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Guidance on

Impact of High Airflow and Hot / Cold Aisle Containment on Gaseous Fire Extinguishing System Performance in Data Centers

Revision table

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FOREWORD

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Note: The English version of this document SC-EXT-139 is the approved Euralarm reference document.

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1. Introduction

From its origins as a project initiated by the National Fire Protection Association (NFPA) Fire Protection Research Foundation (FPRF), the intent for the Fire Suppression Systems Association (FSSA) and the Fire Industry Association (FIA) Research Report "Effect of High Airflow and Aisle Containment on Clean Agent System Performance in Data Centers", hereafter termed the 'report', was to explore whether the continued movement of air, in the form of cooling as often prevails, had any impact on the fire protection system and whether this was good or bad.

This Euralarm guidance is intended to aid interpretation and foster a practical application of the report for the European market and complement the conclusions at the back of the report.

Fundamentally most fire regulations pertain to the preservation of life. However, the protection of property is more a focus of the business, and nowadays the availability of a service is often inextricably linked to that. Protecting Information Technology Equipment (ITE) from fire whilst also safeguarding the continued ITE operation is paramount. Total flooding gaseous fire protection systems, also termed clean agent fire extinguishing systems, are thus used to protect this critical ITE, even through a fire and extinguishing scenario – for as long as the ITE is expected to operate.

The exponential growth of data requires for more processing power and more bandwidth, to sate the ever-increasing demand for computational capacity globally. These increases in demand bring challenges of heat generation and, despite chips and processors becoming more tolerant, have also increased heat output and thus the demand for improved and more efficient cooling. Nowadays data centers (DCs) are designed and constructed quite differently to those of before, from when these fire protection systems originated, and now have targeted air flow through specific routes, rather than just generally into and around the protected space.

As the design of the white space - the area within a DC where ITE is at work - has appreciably changed, an evaluation as to the impact of this on the fire protection system needed review.

2. Scope

This guidance is aimed at fire system designers, IT managers and DC operators.

Research has been conducted into the impact high airflow, as well as contemporary cooling approaches, could have on the efficacy of a total flooding gaseous fixed fire extinguishing system.

This guidance is to explain the salient points of that research, to signpost the reader - should more detail be required - and to discuss practical applications that potentially arise from the findings.

This guidance and the report exclude discussion about the choice of clean agent.

This guidance and the report look solely at the deployment of an extinguishing system – following detection of a fire event – and not of the consequence of the airflow on the detection.

This guidance does not absolve the need for specific stakeholders utilising the report to be familiar with it in full - the tests and results – to be able to challenge the system designer in order to ensure a robust outcome.

NOTE: *Clean agent fire extinguishing systems, used in DC applications, have evolved on the premise of early detection and prompt deployment, ideally during the incipient stages of a fire's evolution, so minimal losses or impact arises. The importance of quickly achieving concentration at the critical asset cannot be understated. Delay can result in negative outcomes, arising from failure in the cooling system or through design, affecting agent liberation as well as concentrations which can influence life safety as well as fire extinguishing performance. Beyond this statement, human safety is excluded from this paper; a system designer should duly consider the proximity of discharge nozzles to personnel within a space e.g. if installed within aisle containment.*

3. Key Points in the Report

The report comprises 44 pages overall. To aid reading of this guidance paper, we shall cite the page number given to the report, in italics; the eighth page of the PDF being page *1* of *38* of the report. Page *i* provides an Executive Summary and Page *ii* Background, with page *36* and *37* providing Conclusions.

The following point to specific relevant information within the report:

- Page *2* describes the arrangement: a nominal 206 m^3 volume with two rows of ITE racks to emulate aisle containment. Floor and ceiling voids are present and were used or not to simulate a hot aisle, where the room is fed directly from the Computer Room Air Handling Unit (CRAH/AHU) and the ITE waste heat extracted into the aisle between the ITE racks, or a cold aisle scenario where the ~460 mm deep floor void was used as a supply plenum to feed between the ITE racks, then through the ITE racks as waste heat would exhaust into the room.
- Pages *3* and *4* have a dimensioned section and a photograph.
- Pages *7* and *8* shows the measurement locations for the cold and hot aisle tests respectively.
- Page *9*, *Section 3.3* sets the pass/fail criteria. A result was deemed acceptable when achieving 95% target concentration at all relevant measuring points within 2 minutes from the end of discharge, with examples on pages *10-12*. Page 13 examples an unacceptable result.
- Pages *14* and 23 depicts the airflow, immediately preceding the results from each series of tests.
- Pages *15 and 16* tabulate the results of the cold aisle permutations against agent type and airspeed, along with where nozzles were installed and omitted [*Table 1*], and page *25* does the same for the hot aisle configurations [*Table 2*].

4. Air Flow

For many reasons it was once commonplace for a fire system to interrupt the cooling / air movement.

Most testing, for product and system type-approval, was and still is conducted without air movement.

Nowadays it is rarely possible to decelerate or still the air, even temporarily, as the ITE will rapidly overheat, and therefore if continued cooling is required, and higher flow likely, it was important to understand the effect of this upon the fire protection system.

There is no universal definition for 'high airflow', and the report does not explore a specific value or threshold for this; it will change subject to how the air is channelled. The report uses still, without the CRAH air handling unit operational, and then it runs at different speeds with air changes per hour (ACH) being the measurement.

Effectively 60 ACH being the equivalent of all the air rotating one full revolution through the protected space in one minute, 30 ACH requiring two minutes and 15 ACH needing four, against a typical extinguishing discharge time of 10 seconds for a halocarbon agents and 1 or 2 minutes for inert gases.

The incremental ACH used in the report was thus intended to be indicative of some of the cooling likely found in use today. This may allow some comparison but there was no intent to allow interpolation. In similar vein, the report explored whether the air handling could itself liberate the extinguishant and compensate for a poorly engineered design, which also serves to prevent one wrongly extrapolating the results.

The report does not cover different volumes of data centers so there is no conclusion regarding the scaling thereof.

5. Approvals and AHJs

There are noticeable differences between the United States and Europe. The acceptance of a practical application of the research findings may regionally differ. This stems from an attitude towards liability and the discretion allowed, given to or applied by an authority having jurisdiction (AHJ). Parts of Europe might not reject a custom engineered solution, even when that actual application has not been proven, whereas this may be less likely in the USA.

American code enforcement (e.g. AHJs, Building Code Inspectors, Plan Checkers, Building Code Officials) expect full compliance using an approved product and system, such as to UL 2166, as emphasized in the conclusions on pages *36* and *37*.

Conversely, European system design Standards, such as EN 15004-1, are often voluntary. European AHJs may therefore have more flexibility which allows stakeholders to better utilise the report findings; for instance, a custom engineered approach being detailed and documented, and accepted by all parties, is then recorded as an 'agreed variation' on the system certification.

That said, one must be cognizant to the requirement of a specific region, customer, stakeholder and insurer and requires diligent scrutiny. For example, see the following regarding nozzle requirements.

6. Standardized Nozzle Positioning

For a general case, i.e in still air, conditions for the positioning of nozzles are defined and/or verified by testing in the Standards. Similarities exist across different Standards, but nuances may permit in one jurisdiction what is precluded in another. In some cases, this is very prescriptive, whereas others are more performance or outcome oriented.

	EN 15004 / ISO 14520	VdS / CEA	NFPA 2001
Choice and location	Type, number and placement shall be such that the design concentration is achieved in all parts of the enclosure. Nozzles shall be approved, located with the geometry of the enclosure taken into consideration.	Nozzles shall be arranged so that homogenous mixture of extinguishing concentration is achieved.	Discharge nozzles shall be listed for the intended use. Nozzles shall be installed so as to be free of obstructions that could interfere with the proper distribution of the discharged agent in accordance with the manufacturer's installation and maintenance manual. Each volume, room, and raised or sunken floor to be protected shall be provided with nozzles.
Coverage area	Nozzles shall be suitable for the intended use and shall be approved for discharge characteristics, including area coverage and height limitations.	Maximum area coverage shall not exceed 30m² per nozzle. If protected space is higher than 5m, additional layer(s) at intermediate levels.	Listing criteria shall include flow characteristics, area coverage, height limits, and minimum pressures. Maximum area coverage and the minimum and maximum protected area height limitations need be proven and applied.

Furthermore VdS / CEA has additional requirements: some general, others specific to the type of agent.

	VdS 2381 / CEA 4045 (halocarbon agents)	VdS 2380 / CEA 4008 (inert gases)
IT equipment	In case of an inadequate distribution of extinguishing agent inside the IT equipment, a local protection system with a different extinguishing agent* shall be implemented in addition to the total flooding system.	In case of an inadequate distribution of extinguishing agent inside the IT equipment, besides the total flooding system, a local protection system in accordance with Annex A.2 shall also be implemented.
Additional nozzle requirements	For FK-5-1-12 an area around nozzle with radius of 0,2m must be kept clear. In the jet direction of each nozzle hole, a cylinder with a diameter of 10% of the evaporation distance is to be kept clear, across the entire evaporation distance. Only single objects with a small cross section are permitted.	
Cold / Hot aisle containment	The room, false floor, false ceiling and containment areas shall be equipped with an adequate number of nozzles for the homogenous concentration build-up. Alternatively, evidence of the required extinguishing agent distribution may be provided to VdS in support. Under certain conditions there is no need for extinguishing nozzles in the containment area. Requirements for the air-conditioning technology: redundant design of the air-conditioning technology; emergency power supply to the air-conditioning technology; circuit integrity maintenance over a period of at least 30 minutes; the air-conditioning technology shall be switched off immediately after the end of the discharge time; exchange of signals (e.g. fault and operation) between air-conditioning and fire extinguishing system.	
Particularities	There may be a negative effect on the IT hardware, originating from effects such as sound pressure or frequency from alarm devices. Possible measures to reduce these effects may be: sound pressure; absorbers on the nozzle; sound pressure absorbers on the pneumatic alarm devices; adequate containment of the IT equipment with sound absorbent effect; adequate use of other hard disks (e.g. SSD); constructional measures for sound reduction.	

* Note that most Standards do not permit the mixing of different agents within the same protected area.

7. Conclusion

The report helps in the understanding of how the airflow impacts a clean agent extinguishing system, as well as how it can be used to positive effect – improving fire protection performance – which might be possible. Caution must be applied to prevent abuse of this, e.g. cost cutting used to win a project at the expense of system safety or efficacy.

In general, continued air movement had no negative consequence on the performance of the extinguishing system.

Should one expect OEMs to obtain new product approval listings and re-write their design manuals to reflect the findings of this report? This is unlikely. There are too many variables, no proven nor agreed testing methodology, and the cost of such testing would be significant and possibly prohibitive. However, in Europe, this may not prevent a system design being custom engineered, using practical application of the report findings, married to stakeholder agreement enabling such.

It is for the design team to work together, including critical stakeholders and AHJs, for a holistic and suitably comprehensive approach; to optimise the design of the system, in business-as-usual, as well as through incident and crisis management, to formulate an agreeable solution. The FIA/FSSA report and this Euralarm Guidance should help this discussion, and the body of test evidence in the report, tabulated on pages *15* and *16* for cold aisle configurations and page *25* for hot aisle arrangements along with supporting graphs and page *35* information, will assist.

8. Bibliography

- Research Report released Nov 2023 by the Fire Industry Association (FIA) and the Fire Suppression Systems Association (FSSA): "Effect of High Airflow and Aisle Containment on Clean Agent System Performance in Data Centres" (Download report)
- EN 15004 Fixed Firefighting Systems - Gas Extinguishing Systems
- ISO 14520 Gaseous Fire-Extinguishing Systems
- VdS 2381/CEA 4045 Fire Extinguishing Systems using Halocarbon Gases
- VdS 2380/CEA 4008 Fire Extinguishing Systems Using Non-Liquefied Inert Gases
- NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems

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