A White Paper from the European Data Centre Association Technical Committee

Fire Protection Options in Data Centres

Table of Contents

Fire Protection Options in Data Centres

1. Executive Summary

The European Data Centre Association (EUDCA) represents the interests of the European commercial Data Centre operator community, both politically and commercially. Established in 2011, the association is registered under Belgian Royal Charter and is run by its members, for its members. Our aim is to streamline the available information into a clear understandable format, to support you in your processes.

The risk of Data Centre fires is real. Any partial or total interruptions of critical services could have huge knock-on effects and the induced operational risks are so important in terms of resources, cost and reputation, which is the most difficult to recover.

Further, as critical facilities continue to become larger and more complex, with a significant growth in power concentration, the risk of fires will increase. Therefore, fire systems need to be designed-in from the earliest stages.

"Start with the End in Mind" (©Uptime Institute)

A fire protection concept consists of a series of coordinated passive and active measures, such as fire compartmentalization with fire-resistant construction elements limiting spread, technical measures (fire and extinguishing systems), as well as organizational and staff-related measures, etc…

This subject is very wide; therefore, this paper is focused on active fire protection systems by automatic extinguishing of fires in white spaces, together with the advantages and attention points associated with the selection of different systems.

Fire safety strategy has to be defined by fire risk assessments based on Business Impact Analysis with Recovery Times Objectives and Recovery Point Objectives. From this analysis phase, the critical elements requiring active protection will be identified, such as servers and critical infrastructures.

The selection of the type of the extinguishing agent should be considered key elements such as risk analysis, insurances, Health & Safety authority, operational limitations, environmental requirements, Building Codes, EU & national regulations and/ or, in the absence of these, by the specific standards/norms related to appropriate technology.

Fire Protection Options in Data Centres

2. Introduction

Data Centres are large, complex, mission-critical facilities. The high value equipment contained within Data Centres needs to be running 24/7/365 on one hand to secure business services and on the other hand to ensure availability, continuity and integrity of sensitive data.

Any partial or total interruptions of critical services could have huge knock-on effects and the induced operational risks are very important in terms of resources, cost and reputation.

Fires may not be the most common cause of Data Centre downtime, but they do occur and can cause major service interruptions for the longest periods of downtime. Fire is one of the key operational disruption risks due to fire load of infrastructures (electricity, electronics components,) which represents the latent energy produced by the combustion.

Therefore, fire safety solutions are significant considerations to design and to operate critical facilities of Data Centres.

Technology solutions are dependent on EU & National regulations (Environment & Health and Safety work), building codes, and insurance guidelines which also influence the choice of the fire suppression system in order to be compliant.

This report therefore provides clear description of each automatic fire suppression system commonly applied to white spaces. When designing or retrofitting a Data Centre, it will be also important to take into consideration early fire detection systems, as well as protecting the critical infrastructures such as electrical rooms, UPS rooms, diesel engines and carrier rooms on the principle of a risk-based analysis. Areas of particular risk such as fuel storage, loading bays, waste facilities and general goods stores must also be taken into consideration.

3. Key misconceptions & concerns

A few key misconceptions and points of concern about fire safety solutions within data centres are considered below.

- Unexpected risks

Areas should be properly reviewed for potential contents, especially where tenancy changes may bring unknown fire load into the building. Two key areas are storage facilities and corridors. “Storage” is a very broad term and the actual contents and methodology of storage must be considered to select suitable protection. Corridors are typically considered to be low risk areas, but the provision of heavy cabling routes can elevate the risk significantly.

- Risk of water damage

Sprinkler and water mist systems are designed to only release water to a space in the case of actual fire. These systems release water to areas already damaged by fire; sacrificing some of the area in order to save the rest. Where there are concerns about water damage, the water quantity released by a handful of sprinklers is much less than the amount the fire brigade would otherwise have to spray into the building if the fire is not controlled. The sprinkler discharge is also much more focused onto the source of fire.

Despite the popular presentation in pop-culture that water is released everywhere, closed-head sprinklers only release one at a time as the fire spreads to each temperature-rated head. The risk of stand-alone mechanical failure of a sprinkler head is remote (a common figure given is 1 in 16 million). Suitable design, installation, and maintenance of sprinkler systems will provide reliable operation. Various control methodologies are available which are discussed later in this document.

- Clean agents and personnel safety

Unlike previous versions (such as CO2, Halon, etc.) current clean agent/ gaseous extinguishing systems are designed to allow limited human presence within the protected space. Every effort should still be made to evacuate the space prior to discharge however, and suitable alert and hold devices must be provided.

- Inert gas and noise for hard drive disks

Studies have shown that the release of inert gas extinguishing systems can pose a risk of damage to hard disk drives. However, this risk can be mitigated with the use of engineered release nozzles, the suitable placement of nozzles away from racks, and the use of solid-state drives.

4. Technology solutions for white spaces

The following described technologies are typical available solutions and do not represent an exhaustive list.

The primary fire protection systems used within Data Centres typically include 2 main extinguishing agents.

1. **Water**, such as sprinklers or water mist (both high & low pressure). All of these systems are available in wet, dry, deluge and pre-action arrangements. The latter including non-interlock (Type B), single-interlock (Type A), and double-interlock release mechanisms.
2. **Gas**, such as synthetic gas and inert gas

4.1. Water agent

4.1.1 Sprinklers

The most traditional suppressing medium. Adaptable to most situations although comes with concerns about water discharge to critical areas. As cooling air velocities increase in the industry, there is a risk that these will start impacting sprinkler discharge.

4.1.2 High Pressure Water Mist

Nozzle design, along with pre-determined pressure criteria creates a mist of small water droplets. (FM Global defines pressure as above 34.5 bar but can reach up to above 140 bar depending on supplier), Those smaller droplets absorb heat at a faster rate than larger droplets due to the higher surface-area-to-mass ratio. As a result, a rapid absorption of heat occurs, causing temperatures to drop while oxygen is displaced due to the expansion upon water evaporation. This system uses less water than a traditional sprinkler system, which minimizes damage to critical equipment, and reduces equipment and pipework sizes. Due to the smaller droplet size, this system is more susceptible to interference from air flow, so higher cooling air velocities may be problematic. CFD analysis may be used to determine velocity profiles prior to design.

4.1.3 Low Pressure Water Mist

A system sitting in between traditional sprinklers and high-pressure water mist in regard to droplet size, cost, water demand. Defined by FM Global (FMG) as having a system pressure of 12.1 bar or less.

4.1.4 Release Types

Wet Systems

Wet systems are the most basic and responsive system. Pipework is charged with water throughout to allow immediate application of water to a fire following operation of sprinkler head. This is therefore usually not a preferred approach in Data Centre critical spaces (although suitable for non-critical areas such as offices should protection be desired there). This system type has a low but comparatively higher potential for false discharge, water leaks or pipe failure, which could damage equipment and disrupt service.

The following figures for the following are typically provided by the industry:

Accidental discharge of water (all causes): 1 in 500,000 (per year of service) (Source: Loss Prevention Council [LPC])

Accidental discharge of water due to manufacturing defects: 1 in 14,000,000 (per year of service) (Source: Factory Mutual (USA) and LPC)

Dry Systems

The pipes downstream of the control valve are filled with pressurized air or nitrogen. The dry control valve releases water to the system when a sprinkler head is triggered. Whilst this system would avoid the risk of sitting water within data hall critical spaces, they are not traditionally used as they lack a resilience to false/accidental head operation. Due to the delay in discharge from having air/N2 filled pipes, these systems allow a larger fire size to generate prior to response; there is a resultant risk of increased fire damage and a higher system water demand which can require larger water storage tanks.

Pre-action Systems

Like dry pipe systems, pre-action pipes do not hold water within the sprinkler piping and are instead filled with compressed air or nitrogen. Unlike a dry pipe system, elements of the pre-action valve govern the release of water. Due to the system control of water discharge, certain design standards impose limits to water discharge time of 30-60 seconds. This can impact system size and placement of control valves. Additional CAPEX costs for these systems include galvanised pipe for dry pipe sections plus air compressors, or nitrogen generators (which are intended to reduce the need for corrosion resistant pipe. Also true of dry systems.

There are three types of pre-action systems:

A. ***Non Interlock:*** Operate very similarly to Dry systems, but the control valve may also be opened by a confirmed fire signal from the fire detection & alarm system, interfaced to the associated control panel, thereby offering a response similar to wet and single interlock pre-action systems. These are known as Type B systems in EN standards.

B. ***Single Interlock***: This system requires receipt of a confirmed fire signal from the building's fire alarm system. For resilience this is typically from coincident operation of 2+ heat or smoke detectors within one protection zone (typically data centes do not rely on a single fire detection event to generate significant cause & effect elements /govern water release as this is not resilient enough). Once this happens, the pre-action valve allows water to enter the piping system ready for a head to operate. If a sprinkler head activates before this, it will sound a fault alarm, but no water will discharge. These are known as Type A systems in EN standards.

C. ***Double Interlock***: Double Interlock systems require both the confirmed fire signal from the fire alarm system plus the operation of an automatic sprinkler head in the area before water releases into the pipes. The disadvantage to this system is the significant delay in response time that can occur between fire ignition, detection, and reaction. As for dry systems above, due to the delay in discharge these systems allow a larger fire size to generate prior to response; there is a resultant risk of increased fire damage to equipment and a higher system water demand which can require larger water storage tanks.

System Maintenance

Each control valve type requires a similar maintenance schedule, but the pre-action systems are slightly more demanding due to their additional interfaces and mechanisms.

4.2. Clean agent

4.2.1 Context and considerations

In case of fire, the entire computer room is flooded with the fire suppression agent (Inert or synthetic gas). The quantity of clean agent is calculated based on the overall volume of the protected room. Due to the large volume of gas necessary for extinguishment, the discharge force is significant. In order to contain the clean agent long enough to suppress a fire, the protected room must be airtight.

According to these 2 major considerations, a protected computer room by clean agent must be designed with specific requirements such as strength and quality of the building components with pressure relief dampers to avoid a structural damage and sealing of walls, floors, return air ducts to ensure sufficient gas retention. Ventilation systems must be isolated prior to discharge but recirculation is allowed.

Whilst not as harmful as they used to be, gas system activation requires evacuation of staff within the protected area. Warning signals are given by a combination of sounders, bells, and flashing beacons. These systems are provided with cancel and hold buttons to assist in escape, plus manual release.

4.2.2 Inert gas (Nitrogen & Argon)

Inert gases, usually involving argon and nitrogen or a mixture thereof, are based on removal of the oxygen-rich air feeding the fire. Once discharged, which can take up to a couple of minutes, large quantities of gas displace the existing air and deprive the fire of its oxygen. Extinguishing generally takes between 60 and 120 seconds. Inert systems require more containers to be shipped, handled and installed, requiring a greater system footprint than other clean agent solutions.

Due to the longer discharge travel distance compared to synthetic systems, operators are more likely to be able to use common manifolded systems to protect multiple areas.

To accommodate the large volume of required gas, inert gas systems are stored under very high pressures (300 bar) and require more real estate to store a larger number of cylinders relative other systems. The cost of replacement of cylinders after discharge is relatively important.

In addition, the high pressure of inert gas systems has other consequences. For instance, higher pressures may result in more noise in the data centre over longer discharge times so operators need to assess whether or not the duration, magnitude and frequency of the noise will impact Hard Disc Drives present in the protected room.

Indeed, several years ago the fire protection industry became aware of potential disruptions to magnetic Hard Disk Drives and storage systems during the discharge of inert gas extinguishing systems.
The vibrations generated by these sound waves can have an impact on the proper functioning of HDDs.
To limit the level of noise, various measures and considerations should be considered during the design phase; namely:

- Regulation of the inert gas ejection pressure;
- Extension of the discharge time of the inert gas;
- Increase of the number of ejectors to reduce the flow per ejection point;
- Installation of special silent nozzles;
- Urbanization of the computer room;
- Nature of the materials (partition walls, raised floor, etc...).

4.2.3 Synthetic gas

These agents include hydrofluorocarbon-based (HFC) products and others, such as fluorinated ketone. Although clean agents vary in their product characteristics, they are commonly electrically non-conductive, gaseous materials which extinguish a fire by absorbing heat rather than removing oxygen. They can act fast, for instance discharging within 10 seconds and extinguishing the fire within 30 seconds, generally before reaching the flame stage.

Due to the conversion of stored liquid to released gas there is a shorter pipework range available compared with inert gas systems. Therefore, due to limited discharge travel, large sites will require distributed bottles arrangements. Compared to the problem of noise during an inert gas discharges, the vibrations generated by the sound waves have no impact with the usage of silent nozzles.

5. EU-Regulations

Perhaps where we have seen some of the biggest changes in fire protection has been legislation that reduces or even prohibits the use of some established fire protection solutions. The fact that Halon-based systems are no longer viable is something of which most people are probably aware. More recently, regulation impacting future use of HFC-based systems, which were introduced some years back as an alternative to Halon, is now starting to impact the market in earnest.

Although HFCs are not ozone depleting, they do have relatively high Global Warming Potentials (GWPs).

The European F-Gas Regulation (REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014) is dictating a very aggressive phase-down of HFCs compared to a slower pace for the rest of the world under the Montreal Protocol, (global agreement). Given that fire suppression systems have a typical lifespan of 25 years, this has an impact on the purchase of new and use of existing products that use HFCs, such as HFC-227ea/FM200 which has been replaced by Novec 1230 / FK-5-1-12.

6. Advantages & Attention points

Solutions	Advantages	Attention points
Sprinklers-Wet pipes	○ Simple installation with a single system combining thermic detection & extinguishing ○ Capex & Opex ○ Ease of operation and maintenance ○ Wider product choice.	• Design • Late thermic fire detection • Business interruption • Water damage to building materials • Risk of water leakage Water Impact on ICT Hardware and electrical equipment
Sprinklers-Dry pipes	○ Advantages of wet pipes systems ○ No risk of water leakage ○ Wider product choice.	• Design • Late thermic fire detection • No resilience • Larger water demand • Business interruption • Water damage to building materials • Water impact on ICT Hardware and electrical equipment
Sprinklers- pre-action systems	○ Advantages of wet pipes systems ○ No risk of water leakage ○ More secured than Sprinklers-Dry pipes ○ Wider product choice.	• Design • Business interruption • Water damage to building materials • Water impact on ICT Hardware and electrical equipment • Capex & Opex
Water mist systems	○ Limited water damage (vs Sprinklers solutions) ○ Fire treatment time ○ Ease of operation and maintenance	• Design • No acceptance for higher risks/storage occupancies • Rely on 3d party test certification • Risk of impact from air velocities • Capex & Opex • Water risks (residual)
Clean agent-Inert gas	○ No direct impact on ICT Hardware and electrical equipment by extinguishant ○ No business continuity impact ○ No impact on Environment	• Design and Operations • Full volume release (complete bottle replacement) • Gas retention (high room build quality & sealing solutions) • Overpressure (solid construction and overpressure solutions)

	○ Use of common manifold systems	• Ventilation systems must be isolated - recirculation allowed. • Capex & Opex • HDDs: moderate noise emission with use of silent nozzles and additional measures • Regulation: Health at work (Oxygen reduction) and gas storage
Clean agent-Synthetic gas	○ Storage volume < Inert gas systems ○ No direct impact on ICT Hardware and electrical equipment by extinguishant ○ No business impact ○ Ozone Depletion Potential = 0 ○ Low Global Warming Potential (FK 5-1-12 GWP =1 & ODP= 0)	• Design and Operations • Full volume release (complete bottle replacement) • Gas retention (high room build quality & sealing solutions) • Overpressure & underpressure (solid construction and over/under pressure solutions routed to outside) • Ventilation systems must be isolated - recirculation allowed. • Capex & Opex • HDDs: low noise emission with use of silent nozzles • Regulation: Health at work and gas storage • Some have high Global Warming Potential HFC227ea GWP= 3220 FK-5-1-12 GWP $\leq$1

Key considerations of these systems choices are clearly safety, costs of implementation and operations, impacts on critical services and on business continuity.

7. Other technology solutions

Moreover, other solutions to prevent or to extinguish a fire exist on the market and they are probably less used than the solutions previously described, as for example the following technologies:

Hybrid Water Mist systems are a combination of clean agent inert gas and water. The mist is produced in a manner that maximises the best attributes of each. Inert gas is injected into the water stream at the nozzle producing extremely small droplets and also acting to reduce the oxygen concentration in the protected risk. This translates into a Water Mist system that is practically dry making it suitable for protection of critical infrastructures.

Condensed aerosol fire suppression is a particle-based form of fire extinction. It is similar to gaseous fire suppression (or dry chemical fire extinction). This system employs a fire-extinguishing agent consisting of very fine solid particles as well as gaseous matter. The condensed aerosol microparticles and effluent gases are generated by the exothermic reaction; the particles remain in vapor state until the process of being discharged from the device. Then, it is "condensed" and cooled within the device and discharged as solid particles.

Hypoxic air technology for fire prevention, known as oxygen reduction system, is an active fire protection technology based on a permanent reduction of the oxygen concentration in the protected rooms. Unlike traditional fire suppression systems that usually extinguish fire after detection, hypoxic air is able to prevent fire. Reduced oxygen concentration will result in health risks for people who might suffer from symptoms at different concentrations. The symptoms are both dependent on the oxygen concentration and on the exposure time. Data centres are often positively pressurised and hypoxic systems can't deal with this level of leakage and on this basis are not generally recommended as being a practical solution in addition a the health risks.

Dioxide C02 Fire Suppression System is an engineered system available in different configurations: total flooding for unoccupied areas and local application. Gaseous carbon dioxide rapidly suppresses fire by a combination of cooling and oxygen displacement. Discharge duration and agent flow rates are customized for the individual application. Always use caution when considering a CO_2 fire protection system because a person must never occupy the protected areas. Even small amounts of CO_2 can be harmful or fatal if inhaled. Generally, CO_2 fire suppression systems flood the protected space with a 34% concentration of CO_2. A 7.5% concentration is considered hazardous to humans. Due to the risks (Activation, maintenance and operations), involved with the use of carbon dioxide system (Activation, maintenance and operations), this technology is rarely used for white spaces and sometimes used for specific & local applications.

8. Other considerations

Data centres present more complex challenges for fire suppression than most conventional office buildings, largely due to four main features they typically possess: open areas, sensitive equipment, climate control, standby power….

When designing or retrofitting a Data Centre, it will be also important to take into consideration early fire detection system, as well as protecting critical infrastructures such as electrical rooms, HVAC, UPS (Static and Dynamic) rooms, batteries, diesel engines, carrier rooms on the principle of a risk-based analysis (Assets and people) and insurance requirements. Areas of particular risk such as fuel storage, loading bays, waste facilities, offices spaces, technical corridors and general goods stores must also be considered.

For example, the most widely used system today is lithium-ion battery technology and, due to its energy density and potential for thermal runaway (where excessive heat creates even more heat), can lead to fire or explosion, requiring rapid suppression. Current industry stance is that neither mist nor gas are suitable for their protection, and sprinklers must be used. Sprinkler demand for these units can be high so product safety testing such as UL 9540A is encouraged to determine actual risk and design requirement.

Data Centres have many different sizes and configurations, which are important factors in determining the appropriate design of a fire suppression system with dedicated solutions depending on the content to be protected. Areas requiring fire protection can range from an entire building to a single floor, a room, or just specific equipment or assets.

9. Standards & norms

The various solutions described above must be designed, installed and maintained in accordance with EU/National regulations, Building codes, insurance requirements, and Health and Safety Requirements. Typically, the design of data centre buildings does not require automatic fire protection systems purely under local building codes, and the provision of these systems are not used to gain concessions to the passive fire safety design (escape distance lengths etc.). In these situations, systems are often designed to the preferred standards of the data centre owner, which may be equivalent codes like NFPA or Factory Mutual Global Data Sheets (FMDS) rather than local design codes.

The following list is not exhaustive but includes specific standards relate to the appropriate technologies described.

EN *(which must be read with any additional documents specific to country)*

BS / EN/ ISO

EN 12845: Fixed firefighting systems - Automatic sprinkler systems - Design, installation and maintenance

EN 14972: Fixed firefighting systems - Water mist systems - Part 1: Design, installation, inspection and maintenance

EN 15004: Fixed firefighting systems - Gas extinguishing systems

EN 15276-2: Fixed firefighting systems. Condensed aerosol extinguishing systems. Design, installation and maintenance

EN 16750: Fixed firefighting systems - Oxygen reduction systems - Design, installation, planning and maintenance

EN 50600 Information Technology - Data Centre Facilities and Infrastructures

BS 6266: Fire protection for electronic equipment installations – Code of practice

ISO 6183: Fire protection equipment -- Carbon dioxide extinguishing systems for use on premises -- Design and installation

ISO 7240-14: Fire detection and alarm systems design, installation, commissioning and service of fire detection and fire alarm systems in and around buildings

NFPA

NFPA 13: Standard for the Installation of Sprinkler Systems

NFPA 17: Standard for Dry Chemical Extinguishing Systems

NFPA 20: Standard for the Installation of Stationary Pumps for Fire Protection

NFPA 22: Standard for Water Tanks for Private Fire Protection

NFPA 75: Standard for the Fire Protection of Information Technology Equipment

NFPA 750: Standard on Water Mist Fire Protection Systems

NFPA 770: Standard on Hybrid (Water and Inert Gas) Fire-Extinguishing Systems

NFPA 855: Standard for the Installation of Stationary Energy Storage Systems

NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems

FMDS

FMDS 2-0: Installation Guidelines for Automatic Sprinklers

FMDS 3-2: Water Tanks for Fire Protection

FMDS 3-7: Fire Protection Pumps

FMDS 4-2: Water Mist Systems

FMDS 4-6: Hybrid (Water and Inert Gas) Extinguishing Systems

FMDS 4-9: Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems

FMDS 4-10: Dry Chemical Processing Systems

FMDS 5-31: Cables and Bus Bars

FMDS 5-32: Data Centers and Related Facilities

FMDS 5-33 Electrical Energy Storage Systems

10. Conclusion

In summary, there is no standard fire solution for a Data Centre which can vary in size from a single computer room to a Hyperscale Data Centre.

As critical facilities become larger and more complex, with a significant growth in power concentration, the risk of fires will increase and fire systems need to be designed into them from the earliest stages.

"Start with the End in Mind" (©Uptime Institute)

Any partial or total interruptions of critical services could have huge knock-on effects and the induced operational risks are so important in terms of safety impacts, direct or indirect economic losses, resources and time and cost to repair. This is without forgetting the potential costs of damage to reputation and brand image (Corporate Data Centre and co-location services by Data Centre Operators) which can be the most difficult to recover.

All the stakeholders of a Data Centre need to understand the pros and cons of the available solutions and, importantly, how the fire systems themselves can support the challenges presented by Data Centre installations and their evolution in the long term.

Fire safety strategy has to be defined by fire risk assessments based on Business Impact Analysis with Recovery Times Objectives and Recovery Point Objectives. From this analysis phase, the critical elements will be identified such as servers and critical infrastructures.

The selection of the type of the extinguishing agent should consider key elements such as risk analysis, insurances, Health & Safety authority, Environmental requirements, Building Codes, EU & National regulations and / or, in the absence of these, by the specific standards/norms related to appropriate technology.

Most fires in mission critical facilities can be prevented if common mistakes are avoided. Human error plays a large role in preventing fire risks and must be mitigated through training and procedures that are enforced.

All these systems are becoming more and more complex, and require high levels of expertise as well as Maintenance Operating Procedures and Emergency Operating Procedures for Facilities Staff.

Fire Protection Options in Data Centres

Authors:

Bruno FERY, Head of Datacentre Services, EBRC

James PEROU, Senior Fire engineer, ARUP