

White paper

Using air sampling smoke detection to protect mission-critical facilities from fire



Overview

Mission-critical refers to the operations that are critical to an organisation's ability to carry out its mission. In other words, mission-critical operations are those operations that are essential to an organisation's ability to perform its intended function. A mission-critical facility is one that guarantees it will continue to operate, regardless of external conditions.

A critical banking facility is an example of such a facility that must maintain operation 24 hours a day 7 days a week. In fact, a minor interruption in service, or loss of data could seriously impact the operational continuity resulting in economic loss especially during high transaction periods.

72% of mission-critical applications experience nine hours of downtime per year¹. 90% of businesses go bankrupt within two years of a significant failure²

The average cost per hour of downtime for a financial brokerage house is estimated at US\$6.5 M³.

Of the companies that experience a disaster but have no tested business recovery plans in place, only one in ten are still in business two years later.

The biggest risk to continuous operation within a computer room after a fire is the smoke damage to electrical equipment, not the flames.

This paper discusses smoke detection systems and their role in prevention of fire and smoke contamination within a mission-critical facility.



The fire risk within today's Data Center

Today's computing technology is becoming smaller and therefore requires less space, but the heat being dissipated by the digital hardware is also increasing. The result is that the heat density on the chip and in the cabinet is growing at an unprecedented rate. By illustration:

The average Intel 486 CPU consumes about 10 W, the latest Pentium 4 consumes 100 W.

With the processing density and power consumption of blade servers it is not uncommon for standard 47 U cabinets to consume in excess of 21 KW....that's a lot of heat!!

This high heat load requires significant cooling via the computer room air conditioning (CRAC) system to remove the heat generated within equipment cabinets. Failure to cool this equipment will result in equipment over-heating and provide the potential for a fire.

Mechanical cooling and airflow movement is an essential parameter within the fire detection design and is discussed further in this paper.

The Detection Strategy

Within a data center the type of smoke generated and the dynamics of the airflow creates a challenge for the fire engineer to design an effective fire detection system. It is the detection of smoke that is the most critical part of the fire protection system. Detection systems serve the basic function of alerting occupants within the building of a fire and are used to activate other systems such as mechanical exhaust and fire suppression systems.

The traditional smoke detectors known as Early Warning Smoke Detectors (EWSD) or conventional spot type detectors are of ionization or photoelectric type. Ionization type detectors were designed to detect very small particles such as the type produced by flammable liquids. Photoelectric detectors detect larger particles such as those produced by materials like plastics. Given this fact photoelectric detectors are more suitable to detect the fire type we expect within a computer facility, however there are other factors contributing to photoelectric detector's deficiency within these environments.

Within the fire industry detectors are categorized as Early Warning Smoke Detection (EWSD) and Very Early Warning Smoke Detection (VEWSD). In fact some people use these terms very loosely and do not differentiate the two correctly. An EWSD system provides detection of a fire condition prior to the time that it becomes threatening to the occupants of a building. Generally this is the time that smoke is visible. Let's use the example of a paper basket fire within a standard office. Seconds after the paper has ignited, smoke will generate and rise to the ceiling.

This visible and hot smoke will eventually enter the smoke detection chamber and trigger the alarm to alert the occupants that a fire has commenced. In contrast, if a computer terminal within the same room had a fault within the electronics resulting in a thermal event, it may smoulder for hours before a flame ignites. We refer to the smouldering stage as the incipient stage to a fire. During this incipient stage the human eye will not see the particles but the human nose may smell them. EWSD are not sensitive enough to detect smoke at the incipient stage of an electrical-type fire. Only a VEWSD will detect an incipient fire and thus the term "VERY EARLY WARNING". This stage of a fire could last for hours or even days.

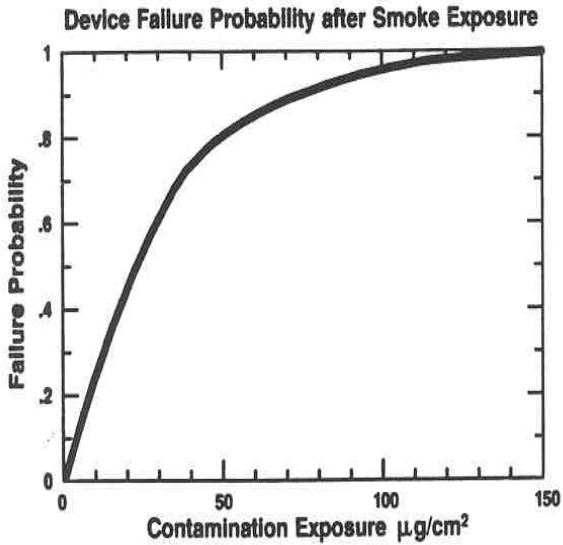
Spot type smoke detectors are 'passive' detectors in that they wait for smoke and rely on the airflow to transport the smoke to the detector. Therefore their performance is affected by high airflow. Since the rate of smoke generation in a smouldering fire is relatively small, and the airflow velocity in the room is quite high, the movement of smoke is dominated by the airflow of the mechanical systems. Furthermore the smoke generated during the incipient stage is not hot therefore there is very little thermal lift. This often prevents smoke from moving directly to the ceiling, where spot type detectors are located, causing the smoke to dissipate more widely. An aspirating smoke detection system is 'active', constantly sampling the air from multiple points throughout the environment. It is not totally dependant on thermal energy to transport the smoke to the detector.

The effects of smoke contamination

So why is the detection of smoke at the earliest possible stage important? Because the biggest risk to the continuous operation within a computer room facility is the smoke damage to electrical equipment, not the fire. In fact according to the USA Federal Commission of Communications, 95% of all damage within these facilities is non-thermal.

The by-products of smoke from PVC and digital circuit boards are gases such as HCL and these gases will cause corrosion of IT equipment. Graph 1 depicts the increased risk of failure possible with an increase of particulates in a computer room. Even at 16 micrograms per square centimeter there is moderate corrosion with long-term effects on electronics, at 30 micrograms/cm² the corrosion is active and the effects are short term. Above this the damage to equipment is detrimental to ongoing performance.

Smoke Damage Probability



Graph 1: Contamination and failure probability⁴

Aspirating Smoke Detection – how it works

Aspirating smoke detection systems are quite different from conventional spot type smoke detectors. Aspirating systems typically comprise a number of small-bore pipes laid out above or below a ceiling in parallel runs, some meters apart. Small holes, also some meters apart, are drilled into each pipe to form a matrix of holes (sampling points), providing an even distribution across the ceiling. Air or smoke is drawn into the pipework through the holes and onward to a very sensitive smoke detector mounted nearby, using the negative pressure of an aspirator (air pump).

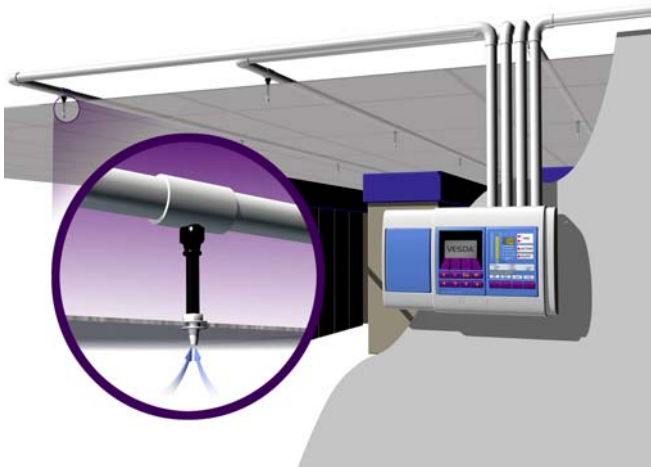
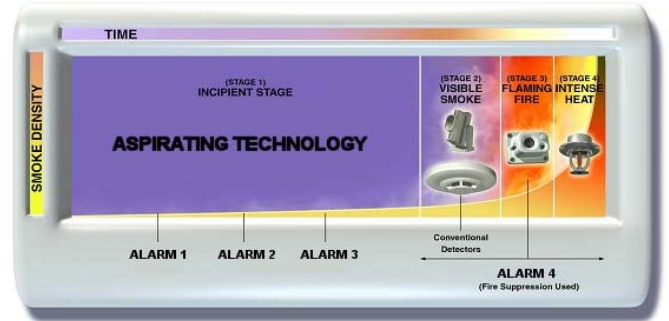


Illustration 1: Air Sampled through a capillary and sample point

The VESDA aspirating smoke detector is a form of air pollution monitor. It has sensitivity some hundreds of times higher than conventional smoke detectors, yet its false alarm rate is exceptionally low (according to independent surveys). This reliability comes from its high immunity to the major sources of false alarms—dust, draughts and electrical interference. Accordingly, the entire zone is monitored for the early symptoms of overheating materials, possibly hours before a fire develops. This generally allows plenty of time for human intervention, or automatic intervention by the operation of an electric circuit breaker for example (which removes the source of heat—the electric current). The primary role of aspirating smoke detection is, therefore, fire prevention.



Graph 2: Smoke Density versus Time

Graph 2 illustrates the stage at which a VESDA smoke detector can detect smoke. One of the most exciting features of the VESDA System is its flexibility in the setting of its sensitivity. The detector alarm thresholds can be set up to 20% obscuration/m. Obscuration is the effect that smoke has on reducing visibility. Higher concentrations of smoke, result in higher obscuration levels, lowering visibility.

The first three thresholds would typically be set with Alert 0.03 % obscuration/m, Action at 0.06 % obscuration/m and Fire1 at 0.12% obscuration/m in a relatively clean environment. Then there is the opportunity to set Fire2 threshold at 10 % obscuration/m for example, acting as confirmation of a serious fire event, with the option to activate a suppression system at that point.

The provision of these alarm thresholds allows for activating an early and controlled response. For example, the Alert Alarm (the first alarm) condition may be used to call local staff to investigate an abnormal condition. Should the smoke condition continue to increase the Action threshold may be used to initiate smoke control, begin a warning sequence via the evacuation system and alert further staff members via paging or SMS to mobile phones. The FIRE1 Alarm (the third threshold) indicates that a fire condition is very close or has started. At this stage the building is evacuated, the zone on the fire alarm control panel is activated and the signal transmitted to the local monitoring company and fire

brigade. The FIRE2 Alarm threshold will activate once the level of smoke is significant enough to calculate that a fire has started and therefore suppression systems can be activated.

For the first time, one product can provide very early warning as well as initiate suppression at a much later stage. Of course, if building fire systems and procedures have operated correctly, then early intervention should preclude operation of the FIRE2 threshold—but it's a safety net providing control of the last line of defence.

How much smoke should we detect?

Obscuration as a unit of measurement has become the standard definition of smoke detector sensitivity used in the industry today. Obscuration is the effect that smoke has on reducing visibility. Higher concentrations of smoke, result in higher obscuration levels, lowering visibility.

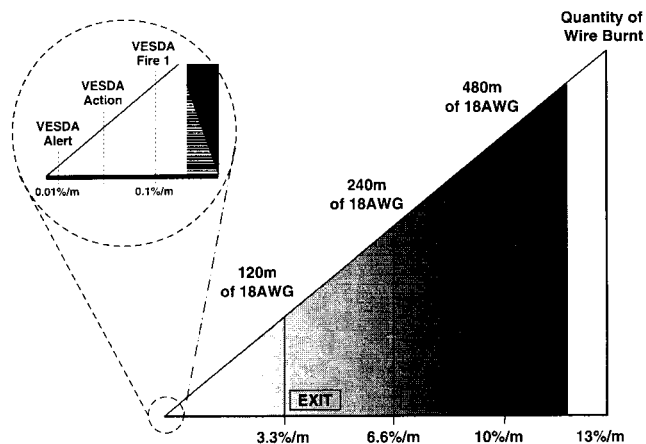
Typical smoke detection sensitivities for smoke detectors:

Photoelectric: 2 - 12% obscuration per meter

Beam: 10 - 25% obscuration per meter

Air sampling: 0.005 - 20% obscuration per meter

Tests performed by Vision Systems have shown that by burning a measured length of wire within a controlled room we can determine the resulting obscuration/m. For example, in a room with a volume of 350 cubic meters (3500 sq. ft) burning the insulation from approximately a 1 m (3 ft) length of 18 AWG wire would produce 0.1% obscuration per meter at ceiling level, easily detectable by a VESDA very early warning smoke detection system. Obviously, having 1 meter of wire burn is a significant fire event in a Telco facility.



Graph 3: Smoke obscuration measured based on a burning wire within a 1000 m² (10000 sq. ft) room
The amount and color of smoke created in a computer room during a fire is dependent on the type and amount of material burned. Smouldering combustion of a printed circuit board may produce a

heat release rate of one or two kilowatts and the heat release rate of a single resistor is as low as 10 W. By comparison the heat released from a paper basket fire may be between 2 to 4 kW (UL standard paper burn (3 sheets)). The fire size to be detected must clearly be less than or equal to 1.0 kW within a data center if we are to measure the performance of a VEWS.

Current testing practice within telecommunications and computer rooms today use a practical onsite test to determine the effectiveness of a fire detection system. In the past, system testing was conducted with a can of smoke that was sprayed into the end of the pipe network or into the point detector to determine if the system was working. But this test does not check the system's performance to a real small fire scenario, which is the benchmark for VEWS.

A common test used today is the BS6266 "Code of Practice for Fire Protection for Electronic Data Processing Installations". This test involves electrically overloading a short length (1 or 2 meter) of PVC-coated wire which produces a small amount of light grey smoke barely visible and simulates a smouldering fire of approximately 100 W.

Typically, the test is performed within the room during the commissioning process and the VEWS should give an alarm indication within 60 - 120 seconds.

Computational Fluid Dynamic Modelling (CFDM) is used to determine the effects of such fires within high airflow environments. It can calculate the theoretical growth of incipient fires, smoke development and the contamination that results from such smoke. Such models can be used to determine the level of contamination (mass of particulate per cubic meter) for specific fire sizes. This is useful in estimating the amount of contamination to which IT equipment is exposed during various fire conditions. As shown in Graph 1 the contamination exposure caused by fires will increase the probability of IT equipment failure.

Use of a VEWS detector to detect such contaminants can reduce the risk of such damage occurring. In many cases the contaminants are present at very low levels, often as a result of high background smog/smoke levels, often introduced from poor quality air during the use of 'economy cycle' HVAC. Without the use of VEWS the low levels of these contaminants can go un-noticed for long periods of time causing insidious but permanent damage.

In addition, the use of the event log of a sophisticated VEWS can be used to support a warranty or product replacement claim on an equipment vendor where equipment fails within its warranted terms of use. This is especially important where the vendor's warranted terms of use reference the quality of the

environment rather than the deposition of contaminants on the equipment, as is often the case.

Beyond conventional design techniques

Although the design of fire protection systems has primarily been based on traditional prescriptive fire codes, there is an increasing emphasis on performance-based codes that address individual environmental requirements. Performance-based design determines the best fire protection system by assessing the function, risk factors, and internal configuration and conditions of a specific environment.

When designing a fire detection system for VERY EARLY WARNING the designer must consider the following:

1. The airflow characteristics and the air change rate within the room.
2. The coverage area per detector or sample point.
3. The sensitivity required per sampling point.
4. The room size and characteristics—raised floor, tall ceilings etc.
5. The annunciation of emergency response systems.
6. The activation of mechanical control systems such as air extraction and suppression systems.

The detection system must be designed for conditions when the air handling system is either operational or out of service.

Illustration 2 shows the detection method on the CRAC return air path, relevant in circumstances where the CRAC is operational. This method of VEWS is suitable for rooms that use EWSD spot type detectors as the detection scheme in circumstances where the CRAC is out of service.



Illustration 2: Smoke detection at the CRAC return air grille.

Illustration 3 shows the ASD pipe network configured for both circumstances; where the CRAC is operational and out of service. The sampling pipes on the ceiling and within the floor void are used for detection where the CRAC is out of service. The pipe used to detect smoke across the return air path is used for detection where the CRAC is operational. This design method is suitable for rooms where the ceiling height is not tall and room is small in area.

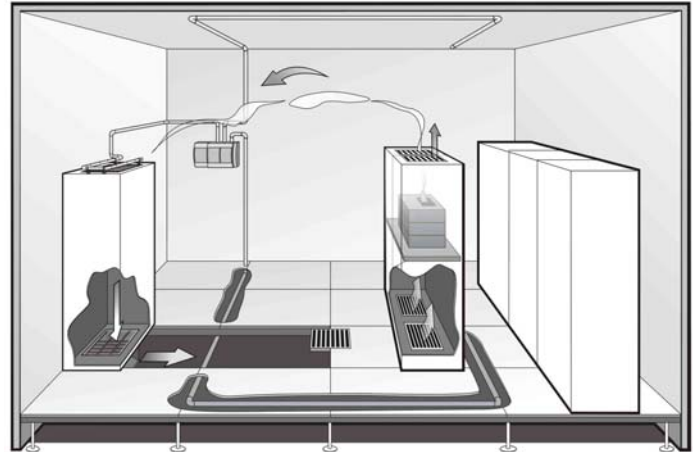


Illustration 3: ASD pipe network configuration that provides smoke detection when the CRAC is operational **and** when it is not.

For large rooms with high airflows it is recommended that a combination of both on-ceiling detection, underfloor detection and return air be used.

Coverage area

The area coverage of the detector is a very important criterion of the design. This is true from both a performance and cost-effectiveness perspective.

Illustration 4 shows a grid layout for an ASD detector for a 2000 m² (20000 sq. ft) area (this is the maximum area coverage permissible within the BS, AS and NFPA codes). Each sample point of an ASD detector is treated the same as a spot type detector within most prescriptive codes. You can see below that the area coverage for a sample point is

NFPA 72 “National Fire Code for the USA” recommends the area coverage for spot type detectors to be reduced within high airflow environments to as low as 11.5 m² per detector for rooms that have 60 air changes per hour.

British Standard – BS 6266 (1992), Section 5.2.5.1 Detector Spacing–General–“From the point of view of automatic fire detection, EDP areas present fire risks quite different from those in many other premises. The concentration of high value equipment, sensitive to damage by even a small fire or smoke, and particularly the high potential

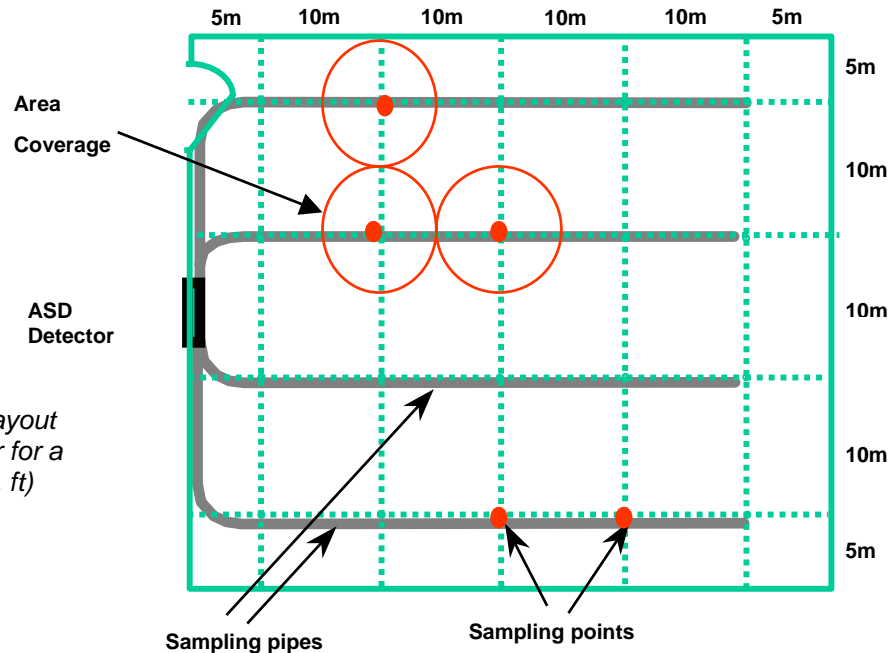


Illustration 4: Grid layout for an ASD detector for a 2000 m² (20000 sq. ft) area.

effectively the circle or close to the square around it, which is 10 m x 10 m = 100 m² (10000 sq. ft) (illustration 4 is designed as per Australian Standard 1670 and would be suitable for a low airflow environment). For ASD applications in high airflow environments, we can decrease the area coverage for the sample point by adding more holes and making the distance between each pipe less.

The prescriptive codes and standards today describe detection techniques for on-ceiling detection. But new codes such as NFPA 76 "Standard for the Protection of Telecommunication Facilities" is the first code that uses a prescriptive and performance based approach for the fire protection of telecommunication facilities. This code specifies both the area coverage as well as the sensitivity of the detector. Presently NFPA 76 requires that "Every type of sensor and port installed in a space shall be limited to a maximum coverage area of 200 sq. ft. (reference page 51, section 6-5.3.1.2*) Exception: When (2) levels (high and low) of ports or sensors are provided, each level shall be limited to a coverage of 400 sq. ft. or less per port or sensor.

consequential losses, make it important to use close spacing of detectors. Detector density should be high enough to enable the smallest fire to be detected quickly without unduly increasing the false alarm risk. A reason for a higher than normal density of detectors is the influence of the air-conditioning system, which dilutes the smoke being produced by fire."

Section 5.2.5.2 Point Detectors–“Recommended area coverage per detector for the different location zones” are given in table 1. As follows: EDP equipment room (ceiling height above 3 meters), require a maximum spacing of 15 - 25 square meters (150 - 250 square feet).

As well as codes there are insurance companies such as Factory Mutual who specify in their Property Loss Prevention Data Sheet (5-48) for Automatic Fire Detectors page 7 "A maximum coverage of 200 sq. ft. (20 m²) per detector may be necessary where room air is changing at a rate of 20 air changes per hour"

So the message is that more detectors should be used in high airflow environments to increase the chance of seeing a fire, however this requirement can

be offset by the use of a VEWS which can support a large number of sampling points in a single pipe network.

Sensitivity of Aspirating Smoke Detection

Although reduced spacing will increase the probability of smoke being detected, it does not determine if the smoke generated has an obscuration density high enough to trigger an alarm. Therefore the sensitivity of the system is also fundamental to the design of the VEWS system.

The sensitivity of the aspirating detection system's sampling point is extremely important to ensure consistent and sensitive detection within the zoned area. But what codes and standards do not take into account for aspirating smoke detection systems are their ability to use cumulative air sampling within an environment.

Cumulative air sampling refers to the way the Aspirating Smoke Detector samples smoke over the network of sampling points, allowing each to contribute to the smoke being sampled at the detector. Within a high airflow environment this phenomena becomes very useful as particles of smoke are spread through the room allowing the cumulative sampling effect to take place.

Take the example of a 200 square meter room with 10 sample points on the ceiling. If the detector sensitivity is set to 0.1% obscuration/m this effectively makes each sample point's sensitivity $0.1 \times 10 = 1.0\%$ obscuration/m. That is, if only one sample point was exposed to smoke it would require 1.0% obscuration/m to trigger an alarm. This is because the fluid mechanics of the model takes into account dilution caused by the other holes.

Using the same example, if smoke enters three holes the effective sensitivity required to trigger an alarm is 0.1×10 divided by 3 = 0.33% obscuration/m. Clearly, cumulative sampling allows much lower levels of smoke to be detected and therefore, allows very early warning.

If the same room was designed with EWSD and each detector was rated at 5% obscuration/m, the alarm would only trigger once the smoke density has reached this point throughout the room or at one detector.

In-cabinet and integrated-equipment detection

Interest is developing regarding the application of ASD within data racks & enclosed equipment cabinets and integrated in specific equipment or assets. It is desirable to fit ASD within these cabinets because in some circumstances it would not be acceptable for smoke from a fire within the cabinet to

'breach' the cabinet, enter the mission-critical facility, contaminate other systems or processes and possibly activate main alarms and suppression systems.

In-cabinet smoke detection and action enables an excellent very early warning solution because:

- i. The sampling is performed closest to the source of the fire, before dilution, which allows earliest detection
- ii. Sampling within the enclosure allows clear identification of the source of the problem. This "addressability" reduces time, effort and error in identifying and remedying the problem.
- iii. The detection occurs before any spread of the risk; loss can be minimized:
 - Smoke is not allowed to contaminate or otherwise affect other systems in the data centre
 - Compartmentalization ensures that in worst cases the estimated and possible maximum loss and business interruption estimates are minimized (for insurance assessment)
- iv. The background dust and smoke levels within sealed enclosures are relatively consistent. Also, the airflow dynamics within a sealed enclosure can be predicted with relative confidence by computational fluid dynamic models. This ensures that detection systems can be designed, built and commissioned with confidence of their efficiency and performance.
- v. Fire responses can be more automated, and cost and downtime from fire responses, such as use of suppression, is reduced.
- vi. Better control of the issue management and escalation processes is possible—an alarm can be routed to the data centre manager as an "environmental alarm", rather than reporting via the main fire alarm system. This staged response to a fire threat allows IT staff investigation and possible intervention, an ability to move processes or data from problem equipment, action such as power-down of problem equipment and, if necessary, suppression of an escalated fire. Such a staged response will often negate the need for suppression to be fitted or, if fitted, will negate the need for expensive suppressant to be released.
- vii. Cause & effect is localised, ie. fire controls used are specific to the cabinet rather than the room. Use of common area protection systems means that the common area is unprotected until the system is re-charged.

viii Integration with existing communications systems is possible—remote and centralized monitoring and maintenance (especially for unmanned or automated facilities), eg over LAN, MAN, WAN becomes cost effective. Also, coupling advanced smoke detection with a full suite of environmental monitoring systems (power loss, access-control, security, temperature, water loss, humidity etc) offers a number of synergies.

Conclusion

Due to the huge financial loss and potential business risk, a mission-critical facility cannot risk downtime especially of the size and duration potentially caused by fire and smoke contamination. The most important system that contributes to the prevention of fire and smoke damage is a very early warning smoke detection system such as a VESDA system, that meets the performance objective to detect smoke at the very early stages of a fire.

The VESDA Aspirating Smoke Detection System features provide the designer flexibility by meeting design requirements of prescriptive codes as well as facilitating use of today's performance-based fire engineering methodologies. These enabling features include:

- Detection of both small incipient smouldering fires and large flaming fires
- Flexibility to design on ceiling, under floor voids, cable ducts and across return air intakes, as well as in targeted equipment sampling
- Multiple alarm levels that can be used to provide:
 - initiation of orderly shutdown of computer systems and processes and power systems
 - removal of contaminated air (via activation of air handling systems, baffles etc)
 - communication of reliable early warning (to fire wardens, brigades, etc.)
 - initiation of staged evacuation
 - initiation of automatic suppression

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4. 2nd International Fire Protection Seminar Buenos Aires 1999 - Telecommunication Facilities.
5. BS 6266 (2002)
6. NFPA 72 (2002), NFPA 76 (2002)
7. AS1670 (2004)

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