualified and experienced contractors to appropriate standards. This increases the reliability of the anticipated effective performance of the system in the event of a fire, and to satisfy insurers and/or approving bodies.

Insurers usually require independent certification of installers of automatic sprinkler systems for the purposes of property protection. Building control bodies may accept the certification of the installation or maintenance of sprinkler systems as evidence of compliance with the relevant standard. Nonetheless, a building control body will wish to establish, in advance of the work, that the scheme is adequate for the purposes of the Building Regulations.

In the UK, there are two third party certification schemes for sprinkler installers that are applicable to commercial and industrial buildings: one is operated by the LPCB and known as the LPS 1048 scheme[43] and the other is operated by Warrington Certification Limited and comes under the FIRAS certification scheme.[44]

Under the LPS 1048 scheme, certificated installers are listed in the LPCB Red Book.[42] There are four different approval levels for sprinkler contractors which allow contractors to carry out particular categories of work. Sprinkler contractors can only carry out work to their approved level. LPS 1048 approved sprinkler contractors are regularly assessed for their continued capability to undertake sprinkler contracts and for their compliance with the requirements of the scheme.

An LPS 1048 certificate of conformity is issued by the sprinkler contractor or its supervising body or the LPCB supervisory service for each system, installation, extension or alteration. This certificate states that the sprinkler system complies with all the appropriate requirements of the installation standard and, where applicable, lists details of any accepted minor departures. Major non-compliances are not permitted. It should be noted that a sprinkler contractor's own completion certificate is not an LPS 1048 certificate of conformity. This certificate only remains valid if the system, installation, extension or alteration covered by the certificate is maintained in accordance with the original installation standard.

Specifiers should use suitably qualified and experienced third party certified contractors to design, install and commission the sprinkler system to the appropriate standards. Additionally, the specifier of the system must ensure that the installing company is approved to the level appropriate to the system (as designed) and to be installed.

Certification schemes for sprinkler installers reduce the likelihood of problems occurring but cannot completely prevent them. However, if problems do occur and are reported, they can be investigated and dealt with. The reporting of complaints under the current LPS 1048 scheme is voluntary.

Where an LPS 1048 approved sprinkler contractor has not been granted approval to self-certificate its work, an LPCB approved third party supervising body will inspect the contracts it undertakes. (Note: the LPCB certification scheme in The Netherlands[45] has 100% onsite inspection of all sprinkler systems when they are being installed.) In addition to the LPS 1048 scheme, the LPCB also operates the LPS 1301 scheme that is applicable to residential sprinkler installers for domestic and residential buildings.[46]

9.5 WATER SUPPLIES

Sprinkler system water supplies need to be adequate (provide sufficient flow and pressure to satisfy the system design requirements) and reliable (available in a fire event). Inadequate or lack of water supplies can be caused by, for example:

- an empty or partially filled water tank
- a faulty and/or switched off pump
- inadequate town mains pressure
- frozen water
- a leaking or corroded tank
- a main valve fully or partially closed.

At the earliest stage, prior to selection of the water supply, the town mains at the site should be performance-tested to determine its pressure and flow characteristics and the minimum available pressure. The results of the performance test will determine whether the town mains can be used as a water supply for the sprinkler system.

If the town mains is used as a water supply, regular maintenance will include further performance tests to check the pressure and flow characteristics and the minimum available pressure continues to be adequate.

Life safety sprinkler systems require additional life safety features including duplicate water supplies.

9.6 INSPECTION AND MAINTENANCE OF THE SYSTEM

Poor maintenance, resulting in, for example, partially opened/closed valves or switched-off pumps, can lead to a sprinkler system not operating or operating ineffectively in the event of a fire. Guidance on the maintenance of sprinkler systems is given in the standards and should only be carried out by a competent person.

Routine maintenance by a competent onsite person may include checking of pressure gauges, alarm systems, water supplies, anti-freezing devices and automatic booster pumps.

If a sprinkler system forms an integral part of the fire safety strategy of the building, it is important that adequate management procedures are in place to cater for those periods of time when part of the sprinkler system is not functional during maintenance work.

The measures will include the following:

- restore the system to full working order as soon as possible
- limit any planned shutdown to low-risk periods when people using the building are at a minimum or when the building is not in use. This is particularly important when the system is a life safety system or forms part of the fire safety engineering requirements
- there may be a need to isolate the area without the benefit of working sprinklers from the rest of the premises by fire-resisting material
- avoid higher risk processes such as hot work
- extra staff should be trained and dedicated to forming fire patrols

- phased or staged evacuation strategy may need to be suspended. Evacuation should be immediate and complete
- maintenance should be carried out on a zoned basis, to prevent leaving the whole system ineffective
- inform the local fire and rescue service
- notify the users of the building, ie the responsible person and other occupants.

Life safety sprinkler systems have special requirements, intended to increase the reliability of the system and its ongoing availability, including:

- increase in number of zones
- system to be wet type
- 'quick' response sprinkler heads except for rooms greater than 500 m^2 in area and 5 m in height, where 'standard response A' and 'special response' can be used
- duplicate control valve sets
- duplicate water supplies
- additional precautions for maintenance.

The responsible person (usually the building owner) should ensure that the programme of weekly and monthly inspections and checks are carried out by competent onsite personnel. They should arrange for a test, service and maintenance schedule with quarterly, half yearly and yearly routines to the agreed standard carried out by a competent sprinkler maintenance contractor.

The building owner is responsible for employing a competent sprinkler maintenance contractor to ensure that adequate management procedures are in place to cater for those periods when the sprinkler system is not functional during maintenance work.

Third party certified sprinkler contractors and components reduce the likelihood of problems occurring in installed systems

Regular inspections of installed sprinkler systems should be carried out by the sprinkler maintenance contractor and/or risk assessor to identify problems and rectify them, eg changes of fire hazards, faulty or damaged components. Other inspections may also be carried out by insurance surveyors and/or fire and rescue service inspectors and/or certification scheme assessors.

The use of third party certified installers that undertake maintenance of sprinkler systems provides a means of ensuring that the maintenance of installations have been conducted by suitably qualified and experienced contractors to appropriate standards, therefore increasing the reliability of the anticipated effective performance of the system in the event of a fire and to satisfy insurers and/or approving bodies. The sprinkler system will be maintained according to the installation standard that was used to design the system.

9.7 NEW OR NOVEL SPRINKLER PRODUCTS

New and novel sprinkler products, not yet included in standards, may be suitable for use but robust technical evidence needs to be in existence to prove these are fit for their intended purpose and should be confirmed early with the relevant jurisdictional authorities.

An LPCB technical approval route exists, which is intended to approve new or bespoke products against a set of requirements agreed with an independent panel of technical experts, usually comprising manufacturers, insurers, end users and other stakeholders.

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

Automatic fire sprinkler systems are a well established technology and have demonstrated their reliability and effectiveness in protecting life and property in industrial and commercial buildings over many years. The benefits of automatic sprinkler systems are well known.

Critical success factors for reliable and effective sprinkler systems include:

- good planning and correct specification
- correct and appropriate design, installation and commissioning
- regular inspections and ongoing maintenance to suitable standards
- adequate and available water supplies
- sprinkler products that are fit for purpose
- consideration of the sprinkler system as part of the overall package of fire safety measures in the building.

Several potential problems with installed sprinkler systems have been identified which could result in a system not operating, or not performing effectively in the event of a fire, or unwanted, false operation. These problems relate to the failure of (or inadequate) water supplies, incorrect design and installation, poor maintenance and faulty sprinkler products.

Human error plays a large factor in these failures, as with any fire protection system.

Using third party certified sprinkler installers and maintenance companies, and third party approved and listed sprinkler components, can increase the reliability of the anticipated effective performance of the system and its components in the event of a fire. Certification of systems and components reduce the likelihood of problems occurring but cannot completely prevent them. However, if problems do occur and are reported, they can be investigated and dealt with.

10.2 RECOMMENDATIONS

The following recommendations on dealing with or avoiding these problems are divided into the various stages of the lifecycle of the sprinkler system and aimed at the relevant stakeholders:

- At the planning and specification stage, the specifier should:
  - ensure participation by insurers and other relevant jurisdictional authorities (building control bodies, local water supply company, local authority fire service, etc) at the earliest stage
  - produce a clear and complete design specification for the tender documentation for the sprinkler contractor(s), which includes all the details needed to prepare the design proposal, including the purpose of the system, the extent of sprinkler protection including permitted exceptions and the correct sprinkler fire hazard assessment
  - confirm details of the design brief with the relevant jurisdictional authorities, eg the purpose of the system, the extent of sprinkler protection including permitted exceptions and the sprinkler fire hazard assessment
  - use suitably qualified and experienced third party certified contractors to design, install and commission the sprinkler system to appropriate standards
  - specify the use of third party certified sprinkler products to appropriate standards in sprinkler installations
  - provide information to the eventual building user as required by Regulation 16B.[5]
- For the design and installation stage:
  - new and novel sprinkler products, not yet included in standards may be suitable for use but technical evidence needs to be provided to prove these are fit for their intended purpose and should be confirmed early with the relevant jurisdictional authorities.
- For the building-in-use stage, the responsible person under the Fire Safety Order (usually the building owner) should:
  - ensure that a programme of weekly and monthly inspections and checks are carried out by a competent onsite person and employ a competent third party certified sprinkler maintenance contractor to carry out testing, servicing and maintenance of the sprinkler system to the agreed standard
  - employ a competent sprinkler maintenance contractor to ensure that, if a sprinkler system forms an integral part of the fire safety strategy, adequate management procedures are in place to cater for those time periods when any part of the sprinkler system is not functional during maintenance work, or any other reason, eg loss of supply by the water company
  - ensure that regular inspections of the sprinkler system are carried out by the sprinkler maintenance contractor and/or risk assessor to identify problems

and rectify them. For example, if there is a change to the fire hazard and its classification, the sprinkler system should be redesigned and altered accordingly. If components are faulty or damaged or old, these should be removed and replaced
  - ensure that, if the town mains is used as a water supply, maintenance includes performance tests to check the pressure and flow characteristics and the minimum available pressure continues to be adequate.
- Insurance surveyors/fire and rescue service inspectors/ certification scheme assessors may also carry out other inspections
- Providers of certification schemes should consider increased onsite inspections of the systems when they are being installed (rather than their designs) and compulsory (rather than voluntary) reporting of complaints within their certification schemes to identify and eliminate more unwanted problems
- At all stages, education of all the stakeholders involved with sprinkler systems (including occupants of the building) is necessary so there is an understanding of the consequences of their actions.

APPENDIX
UK FIRE STATISTICS DATA AND ANALYSIS

UK FIRE STATISTICS DATABASE AND FDR1 CODES

The bulk of the UK Fire Statistics are collected by the Fire Statistics and Social Research Branch, Fire and Resilience Directorate, Communities and Local Government. They are based on the FDR1(94) forms[47] filled in by the fire and rescue service after a fire has been attended. Since 1994, only a fraction of all reported fires have been transferred to the electronic database. However, all fires where injury or death occurred are in the database. Each reported fire thus has a weighting figure (>1) which is the reciprocal of the fraction of reported fires recorded (varying from fire and rescue service to fire and rescue service).

Because the statistics are only based on fire and rescue service reports, the sample is biased when it comes to considering the population of all fires and there may be a large number of small fires that are unreported. Estimates from the British Crime Survey[48] put this percentage at between 85% to 90% for domestic properties. The percentages for other types of buildings are less well known. This bias in the sample obviously requires that care be taken when interpreting the statistics. For example, looking at the statistics (alone), estimating the effectiveness of sprinklers may give a lower value than the actual value, since in many fires the sprinklers will be sufficiently effective obviating the need for the fire and rescue service to be called out. It is noted, though, that the UK residential sprinkler standard recommends that the fire and rescue service are called out to switch the system off.

PROCEDURE

The UK Fire Statistics database 1994 to 2005 was sampled to include all fires where sprinklers were present. In technical terms, this meant all fire records where one or more of the following criteria were satisfied: field SYS1 = "W", and/or field SYS2 = "W", and/or field SYS3 = "W". The interest here is for automatic sprinkler systems and therefore a further filter to the data was applied such that the field MANAUTO<n> = "A" (automatic), where <n> is 1, 2 or 3 depending on which of the SYS<n> fields is "W".

The fields of interest were as follows:

- whether the sprinklers operated or not, and their effect if they did operate (OPER<n>)
- the number of sprinkler heads operated (HEADS<n>)
- the reason for the system not operating, if applicable (REASON<n>)
- the type of property (ie building) where the fire started (TOP)
- the type of business carried on, if any, where the fire started (TOB)
- the function of the room where the fire started (USEROOM)
- the weighting given to this record as a consequence of the sampling procedure (see above). The sum of the weights is an estimate of the number of fires attended (WEIGHT).

Tables 2 to 5, 7, 9, 11, 13 and 15 illustrate the relationships between some of these parameters.[32, 33] (Please note that totals are not consistent between the tables due to rounding and coding errors.)

SIGNIFICANCE TESTING

Tables 5, 7, 9, 11, 13 and 15 were examined to see if there are any combinations of parameters that occur more or less frequently than if the distribution followed a smooth trend.

Suppose the expected value Eij for any column i and row j is defined as:

Eij = {observed total for column i} x {observed total for row j} / {observed total for all rows and columns}

For example, in Table 15 the number of fires in which the room of origin was of type 'other', and the reason for non-operation was also 'other', is 2. The row total is 547, and the column total is 126. The total number of all fires is 10 458. Hence, the expected value is given by:

$$Eij = 126 \times 547 / 10\,458 = 6.59$$

The measure of significance is defined as:

$$Sij = (Oij - Eij)^2 / Eij$$

where Oij is the observed value for column i and row j. Continuing the above example, the significance measure would be given by:

$$Sij = (2 - 6.59)^2 / 6.59 = 3.20$$

The significance measure is similar to a chi-squared test, but the interpretation is not the same because the observed values are based on weighted samples. (Hence, the uncertainty is larger than would be the case for the

chi-squared test. Nevertheless, a 'large' (positive or negative) value for Sij indicates a significant variation from the trend.

Tables 6, 8, 10, 12, 14 and 16 show values of Sij for different combinations of parameters. A positive value for Sij indicates that (Oij – Eij) is > 0, and vice-versa. A blank value for Sij indicates that Eij < 5 (ie potentially spurious large values of Sij arising from small Eij are suppressed).

As a rough guide, a value |Sij| > 30 is probably a significant difference.

Table 2: **Reasons quoted for sprinkler system not operating or if operated did not control fire**

Reason	Number of fires 1994–2005
Stated unknown	267 (4921–4024)
Other	339
System shut off to prevent excessive damage by sprinkler system	10
System out of commission, obsolete or no longer required	45
System shut off for other reasons prior to fire	157
Manual system which was not operated	2
Not enough agent discharged to control fire	62
Agent discharged; could not reach fire	54
Low mains pressure or water supply failed	7
System defective, including piping damaged, lack of maintenance, heads painted over	59
Heads or actuating system faulty	17
Small fire, extinguished promptly by other means (including firefighting)	4905
Fire contained within machinery, gutter, trunking etc	216
Fire above sprinkler heads or operational part of sprinkler system	72
Fire in area not covered by sprinkler system	177
Heat/smoke deflected away from heads/venting points	24
Heat/smoke deflected from auto-venting system actuation device	5
Fire flashed into inaccessible area	8
Rapid build-up of heat due to nature of fire load	7

Notes:

1. The reason 'unknown' also covers 4024 cases where the sprinklers did operate and either extinguished or controlled the fire.
2. The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.

Table 3: Effect of sprinkler activation (if applicable) and reasons for not extinguishing or controlling fire

Reason	Whether or not sprinklers operated			
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate
Unknown (stated)	–	–	37	230
Other	–	–	152	187
System shut off for other reasons prior to fire	–	–	–	157
Not enough water discharged to control fire	–	–	14	48
Water discharged; could not reach fire	–	–	50	4
System defective, including piping damaged and lack of maintenance	–	–	5	54
Small fire, extinguished promptly by other means (including firefighting)	–	–	26	4878
Fire contained within machinery, gutter, trunking etc	–	–	26	190
Fire above sprinkler heads or operational part of sprinkler system	–	–	29	43
Fire in area not covered by sprinkler system	–	–	25	152
Other, specified	–	–	23	103
Total	1259	2765	387	6046

Notes:

1. There may be a selection bias that affects the numbers in Table 3. If the sprinklers are successful in extinguishing or controlling the fire, it is less likely that the fire and rescue service will attend and therefore the fire will not be recorded in the fire statistics.
2. The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.

Table 4: Number of sprinkler heads operated

Number of sprinkler heads operated	Whether or not sprinklers operated			
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate
0	4	13	9	6027
1	814	1203	159	9
2	217	661	74	5
3	76	314	38	1
4	77	210	22	0
5	12	70	18	0
6	23	83	16	0
7–9	7	54	19	0
10–19	17	77	12	0
20+	12	74	16	2
Total	1259	2759	383	6044
Average number of heads actuated	2.01	3.44	3.82	0.01

Notes: It is not clear how 1, 2, 3 or 20+ heads actuated constitutes 'did not operate'. Presumably this was an error in coding/transferring the data from the paper FDR1 forms to the electronic database.

Table 5: **Effect of sprinklers in different types of property**

Type of property	Whether or not sprinklers operated				
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate	Total
Restaurant, including cafes and takeaway food shops	26	32	0	57	115
Passenger terminals (not railways), including at airports, docks	1	6	0	46	53
Hospital – other, including nursing and convalescent homes for others, drug rehabilitation centre	0	2	5	76	82
Purpose built flat, sheltered accommodation	25	54	3	6	88
Purpose built flat, other or unspecified	158	368	38	135	699
Hotel, boarding house, guest house, including all commercially run establishments providing sleeping accommodation	17	3	2	62	83
Single shop, including bank, building society, travel or estate agents	41	89	7	308	446
Supermarket	33	38	8	206	286
Department store	41	45	0	142	227
Shopping mall/centre/indoor market, covered area	82	101	9	730	921
Offices, permanent standalone structure	38	39	0	101	179
Industrial premises, including factory, mill, electricity sub-station, portable buildings and 'containers'	680	1640	277	3616	6213
Car park building or structure, including multi-storey and underground car parks	15	52	1	19	87
Warehouse	42	142	16	270	469
Others, specified	61	153	22	274	510
Total	1259	2765	388	6046	10 458

Table 6: **Significance of effect of sprinklers in different types of property**

Type of property	Whether or not sprinklers operated			
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate
Restaurant, including cafes and takeaway food shops	10	0	–	-1
Passenger terminals (not railways), including at airports, docks	-5	-5	–	8
Hospital – other, including nursing and convalescent homes for others, drug rehabilitation centre	-10	-18	–	16
Purpose built flat, sheltered accommodation	20	41	–	-40
Purpose built flat, other or unspecified	65	181	6	-180
Hotel, boarding house, guest house, including all commercially run establishments providing sleeping accommodation	4	-16	–	4
Single shop, including bank, building society, travel or estate agents	-3	-7	-6	10
Supermarket	-0	-19	-0	10
Department store	6	-4	-8	1
Shopping mall/centre/indoor market and covered area	-8	-83	-19	73
Offices and permanent standalone structure	13	-1	-7	-0
Industrial premises, including factory, mill, electricity sub-station, portable buildings and 'containers'	-6	-0	9	0
Car park building or structure, including multi-storey and underground car parks	2	38	–	-20
Warehouse	-4	3	-0	-0
Others, specified	-0	2	0	-2

Notes:

For the significance testing, whether a positive or negative score is good or bad depends on the context. Thus looking at the OPER field, if this is A or B (yes and extinguished/controlled fire), a positive result is good – better than the trend – but if the field is C or N (did not operate or control fire) then a positive result is bad.

As a rough guide, a value of which the magnitude is greater than 30 indicates an effect that is probably significant.

Table 7: **Reasons for sprinklers failing to operate or control fire in different types of property**

Type of property	Reason											
	0	9	13	21	31	61	71	72	73	74	Other reason	Total
Restaurant, including cafes and takeaway food shops	60	1	–	–	–	–	52	–	–	2	0	115
Passenger terminals (not railways), including at airports, docks	8	–	–	1	–	–	40	2	–	1	1	53
Hospital – other, including nursing and convalescent homes for others, drug rehabilitation centre	11	6	–	2	–	–	61	1	–	2	0	82
Purpose built flat, sheltered accommodation	81	1	1	–	2	–	1	–	–	–	2	88
Purpose built flat, other or unspecified	551	15	9	3	9	17	71	–	2	8	14	699
Hotel, boarding house, guest house, including all commercially run establishments providing sleeping accommodation	20	–	5	3	–	–	54	–	–	2	0	83
Single shop, including bank, building society, travel or estate agents	145	7	7	2	1	–	243	4	4	25	7	446
Supermarket	78	13	–	3	–	2	176	2	5	5	1	286
Department store	86	6	7	1	–	–	115	3	1	7	1	227
Shopping mall/ centre/indoor market, covered area	200	29	9	12	6	1	610	16	4	20	14	921
Offices, permanent standalone structure	88	7	–	–	–	5	69	7	–	1	1	179
Industrial premises, including factory, mill, electricity sub-station, portable buildings and 'containers'	2480	201	91	29	31	31	2978	171	51	88	63	6213
Car park building or structure, including multi-storey and underground car parks	67	1	1	–	–	–	16	–	–	1	1	87
Warehouse	191	18	15	4	1	2	211	6	2	3	16	469
Others, specified	226	33	12	2	4	1	208	4	3	12	5	510
Total	4291	339	157	62	54	59	4905	216	72	177	126	10 458

Notes:

1. The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.
2. Reason codes are as follows:

0	Unknown (stated)
9	Other
13	System shut off for other reasons prior to fire (eg maintenance, repairs)
21	Not enough water discharged to control fire
31	Water discharged; could not reach fire
61	System defective, including piping damaged, lack of maintenance, heads painted over
71	Small fire, extinguished promptly by other means (including insufficient heat generated by the fire)
72	Fire contained within machinery, gutter, trunking, etc
73	Fire above sprinkler heads or operational part of sprinkler system
74	Fire in area not covered by sprinkler system

For Other reason, amalgamated in this table, see Table 2.

Table 8: **Significance of reasons for sprinklers failing to operate or control fire in different types of property**

Type of property	Reason										
	0	9	13	21	31	61	71	72	73	74	Other reason
Restaurant, including cafes and takeaway food shops	3	–	–	–	–	–	-0	–	–	–	–
Passenger terminals (not railways), including at airports, docks	-9	–	–	–	–	–	10	–	–	–	–
Hospital – other, including nursing and convalescent homes for others, drug rehabilitation centre	-15	–	–	–	–	–	12	–	–	–	–
Purpose built flat, sheltered accommodation	56	–	–	–	–	–	-39	–	–	–	–
Purpose built flat, other or unspecified	243	-2	-0	–	–	–	-201	-14	–	-1	4
Hotel, boarding house, guest house, including all commercially run establishments providing sleeping accommodation	-6	–	–	–	–	–	6	–	–	–	–
Single shop, including bank, building society, travel or estate agents	-8	-4	0	–	–	–	5	-3	–	41	1
Supermarket	-13	2	–	–	–	–	13	-3	–	–	–
Department store	-1	-0	–	–	–	–	1	–	–	–	–
Shopping mall/centre/ indoor market, covered area	-84	-0	-1	8	–	-3	73	-1	-1	1	1
Offices, permanent standalone structure	3	0	–	–	–	–	-2	–	–	–	–
Industrial premises, including factory, mill, electricity sub-station, portable buildings and 'containers'	-2	-0	-0	-2	-0	-1	1	14	1	-3	-2
Car park building or structure, including multi-storey and underground car parks	28	–	–	–	–	–	-15	–	–	–	–
Warehouse	-0	1	10	–	–	–	-0	-1	–	-3	19
Others, specified	1	17	2	–	–	–	-4	-4	–	1	-0

Notes:

1. For the significance testing, whether a positive or negative score is good or bad depends on the context. Thus looking at the OPER field, if this is A or B (yes and extinguished/controlled fire), a positive result is good – better than the trend – but if the field is C or N (did not operate or control fire) then a positive result is bad. For Other reason, amalgamated in this table, see Table 2.

As a rough guide, a value of which the magnitude is greater than 30 indicates an effect that is probably significant.

2. The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.

3. Reason codes are as follows:
   - 0 Unknown (stated)
   - 9 Other
   - 13 System shut off for other reasons prior to fire (eg maintenance, repairs)
   - 21 Not enough water discharged to control fire
   - 31 Water discharged; could not reach fire
   - 61 System defective, including piping damaged, lack of maintenance, heads painted over
   - 71 Small fire, extinguished promptly by other means (including insufficient heat generated by the fire)
   - 72 Fire contained within machinery, gutter, trunking, etc
   - 73 Fire above sprinkler heads or operational part of sprinkler system
   - 74 Fire in area not covered by sprinkler system

For Other reason, amalgamated in this table, see Table 2.

Table 9: **Effect of sprinklers in different types of business**

Type of business	Whether or not sprinklers operated				
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate	Total
No business	270	614	75	524	1483
Manufacture of food products and beverages (including distillery)	39	141	20	212	411
Manufacture of textiles	78	284	39	354	755
Manufacture of wearing apparel; dressing and dyeing of fur	5	20	2	104	131
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	9	17	2	32	61
Manufacture of wood and of products of wood and cork (including sawmill) except furniture, (for furniture see 'Manufacturing not elsewhere classified', manufacture of articles of straw and plaiting materials	30	144	21	79	275
Manufacture of pulp, paper and paper products	136	318	44	1156	1654
Publishing, printing and reproduction of recorded media	8	61	10	95	174
Manufacture of chemicals and chemical products (including Tarmac)	34	39	7	156	237
Manufacture of rubber and plastic products	57	144	34	313	550
Manufacture of basic metals (including casting)	22	36	2	68	128
Manufacture of fabricated metal products, except machinery and equipment (including electroplating)	11	26	4	40	81
Manufacture of machinery and equipment not elsewhere classified	17	13	6	42	78
Manufacture of electrical machinery and apparatus not elsewhere classified (including batteries)	12	14	4	53	84
Manufacture of motor vehicles, trailers and semi-trailers	20	23	5	150	199
Manufacture of other transport equipment	3	18	1	71	93
Manufacturing not elsewhere classified, not specified (including manufacturing of furniture)	97	166	13	321	598
Recycling (including scrap dealing)	7	54	20	38	120
Wholesale trade and commission trade (including importers), except of motor vehicles and motorcycles	14	52	0	61	126
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (including opticians)	177	262	17	1222	1678
Hotels, motels, YMCA, YWCA, public houses, restaurants (including 'take-away'), night clubs, holiday centres, camping and caravan sites	53	70	13	240	376
Supporting and auxiliary transport activities; activities of travel agencies, airport terminals, commercial parking of vehicles (including storage/ warehousing)	45	82	6	169	302
Financial intermediation (banks, building societies, etc) except insurance and pension funding	9	6	0	37	53
Other business activities (including auditors, auctioneers, solicitors, employment agencies, security, industrial/commercial cleaning, exhibitions)	8	26	6	31	72
Public administration, penal system establishments (but see Health and social work, for health services); compulsory social security	12	10	0	32	54
Health and social work (all hospitals – including prison, facilities, dental, veterinary, creche activities)	2	2	5	91	100
Recreational, cultural and sporting activities (including betting shop, library, TV production)	8	30	3	56	98
Other	72	95	27	295	490
Total	1255	2765	388	6041	10 458

Table 10: **Significance of effect of sprinklers in different types of business**

Type of business	Whether or not sprinklers operated			
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate
No business	48	126	7	-129
Manufacture of food products and beverages (including distillery)	-2	9	1	-3
Manufacture of textiles	-2	35	5	-15
Manufacture of wearing apparel; dressing and dyeing of fur	-7	-6	–	11
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	0	0	–	-0
Manufacture of wood and of products of wood and cork (including sawmill) except furniture, (for furniture see 'Manufacturing not elsewhere classified', manufacture of articles of straw and plaiting materials	-0	70	12	-40
Manufacture of pulp, paper and paper products	-19	-33	-5	42
Publishing, printing and reproduction of recorded media	-8	5	2	-0
Manufacture of chemicals and chemical products (including Tarmac)	1	-9	-0	3
Manufacture of rubber and plastic products	-1	-0	9	-0
Manufacture of basic metals (including casting)	3	0	–	-0
Manufacture of fabricated metal products, except machinery and equipment (including electroplating)	0	1	–	-1
Manufacture of machinery and equipment not elsewhere classified	6	-3	–	-0
Manufacture of electrical machinery and apparatus not elsewhere classified (including batteries)	1	-3	–	1
Manufacture of motor vehicles, trailers and semi-trailers	-1	-16	-1	11
Manufacture of other transport equipment	-6	-2	–	6
Manufacturing not elsewhere classified, not specified (including manufacturing of furniture)	9	0	-4	-2
Recycling (including scrap dealing)	-4	17	–	-14
Wholesale trade and commission trade (including importers), except of motor vehicles and motorcycles	-0	10	–	-2
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (including opticians)	-3	-74	-33	66
Hotels, motels, YMCA, YWCA, public houses, restaurants (including 'take-away'), night clubs, holiday centres, camping and caravan sites	2	-9	-0	2
Supporting and auxiliary transport activities; activities of travel agencies, airport terminals, commercial parking of vehicles (including storage/ warehousing)	2	0	-2	-0
Financial intermediation (banks, building societies, etc) except insurance and pension funding	1	-4	–	2
Other business activities (including auditors, auctioneers,solicitors, employment agencies, security, industrial/commercial cleaning, exhibitions)	-0	2	–	-2
Public administration, penal system establishments (but see Health and social work, for Health services); compulsory social security	5	-2	–	0
Health and social work (all hospitals – including prison, facilities, dental, veterinary, creche activities)	-8	-23	–	19
Recreational, cultural and sporting activities (including betting shop, library, TV production)	-1	1	–	-0
Other	3	-9	5	0

Notes:

For the significance testing, whether a positive or negative score is good or bad depends on the context. Thus looking at the OPER field, if this is A or B (yes and extinguished/controlled fire), a positive result is good – better than the trend – but if the field is C or N (did not operate or control fire) then a positive result is bad.

As a rough guide, a value of which the magnitude is greater than 30 indicates an effect that is probably significant.

Table 11: **Reasons for sprinklers failing to operate or control fire in different types of business**

Type of business	Reason											
	0	9	13	21	31	61	71	72	73	74	Other reason	Total
No business	945	50	49	9	15	19	273	41	12	29	41	1483
Manufacture of food products and beverages (including distillery)	185	24	6	1	–	5	152	26	–	10	3	411
Manufacture of textiles	393	34	9	2	2	–	283	17	10	1	3	755
Manufacture of wearing apparel; dressing and dyeing of fur	25	4	15	–	–	–	79	–	–	8	0	131
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	27	1	1	–	–	–	29	2	–	–	0	61
Manufacture of wood and of products of wood and cork (including sawmill) except furniture, (for furniture see 'Manufacturing not elsewhere classified', manufacture of articles of straw and plaiting materials	186	6	4	1	2	5	50	12	6	2	1	275
Manufacture of pulp, paper and paper products	471	35	13	14	11	–	1049	41	2	6	13	1654
Publishing, printing and reproduction of recorded media	70	6	–	–	1	–	78	7	–	10	2	174
Manufacture of chemicals and chemical products (including Tarmac)	75	6	1	–	1	–	147	2	–	4	0	237
Manufacture of rubber and plastic products	215	14	–	4	1	11	276	10	–	13	6	550
Manufacture of basic metals (including casting)	64	5	–	–	–	–	55	–	1	2	0	128
Manufacture of fabricated metal products, except machinery and equipment (including electroplating)	40	1	1	2	–	1	27	–	6	1	2	81
Manufacture of machinery and equipment not elsewhere classified	30	7	–	1	–	–	26	10	–	4	1	78
Manufacture of electrical machinery and apparatus not elsewhere classified (including batteries)	37	2	–	–	–	–	37	6	2	–	0	84
Manufacture of motor vehicles, trailers and semi-trailers	74	12	–	–	–	2	102	7	–	1	1	199
Manufacture of other transport equipment	21	–	–	–	–	–	68	1	–	2	1	93
Manufacturing not elsewhere classified, not specified (including manufacturing of furniture)	282	13	8	–	–	6	271	1	7	4	5	598
Recycling (including scrap dealing)	61	20	2	2	1	–	31	–	–	2	0	120
Wholesale trade and commission trade (including importers), except of motor vehicles and motorcycles	66	1	–	–	1	–	57	–	–	–	1	126
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (including opticians)	477	47	26	16	3	2	999	19	14	60	16	1678
Hotels, motels, YMCA, YWCA, public houses, restaurants (including 'take-away'), night clubs, holiday centres, camping and caravan sites	124	8	5	3	5	–	220	1	–	4	7	376
Supporting and auxiliary transport activities; activities of travel agencies, airport terminals, commercial parking of vehicles (including storage/warehousing)	129	3	12	–	–	–	135	2	1	3	16	302
Financial intermediation (banks, building societies, etc) except insurance and pension funding	16	4	–	–	–	–	32	–	–	–	0	53
Other business activities (including auditors, auctioneers, solicitors, employment agencies, security, industrial/commercial cleaning, exhibitions)	34	1	2	3	4		24	1	1	1	0	72

Table 11 (contd)

Type of business	Reason											
	0	9	13	21	31	61	71	72	73	74	Other reason	Total
Public administration, penal system establishments (but see Health and social work, for health services); compulsory social security	21	2	–	1	–	1	26	–	–	2	0	54
Health and social work (all hospitals – including prison, facilities, dental, veterinary, creche activities)	12	7	–	1	–	–	79	1	–	–	0	100
Recreational, cultural and sporting activities (including betting shop, library, TV production)	41	1	–	–	2	1	52	1	–	–	0	98
Other	170	24	4	2	6	6	244	8	9	10	7	490
Total	4291	339	157	62	54	59	4905	216	72	177	126	10 458

Note: The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.
For reason codes, refer to Table 7. For Other reason, amalgamated in this table, see Table 2.

Table 12: **Significance of reasons for sprinklers failing to operate or control fire in different types of business**

Type of business	Reason										
	0	9	13	21	31	61	71	72	73	74	Other reason
No business	186	0	32	0	7	14	-256	4	0	1	30
Manufacture of food products and beverages (including distillery)	2	9	-0	–	–	–	-9	36	–	1	–
Manufacture of textiles	23	4	-1	–	–	–	-14	0	4	-11	-4
Manufacture of wearing apparel; dressing and dyeing of fur	-15	–	–	–	–	–	5	–	–	–	–
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	0	–	–	–	–	–	0	–	–	–	–
Manufacture of wood and of products of wood and cork (including sawmill) except furniture, (for furniture see 'Manufacturing not elsewhere classified', manufacture of articles of straw and plating materials	47	-1	–	–	–	–	-48	7	–	–	–
Manufacture of pulp, paper and paper products	-64	-6	-5	2	1	-9	96	1	-8	-18	-2
Publishing, printing and reproduction of recorded media	-0	0	–	–	–	–	-0	–	–	–	–
Manufacture of chemicals and chemical products (including Tarmac)	-5	-0	–	–	–	–	12	–	–	–	–
Manufacture of rubber and plastic products	-0	-1	-8	–	–	–	1	-0	–	1	-0
Manufacture of basic metals (including casting)	3	–	–	–	–	–	-0	–	–	–	–
Manufacture of fabricated metal products, except machinery and equipment (including electroplating)	1	–	–	–	–	–	-3	–	–	–	–
Manufacture of machinery and equipment not elsewhere classified	-0	–	–	–	–	–	-3	–	–	–	–
Manufacture of electrical machinery and apparatus not elsewhere classified (including batteries)	0	–	–	–	–	–	-0	–	–	–	–
Manufacture of motor vehicles, trailers and semi-trailers	-1	4	–	–	–	–	1	–	–	–	–
Manufacture of other transport equipment	-8	–	–	–	–	–	14	–	–	–	–
Manufacturing not elsewhere classified, not specified (including manufacturing of furniture)	5	-2	-0	–	–	–	-0	-10	–	-4	-1
Recycling (including scrap dealing)	3	–	–	–	–	–	-11	–	–	–	–
Wholesale trade and commission trade (including importers), except of motor vehicles and motorcycles	4	–	–	–	–	–	-0	–	–	–	–
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (including opticians)	-65	-1	0	4	-4	-6	57	-7	1	35	-1
Hotels, motels, YMCA, YWCA, public houses, restaurants (including 'take-away'), night clubs, holiday centres, camping and caravan sites	-6	-2	-0	–	–	–	11	-6	–	-1	–
Supporting and auxiliary transport activities; activities of travel agencies, airport terminals, commercial parking of vehicles (including storage/warehousing)	0	-5	–	–	–	–	-0	-3	–	-1	–
Financial intermediation (banks, building societies, etc) except insurance and pension funding	-1	–	–	–	–	–	2	–	–	–	–

Table 12 (contd)

Type of business	Reason										
	0	9	13	21	31	61	71	72	73	74	Other reason
Other business activities (including auditors, auctioneers, solicitors, employment agencies, security, industrial/commercial cleaning, exhibitions)	1	–	–	–	–	–	-2	–	–	–	–
Public administration, penal system establishments (but see Health and social work, for Health services); compulsory social security	-0	–	–	–	–	–	0	–	–	–	–
Health and social work (all hospitals – including prison, etc facilities, dental, veterinary, creche activities)	-20	–	–	–	–	–	22	–	–	–	–
Recreational, cultural and sporting activities (including betting shop, library, TV production)	0	–	–	–	–	–	1	–	–	–	–
Other	-5	4	-2	–	–	–	1	-0	–	0	0

Notes:

1. For the significance testing, whether a positive or negative score is good or bad depends on the context. Thus looking at the OPER field, if this is A or B (yes and extinguished/controlled fire), a positive result is good – better than the trend – but if the field is C or N (did not operate or control fire) then a positive result is bad.

   As a rough guide, a value of which the magnitude is greater than 30 indicates an effect that is probably significant.

2. For reason codes, refer to Table 7. For Other reason, amalgamated in this table, see Table 2.

Table 13: **Effect of sprinklers in different types of room of fire origin**

Type of room of fire origin	Whether or not sprinklers operated				
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate	Total
Not known	41	160	37	294	533
Corridor, hall	10	19	3	91	123
Other access areas including atrium, reception room, covered walkway in precinct	12	33	4	46	94
Common/staff/day/rest/recreation room	10	4	0	64	78
Shop floor, showroom, display hall (area used for trading) including ticket office/booking hall	55	80	2	441	578
Canteen, restaurant, mess	6	13	0	64	82
Kitchen including kitchen/diner	39	48	7	311	404
Cloakroom including lavatory, bathroom, locker room, sluice room	67	6	1	132	205
Office	35	41	9	132	217
Print room including photographic use, dark room, photocopying	1	44	0	50	94
Drying and heat treatment room including blacksmith, bakery, grain drying	38	113	24	276	451
Paint spraying room including varnish/lacquer spraying	27	37	12	54	129
Preparation room	11	29	11	78	128
Other factory/production rooms including workshop, turbine hall in power station	365	962	131	2521	3979
Other, including ballast room on ship, post office sorting room, telephone intake room, crematorium furnace room, security kiosk, car wash	10	5	1	43	59
Store room including stockroom, warehouse, pantry, larder	138	309	52	509	1007
Loading bay, packing department	15	89	6	85	196
Refuse including incinerator room, ash pit, refuse room, refuse chute, wheelie bin in under-cover storage area	202	429	38	153	823
Car park (under cover/enclosed)	17	83	1	50	151
Dust extractor	15	32	9	25	81
Power house, plant/generator/turbine/meter room	28	25	7	110	170
Boiler room including compressor/engine/pump/tank room	19	52	6	63	139
Roof space not used for storage	1	15	0	45	61
Other room or compartment not listed elsewhere, including bus shelter, beach hut, unoccupied/unused room, unspecified outhouse (not attached)	27	32	14	54	128
Other rooms	72	106	12	356	547
Not known	1255	2765	388	6041	10 458

Table 14: **Significance of effect of sprinklers in different types of room of fire origin**

Type of room of fire origin	Whether or not sprinklers operated			
	Yes, and put out fire	Yes, and controlled fire	Yes, but did not control fire	Did not operate
Not known	-8	3	16	-1
Corridor, hall	-2	-5	0	5
Other access areas including atrium, reception room, covered walkway in precinct	0	2	0	-1
Common/staff/day/rest/recreation room	0	-14	0	8
Shop floor, showroom, display hall (area used for trading) including ticket office/booking hall	-3	-35	-18	35
Canteen, restaurant, mess	-2	-3	0	5
Kitchen including kitchen/diner	-2	-33	-4	26
Cloakroom including lavatory, bathroom, locker room, sluice room	71	-43	-6	1
Office	3	-4	0	0
Print room including photographic use, dark room, photocopying	-9	14	–	-0
Drying and heat treatment room including blacksmith, bakery, grain drying	-5	-0	3	1
Paint spraying room including varnish/lacquer spraying	8	0	0	-6
Preparation room	-1	-1	0	0
Other factory/production rooms including workshop, turbine hall in power station	-27	-8	-2	21
Other, including ballast room on ship, post office sorting room, telephone intake room, crematorium furnace room, security kiosk, car wash	1	-7	0	2
Store room including stockroom, warehouse, pantry, larder	2	7	6	-9
Loading bay, packing department	-3	27	-0	-7
Refuse including incinerator room, ash pit, refuse room, refuse chute, wheelie bin in under-cover storage area	108	207	2	-219
Car park (under cover/enclosed)	-0	47	-4	-16
Dust extractor	3	5	0	-10
Power house/plant/generator/turbine/meter room	3	-9	0	1
Boiler room including compressor/engine/pump/tank room	0	6	0	-4
Roof space not used for storage	-5	-0	0	3
Other room or compartment not listed elsewhere, including bus shelter, beach hut, unoccupied/unused room, unspecified outhouse (not attached)	9	-0	0	-5
Other rooms	1	-10	-3	5

Notes:

For the significance testing, whether a positive or negative score is good or bad depends on the context. Thus looking at the OPER field, if this is A or B (yes and extinguished/controlled fire), a positive result is good – better than the trend – but if the field is C or N (did not operate or control fire) then a positive result is bad.

As a rough guide, a value of which the magnitude is greater than 30 indicates an effect that is probably significant.

Table 15: **Reasons for sprinklers failing to operate or control fire in different types of room of fire origin**

Type of room of fire origin	Reason											
	0	9	13	21	31	61	71	72	73	74	Other	Total
Not known	219	23	9	3	2	–	192	14	15	49	6	533
Corridor, hall	29	3	11	2	–	–	68	–	1	8	1	123
Other access areas including atrium, reception room, covered walkway in precinct	44	2	–	7	–	–	41	–	–	–	0	94
Common/staff/day/rest/recreation room	26	–	–	–	–	–	52	–	–	–	1	78
Shop floor, showroom, display hall (area used for trading) including ticket office/booking hall	147	14	2	2	2	–	391	4	4	4	7	578
Canteen, restaurant, mess	21	2	–	–	–	–	49	1	1	8	1	82
Kitchen including kitchen/diner	93	9	–	4	–	–	287	4	–	–	7	404
Cloakroom including lavatory, bathroom, locker room, sluice room	73	–	–	3	–	–	117	5	–	7	0	205
Office	78	8	10	–	–	6	102	–	7	3	3	217
Print room including photographic use, dark room, photocopying	46	1	–	–	–	–	44	3	–	–	1	94
Drying and heat treatment room including blacksmith, bakery, grain drying	178	14		1	3	1	208	26	10	5	5	451
Paint spraying room including varnish/lacquer spraying	63	7	2	–	–	1	42	1	4	4	4	129
Preparation room	41	8	–	2	6	–	58	6	1	6	1	128
Other factory/production rooms including workshop, turbine hall in power station	1440	111	46	20	17	27	2147	111	20	21	20	3979
Other, including ballast room on ship, post office sorting room, telephone intake room, crematorium furnace room, security kiosk, car wash	16	2	–	2	–	–	39	–	–	–	0	59
Store room including stockroom, warehouse, pantry, larder	455	45	34	5	5	3	409	4	2	13	31	1007
Loading bay, packing department	109	9	5	3	2	1	57	5	–	3	2	196
Refuse including incinerator room, ash pit, refuse room, refuse chute, wheelie bin in under-cover storage area	658	13	15	3	11	15	75	–	3	12	17	823
Car park (under cover/enclosed)	105	1	1	–	–	1	42	–	–	1	0	151
Dust extractor	47	4	1	–	–	–	19	5	–	5	0	81
Power house, plant/generator/turbine/meter room	55	11	–	–	–	1	90	7	–	2	4	170
Boiler room including compressor/engine/pump/tank room	71	2	2	1	5	1	51	3	–	1	2	139
Roof space not used for storage	16	1	–	1	–	–	41	–	2	–	0	61
Other room or compartment not listed elsewhere, including bus shelter, beach hut, unoccupied/unused room, unspecified outhouse (not attached)	62	13	8	–	2	–	25	1	–	6	10	128
Other room	199	36	11	3	0	2	258	16	1	18	2	547
Total	4291	339	157	62	54	59	4905	216	72	177	126	10 458

Notes:
1. For reason codes, refer to Table 7.
2. The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.

Table 16: **Significance of reasons for sprinklers failing to operate or control fire in different types of room of fire origin**

Type of room of fire origin	Reason										
	0	9	13	21	31	61	71	72	73	74	Other reason
Not known	0	2	0	–	–	–	-13	1	–	180	-0
Corridor, hall	-9	–	–	–	–	–	2	–	–	–	–
Other access areas including atrium, reception room, covered walkway in precinct	1	–	–	–	–	–	-0	–	–	–	–
Common/staff/day/rest/recreation room	-1	–	–	–	–	–	6	–	–	–	–
Shop floor, showroom, display hall (area used for trading) including ticket office/booking hall	-34	-1	-5	–	–	–	53	-5	–	-3	0
Canteen, restaurant, mess	-5	–	–	–	–	–	3	–	–	–	–
Kitchen including kitchen/diner	-32	-1	-6	–	–	–	50	-2	–	-7	–
Cloakroom including lavatory, bathroom, locker room, sluice room	-2	-7	–	–	–	–	5	–	–	–	–
Office	-1	0	–	–	–	–	0	–	–	–	–
Print room including photographic use, dark room, photocopying	1	–	–	–	–	–	-0	–	–	–	–
Drying and heat treatment room including blacksmith, bakery, grain drying	-0	-0	-7	–	–	–	-0	29	–	-1	-0
Paint spraying room including varnish/lacquer spraying	2	–	–	–	–	–	-6	–	–	–	–
Preparation room	-3	–	–	–	–	–	-0	–	–	–	–
Other factory/production rooms including workshop, turbine hall in power station	-23	-3	-3	-1	-1	1	42	10	-2	-32	-16
Other, including ballast room on ship, post office sorting room, telephone intake room, crematorium furnace room, security kiosk, car wash	-3	–	–	–	–	–	5	–	–	–	–
Store room including stockroom, warehouse, pantry, larder	4	5	24	-0	-0	-1	-8	-14	-4	-1	29
Loading bay, packing department	10	2	–	–	–	–	-13	–	–	–	–
Refuse including incinerator room, ash pit, refuse room, refuse chute, wheelie bin in under-cover storage area	305	-7	1	–	–	–	-251	-17	-1	-0	5
Car park (under cover/enclosed)	30	–	–	–	–	–	-12	–	–	–	–
Dust extractor	5	–	–	–	–	–	-10	–	–	–	–
Power house/plant/generator/turbine/meter room	-3	6	–	–	–	–	1	–	–	–	–
Boiler room including compressor/engine/pump/tank room	4	–	–	–	–	–	-3	–	–	–	–
Roof space not used for storage	-4	–	–	–	–	–	6	–	–	–	–
Other room or compartment not listed elsewhere, including bus shelter, beach hut, unoccupied/unused room, unspecified outhouse (not attached)	2	–	–	–	–	–	-20	–	–	–	–
Other room	-3	19	1	–	–	–	0	2	–	8	-3

Notes: For reason codes, refer to Table 7. For Other reason, amalgamated in this table, see Table 2. The shaded reasons are not sprinkler failures, since they are outside the design specification for the system.

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