Fire Protection Association

ACTIVE FIRE PROTECTION GUIDE
Suppression and Extinguishing Systems Series Overview

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1 Introduction

This document is part of a series of Active Fire Protection Guides (AFPGs) produced by the RISCAuthority Suppression & Detection Working Group to provide summary information on the main types of fire protection technologies currently available.

For the purposes of this guide 'Active Fire **Protection**' is a general term used to describe all '**suppression**' and 'extinguishing' system technologies. It is recognised that the term 'Active Fire **Suppression**' is commonly used to mean all systems, but this has been shown to introduce legal confusion into the performance expectations of the considered system. In this guide, the clear differentiation is as follows:

- an 'extinguishing system' requires no further actions to end the fire event,
- a 'suppression system' acts to control and contain the fire for a period of time to allow other actions to be taken to finish the job off – such as arrival of the fire service.

Many legal cases, where 'extinguishing systems' have failed to perform their function have been complicated by the use of the term 'suppression system' on the sales and marketing documentation.

This guide provides overarching information to support the AFPG Active Fire Protection Series with information that is relevant to all protection technologies, or where additional information is required to support these deliberately succinct guides.

Active fire protection systems (AFPS) may be installed for many reasons including preservation of life, preservation of property and business, and as a compensatory feature to mitigate issues where other demanded requirements in Building Regulations cannot be met.

Choosing the most appropriate technology for any given situation requires the specifier to understand many important factors, such as the risk that needs protecting, the protection objective and how it fits in with the overall building/business fire management strategy, and the advantages/disadvantages and limitations of each technology type. This document and the associated guides are not intended to give definitive advice on system selection but should be considered as a primer, presenting key 'need-to-know information' for each of the main fire protection technologies, and act as a starting point in collating the relevant information needed to make a good choice of system using the individual documents of the library.

This overarching guide should be read in association with its sister guidance on Detection (AFPG-30) and the guides it refers to.

2 Fire protection basics

To cater for the myriad of potential applications, active fire protection systems come in many forms and use a great variety of media in all of their physical states. In the suppression and extinguishment of fire these systems will all act to restrict one, or a number of the key ingredients of fire, namely the availability of oxygen, fuel, and heat and for the combustion chemistry to be able to progress unimpeded.

In considering active fire protection systems, it is important not to lose sight of the fact that their need for deployment represents missed opportunities earlier in the loss scenario that have not been acted upon. Pre-emptive fire detection through improved levels of monitoring and detection can invoke corrective actions before the situation leads to fire and this represents the most efficient response, with the lowest consequential damage and exposure of personnel (occupant and attending services) to harm. In a similar vein, consideration needs to be given to the role that equipment monitoring and control have to play, as active fire protection systems in their own right. It has been estimated that 90% of all electrical fires will extinguish following the removal of power – this would be an excellent reliability figure for any installed active fire protection system. The design advice therefore is that active fire protection needs to be considered as just one component of holistic fire safety planning and that the objective should always be to prevent the systems from needing to operate, but that if they are required, they should act quickly to save more than they may damage.

Whether proposing sand buckets or an advanced high-hazard sprinkler systems the list of considerations is common. These are outlined briefly below (in no particular order) and commented on in greater detail in the following sections:

- Protection requirement
- Extent of protection
- Control ambition
- Proximity and availability of assistance
- Allied operational control actions
- Measurement criteria
- Installation type
- Personnel safety
- Response time
- Method of operation
- Consequential damage
- System reliability
- Single points of failure/common points of failure
- Testing approval and certification
- System upkeep
- Environmental credentials
- Overall suitability.

2.1 Protection requirement

The starting point for the selection and design of any AFPS is to have a very clear statement of its protection ambition, the timescales on which it must be achieved, what constitutes success or failure, and what its dependencies are in relation to the overall fire safety management plan for the building or business.

Usually, AFPSs are installed for the purposes of one or more of the following:

- Life safety
- Property protection
- As a compensatory feature where other safety requirements of Building Regulations cannot be met.

Life-safety measures are normally at the request of fire safety legislation, whereas property-protection measures are a voluntary part of normal business resilience planning or may be required to satisfy appropriate terms of insurance. **The critical difference between 'life safety' and 'property protection' systems are the timescales and resilience with which the systems must function.** In the protection of a building, a system designed for life-safety is usually installed to assist occupants escape the building only, a relatively short period of time which can be as short as 10 minutes, after which the system has no further role to play. A system designed for property protection must remain effective for a considerably longer period of time, sometimes 90 minutes or even longer, to support and assist the arrival of the fire service or other control measures.

In respect of system resilience and the ability to assure function, property protection systems are normally designed with higher levels of contingency and robust specification for design, installation and maintenance.

2.2 Extent of protection

The key types of AFPS can be categorised in terms of the domain that the supporting standards seek to protect, namely:

- Building protection systems
- Compartment protection systems
- Item (or local) protection systems.

Often these are confused which can lead to inappropriate selection when potential comparisons are being made. They are important to understand in the context of 'onion-skin' protection, where smaller systems that result in lower levels of consequential damage should act to prevent larger systems having to be deployed i.e. the AFPS system protecting the machine that is within a compartment of a building, should operate before the compartment system is needed, and that in turn should operate before the building protection system is required.

An AFPS becomes a building protection system by merit of the standards they are referenced in. The most widely installed building protection system technology is fire sprinkler systems for the protection of commercial premises. The 'building' element confirms that all areas of the building are protected with few exceptions, including hidden voids in ceilings and under floors, and that the water application rates are matched to the hazard in each location. These building system standards go even further still to assure the quality of the products used, the qualifications of the designers and installers, and even the maintenance and surveying regimes applied to their upkeep. There is therefore much more in a name when the term 'commercial sprinkler system' is used, than just describing the water-based technology used.

Compartment protection systems, of which implementations of gaseous and watermist technologies are common, seek to protect only what is in the compartment itself and their jurisdiction goes no further than the passive boundaries of the compartment. Computer server rooms and engine test bays are common examples of where compartment protection systems are deployed.

Item protection, often called local protection, is used where the specific threat that needs to be protected against is allied to a specific piece of equipment and its location. The provision of a highly targeted response, using the most appropriate agent for the specific risks in quantities required to only tackle that risk, offer up the possibility of providing the fastest, most efficient, and minimally damaging response possible.

2.3 Control ambition

As described previously for the purposes of this guide 'Active Fire **Protection**' is a general term used to describe all '**suppression**' and '**extinguishing**' system technologies. It is recognised that the term 'Active Fire **Suppression**' is commonly used to mean all systems, but this has been shown to introduce legal confusion into the performance expectations of the considered system. In this guide, the clear differentiation is as follows:

- an 'extinguishing system' requires no further actions to end the fire event,
- a 'suppression system' acts to control and contain the fire for a period of time to allow other actions to be taken to finish the job off – such as arrival of the fire service.

Even for extinguishing systems, complete extinguishment of a fire is seldom achieved by the application of agent alone, it is usual to additionally require the system to isolate sources of fire sustaining parameters including oxygen, heat, and fuel by way of interlocks built into the overall design (see later).

Other differentiators between extinguishing systems and suppression systems are the time basis for which they operate, and the residual benefit they provide once the application of agent has finished. In general terms:

- Gaseous, aerosol, dry chemical, wet chemical, and specific application systems (such as kitchen systems), are considered extinguishing systems because the fire must be completely put out within or very soon after the agent discharge period (a discharge shot) because if they fail in this action for whatever reason there is little persisting residual benefit from their operation once the discharge has ended.
- Heavyweight water-based systems including commercial sprinkler systems, deluge systems, and water foam systems are considered suppression systems because their design basis does not assume extinguishment is possible, and the role of the system is to contain the fire and prevent spread until additional assistance is forthcoming. Even after exhaustion of the water supplies there can be great residual benefit due to the wetting of fuels and application of foam essentially removing fuel permanently from the fire scenario.
- Watermist systems present a special challenge due to the complexity of their mode of function and relationship with the fire size (see later) – the driving force for steam production. To this end, watermist system are best assumed to be suppression systems, with little residual benefit should the water supplies ever be exhausted due to the small quantities of water used and limited wetting of solid fuels possible.

There is also a need to appreciate the role of the fuels and their presentation to understand if extinguishment or suppression is a viable protection ambition. Extinguishment of accessible liquid fuels, gaseous fuels, and simple surface-only burning solid fuels can be possible, subject to control of the aforementioned factors that can sustain or reignite fires. The assured extinguishment of inaccessible fires of all types, and solid fuel fires, in configurations that allows the fire to burrow or smoulder (such as cardboard and timber) are almost impossible to manage to the point of assured extinguishment, and suppression must be the assumed ambition with a requirement for FRS damping down follow-on actions.

2.4 Proximity and availability of assistance

In association with the aforementioned requirements consideration must be given to the availability and proximity of assistance. Whilst the FRSs are not obligated to protect business and property, any systems installed that make fires safer to approach, or provide facilities that improve effectiveness, such as dry and wet risers and capable hydrants, will court improved intervention by them. Historically fire and rescue service appliances were stationed at locations of major commerce and population density.

New approaches to managing protection of the population within available FRS budgets means that the location and availability of crews are commonly adjusted throughout the day, following the population from places of work to their places of sleep in the evening. It can therefore be quite complicated to understand how long their response might be for a particular weight of response, and the probability of delivery of that response associated with it. Where a location is remote from help in a timely fashion, the AFPS will need to extinguish the fire, or the time of function of a suppression system might need to be adjusted accordingly to suit the local situation.

Insurers have analytical tools available to them through the RISCAuthority scheme that can model with great accuracy the time, weight, and probability of FRS response for the UK that should be consulted in support of AFPS design[a].

Finally, it is worth noting that to reduce the impact of false and unwanted alarms from automatic detection systems, many

[a] RISCAuthority Fire and Rescue Service Response Toolkit

FRSs implement a process of 'call-challenging' to see if the need for a response is real. This can lead to a delay in the provision of assistance or the allocation of a reduced weight response (one vehicle only where more should attend, sending of a lightweight vehicle to investigate, or no response until backed up a 999 call). The local FRS policy needs to be understood as a key contributing factor to the selection and design of the intended AFPS. Again, your insurer, through RISCAuthority, has tools available to it to interrogate local FRS automatic fire alarm call management policies[b] or this can be gained from direct contact with the local service.

2.5 Method of operation

As stated previously, AFPS work by acting on the parameters that fires need to sustain themselves, namely oxygen, heat, fuel, and fire chemistry. The suppression of these parameters may be permanent, such as reducing the oxygen concentration below the threshold the fire needs in the whole compartment and holding it for a period of time, or dynamic, suppressing it at a higher rate than it is being made up from the surroundings, as might be the case when using a portable CO_2 extinguisher.

AFPSs more commonly use a combination of methods to resolve the fire event which are sometimes less obvious. Whilst heat removal from fire is an important feature of commercial sprinkler systems, the dominant mechanism of operation in storage applications is actually fuel removal – as dry fuel such as cardboard, becomes a wet non-combustible material (and hence why it is equally as important for sprinkler heads to deliver water around the fire, as well as on it – a process known as prewetting).

Chemical gaseous systems' dominant mode of operation is heat removal from the endothermic breaking of strong bonds within their molecular structure. It is often a fluoride bond which gives rise to the generation of hydrogen fluoride as a by-product (see later).

2.6 Allied operational actions

Whilst AFPSs attempt to suppress or extinguish fires by the aforementioned methods or removing oxygen, heat, fuel or interrupting the combustion chemistry, there are many forces that may act to keep the fire going as follows:

- Oxygen – fresh oxygen may be introduced through uncontrolled natural or forced ventilation. It may also be available in stored form within the compartment in compressed air systems, or bottled, may be encapsulated in packaging (cardboard boxes, or cushioning), or may even be chemically available within the fuel itself or other materials present.
- Heat – whilst the fire produces heat, other sources that caused the initial fire include electric arcing, electrical heating, frictional heating, radiation and fluid heating, communicated heating from another compartment, and chemical heating.

[b] RISCAuthority Automatic Fire Alarm (AFA) Response Policy Toolkit

- Fuel – more fuel may become available to the fire as a result of spillage and liquid release from damaged systems, from the breakdown of protective layers by the fire to reveal new fuels, from the breakdown of retarding agents, and from the continuation of transport systems (conveyancing) introducing fresh fuel to the fire.

All systems purporting to be 'extinguishing systems' would be expected to be linked with the isolation of all relevant sources of oxygen, heat, and fuel that may act to sustain a fire, or allow it to reignite after the system has been activated. If this is not achieved, then commonly total loss of the item, compartment, and building can follow.

2.7 Measurement criteria

Allied to an AFPSs means of fire control is the specification of required quantities. Most are straightforward, but not all.

- **Sprinkler systems** are specified in terms of their water coverage rate at floor level in litres per minute per metre square (l/min/m^2) where 1 litre distributed over 1m^2 gives a pool 1mm deep. The application rate required for different situations and different stored commodities in a range of formations is determined through large-scale testing. Values of 5 to 40mm/min/m^2 are typical - an intense rainfall event is 0.3 l/min/m^2.
- **Inert gas and CO_2 systems** are specified in terms of the amount of agent that must be added to displace the required amount of oxygen from the enclosure to bring the residual quantity to below the oxygen index of the material on fire plus a safety factor. The required amounts vary slightly because of the marginally different physical properties of each agent and the impact that this can have of cooling (heat removal). The units used are % agent, or % residual oxygen.
- **Chemical gaseous agents** are specified in terms of the amount of agent required to achieve extinguishment of a suite of design fires (the extinguishing concentration) onto which is added a safety factor to give the 'design concentration'. The units used are % agent.
- **Condensed aerosol (powder) systems** are specified in terms of the fixed 3-dimensional application of agent to a compartment – g/m^3. Whilst a simple calculation to deliver, it is a very difficult parameter to physically measure (unlike the gaseous and sprinkler equivalents).
- **Watermist systems** are perhaps the most complex to describe as uniquely it is the fire size that determines the system's ability to function. Watermist systems deliberately produce very small droplets to encourage the generation of steam, that through increased volume, displaces oxygen from the protected space. In this respect small fires may be problematic as they do not possess the power to generate steam sufficiently quickly, or in enough quantity, whereas larger fires can (subject to control of ventilation). Determination of required rates is therefore most safely made by full-scale testing of the system with the specification normally being one of nozzle spacing and water flow rate.

- **All other local and specialist systems** operating parameters are established and reported through standards testing. Where none exist, bespoke testing is normally undertaken.

2.8 Installation type: fixed, local, mobile, or portable

AFPSs may be fixed, local, mobile or portable.

- **Fixed systems** are typically designed to their surrounding and remain in place. They may act on the entire protected space or, detection system permitting, may operate in just a zone of the system where the fire is and bring in more resource as required. Recent advances in detection, allied with steerable delivery mechanisms can now allow for a highly targeted and even autonomous response.
- **Local systems** these systems are normally designed to specifically address the fire risks associated with the particular item they are protecting. The advantage is that the optimum agent may be selected for the application, and it may be specifically applied direct to the areas of highest hazard, increasing effectiveness and reducing agent quantities and consequential damage.
- **Mobile systems** are designed with the flexibility to respond to the location of where the fire incident is. These may be vehicle mounted – land, water or air – and the agent is generally chosen to deal with the specific situation that the mobile capability is provided for.
- **Portable hand-held systems**, including hose reels, provide a means for delivering a first aid response at the time when the fire is smallest, and it is safe to tackle with the limited resource of the small device and limited training of the operator.

2.9 Personnel safety

A primary selection consideration for any AFPS is whether the space it is to be used within is:

- occupied,
- sometimes occupied,
- always unoccupied, or
- unoccupiable.

Fires can exist at lower oxygen levels than will sustain life and can quickly generate conditions lethal to humans in terms of heat, flaming, and toxicity. Some agents are lethal to humans in their own right, and some will break down in fire to produce highly toxic and corrosive by-products. All agents will act to stir up the contents of an enclosure during discharge to bring potentially toxic fire products down to ground level from the ceiling.

It is therefore not surprising that many suppression systems are not considered suitable for occupied spaces and where they are to be used, strict systems of control (lock-off procedures) must be applied to ensure humans are never exposed.

A somewhat deceptive term used in the field of chemical gaseous extinguishing agents is to call them 'clean agents'. Whilst some might be safe and cause little damage during an accidental discharge, when exposed to fire they may generate highly toxic and corrosive hydrogen fluoride gas in considerable quantities, and also stir up smoke in the protected space – on all but very small fires it is difficult to see what is 'clean' about their action.

Another challenge on the use of systems unsafe for human exposure is whether they actually get used in the timely fashion needed to meet the protection ambition. Carbon dioxide systems, whilst exceedingly capable are almost instantly fatal to humans caught in a discharge. It is not therefore surprising that those faced with the decision to discharge the system often wait much longer for assurance that all occupants have left before actioning the system. Human-safe systems are generally operated much earlier resulting in reduced fire damage and may even save occupants.

2.10 Response time

Depending upon the risk to be protected, the response time of the system will need to be considered. A major component of this lays with the detection system that ultimately decides if an extinguishing or suppression response is required, but even after that the AFPS has a role to play in timely delivery.

By way of example, 'dry' pipe sprinkler systems are used where freezing of water in unheated pipes may be problematic. The impact that this might have on response time can be significant. It is not unknown for it to take 10 minutes for water to issue from a large dry pipe sprinkler system from when the system is operated and consideration needs to be given to whether this is coherent with rates of fire spread within the protected space. At the other extreme, rapid events, such as the protection of munitions, often use explosive pressurisation systems to deliver agents on the timescales necessary to be effective.

2.11 Consequential damage

For property protection, the objective of the function of all AFPSs is to save more that they destroy, and to limit the reinstatement time of property and capability to be as short as possible. This is particularly important in heritage protection where the item itself must survive, not just limit spread to other places. In this respect it is vital to match the sensitivities of what is being protected with the challenges inherent in each system. Whilst the sensitivities of electrical systems to water, for example, are well known and understood, perhaps too little consideration is given to how electrical systems may be impaired by systems or fires that generate corrosive by-products that have the potential to lead to further resistive-heating generated fires later in the equipment's life. Compatibility of AFPS should be checked with the protected equipment's manufacturer just in case its use voids warranty.

The best way of limiting consequential damage is to respond pre-emptively where possible, and respond at the smallest scale possible (item, compartment, building) where not, and at all times to prefer agents to which the protected items are insensitive.

2.12 System reliability

Systems must be reliable in their ability to function correctly when required, and to not operate when inappropriate (false discharge). The reliability of any system is collectively determined by the design, and quality of the components that form it, the extent of inbuilt resilient features (such as duplication), its maintenance regimes, and the standards and certification of those responsible for design, installation, care, and maintenance throughout its life. Some systems might be considered more 'susceptible' to failure than others due to their basic architecture.

Sprinkler systems have the highest of all reliability ratings for any system in part due to the rigour of the installation codes and maintenance requirements, but also because they use wide-bore heads – the narrowest restriction in the system – they are very tolerant of poor water supplies. By comparison, a survey of high pressure watermist systems on a cruise ship showed that 60% of the heads would have been unable to pass water due to their micro-bore architecture of the nozzles and problems with the stored water supplies. The more susceptible a system is to deviations from perfection, the more controls that need to be put in place to confirm their ability to perform when required and this can add significantly to up-front, and through-life costs.

Accidental system discharge can result from problems within the detection system, physical damage, electrical interference, or within the design of the suppression system itself. Activation without need can result in extensive and unnecessary consequential damage, significant reinstatement costs of damage caused and the AFPS, capability downtime, and mistrust of the system which might lead to disablement and exposure to future fire risks.

Selection of an AFPS on the basis of reliability is as important as any other selection criteria.

2.13 Single points of failure and common points of failure

In the design of any safety system, it is imperative that the reason behind the source and circumstance of the fire will not also cause the fire protection system to fail. In its simplest form this might pertain to the security of electric power supplies both causing the fire, and then being required to power detection and water pumping systems. This can extend to where the cause of fire has been associated with a breach of the compartmentation (ventilation), that might be necessary for correct function of the AFPS, as might be the case for gaseous, condensed aerosol, and watermist systems. Some systems, such as those using chemical gaseous agents may have vulnerabilities in intensely hot environments (metal compartments) where the agent may be consumed before reaching the fire.

2.14 Testing and approval and certification

Whilst some systems are more inherently likely to function robustly than others as previously discussed, all good systems should sit within a certification framework that ensures the best system is selected, delivered, and maintained throughout its lifespan. This extends also to change management where the system must adapt as alterations are made to the protected risk and the hazards presented. The more mature and proven technologies benefit from over 100 years of development and standards support. Newer technologies become more viable as lessons in their performance and capabilities are learned and proven. That said, it will seldom be the case that just because competing systems have standards associated with them, that they can automatically be assumed equivalent in terms of performance and reliability. There remains a need to look beyond the certification accolade and thoroughly understand the testing regimes to which the systems have been subjected and consider the relevance of these to the situation requiring protection. It is not uncommon for some tests to be so generic that they bear little relevance to the application for which the system is used.

2.15 Upkeep

An important consideration in the selection of a protection system is how it has been certificated and how that certification will be maintained through life. By way of example, sprinkler systems are certificated as a kit-of-parts. The benefit of this is that the component parts may be sourced from a wide variety of manufacturers so the provision of parts for their through-life upkeep is assured. Watermist systems on the other hand are tested and certificated as complete systems. The parts are not interchangeable and if for example, the manufacturer of that system ceases to trade, the continued upkeep of the systems as a certificated facility becomes impossible. This has been a major consideration for major property landlords post-Grenfell who require a guarantee of through-life support and certificated upkeep.

2.16 Environmental credentials

In recent years fire protection agents have been held to account for their environmental impact and many have been, or are in the process of being outlawed on this basis. Halon agents were outlawed on the grounds of contributing to ozone depletion, HCFC and HFC agents are being phased out on the grounds of greenhouse gas contribution, and NOVEC™ 1230 and fluorine based firefighting foams similarly on the ground of environmental persistence. All agents going forward will need to have environmental credentials that allow their installations to remain in place for many years without being subject to the costly upheaval of universal replacement and disposal programmes.

2.17 Overall suitability

The previous sections show that there are a large number of criteria that need to be considered aside from 'cost' in determining the most appropriate system for any given risk. The effort and resource applied to this should be determined from the legal requirements, likelihood, consequence, and severity of the risk. In respect of business and property protection, whilst there is no legal requirement for protection, the resilience of any business is a key responsibility of all managing directors and the application of AFPSs is a vital tool for ensuring the safety of the workforce, the protection of the property, and the continuity of the business conducted within it.

3 Active Fire Protection Systems for the suppression and extinguishment of fires

The AFPG library series contains 18 documents that describe specific suppression and extinguishing systems with an additional two to assist users transfer protection from systems that are now deemed environmentally unacceptable. A brief introduction to these is included in the sections below and extended information is provided on points common to one or more guides.

3.1 Water-based systems

The principal modes of operation of water-based fire protection systems are heat removal from the fire, fuel removal by soaking of combustible materials, and where used, the application of a foam blanket to liquid fuel fires. The situation is different for watermist systems, that, through the production of very small droplets seek to maximise steam generation for the dilution and displacement of oxygen locally available to the fire, or from the protected compartment.

3.2 Sprinkler systems for property protection (see AFPG-13)

The term 'Sprinkler system' (PP) not only describes the technology, but 'implies' a whole assurance and management scheme that ensures its ability to perform as intended when needed.

Sprinkler systems for property protection:

- are a 'building' fire protection system
- are designed to 'suppress fires' so follow-on actions by FRS are required
- are designed specifically for the hazard of the fuel and its arrangement within the protected space
- assume a single seat of fire
- have certificated components that are interchangeable between manufacturers
- have the best performance and reliability credentials of any active fire protection system through up-to-date rulesets, certification of product and installers, and strict maintenance regimes
- can have severely impaired performance due to poor head location and inadequate maintenance
- differ greatly from life-safety sprinkler systems in terms of their protection objective, resilience of function, and duration of operation.

** Property protection (commercial and industrial) vs. life safety (domestic and residential) sprinkler systems - the performance of property, and life safety, sprinkler installations are very different and to avoid confusion should be thought of as entirely separate systems. Property protection systems strive for much higher levels of resilience (ability to function), through rigor in the supporting standards, design, product specification, and maintenance, that are not matched by life safety (domestic and residential) systems which generally seek to only assist occupant escape.*

3.2.1 Sprinkler systems for life safety (see AFPG-14)

Sprinkler systems for life safety (LS) aim to assist evacuation of the building before structural collapse occurs unless specifically designed to meet other objectives.

- Standards for domestic and residential sprinkler systems are 'loose' in comparison to property protection (PP) standards (see AFPG-13) and their specification for all but 'vanilla' installations must be conducted by the fire engineer who has responsibility for the building's overall fire safety management plan.
- Competency in all aspects of design, installation, and maintenance is key to system performance, as is product certification.
- These systems are not generally recognised by insurers as beneficial for property and business protection.
- A key standard, BS 9251 (Residential and Domestic Occupancies), has recently been updated to allow limited coverage of commercial and industrial areas which RISCAuthority consider are better protected with the LPC Sprinkler Rules (see TB202).
- The use of CPVC pipe, which is intolerant of contact with many materials, requires special attention if escape of water (EoW) events are to be avoided.

As stated above, life safety sprinkler systems differ greatly from their property protection counterparts in terms of their duration of operation, building coverage, resilient features, and protection remit.

3.2.2 Watermist (see AFPG-02)

Watermist is the provision of finely divided water droplets, typically 200μm that are created at high to medium pressures through small orifice nozzles. The mist produced can be delivered by compressed gas or pumps (mains water supply pressures are too low).

Watermist:

- may be implemented as a 'compartment' or 'local application' protection fire protection system
- can be used for building protection if specifically design to be so but this is not native with installation to life-safety standards
- can be designed to be either an extinguishing or suppression system depending upon design and application

- generally requires relevant full-scale testing to assure performance because the mode of operation is the most complex of any AFPS
- has good environmental credentials
- has few toxicity issues aside from deep-lung-penetration of fine droplets and Legionella potential from stored water.
- is usually unsuitable for use with firefighting foam.

Watermist systems are most effective on large fires in small, sealed enclosures where steam generation, and therefore oxygen displacement, is optimised. It has limitations to the management of deep-seated solid fuel fires, small fires, and fires in ventilated compartments.

In comparison to other water-based systems, standards remain in an early phase of development and due to the challenges of micro-bore architecture and water quality, concerns remain about their long-term ability to function when required. They are often proposed as alternatives to sprinkler protection but in many cases this is misguided, comparing a compartment protection system with a building protection system.

3.2.3 Deluge systems (see AFPG-18)

'Deluge systems' are principally used for:

- the suppression of fire in high-hazard applications where a rapid heavyweight response is required to address an unfolding fire scenario which might otherwise propagate at a rate faster than a normal type of sprinkler system could respond to, and,
- the protection of critical equipment at-risk (i.e. LPG tanks), places (i.e. escape routes), or structural elements (i.e. beams and columns) from involvement in fire from another source (they may also be used for blast mitigation).

They are characterised by:

- open delivery nozzles/heads to issue fire suppressing/cooling agent to the whole protected zone, volume, or item (many heads in simultaneous operation)
- open (no-bulb) medium velocity and high velocity solid cone spray heads designed to penetrate the opposing forces of fire and obstruction by complex structure, and wet surfaces effectively
- activation made by pneumatic, hydraulic, electrical, and manual means
- detection of fire made by 'wet pilot', 'dry pilot' or electrical detection system
- an ability to deliver water, water and foam, and other fire suppressing media, including dry-powder and gaseous agents
- prevalence in the oil and gas, chemical manufacturing, and heavy electrical (transformers) sectors.

When used to protect equipment and infrastructure, a deluge system's prime objective is to keep the target's temperature below 100°C. Any surface above 100°C will become difficult to cool as water will boil off and not 'wet', resulting in hot spots that may endanger a vessel's contents and also cause asymmetric stress leading to structural failure and rupture.

The terms 'deluge system', 'water spray system', and 'drencher system', are often used interchangeably.

3.2.4 Water foam cannons (see AFPG-19)

'Water foam cannons' are principally used for:

- the suppression of fires in harsh environments where a heavyweight response is required
- the control of large liquid fuel fires (Class B) that might manifest in industrial processing, fuel storage, and aircraft crash response
- blanketing of fuel that might become involved in fire (bunds and spills)
- structural cooling
- escape route security
- aircraft hangar protection - one of four acceptable options for foam delivery
- runway crash response.
- They are characterised by:
- a manual, automatic, or remotely steerable branch that may be fixed, portable, or vehicle mounted
- the application of foam as a directed jet or fan within an arc of coverage that blankets the supply of oxygen to the fuel, controls fuel vapours, and cools the fuel and surrounding structures preventing reignition and preserving stability
- delivery of water and foam mixtures in the range 500 to 20,000 l/min
- operating pressures between 4-16 bar
- throw distances which can be in excess of 100m
- placement of multiple monitors to cover the assets with their collective arcs of foam distribution.

The terms 'monitor' and 'cannon' are often used interchangeably.

3.3 Gaseous systems - general

NOTE: *It should be noted that when gaseous extinguishing systems are considered, RISCAuthority advice is to always consider inert gases over their chemical counterparts for reasons of design simplicity, limitation of consequential damage, safety, and long-term permissibility as environmental regulations change.*

Where concerns for safety are included in the guides, figures presented can be reviewed against the table below relating to NOAEL and LOAEL values.

No **O**bservable **A**dverse **E**ffects **L**evel (**NOAEL**) - The highest concentration of a gas which should not adversely affect people that come into contact with it.

Lowest **O**bservable **A**dverse **E**ffects **L**evel (**LOAEL**) - The lowest concentration of a gas that has been reported to cause adverse health effects in people or animals.

F-gases are gases that contain fluorine. There are a range of these gases which include Hydrofluorocarbons (HFC), Perfluorocarbons (PFC) and Sulphur Hexafluoride (SF_6) and have a global warming potential greater than one.

Agent	Design Concentration (%)	NOAEL (%)	LOAEL (%)	Occupied Space (Y/N)	Global Warming Potential	Ozone Depletion Potential
Inergen	37-42	43	52	Y	0	0
Argonite[1]	42-47	43	52	Y	0	0
Nitrogen	37-42	43	52	Y	0	0
FM200	8-9	9	10.5	Y	3220	0
Novec 1230	5-6	10	>10	Y	1	0
HFC-125[2]	10-12	7.5	10	N	3500	0
CO_2[3]	34-50	3	10	N	0	0

Notes:

1. Argonite has a limited exposure time of three minutes within the compartment. The design concentration is greater than NOAEL.
2. HFC-125 is not suitable for occupied spaces. The design concentration is greater than NOAEL.
3. CO_2 is a toxic gas; death will be very rapid if exposure occurs at the design concentration.

Some of these gases are commonly found in chemical gaseous suppression systems.

Regulation (EU) No 517/2014 on fluorinated greenhouse gases (the F-gas Regulation) is in place to protect the ozone layer and mitigate climate change. This will be achieved by phasing down the amount of HFC that can be placed on the EU market by slowly reducing quotas permitted to HFC producers and importers.

The UK has international obligations under the UN Montreal Protocol on substances that deplete the ozone layer (the Montreal Protocol). The regulation bans the use of F-gas in certain applications and sets out the requirements for strict service and maintenance of systems containing these gases together with leak detection requirements. Any company or technician involved in this activity will be required to be certified, trained, and hold a valid F-gas certificate.

Protection of compartments with gaseous systems demand that the compartment is well sealed and then provided with a device suitable for venting overpressures during agent discharge, but will reseat to hold the column pressure of gas for the required hold time. For inert gases the compartment must vent around 40% of its volume in 1 minute. Chemical agents typically must vent around 10% of the compartment's volume in 10 seconds. Inert agents produce positive pressures only, whilst chemical agents can produce both positive and negative pressures on discharge as the liquid agents flash evaporate to gas.

The ventilation devices should be positioned and ducted to prevent exposure of personnel and other areas to the fire/agent efflux. Failure to seal the compartment, and then install the correct ventilation device, can result in destruction of the compartment boundaries, failure to extinguish the fire, huge hydrogen fluoride generation (chemical agents only), unintended contamination of adjacent areas and personnel to the raw agent, toxic agent derivatives, and toxic fire products.

The main agent types are discussed in the following sections.

3.3.1 Inert gaseous systems

Inert gaseous systems act by diluting and displacing oxygen local to the fire, or from the compartment they are installed in to protect. All inert gas systems with the exception of carbon dioxide have the following attributes:

- they are 'compartment' and 'local application' protection fire protection systems
- they must be designed to ensure extinguishment
- their performance greatly depends on ventilation and sealing of the compartment it is protecting
- they have good environmental credentials
- they have few toxicity issues aside from asphyxiation potential from homogeneity challenges and poor design (being completely inert the agent does not break down in fire).

Inert gas systems are the cleanest form of gaseous protection which makes them especially suitable for the protection of sensitive electronic equipment like computer servers. Working with the fire to remove oxygen, they are robust in their performance.

In an accidental discharge, systems designed for 12.5% residual oxygen, can be safe for a short period of time for healthy persons, but where a fire may have already consumed oxygen, or the design demands more agent, occupation during discharge might be dangerous.

The amount of agent required depends upon the oxygen index of the fuels being protected. In typical applications agent will be added to achieve a residual oxygen concentration of 12.5% but some liquid fuels might require a much lower value for extinguishment.

3.3.1.1 Inergen/IG541 (see AFPG-03)

Inergen/IG541 is a blend of naturally occurring gases, Nitrogen (42%), Argon (50%), and a small amount of Carbon Dioxide (8%).

3.3.1.2 Argonite/IG55 (see AFPG-05)

Argonite/IG 55 is a blend of naturally occurring gases, Nitrogen (50%) and Argon (50%) and has a density similar to that of air.

3.3.1.3 Nitrogen/IG100 (see AFPG-06)

Nitrogen/IG 100 is a naturally occurring gas present in the earth's atmosphere at 79% by volume. Inert Gas IG 100 is a clean agent fire extinguishing system using 100% Nitrogen and is used in total flooding systems.

3.3.1.4 Carbon dioxide (see AFPG-09)

Carbon dioxide, whilst not strictly an inert gas, functions in the same manner, but differs in that it is a liquifiable gas, which reduces greatly its storage requirements, and is very quickly lethal to humans at extinguishing concentrations. It is a naturally occurring gas that is present in the earth's atmosphere at 0.037% by volume and is classed as an inert gas and clean agent for fire extinguishing purposes.

Between the 1920s and 1960s carbon dioxide was the only gaseous fire suppression agent used to any degree. A common misconception is that the hazard of carbon dioxide is from asphyxiation, but this is incorrect. As a waste product of the body exhaled during breathing, the hazard presented is actually one of poisoning.

Carbon dioxide remains an immensely effective inert type agent with many benefits subject to controlling the health and safety risks. It is particularly suited to cabinet protection and the protection of other small spaces that are not occupiable.

3.3.2 Chemical gaseous systems

Chemical gaseous agents act by removing heat from the fire which is extracted through the endothermic breaking of strong molecular bonds. As a dynamic process the gas needs to be discharged rapidly into the protected space to minimise the production of toxic and corrosive breakdown products such as hydrogen fluoride, and consumption of the agent.

All chemical agent systems have the following attributes in common:

- they are 'compartment' and 'local application' protection fire protection systems
- they must be designed to ensure extinguishment
- performance greatly depends on ventilation and sealing of the compartment they are protecting
- they will produce hydrogen fluoride in a fire which can be harmful to personnel and damage equipment
- if they fail to extinguish a fire the amount of hydrogen fluoride generated can be critically injurious to life and severely damaging to equipment
- whilst not ozone depleting, they do have long atmospheric lifetimes, and have significant global warming potential
- they are in the process of being phased out on environmental grounds.

3.3.2.1 Novec™ 1230 (see AFPG-04)

UPDATE: *Since the original release of this document Novec™ 1230 is now being voluntarily withdrawn from the market by its manufacturer 3M due to its classification as a 'forever chemical'. Whilst other manufacturers can supply FK-5-1-12 (the general name for Novec™ 1230) both EU and US environmental policy changes means its days are numbered for use in fire extinguishing systems. Readers are directed to AFPG-16 Migration of Novec™ 1230 and HFC gaseous extinguishing agents to environmentally acceptable alternatives.*

Novec™ 1230 fluid (FK-5-1-12) was developed as a halon replacement and hydrofluorocarbon (HFC) alternative. It belongs to a family of chemicals called halocarbons, a group which includes HFCs and fluoroketones. Novec™ 1230 is a C-6 Fluoroketone (full name: dodecafluoro-2-methylpentan-3-one) with a boiling point of 49.2°C.

3.3.2.2 FM200 (see AFPG-07)

FM200 (HFC 227ea) heptafluoropropane is a gaseous firefighting agent that is a hydrofluorocarbon (HFC) comprising elements of carbon, hydrogen and fluorine. It is manufactured by various suppliers such as Dupont™, Ansul, and Chemours, and is marketed as a clean agent fire suppressant which meets NFPA 2001.

3.3.2.3 Pentafluoroethane/HFC-125 (see AFPG-08)

HFC-125 Pentafluoroethane is a gaseous firefighting agent that is a hydrofluorocarbon (HFC) comprising elements of carbon, hydrogen, and fluorine. It is also known as FE-25, Ecaro, R-125 and MH125 and is marketed as a clean agent fire suppressant which meets NFPA 2001 standard for clean agent fire extinguishing systems.

3.4 Other specialist systems

3.4.1 Oxygen reduction systems (see AFPG-10)

Oxygen Reduction Systems (ORSs) are a form of fire protection that seeks to prevent the ignition of materials by maintaining a permanently depressed oxygen concentration within the protected space that they reside. In this sense they are neither suppression nor extinguishing systems but may be considered a form of 'inerting' system. The held oxygen concentration must be selected to be that of the material in the protected space that requires the lowest value for the prevention of ignition. This 'ignition threshold' is a parameter derived from a test procedure specific in ORSs standards that describes the % oxygen that will prevent ignition of a specific material arrangement from the experimental ignition source. With key applications in data centres and warehousing, both occupied environments, the lowest oxygen value used is typically around 15%. In terms of the 'fire triangle', the lower the oxygen content, the greater the heat (ignition strength) required to initiate and sustain ignition and hence a lowering of the probability of fire starting.

The systems may be configured to accommodate different occupied working models to ensure the health and safety of personnel, however the ORS 'ignition threshold' of a material is not an accepted material physical property in the same way that , for example, 'heat of combustion' is. It is a property based around a very specific test procedure outlined in EN 16750 Fixed Fire Fighting Systems – Oxygen Reduction Systems – Design, Installation, Planning and Maintenance. There is concern that the test is very specific to a limited condition which may poorly replicate the majority situations that arise in real-world, real-scale, scenarios, and may favour the delivery of high oxygen threshold results in comparison to other methods such as Limiting Oxygen Concentration (LOC).

ORSs use devices to separate air into its primary constituent components of oxygen and nitrogen, and re-introducing the nitrogen-rich, oxygen-lowered stream back into the protected space. Unlike other suppression systems priced on purchase and maintenance costs, it is important to understand the energy running costs for oxygen reduction systems.

3.4.2 Condensed aerosol systems (see AFPG-11)

Condensed aerosol systems are an extinguishing technology using standard potassium firefighting salts to interrupt the chemistry of the combustion process. The salts are combined with other materials to form a highly combustible ceramic solid which, on activation is ignited to provide a smoke-like emission of salts that may chemically inhibit fire. Housed in a metal cannister with burst disk at the delivery end, the hot gaseous discharge is usually cooled by chemical or mechanical means.

They are commonly used in the protection of small spaces, such as cabinets; engine bays; for local application; and in the protection of larger compartments subject to appropriate testing. These are 'extinguishing' systems and should be designed on the basis of having no 'suppression' capability, and that there is no requirement for follow on actions such as the attendance of Fire and Rescue Services to assure a proper conclusion to the fire event.

3.4.3 Kitchen fire protection systems (see AFPG-15)

Typical kitchen fire protection systems (KFPS) deliver wet-chemical agents containing potassium salts to the fire that, on contact with burning oil, grease, and fat react to form a soapy film (saponification). The soapy layer acts to cool the fire, deprive it of oxygen, and inhibit vapour release. Whilst most systems differ only in the means of detecting and applying the agent, some systems augment the cooling effect by also delivering watermist post wet-chemical discharge to enhance cooling to prevent reflash. Wet-chemical agents are non-toxic, and non-corrosive to kitchen equipment.

The term KFPS describes a suite of sub-systems that must perform as one to meet the protection ambition including, detection, alarm and activation, active protection of cooking equipment and ducts, equipment interlocks, lids, thermostats, level sensors, isolation of sources of fuel and heat, and maintenance plus full cleaning of ducts, canopies, and grease traps/filters. Whilst some of these systems are procured and maintained separately, they must be operated within an in-house management framework that ensures the correct function of all components (correct function cannot be assured by a single quality scheme).

Effective design requires an initial risk assessment to be made as kitchen equipment varies greatly in type and risk and some specific design detailing may be required. The performance of the systems can be severely impaired by poor or neglected cleaning procedures of hoods, filters, grills, and ductwork, and through unmitigated kitchen reconfiguration.

3.4.4 Fixed dry chemical systems (see AFPG-17)

Dry chemical agents act by interrupting the chemistry of combustion and can be applied to a fire from hand-held extinguishers, hose-reels, monitors, fixed piped installations, and as condensing aerosols. Most commonly seen in hand-held extinguishers around the home and workplace, and in high-risk industrial protection (particularly marine and offshore), they are now seeing extended use to make up for the outlawing of the chemical gaseous agents, such as FM200 and NOVEC™ 1230, on environmental grounds. Fixed piped systems have a reputation for reliability and effectiveness where the chemical is correctly matched to the application. These systems should also be considered as a possible option for commercial kitchen protection (see AFPG-15). Condensing aerosols are considered separately in AFPG-11. Where dry chemical systems do not provide enough cooling to prevent reignition, but the rapidity of their action is still desirable, the system may be combined with deployment of a follow-on 'wet chemical system' (often termed 'twin-agent' systems).

4 Special considerations

4.1 Migration of foam sprinkler systems to fluorine-free foams (see AFPG-12)

Fluorine containing foams that have become synonymous with the protection of high hazard liquid fuel risks are in the process of being phased out due to their environmental persistence, bio-accumulation potential, and toxicity. The candidate fluorine-free alternatives are currently less efficient, lacking the chemistry that supports the formation of a surfactant aqueous film over the fuel to seal in vapours. As such they are more reliant upon the creation of a smothering foam layer which may require a greater level of aspiration at the nozzle than some sprinkler and drencher systems might be able to provide without significant system redesign and component change. This raises some great challenges for the design and certification of sprinkler and drencher systems where formerly, the augmentation with foam required only the addition of the dosing mechanism when using foam in non-aspirated form.

AFPG-12 and the associated questionnaire seeks to assist those with foam-enhanced fixed sprinkler and drencher-type systems to adapt to, or reduce their dependency on fluorine-based foam technologies.

4.2 Migration of Novec™ 1230 and HFC gaseous agents to environmentally acceptable alternatives (see AFPG-16)

Novec™ 1230 is being voluntarily withdrawn from the market by its manufacturer 3M due to its classification as a 'forever chemical'. Whilst other manufacturers can supply FK-5-1-12 (the general name for Novec™ 1230) both EU and US environmental policy changes means its days are numbered for use in fire extinguishing systems. AFPG-16, in association with other RISCAuthority AFPGs, describes potential candidate replacement options for consideration, and describes the specific features that might support the selection of one option over another. This guide is equally pertinent to the replacement of HFC agents which are similarly being phased out under F-Gas regulation owing to their greenhouse gas contribution.

5 Closing

With so many options for active fire protection, and complex requirements to satisfy, it is likely that any choice made will have a component of compromise to its selection. That said, to avoid bias, prospective purchasers of systems are directed to seek advice from fire protection companies that provide the full range of suppression and extinguishing, and detection technologies to give the best chance of being recommended the most appropriate system for the requirement. The user is also advised to consult with their insurer who will have the suitable skills and experience to recommend appropriate systems.