

Arup**Fire**

British Automatic
Sprinkler Association

BASA

Use and Benefits of
Incorporating Sprinklers
in Buildings and
Structures

DRAFT 2

Draft

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Appendix A

Sprinkler trade-offs in current fire safety guidance

1 Executive Summary

The primary purpose of this document is to aid an informed decision making process as to the benefits of incorporating sprinklers within a particular design. Key stakeholders that will benefit from a greater understanding include property developers, approval authorities, architects, designers and end users of buildings.

Sprinklers systems are often encountered in modern day building design. They are provided to protect life and/or property against fire, and have been shown to do this effectively. A report published in 2005 by the NFPA based on the most recent data concluded:

- When sprinklers are present, the chances of dying in a fire are reduced by one-half to three-quarters, and;
- The average property loss per fire is cut by one-half to two-thirds, compared to fires where sprinklers are not present.

In designing buildings, sprinklers should not be considered in isolation - instead they should be considered as part of a complete package of fire safety measures that complement each other.

This document therefore describes the role sprinklers have in building fire safety and the design trade-offs that can be realised if they are incorporated in a design.

Key areas covered in this document include the following:

- A review of current UK fire safety guidance documents, highlighting the accepted design trade-offs that are permitted when an automatic sprinkler system is installed in a building. This includes a review of future code developments and their potential implications.
- A discussion of trade-offs and alternative solutions that may be achieved in a sprinklered building by the use of a fire engineering approach.
- Advice relating to the effect of sprinklers on design fire sizes which can be used in performance based design using fire engineering principles.
- The development and use of residential sprinkler systems and the associated design trade-offs.
- A discussion of cost versus benefit of installing an automatic sprinkler system in a building.

2 Introduction

2.1 Fire safety objectives

In order to formulate a rational approach to fire safety the first step is to identify the fire safety objectives that are to be met. Only then can the required fire protection measures be selected to achieve a safe, robust and economic design.

There can be a variety of fire safety objectives for different buildings. The most commonly identified objectives are:

- a. Life safety
- b. Prevention of fire spread (from building to building)
- c. Asset protection and business continuity

Within the UK life safety and prevention of fire spread are addressed by the Building Regulations. Asset protection and business continuity is not specifically addressed by the Building Regulations but often forms a fire safety objective of business owners and their insurers.

2.2 Fire safety measures

The package of fire safety measures applied to a building should aim to meet the relevant fire safety objectives. The economy and robustness of such measures should also be considered.

Fire safety measures take a number of forms and they should be tailored for each individual design, taking into account the characteristics of the building and its occupants. One particular solution or set of fire safety measures may be appropriate for one building but wholly inappropriate in another. There may also be a number of different options for providing a safe and functional design for a particular design. The challenge to designers and fire safety engineers is to select the package of fire safety measures that meet the requirements of all stakeholders.

Table 1 below summarises the main types of fire safety measure and their interactions:

Fire safety measure	Primary contribution	Secondary contribution
Means of escape (e.g. escape staircases, fire exits, signage and lighting, fire alarms etc.)	Life safety	-
Preventing rapid fire growth (e.g. fire retardant wall and ceiling linings)	Life safety	Asset protection & business continuity
Fire containment (e.g. fire resisting walls and doors, fire compartmentation)	Asset protection & business continuity	Life safety
Preventing external fire spread (e.g. space separation, restrictions on roof coverings etc.)	Life safety	Asset protection & business continuity
Control and extinguishment (e.g. sprinklers, hand held fire extinguishers, access and facilities for the fire service)	Asset protection & business continuity	Life safety

Table 1: Interaction of fire safety measures

It is important that the interactions identified in Table 1 are understood so that trade-offs can be realised. This document focuses in detail on the interactions and trade-offs associated with the provision of automatic sprinkler systems in buildings.

2.3 Sprinkler Systems: Background Information

The sprinkler as a device to detect and control a fire is generally well-known although there are some popular misconceptions as to their operation, particularly with respect to the number of heads that operate. The assumption is made in this report that readers are familiar with the general principles of operation.

Sprinklers have been incorporated in buildings for some considerable time and were originally seen and developed as a means of reducing fire losses to property and contents. Over recent years there has been a growing recognition of their use as a means to contributing to life safety which is recognized in current UK guidance to the Building Regulations.

The recognition of their contribution to life safety can be largely attributed to their good record in detecting, suppressing and controlling a fire to a much smaller size than would otherwise be the case without sprinklers. This advantage is first seen in increasing life safety outside-the room or compartment of origin. Now, with fast response sprinklers, there is evidence that even in the room or compartment of origin, persons are better protected with a sprinkler system.

Most proponents of sprinklers recognise their limitations. There are however, clear advantages in their use, many of which should either reduce the overall building cost or which may allow the approval of a particular design which would otherwise be considered 'unsafe'. These aspects are addressed in the examples given in this Report.

Sprinklers enjoy recognition far beyond the UK and in many jurisdictions sprinklers are required to be installed in large commercial and industrial properties; this Report however concentrates on their recommended use in the UK.

2.4 Evidence of Sprinkler Performance & Reliability

A number of comparisons of fire damage with and without sprinklers have been made as a result of accidental ignition and malicious fire-setting. In general the extent of fire damage has been markedly reduced in sprinklered premises often to the extent that business can be continued the following day whereas the unprotected premises have been out of action for considerable periods or even permanently.

In Australian fire tests on a redundant sprinklered office building, it was found necessary to turn off the sprinkler system in order to allow the fire to develop in order to conduct the experiment. Even with the resulting increased fire development, the system extinguished the fire when it was turned on.

Similarly fire tests carried out by Greater Manchester Fire Brigade, which were recorded on video, demonstrated the dramatic effect of sprinklers in detecting and quenching fires.

The fire in the First Interstate Bank, Philadelphia USA, spread internally and externally from floor to floor until it reached a sprinklered floor. At that point, the operation of the concealed sprinklers stopped further fire spread. The advantage to fire fighters of having sprinklers in tall buildings was well, demonstrated by this incident.

Real fire data collected by the National Fire Protection Association (NFPA) for 1999 showed that across all types of premises protected with a wet pipe sprinkler system:

- 62.3% of reported fires were controlled by a single sprinkler head.
- 96.3% of reported fires were controlled by 10 or fewer sprinkler heads.

A report published in 2005 by the NFPA based on the most recent data concluded:

- When sprinklers are present, the chances of dying in a fire are reduced by one-half to three-fourths, and;
- The average property loss per fire is cut by one-half to two-thirds, compared to fires where sprinklers are not present.

These figures are considered to understate the potential value of sprinklers as they exclude unreported fires but do include all types of sprinkler system regardless of age or operational status.

As even more emphasis is placed on proper operation of sprinkler systems, the need for increased reliability and availability is being met by established independent third party certification of components, systems and companies. The merit of such schemes is referenced within current UK fire safety guidance such as Approved Document B, BS5306, BSEN 12485 and The Loss Prevention Councils Technical Bulletin's also directly address the issue of availability and reliability.

There are occasions where sprinklers fail to control a fire. The most recent data from the NFPA for USA fires concluded that sprinklers failed to operate in only 7% of building fires. However nearly all of these failures were due to human influences (2/3rds of the cases where sprinklers failed were because the system had been shut off before the fire began). Due to this sprinklers cannot claim to be 100% effective and so it is occasionally suggested that they should not be used in trade-offs with other fire protection measures. This argument is flawed in that it assumes other fire protection measures are 100% effective which is clearly not the case. For example, fire doors may fail to prevent fire spread either due to doors being left open or because they are poorly fitting. In the design of buildings a balance should be found between passive and active fire safety measures that address the needs of the building in the most rational and economical way.

A comparison of the reliability of sprinklers compared to passive fire protection can be found in PD 7974 – Part 7 *Application of fire engineering principles to the design of buildings*. The document gives probability figures for successful sprinkler activation between 0.75 and 0.95 (the latest U.S. data suggests a probability of 0.93). These figures compare favourably with passive fire system figures which include the following:

- Probability of fire doors being blocked open = 0.3
- Probability of self-closing doors failing to close correctly on demand = 0.2
- Probability that fire resisting structures will achieve at least 75% of the designated fire resistance standard = 0.25 for suspended ceilings and 0.65 for partition walls.

2.5 Summary of UK Sprinkler Design Standards

To make sure a sprinkler system will work it must be properly designed and fitted.

There are currently three recognised standards for the installation of sprinkler systems in the UK which are:

- BS 5306-2: 1990: fire extinguishing installations and equipment on premises. Specification for sprinkler systems.
- BS EN 12845: Fire fighting systems – Automatic sprinkler systems – design installation and maintenance (there is both a 2003 and 2004 version – both incorporate the same design specifications).
- BS 9251: 2005: Sprinkler systems for residential and domestic occupancies: Code of practice.

The BS 5306 and BS EN 12845 are generally used for industrial and commercial buildings.

The Loss Prevention Council Board (LPCB) also publishes a set of rules for the design of sprinkler systems which take the form of Technical Bulletins. These complement the BS 5306 and BS EN

12845 standards, and most industrial and commercial installations follow the relevant Technical Bulletins in order to meet insurer's requirements.

When industrial and commercial sprinkler systems are used to satisfy life safety requirements of the Building Regulations, it is usually necessary to provide the additional life safety features specified by BS 5306 or BS EN 12845. Typical additional requirements include increased zoning, quick response sprinkler heads and a higher standard of water supply.

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3 Sprinklers & Prescriptive Building Codes

3.1 Introduction

Sprinkler systems are widely referenced in the guidance to the Building Regulations, however there are only a few circumstances where they are generally *required*. These circumstances are:

- a. To facilitate fire service activities in buildings where external rescue is difficult to achieve (e.g. tall buildings that exceed the reach of fire appliances rescue apparatus).
- b. To reduce the fire hazard in buildings where the occupancy characteristics are such that the risk to life from fire is considered excessive.

In most situations sprinklers are considered as an option, with an associated trade-off.

The word 'trade-off' is used to describe a concession that is made in recognition of the benefits that sprinklers provide in relation to life safety. 'Trade-off' implies that the sprinklered and non-sprinklered options are 'equivalent'. However, in many cases the sprinklered option can be considered to provide a higher level of life safety and property protection than a non-sprinklered option. Only by adopting a fire engineered approach can the full benefits of sprinklers in a design be fully realised.

3.2 Review of current prescriptive codes and guidance

The legislation and resulting guidance in the UK, emanates from the Building Regulations, 2000 for England and Wales, the Building Regulations (NI) 2000 for Northern Ireland, and the Building (Scotland) Regulations 2004 for Scotland.

Guidance on meeting the regulations is provided by Approved Document B for England and Wales, Technical Booklet E for Northern Ireland and the Technical Handbooks (domestic and non-domestic) for Scotland. The Republic of Ireland has its own version of the Approved Document 'B' with the same references to sprinklers.

The objective of the Building Regulation guidance is to protect life. The fire protection measures provided for life safety can often be of benefit in terms of asset protection and business continuity, although this is not specifically addressed in the guidance. Thus, insurance requirements for fire protection can sometimes exceed the recommendations of Building Regulation guidance.

British Standards for sprinklers are referenced throughout most UK fire safety guidance documents including Health Technical Memorandums FIRECODE (Healthcare) and Building Bulletins (schools).

Table 2 below provides a review of the current guidance documents in order to highlight where references to sprinklers are made, and where sprinklers allow for aspects of the design or construction to be modified.

It should be noted that Table 2 only considers design recommendations and trade-offs that are written into the current guidance. Other trade-offs and alternative solutions are achievable with the use of sprinklers, based on adopting a Fire Engineering approach to building design. These additional trade-offs are considered in Section 4 of this report.

3.3 Future code developments

3.3.1 Approved Document B Consultation Document

In July 2005 the ODPM issued a document for consultation concerning proposed amendments of Part B: Fire Safety of the Building Regulations 2000 and the supporting fire safety guidance of Approved Document B.

The proposed changes are intended to clarify existing guidance, permit increased design flexibility in certain areas and update the ADB guidance to reflect recent research and experience.

One of the main areas of development since the guidance was last revised has been UK research into residential sprinklers and the introduction of a residential sprinkler design standards (BS 9251). Residential sprinklers are considered in greater detail in Section 6.

A review of the proposed amendments to ADB has highlighted the following areas where sprinklers (residential or otherwise) have an impact:

Tall apartment buildings:

The ODPM is minded to recommend the provision of sprinklers to apartment buildings greater than 30m in height.

Internal planning of dwellings & apartments:

Provision of a residential sprinkler system may be offered as an alternative to providing secondary escape from the upper levels of apartments or dwellings with a floor >4.5m above ground level.

Residential care homes:

The ODPM is considering recommending sprinklers for residential care homes that use progressive horizontal evacuation.

Compartmentation:

In the current ADB there is no limit in compartment area/volume for single storey storage uses (e.g. warehouses) regardless of whether sprinklers are provided. The ODPM is considering repealing local acts that may limit compartment size and introducing a new limit of 440,000m³ for single storey non-sprinklered premises. The benefit of sprinklers would continue to be recognised by allowing unlimited compartment areas in sprinklered single-storey premises.

The ODPM is also considering extending the compartmentation limits for multi-storey industrial buildings to include single storey buildings. In this case larger compartment areas would be permitted for sprinklered premises.

It is proposed that guidance for school premises is to be removed from ADB and will take the form of Building Bulletin 100 (see 3.3.2 below), which will recognise the benefits of sprinklers in recommending maximum compartment limits.

External fire spread:

It is proposed that fire spread between buildings on the same site be considered for all building types (previously only residential/assembly were considered). This may mean increased reliance on the use of sprinklers to prevent fire spread between buildings, particularly of the storage uses.

Firefighting provisions:

Although both the existing and proposed ADB differentiate between sprinklered and non-sprinklered premises, the method of determining firefighting shaft provisions may change from an area requirement to coverage based on length of hose (all parts of building within 60m hose coverage for sprinklered buildings and 45m for non-sprinklered buildings).

The proposed ADB permits sprinkler systems to be designed to either BS 5306 Part 2: 1990 or BSEN 12485:2004.

3.3.2 Building Bulletin 100 (BB100) Consultation Document: Designing & Managing against the risk of fires in schools

Over recent years there have been many large fire losses in schools, to the extent that sprinklers are often considered as a means to protect new school buildings against both accidental fires and arson.

BB100, provided by the Department for Education and Skills, is intended to form the main source of Fire Safety design guidance for new school buildings (it is cross referenced by the ADB consultation document which has removed specific references to school buildings). The document was issued for consultation in August 2005 and it recognises some of the benefits of sprinklers in achieving a satisfactory design.

A review of the BB100 consultation document has highlighted the following areas where sprinklers have an impact:

Arson:

In areas where arson is a regular occurrence, the provision of an automatic sprinkler system should be considered (subject to the outcome of a risk assessment).

Structural fire resistance:

For schools with the topmost occupied floor <5m above ground (typically 1 and 2 storeys), fire resistance of the structure may be reduced from 60 minutes to 30 minutes if the building is sprinklered.

For schools with the topmost occupied floor between 18m and 30m above ground, fire resistance of the structure may be reduced from 90 minutes to 60 minutes if sprinklered.

Compartmentation:

Maximum compartment areas can be increased from 800m² to 2000m² if sprinklered.

3.3.3 Joint Code of Practice for Sprinkler protection of schools

The *Joint Code of Practice for Installation of Sprinklers in Schools* is aimed at providing a better value solution to promote the incorporation of sprinklers in schools. The specifications within the code of practice are those developed by Zurich Municipal, Royal Sun Alliance, and other insurers over the past five years and the basis of the document is the Loss Prevention Council Rules for Automatic Sprinkler Systems. The document arose due to a number of reasons:

- The sprinkler rules are often poorly understood by most in the building trade.
- There is still a wide perception that all the sprinkler heads go off at once. There is therefore a need to foster a better understanding among designers and building owners how sprinkler systems work.
- Even within the sprinkler/insurance industry, it has been possible to design sprinkler systems for use in schools in a number of ways. The standard most often applied is too onerous and costly for it to be economically viable.

The Joint Code of Practice, which calls for the sprinkler system to be remotely signalled by a monitored line method reduces the stored water supply and hence the tank, tank housing and ground works for the tank by 50%. The authors of the Joint Code believe that this can save as much as £15,000.

3.3.4 Future Health Technical Memoranda

Updates of HTM 81 *Fire precautions in new hospitals* and SHTM 86 *Fire risk assessments in existing hospitals* have been prepared in draft format and it is intended that these documents be published after a consultation/review period. It is understood that the current recommendations and trade-offs in the current documents will be incorporated in the new documents.

4 Trade-offs and Alternative Solutions

4.1 Introduction

This section considers aspects outside of the prescriptive guidance. The trade-offs mentioned may or may not be appropriate depending on the details of the proposed design. The approval authorities will usually require supporting evidence and/or analysis if such an approach is adopted. It is therefore advisable to consult an appropriately qualified fire engineer to develop alternative solutions that lie outside the scope of the prescriptive codes.

Sprinklers systems are increasingly accepted as making a contribution to life safety, in the first instance outside the area of origin but also within it. Within the current fire safety guidance, there are already a number of established 'code compliant' trade-offs that can be incorporated into a design with sprinklers – these are outlined in section 3 of this report.

However, a limitation of the prescriptive fire safety codes is that they are required to be applicable to a wide range of building types, with the requirements for a particular building depending on the use classification. This means that within a single use classification the function, population and fire load of a building can vary considerably. For example both Nightclub and Libraries belong to the same classification of 'places of assembly'. The code guidance therefore tends to be based on worst case assumptions for populations and fire loads which may or may not be present in a particular design.

This ultimately means that there are usually further opportunities for trade-offs and increased design flexibility if a building is considered on its individual merits, particularly if a fire engineered approach to fire safety design is adopted.

This section of the report therefore includes the following:

- Specific examples of further trade-offs that could be applied to a design, beyond those considered in the codes.
- Ways in which sprinklers can be taken into consideration for fire engineering analysis in order to achieve the required design goals.

Many alternative solutions require the development of an appropriate design fire size. It is usually considered appropriate to consider the effect of sprinklers on the design fire size. This is discussed in detail in Section 5.

The use of residential sprinklers and the associated trade-offs and alternative solutions are considered separately in Section 6.

4.2 Examples of Alternative Solutions

4.2.1 Use of non-fire resisting glass in fire walls:

The use of drencher protected glazing for fire separations increases the architectural flexibility of a project and as well as providing an alternative means of achieving compartmentation in a building. This topic has been subject to a number of research studies [51] [52].

Specially designed sprinkler heads have now been developed by Tyco for drencher protection of toughened glazing that have passed the American ASTM standard furnace test for a period of two hours.

4.2.2 Means of escape:

Escape travel distances are limited by the prescriptive guidance in order to limit the time taken to reach an exit. Extension of escape travel distances may be facilitated by the provision of automatic sprinklers (amongst other considerations). This is because sprinklers have the ability to control fire

growth and hence conditions can remain tenable for longer than if sprinklers were not present. This allows extra time for escape and therefore it may be acceptable to travel further to an exit.

A performance based approach to means of escape design can take the form of a time based comparison between:

- The time *required* to reach a place of relative safety (Required Safe Escape Time – RSET).
- The time *available* for occupants to reach a place of relative safety prior to untenable conditions being achieved (referred to as the Available Safe Escape Time - ASET), and;

The aim of a performance based design is for RSET to be less than ASET, to allow safe evacuation. A detailed explanation of the approach can be found in PD 7974-6:2004. However, the key features of the approach and the impact of sprinklers can be summarised as follows:

- RSET is the sum of the fire detection/alarm time, the recognition/response time and the travel time to a place of safety. Sprinklers can help to reduce RSET by detecting a fire at an early stage.
- ASET is determined by the onset of untenable conditions within the area being considered. Untenable conditions can be caused by smoke toxicity, and heat from fire and/or smoke. Sprinklers can help to extend ASET by limiting the amount of smoke production from a fire and by reduction heat exposure.

Trade-offs relating to travel distance is more likely to be realised if fast response sprinkler heads are provided.

In a similar way, sprinklers could be used to justify a shortfall in the exit width provision in a building.

4.2.3 Firefighting Access

It is not always possible to achieve the full requirements for firefighting access recommended by the code due to site constraints. This could potentially impact on set-up time for firefighting operations and/or reduced ability to fight a fire and save lives.

In such situations the fire authority may consider the use of a sprinkler system a compensatory feature as the fire is likely to be controlled to a smaller size than if unsprinklered. This takes into account fire service arrival times and potential fire sizes on arrival.

4.2.4 Surface spread of flame

The advantage of upward water spray in modifying flame spread characteristics is being recognised. Wetted surfaces will not promote flame spread as easily as those that are dry.

4.2.5 Reduced requirement for fire detection systems

Many buildings, due to their size and complexity, require a means of automatic detection of fire to raise an alarm. This is commonly achieved by the provision of a smoke or heat detection system.

Where sprinklers are provided, each sprinkler head serves as a heat detector, thus providing a means of automatic detection. Thus in many sprinklered buildings the extent of automatic detection can be reduced.

4.2.6 Rationalising passive fire protection to structural elements

The ability of a structure to remain stable in the event of fire is a fundamental prerequisite of building safety. Recommendations for fire resistance in the UK depend on the height occupancy profile and potential fire load associated with any given building type.

The traditional approach for determining fire protection requirements is:

- i. To adopt the fire resistance periods recommended in the Building Regulations standard guidance (e.g. Approved document B for England and Wales),
- ii. Demonstrate compliance with this fire resistance period by way of Standard Fire Tests conducted in accordance with the recommendations of BS 476.

Alternative approaches can be adopted providing the impact on the overall fire strategy is addressed and appropriate sensitivity studies are conducted. An alternative approach that has been applied to a number of UK projects over recent years is the 'Time Equivalence' method.

The time equivalence method is a series of calculations which compare the response of an element of structure in a real fire to that of a standard test furnace. The real fire conditions are calculated and the equivalent thermal dose in the real fire is related back to the equivalent exposure in the standard test. Therefore the equivalent period can be utilised to specify the required applied fire protection with the comfort of understanding that it will survive at least the same period as that assessed under the BS476 regime.

One way of calculating 'Time Equivalence' is detailed in BSEN 1991-1-2:2002. The approach includes various factors which allow for appropriate increases or decreases in the calculated period of fire exposure (and hence passive fire protection requirements) depending on the building design.

One such factor is for the presence of a sprinkler system in the building. Sprinklers have well documented advantages in limiting fire growth and have been shown to have a high degree of reliability. Thus, if sprinklers are provided in a building there is a much reduced risk of flashover fire occurring. For these reasons, the time equivalence value may be reduced by a factor of 0.61 compared to an equivalent non-sprinklered building. This can sometimes allow a reduction in passive fire protection that would not be possible without the provision of sprinklers.

4.2.7 Risk Assessments and existing buildings

The Regulatory Reform (Fire Safety) Order 2005 was approved by Parliament on 7 June 2005. The primary purpose of this fire safety law is to reduce death, injury and damage caused by fire. This legislation amends and consolidates a significant number of areas of fire safety law that previously were in place in England & Wales (Northern Ireland and Scotland have their own laws, with similar provisions.).

The Order places a general duty of fire safety care on employers, occupiers and owners of almost all premises and requires them to provide and maintain adequate fire precautions. The extent of fire precaution measures need to be determined through a fire risk assessment process. The fire risk assessment is used to identify risks that can be removed or reduced and assist with the decision making process regarding the nature and extent of the general fire precautions to protect people against the fire risks.

The legislation focuses on fire prevention in all non-domestic premises, including the voluntary sector and self-employed people with premises separate from their homes. Fire certificates will be abolished and will cease to have legal status.

The Fire Safety Order 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 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, e.g. 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, all must take all reasonable steps to work with each other.

The responsible person has a duty to carry out a fire risk assessment which must focus on the safety in case of fire of all 'relevant persons'. The risk assessment should pay particular attention to those at special risk, such as the disabled and those with special needs, and must include consideration of any dangerous substance likely to be on the premises. The significant findings of the fire risk assessment must be presented to the Fire and Rescue Authority where requested, to demonstrate compliance with the requirements of the fire safety order.

Many existing buildings are unlikely to meet the current fire safety guidance and some of the original fire safety provisions may have deteriorated. Sprinklers offer one way to improve the standard of existing buildings to an acceptable level and may offer a more cost effective solution than upgrading other features such as passive fire protection.

PD7974-7:2003 *Probabilistic risk assessment* provides guidance in support of BS7974:2001 *Application of fire safety engineering principles to the design of buildings – code of practice*.

4.2.8 Historic Buildings

Refurbishment and/or renovation of historic buildings to meet current fire safety standards can be problematic due to the constraints of existing structure and the need to preserve original building features.

The provision of sprinklers can be used to compensate from the standard code recommendations. For example, if old doors needed to be retained to preserve the character of the building, but the doors failed to meet current fire resistance standards, a sprinkler head located close to the door could be used to improve the performance of the door as a fire resisting barrier.

Scotland has pioneered the use of sprinklers to protect historic buildings and a significant body of experience has now been built up in relation to designing and installing these systems in a sympathetic and non-intrusive way. Buildings protected so far include Duff House, in Banff, the National Library of Scotland in Edinburgh, Newhailes House in East Lothian and Broughton House in Dumfries and Galloway.

Practical guidance on the use of sprinkler systems in historic buildings can be found in Historic Scotland's Technical Advice Note No.14: *The Installation of Sprinkler Systems in Historic Buildings* (1998).

A fuller and more up to date account of the arguments relating to the installation of sprinklers (and other automatic suppression systems) in historic buildings can be found in Section 5.10 of Technical Advice Note 28 *Fire safety Management in Heritage Buildings* (2005).

4.2.9 Arson

Multi-seat fires are not unusual with arson attacks whereas fire safety guidance normally assumes a single outbreak. Yet the provision and operation of sprinklers in premises maliciously ignited has been demonstrably beneficial [41]. A sprinkler system will automatically raise the alarm and call the fire service, while at the same time control the fire development. The resulting fire will be smaller upon fire brigade arrival.

5 Design Fire Sizes where Sprinklers are Present

5.1 Introduction

An important aspect when undertaking fire engineering analysis to support alternative solutions is the selection of a design fire size that is representative of the building and its contents. The benefit of sprinklers is that they can be assumed to reduce the design fire size which can impact have the following impact:

- Conditions within a building may remain tenable for a longer period of time, allowing escape provisions to be rationalised.
- Less smoke is produced, resulting in reduced smoke extract requirements.
- The temperature of smoke is reduced, allowing the use of non-fire resisting glazing to atria and lightwells.
- The radiation from a fire will be reduced, potentially allowing reduced levels of protection to escape routes.

In order to select an appropriate design fire size it is important to understand the likely effect of a sprinkler system on a fire.

The effectiveness of a sprinkler system will depend on a number of factors including:

- I. The fire size at the time of sprinkler activation.
- II. The type of sprinkler system (e.g. wet, dry, pre-action etc).
- III. The type and location of sprinkler heads.
- IV. The geometry of the protected space.
- V. The type of fuel and its orientation.
- VI. The extent to which the fuel is shielded.

There are a number of possible outcomes in relation to the effect of a sprinkler system on a fire (some more likely than others). Some of the possible outcomes are summarised as follows:

- a) The sprinkler system reduces the rate of heat release to zero, extinguishing the fire (in practice this is often the outcome)
- b) The sprinkler system halts the increase in the rate of heat release, and the fire continues to burn at a constant rate.
- c) The fire continues to grow but more slowly than before.
- d) The sprinkler system has no effect and the fire continues to grow in an uncontrolled manner (e.g. water supply is turned off).

Outcomes a, b, c and d above are shown graphically in figure 1:

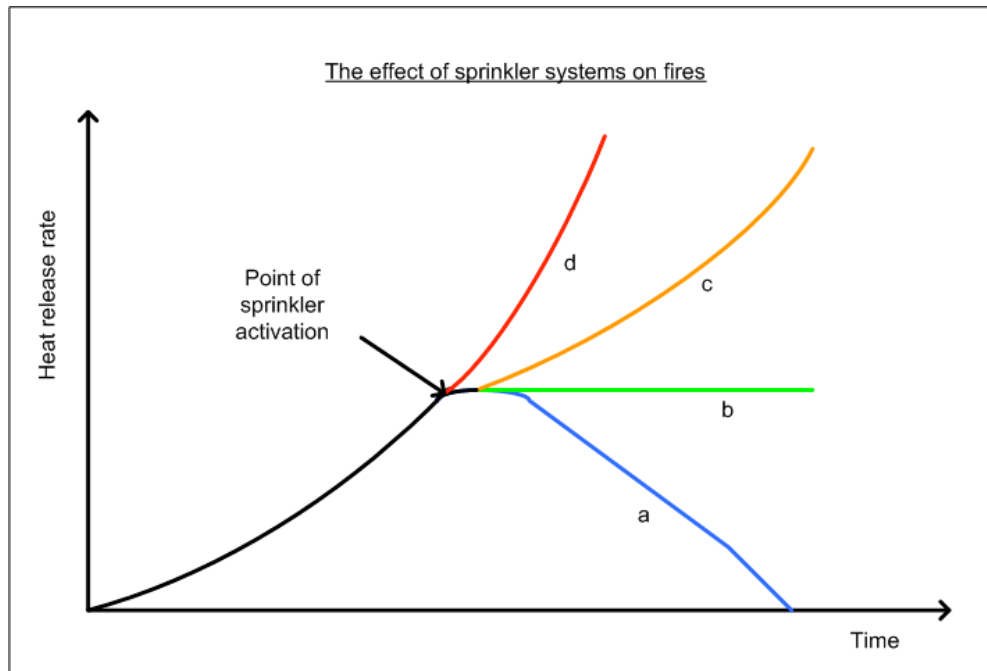


Figure 1: The effects of sprinkler systems on fire development

Scenarios c) and d) may occur if one of the following factors is present:

- Interruption of the water supply rendering the sprinkler system ineffective (e.g. system shut down for repair/maintenance).
- The fuel is shielded from the sprinkler spray so that water is not applied to the fire or surrounding fuel.
- The hazard being protected is beyond the capabilities of the system. For example, if the fire load is much greater than the sprinkler system classification is designed to control, or if the location of the sprinklers results in a delayed response (e.g. sprinklers are located too high above the fire).

The good track record of sprinklers in limiting fire damage suggests that scenarios a) or b) are the more likely scenarios. However, consideration should be given to the risk of either c) or d) occurring if there are reasons to suspect that sprinkler performance may be inhibited.

If a sprinkler is able to detect a fire in the early stages of development, it is more likely that the fire will be controlled or even extinguished. The point at which a sprinkler operates can be estimated using fire engineering analysis that takes into account the location of the sprinkler heads, the type of sprinkler head and the rate of fire growth. The following graph illustrates the differences in sprinkler activation times for different sprinkler heads and different fire growth rates. The data for the graph was based on a ceiling height of 6m and was calculated using the FPETool computer program developed by the National Institute of Science & Technology (NIST).

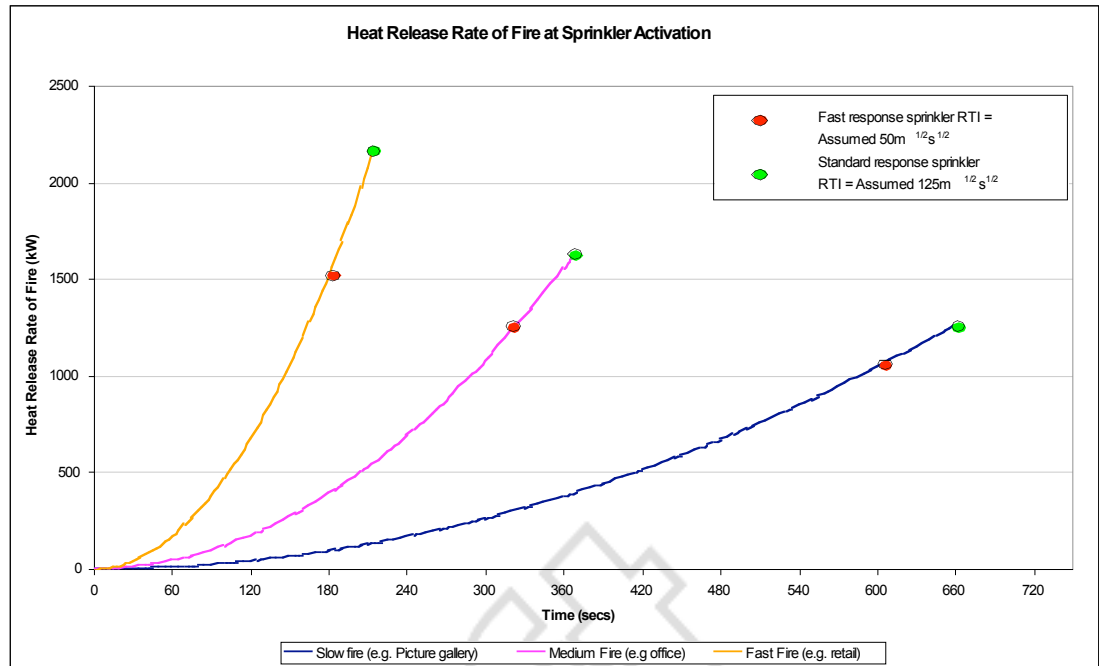


Figure 2: Heat release rate of fire at sprinkler activation

5.2 Fire safety design guidance for sprinklered fires

5.2.1 Steady state design fires – the 5MW fire

The 5MW (convective heat release rate) fire was proposed by the Building Research Establishment as a design fire for defining smoke ventilation provisions in enclosed shopping centres [18]. Where fast response sprinklers were provided the proposed fire size was reduced to 2.5MW (convective heat release rate). [42].

The 5MW (3m x 3m) design fire size originated from experimental research [43]. It can be concluded from the research report that the fire load in the mock-up was shielded from the sprinklers so that the sprinklers were prevented from effectively tackling the fire. Even so, upon operation the sprinklers prevented fire growth beyond the shielded 3m x 3m area.

The inherent conservatism of the 5MW fire is currently not recognised in fire safety guidance where it is presented e.g. within BR 186 *Design principles for smoke ventilation in enclosed shopping centres*. Statistical data indicates that a 5MW fire is only likely to occur in less than 5 per cent of fires in sprinklered shops (even including storage areas where stacked goods are more common). Additionally, where sprinklers operate it is unlikely that the heat release rate would be sustained at 5MW.

Accordingly, consideration should be given to adopting a more representative design fire for sprinklered shopping centres and other sprinklered premises. This has started to be addressed by more recent fire engineering design guidance which is summarised in the following sections.

Note: Despite the above, in some circumstances a sprinklered fire may exceed 5MW in size – e.g. in high bay racking where significant shielding is present, or where highly flammable materials are involved. Each building should therefore be considered on its individual merits when determining appropriate design fire sizes.

5.2.2 CIBSE Guide E – Fire Engineering

The guidance in CIBSE Guide E, Section 10.6.4. states:

“ In a room equipped with sprinklers, fire may grow until the heat of the plume sets off the first sprinkler heads; the effect of sprinklers on the design fire size can be taken into account by assuming that the fire stops growing when the sprinklers are activated. The design fire is then estimated as the size the fire has grown to at the moment of sprinkler activation unless there is a reason to suspect that the fire will continue to spread after the sprinklers have been activated. Since the sprinklers will cool most of the smoke to below 100°C, flashover is not likely to occur where they are installed. It can therefore be assumed conservatively that the fire will have a constant rate of heat release.”

5.2.3 PD 7974-4:2003 Application of fire safety engineering principles to the design of buildings

PD 7974 recognises that sprinkler systems can be used either to control a fire (thus preventing it from spreading), or to suppress a fire. An example of a system designed to suppress a fire is Early Suppression Fast Response (ESFR) which utilise high sensitivity heads and special water discharge characteristics. This type of system is sometime applied to rack storage where only roof protection is provided.

PD 7974 gives an equation for determining the effectiveness of sprinkler systems in reducing the heat release rate of furnishing fires:

$$Q_{(t-t_{act})} = Q_{t_{act}} e^{-\frac{(t-t_{act})}{3.0(w'')}}^{-1.85}$$

Where:

Q is the heat release rate (kW)

t is any time following t_{act} of the sprinklers (sec)

w'' is the water spray density (mm/sec)

Note: the model is based on tests carried out with wood cribs (which simulate deep seated fires) and thus could be considered as conservative in providing results.

The above equation allows the variation of fire size with time to be modelled if the building and sprinkler system characteristics are known.

Example: An office building is sprinkler protected (Ordinary Hazard I system) with standard response sprinkler heads. The ceiling height is 3m. Based on this information, the sprinkler activation time and the effect of the sprinklers on the fire can be modelled using fire engineering equations. The results for the above example are shown graphically below:

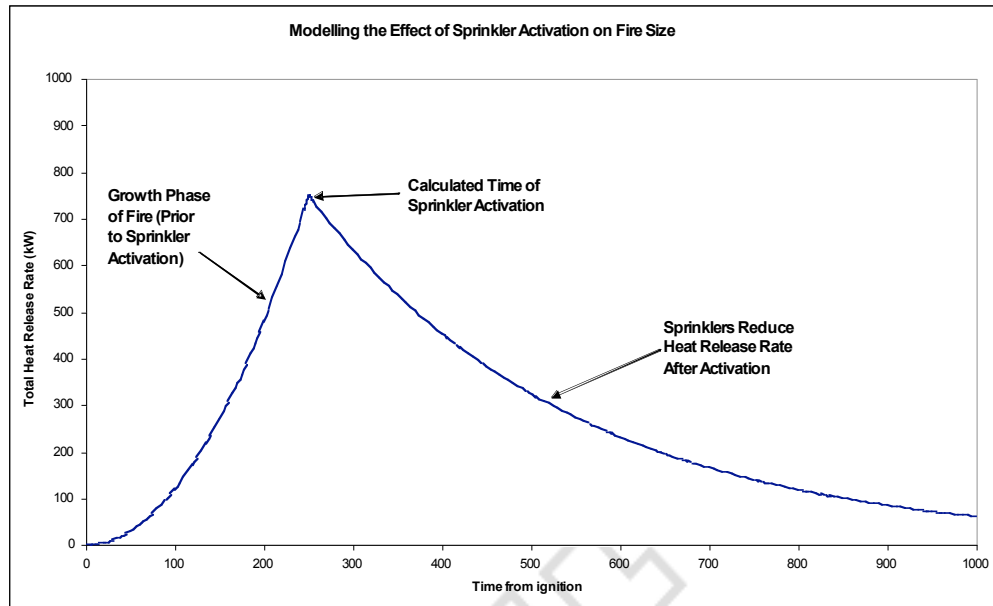


Figure 3: Modelling the effect of sprinkler activation on fire size

5.2.4 BS 5588 Part 7: Code of Practice for the Incorporation of Atria In Buildings

Atria require special consideration in fire safety design of buildings due to their potential to allow smoke and fire to spread within a building. In many cases the use of standard sprinkler systems at atrium roof level may not provide significant benefit to the design, as sprinklers may fail to activate in time to adequately control a fire in the atrium base.

BS 5588 Part 7 therefore provides the following guidance with respect to sprinklers within atria:

If sprinklers are mounted at high level below the atrium ceiling they will react much more slowly, if at all, than if mounted below a typical high ceiling.

In atria where the ceiling is more than 20m above the atrium base, ceiling mounted sprinklers are unlikely to be effective and there is therefore little benefit in their installation.

Where it is not practical or desirable to provide the traditional type of thermally operated sprinkler heads to protect the atrium base, it may still be possible to provide some alternative form of fire suppression system to provide a similar level of performance.

For a number of atrium types BS 5588 Part 7 recommends that the amount of combustibles in the atrium base be restricted, unless suitable sprinkler protection is provided. In these cases BS 5588 Part 7 considers that sprinklers will perform adequately is the maximum height above the base of the atrium is limited to:

- 10m for quick response sprinklers;
- 7.5m for standard response sprinklers.

BS 5588 Part 7 considers that sprinklers conforming with the above will be capable of limiting the heat output of the fire to 2.5MW convective heat flux. An alternative approach to sprinkler protecting atrium bases with high ceilings is outlined in section 7.5.

5.2.5 Computer modelling the effect of sprinklers on a fire

It is now possible to model sprinkler activation and the effect on the heat release rate using the computational fluid dynamics (CFD). One such program is "Fire Dynamics Simulator (FDS)". FDS is a large eddy model developed by the National Institute for Safety and Technology (NIST) for fire driven

fluid flow. The program uses correlations based on thermal inertia to estimate the time to activation for sprinkler heads. Once activated the sprinkler sprays are modelled by particles that represent a sampling of the water droplets ejected from the sprinkler. The sprinkler sub model attempts to account for cooling, wetting, evaporation and entrainment. It should be noted that the sprinklers in FDS are insensitive to thermal radiation.

There are also a number of other computer models developed to determine the interactions between sprinklers, ventilators and thermally buoyant layers. These are:

RADISM – developed by Hinkley from a joint FRS-Colt International project, UK

LAVENTS – developed by Cooper at NIST, USA

SPLASH – developed by Gardiner (1988) and Jackman (1992) from a joint collaboration between Branforsk, Sweden, FRS and South Bank University, UK

JASMINE – a two phase version developed by Kumar et al at FRS, UK

Results from the large experiments in Ghent in Belgium were used to test RADISM and results from the SP Boras experiments have been used to test the predictions of SPLASH and JASMINE.

Careful consideration should be given to using computer modelling to predict the effect of sprinklers fire growth due to the large number of variables present. While computer models play an important role as part of an engineers 'tool kit', the limitations of the model should be understood and the results carefully considered in the appropriate context.

6 Residential Sprinklers

6.1 Background

Sprinkler protection to residential occupancies is a relatively new concept in the UK and has been subject to much debate. Residential sprinklers were first developed and applied in the USA in the 1980's. The UK started to catch on in the late 1990's with residential sprinklers occasionally being installed in residential buildings to overcome design issues such as limited fire brigade access or the lack of secondary escape routes. Unlike commercial sprinkler systems, residential sprinklers were aimed at protecting life rather than property.

Due to uncertainty over the effectiveness of residential sprinklers the ODPM commissioned a three year study to help understand whether the systems can provide a significant benefit in protecting life at a reasonable cost. This research culminated in the issue of the BRE Report 'The effectiveness of sprinklers in residential premises' in January 2004. The findings of the report prompted the Scottish Executive to include requirements for residential sprinklers for high rise domestic buildings in the revised Technical Handbooks.

From 2000 to 2005 residential sprinklers were generally designed in accordance with the British Standard Draft for Development DD251:2000. In 2005 this document was replaced by BS 9251.

BS 9251 covers two occupancy types:

- Domestic (single family dwelling units).
- Residential occupancies (HMO's, blocks of flats, halls of residence).

6.1.1 Effectiveness of residential sprinklers

As part of the BRE research program, a number of fire tests were conducted in a two storey test 'house' with a loft conversion, and a three room compartment. Tenability conditions were measured for both sprinklered and unsprinklered arrangements.

The findings of the research included the following:

- In all sprinklered fires within the house, conditions within the room of fire origin were such that death would not have occurred. In the unsprinklered fires, conditions reduced to an extent that would result in death.
- Tenable conditions (apart from visibility) could be maintained for the rest of the house if sprinklers were provided in the room of origin and the door left open. If unsprinklered, untenable conditions would be present throughout the house if the door was left open.
- Sprinklers had no significant effect on visibility.
- Several tests test for the three room apartment resulted in unsurvivable conditions even when sprinklers were present – this was due fire growth being slower than normal, producing a lot of smoke.

Full details of the findings of the report can be found in the report: Effectiveness of sprinklers in residential premises. BRE project report 204505.

In summary it was found that for the majority of scenarios experimentally studied, the provision of residential sprinklers proved effective in potentially reducing casualties in the room of fire origin and connected spaces.

6.2 Residential Sprinklers and Building Regulation Guidance

In May 2005 Scotland was the first area in the UK to introduce a requirement for residential sprinklers into the Building Regulation guidance, primarily as a consequence of several serious fires in

residential care homes and the findings of the BRE report. This requirement applies to buildings greater than 18m in height (including apartment buildings), residential care buildings and sheltered housing.

The proposed ADB which was issued for consultation in July 2005, has incorporated revised proposals including the following:

- A recommendation for the provision of sprinklers to apartment buildings greater than 30m in height.
- A recommendation for sprinklers for residential care homes that use progressive horizontal evacuation.
- An option for residential sprinklers as an alternative to providing secondary escape from the upper levels of apartments or dwellings with a floor >4.5m above ground level.

Whether the above recommendations for tall buildings and residential care homes are implemented will depend on the final Regulatory Impact Assessment showing that sprinklers are justified.

6.3 Further Residential Sprinkler Trade-offs

Since their introduction in the UK residential sprinklers have occasionally been adopted as part of an alternative solution to standard building regulation guidance. Most cases have involved multi-storey dwelling houses although there have been some larger sprinklered apartment buildings.

Examples of the type of trade off that have been allowed as a result of residential sprinklers are as follows:

- Relaxation of the requirement for a second escape route for houses with four storeys or more.
- Relaxation for the requirement for a second escape route for multi-level apartments.
- Relaxation of the requirement for existing staircases to be enclosed when converting the loft of a two storey dwelling.
- Relaxation of the fire brigade access requirement to be within 45m of entrance door to dwelling.
- Relaxation of the requirement for internal fire spread (linings), e.g. Class 1 instead of Class 0.
- Relaxation of the 7.5m dead-end travel distance limit for apartment buildings.
- Relaxation of the requirement for 30 minute fire resistance of walls and floors and doors (providing they are of sound construction).
- Relaxation of requirements for heat detectors in bed-sits with cooking facilities and in kitchens.

In addition to the residential specific examples given above, residential buildings can also often benefit from the general trade-offs and alternative solutions described in sections 3 and 4 of this report, e.g. number of firefighting shafts, reduced structural fire resistance etc.

7 Special Applications

7.1 Sprinklers for special risks in the process industries

There are a number of special risks, particularly in the process industries, where sprinklers, drenchers and water curtains are mandatory or highly recommended. Whilst their value is not questioned, their application is considered to be outside the scope of this Report.

Reference can be made to members of the British Automatic Sprinkler Association to confirm the appropriate requirements. Typical areas include oil platforms, protection of flammables, processes and power stations and any fire risk where an incident would have catastrophic consequences.

7.2 High bay warehousing and storage

Warehouses, particularly those incorporating high rack storage, are often subject to large fire losses. Conventional sprinklers are not appropriate in many instances as the rack storage can shield a fire from the sprinkler spray while it grows beyond the controlling abilities of the system.

Two approaches that are used to provide protection in these circumstances include:

- In-rack sprinkler protection (arrays arranged to be within the racking as well as above).
- Early Suppression Fast Response (ESFR) sprinklers above racking.

7.3 Protection of a building exterior

In addition to the use of sprinklers to protect glazing within buildings (see section 4.2.1) Systems are being designed and approved to address space separation by drenching the perimeter elevation. Whilst not a new concept in North America where buildings have to be protected from fire outside, in the UK the responsibility is to contain a fire relative to the boundary, to protect the adjacent building. The provision of glazing drenching in reducing heat transmission, can provide the equivalent to fire-resisting construction.

7.4 Transport

Heavy Goods Vehicle's can be the cause of large fires. When they occur in enclosed spaces (such as underground loading bays), the resulting fire can affect the structure, prevent fire brigade access and overwhelm smoke control systems. The provision of sprinklers can assist in reducing the smoke temperatures and prevent the fire spread to adjacent vehicles.

The control of fires by sprinklers in rail vehicles and aircraft can be addressed by specially designed spray systems that require minimum water reserves.

7.5 Atrium Bases

By linking floors together, atria provide a path for fire and smoke to spread quickly through a building. Atria therefore need to be considered carefully when developing a fire safety strategy for a building. For many atrium types, BS 5588 Part 7 recommends that sprinklers be provided throughout the building, however, where the height of the atrium is above a certain limit (typically 10m), the effectiveness of sprinklers to control a fire in the base of the atrium is reduced (due to longer activation times). In these circumstances BS 5588 Part 7 recommends that the buildings be subject to management controls to limit the amount of fire load present in the base of an atrium, which limits the use of the space.

There is however an alternative approach that can be adopted, to allow flexible use of the atrium base. This approach utilises 'open head' sidewall sprinklers that are intelligently operated by infra-red detection. This approach has LPC approval for atria up to 16m wide and an OHIII fire load [44].

8 Water Mist Suppression Systems

8.1 Background

Although this document examines the benefits and uses of sprinkler systems in buildings, it is appropriate that the developing field of water mist suppression be included for completeness.

Water mist systems, like sprinkler systems, are active fire suppression systems. Water mist systems closely resemble sprinkler systems in that they also have a water supply, a distribution network, a means for detecting the fire and a mechanism for discharging the mist (in the case of mist systems) or the spray (in the case of sprinklers).

Several proprietary systems are available ranging from low pressure (8 - 12 bars) systems providing a fine water spray extinguishing medium to very high pressure (up to 110 bars) systems producing a very fine water particle mist. The water is propelled either by pumps or by an inert gas and dispersed from nozzles that are designed to deliver water in a range of fine droplet sizes to the area of fire. High pressure water mist systems resemble gaseous extinguishing systems while low pressure systems are more akin to sprinklers or water spray/deluge systems. The water mist acts on a fire by cooling, displacing oxygen and by blocking radiant heat.

Mist suppression technology developed in response to a need for halon suppression alternatives, particularly for industrial applications. These systems are usually used to protect against a specific hazard (e.g. fire in a turbine hood) and are usually adopted as a property protection measure.

However more recently systems have been applied to buildings from all purpose groups, most commonly as an alternative to a conventional sprinkler system or as a compensatory feature to meet the life safety requirements of the Building Regulations.

In a recent study the BRE has reported that more than 1000 water mist systems are installed in various building types throughout the UK. According to the water mist companies approximately one third of the existing systems are used to protect residential premises (flats, maisonettes and dwelling houses), with factory/industrial being the next most popular.

8.2 Water mist design standards and guidance

At present, there are no British or European standards for water mist systems. Although some moves have been made towards a draft European standard prEN 14972 – *Fixed firefighting systems – watermist systems – design and installation*, progress is very slow. British Standards are also working in this area and a water mist supplier/installer has been asked to draft a possible standard for water mist in domestic and residential premises.

The US National Fire Protection Association has published NFPA750 Standard on Water Mist Fire Protection Systems which gives useful general guidance on the application of water mist systems but does not provide a design guide for individual risk applications.

The mist systems that have been installed in buildings to date have generally be accepted on the basis of compliance with the guidance that is available, performance tests undertaken by the manufacturers of the system and by demonstrations to approval bodies.

8.3 Sprinklers and mist compared

In comparison with sprinklers, water mist systems use comparatively small amounts of water to fight fires which may offer benefits in respect of installation costs and reduction in water damage post-fire. Mist systems also offer the potential for installation in locations which are too small to accommodate the tanks and pumps of a conventional sprinkler system.

The absence of a design and installation standard akin to BS 5306 Fire extinguishing installations and equipment on premises Part 2 Specification for sprinkler systems or BS EN 12845: 2004 Fixed firefighting systems - Automatic sprinkler systems - Design, installation and maintenance should be recognised as each type of mist system will have its own strengths and weaknesses. As most of the mist design concepts are proprietary, inherent weaknesses may not become evident until after installation. Some research has been undertaken into the appropriate use of these systems in confined spaces and large volume areas. High ceilinged spaces with large floor areas may present problems in designing nozzle layout to ensure all potential fire locations fall within the effective range of the nozzle distribution and such locations may be unsuitable for the installation of quartzoid bulb mist heads. Where it is not possible to use quartzoid bulbs then careful consideration of the selection and zoning of fire detection devices must be undertaken if spurious alarms and actuations are to be avoided. At the same time, the method of detection must also ensure that enough water is discharged to achieve the necessary mist configuration and pattern. Studies have also indicated that the design of some water mist systems needs careful consideration where the protected location is prone to significant air movement as this may impact on the effectiveness of the mist.

Tests have also shown that some mist systems are also less effective at extinguishing slow, deep-seated fires in 'normal combustibles' than traditional sprinkler systems. Careful risk assessment should therefore be made before any conclusion is reached as to the type of protection needed for any particular location or occupancy. The risk assessment needs to take into account the fact that (unlike sprinkler systems) each mist system has to be specifically designed for the space it is to protect. In the absence of any recognised international standards for the design of water mist systems, care needs to be taken to ensure that the system components and design are appropriate to the application.

It has been suggested by a range of authorities including the FPA, that proposals for water mist systems should be subject to detailed scrutiny where such applications are novel or not covered by standards. In particular, the supplier or installer of a proposed system should be able to demonstrate that test fires have been satisfactorily extinguished or suppressed (whichever is the desired result from the system) in rooms of the same size and same occupancy as the intended application.

Other issues to be considered include the chosen method of system actuation. Mist nozzles can be open or fitted with quartzoid bulbs. Open nozzle systems will therefore require a separate detection system (analogous to that which is required for a pre-action sprinkler system), which could be subject to the sorts of stimuli which result in spurious or unwanted false alarms. Closed heads with bulbs are subject to the same constraints as sprinkler systems with the disadvantage that many mist systems are designed to incorporate only with storage of very limited amounts of water. If a very rapid fire occurs which causes all the heads in a room to operate it is possible that the supply/duration of stored water may be inadequate unless it is designed for this eventuality. It should be noted that some medium and high-pressure mist systems depend on stored water of at least the purity of potable water or need the installation of special filtration equipment. Where the available mains water does not meet such standards larger quantities of water need to be stored.

Applications where independent test-derived data exists to prove that mist systems are adequate (apart from marine applications) include: engine test cells, diesel generator rooms, battery and UPS accommodation, telecommunications cubicles and cable tunnels. At least three manufacturers claim satisfactory installations in hotels, historic buildings and also museums and galleries and while there is little empirical, independent test data to support some of the claims it would appear that mist systems are capable of fulfilling their intended design purpose. It should also be noted that there is little real

fire experience of land based mist systems - possibly due to the relatively few installations in existence at the time of writing.

Although many of the issues identified will be resolved in time it is suggested that, at the time of writing, caution should be exercised in specifying water mist systems for the protection of very large open areas or complete buildings until design and standards issues are resolved and British or European standards are published.

8.4 Application of Water Mist to Protect Domestic and Residential Accommodation

A number of UK companies are actively promoting water mist systems as an alternative to sprinkler protection for domestic and residential properties. While some of the systems proposed follow the well-established design model for marine water mist systems, others are hybrid systems which do not follow any established standard or code of practice. Concerns regarding the 'ad hoc' nature of some systems have been expressed by a number of authorities including the Fire Protection Association and insurers as well as some consulting fire engineers. A number of fire brigades have supported the use of such systems (reportedly on the basis that 'any protection is better than none') having been attracted by apparent lower costs when compared with full sprinkler protection. However concerns have been expressed at whether some of the domestic mist systems being installed will perform correctly in a real fire situation.

It is likely that with the appearance of authoritative standards, approved equipment and components together with further development and independent testing, water mist systems will have a part to play in domestic/residential fire safety. At the time of writing (July 2005) the British Standards committee FSH 18/2 responsible for fixed fire suppression systems have invited one of the most active UK water mist companies to draft a standard for the design and installation of water mist systems in dwellings. Any Draft for Development (DD) and eventual British Standard will, however, have to prove that such water mist systems will provide an equivalent level of protection to a BS 9251 sprinkler system.

However, until the new BS (or DD) is issued, care should be taken in the specification of water mist systems for domestic and residential properties. Where such systems are used as a form of alternative compliance in respect of the requirements of Approved Document B (or the Scottish Building Standards), care should be taken to ensure that the system is capable of achieving the required level of protection.

8.5 Trade-offs using water mist suppression

Until guidance detailing performance requirements for mist systems is developed in the UK, design trade-offs should be considered on a case by case basis taking into account the characteristics of the building and the design/performance of the mist installation in question.

Further information relating to fire suppression using water mist systems can be found in the BRE Report *Fire suppression in buildings using water mist, fog or similar systems*.

9 Cost versus Benefit

9.1 Introduction

Only by understanding the costs and benefits associated with the use of sprinklers can an informed decision be made as to whether or not they should be incorporated in a particular design. This section provides information to assist this process from a building owner's perspective, rather than from a national perspective.

In many circumstances a decision will be made to incorporate sprinklers in a design solely on the basis that they are recommended by the prescriptive building code (e.g. commercial buildings >30m in height). In such cases, the design team may seek to agree appropriate trade-offs with the approval authorities (as referenced in sections 3 and 4).

On the other hand, sprinklers may not be required to comply with the Building Regulations, but may still be considered as part of the design process due to the benefits they provide.

The perceived benefits and cost of sprinklers will vary depending on the role of an individual or organisation. For example, a builder may focus on the requirements of the contract, e.g. to comply with the building regulations and meet the construction budget. However a building owner may have insurance and business protection considerations. Because of the range of issues involved, a decision relating to the provision of sprinklers should typically involve:

- The building owner
- The building operator (if not the owner)
- The prospective tenant(s)
- The approval authorities (Building Control, Fire Service)
- The design team
- The builder
- The insurers
- The Water Authority

9.2 Benefits of sprinklers

Why would sprinklers be considered as part of a design when they are not required them under the Building Regulations? The main benefits include:

- Sprinklers can permit trade-offs that improve the aesthetics and functionality of a building.
- In some circumstances the savings achieved via trade-offs can result in a more cost effective design.
- Sprinklers can be a requirement of insurers, or can substantially reduce insurance premiums.
- Sprinklers can significantly reduce the impact of fire on a building and its contents (asset protection).
- Sprinklers can reduce business disruption and building downtime cause by a fire (business continuity).

The above points are considered in greater detail in the following sections, with the exception of trade-offs which are covered in Sections 3 and 4.

9.2.1 Insurance considerations

It is generally accepted that the installation of sprinklers reduces the risk of loss or damage to the contents and fabric of a building, by giving early detection and reducing the growth of a fire. These points are recognised by insurance companies, enabling them to offer a lower premium for fire insurance because of a lower cost of claims. In some buildings sprinkler protection will be a condition of carrying the risk.

Financial losses from fire fall into two main categories:

- Direct loss: This includes the direct cost of repairing or replacing damage caused by a fire to the building and/or contents.
- Consequential loss: This includes indirect losses as a result of a fire such as business interruption, loss of profits and revenue.

It has been reported that insurance companies can sometimes offer a 65% reduction in premiums where risk of fire outbreak, size or likely damage is demonstrably less than with an unsprinklered risk. An example of premium reduction is for a paper/plastics warehouse, where an unsprinklered risk would attract a premium of 0.5% of the total building value, whereas a sprinklered risk would attract a premium of 0.115%. Some insurance companies will insist on new and existing premises being sprinkler-protected as a condition of insurance. As an example of the cost benefit of a sprinklered building against an unsprinklered building, a warehouse in east London with a building and contents value of £2.0 million would attract an annual premium for fire insurance of 0.35% of gross value or £7,000. If the same building is fitted with an operational sprinkler system, the premium would be reduced to 63% of gross value or £3,260. The figures above do not include for business interruption insurance which would show a similar difference between sprinklered and unsprinklered premises. Based on these figures the cost of the sprinkler system could be recouped within a few years.

9.2.2 Asset protection

Traditionally, property protection has been the most recognised arena for sprinklers. Properly applied however, life safety provisions go a long way to addressing asset protection. For example, in that much property and contents damage is attributed to smoke, the control of smoke production and movement for life safety purposes as embodied in current guidance, will also address the needs of property protection. The same can be said for heat production from fires. Sprinklered fires, in being smaller, will be producing less smoke and heat, thus less property damage should arise.

From the results of a survey published in Fire Prevention Science and Technology No.17 70% of a compartment area could be expected to be involved in a non-sprinklered fire, with 50% or more of the building structurally damaged. The same report stated that it could be expected that 9% of a compartment area could be involved in a sprinklered fire, with no structural damage.

9.2.3 Business Continuity

The term 'asset protection' may have been limited to the structure and contents of a building. In the event of fire however, productivity and general business losses should be included and are sometimes the subject of insurance claims. Some insurers report that the economical impact of a fire on a business is such that 80% of businesses that experience a fire do not re-start.

In many circumstances reduced trade and business as a result of a fire can have a far greater financial impact than the material damage resulting from a fire. An example would be a fire in a food processing facility in which smoke contamination could cause shutdown of production while the clean-up operation was undertaken. In this respect, a fire is less likely to cause damage if it is sprinklered due to the reduction in fire size/smoke produced.

Schools are another example where sprinklers have significant benefit in ensuring the on-going operation of a school. If a fire is started and is successfully controlled by a sprinkler, the down-time of the school could be less than a day.

9.2.4 Flexibility of Design

The flexibility addressed in this paragraph is that expected within the application of 'traditional' codes i.e. the extension of the normal bounds of fire precautions as opposed to the 'unusual features' discussed in section 4. This flexibility may only be possible and successful with the use of fire safety engineering.

Where a design of system or detail can be achieved under unsprinklered fire conditions, the advantages of a sprinklered fire may provide increased design flexibility - as a result of smaller and well defined fire size, smoke volumes, heat output etc. For example, it may be possible with sprinklered premises to provide protection to a lower standard of fire resistance than would otherwise be accepted. There is a wider range of protection systems and solutions with lower standards of protection. Thin film intumescent are more widely available at the lower periods of fire resistance. Panel sizes and pane thicknesses in fire resisting glazing are larger and thinner at the lower periods.

If the advantages of sprinkler protection are recognised and can be incorporated in a design, there are a number of areas where flexibility may be available to the designer. Aspects of the design where some advantage can be expected include:

- i. increased compartment volumes and sizes, leading to extended travel distances,
- ii. a reduction in periods of fire resisting separation between compartments,
- iii. reduced standards of fire resistance to elements of structure with savings in protecting materials and increased choice,
- iv. increased unprotected areas relative to adjacent boundaries with reduction in fire resisting materials on elevations and increased areas of external glazing, and
- v. reduced number of firefighting shafts with savings in the number of shafts required, thus giving greater usable floor area.

9.2.5 Sustainability and Environmental benefits

Sustainable development means consideration of the natural environment, with concern for the socio-economic needs of present and future generations.

When selecting the fire protection measures for a building consideration should be made with regards to sustainability. The commonly used methods and materials that are used for providing fire protection often utilise materials from non-sustainable sources, and require excessive amounts of CO₂ in their manufacture. Until recently Halon was commonly used as a fire suppression mechanism. This is now banned due to its overall effect on the ozone layer. This has forced us to consider alternatives, some of which can be considered to be more sustainable than others, such as water based suppression systems.

The products of a building fire discharged into the environment are primarily dependent upon the materials burning. The presence of plastics and modern materials, even fire retardants, can lead to significant amounts of toxic gases being emitted into the atmosphere. All building fires discharge large quantities of hydrogen chloride (HCl), hydrogen cyanide (HCN) and large amounts of carbon monoxide (CO).

The provision of sprinklers can enable mitigation and limitation strategies to be developed to address sustainability issues in the design and alteration of buildings. Sprinklers may not only provide benefits in terms of costs and life safety but also can impact on environmental issues, either by limiting the damaging effect of fire or by enabling reduced passive fire protection measures. Typical examples of this are:

- Reduction of fire doors and dampers.
- Reduction of fire resisting partitions and walls.

- Reduction of fire resisting glazing.
- No need to construct temporary and permanent accommodation as large destructive fires are prevented.
- Reduced amounts of fire and smoke damaged contents require disposal post fire.
- Reduced need to provide additional transportation to alternative sites.
- Reduced impact on the habitats of wildlife.
- Prevention of loss of important documents (historical importance to future generations) .
- Reduced exposure to harmful materials and substances such as asbestos that may be release in a large fire.
- Reduced risk of polluting ground, air and watercourses.

The Scottsdale Report (1985-1995) evaluated all sprinkler systems Scottsdale, USA, where sprinklers have been compulsorily installed in all new single family, multi-occupied and commercial buildings since 1985. The evaluation revealed that the installation of sprinklers led to a 95% reduction in environmental damage.

9.3 Costs associated with providing sprinkler systems

9.3.1 Capital costs

The main cost associated with the incorporation of sprinklers is the capital cost of the installation. Estimating the cost of sprinkler pipe work and sprinkler heads can be relatively straight forward (usually on a £/m² basis). However the water supply requirements can vary considerably depending on:

- The availability of town's main supplies and water pressure.
- The height of the building.
- The hazard classification.

Guide prices for installations including sprinkler heads, all associated pipework, valve sets, booster pumps and water storage have been estimated as being:

System Classification	£/m ² of serviced area (Outer London, June 2004) (exclusive of VAT) [48]
Light Hazard	23-28
Ordinary Hazard	27-37
Extra-High Hazard	33-39

Note 1: Costs are project specific and subject to change. While the above figures could be used for rough estimates, a detailed estimate should always be made when sprinklers are being considered.

An alternative guide to sprinkler system capital costs is as a percentage of the build cost.

For school premises, the costs of providing sprinkler protection has been estimated as being between 2 and 3% of the construction cost when sprinklers are included in the original design brief. This excludes mark-ups by main contractors or project professionals.

9.3.2 Maintenance costs

Annual maintenance costs should also be factored in to the cost benefit analysis. Again it is advisable to seek accurate maintenance costs for the specific system type to be installed when undertaking cost/benefit studies. As a guide the following typical maintenance costs could be expected:

Protected building	Typical maintenance cost per annum
Small domestic property	£75
Small school	£250-£350
Large school	£500-£750
Large warehouse or retail premises	£750-\$1500

9.4 Comparative Examples

For the purposes of this section, four buildings are examined from the application of the England and Wales Building Regulations and its supporting Approved Document 'B'(2) (A D), plus relevant British Standards. In all other respects than those highlighted, the buildings should be assumed to conform to the recommendations of the AD. A summary of differences with and without sprinkler protection is included with each example.

9.4.1 Office Building <30m height

The model is an 8 storey, steel-framed structure, 27m high with storey floor area 2,000m², 25m x 80m long, total floor area being 16,000m². A minimum of four stairs would be required for normal use. The building is to be located 10m from the relevant boundary and the design preference is for 60% glazing along the building length.

Requirements without sprinklers	Requirements if sprinklers were provided (trade-offs)
90 minutes fire resistance for the structure	Reduced to 60 minutes
3 firefighting shafts recommended (including firefighting lifts)	Reduced to two firefighting shafts (including firefighting lifts)
The remaining stair would require 90 minutes fire resistance	The remaining two stairs would only require 30 minutes fire resistance
To meet external fire spread requirements for 60% unprotected façade floors would need to be compartmented in pairs (requiring firestopping or fire dampers at each of the three compartment floors)	With sprinklers there would be no need for compartmentation to meet 60% unprotected façade – Therefore no requirement for compartment floors (hence no firestopping/dampers between floors)

9.4.2 Department Store

The design brief is for city centre, five storey, steel-framed department store of 6,000m² floor plan, 100m x 60m wide and 25m height. Six stairs/lifts cores are required for normal building use. The distance to the centre of the road boundary is 10m.

Requirements without sprinklers	Requirements if sprinklers were provided (trade-offs)
90 minutes fire resistance for the structure	Reduced to 60 minutes
Each floor to be divided into at least four	Each floor would only need to be divided into

separated sections by 90 minute fire resisting walls to satisfy fire compartmentation and external fire spread requirements.	two separated compartments by 60 minute fire resisting walls to satisfy fire compartmentation and external fire spread requirements.
Seven firefighting shafts would be required (each with a firefighting lift)	Five firefighting shafts would be required (each with a firefighting lift)

9.4.3 Warehouse

The design brief is for an extensive steel-framed, single-storey warehouse, 15m high and located 20m from the relevant boundary. The floor area is 16,000m² and the preferred dimensions 250m x 60m. The contents are 'high fire risk' as defined in the Approved Document (Table 3, Note 6) which normally limits the travel distances to final exits to 25m.

Requirements without sprinklers	Requirements if sprinklers were provided (trade-offs)
60 minute fire resistance for the structure and for external walls required to be fire resisting	30 minutes fire resistance for the structure and the walls required to be fire resisting
Without sprinklers, 55% of the wall parallel to the boundary and its supporting structure would have to provide 60 minutes fire resistance.	With sprinklers, only 15% would have to be fire-resisting and at the lower period of 30 minutes.
Without sprinklers the risk may warrant the provision of fire resisting corridors within the building to limit travel distances.	With sprinklers, a fire engineered approach could be adopted to justify extended travel distances within the space.

9.4.4 Domestic

The design brief is for a four storey town-house to be built for sole occupancy. The height of the topmost storey is 8.5m above ground level.

This comparison will be on the basis of the proposed amendments to Approved Document B, as described in section 3.3.1 of this report.

Requirements without sprinklers	Requirements if sprinklers were provided (trade-offs, based on proposed amendments to ADB)
<p>The building should be provided with a protected escape stair serving all levels with an additional alternative escape route provided from the topmost storey.</p> <p>If the alternative escape route is provided by a second internal stair it will require to be separated from the remainder of the accommodation by 30 minute fire resisting construction.</p> <p>If the alternative escape route is provided by an external stair, it will require weather protection and areas of the external wall within 1800mm of the stair will require 30 minutes fire resistance. Any glazing in the fire resisting areas of the wall will</p>	<p>The building should be provided with a protected escape stair serving all levels.</p> <p>There would be no requirement for a secondary escape stair.</p>

need to be 30 minute fire resisting (integrity only).	
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10 Common Misconceptions About Sprinklers

Some of the more substantive misconceptions with sprinklers and systems are examined in this Section.

10.1 Aesthetics

Where sprinklers are seen to be appropriate, their use in sensitive interiors is being addressed by the development of concealed heads, coloured and smaller sized heads and moulded surrounds. Examples of how sprinkler heads and pipework may be concealed can be found in Historic Scotland's Technical Advice Note No. 14: The Installation of Sprinkler Systems in Historic Buildings (1998). [40].

10.2 Active/Passive Reliability Debate

It is sometimes perceived that passive systems are more reliable than active systems (here limited to sprinklers). The impression given is that passive systems are seen, easy to maintain or require no maintenance and are long-lasting, requiring little or no attention in their lifetime. In practice however, many passive provisions are unseen and may be incomplete from the time of their installation or poorly maintained, in either case leading to false security and poor performance in fire. Well documented examples of this include wedged-open or poorly fitting fire doors, punctured or incomplete cavity barriers and non-existent or poor fire-stopping.

Insufficient concrete cover to reinforcement and the wood-wool 'scare' of a few years ago should also be included. The undesirable outcome of many (including major) fire incidents have been attributed, in part at least, to the poor performance of passive systems.

The criticism of the (active) sprinkler system is that they may not be working when required, instances are known where they were turned off etc. The accumulation of statistics over many decades on sprinklered buildings and their comparative performance with non-sprinklered premises however, gives a very different story [45]. Further, the potential performance of active systems are more easily monitored effectively. Their state of readiness can be known and monitored and the measures required to increase their readiness are conceptually simple and inexpensive.

The performance of sprinkler systems in terms of reliability is exceptionally high compared to other forms of protection, even for systems installed to older regulations. British Standard 5306 Part 2 and the Loss Prevention Council Rules ensure stricter design and maintenance criteria to raise performance and reliability parameters further.

10.3 Water Damage

The concept is that with a sprinkler system, a disproportionate level of water damage will result over that from normal fire fighting operations. This idea may be largely based on the misconception that in a fire, a large number of sprinkler heads operate as a matter of course.

In fact, the vast majority of sprinklered fires (85%) are controlled with less than four heads operating, 65% from only one head [45]. Further, water usage is much reduced from sprinklers over that required by fire hoses. The Bailey Report [46] quotes LPC figures of 30-100 litres/minute from each sprinkler head as compared to 600 and 1100 litres/minute from hand-held fire brigade hose and platform monitor respectively. Water from a sprinkler head is 6-10 times less than that expected from fire fighting operations.

10.4 Accidental Operation

The concept here is that the water-filled sprinkler system is prone to unwanted operation leading to water damage. Such action is seen to be initiated by accidental or malicious breaking of a sprinkler head or by the leaking or breaking of the water supply system. Statistics state the likelihood of a

sprinkler head operating spuriously is 1 in 500,000. The incidence of accidental operation due to mechanical damage is statistically low and can be mitigated against by provision of sprinkler head guards.

10.5 Interaction with Smoke Layers

The interaction of buoyant fire products with falling sprinkler spray is seen to be counter-productive in that the spray is thought to bring down the smoke layer which would otherwise be above the heads of escapees and fire-fighters. Some such behaviour can be observed in experimental fires (unless the sprinkler spray is applied from the side, beneath the rising smoke). But the advantages of the sprinklered fire over one unsprinklered in terms of combustibles burnt, volumes and smoke temperatures and quantities of toxic products, far outweighs any disadvantage of bringing down the smoke (27). Full scale fire tests conducted by Colt at their Ghent laboratory, confirm that the problem is minimal for means of escape (31). By the time sprinklers are operating, persons are moving away from the immediate fire area.

10.6 Reliability

The concern is that when required, a sprinkler system may not be working properly, or at all, the concern being backed up by an awareness of fires occurring while systems have been turned off. These happenings should however be seen in the context of the successful operation of sprinkler systems where reliability figures are typically in the upper 90's% (over 99% in Australasia). Of the small number of failures recorded by a recent U.S. study, 2/3rds of recorded failures are due to valves that were shut before the fire began. The British Standard and LPC Rules now mitigate against even this small failure rate. The reasons for failure are well known and ways of improving reliability can be introduced, using Australian/New Zealand experience or by increased monitoring by linking to other well-used facilities. PD 7974-7 gives the following values for the probability that a sprinkler system will operate successfully on demand:

- Maximum: 95% (applicable to new systems in areas where statutory enforcement is in place)
- Typical: 90% (new life safety systems) or 80% (new property protection systems).
- Minimum: 75% (older systems)

The above values assume that no more than four sprinkler heads operate. This was considered as the limiting case for a "successful" sprinkler operation, as no more than four heads operating is the fire size typically used in a fire engineering study.

10.7 Maintenance Costs

With sprinkler heads being effectively maintenance free, any costs associated with maintaining a sprinkler system will be associated with weekly tests to alarm gongs, and the upkeep of additional water supply/alarm equipment.

Maintenance costs are difficult to quantify as they are dependent upon the equipment used, however, typical costs are given in 9.2.3.

10.8 Sprinklers and *Legionella pneumophila*

Legionellosis is the generic term used to cover diseases caused by bacteria from the genus *legionella*. This genus can cause legionnaires disease in susceptible individuals and can cause Pontiac fever in otherwise healthy individuals. The disease is contracted by inhaling fine aerosols from a water source contaminated with legionella.

Therefore for human infection to occur, any legionella present in a sprinkler system would have to grow to an infectious level, be present in an aerosol and be inhaled by a susceptible individual.

Some form of legionella will probably be present in all water systems, including water that comes from the mains. However, the issue is whether or not the conditions within a sprinkler system would support the existence and growth of the legionella genus.

Generally the conditions within the sprinkler system are not thought to be able to support the growth of legionella, although there is the possibility that a poorly maintained tank might offer conditions for legionella to multiply. For this to occur the tank would need to allow organic material and heat to enter.

The Loss Prevention Council have issued Technical Briefing Note No.14 Legionella and Fire Fighting Systems (1999). This note covers the subject of legionella and fire fighting systems (FFS). In the note it gives the following recommendations for controlling legionella:

- Incorporate FFS into any existing legionella monitoring system for the site;
- Minimise production of aerosols during testing and maintenance
- Maintain tanks and piping at < 20°C by shielding from possible heat sources
- Annual inspection of tanks to monitor corrosion and deposit build-up, with appropriate remedial actions.
- Annual monitoring of water tank bacterial concentration by dip slide. Concentrations above 10⁵ cfu/ml indicate that chemical treatment of the water may be necessary.

Therefore sprinkler systems that are fed directly from the public mains water presents no significant risk of infection, however there is the possibility that poorly maintained sprinkler water tanks could present a risk of infection but this would be most likely restricted to those working on the sprinkler system and the chances of an infection being acquired must be considered remote in the extreme.

11 Limitations in the Use of Sprinklers

11.1 Enclosed Structures/Areas

Where fire originates within vehicles, cabinets or fire-resisting structure, the enclosure may inhibit sprinkler action by shielding. The operation of sprinklers outside these enclosures may still offer the benefit of controlling additional spread whilst not extinguishing the fire at its source.

11.2 Excessive Height

Sprinkler operation may be delayed and resulting fire size excessive due to vertical distance between fire and sprinkler head. There is also the risk that sprinkler operation may not be related to fire-location. Rising fire products may be deflected sideways and any sprinklers that operate as a result may not be above the fire. BS 5588 Part 7 suggests height limits for which sprinklers will cease to be effective in controlling fires to a specified size – refer to section 5 of this report for further information of the potential impact of sprinklers on fire sizes. An alternative system for the protection of atrium bases is referred to in Section 7.5.

11.3 Electrical Apparatus

Of limited significance since there are other 'active' measures of detecting and fighting electrical fires, the use of sprinklers in such environments is not recommended. This is particularly so where there is a danger of electricity conduction through water spray and run-off. Water spray systems may be used for the protection of transformer and other oil filled electrical apparatus.

Other options for treatment of electrical installations include:

- Gaseous suppression systems
- Enclosure of item in fire resisting construction

11.4 Sensitive Interiors

While sprinkler systems have been shown to be very reliable, the introduction of sprinkler system to a building does introduce an additional water source that could potentially lead to water damage due to leakages if faulty. The additional need for fixings, supports and routing of pipework may also impact on the building fabric.

Where it is imperative to protect the building fabric or its contents from water damage, the use of passive fire protection measures or management controls to minimise fire risk should be considered. It is worth noting however that an unsprinklered fire may result in considerably more damage, due to the spread of fire and smoke and the water used to extinguish it (refer section 10.3). A fire risk assessment can help to inform the decision making process.

11.5 Availability of Water Supplies

Water supplies to sprinkler systems which have been taken from a towns main connection and which at the time of installation met the demand characteristics, may have been subject to pressure reduction, by the water supplier and therefore have impaired efficiency. This situation should be recognised under the testing procedures required to meet BS5306 Part 2 and the fire risk assessment process. If water supplies are found to be insufficient, on-site storage of water may become necessary.

11.6 Extreme events

The effectiveness of sprinklers in controlling fires is well documented. However, situations can arise where a fire occurs as a result of an impact or explosion. In such situations the sprinkler system may suffer mechanical damage which can affect water supply and reduce the effectiveness of the system or render the system inoperable. If such events are to be designed for then careful consideration should be given to sprinkler system layout and detailing to reduce the risk of the system being affected. E.g. increased zoning of system, greater protection to distribution pipes etc.

It should be recognised however that most fire protection measures are vulnerable to extreme events, including passive fire protection, means of escape provisions and firefighting facilities. At present the Building Regulations fire safety guidance does not require buildings to be designed to withstand extreme events.

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Appendix A

**Sprinkler trade-offs in
current fire safety
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Table 2: Sprinkler Trade-offs in current guidance

Approved Document B – Fire Safety (England & Wales) (2000 edition consolidated with 2000 & 2002 amendments)	
<p><u>Means of Escape</u></p> <p>All buildings (except in the residential purpose group and car parks for light vehicles) over 30 metres high must be sprinklered to 'life safety standard'. This requirement compensates for the difficulties the fire service have in performing external rescue at this height.</p> <p>Note 1: Discounting of stairs is still required for calculations associated with occupancy in sprinklered buildings (5.13). Access lobbies or corridors to staircases are still required in sprinklered buildings unless stair design includes for discounting (5.24d).</p> <p>Note 2: The ODPM is considering introducing a requirement for sprinklers in residential building over 30m – see following section.</p> <p>Enclosed walk-in store rooms of shops do not require to be fire separated if they are fitted with a sprinkler system.</p> <p><u>Compartmentation</u></p> <p>Maximum dimensions of building or compartment are increased for many purpose groups if the premises are sprinklered (to 'life safety standard')</p> <p><u>Fire Resistance</u></p> <p>Reductions in the fire resistance of elements of structure are permitted in sprinklered premises (to 'life safety standard') for most purpose groups other than residential.</p> <p><u>Mechanical smoke extract from basements</u></p> <p>As an alternative to natural venting, mechanical smoke extract can be used provided the basements are sprinklered (19.13).</p> <p>Note: The exception is basement car parks where mechanical ventilation may be used in the absence of sprinklers.</p> <p><u>Firefighting Access</u></p> <p>The number of firefighting shafts can be less in sprinklered premises.</p>	<p>Clause 5.20d and Table A2</p> <p>Clause 6.54.</p> <p>Table 12</p> <p>Table A2</p> <p>Clause 19.13</p> <p>Clause 18.7 and Table 22</p>

<p><u>External Fire Spread</u></p> <p>Space separation between buildings can be modified where sprinklers are fitted due to reduced fire intensity. The boundary distance as determined by the various methods, may thus be halved for sprinklered premises (14.17) and the permitted radiating areas ("unprotected" in AD) in compartments or small buildings can by implication, be increased (Table 16, Note b).</p> <p>Where external walls of portal frame buildings require fire resistance to restrict fire spread to other building, the SCI recommendations for special foundation/connection design do not need to be followed if the building is sprinklered to life safety standard (13.4, Note 1).</p>	<p>Clause 14.2b, Clause 14.17, Table 16, Note b</p> <p>Clause 13.4, Note 1</p>
<p>Scotland – Technical Handbooks for Domestic and Non-domestic Buildings (2005 edition)</p>	
<p><u>NON-DOMESTIC</u></p>	
<p><u>Compartmentation</u></p> <p>Maximum compartment areas can be increased where there is automatic fire suppression.</p> <p><u>Fire resistance</u></p> <p>For buildings with different uses sprinklers allow a lower fire resistance duration. Reduced fire resistance of external walls is permitted if sprinklers are present. Also reduced boundary distances are permitted for shop, entertainment, Class 1 factory and storage buildings if sprinklers are present.</p> <p><u>Occupancies requiring sprinklers</u></p> <p>Residential care buildings, enclosed shopping centres and sheltered housing require life safety sprinklers (2.15.1).</p> <p>Some areas in hospitals may require automatic fire suppression (depending on hospital layout).</p> <p>Exceptions for areas of sprinkler coverage in shopping centres are given in Annex 2C (e.g. car parks, malls >10m in height, stair enclosures).</p> <p><u>Mechanical ventilation of basements</u></p> <p>Basements can be provided with mechanical ventilation for fire service use if they have automatic fire suppression (2.14.7).</p>	<p>Clause 2.1.2 and 2.1.3</p> <p>Clause 2.1.5</p> <p>Clauses 2.6.1, 2.6.2 & 2.6.3</p> <p>Clause 2.15.1</p> <p>Annex 2B</p> <p>Annex 2C</p> <p>Clause 2.14.7</p>
<p><u>DOMESTIC</u></p>	
<p>High rise domestic occupancies (including blocks of flats) require a life safety fire suppression system (Standard 2.1.5).</p> <p>Note: High rise is defined as having a storey >18m above ground.</p>	<p>Standard 2.1.5</p>

Northern Ireland – Technical Booklet ‘E’ – Fire Safety

Means of Escape

All buildings (except in the dwelling purposes group) over 30 metres high are required to be managed under phased evacuation and must be sprinklered to 'life safety standard'.

Clause 1.49c) and Table 3.2

Note: By implication discounting of stairs is still required for calculations associated with occupancy in sprinklered buildings (1.47).

Compartmentation

Maximum dimensions of building or compartment are increased for many purpose groups if the premises are sprinklered (to 'life safety standard')

Table 3.4 and Note 1

Fire Resistance

Reductions in the fire resistance of elements of structure in sprinklered premises (to 'life safety standard') for most purpose groups other than residential.

Table 3.2, and Note 3

Mechanical Smoke Extract from Basements

As an alternative to natural venting, mechanical smoke extract can be used provided the basements are sprinklered.

Clause 5.12

Firefighting Access

The number of firefighting shafts can be less in sprinklered premises.

Clause 5.3a and Table 5.1 (but note anomaly of para 5.4)

External Fire Spread

Space separation between buildings can be reduced where sprinklers are fitted due to reduced fire intensity (4.6b). The boundary distance as determined by the various methods, may thus be halved for sprinklered premises (4.1 1) and the permitted radiating areas in small buildings or compartments can by implication, be increased (Tables 4.3 and 4.4).

Clause 4.6b, 4.11 and Tables 4.3 and 4.4

British Standards 5588 Series:

Fire precautions in the design, construction and use of buildings

The 5588 Series provide a direct supporting role to the guidance above, usually providing greater detail on specific areas of design.

BS 5588 Part 4 – Smoke control using pressure differentials

This guidance document has now been superseded by BS EN 12101-6:2005 Smoke and heat control systems – Specification for pressure differential systems – Kits.

Sprinklers allow temperature rating of fans and ductwork to be reduced where mechanical air release is adopted.

BSEN 12101-6
Table 7

BS 5588 Part 5 – Firefighting Shafts

The number of firefighting shafts can be less in sprinklered buildings (7.1.2 and Table 5). Note the requirement is similar, but not identical to the Approved Document B recommendation.

Clause 7.1.2
and Table 5

Sprinklers in firefighting lobbies should be sited so they do not drench lift landing doors/controls (7.2.8).

Clause 7.2.8

Sprinklers permit the use of mechanical smoke exhaust from basements (13.3.3).

Clause 13.3.3

Guidance is given on access to sprinkler infill points (5.4.2.b).

Clause 5.4.2b

Manual overrides to sprinkler systems are required in the fire control centre (10(3)).

Clause 10(3)

BS 5588 Part 6 – Places of Assembly

Where a safety curtain is provided to stage areas it should be protected with a hand operated drencher system (13.2d - 9,10,11).

Clauses 13.2d -
9,10,11

Areas in which sprinkler coverage is recommended include: exhibition halls, stage areas and storerooms for hazardous substances. (25.2).

Clause 25.2

The relationship between sprinkler systems and smoke control for means of escape, is covered (30.2.3,c,2,and 30.2.4.2,b,1 and 2).

Clauses 30.2.3
and 30.2.4

BS 5588 Part 7 – Atrium Buildings

Sprinklers can be used in conjunction with smoke retarding construction and/or a temperature control system to maintain compartmentation between storeys (8.2(b), 16.1)

Clause 8.2(b),
and Clause 16.1

If practicable, sprinkler protection to the atrium base can allow fire load in the atrium base to be the same as the associated floor areas (10 and 27b(3)).

Clause 10 and
27b(3)

Sprinklers permit the use of pressurization as a means to protect escape routes (17.1c(2)) and 24.6(1).

Clauses 17.1©
and 24.6(1)

Section 18 gives general design considerations for sprinkler systems and atria.

Section 18
(refer exemplar)

A number of atrium types require sprinkler protection to the associated floor areas (see Exemplars).

Sprinklers can assist in means of escape design incorporating balcony escape (22.2).

Clause 22.2

Sprinklers allow smaller design fires to be considered hence less onerous smoke control provisions (24.3).

Clause 24.3

A sprinklered atrium building may be treated as a building with compartment floors when assessing external fire spread to adjacent sites (28.2).

Clause 28.2

A lower smoke clearance air change rate is required for firefighting in sprinklered atrium buildings (29.2.2) – 4 air changes per hour as opposed to 6.

Clause 29.2.2

<p><u>BS 5588 Part 10 – Shopping Complexes</u></p> <p>Enclosed shopping centres are required to be sprinklered. 'As a means of appropriately restricting fire growth in covered complexes, 'sprinkler protection is fundamental' (5.3).</p> <p>Use of sprinklers in malls allows retail flexibility (5.3).</p> <p>The required extent of coverage and maintenance requirements of sprinkler systems are give (18.2).</p> <p>Recommendations are given for the protection of car parks (10.3.2(5)).</p> <p>Design fire sizes for are suggested for sprinkler controlled fires (20.2).</p> <p><u>BS 5588 Part 11 – Shops, offices, industrial, storage</u></p> <p>Recommendations are given for the extent coverage (where provided) (37.2).</p> <p>Recommendations are given with respect to special risk protection (37.3.2).</p> <p>A reduced number of firefighting shafts is permitted if building is sprinklered (40.4.2 & Table 12)</p> <p><u>BS 5588 Part 12 – Fire Safety Management</u></p> <p>Guidance is given in relation to inspection/maintenance of sprinkler systems (where provided)</p>	<p>Clause 5.3</p> <p>Clause 18.2</p> <p>Clause 10.3.2(5)</p> <p>Clause 37.2</p> <p>Clause 37.3.2</p> <p>Clause 40.4.2 & Table 12</p> <p>Clauses L2.4, L3.3, L6.1 & L6.7</p>
<p>Healthcare Technical Memoranda (HTM's)</p>	
<p><u>HTM 81 - New Hospitals</u></p> <p>Sprinklers permit reduced fire resistance of compartment walls and the minimum compartment floor areas required for progressive horizontal evacuation are reduced (5.4 to 5.10).</p> <p>Sprinklers allow unlimited amounts of glazing in sub-compartment walls (5.27 to 5.29).</p> <p>Sprinkler permit reduced fire resistance to elements of structure (6.2 to 6.4 and 6.10).</p> <p>There is no requirement to use materials of limited combustibility for compartment walls and elements of structure (6.5 to 6.11).</p> <p>Fire hazard rooms do not require a fire resisting enclosure if sprinklered (6.28 to 6.34).</p> <p>Required separation distances between buildings can be halved if sprinklers are provided (6.63 to 6.76).</p> <p>A reduced number of firefighting shafts is permitted if sprinklers are provided (7.19 to 7.20).</p>	<p>Clause 5.4-5.10</p> <p>Clause 5.7-5.29</p> <p>Clause 6.2 to 6.4 and 6.10)</p> <p>Clause 6.5 to 6.11</p> <p>Clause 6.28 to 6.34</p> <p>Clause 6.63 to 6.76</p> <p>Clause 7.19 to 7.20</p>

<p><u>HTM 86 & SHTM 86– Fire risk assessment in hospitals</u></p> <p>If sprinklers are provided they may be used to partly compensate for higher levels of risk/hazard or deficient precautions when undertaking a fire risk assessment.</p>	<p>Section 33</p>
<p><u>Scottish Health Technical Memorandum (SHTM) 82, Supplement A – Automatic fire control systems and voice alarm systems (for new healthcare premises)</u></p> <p>Where patients are highly dependent and moving the patients in a fire scenario may not be practical or advisable (except as a last resort), patient access areas and adjacent areas below and/or above should be provided with an automatic sprinkler system.</p> <p>This affords a very high degree of protection for highly dependent patients, which may reduce the need for patient evacuation and allow staff to remain in attendance for a longer period of time.</p>	<p>Clause 3.4</p>
<p><u>HTM 88 Fire Precautions in housing providing NHS-supported living in the community</u></p> <p><u>A residential sprinkler system can be used to allow an open plan stairway for a two storey dwelling (instead of a full enclosure to the stairway).</u></p>	<p>Clause 11.4</p>
<p>London District Surveyors' Association Guides</p>	
<p>Although only applicable in Inner London boroughs, these guides enjoy a wider application than implied from the source of publication, since they have been unique in addressing the particular issues.</p>	
<p><u>LDSA Guide No.1 – Section 20 Buildings</u></p> <p><i>Section 20 of the London Building Act (hence the guidance of LDSA guide No.1) only applies to the area administered by the former London County Council. This includes the following boroughs: Camden, Greenwich, Hackney, Hammersmith and Fulham, Islington, Kensington and Chelsea, Lambeth, Lewisham, Southwark, Tower Hamlets, Wandsworth, and Westminster.</i></p> <p>Sprinklers required in all applicable buildings that exceed the height/volume limits of section 1.02 of the guide with concessions for flats/maisonettes, and open sided car parks (2.07), with subsequent design fire sizes for smoke control provided (2.10 and 2.11).</p> <p>Vent shafts for internal firefighting stairs are not required in sprinklered buildings (2.15(3))</p>	<p>Clauses 2.07, 2.10 and 2.11</p> <p>Clause 2.15(3)</p>

<u>LDSA Guide No.3 - Phased Evacuation</u>	
Automatic smoke detection not necessarily required in sprinklered building (2.3-10,16, Appendix DI Note b).	Clause 2.3.10-16 & Appendix D
Requirement for sprinklers in high rise buildings (>28m) with system included in the Fire Certificate (2.4).	Clause 2.4
Smoke control is required and should be modified in sprinklered premises (2.5).	Clause 2.5
Access for fire brigade - no concessions made for sprinklered premises (2.9).	Clause 2.9
Building Research Establishment Documents	
The BRE documents are often referred to for design of smoke ventilation, particularly in shopping centres.	
BR 186 - Smoke Ventilation in Enclosed Shopping Centres	
Sprinklers within shops and malls - design fire size, limiting fire size and cooling smoke to assist means of escape (Chapter 2).	Chapter 2
<u>BR 368 – Design Methodologies for Smoke & Heat Exhaust Ventilation</u>	
Interaction of sprinklers with smoke ventilation systems is considered.	Chapter 11
Loss Prevention Council	
The LPC Design Guide for the Protection of Buildings 2000	
The LPC design guide primarily provides recommendations for fire protection in connection with business risk management.	
Reduced fire resistance for elements of construction and compartmentation is allowed if the building is sprinklered.	Table 2.1 & 2.2
Compartment areas may be increased if the building is sprinklered	Table 2.3
Recommendations for sprinkler design are provided in Clause 2.7.	
Sprinklers permit uninsulated door openings in compartment walls.	Clause 3.2.2.2
Additional measures for preventing vertical fire spread up the exterior of the building are not required if the building is sprinklered.	Clause 3.3.1.3
Sprinklers provide one option for the protection of large ceiling voids (>600mm) containing cables.	Clause 4.7
Sprinklers are recommended for the protection of atrium buildings	Section 7
Fire Safety – An Employer’s guide	
This document is used by employers when undertaking a fire risk assessment as required by Fire Precautions (Workplace) Regulations and the Management of Health & Safety at Work Regulations.	
Sprinkler systems can be taken into account when undertaking a fire risk assessment of a building. Sprinklers are acknowledged as an effective means of reducing the risk to life from fire.	Page 62

Guide to Safety at Sports Grounds

Consideration should be given to the provision of sprinklers in high fire risk areas, e.g. large store rooms or underground car parks, when situated under or adjacent to spectator accommodation.

Clause 15.13

British Standard DD 9999

DD 9999 is a Draft for Development and when published in due course as BS 9999, it will supersede a majority of the BS 5588 series of British Standards, which will then be withdrawn. The guidance in DD 9999, in particular for means of escape, is based on fire safety engineering principles, although it is not intended as a guide to fire safety engineering.

The concept behind the development of DD 9999 is that technical guidance on fire safety is provided for the user at three different levels. This permits the user to adopt a design approach that corresponds to the complexity of the building and to the degree of flexibility required. This document recognises the following advantages of incorporating sprinklers. Examples are as follows:

- The successful action of sprinklers can avoid flashover and reduce probability of fire spread between buildings. Consequently boundary distances can be reduced
- The successful action of sprinklers can significantly reduce rate of fire growth, avoid flashover and reduce the need for fire resistance and traditional levels of compartmentation.
- Automatic sprinkler installations can provide an efficient means of fire control within a building compartment. Such provision limits fire growth, fire spread, heat and smoke generation and can extinguish the fire, or at least reduce the fire growth rate. This means that if sprinkler systems are installed, the fire growth rates can be taken to be one category lower than if no sprinklers are provided. **EXAMPLE** The provision of an automatic sprinkler installation appropriate to the building risk category permits a reduction in the risk profile giving a larger allowable travel distance and smaller doors. An unsprinklered building with a risk profile B3 would have the risk profile reduced to B2 with the introduction of a suitable automatic sprinkler system. This would also have the effect of reducing a "not allowable" B4 profile to a B3 category.

Smoke and fire spread are major causes of property, contents and business interruption losses and the detection and control of these aspects will reduce their effects. The inclusion of sprinklers as a significant measure to reduce fire severity and development would usually provide significant property protection, and could also result in significant reductions in other areas of fire precautions. The issues of life safety and property protection when addressed together result in mutual benefit.