Development of Performance Equivalency Methodology for Detection and Suppression System Integration

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ABSTRACTS

Many countries around the world have adopted Performance-Based Design (PBD) methods. The general approach of a performance-based design involves quantitative and qualitative statements to which a design must comply. Performance-Based Design regulations (1) permit innovative design solutions that meet the performance requirements established and (2) encourage cost-effectiveness and flexibility in design. The ultimate success of a PBD relies on the ability to apply well-defined methodologies to prove the equivalent (or better) system performance in code compliance.

When a fire detection system is designed to actuate a suppression system such as a gaseous suppression system, certain norms or industrial practices are applied. They are seen as deemed-to-satisfy (DtS) solutions. However, when different fire detection technologies are considered for the same purpose, the ability to prove equivalent or better performance becomes critical. When an equivalent or improved performance is established, a new technology and design concept can be adopted. When better performance is evident a system design can be optimised to satisfy not just building and life safety regulations but business continuity needs. The latter is very much relevant to the current and future development of fire engineering as increasingly Performance-Based design provides risk-informed fire safety solutions.

This paper focuses on the integration of gaseous suppression systems with two different fire detection technologies in computer rooms and telecommunications facilities. One is the conventional spot-type smoke detector and the other advanced Air Sampling-type Detector (ASD). The performance comparison method, a tool for "equivalent" or "better" solution design and how to benchmark against the implied performance level in deemed-to-satisfy provisions is described. Different double knock (coincidence) detection schemes are also discussed.

Performance-Based Design promotes innovative optimal solutions. Finding the right solutions to satisfy building and life safety regulations and at the same time, meet risk management and business continuity requirements remains a challenge for the fire community. This paper presents the progress made in the area of assessing various fire detection technologies in the context of meeting performance criteria for the purpose of suppression system integration.

INTRODUCTION

Gaseous suppression systems are commonly found in computer rooms, telecommunication facilities, museums, libraries, off-shore facilities, aviation and military installations. According to research [1], applications of gaseous suppression system in telecommunication facilities account for over 60%. A number of key attributes makes gaseous system a preferred option over other forms of fire suppression [2]:

1. the ability to extinguish shielded, obstructed or three-dimensional fires in complex geometries because of its ability to uniformly distribute throughout an enclosure (total flooding).
2. the ability, through the use of detection, to extinguish fires at a very early stage (well before direct or indirect fire/smoke damage occurs).
3. Cause no collateral damage due to agent discharge (no residues).

Gaseous suppression systems are suited to suppressing and extinguishing fires in areas where an electronically non-conductive medium is desirable, where clean up of other agents presents a problem, where the enclosures are usually occupied, therefore a non-toxic agent is required, or where

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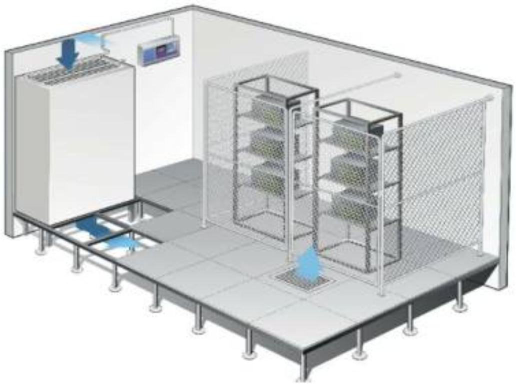
smoke contamination must be kept to a minimum. Owing to these benefits, gaseous suppression systems have become popular in mission and process-critical facilities.

However, due to its relatively long discharge time and large agent volume, fire may grow to a substantial size from detection to actual agent release. Therefore a rapid detection of a fire in its incipient stage is always a crucial system design consideration.



Both prescriptive and Performance-Based codes govern the fire detection system design. Standard Fire Detection (SFD), Early Warning Fire Detection (EWFD) and Very Early Warning Fire Detection (VEWFD) system performance is either deemed-to-satisfy the implied building and life safety measures inherent in prescriptive codes or meet the actual protection objectives and risk management requirements through PBD.

Because of simple implementation, spot-type detectors working as SFD (some newer ones for EWFD and few promoted as VEWFD) have been applied in these applications as inputs for gaseous suppression system release. When new detection technology such as Air-sampling type smoke detector (ASD) systems became popular in the market, both prescriptive and PBD codes recognised it as a VEWFD apparatus for both high and low airflow environments. When it comes to suppression system integration, there are some barriers however. So in reality, even though ASD is recognised for primary detection, many mission and process critical facilities today have either a single SFD or EWFD based detection system for gaseous suppression (promoted as very early extinguishment of a small fire) or have an additional VEWFD system for just the very early warning detection, despite the fact that some of the ASD systems are capable of delivering the equivalent or superior performance to a spot-type detector for the purpose of extinguishing agent release.

This study focused on the development of a detection equivalency method using two different detection technologies for gaseous suppression release. An optimal and cost effective fire safety system design can be achieved using VEWFD features for both prescriptive code compliance and Performance-Based code requirements specifically designed to address unique fire hazards and risk management in mission and process critical facilities.

PRESCRIPTIVE AND PERFORMANCE-BASED CODES

Risk management and business continuity are very important considerations of a fire protection solution in the context of Performance-based design. A prescriptive code, while simple to comply and implement, usually dictates what to do but fails to state clearly the objectives and performance measures. In contrast, Performance-based design has clear design objectives, agreed by all stakeholders and uses sound engineering approaches to establish a cost-effective solution. In doing so, issues concerning risk management and business continuity are usually taken into account. The SFPE Engineering guide to Performance Based fire protection analysis and design of buildings [3], International Performance Based Design Guidelines [4] (covering Australia, New Zealand, USA and Canada), British BS7974:2001 Application of fire safety engineering principles to the design of building [5] for example are some of the most commonly mentioned industrial guidelines to support the Performance-based design. Most of these clearly state the need for a "risk-informed" design approach.

In many buildings housing mission and process critical operations such as a computer room and telecommunication exchange, there are usually both prescriptive and performance-based codes. The former is mainly designed for building and life protection and the latter "business-use" related, taking into account the need for business continuity and asset protection.

Following is a summary of code specified automatic detection and actuation requirements for gaseous suppression release.

Table 1: Gaseous suppression (clean agent) system codes in USA, UK and Australia

Key	NFPA 2001:2000 [6]	BS7273: Part 1: 1990 [7]	AS 4214.1 – 1995/1997Amenmdment [8]
Detection systems	Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with appropriate NFPA protective signalling systems standards such as NFPA 72 [9]. Automatic detection and automatic actuation shall be used.	The detection system should follow the recommendations of BS 5839: Part 1 [10], unless a higher level of protection would be provided by following the recommendations of BS 6266 [11]. Where coincidence connection is used, the minimum detector density for normal commercial or industrial purposes should be twice the minimum required by BS 5839 : Part 1 or BS 6266.	Automatic fire detection, alarm and control systems for gaseous systems shall comply with the relevant requirements of AS 1670 [12] and this standard. Where the operation of the detection circuits are required to actuate extinguishant discharge, the detectors shall be evenly located at the half the area coverage specified in AS 1670.
Detection method	Automatic Detection shall be by any listed method or device capable of detecting and indicating heat, flame, smoke, combustible vapors, or an abnormal condition in the hazard, such as process trouble, that is likely to produce fire.	The type of detectors used is of paramount importance and reference should be made to BS 5839 Part 1.	Any approved device, or combination of devices, appropriate to the fire risk and air flows in the protected area, that are selected and sited in accordance with AS 1670, may be used for automatic detection.
Response procedure	Abort switches generally are not recommended, however, where provided, the abort switches shall be located within the protected area and shall be located near the means of egress for the area.	Operation of the system should follow a sequence leading to the release of fire extinguishing medium, encompass coincidence connection in order to avoid unwanted discharges.	A Local Control Station (LCS) shall be installed immediately adjacent to the main entrance and at each emergency exit from the protected area to provide local control of the extinguishant discharge.
Agent release	For clean agent extinguishing systems, a pre-discharge alarm and time delay, sufficient to allow personnel evacuation prior to discharge, shall be provided. Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.	A time delay facility may be incorporated in the system to allow personnel to evacuate the protected space prior to discharge of the fire extinguishing medium. This time delay should not exceed 30 seconds unless a longer period is specified by the appropriate authority.	For most fire risks, the extinguishant discharge shall be preceded by a time delay. The automatic discharge of a system, when personnel are present in the protected area or adjacent areas, shall be capable of being prevented by means of a discharge control.
Double knock / coincidence scheme	For unwanted System Operation, care shall be taken to thoroughly evaluate and correct any factors that could result in unwanted discharges.	Every care should be taken to avoid the consequences of inadvertent discharges. A method of minimising the possibility of false alarm is by using coincidence connection of smoke detectors.	All systems shall be provided with a manual mechanical release, where practical. Systems shall be capable of automatic and manual operation. Additional detectors may be required.

Following is some of the Performance-based codes designed specifically for computer rooms and telecommunications facilities.

Table 2: Commonly used PBD codes for mission and process critical facilities

Key	NFPA 76:2002 [13]	NFPA 75:1999 [14]	BS6266:2002 [11]
Detection system	The confirmation of the presence of smoke can be accomplished by : (1) Cross-zoning (2) Time/smoke density factors (3) Activation of multiple detectors (4) Manual pull station in combination with detection strategy (5) Heat detection (6) Automatic suppression system actuation.	The equipment used shall be a listed smoke detection-type system and shall be installed and maintained in accordance with NFPA 72. Automatic detection systems shall be installed: (a) At the ceiling level throughout the area (b) Below the raised floor (c) Above the suspended ceiling and below the raised floor.	Recommendations for electronic equipment areas protection are complementary to the BS 5839-1. Smoke detection is often the most appropriate form of detection for electronic equipment areas. Aspirating smoke detection systems are particularly suitable. Point-type heat detectors are considered unsuitable as primary detectors.
Gaseous suppression system	Where provided, clean agent extinguishing systems should be designed, installed, and maintained in accordance with the requirements of NFPA 2001.	Where gaseous agent total flooding systems are used, they shall be designed, installed, and maintained in accordance with the requirements of codes such as NFPA 2001.	The vulnerability of electronic equipment rooms to fire damage, necessitates very early and effective action to suppress the fire.
Detection sensitivity	Application of VEWFD, EWFD and SFD.	See “Detection system” above.	The sensitivity of fire detection systems covers a wide range. A highly sensitive system can detect an incipient fire condition. Normal sensitivity systems are likely only to detect a fire when it has reached a sustained smouldering or flaming stage, when fire and smoke might already have caused some damage to sensitive equipment.
Gas release	Detection systems used to actuate clean agent suppression systems should be designed so that the selected EWFD and VEWFD smoke detection systems with spacing that is less than that normally required by NFPA 72.	Gaseous agent systems shall be automatically actuated by an approved method of detection meeting the requirements of NFPA 72, and a listed releasing device compatible with the system.	Detection systems can be used additionally for the following purposes: a) to isolate the power supply or initiate programmed shut-down of the electronic equipment; b) to shut down air-conditioning; c) to initiate the release of fire suppression media.
Double knock / coincidence scheme	Detection should be either cross-zoned or an equivalent method should be used to limit the possibilities of false discharges.	Not specified but made reference to NFPA 2001.	Where any actions could result in disruption of operations or other serious inconvenience, careful consideration should be given to reduce the possibility of false operation. This might include the use of coincidence connection in accordance with BS 7273-1 and the initiation of different actions at different stages of alarm.

As illustrated in Tables 1 and 2, gaseous suppression system design codes make reference to general fire alarm code and sometimes Performance based code for automatic actuation system. However, although many fire alarm codes such as NFPA 72 allow Performance-based designs, because they were developed predominantly as prescriptive codes, many mission critical facilities rely on conventional detection technology to activate gaseous suppression system. Such solutions are low cost but certainly not an effective one when the need for protection and addressing specific risks must be taken into consideration.

On the other hand, codes such as BS 7273 and BS 6266 play a significant role in mission and process critical facilities protection in certain regions. These codes provide a framework for the development of a truly cost effective and optimal protection solution. Considering the actual risks and how to respond to an emergency in these facilities, VEWFD technology is actively promoted. Other system features such as coincidence detection and staged alarms are also clearly described.

NORMAL DESIGN PRACTICE

Codes with prescriptive provisions are seen as minimal rather than the optimal protection measures for the purpose of building and life safety. The smoke propagation, fire size and impact on business, contents, environment, etc. are not a prime concern. It leads to the fact that many high-value, mission critical facilities today are still protected only with conventional technology because of perceived low initial investment.

Photoelectric spot detectors (detecting smouldering fires), sometimes combined with ionisation detectors (detecting flaming fires) depending on the fire hazard or criticality of risk, are most common even though in a high air change environment such as a computer room, spot-type detectors performance can be severely affected by smoke dilution, smoke entry (into detection chamber) lag time, air velocity, etc. Others use heat detectors despite some codes recommend not to use because of a much delayed detection in fast moving air and fully air conditioned environments. Because the fire systems in these facilities are designated to comply with prescriptive codes such as NFPA 72, BS 5839 or AS 1670 as minimum, they are acceptable even the designs don't necessarily represent the true intent of the codes where in many cases, ideally Performance-based design should be utilised, taking into account the needs of business continuity and asset/content protection to develop an optimal fire protection solution.

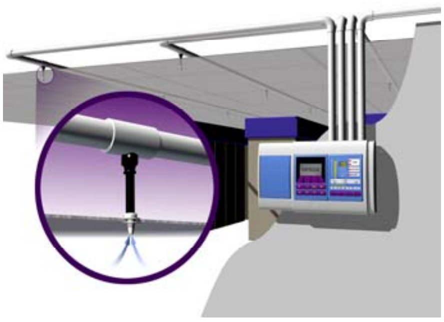
There are many computer rooms and telecommunications facilities around the world that apply industrial best practice to ensuring business continuity. Codes such as NFPA 75, 76 and BS 6266 are Performance-Based design considerations, developed to complement other, mainly prescriptive, codes. In these codes, VEWFD is differentiated from EWFD and SFD. VEWFD is usually represented by high sensitivity Air-sampling type smoke detector (ASD). Vision Systems' VESDA® is one such system, with advanced features such as ultra high and wide sensitivity range, adjustable multiple alarms and thresholds and continuous, absolute smoke obscuration measurement.

In countries such as Australia where the building code is Performance-Based, VEWFD has been used widely as primary (building code compliance) and secondary fire protection (enhanced fire protection to meet specific performance objectives). Because of wide sensitivity range and flexible smoke alarm threshold settings of some of the VEWFD, the systems are designed so that very early warning part of the system (high sensitivity alert alarm settings) is used to ensure business continuity and early intervention of a potential fire incident, while standard alarm settings are used for fire brigades notification, evacuation and suppression system actuation.

VERY EARLY WARNING FIRE DETECTION SYSTEMS

In their simplest form, ASD systems continually draw samples of air from the equipment or area requiring protection and assess these samples for the presence of smoke. The detector is a form of nephelometer – an air pollution monitor having remarkably high sensitivity, typically hundreds of times higher than conventional smoke detectors. Such high sensitivity is required to detect the earliest traces of airborne particles or aerosols released due to the overheating of materials. One particular interest is how these systems handle fires in LOS or high airflow environments in which the smoke density and heat intensity can be dramatically reduced, preventing many conventional detection technologies from functioning effectively. Many ASDs can actively aggregate lower density smoke from sampling points to minimise the dilution effect.

An ASD system is typically implemented as a number of small-bore pipes distributed across a ceiling (above or below) with sampling holes drilled into each pipe at suitable intervals. Air is then continuously drawn into the pipe network via the holes to the centrally-located detector using an air pump or aspirator. The density of smoke in the sampled air is compared to a set of pre-defined smoke thresholds. If the amount of smoke in the sampled air exceeds the set thresholds, alarms are issued accordingly.



Typically, the pipes and holes are laid out according to a grid pattern that places each hole where a conventional point detector would otherwise be located to meet the prescriptive codes. The true effectiveness of air sampling systems is thought to be its flexibility in application. Placing the sample holes at points where smoke is most likely to travel (i.e. affected by mechanical air conditioning) provides the most effective means of very early warning smoke detection, typically at return air grilles. It is also possible to use these systems to initiate fire suppression systems at a much later stage in the fire development cycle.

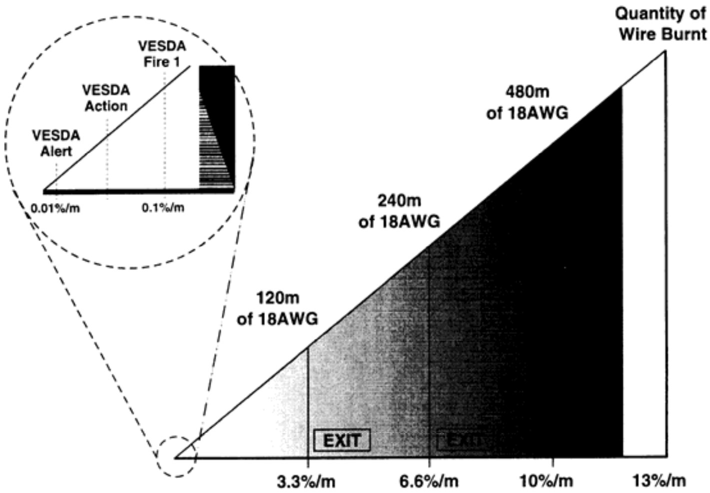


Figure 1: Smoke Obscuration measured based on a Burning wire within a 1000m^2 room

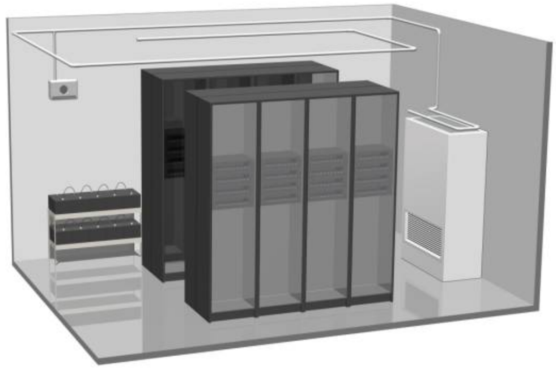
How sensitive can ASD be? VESDA®, a Very Early Smoke Detection ASD system, for example can set alarm levels from 0.005% Obs./m to 20% Obs./m (0.0015 to 6.1% Obs./ft). Obscuration is the effect that smoke has on reducing visibility. Higher concentrations of smoke result in higher obscuration levels, lowering visibility. Figure 1 shows the relative smoke density and its affect on a typical EXIT sign. At 3% Obs/m (0.915% Obs/ft) visibility of the EXIT sign is already hampered [15].

ASD can provide warning alarms at around 0.005% Obs/m (0.0015% Obs/ft), some hundred times more sensitive than conventional detection systems. Staged alarms and associated time delays ensure these systems are quite immune to nuisance alarms.

The provision of staged alarms allows for activation of controlled and escalated responses. For example the ***Alert*** (i.e. the first alarm) condition may be used to call authorised staff to investigate an abnormal condition. Should the smoke condition continue to increase, the ***Action*** (i.e. the second alarm) condition could activate smoke control measures; begin warning sequences via the evacuation system and notify further staff members. ***Fire 1*** (i.e. the third level) alarm indicates that a fire condition is very close or has started. At this stage the environment is evacuated. With the provision of a ***Fire 2*** alarm level, ASD can initiate suppression systems.

CHALLENGES AND ISSUES

Unique environmental conditions in the protected areas present a challenge to fire protection. High airflow, small, mainly very low or non-thermal energy fire hazards, obstruction to the smoke movement due to high density equipment layout just to name a few. These challenges also present opportunity for gaseous suppression systems working on a total flooding concept. But for automatic actuation of clean agent using a fire detection system, especially VEWFD, there have been some claims in relation to the detection performance.



Claim #1: Detection performance is dependent on airflow"Detection performance is often dependent on normal air flow conditions to move particles of combustion to the sampling points of ASD or a spot-type detector. The activation of the suppression system is fully dependent on the proper operation of the HVAC system to detect a fire. If one of the HVAC units is not operating, or the air flow pattern is disturbed for any reason, it is very possible that smoke particles would never make it to the sampling points."

Claim #2: Unpredictable detection sensitivity
"Because of the air movement, it is impossible to predict the smoke level at which the detection system will respond in a fire situation, especially for ASD when the activation of the system is dependent on the distribution of combustion particles throughout the room. With spot-type smoke detectors, the level of smoke obscuration at each smoke detector is a known value and what happens in the rest of the room is irrelevant."

Claim #3: Lack of address-ability"ASD has little value in determining the approximate location of the fire source. Addressable spot-type smoke detectors provide the exact location of the activated detector."

Table 3 is a comparison of two different detection technologies.

Table 3: Different detection technology in high airflow environments

Claim	Normal Design Practice (Comply to DtS code use SFD spot-type detectors)	Alternative Design Practice (Comply to DtS and PBD codes use VEWFD ASDs)
1	Highly dependence, fire sizes at the time of detection vary.	Low dependence, if necessary fire size at the time of detection can be defined and controlled by variable alarm setting.
2	Nominal sensitivity is specified but not a reliable indication of detection, affected by environmental conditions [16] [17]. Fire sizes at the time of detection vary.	***Fire*** alarm setting can be defined and refined for optimal detection. ASD is not subject to higher airflow effect. Once setup, absolute detection provides higher level of certainty.
3	Fire location is difficult to pinpoint in high airflow environment. Address-ability is not a prime design consideration. The objective of gaseous suppression design is to extinguish fire using total flooding concept.	Earliest detection of a fire event gives time to investigate and intervene. Later stage ***Fire*** alarm used for gaseous suppression system activation is a safety net to ensure earliest possible fire suppression.

While there are shortcomings with spot-type detectors for mission critical facilities protection, the design is deemed to satisfy code requirements as minimal for building and life safety. VEWFD ASD technology, however, provides an optimal system design, taking into account PBD code requirements.

In order to apply such an alternative design, the equivalency in detection performance between these two different detection technologies need to be established.

The questions are (1) how to set an ASD detector ***Fire*** alarm threshold for gaseous suppression actuation that can deliver similar results as if spot-type detectors are used; (2) how to set up the double knock (coincidence) detection scheme if ASD is used.

EQUIVALENCY METHOD: COMPUTER MODELS & PARAMETERS

As mentioned before, the normal practice of activating gaseous suppression systems is by means of alarm notifications issued by spot-type detectors that commonly operate on a double knock (coincidence) detection scheme. This design is deemed to satisfy the prescriptive codes. Therefore it was used as detection performance benchmark in this research.

Fire-modelling tools (Fire Dynamics Simulator developed by NIST) was used to determine the appropriate ***Fire*** alarm level for ASD to establish an equivalent or better detection performance to the benchmark using conventional spot-type detectors. The study takes into account various room geometries (area, ceiling height), airflow conditions, fire location and detector coverage based on both prescriptive and PBD requirements. The input parameters are summarised in Table 4 and 5.

Table 4: Computer room geometry and environment

Parameter	**Computer Room Specification**					
	Small		Medium		Large	
Floor Area	3227 sq.ft		6450 sq.ft		9675 sq.ft	
Length/Width	66 x 49 ft		98 x 66 ft		118 x 82 ft	
Floor Void Height	1.3 ft					
Ceiling Height	12 ft	20 ft	12 ft	20 ft	12 ft	20 ft
Return-Air Grille Area	3 x 13 ft	3 x 20 ft	3 x 23 ft	5 x 23 ft	5 x 23 ft	6 x 30 ft
Supply Vent Area	15 x (2 x 2 ft)		35 x (2 x 1.3 ft)		54 x (2 x 2 ft)	
Room Air Circulation per Hour	Still air, 10, 30, 60					

Table 5: Key fire model parameters

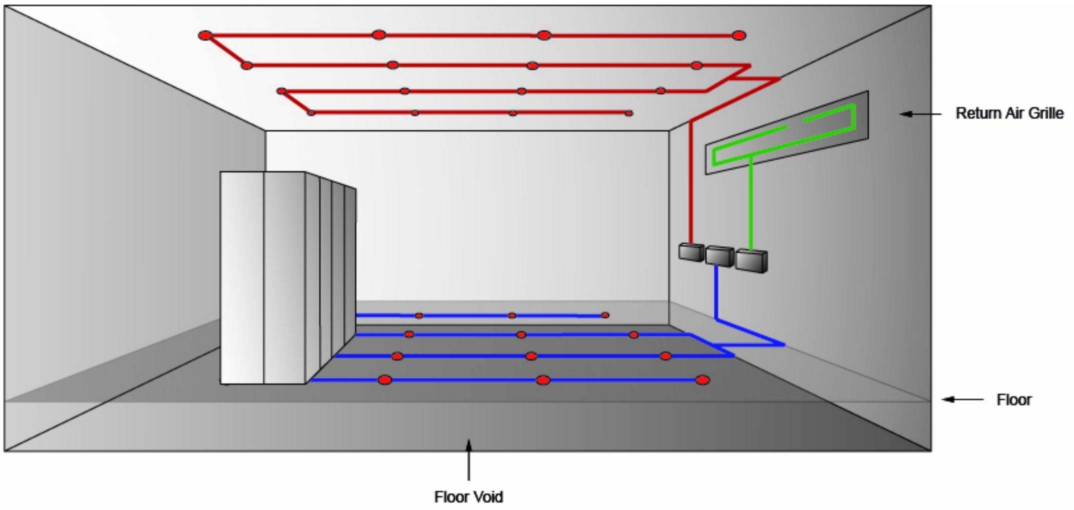
Parameter	**Description**	
	Open Plan Room	**Floor Void**
Grid (Fire Source) (m×m×m)	0.05×0.05×0.05	
Grid (m×m×m)	0.2×0.2×0.1	
Fuel Type	PVC cables	
Model Construction	Whole enclosure is modeled	
Fire Growth Rate	T^2 slow (90kW at 180sec)	
Fire Base (m x m)	0.6 x 0.6	
Fire Location	Away from Return-Air Grille	(1) Away from Return-air Grille (2) Next to Return-air Grille
Ceiling Sampling	Yes	
Return-Air Sampling	Yes	
Floor Void Sampling	Yes	

EQUIVALENCY METHOD: SENSITIVITY STUDY

The sensitivity study involved the following:

- Investigate the performance of spot-type detectors with three different nominal sensitivities of 1% Obs/m (0.305% Obs/ft), 4% Obs/m (1.22% Obs/ft) and 7.5% Obs/m (2.288% Obs/ft), in typical computer rooms and telecommunications facilities, with changing parameters (geometry, airflow conditions, fire location).
- Benchmark the performance of spot-type detectors and develop an ASD system that offers equivalent or better performance under various room conditions.
- Devise Double knock (coincidence) detection activation schemes with total ASD or in combination with spot-type detectors.

The fire source was positioned at the center of four sampling points/detectors as worst-case scenario. Detection points, representing either spot-type detectors or ASD sample holes, were positioned as shown in the illustration below. Once the smoke profile at each individual detection location was obtained, they can be integrated to derive the aggregated smoke trend of an ASD detector. The calculated smoke obscuration level is then compared with the pre-determined ***Fire*** alarm threshold for alarm notification.



For ASD detector, average transport time was used. For spot-type detectors, the detector activation relies on number of factors including temperature raise, air velocity and smoke density [17]. To simplify the analysis, 20 seconds entry lag time were adopted as a conservative approximation to the spot-type detectors after the smoke density has reached the detector nominal sensitivity.

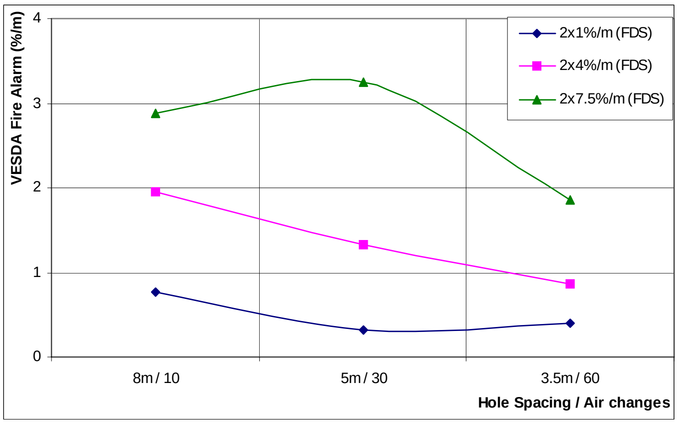
Number of detectors required varies depending on the room size, air change rate, etc. NFPA 72 spot-type detector spacing rule was adopted. To be consistent, ASD sampling holes were positioned to coincide with the spot-type detectors.

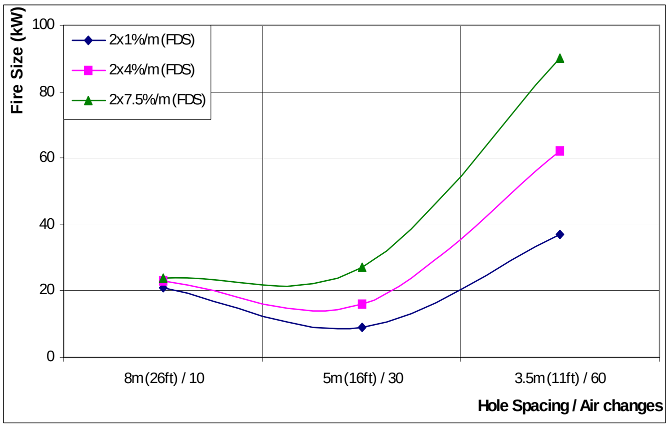
In order to determine which ASD ***Fire*** alarm threshold setting would provide an equivalent suppression release performance to that of a design using spot-type detectors with double knock (coincidence) detection scheme, the obscuration levels were calculated at the point that the second spot-type detector reached the alarm condition.

Once the equivalent performance has been established, the fire size at time of detection for each scenario was recorded. Applying the ASD flexible alarm threshold setting and use the fire size as basis, a "better" performance with a different set of ***Fire*** alarm set points can then be derived. This also allows the system to be designed so that the fire size at the time of detection is relatively close regardless the enclosure geometry and conditions. For instance, to detect a fire size of 20kW, the ASD ***Fire*** alarm may be set more sensitive if airflow is higher, or same airflow but large area or higher ceiling.

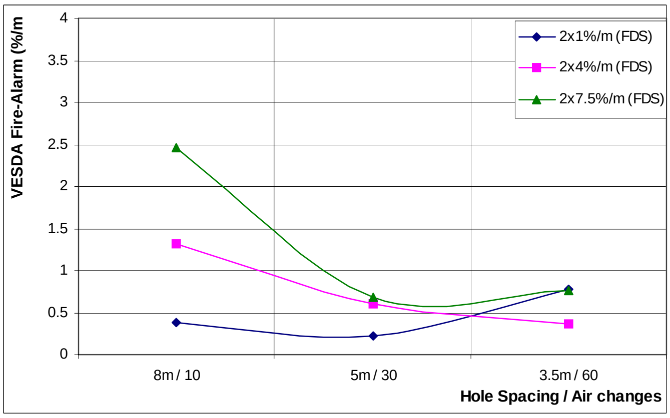
EQUIVALENCY METHOD: BENCHMARK

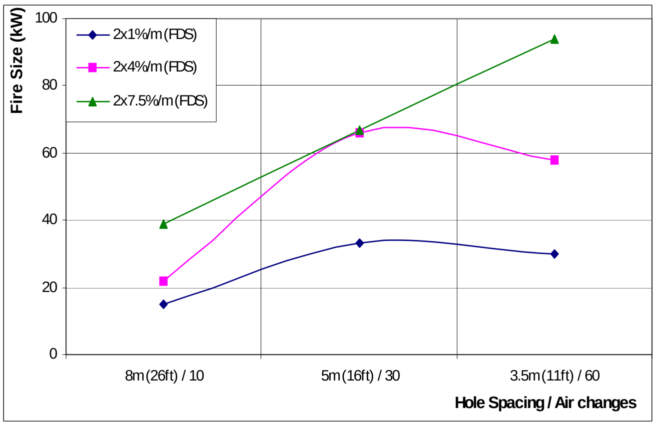
Following is ASD ***Fire*** alarm thresholds and corresponding fire size at the time of the second spot-type detector was in alarm condition for rooms.



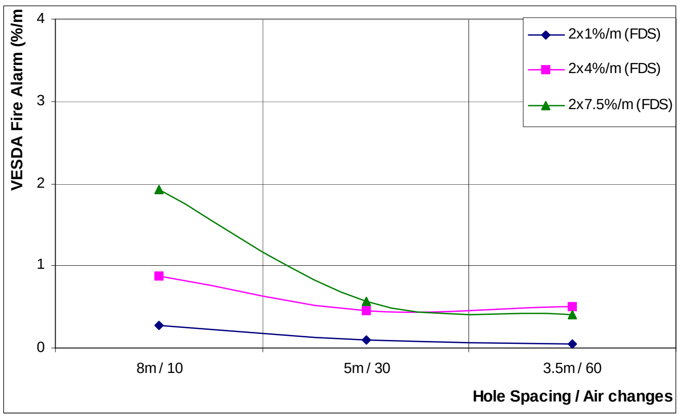


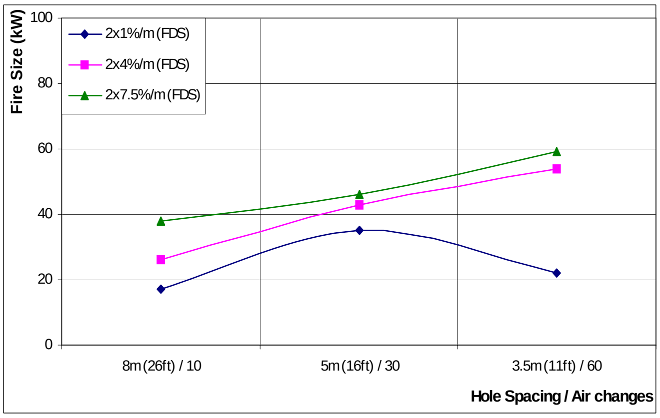
300m², 3.6m ceiling height





600m², 3.6m ceiling height





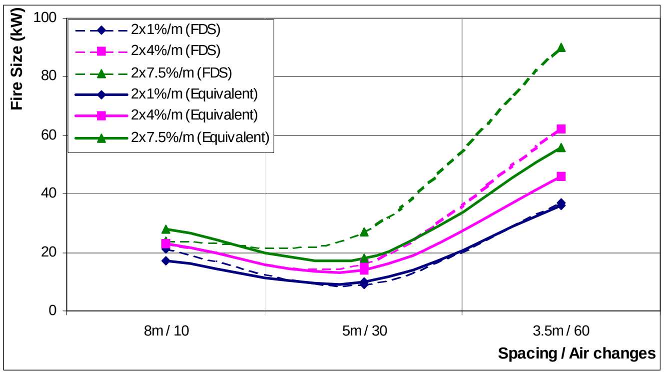
900m², 3.6m ceiling height

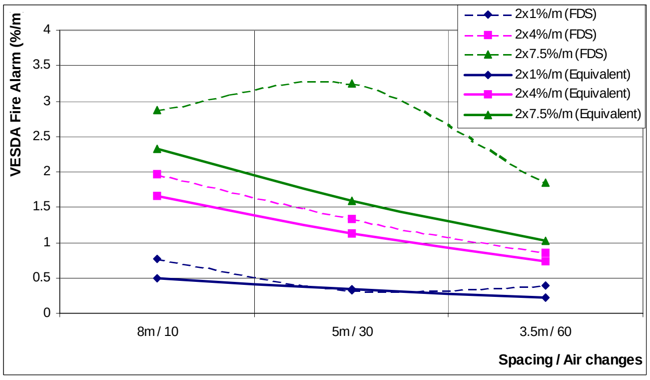
(a) Predicted ASD ***Fire*** alarm thresholds (b) Fire size at predicted alarm time

Figure 2: Benchmark: ASD ***Fire*** alarm threshold & fire size at the time of activation

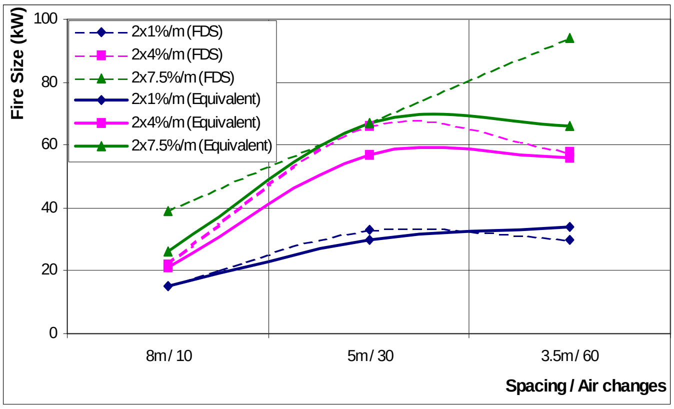
EQUIVALENCY METHOD: EQUIVALENT PERFORMANCE

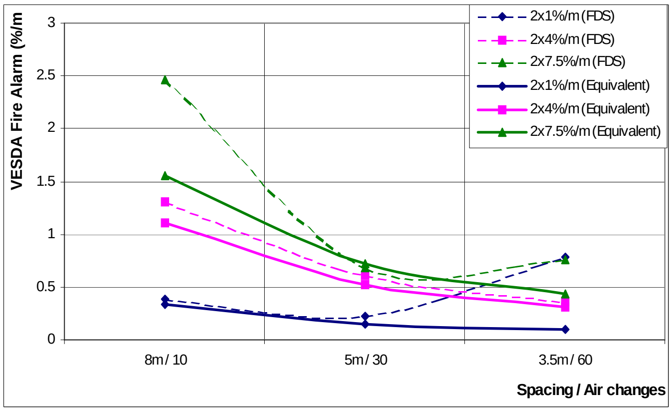
Following is ASD ***Fire*** alarm thresholds for equivalent detection performance after normalising fire size at the time of the second spot-type detector was in alarm condition. The general trend is that the ASD requires higher sensitivity setting in rooms when (1) the airflow is higher; (2) the room size is increased and (3) the ceiling height is increased.



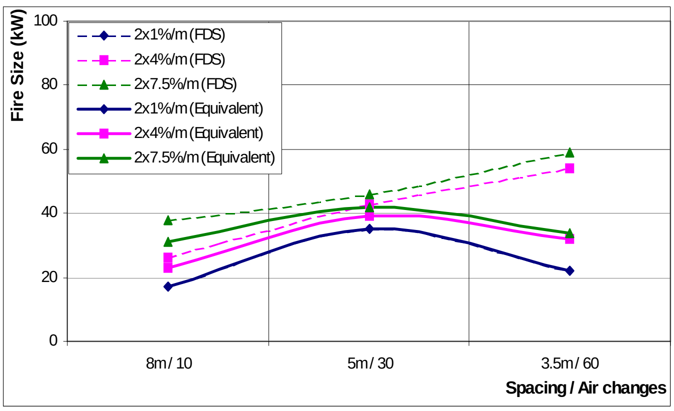


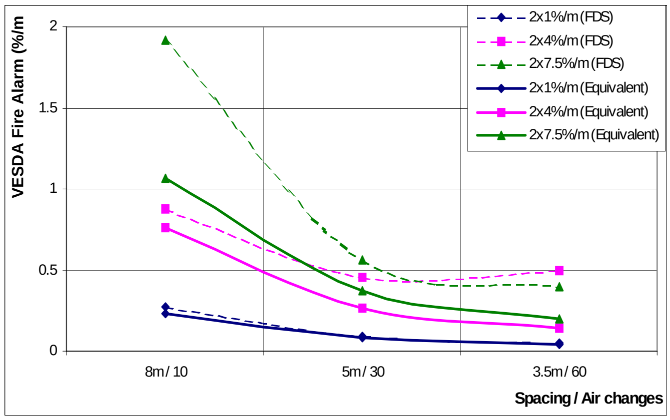
300m², 3.6m ceiling height





600m², 3.6m ceiling height





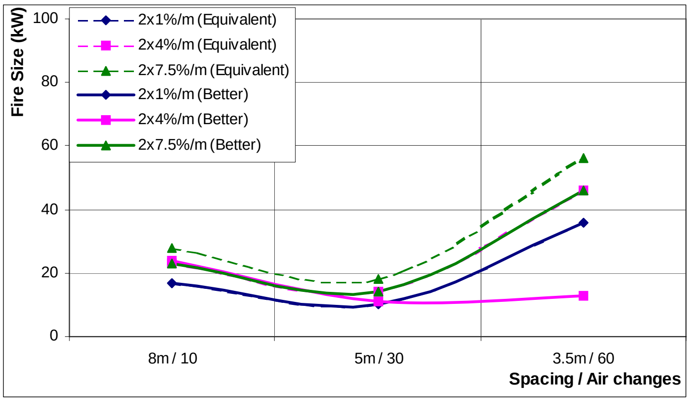
900m², 3.6m ceiling height

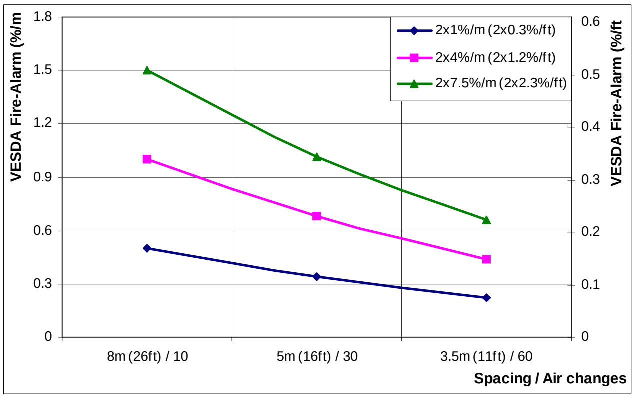
(a) Normalised fire size at fire alarm (b) ASD ***Fire*** alarm threshold (equivalent performance)

Figure 3: Equivalent performance: ASD ***Fire*** alarm threshold & fire size at the time of activation

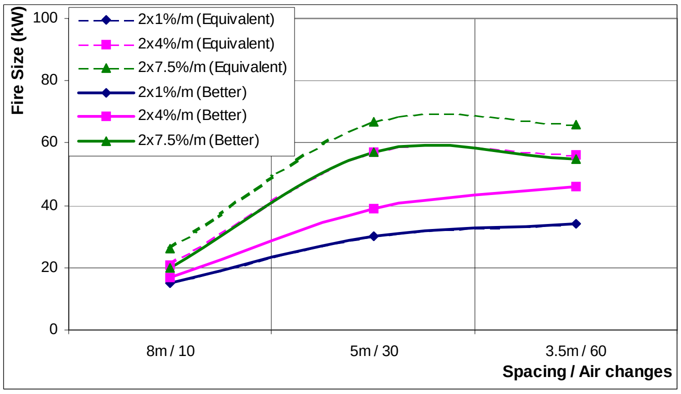
EQUIVALENCY METHOD: BETTER PERFORMANCE

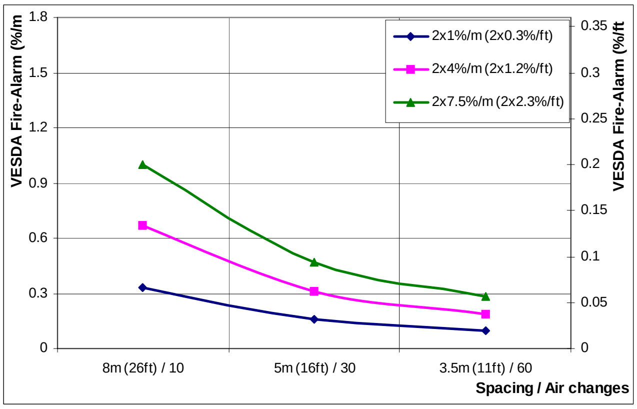
Following is ASD ***Fire*** alarm thresholds for better detection performance after standardised fire size using the alarm time of the second spot-type detector as a basis. The approach is that the ASD ***Fire*** alarm can be set such that the fire size is relatively close even the room geometry or conditions have been changed. This will generally lead to a higher sensitivity alarm setting.



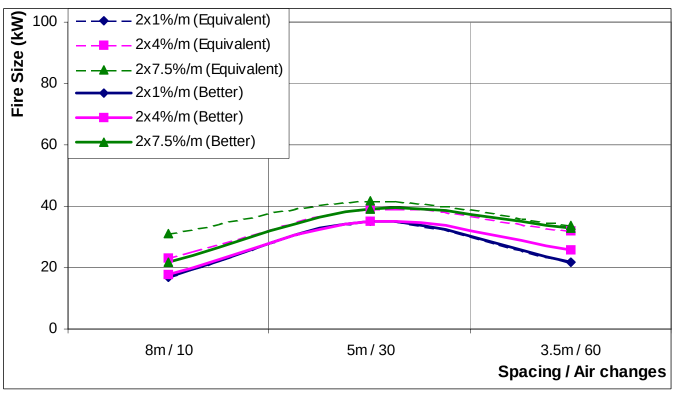


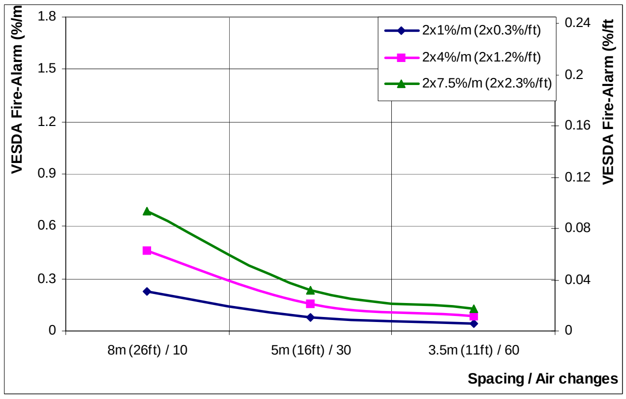
300m², 3.6m ceiling height





600m², 3.6m ceiling height





900m², 3.6m ceiling height

(a) Standardised fire size at ***Fire*** alarm (b) ASD ***Fire*** alarm threshold (better performance)

Figure 4: Better Performance: ASD Fire alarm threshold & fire size at the time of activation

DOUBLE-KNOCK (COINCIDENCE) DETECTION SCHEMES

Interfacing ASD for gaseous fire suppression based on a standard double knock (coincidence) detection concept (Figure 5) can adopt one of the following schemes:

1. Hybrid Method, where a combination of ASD and photoelectric spot type point detectors is used (Figure 6 (a)).
2. Total ASD Method, where more than one ASD detector is used (Figure 6 (b)).

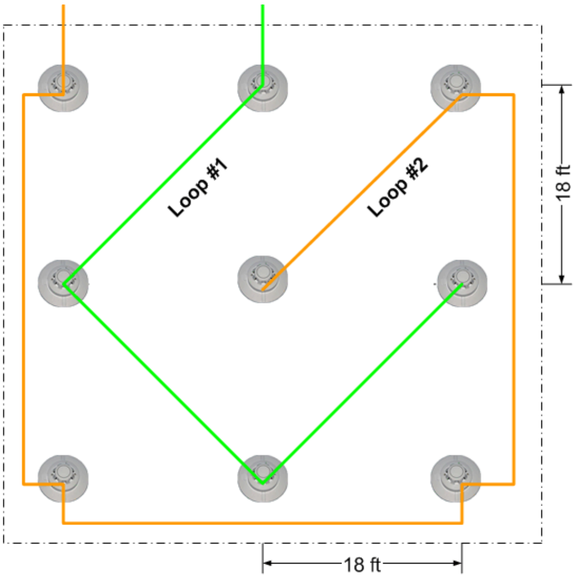
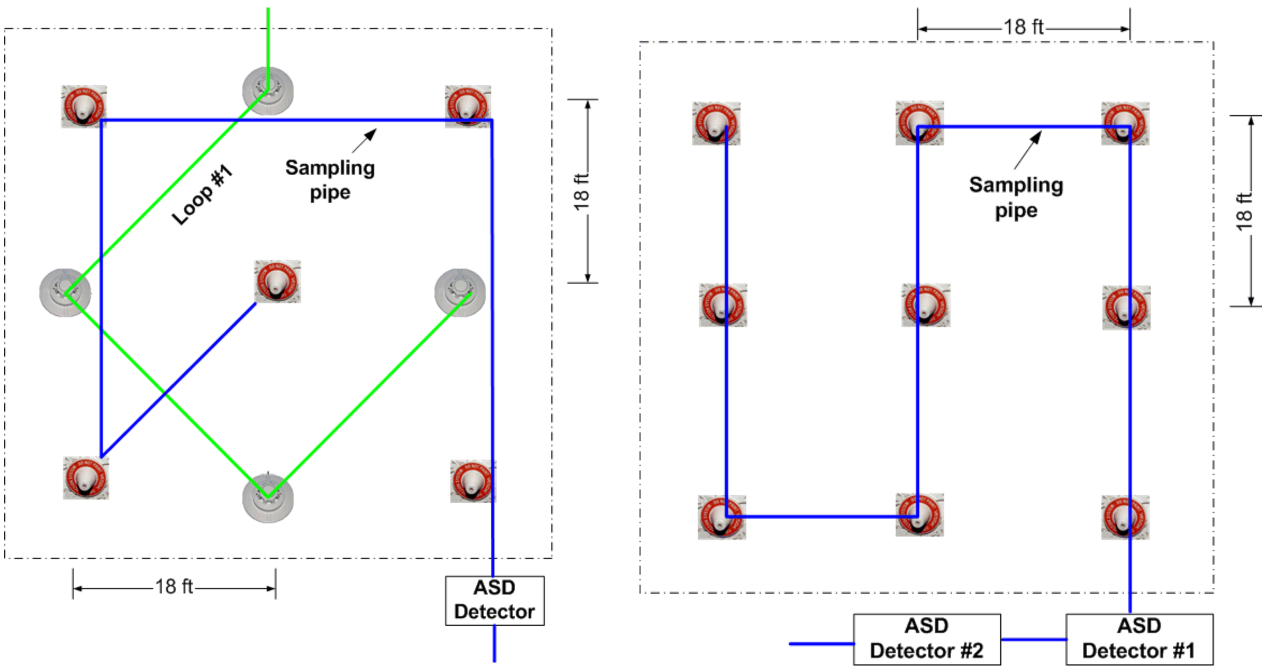


Figure 5: Spot-type detectors as standard double knock (coincidence) detection scheme



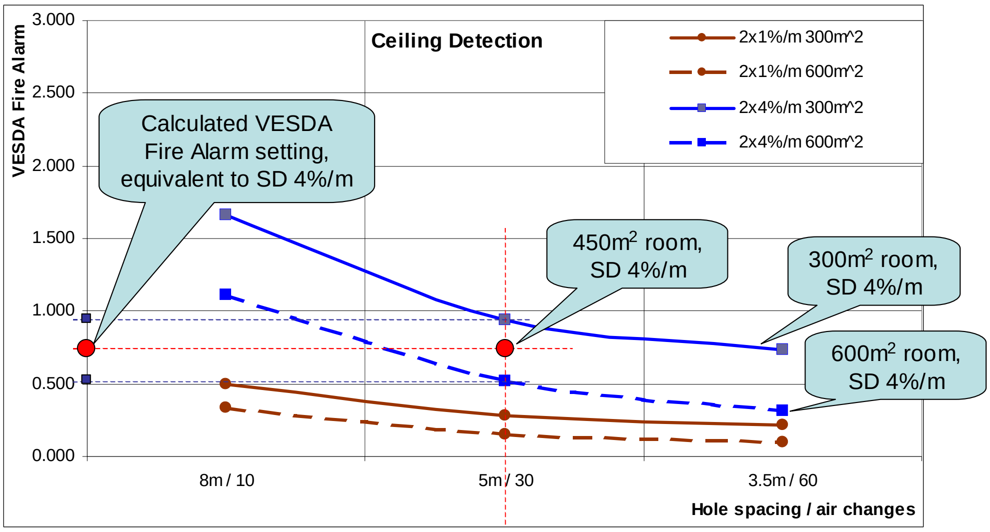
(a) Combination of ASD and spot-type detectors (b) All ASD detectors

Figure 6: ASD for double knock (coincidence) detection scheme

APPLICATION TOOL DEVELOPMENT

Once the equivalency in detection performance has been established, a design tool was developed to aid the design process. The tool involves the following key elements:

1. Initialisation: define system settings such as imperial or metric unit, code compliance and prescriptive requirements on detector nominal sensitivity and area coverage.
2. Calculate the initial ASD detector ***Fire*** alarm setting use spot-type detector "equivalence" or "better" design concept, apply either for ceiling or floor void protection or both.



3. Calculate improved ASD detector ***Fire*** alarm setting, taking into account number of factors such as ceiling height, airflow, actual sampling point spacing applied.
4. Calculate final ASD detector ***Fire*** alarm setting, considering extra large open plan room, air circulation such as upward or downward airflow use suspended ceiling/floor void as plenum.

When the second ASD detector is used for double knock (coincidence) detection, a set of procedure is provided to work out the ***Fire*** alarm setting for the detector. Figure 7 illustrates the Application Tool.

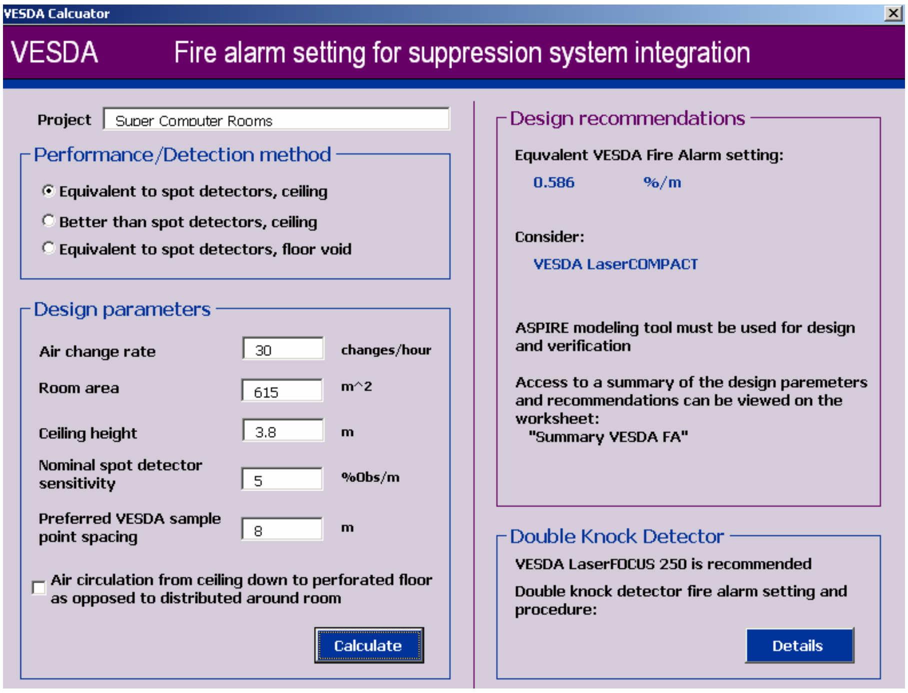


Figure 7: Application Tool: ASD ***Fire*** alarm setting for gaseous suppression activation

DISCUSSIONS

Smouldering combustion of one or more circuit boards may produce a heat release rate of one or two kilowatts. By comparison, the heat release rate from a typical trash can fire is on the order of 15 kW or higher [18]. According to [2], the fire size at the activation of gaseous suppression system could be as low as 0.1 kW with Air-sampling type detection (ASD) system. In this study, it was observed that for a double knock (coincidence) detection scheme to work with spot-type detectors, the fire size at the time of activation would exceed 50 kW. A gaseous suppression system integrated with VEWFD detection technology can deliver a consistent and optimal performance for both very early notification of a fire event and activating suppression system automatically when required.

1. ASD systems for Very Early Warning Fire Detection

- ASD wide sensitivity range allows minimal amounts of smoke to be detected. In contrast, spot-type detectors alone are unable to detect such small amounts of smoke.
- ASD's ability to actively sample air increases the chance of any smoke passing close to its sample holes to be collected. Because of its smoke aggregation nature, it helps to overcome the effects that the air conditioning would have on the movement and dilution of smoke.
- The pre-programmable multiple alarm threshold levels (***Alert*** and ***Action*** alarms) allow for the setting of pre-alarms, making it possible for investigation and staff intervention very early in a fire event.
- ASD pipes can be placed on the ceiling, under the floor void or at the return air grilles which provide the best protection under all conditions (air conditioning on or off).

2. ASD systems for suppression release control

- The wide sensitivity range means the ***Fire*** alarm can be used for suppression release and avoid unnecessary dumps.
- Extinguishing agent should only be released as a last resort after the initial investigation and intervention.
- When manual release is allowed, the suppression system can be manually activated during the investigation and intervention stage. This provides the earliest and reliable agent release.
- Flexible double knock (coincidence) detection schemes mean the option of a total ASD or combination of ASD and spot-type detectors, taking into account system reliability, cost, maintenance and overall detection performance requirement of the facility.

APPLICATION OF ASD & GASEOUS SUPPRESSION INTEGRATION

Two Double Knock (coincidence) detection schemes may be considered [19]. The first one is a total ASD Method and the second a Hybrid Method involving a combination of ASD and spot-type detector. Following is an example of how these two schemes work. Note that the procedure shall be modified to suit local code requirements or specific site needs.

a) The activation of any ASD ***Alert*** Alarm condition shall cause the following sequence of events:

Step	Event
1	LED to light at the remote Display Module if fitted or message sent to the monitoring software if installed.
2	Send ***Alert*** alarm condition to the Fire Alarm Control Panel (FACP).
3	Alarm horn/strobe to pulse inside the protected area (i.e. using ***Alert*** relay output of ASD) or send signal to on-site personnel or security.
4	The source of the alarm condition to be investigated, Personnel to address the fire event and take preventative measures

b) The activation of a ***Fire*** Alarm condition on any ASD (or any spot-type detector when a Hybrid Method is adopted) shall cause the following sequence of events:

Step	Event
1	LED to light at the ASD Display Module if fitted or message sent to the ASD monitoring software if installed.
2	A ***Fire*** alarm condition to occur at the Pre-Action control panel.
3	Alarm horn/strobe to pulse inside the protected area (i.e. using ***Fire*** relay output of ASD).
4	Alarm signal to be sent to the building FACP.
5	Shut down of the Air Handling equipment if applicable.

c) The activation of a ***Fire*** Alarm condition on a second ASD detector (or any ASD should a spot detector activate first when a Hybrid Method is adopted) shall cause the following sequence of events:

Step	Event
1	LED to light at the ASD Display Unit if fitted or message sent to the ASD monitoring software if installed.
2	A Pre-Discharge condition to occur at the Pre-Action control panel.
3	Pre-Discharge horn/strobe to sound continuously inside the protected area (i.e. using ***Fire*** relay output of ASD).
4	The activation of a 30 seconds discharge time delay.
5	The activation of Pre-Action solenoid.

d) The **Discharge Condition**, which occurs upon the lapse of the time delay or manual release, shall cause the following sequence of events:

Step	Event
1	Discharge condition to occur at the Pre-Action control panel.
2	Suppression agent to discharge.
3	Discharge strobe outside protected area to pulse.

For the **Discharge Condition**, consider the following points:

- The activation of the manual pull shall cause an immediate discharge of the suppression agent and all other functions described in parts b), c) and d) above.
- Depressing the abort button during the second ***Fire*** alarm condition (either from ASD or spot-type detector if fitted) shall prevent the discharge of the suppression agent.
- Releasing the abort button shall cause an immediate discharge of the suppression agent after the normal countdown.

CONCLUSIONS

For mission and process critical with high establishment and replacement cost alone justify a higher value fire protection solution. Gaseous total flooding suppression system is a good fit for protection in the areas of telecommunications, computer and control rooms, process critical equipments, cultural heritage, healthcare facilities, etc. Very early detection and fast suppression is key to limiting effects [20]. The success fire extinguishment relies on the ability to reliably detect the presence of a fire in its earliest stages. In a normally challenging environment for fire detection with high air flow and dense equipment layout, Very Early Warning Fire Detection (VEWFD) system such as high sensitivity Air Sampling-type Detector (ASD) systems is an optimal solution to satisfy both risk management and business continuity (comply with NFPA 75, NFPA 76 or other Performance-Based codes) and building and life safety requirements (comply with NFPA 72 or other prescriptive provisions).

A detection equivalency method was developed, resulting an Application Tool, so ASD detectors can be readily specified as an alternative to the conventional spot-type detector design. Based on the

ASD flexible design concept, detection performance for gaseous suppression system integration can be benchmarked when different detection technologies are considered. Once an equivalent or improved performance has been established, an advanced technology for the application shall be selected to strive an optimal balance of value, features and performance along with the initial (usually slightly higher) capital investment.

For ASD systems to be designed as an alternative to the spot-type smoke detectors, one must pose some key systems attributes. They must be reliable, having very wide sensitivity range, multiple alarm threshold settings and reporting continuous and absolute smoke obscuration level in the protected area. Alarm setting for gaseous suppression activation must take into account the method of double knock (coincidence) detection. With a proper fire alarm setting based on the airflow characteristics, room area and ceiling height, the detection performance can be enhanced and more consistent in fire size at the time of suppression agent release.

Reliable, high sensitivity VEWFD systems with very wide sensitivity range detect the fire events at their earliest stages so the gaseous suppression can work effectively to extinguish fires.

FUTURE WORK

The discharge of some extinguishants in fire extinguishing concentrations creates serious hazards for personnel in both the protected area and areas to which the gas may migrate [8]. ASD systems with a wide sensitivity range and continue smoke detection may be used to monitor the gas concentrations after the activation resulting reduced visibility. A high concentration can trigger additional warning system such as sounders and strobes to alert occupants in and outside the protected area.

We are seeking the opportunity to work with gaseous suppression system manufacturers to deliver value-added fire protection solution.

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