Protection of Data Centres

Economic and Environmental Consideration of Alternative Technologies

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Introduction

Data centres are provided with fire protection measures to protect critical data and business interruption. At least part of the protection is provided by either a gas extinguishing or water sprinkler or mist based system. The consideration of a particular type of system has historically been determined by specialist consultants, who in turn have been influenced by manufacturers and their own experience. Regular builders and owners of data centres have also developed their own strategies, some of which have been imported from the other countries, particularly the US. This article provides a brief summary of the alternative technologies and compares the relative merits, costs and environmental influences.

Sprinkler Systems

Most data centres have some form of sprinkler protection. Sprinklers provide a well proven, prescriptive form of protection, covered by thorough standards and third party certification of both product and installation companies. Sprinklers are essentially nozzles held closed with a frangible bulb that acts as a heat detection device. When sufficient heat has been generated, the bulb ruptures opening the nozzle. Sprinkler systems are designed as wet, dry (pre-action) or alternate (a combination) dependent on the design criteria for the risk, and likelihood of freezing. The nozzles are fixed to a pipe network that is feed by a central pump set. The size of the pipe work, pump set and amount of water storage is determined by the design criteria known as hazard classification. Under the BS EN12845 standards, an ordinary hazard 1 requires a system capable of flowing water over a protected area of 72m^2. Since typically a sprinkler covers 12m^2, this is equivalent to 6 nozzles operating. FM requirements for light hazard are more onerous with the design of 144m^2 of coverage. The flow is also determined by the water density, typically 5mm/m^2 for these category hazards.

Sprinklers can provide protection throughout the building. Their performance in fire scenarios is well proven, but the response time is relatively slow, since heat is the activating mechanism. The water generated per sprinkler is also large (typically 60-70 l/min), so the consequential damage can be considerable if delicate or costly equipment are to be protected. It is for this reason that data halls that are sprinkler protected are based on the pre-action type, whereby the pipe work is normally dry, and only fills with water when a primary detection system has been activated. Any activation of a sprinkler will only occur with heat, and the damage is generally limited to one or two sprinkler activations (normally well within the maximum area coverage to which it has been designed).

Sprinklers cannot penetrate fires in cabinets, and are in general designed for fire control, and life safety systems.

Water Mist Systems

Water mist is a relatively new technology that has been developed for marine applications and extended into land-based use. Water mist is based on using less quantity of water than sprinklers, but in a finer droplet form. Essentially it uses a different application technology to achieve this. Water mist is commercially available in two forms – low pressure systems operating at less than 10 bars, and high pressure systems that typically operate at around 100 bars. The water density required is dependent on the type of fire and the application. For example, very hot fires (Class B and Class F) can be extinguished with very small quantities of water (water density below 0.5 mm/m^2). For Class A or deep seated fires, extinguishing cannot necessarily be achieved but the tested performance must be equal or better than the equivalent sprinkler design. In this case more water is required, but with water density at typically 1.2mm/m^2 (high pressure systems) to 2mm/m^2 (low pressure systems), is much less than the equivalent sprinkler system. Since less water is used, the collateral damage and clean up is less. Additionally infrastructure such as break storage tank, pump sets and pipe sizes are considerably smaller than the sprinkler system equivalent. Water mist is the only practically solution besides carbon dioxide for the protection of diesel generators as it can be applied locally. However, since the application is very much manufacturer dependent and until recently the technology had been beset with virtually no standard (by its nature it is not possible to have a prescriptive standard for all systems), it is essential that the chosen product has evidence of fit for purpose testing, or third party accreditation. However, today two standards exist - the European

Technical Specification TS EN 14972 and the NFPA 750, and a draft BS is in the final stages of preparation. Sadly, the LPCB (possibly dominated by its sprinkler element) falls far behind in this area of accreditation, and one must seek those of international organsiations that have their own test protocols or endorse those of the International Maritime Organisation. Example organisations include FM, UL and the VdS.

Gas Extinguishing Systems

In the protection of actual data halls, the aforementioned technologies of sprinklers/water mist are only designed for the control of a fire (although extinguishing is often achieved). Gas extinguishing systems are actuated via smoke detection so are much more rapid in deployment, with a total discharge time between 10 seconds and 2 minutes depending on the gas used and design criteria. Gas systems are clean agents, i.e. do not create and residue on discharge. Gas is contained in cylinders that are stored adjacent to the risk, or remotely, again dependent on the gas type. Often reserve cylinders are installed in case of discharge (accidental or otherwise) so that business downtime is not affected. Since gas discharges rapidly and increases pressure in the risk, pressure relief dampers are required to prevent structural damage. These must be ducted to the outside, or via complicated cascade venting, that is often tricky to implement.

Gas systems are normally one of two types – synthetic or inert. Synthetic gas systems are liquefied gases super-pressurised with dry nitrogen to discharge as a gas in 10 seconds. Synthetic (or chemical) gas types are FM-200, HFC-125, FE-13 or Novec 1230. All are halocarbon based, having a hydrocarbon stem (e.g. propane) and fluorine as the active extinguishing chemical. Extinguishing is achieved by chemical cooling and inhibition of the flame and design concentrations vary between 6% and 16%, or 62kg to 85kg per $100m^3$. Halocarbons are global warming gases covered by the fluorinated hydrocarbon regulations. Novec 1230 is a derivative that is excempt from these regulations but on contact with water or fire will break down into its halocarbon base. Generally the systems are modular, i.e. are contained in single containers, with individual pipe networks, and must be located immediately adjacent or within the risk. All need pressure relief, for both negative and positive pressurisation. FM-200 and HFC-125 are the cheapest systems with Novec probably the most expensive solution of all. FE-13 is the most flexible and safest in terms of design and concentration respectively. Refill costs are determined by the gas cost.

Inert gas systems consist of pressurised inert gas at typically 300 bar stored in 80 litre or 140 litre cylinders. The extinguishing mechanism is through the reduction of oxygen to 12% by volume which equates to a flooding factor of 51%. Pressure is reduced to 60 bar before entering the pipe work in the risk. Discharge time is typically 60 seconds but can be extended to 120 seconds to reduce free vent areas as required for pressure relief. Inert gas systems are often configured to protect multiple areas with sufficient cylinders to protect the largest volume, and directional valves to direct the gas into in the appropriate volume. Directional valves can be fed by individual pipe work from the cylinder bank or from a high pressure extended manifold that extends throughout the protected building. Where less cylinders are required from the total maximum, different actuation circuits and non-return valves are used in the pneumatic actuation circuit or simpler more flexible binary systems can be used. Inert gas systems can be located remote from the risks.

Synthetic and inert gas systems are covered under the design standard series BS EN15004.

Hypoxic Systems

Hypoxic systems are relatively new but have significant advantages, and are seen to be the future of protection in applications such as data centres, archives, museums, etc. Hypoxic systems work by injecting oxygen at a level of between 10% and 12% so that the ambient air is maintained typically at 15%. In such systems, a fire cannot start, and so they are often referred to as prevention systems. At sea level, 14.5% to 15% oxygen content is equivalent in human physiology to being at around 2,500m altitude, or in a commercial aeroplane. With very rare exceptions this level is safe for use in occupied areas – in fact, more than 5 million people live at altitudes with the same or less equivalent oxygen. Hypoxic systems differ from nitrogen inject systems, in that the latter inject nitrogen (or atmosphere with less than 5% oxygen content), and therefore cannot be fail safe. The hypoxic air is produced by forcing compressed air through a membrane that separates the nitrogen and oxygen molecules. The oxygen reduced air is then injected to the risk. Consideration needs to be made of inward air leakage, and any risk where this is below 3% can usually be protected. Open doors can normally be accommodated but through drafts should be avoided. Areas subject to occupation can be fed with a continuous stream of Hypoxic air to provide some degree of air change. Systems normally are designed to be fire safe (below 16%) within 48 hours, and normally operate on a duty cycle of 25% to 35%. Since a large volume of 'safe' air is present in the protected risk, this reservoir continues to provide protection, usually for hours and sometimes for days., Thus true N+1 systems aren't always necessary, but an equivalent level of protection can nevertheless be provided for. Hypoxic systems have several major advantages over traditional extinguishing systems. Firstly, they operate 24/7 and a fire cannot start. On an extinguishing system, a fire needs to be detected and the system needs to operate. If an extinguishing system has been poorly designed, installed or maintained it can fail, and this can only be determined at point of need. The more complicated the system (e.g. multiple areas), then the more likelihood of failure. A hypoxic system can cover multiple areas at the same time, all of the time, thereby avaoiding the protection downtime that is usual following a discharge with gas extinguishing systems. There is no cost of refill, and no business interruption during this process. There is no need for pressure relief or extensive pipe networks (the hypoxic air can be injected into a central duct, CRAC unit, or through room injection points), so the installation time is minimal as is the plant space required. Cost-wise the systems become competitive above volumes of 2,000m^3 dependent on the complexity, and for larger data halls in excess of 7,500m^3 are significantly cheaper than conventional extinguishing systems. Although the compressor needs power to operate, the duty cycle on a correctly designed system is less than 50% (so it is not running all of the time), and power consumption in comparison with air handling systems is extremely small.

Example Configurations

Alternative methods of protection can be provided within a specific building and the table below, indicates the possible combinations of protection that can be provided.

Corridors	Plant Rooms	Data Halls	Offices
Sprinkler	Sprinkler	Sprinkler – Pre-action	Sprinkler
Water Mist	Water Mist	Water Mist – Pre-action	Water Mist
Sprinkler	Gas	Gas	Sprinkler
Nil	Water Mist	Water Mist – Pre-action	Nil
Sprinkler	Hypoxic	Hypoxic	Sprinkler
Sprinkler	Gas	Hypoxic	Sprinkler

Cost/Benefit Analysis

The size and complexity of the risk often helps in the determination of the particular solution. Small risks are often best protected by an FM-200 or HFC-125 system, large risks by hypoxic or inert. Water mist is applicable for local application hazards and in lieu of sprinklers where collateral damage is a concern, space savings are required or pipe runs clash with other services. Water mist can be more cost effective, too, dependent again on the size, and complexity, particularly with regard to civil works required e.g. tank houses, or the break tanks.

Environmental Analysis

In terms of total equivalent warming impact and other environmental considerations, the following pointers need to be taken into account. Synthetic gases use the least hardware but the contents, although considered non-emissive, are global warming gases but with very small impact (relatively 0.003% of the total emissions). Novec has a global warming potential of 1 in relation to CO_2 but will breakdown to derivatives of FM-200 upon a chemical reaction such as a fire scenario, so then contributes to global warming. Inert gases are non-chemical and so do not contribute to global warming. However large amounts of energy are required to manufacture seamless cylinders with the large wall thicknesses required for the pressures involved, and energy is used in compressing the gases. Extensive large pipe networks are also required, as is the case for sprinkler systems. Hypoxic systems only have an environmental impact of electricity use for the compressor but the compressor heat generated can be used as a secondary heating system, and the rich oxygen waste product can also sometimes be recycled, so the green credentials are quite high. Water mist systems, particularly high pressure use minimal amounts of pipe work, and probably have the least impact. However, when running the pumps have a quite a large power requirement, typically 37kW – 45kW for a data centre application.

Summary

This is a draft paper summarising the practical experiences of the author over 18 years of experience including throughout the halon changeover. It does not cover all aspects, but reflects on experiences in actual discharge scenarios, costs, expert witness work and complex installation projects. On personal recommendations based on cost, reliability and environmental impact then the optimum solution for data centres would be hypoxic systems to protect the data halls and peripheral UPS, battery and build rooms, and high pressure water mist to protect the DRUPS. Corridor and /or office protection can be a small separate sprinkler system, or off the water mist system to save further in cost and space. Where critical control rooms are also on-site, hypoxic air, with continuous flow, is able to provide an assurance against business interruption.

About the author:

Dr Tim Nichols is an author of a book on Fire Extinguishing Systems, and CFD trainer for the Fire Industry Association. He is Director of an independent manufacturer that manufactures all types of gas, water mist and extinguishing systems, and can therefore be unbiased in the approached used. He has written several papers on fire engineering and undertaken expert witness work.

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