Early Warning Fire Detection

CLEANROOMS & ASSOCIATED CONTROLLED ENVIRONMENTS

Design Guide

October 2020

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Executive Summary

Outlook: Cleanrooms & Associated Controlled Environments industry

In 2019, the global cleanroom technology market size was around US$ 3.7 bn and is expected to grow at a CAGR of 3.8% from 2020 to 2027 (US$ 5.30 bn) across the main end-user segments of pharmaceutical, medical device, biotechnology industry, hospitals and diagnostic centres. Likewise, the global semiconductor manufacturing equipment market is estimated to be US$ 62.4 bn in 2020 and projected to reach US$ 95.9 bn by 2025; at a CAGR of 9.0%. The semiconductor foundry market covers semiconductor fabrication plants (FAB) and was valued at US$ 42.03 bn in 2019, and is expected to reach US$ 62.2 bn by 2025, at a CAGR of 6.75%. Continuing and emerging electronics advancement in our increasingly tech-driven world, artificial intelligence, automation and renewable energy all drive demands ranging from semiconductors, integrated circuits, microelectromechanical systems and sensors manufacturing to LCD/LED and solar panel production. These in turn require both new builds and retrofits of existing cleanrooms or facilities with controlled environments to meet the production output increases and changes of technology or manufacturing methods.

Diverse industries rely on cleanroom-type controlled environments for critical operation and service delivery

The building occupancies in facilities with Cleanrooms & Associated Controlled Environments spread across a wide range of industries from aerospace, chemical, manufacturing, semiconductor/microprocessor production and server rooms to research laboratories, biotech, pharmaceuticals, storage and hospitals. Depending on the type of business operation, the controlled environments can be for the whole building, part of a building or special areas and enclosures within a building. While large-scale buildings with controlled environments are often purposefully designed and built as “cleanrooms”, small-scale buildings or areas within a building require specially controlled environments, which can often be set up using a modular cleanroom concept.

The need for controlled environments for business operation are due to the fact that strict and often highly sensitive manufacturing processes or goods stored in these facilities will not be possible without the right ambient conditions. Examples of these are sterile and aseptic technology in hospitals or food processing, microelectronics and semiconductor production in industrial manufacturing.

While cleanroom-type building design and construction are done to meet requirements of the facility owners or operators, common design considerations include facility parameters/dimensions, local utility for firefighting (e.g. water supply), the nature of business operation (for occupancy), materials handling and construction methods (wall, floor and ceiling). To cater for operation in cleanroom-type facilities, great emphasis is placed in specialist HVAC system design and operation to ensure the respective ISO Class requirements are met, along with correct room/area air pressurisation and flow patterns being maintained. In ambient-controlled storages, considerations are given to types of storage spaces; space configuration, durable and functional requirements, energy-efficiency, safety and security of people and goods, health and comfort level, as well as issues stipulated in relevant industry codes of practices such as the EU Guidelines for Good Manufacturing Practice (GMP).

Risk management, business continuity and life safety are all paramount to operation

Due to the use and storage of hazardous materials and perilous manufacturing processes in industrial facilities, an estimated average of over 37’900 fires at industrial or manufacturing properties occur each year in the USA, with annual losses from these fires estimated at US$ 1.2 bn in direct property damage. The extent of flames spreading from these fires is comparably much more severe when fires spread beyond the level of fire origin and/or beyond the building of fire origin at 41% (industrial) and 21% (manufacturing) respectively for the reported period.

Healthcare facilities

While healthcare facilities and hospitals are generally perceived as a safe place, an estimated average of 5’700 medical facility fires are reported to fire departments in the USA each year. Nearly a fifth of those (1’100 fires) were in hospitals. While about 80% of resulting fire damages are limited to the object of fire origin, fires such as surgical fires in operating theatres often present significant risk to life safety with fire potentially spreading rapidly with the presence of extremely flammable materials in an often small and enclosed space with large amount of fresh air circulating. The ECRI Institute estimates over 200 surgical fires occur annually in the USA with some of them causing serious injury, disfigurement, and even death.

Semiconductor fabrication plants (FAB)

While large fires in a FAB are not a common occurrence, even a small fire or damages from smoke contamination due to overheating can have significant consequence in property loss, production and delivery interruption. A fire in 2013 at a memory chip FAB in Asia resulted in costs to its insurers of around US$ 1.0 bn, not including potentially higher losses for contingent business interruption (CBI). The cost of the claim reflected the time and the expense of restoring specialist “cleanrooms” used in the production of semiconductors, as well as CBI losses suffered by computer equipment manufacturers further down the value chain. Because of such an enormous risk, each incident further hardens the determination for businesses to adopt rigid risk management regimes and for the insurers to manage risks through the recommendation of best practices in fire safety and protection.

Electrical equipment and use and storage of flammable substances are the prime causes for fires

Leading causes of fire in industrial and manufacturing properties are found to be electrical distribution, heating and lighting equipment. In the healthcare facilities and hospitals, except for the cooking equipment that contribute to a high percentage of fires, the other main causes of fire are similar to these found in the industrial and manufacturing buildings.

Another major cause of fire involves the use and storage of highly flammable substances in the business operation or production processes. Hazards in large cleanrooms include the use of extreme high-temperature furnaces, high power lasers, toxic, flammable, oxidizing and pyrophoric gases, that are connected to a range of equipment. Wet chemical hoods need the use and storage of large quantities of concentrated acids, bases, solvents, and oxidizers.

In hospitals, examples of extremely dangerous surgical fires inside operating theatres are attributed to hazard profiles of extremely flammable alcohol-based preparations, vapours/aerosols and adhesives, as well as any material or item with a carbon chemical base that can be ignited in an oxygen-enriched atmosphere.

High airflow, large open space, pressure differential, complex equipment and tools layout and occupancy challenge fire safety system design

Together with fire protection system design, efficacy and fit-for-purpose system performance, along with the significant airflow and rapid circulation to achieve and maintain a particular ISO class, large open spaces with complex equipment, tools and test bench configuration, pressurised areas and pressure differentials between adjacent areas with different ISO class requirements, all present challenges to the design of fire detection and suppression systems. For facilities with high airflow and rapid circulation, smoke dilution and movement are key considerations when choosing suitable fire/smoke detection systems and where the detection systems should be located. When there are multi-level building structures such as a large semiconductor fabrication plant with FAB and sub-FAB level, the type of detection and placement of detection points have an impact on the cost of total ownership from first the installation to ongoing service and maintenance.

Various occupancy classifications, found in a wide range of cleanroom-like buildings may require a different type of detection systems (e.g. smoke or heat or a combination of both, point type or line type) for either open spaces, machine tools in-cabinet, as well as underfloor cable trays protection. The same is valid for different hazard classification areas, where requirements of gaseous suppression and pre-action sprinklers are to be in action earlier through reliable initiating devices, such as a fire detection system, and early fire alert to facilitate investigation or egress from large areas with restricted access control.

Risk and Performance-based Design

Fire protection professionals work within the prescriptive constraints of the applicable building codes and standards while applying the best engineering practices to address industry and building occupancies specific needs. In particular, the risks for uninterrupted business operation requirements in facilities with Cleanrooms & Associated Controlled Environments shall be adequately addressed. In this regard, a risk-based approach to the optimisation of fire detection, fire protection and human interaction to supplement prescriptive baseline design is the key to meeting the requirements for building and life safety as well as risk management (such as the guidelines from SEMI for large FAB and local healthcare government agencies' directives on healthcare facilities and hospitals risk management).

Performance-based Design (PBD) is typically implemented when elements of fire safety and protection system design are not covered in the prescriptive codes, due to unique building structures, environmental conditions, added detection for early warning or extended egress considerations, among others. While PBD may be required for some Cleanrooms & Associated Controlled Environments facilities, the majority of them can be designed to the prescriptive codes with added detection and protection based on a risk assessment, applying appropriate system design to these targeted risk areas and locations in addition to meeting the codes and standards for general building and life safety.

To further enhance risk management, fire prevention and protection, FM Global develops property loss prevention Data Sheets for semiconductor fabrication plant and cleanrooms facilities. In addition, NFPA codes are also extended to include cleanrooms, laboratories and ambient-controlled unique storage facilities, such as refrigerated storages.

Design Guide objectives

From early surgical cleanrooms in the 1950s to commercial cleanrooms in early 1960's, to the first release of NFPA 318 in 1992, fire safety and fire protection have always been highlighted for the challenge and uniqueness of fire risks in Cleanrooms & Associated Controlled Environments (such as a semiconductor fabrication plants). While cleanroom technologies, processes, applications of cleanroom related construction as well as protection codes and standards evolved over the years, many aspects of fire safety concerns remain, such as a rapid growth of a fire and the difficulties in manual firefighting. Early Warning Fire Detection is a critical part of the best practice of a fire engineering solution, even though sprinklers or other form of suppression such as gaseous systems or water mist are also effective in potentially reducing the fire damage and time to recover. Only a well-designed Early Warning Fire Detection system provides risk mitigation to potentially prevent a fire from happening or developing out of control before the fire services arrive as well as implementing an early alarm for orderly emergency evacuation. A suitable fire detection system is also required for the actuation of pre-action and co-incidence (or interlock, double interlock) suppression systems or early control of a fire using gaseous suppression systems.

This Design Guide provides design recommendations for Securiton SecuriSmoke Aspirating Smoke Detectors (ASD) and REK aspirating in-line high sensitivity intelligent point type smoke detectors for pinpoint addressability. Where applicable, Securiton SecuriHeat Line Type Heat Detectors will be included, particularly when heat detection is required for the purpose of fire detection in hazadous areas, in-rack detection with in-rack pre-action sprinkler systems or underfloor void cable tray protection in a large FAB.

The design recommendations focus on aspects of prescriptive (Deemed-to-Satisfy) code requirements, risk-based detection point placements and industry practices to address the key issues of best prevention methodologies. The Design Guide encompasses SecuriSmoke Early Warning Fire Detection systems for risk-based protection methods, optimising the level of detection sensitivity and allowing for reliable staged responses, manual and automatic suppression actuation as well as control of other BMS (Building Management System) components (e.g. procedures of power-down forced ventilation fans or enable smoke extraction systems and other smoke management components).

Broad coverage of international and industry codes and standards

This Design Guide focuses on design recommendations for Securiton advanced Aspirating Smoke Detection (ASD) systems, related fire detectors and their integration with key control elements such as HVAC and fire suppression systems. Although it is far from exhaustive in referencing codes and standards and relevant local/regional industry Codes of Practice, this Design Guide's recommendations cover major international and industry codes and practices related to fire detection for Cleanrooms & Associated Controlled Environments facilities. Among them are NFPA 1, NFPA 72, FM Global DS 5-48/DS 8-1 or ISO/AS 7240-20 (from a DtS perspective) and NFPA 76, NFPA 45/318/99, BS 6266, FM Global DS 5-14/DS 1-56/DS 7-7 (from a risk-based protection perspective). Other codes covering Inspection, Test and Maintenance (ITM), such as EN 54-20, UK FIA Code of Practice, ISO 7240-14, BS 5839-1, AS 1851, VdS 2095 and FM Global DS 5-48 are also covered. Due to the extensive use of ceiling sprinkler and in-rack suppression systems in ambient-controlled facilities such as warehousing storages, codes such as NFPA 13, CEA 4001en and FM Global DS 2-0 are referred to in the context of the best placement of Securiton SecuriSmoke ASD products in line with sprinkler or suppression system design.

Ask Securiton

The Design Guide also provides an overview of how other Securiton products such as SecuriHeat Line Type Heat Detection and SecuriFire range of Fire Alarm Systems can be used as part of its comprehensive 360° Fire Protection Solution offerings. Securiton provides high quality technical expertise to support your projects in the Cleanrooms & Associated Controlled Environments industry through its extensive network of offices and distribution partners around the world. Please contact Securiton or any of the local offices in your region.

1 Introduction

Outlook: Cleanrooms & Associated Controlled Environments industry

The global cleanroom technology market size was around US$ 3.7 bn in 2019 and is expected to grow at a CAGR of 3.8% from 2020 to 2027 (US$ 5.30 bn) across main end-user segments of pharmaceutical, medical device, biotechnology, hospitals and diagnostic centres [1]. On the other hand, the global semiconductor manufacturing equipment market is estimated to be US$ 62.4 bn in 2020 and projected to reach US$ 95.9 bn by 2025; at a CAGR of 9.0% [2]. The semiconductor foundry market covers semiconductor fabrication plant[1] (FAB) and was valued at US$ 42.03 bn in 2019 and is expected to reach US$ 62.2 bn by 2025, at a CAGR of 6.75% [3]. Continuing and emerging electronics advancements in our increasingly tech-driven world, artificial intelligence, automation and renewable energy all drive demand ranging from semiconductors, integrated circuits (IC), MEMS[2] and sensors manufacturing to LCD/LED and solar panel production. These in turn require both new builds and retrofits of existing cleanrooms or facilities with controlled environments to meet the production output increases and changes of technology or manufacturing methods.

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The need for controlled environments for business operation are due to the fact that strict and often highly sensitive manufacturing processes or goods stored in these facilities will not be possible without the right ambient conditions. Examples of these include sterile and aseptic technology in hospitals or food processing, microelectronics and semiconductor production in industrial manufacturing.

While cleanroom-type building design and construction are done to meet requirements of the facility owners or operators, common design considerations include facility parameters/dimensions, available local utility for firefighting (e.g. water supply), the nature of business operation (for occupancy), materials handling and construction methods (wall, floor and ceiling). To cater for operation in cleanroom-type facilities, great emphasis is placed in specialist HVAC system design and operation to ensure the respective ISO Class requirements are met and correct room/area air pressurisation and flow pattern are maintained. In ambient-controlled storages, considerations are given to the types of storage spaces; space configurations, durable and functional requirements, energy-efficiency, safety and security of people and goods, health and comfort level, as well as issues stipulated in relevant industry codes of practices such as the EU Guidelines for GMP[3] [4].

Risk management, business continuity and life safety are all paramount to operation

Due to the use and storage of hazardous materials and perilous manufacturing processes in industrial facilities, an estimated average of over 37’900 fires at industrial or manufacturing properties each year in USA, with annual losses from these fires estimated at US$ 1.2 bn in direct property damage. The extent of flames spreading from these fires is comparably much more severe when fires spread beyond the level of fire origin and/or beyond the building of fire origin at 41% (industrial) and 21% (manufacturing) respectively for the reported period [5].

1 FAB: Semiconductor fabrication foundry/plant
2 MEMS: Microelectromechanical systems
3 GMP: Good Manufacturing Practice

Healthcare facilities

While healthcare facilities and hospitals are generally perceived as a safe place, an estimated average of 5'700 medical facility fires are reported to fire departments in the USA each year, nearly a fifth of those (1'100 fires) were in hospitals [6]. While about 80% of fire damages are limited to the object of fire origin, fires such as surgical fires in the operating theatres often present significant risk to life safety with fire potentially spreading rapidly with the presence of extremely flammable materials in an often small and enclosed space with large amounts of fresh air circulating. The ECRI[4] estimates over 200 surgical fires occur annually in the USA with some of them causing serious injury, disfigurement, and even death [7].

Massive damage after a fire in a FAB

While large fires in a FAB are not a common occurrence, even a small fire or damages from smoke contamination due to overheating can have significant consequence in property losses, production and delivery interruption. A fire in 2013 at a memory chip FAB in Asia resulted in costs to its insurers of around US$ 1.0 bn, not including potentially higher CBI[5] losses. The cost of the claim reflected the time and the expense of restoring specialist "cleanrooms" used in the production of semiconductors, as well as CBI losses suffered by computer equipment manufacturers further down in the value chain [8]. Because of such an enormous risk, each incident further hardens the determination for businesses to adopt rigid risk management regimes and for the insurers to manage risks through the recommendation of best practices in fire safety and protection.

Electrical equipment as well as use and storage of flammable substances are the prime causes for fires

Leading causes of fires in industrial and manufacturing properties are found to be electrical distribution, heating and lighting equipment. In the healthcare facilities and hospitals, besides the cooking equipment that contribute to a high percentage of fires, the other main causes of fires are similar to these found in the industrial and manufacturing buildings.

Another major cause of fires involves the use and storage of highly flammable substances in the business operation or production processes. Hazards in large cleanrooms include the use of extreme high-temperature furnaces, high power lasers, toxic, flammable, oxidizing and pyrophoric gases, that are connected to a range of equipment. Wet chemical hoods need the use and storage of large quantities of concentrated acids, bases, solvents, and oxidizers.

In hospitals, examples such as extremely dangerous surgical fires inside an operating theatre are attributed to hazard profiles of extremely flammable alcohol-based preparations, vapours/aerosols and adhesives, as well as any material or item with a carbon chemical base that can be ignited in an oxygen-enriched atmosphere.

High airflow, large open space, pressure differential, complex equipment and tools layout and occupancy challenge fire safety system design

Together with fire protection system design, efficacy and fit-for-purpose system performance, along with the significant airflow and rapid circulation to achieve and maintain a particular ISO class, large open spaces with complex equipment, tools and test bench configurations, pressurised areas and pressure differentials between adjacent areas with different ISO class requirements, difficult or sometimes almost impossible access to the detector's installed location for maintenance purposes, these all present challenges to the design of fire detection and suppression systems. For facilities with high airflow and rapid circulation, smoke dilution and movement are key considerations when choosing suitable fire/smoke detection systems and where the detection systems should be located. When there are multi-level building structures such as a large semiconductor fabrication plant with FAB and sub-FAB level, the type of detection and placement of detection points have an impact on the cost of total ownership from first the installation to ongoing service and maintenance.

Various occupancy classifications, found in wide range cleanroom-like buildings, may require a different type of detection system (e.g. smoke or heat or a combination of both, point type or line type) for either open spaces, machine tools in-cabinet or underfloor cable trays protection, or in different hazard classification areas [9] where requirements of gaseous suppression and pre-action sprinklers

[4] ECRI: Emergency Care Research Institute, PA, USA
[5] CBI: contingent business interruption

to be in action earlier through reliable initiating devices, such as a fire detection system, and early fire alert to facilitate investigation or egress from large areas with restricted access control.

Flexible and reliable early detection is critical

The diverse nature of Cleanrooms & Associated Controlled Environments facilities requires the design of a fire detection system to be simple and flexible to meet Deemed-to-Satisfy (DtS) fire and building safety provisions. The design shall also be able to address risk-based detection needs, over and beyond prescriptive requirements, to ensure business operations and asset protection.

Adequate fire detection systems that automatically notify local fire services can make a huge difference in minimising fire damage. In addition, the ability to detect and alert early, allow facility operators and the occupants to handle the initial outbreak or to remove potential hazards that could lead to a real fire. Early and reliable fire detection is critical to many cleanroom-type facilities to avoid business interruption, and to ensure orderly evacuation. When an advanced Early Warning Fire Detection system can be designed and installed at a low TCO[6], the same level of protection can be realised to achieve building and life safety objectives as well as protection of business assets, regardless of the size and use of the buildings with controlled environments.

Why a Design Guide?

From early surgical cleanrooms in the 1950s to commercial cleanrooms in early 1960's, to the first release of NFPA 318 in 1992, fire safety and fire protection have always been highlighted for the challenge and uniqueness of fire risks in Cleanrooms & Associated Controlled Environments such as a semiconductor fabrication plants. While cleanrooms technologies, processes and applications of cleanroom related construction and protection codes and standards evolved over the years, many aspects of fire safety concerns remain, such as a rapid growth of a fire and difficulties in manual firefighting. Early Warning Fire Detection is a critical part of best practices of a fire engineering solution, even though sprinklers or other form of suppression such as gaseous systems or water mist are also effective in potentially reducing the fire damage and the time to recover. Only a well-designed Early Warning Fire Detection system provides risk mitigation, helping to potentially prevent a fire from happening or developing out of control before the fire services arrive as well as early alarm for orderly emergency evacuation. A suitable fire detection system is also required for the actuation of pre-action and co-incidence (or interlock, double interlock) suppression systems or early control of a fire using gaseous suppression systems.

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[6] TCO: Total Cost of Ownership (of an Early Warning Fire Detection system)
[7] BMS: Building Management System

1.1 Purpose

Who is it for?

The purpose of this Design Guide is to provide fire safety and protection consultants, qualified fire system specifiers, design engineers or technicians, recommendations of applications and uses of SecuriSmoke Early Warning Fire Detection for Cleanrooms & Associated Controlled Environments, including

1. Large scale FAB and high technology manufacturing with low (cleaner) ISO classifications (or approximately equivalency of FS-209E Class), along with any size of modular cleanrooms;
2. Ambient-controlled or humidity-controlled sterilisation occupancies (often confined to relatively higher (dirtier) ISO Classifications as well) such as these under EU or WHO's GMP [4], [10] of sterile products, storage, safe transport to laboratories, hospitals/healthcare facilities, pressurised isolation or containment areas where environmental conditions have an impact on the fire detection system design or a desirable outcome resulting from best design practices.

Cleanrooms & Associated Controlled Environments with mixed occupancies pose similarities in the requirements; this ranges from risk management, emergency response and evacuation to property loss prevention. The uniqueness of room space with ISO classifications such as high airflow and high sensitivity of operation and material handling dictate the use of a suitable Early Warning Fire Detection system, where an early and reliable fire detection system is a key element to eliminating potential false or nuisance alarms or for non-intrusive service and maintenance of fire detection systems.

This Design Guide is also suitable for facility management and end-customers alike to gain a high-level insight to cost-effective, fit-for-purpose and fire-engineered fire detection and protection solutions to meet prescriptive DtS fire detection and protection compliance as well as enhanced fire detection methods to avoid business interruption and mitigating risks through the best fire prevention practices.

1.2 Scope

What does it cover?

The scope of this Design Guide covers detailed recommendations, design considerations and practices for Securiton Early Warning Fire Detection systems (SecuriSmoke ASD 531, 532, 533, 535 and 535 HD Aspirating Smoke Detectors and REK 511) for Cleanrooms & Associated Controlled Environment facilities. Depending on the actual building occupancy and business use, cleanroom-type facilities or buildings containing a cleanroom-like structure may be classified [9], [11] as Industrial Occupancy, Storage Occupancy, Mercantile Occupancy, Business Occupancy, Health Care Occupancy [12] or a combination of various occupancy classifications when the business type and operation within the same facility are taken into account. For a variety of laboratories [13] or similar operations concerning environmental hygiene, sterile processing and transmission prevention, these associated controlled environments may be classified as industrial, educational, health care or business occupancy. Others can be classified by local AHJ[8] based on the types of hazards individually such as a computer or physical therapy laboratory.

General fire detection system design recommendations are subject to the compliance of above-mentioned national and international codes and standards, as well as industry or building operation specific Codes of Practices such as these for the constructions [14] and operation [15] [16] of hospital and healthcare facil-

[8] AHJ: Authority Having Jurisdiction

ities. The scope of this Design Guide emphasises mainly on applicable Cleanrooms & Associated Controlled Environments conforming to ISO Classifications or equivalent [17], [18] within the following building occupancies:

1. Large scale FAB with strict ISO classification requirements.
2. Manufacturing, handling and storage of high precision electronic products, pharmaceutical and bio chemical alike in cleanrooms or associated controlled environments, including research and development laboratories in which hazardous chemicals are stored and handled in a self-contained clean/sterilised zone.
3. Modular cleanrooms designed for all sterile and aseptic applications as well as local protection of large tools and equipment used in a FAB.
4. Specifically, controlled areas within hospital and healthcare facilities, such as operating theatres, MRI[9] scan areas, patient treatment in isolation or containment, sterilising areas and laboratories.

Hazardous and sensitive areas

Cleanrooms & Associated Controlled Environments such as hospital and healthcare facilities in a building as well as storages meeting strict requirements, which often contain chemicals or gases in potentially leaking containers, in corrosive, combustible or explosive ambient conditions. Purpose-built rooms or facilities [14] can provide restricted liquid storage (fuel and non-propellant), flammable and combustible storage, radioactive material storage and hazardous chemical storage (per NFPA 1 Chapter 34.2 Classification of Commodities and Chapter 60.3 Classification of Materials, Wastes, and Hazard of Contents [9]) and the use of UL-listed smoke detector per NFPA 72 [19].

For Cleanrooms & Associated Controlled Environments within the scope of this Design Guide, the design recommendations for fire detection cover large open spaces for production and prefabricated modular cleanrooms, high value tools and equipment in FAB and manufacturing facilities. It also covers other related areas for general operation/administration, high sensitivity areas such as on premise sterilise or aseptic rooms, critical operations support such as record or specimen storages and server rooms as well as other relevant areas such as power supply and distribution, HVAC and mechanicals.

The design recommendations are generally in the context of relevant international codes and practices on prescriptive (or DtS) fire detection requirements for cleanrooms with ISO classifications or equivalent building structure facilities. Enhanced detection design is covered mainly based on risk-informed approaches where extensions of a prescriptive design are provided to address the need for risk management or to prevent business losses and unacceptable interruption. The objectives of life safety are usually stipulated in international codes such as NFPA 101 [11] where boundaries of life safety concerning protection of the occupants are prescribed, or needs of emergency response and planning are stated as compliance of operation in specific industry guidelines such as [15] [16].

Covering a variety of industries and operations

Although this Design Guide does not cover the detail design of fire detection systems together with overall fire protection in hazardous areas, the detection system design recommendations are mainly in line with typical codes and industry practices based on NFPA, ISO/EN/AS/BS, VdS and FM Global or equivalent regional based fire detection system codes and design practices (see Appendix A.1 Summary of Codes and Standards). Following are examples:

1. NFPA 318 Standard for the Protection of Semiconductor Fabrication Facilities [20] and NFPA 99 Health Care Facilities Code [12]
2. FM Global Property Loss Prevention Data Sheet DS 7-7 Semiconductor Fabrication Facilities [21] and DS 1-56 Cleanrooms [22],
3. Hazardous areas where Securiton SecuriSENS Line Type Heat Detection (LTHD) may be used; or the use of SecuriSmoke products together with recommended special hazardous rating accessories (see Appendix C SecuriSmoke ASD Accessories).

[9] MRI: Magnetic Resonance Imaging

To facilitate the best risk management practice and reliable emergency response procedures through early intervention and elimination of potential fire incidents, the Securiton Early Warning Fire Detection product portfolio is also designed to be a flexible yet integral part of a fire safety solution. This Design Guide touches on:

- Use of Early Warning Fire Detection for suppression (mainly sprinklers, pre-action sprinklers, water mist or expansion foam suppression) actuation
- Securiton 360° Fire Protection solution (FACP and ECP[10])
- Securiton Software for local and remote monitoring

Inspection, Testing and Maintenance

The Design Guide also provides key requirements on Inspection, Testing and Maintenance (ITM) of SecuriSmoke Early Warning Fire Detection system as well as world-class technical and application support offered by Securiton through its headquarters teams in Europe and its vast global network of regional offices and distribution partners.

The Design Guide recommendations cover only the key design attributes without reference to all relevant details in national/local standards or industry code of practices. Even when the latest revision of code is referenced, e.g. NFPA 72 (2019), some AHJs[11] still enforce compliance to NFPA 72 (2016) or older revisions. It is therefore important to verify the actual design per project site location with the local AHJ or even municipal/city level fire ordinances requirements.

For simplicity, only the term 'Early Warning Fire Detection' is used in the Design Guide, it refers to both fire and/or smoke detection capable of detection sensitivity of VEWFD (Very Early Warning Fire Detection) similar to EN 54-20 [23] Class A or EWFD (Early Warning Fire Detection) similar to EN 54-20 Class B. However, for some general ambient-controlled but non-ISO grade cleanroom-like facility protection, a simple Standard Fire Detection (SFD) similar to EN-54-20 Class C are applied to meet prescriptive (deem-to-satisfy) fire detection compliance.

1.3 Overview

Table 1 below is an overview of this Design Guide.

Table 1 Cleanrooms & Associated Controlled Environments Design Guide overview

Chapter	Overview
1	Introduction and scope of this Design Guide
2	Cleanrooms & Associated Controlled Environments protection needs
3	Securiton Early Warning Detection and prevention methods
4	Detection design for level of protection optimisation
5	Securiton 360° Fire Protection Solution outline
6	Inspection, Testing and Maintenance
7	Software and Application support from Securiton
8	List of references and literature
Appendices	Additional details (codes; design illustrations and related accessories)

Keywords: Cleanroom, semiconductor fabrication plant (FAB), healthcare, sterile, aseptic, pressurised rooms, air exchange rate, high airflow, laminar and turbulent airflow, unidirectional, non-unidirectional, sprinkler system, ASD (Aspirating Smoke Detector), Early Warn-

[10] FACP: Fire Alarm Control Panel, also known as Fire Alarm Systems (FAS) or Fire Indication Panel; FACP is often categorised into Main and Sub panel; Related devices include Mimic Panel and Repeater Panel. ECP: Extinguish Control Panel.
[11] AHJ: Authority Having Jurisdiction.

ing Fire Detection, detection design, detection installation, incipient fires, FACP, ECP, suppression actuation, performance-based, risk-based, prescriptive, emergency response, risk management, fire prevention.

For easy reference throughout the Design Guide, Table 2 below shows the comparisons between ISO Classifications and USA GSA FS-209E class of cleanrooms. Table 3 shows typical ACR (in ACH, air-change per hour)[12], room airflow velocity (in m/s or fpm (ft. per minute) and FFU[13] coverage (% of ceiling area). The impact of the high airflow resulting from FFU speed and placement for designated cleanroom class must be taken into account when designing the fire detection system.

Table 2 ISO Class and USA Federal Standard 209E [17], [18]

ISO 14644-1	**USA - GSA FS-209E**	**ISO CLASS - Number of Particles per Cubic Meter by Micrometre Size (µm)**					
Class	English (Metric)	0.1	0.2	0.3	0.5	1.0	5.0
ISO 1		10	2				
ISO 2		100	24	10	4		
ISO 3	1 (M1.5)	1’000	237	102	35	8	
ISO 4	10 (M2.5)	10’000	2’370	1’020	352	83	
ISO 5	100 (M3.5)	100’000	23’700	10’200	3’520	832	29
ISO 6	1’000 (M4.5)	1’000’000	237’000	102’000	35’200	8’320	293
ISO 7	10’000 (M5.5)				352’000	83’200	2’930
ISO 8	100’000 (M6.5)				3’520’000	832’000	29’300
ISO 9					35’200’000	8’320’000	293’000

GMP EU Cleanroom Classifications (Grades) A B C D [4] are used as standard for EU-based businesses involved in the manufacture and storage of sterile products. Grade A and B are approximately equivalent to ISO 5, Grade C and Grade D are similar to ISO 7 and ISO 8 respectively.

Table 3 Typical Air Change Rate, airflow and FFU ceiling coverage [24], [25]

ISO 14644-1	**USA - GSA FS-209E**		**ISO CLASS - Air Change Rate, airflow and FFU ceiling coverage**		
Class	English	Metric	ACR (ACH)[#1]	Average Airflow Velocity m/s (fpm)	FFU Ceiling Coverage %
ISO 1			Up to 750 Unidirectional	0.36-0.66 (70-130)	100%
ISO 2			360-600 Unidirectional	0.31-0.51 (60-100)	80-100%
ISO 3	1	M1.5	360-540 Unidirectional	0.31-0.46 (60-90)	60-100%
ISO 4	10	M2.5	300-540 Unidirectional	0.25-0.46 (50-90)	50-90%
ISO 5	100	M3.5	240-480 Non-unidirectional	0.20-0.41 (40-80)	35-70%
ISO 6	1’000	M4.5	150-240 Non-unidirectional	0.13-0.20 (25-40)	25-40%
ISO 7	10’000	M5.5	60-90 Non-unidirectional	0.05-0.08 (10 -15)	15-20%
ISO 8	100’000	M6.5	5-48 Non-unidirectional	0.01-0.04 (1-8)	5-15%
ISO 9			Up to 48 Non-unidirectional	Up to 0.04 (up to 8)	Up to 15%

#1: ACR range depends on the activities and equipment within the room (e.g. less obstructions, lower airflow).

[12] ACR: Air Change Rate (in Air-Change per Hour (ACH))
[13] FFU: Fan Filter Unit

2 Aspects of Fire Safety and Prevention

Cleanroom definition

A cleanroom is defined by ISO14644-1 as a room in which the concentration of airborne particles is controlled, constructed and used in a manner to minimize the introduction, generation, and retention of particles inside the room and in which other relevant parameters, e.g. temperature, humidity, and pressure, are controlled as necessary. In a pharmaceutical sense, clean rooms are those rooms that meet the code of GMP requirements as defined in the sterile code of GMP, e.g. Annex 1 of both the EU and WHO Guides to GMP and other standards and directives as required by local health authorities.

Difficult environments

The wide range of manufacturing, warehousing and business operations require ISO grade cleanrooms. As examples, ISO 1 and 2 are typically found in large FAB, ISO 3 and 4 for production laboratories for electronic integrated circuits; ISO 5 for production areas for photo labs, medical implants, ISO 7 for production locales for TV tubes, hospital operating theatres and ISO 8 for production of ball bearings.

Compared to conventional systems, the key differences of cleanroom HVAC include

- Increased air supply to eliminate the settling of the particulates and dilute contamination produced in the room to an acceptable concentration level, through stringent measurement and control of ACR
- Use of high efficiency filters such as HEPA[14] or ULPA[15] filters with filtration efficiency of up to 99.999% down to 0.12 microns
- Room pressurization with the cleanroom is positively pressurized (to 0.05-inch WC[16] (12.5 Pa)) with respect to the adjacent areas [26].

Challenges for early detection

As shown in Table 3, high airflow (as high as 0.66 m/s (130 fpm)), various flow patterns (luminance or turbulence), FFU ceiling coverage (up to 100%) are all critical factors impacting on how reliable a fire detection system is to the intended detection performance requirement and where the system is installed.

Other fire safety challenges include restricted access that not only require early warning fire alarms for safe occupants' emergency evacuation, but access only for routine service and maintenance. For ambient-controlled warehouses with high-bay racking systems, in-rack early fire detection is also an issue to be addressed. Fast moving air at the return air grills in a cleanroom present added difficulty to detect smoke early, when following the standard fire detection system design practices.

Combine suppression with adequate fire detection is desirable

Due to the high value product, storage and business operations inside a cleanroom-type building, various forms of suppression are routinely installed. These can be a per-action sprinkler systems in a warehouse, chemical or gaseous suppression system in an electronics manufacturing plant or water mist system found in parts of a hospital. Many gaseous suppression systems in these special hazard areas are designed to be released by an early detection system at the early stages of a fire development. Although ceiling-level sprinklers are installed under ceilings as high as 13.8 m (45 ft) for high ceiling storage facilities or factories [27], [28], many ambient-controlled high-bay warehouses also have an in-rack sprinkler system installed [29]. This is due to the ineffectiveness of ceiling level sprinklers to control a fire with a significant fuel load, rapid vertical fire propagation and fire spread from one aisle to another. As such, a multilayer fire detection or ceiling level fire detection combined with risk-based local detection is desirable for early detection of a fire incident, regardless of where it originated.

[14] HEPA (High-Efficiency Particulate Air), rated 99.99% efficient at removing particles $\geqslant$ 0.3 µm
[15] ULPA (Ultra-Low Penetration Air), rated 99.999% efficient at removing particles $\geqslant$ 0.12 µm
[16] WC: Water Column (1 in WC = 249 Pa)

Fire damages cause unacceptable loss and downtimes

On the other hand, business continuity is paramount for the commercial operation to deliver high levels of service relying on high-intensity manufacturing processes to ensure Just-in-Time (JIT) production and delivery. A fire in 2013 at a memory chip FAB in Asia resulted a cost to its insurers at around US$ 1.0 bn, not including potentially higher CBI losses of its own. The cost of the claim reflected the time and expense of restoring specialist “cleanrooms” used in the production of semi-conductors, as well as CBI losses suffered by computer equipment manufacturers further down in the value chain [8]. Any operation interruption due to a fire event similar to this could lead to an unacceptable extended downtime of supply and significant damage to company reputation.

A central element of best fire safety practices is the use of Early Warning Fire Detection. This chapter highlights the following key aspects of fire safety and fire prevention in Cleanrooms & Associated Controlled Environments facilities:

1. Hazard profile and risk management
2. Cleanroom-type environments characteristics
3. Challenges to Early Warning Fire Detection
4. Risk and Performance-based Design (PBD) with Securiton Early Warning Fire Detection

2.1 Hazard Profile and Risk Management

Electrical equipment and flammable materials are major causes for fire

While in general, electrical distribution, heating and lighting equipment are the leading cause of structure fires in manufacturing and industrial properties, cleanroom-type facilities, such as large FAB plants and healthcare facilities, present other unique hazard conditions and risks associated with occupancy and business processes in these built environments.

Hazard profile

Examples of unique hazards in large cleanrooms include the use of extremely high-temperature furnaces, high power lasers, toxic, flammable, oxidizing and pyrophoric gases, that are connected to a range of equipment. Wet chemical hoods need the use and storage of large quantities of concentrated acids, bases, solvents, and oxidizers. Complex power supply networks with electronic circuit boards (PCBs), electrical bus bars and electrical panels throughout the plant have a high combined peak power load [30].

Extremely dangerous surgical fires inside an operating theatre in hospitals are attributed to the hazard profile of highly flammable alcohol-based preparations, vapours/aerosols and adhesives, as well as any material or item with a carbon chemical base can be ignited in an oxygen-enriched atmosphere.

While good housekeeping may reduce the likelihood of a fire from happening, the vast size of the facility or confined space with equally very high airflow required to maintain ISO Class, coupled with significant amounts of stored chemicals and processing equipment in high density, present challenges to risk mitigation and risk management under some of these unique hazardous conditions.

Fire hazards, commodity classifications

Fire hazards inside Cleanrooms & Associated Controlled Environments facilities are generally assessed in line with the classification of occupancy as well as commodities (for example NFPA 1 [9] and FM Global DS 8-1 [31]), where specific to storage fire safety, material, waste and hazard of contents are further divided into varieties of classes (e.g. FM Global DS 8-9 [29] Storage of Class 1, 2, 3, 4 and Plastic Commodities). Flammable and combustible liquids storage is addressed separately because relevant fire hazards in these storages require suitable fire protection measures.

Extended codes and standards

To enhance risk management, fire prevention and fire protection further, large insurers such as FM Global and industry peak body SEMI[17] developed a comprehensive suite of property loss prevention Data Sheets and guidelines for large cleanrooms. These include FM Global property loss prevention Data Sheets for Semiconductor Fabrication Facilities and Cleanrooms [21], [22], SEMI Safety Guideline for Risk Assessment and Risk Evaluation Process [32] and Industrial Risk Insurers (known as AXA SA nowadays) Guiding Principles for the Protection of Semiconductor Manufacturing Facilities [33].

In addition to the above-mentioned industry codes of practices, NFPA and local government bodies alike focus on good fire prevention and protection with specific codes, standards and directives, most noticeably for the healthcare facilities and hospitals. These include NFPA codes for Cleanrooms [20] and Health Care Facilities [12] and Cleveland Clinic (USA) mandated facilities conforming to its Fire Protection and Life Safety Design Standards [16].

Fire incidents affect operation, services and possibly loss of life

Most, if not all Cleanrooms & Associated Controlled Environments facilities are designed for processing and distribution of goods either for their own businesses or as a service hub connecting businesses to their customers. For healthcare and hospitals, the services also extend to these with special needs and how services are delivered in some unique settings. Business continuity and life safety in the event of a fire and emergency evacuation as well as avoiding any loss of life and property loss due to fire, are equally paramount. Regardless of the actual occupancy or type of manufacturing processes or types of services delivered, Early Warning Fire Detection is a key to risk management of these cleanroom-type facilities to ensure a high level of service availability, reliability as well as to facilitate an orderly emergency evacuation. Naturally, any fire or non-fire incident, such as a false fire alarm, can result in significant downtime of the facility's operation and services or lead to unwarranted power shut-downs and evacuation.

Business Continuity and orderly evacuation rely on Early Warning Fire Detection

Figure 1 illustrates two key aspects of using Early Warning Fire Detection system:

(a) How business interruptions and potential losses due to fire damage may be avoided by installing a fire detection system
(b) How early and reliable fire alarm can ensure the safe evacuation when required safe egress time (RSET) is minimised while the available safe egress time (ASET) is maximised

With an Early Warning Fire Detection system, fire incidents or small fire situation can be managed during its incipient stage to avoid business interruption and damages or avoidable site-wide evacuation and power shut-downs, or at least keep them minimal. Even as the fire situation progresses, fire services can be notified automatically and arrive at the scene much earlier before the fire spreads. With pre-action suppression systems installed in the facilities and ensuring the effectiveness of ceiling level sprinkler operation, staged detection system alarms can control mechanical ventilation as needed and actuate the pre-action suppression. A reliable Early Warning Fire Detection system provides pre-signal alerts so potential fire incidents are dealt with well before any interruption to the service occurs, resulting in minimal interruption to the business and loss in facilities having Cleanrooms & Associated Controlled Environments.

[17] SEMI: Semiconductor Equipment and Materials Institute

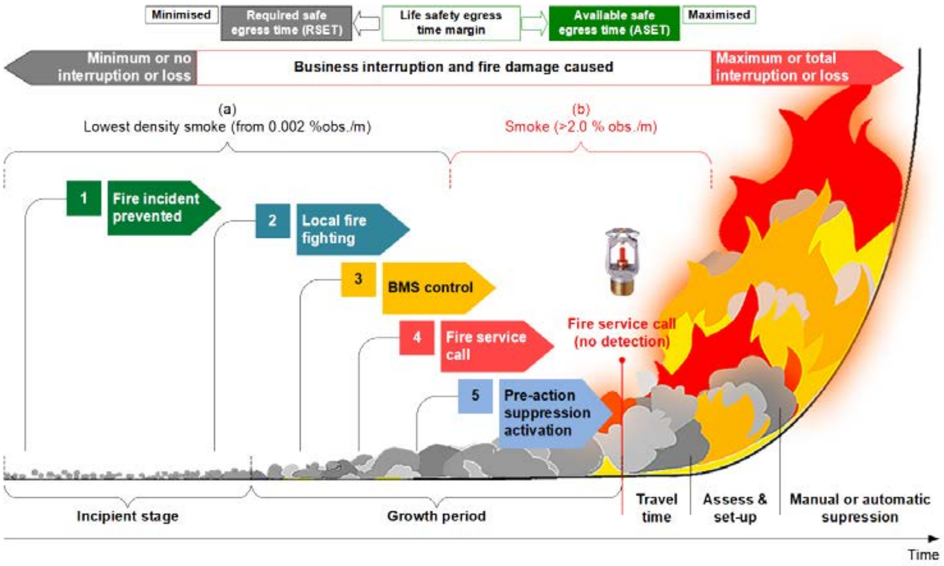


Figure 1 Impact of detection system on life safety and loss due to fire damages

2.2 Cleanrooms Type Environments Characteristics

Cleanrooms and associated controlled environments

The building occupancies in facilities with Cleanrooms & Associated Controlled Environments spread across a wide range of industries from aerospace, chemical, manufacturing, semiconductor/microprocessor, server rooms, research laboratories, biotech, pharmaceuticals, storage and hospitals. Depending on the type of business operation, the controlled environments can be for the whole building, a part of a building or special areas and enclosures within a building. While large-scale buildings with controlled environments are often purposefully designed and built as "cleanrooms", small-scale buildings or areas within a building require special controlled environments can often be set up using modular cleanrooms concept.

Needs for controlled environments for business operation are due to the fact that strict and often highly sensitive manufacturing processes are in place or the storing of goods in these facilities is not possible without the right ambient conditions. Examples are sterile and aseptic areas in hospitals or food processing, microelectronics and semiconductor productions in industrial manufacturing.

While cleanroom-type building design and construction are done to meet requirements of the facility owners or operators, common design considerations include facility parameters/dimensions, available local utility for firefighting (e.g. water supply), nature of business operation (for occupancy), materials handling and construction methods (wall, floor and ceiling). To cater for operation in cleanrooms type facilities, great emphasis is placed in specialised HVAC system design and operation to ensure the respective ISO Class requirements are met and correct room/area air pressurisation and flow pattern are maintained. In ambient-controlled storages, considerations are given to types of storage spaces; space configurations, durable and functional requirements, energy-efficiency, safety and security of people and goods, health and comfort level, as well as issues stipulated in relevant industry codes of practices such as the EU Guidelines for Good Manufacturing Practice (GMP) [4].

Assessing fire system design

Use of high-risk hazardous goods such as flammable substances and high energy production processes in cleanrooms present significant hazards ranging from fire or overheating smoke contamination to explosion. While electrical short-circuits or equipment overload is often causing fire, spontaneous ignition or leaks in containers of highly flammable or self-igniting fluids or gases are also major causes of a fire in cleanrooms. Even small fires or a fire at its incipient stage can cause considerable smoke damage and consequential losses.

A fire system design includes the assessment of potential ignition sources, the suppression methods and agents, detection and/or suppression release. The presence of large machine tools, wet benches and equipment with local gaseous or other types of suppression and the probability for failure of detection and suppression system must also be assessed. Last but not least, special egress time safety margin for early and orderly evacuation as well as local fire services response and its firefighting priority must also be included in the assessment.

Common features in cleanroom-type building design

Features common to the design of the facilities with Cleanrooms & Associated Controlled Environments are ranging from high airflow, rapid air circulation and patterns with specific placements of air inlets, filtration elements, return air shafts, room pressurisation and pressure differentials over other structure layouts associated with the occupancy type of the facilities, such as in ambient-controlled high ceiling warehouses with high-bays, sophisticated material handling equipment to extreme low temperature or high humidity storage environments.

Other specialised construction design guidelines for buildings including cleanroom-type areas should also take into account the requirements of fire detection systems. Examples include FGI's Guidelines for Design and Construction of Hospitals) [14], APHL's Laboratory Facility Construction and Major Renovations Guidelines [34] and NFPA 45 [13].

Although cleanroom-like buildings come in different shapes for different purposes, the design of an Early Warning Fire Detection system can follow a certain set of rules. For the purpose of fire detection system design, the following 4 categories of cleanroom-type facilities are the focus of this Design Guide:

1. Controlled environments and modular cleanrooms
2. Semiconductor Fabrication Facilities (FAB)
3. Hospital and healthcare facilities
4. Ambient-controlled manufacturing and storage

2.2.1 Controlled Environments and Modular Cleanrooms

Ensuring consistency with codes and standards

To ensure industry-wide consistency, regional and global cleanroom classifications and standards have been developed and evolving since 1963. Early FS-209/FS-209E by U.S. Federal GSA standard was officially withdrawn in late 2001 after ISO 14644-1 became mandatory in the Europe Union (E.U.) since November 1999, but other major national standards that referenced to FS 209 include Australia (AS 1386), France (AFNOR X44101), Germany (VDI 2083:3), Netherland (VCCN 1), Japan (JIS-B-9920), Russia (GOST-R 50766) and United Kingdom (BS 5295).

Ventilation is key to cleanness

The benchmark of air cleanliness is particle concentration, therefore Air Change Rate (ACR) is a prime variable in determining ISO and USA Federal cleanness standards (according to Table 2). Other unique building design components include clean room ceilings, partitions, floor systems, placements of filter fan units (FFU), light fixtures and return air grilles. The primary objective is to maintain airflow in parallel flow streams that has two purposes: first, it needs to dilute particle concentrations that may have formed in the room due to personnel or process activity and second, to carry away particles or contaminants generated within the room.

Laminar airflow is typical to ISO Class 5 and better

Stringent cleanrooms for sterile or aseptic processes with a classification rating of FS-209E 100 (ISO 5 or Grade A per EU GMP guidelines) or better are almost invariably designed for unidirectional or "laminar" airflow (the air streamlines are essentially parallel to one another). Typically, laminar flow is achieved by supplying air through HEPA/ULPA filters, ensuring 100% ceiling coverage. As such, in front of the return air grilles, especially in large cleanrooms, the airflow is also found to be unidirectional.

A pressure differential keeps areas isolated

Generally, a 0.05 in WC (12.5 Pa) pressure differential from the clean space to the unrated areas is recommended. In clean spaces with multiple rooms, the trend is to maintain a positive pressure of 0.02 in WC (5.0 Pa) between adjacent clean spaces with differing ratings. The most sensitive areas should be the most highly pressurized to ensure that the air does not get transferred from unclean space to a stringent cleaner room. The only exception to using a positive differential pressure is when dealing with specific hazardous materials where the statutory health and safety agencies require the room to be at a negative pressure.

Typical configurations

Figure 2 illustrates (a) a typical custom designed building with controlled environments for manufacturing, food processing or large-scale labs and (b) a modular cleanroom in various sizes installed within a building structure or warehouse-type facility.

(a) Typical custom designed building with controlled environments

(b) Modular cleanrooms in various sizes installed within a warehouse-type facility

Figure 2 Controlled environments and modular cleanrooms

Apart from airflow and ventilation issues, goods sensitive to ambient conditions need to be stored and handled in an ambient-controlled environment. For example, European Good Distribution Practice Guidelines [35] and WHO require vaccines must typically be stored and handled in a range of 2 to 8°C (35.6 to 46.4°F). Food processing related refrigerated storage facilities usually consist of deep freezers with operating temperature typically in the range of -30 to -15°C (-22 to 5°F), chillers from -9 to 2°C (16 to 36°F) and coolers and loading bays at 0 to 18°C (32 to 65°F). Special design considerations shall be given due to their unique fire hazard characteristics, extreme challenging conditions to the fire detection systems, condensation, and often change of temperature range to suit for operational needs or for the purpose of energy efficiency, which can all affect detection and operation performance if inappropriate detection products are selected.

2.2.2 Semiconductor Fabrication Facilities (FAB)

Semiconductor Fabrication Facilities (FAB)

Large scale semiconductor fabrication facilities with the highest level of cleanness (e.g. ISO Class 1 or 2) are commonly found in IC industry, MEMS (Microelectromechanical systems), sensors manufacturing and large LCD/LED panel productions. As shown in Table 3, ISO Class 1 or 2 can result in an air change rate of 600/hour or more. Due to the variation of the air change rate, higher airflow is designed as unidirectional (laminar) while lower airflow cleanrooms are commonly designed as non-unidirectional (turbulent) airflow in a single-pass or recirculating pattern ([36], [37]).

Air velocity in the room, at inlets and exhausts

The space air velocity in a typical ISO Class 1 cleanroom or spaces within a cleanroom can be in the range of 0.35-0.66 m/s (70-130 fpm). Return air grilles are always located lower near the floor and made as long as possible to increase the collection of dust particles over a larger area. Return air risers behind the grilles are usually designed for velocities not exceeding 9.14 m/s (1800 fpm) but not less than 6.10 m/s (1200 fpm) at the highest point in order to carry particulate matter along with the return air. However, the inlet velocity at the return grille should be in the range of 1.52-2.03 m/s (300-400 fpm) gradually increasing the same to 6.10-9.14 m/s (1200-1800 fpm) [25] at the top of the shafts before exhaust/exit or recirculation via filtration elements.

Maintain a positive pressure from cleanest to least-clean areas

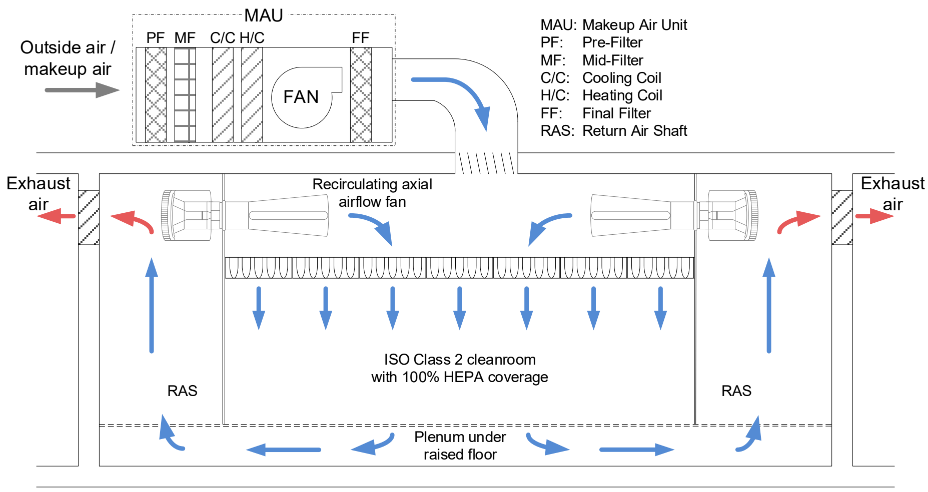
Cleanrooms are also designed to maintain positive pressure to ensure that filtered air always flows from cleanest to least-clean spaces. In a multi-chambered cleanroom where different ISO Classes are implemented based on production processes, the cleanest room is kept at the highest pressure when a differential air pressure of 0.02-inch WC (5.0 Pa) between each level of spaces are maintained.

Special design considerations shall be given to Early Warning Fire Detection system for large FAB due to their unique fire hazard characteristics, extreme challenging conditions to the fire detection systems, high airflow, air circulation and space pressure difference, which can all affect detection and operation performance if inappropriate detection products are selected.

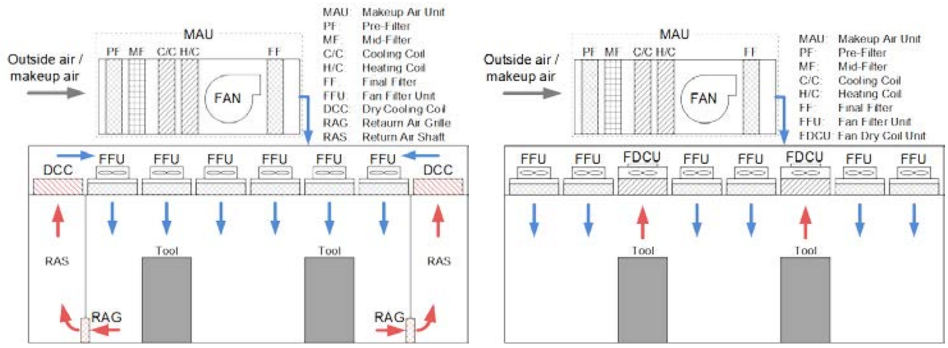
Air circulation

Figure 3 illustrates air circulation to exhaust ventilation cleanroom with raised floor or wall RAS[18] in the form of (a) single-pass or recirculating HVAC system and (b) Wall-return or FDCU[19]-return ventilation scheme.

[18] RAS: Return Air Shaft
[19] FDCU: Fan Dry Coil Unit



(a) Single Pass (red arrows air exhaust out) or recirculating (blue arrows internal) HVAC system



(b) Wall-return ventilation cleanroom (left) or FDCU-return ventilation cleanroom (right)

Figure 3 Air circulation/exhaust ventilation cleanroom with raised floor or wall RAS

Air velocity Figure 4 illustrates airflow and air velocity in a typical high-grade ISO cleanroom such as a large FAB plant with ISO 1 or ISO 2 class.

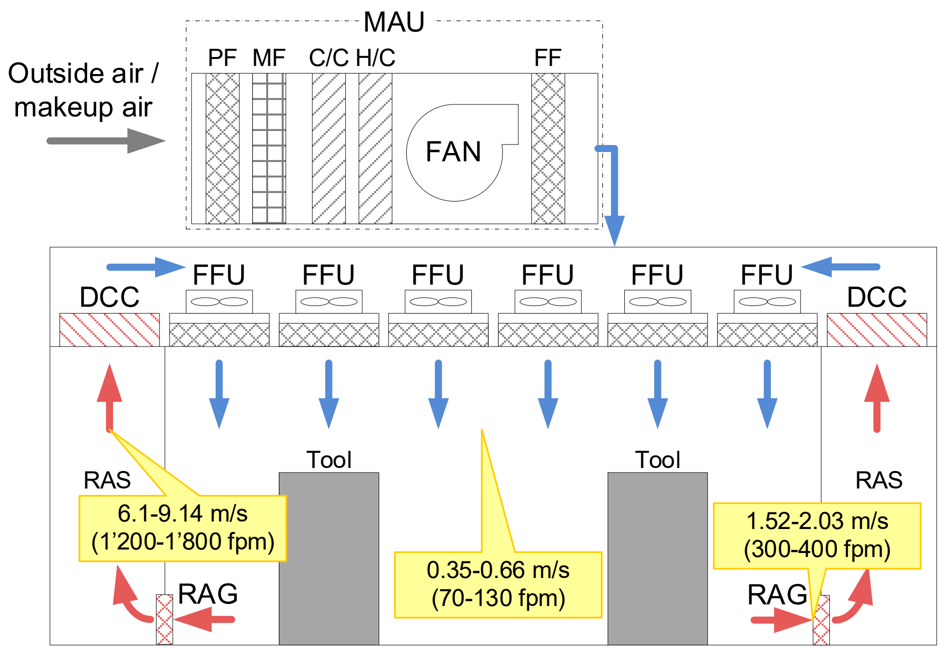


Figure 4 Typical airflow and air velocities in a large FAB

2.2.3 *Hospital and Healthcare Facilities*

Hospitals and healthcare facilities

Hospital and healthcare facilities require a high standard of sterile, aseptic and constant accurate pressurisation to contain or isolate sensitive areas from normal healthcare operations such as general clinics, administrations and public areas. The design of operating theatres for example is often prescriptive from state-level code of practices to international standards such as [38], adopted across Europe with the aim of reducing risk of surgical site infection (SSI) with the optimisation of LAF[20] or UCV[21] ventilation systems to cater for respective operating theatre needs. Often the space airflow velocity is in the range of 0.15-0.30 m/s (29.5-59.0 fpm). The use of various gases for the operating procedures pose unique fire risks in these environments.

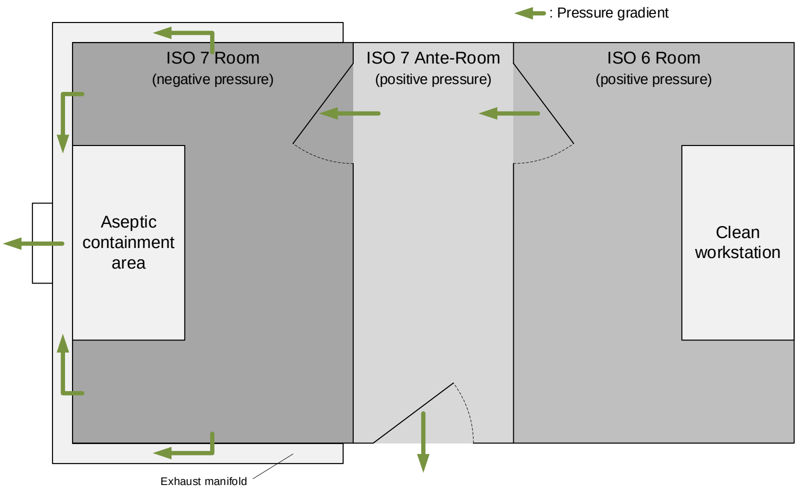
Challenges to fire detection systems

Due to the operational needs, sterile and aseptic rooms are often designed within the healthcare facilities in a way that are integrated with the surrounding areas. Different ISO classes' areas with varied levels of high airflow, together with room pressure differentials and restricted access, present a great challenge to the selection and design of fire detection systems.

Highly sensitive, sterile areas in hospitals

Figure 5 illustrates (a) a typical sensitive and high-risk areas (such as operating theatres and MRI rooms) and (b) a mix of restricted access rooms designed to different ISO classes.

(a) Sensitive and high-risk areas (e.g. operating theatres, MRI, isolated wards)



(b) Mixed occupancy of sterile, aseptic and other healthcare operation areas

Figure 5 Hospital and healthcare facilities

Key design considerations

Key design considerations for an Early Warning Fire Detection system are not only to provide flexible and early detection in high airflow, high pressure differentiation environments and facilitating orderly evacuation in the event of a fire, but also to eliminate the need for access to these restricted areas for fire detection system service and maintenance [19].

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[20] LAF: Laminar Air Flow
[21] UCV: Ultra Clean Ventilation

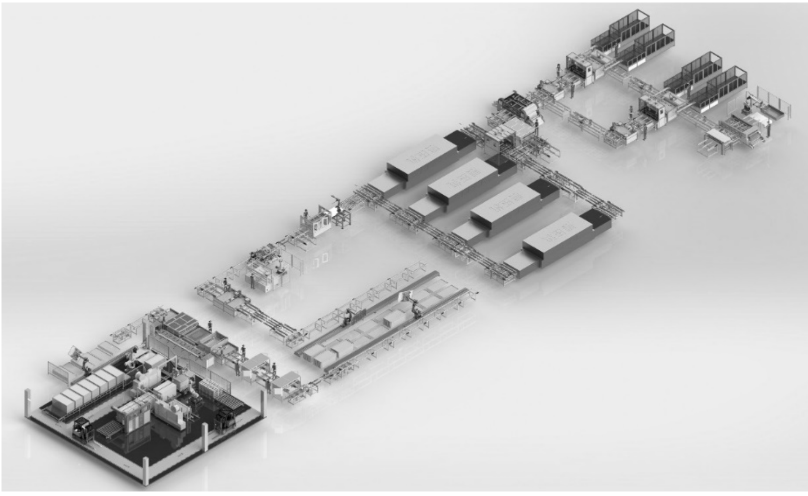
2.2.4 Ambient-Controlled Manufacturing and Storage

Ambient-controlled manufacturing and storage In addition to the buildings with controlled environments and large FAB described in chapters 2.2.1 and 2.2.2 that require a high level of cleanness (hence lower ISO Classes), other ambient-controlled manufacturing and storage areas with relatively lower levels of cleanness (higher ISO Class numbering) have similar environmental, health and safety (EHS) hazards as can be found in large open spaces with high air circulations and the use of high-bay racking with automated storage and retrieval systems (AS-RS).

Hazards and risks Major hazards in photovoltaic (PV), PCB, LCD and LED manufacturing processes come in various forms include HF acid burns, SiH_4/PH_3/NF_3 fires or explosions, Cd, H_2Se and AsH_3 toxicity [39]. Many of the processes are confined to enclosed areas with wet benches or other production tools. For pharmaceutical shipments with temperature-controlled products that are handled multiple times from supplier to end user, the biggest challenge within the supply chain is to maintain the 2 to 8°C (36 to 46°F) range throughout the delivery cycle.

These challenging environmental conditions and building occupancy characteristics underpin the importance of the design and use of Early Warning Fire Detection System capable of operating in dusty, high humidity, high air temperature or potentially corrosive or explosive ambient conditions.

Figure 6 illustrates examples of (a) ambient-controlled manufacturing (e.g. solar panels) and (b) storage facilities (biochemical or pharmaceutical).



(a) High technology manufacturing (solar module production)

(b) High value, ambient sensitive storage (example of pharmaceutical high-bay storage and freezer)

Figure 6 Ambient-controlled Manufacturing and storage

2.3 Challenges to Early Warning Fire Detection

Fit-for-purpose fire protection faces many challenges

Statistically – among the non-residential building occupancies – the collective risks to business interruption, property damage and life loss due to fire remains high across Cleanrooms & Associated Controlled Environments that cover diverse building occupancies like industrial, manufacturing, storage, healthcare and pharmaceuticals. These buildings often come with enormously large open floor plans, forced air circulation with extremely high velocity, manufacturing processes and different hazard classifications within versatile internal compartment structures. Fire detection and protection solutions need to be effective and fit-for-purpose to manage these and other evolving challenges like modification of building uses in response to public health pandemics and strict environmental, health and safety compliance.

Early Warning Fire Detection ensures business continuity and life safety

The use of an Early Warning Fire Detection system represents significant advantages over other conventional detection methods. Proper design of an Early Warning Fire Detection system for specific fire risk mitigation is of fundamental importance to ensure business continuity and to prevent property loss, paired with enhanced life safety for people working in the cleanrooms, hospitals and areas with restricted access control. While there are practical difficulties in choosing suitable detection products, SecuriSmoke ASD and REK Early Warning Fire Detection systems address all the key challenges in order to deliver early and reliable fire detection in Cleanrooms & Associated Controlled Environments facilities (see Table 4). For the purpose of completeness, SecuriHeat Line Type Heat Detection systems and SecuriBeam Linear Type Smoke Detectors are also included where applicable.

Table 4 Challenges and solutions (Early Warning Fire Detection)

Challenge	SecuriSmoke ASD, REK and SecuriHeat
Large Open Space	Active aspirating sampling with powerful fans and approval listings
Forced ventilation with extreme high air velocity and turbulence	Flexible placement of sampling points and spacing between them
Diluted smoke and stratification	Very high, consistent detection sensitivity for incipient fires; position of sampling holes at a lower level
Extreme high or low temperature	Practically no limitation to the detector installation location (SecuriSmoke ASD operating temperature range is -30°C to 60°C (-22°F to 140°F), SecuriHeat controller temperature range is -30°C to 70°C (-22°F to 158°F), sensing tube temperature range is -40°C to 300°C (-40°F to 572°F))
Complex design considerations	Unique features such as option of dual detection chambers, maximum number of sampling holes for all levels of sensitivity, add-on intelligent pinpoint detection REK for better addressability and control
Risk-based detection	Flexible sampling pipe and sampling hole placement for detection at multilevel, compartments, in-rack/above-rack, vertical riser type
Obstructed or difficult access	Active sampling technology with detectors and testing points often located in areas easy to access or outside the protected areas, or positioned at locations such as inside the Return Air Shafts (RAS) in large FABs or machine tools and specialised processing rooms inside a large facility with controlled environments
False alarms	Built-in features for false alarm rejection, redundancy design options (e.g. SecuriSmoke ASD 535 with two detectors, designed to cover one single protected zone)

Challenge	SecuriSmoke ASD, REK and SecuriHeat
Hazardous and challenging environment	With certified accessories and with consideration of overall system design, SecuriSmoke, SecuriHeat and SecuriBeam products can effectively protect these challenging areas
Flexible design caters for pressure differentials across adjacent spaces	Use of Securiton design tools for large scale projects design, give provisions of coverage expansion if needed

2.4 Risk and Performance-based Design

Risk and Performance-based Design are key to mitigate issues affecting uninterrupted business operation

Fire protection professionals work within the prescriptive constraints of the applicable building codes and standards such as NFPA 101 [11] and The International Building Code [40] while applying the best engineering practices to address industry and building occupancies specific needs[22]. In particular, the risks and uninterrupted business operation requirements in Cleanrooms & Associated Controlled Environments facilities shall be adequately addressed. In this regard, a risk-based approach to the optimisation of fire detection, fire protection and human interaction to supplement prescriptive baseline design, is the key to meeting the requirements for building and life safety as well as risk management such as NFPA 99 [12] or local government agency directive (e.g. [41]).

Performance-based Design (PBD) is typically implemented when elements of fire safety and protection system design are not covered in the prescriptive codes among others due to unique building structures, environmental conditions, added detection for early warning or extended egress considerations [42]. A PBD approach is commonly adopted for either of the following:

1. As a means to determine equivalency to a prescriptive code or standard
2. As an approach to achieve broadly defined fire safety goals and objectives

While PBD may be required for large healthcare hubs, large FABs or facilities with controlled environments for mixed and flexible occupancies, the majority of them and other cleanroom-like structure buildings can be designed to the prescriptive codes meeting the codes and standards for general building and life safety with added detection and protection based on a risk assessment and in addition applying appropriate system designs to these targeted risk areas and locations following the industry code of practices such as NFPA 318 [20] and SEMI [43].

[22] Each country or state/province might have its own (or adopted) building and fire code or directives. Examples are the Muster-Verwaltungsvorschrift Technische Baubestimmungen (MVV TB) in Germany or The Regulatory Reform (Fire Safety) Order 2005 in the UK.

Table 5 illustrates how Early Warning Fire Detection system performance, as well as the fire safety goals and objectives are defined.

Table 5 Similarity in Early Warning Fire Detection definitions

VEWFD/EWFD

Sensitivity	BS/EN 54-20 [23] #1	NFPA 76 [44]
Class A or VEWFD	Very high sensitivity: An ASD system is capable of providing very early warning of a potential fire condition, particularly in high-risk areas with the benefits of staged responses.	Systems that detect low-energy fires, before the fire conditions threaten mission critical service, benefits of staged responses with a sampling hole sensitivity alert of 0.66% obs/m (0.2% obs/ft).
Class B or EWFD	Enhanced sensitivity: An ASD system is for applications where an additional degree of confidence is required for the protection of a particular risk such as with unusually high airflow.	Systems that use smoke, heat, or flame detectors to detect fires before high heat conditions threaten human life or cause significant damage to mission critical service.
Class C or SFD	Normal sensitivity: An ASD system designed to give equivalent performance to standard point detection systems meeting the requirements of EN 54-7 [45].	Systems that use fire detection-initiating devices to achieve certain life safety and property protection, in accordance with applicable standards such as NFPA 72 [19].

#1: ISO 7240-20 [46] and AS 7240-20 [47] are derived from BS/EN 54-20.

Country to country differences in prescriptive provisions

Although there might be marginal differences from one country to another in DtS prescriptive building and fire code requirements on fire detection, a combination of DtS prescriptive and risk-based design approach is the best engineering practice to meet prescriptive requirements as well as to satisfy facility operators' need for business continuity and property protection.

Differences exist, for example, between NFPA 72 [19], BS 5839-1 [48] or VdS 2095 [49] for Aspirating Smoke Detectors (ASD) as the equivalency to point type smoke detectors in normal built environments (e.g. air change rate of up to 60 ACH), coupled with other risk-orientated codes of practices (e.g. FIA Code of Practice [50], BS 6266 [51]) and risk management orientated FM Global Data Sheets related to cleanrooms or cleanroom-type buildings such as DS 7-7 [21] and DS 1-56 [22].

3 Early Warning Fire Detection Design

A wide product range is advantageous

When combining the prescriptive and risk-based approaches to design a fit-for-purpose fire detection system for Cleanrooms & Associated Controlled Environments facilities, it is important to select advanced SecuriSmoke ASD detection products. SecuriSmoke ASD products allow for a fully flexible design with quantifiable and reliable detection performance. Advantages include a wide range of models, the maximum number of holes with each sensitivity class, long aggregated pipe length, 5-levels of staged responses and signal interface to suppression, and BMS components. In addition, they offer pinpoint high sensitivity addressable detection when incorporating REK in-line intelligent smoke detectors.

SecuriHeat LTHD products may be used together with the SecuriSmoke product portfolio where heat detection is suitable.

This chapter outlines design recommendations and methods using SecuriSmoke ASD and REK products to protect Cleanrooms & Associated Controlled Environments facilities in the following scenarios:

1. General large open space (include these storages with high-bay racking)
2. Semiconductor Fabrication Facilities (FAB)
3. Hospital and Healthcare
4. Risk-based protection and detection methods (for areas including highly sensitive rooms, modular enclosures and otherwise challenging environments)

3.1 Securiton Detection Product Portfolio

SecuriSmoke Early Warning Fire Detection

This Design Guide focuses on Securiton Early Warning Fire Detection (SecuriSmoke ASD and REK portfolio) systems, mainly for storage and warehousing distribution areas, as shown in Table 6 below.

Table 6 SecuriSmoke ASD and REK products

Model/Factor	Key performance parameters [#1]					
EN 54-20 sensitivity	Total # of holes (Class)			Aggregated pipe length (m)		
	A	B	C	A	B	C
SecuriSmoke ASD 531	6	8	12	75		
SecuriSmoke ASD 532	8	12	16	120		
SecuriSmoke ASD 533	16	50	50	200		
SecuriSmoke ASD 535-1/3	18	56	120	300		
SecuriSmoke ASD 535-2/4	36	112	240	2 x 300		
SecuriSmoke 535 HD (Heavy Duty)	36	112	240	2 x 300		
REK 511-1S	1.2% obs/m (0.366% obs/ft)			Point type addressability for sampling holes located downstream to REK		
REK 511-3S	0.3% obs/m (0.091% obs/ft)					
Rating	IP54 (IP66 for SecuriSmoke ASD 535 HD (Heavy Duty))					
Operational	Temperature			Built-in Relay (Expand)		
SecuriSmoke ASD 531	-10 to +55°C (14 to 131°F)			2 (5-1xRIM36)		
SecuriSmoke ASD 532	-20 to +60°C (-4 to 140°F)			2 (10-2xRIM36)		
SecuriSmoke ASD 533	-20 to +60°C (-4 to 140°F)			3 (10-2xRIM35)		
SecuriSmoke ASD 535	-30 to +60°C (-22 to 140°F)			3 (10-2xRIM35)		
REK	0 to +50°C (32 to 122°F)			1 (NA)		

#1: Highlight performance parameters as per EN54-20 Approvals

Additional fire detection products

However, inside some hazardous areas or as part of detection-suppression integration, heat-based detection and control may be desirable for certain fire hazards; for instance, the use of Securiton SecuriHeat Line Type Heat Detection as in-rack detection to work with in-rack pre-action suppression systems. In addition, Cleanrooms & Associated Controlled Environments facilities also require other forms of detection for general areas. Securiton's other related detection portfolio is listed in Table 7 for reference.

Table 7 Securiton detection portfolio (point type, line type smoke and heat)

Model	Type	Function #1
SecuriBeam	Linear Type Smoke Detector (LTSD)	Detect and Control
SecuriHeat	Line Type Heat Detector (LTHD)	Detect and Control
Smoke Switch LRS	Duct Type (Smoke)	Detect and Control
Fire Door Control	Open/Close	Control
Multi-criteria point type	Smoke with Temperature and/or CO	Detect
Smoke Detectors	Point type (Smoke)	Detect
Temperature Detectors	Point type (Heat)	Detect

#1: Products listed with 'Detect' only function are connected to building FACPs such as Securiton SecuriFire Fire Alarm Systems described in chapter 5, Table 19.

3.2 Design Criteria and Remarks

Key terminologies

Airflow and detection sensitivity are main factors that require a change of SecuriSmoke ASD sampling hole spacing. Table 8 summarises a number of key design criteria for the deployment of Early Warning Fire Detection for the Cleanrooms & Associated Controlled Environments facilities.

To provide clarity, below are some key terminologies related to:

- **Transport Time**: time for (smoke) aerosols to transfer from a sampling hole to the ASD detector
- **Maximum Transport Time**: maximum time for (smoke) aerosols to transfer from the furthest sampling hole to the ASD detector
- **Response Time**: time between the generation of combustion aerosols at their source and the indication of their presence at the ASD detector
- **Reaction Time**: time between (smoke) aerosols reaching a defined level of obscurity (e.g. EOT condition) and the notification of their presence at the ASD detector

Table 8 Key design criteria (SecuriSmoke ASD)

Key design criteria

Model	Key design criteria		
NFPA/FM Global	VEWFD	EWFD	SFD#1
Hole sensitivity	3.28% obs/m (1.0% obs/ft)	4.92% obs/m (1.5% obs/ft)	Point type over number of holes
Hole coverage	18.6 m^2 (200 ft^2)	37.2 m^2 (400 ft^2)	83.6 m^2 (900 ft^2)
Transport time	<60 sec	<90 sec	<120 sec

Model	Key design criteria		
EN/AS/ISO/BS	Class A	Class B	Class C[#1]
Hole sensitivity[#2]	0.4% obs/m (0.12% obs/ft)	1.16% obs/m (0.35% obs/ft)	6.67% obs/m (2.0% obs/ft)
Hole coverage[#3]	15-25 m^2 (166-269 ft^2)	25-35 m^2 (269-388 ft^2)	Up to 7.5 m (25 ft) radius
Transport time[#4]	<60 sec	<90 sec	<120 sec
Reaction time[#5]	<60 sec	<60 sec	<60 sec

#1: SFD/Class C refer to point type detectors, usually tested to an alarm sensitivity of 2.0 dB/m (36.9% obs/m (11.247% obs/ft)).

#2: For Securiton ASD products. Individual hole sensitivity can be determined using SecuriSmoke ASD Pipe Flow design tool.

#3: Hole spacing is more a mixture of DtS (per point type detectors in BS 5839-1 or VdS 2095) and PBD (BS 6266, FIA Code of Practice or VdS 2095 Appendices) provisions with adjustments based on airflow and design to required sensitivity Class A, B or C.

#4: Transport Time of AS7240-20 conformed Class A, B and C are 60 sec, 90 sec and 120 sec respectively in AS1670-1.

#5: Reaction Time of 60 sec after EOT refers to EN54-20 test requirements for relevant tests to Class A, B or C sensitivity.

ASD PipeFlow design tool

Pipe network layout and length of single or aggregated pipe length also determine the transport time from each sampling hole to the detector, hence a maximum transport time from the furthest sampling hole(s). Both sampling hole sensitivity and transport time are calculated with SecuriSmoke ASD PipeFlow design tool (see chapter 7.2.1). PipeFlow offers to calculate a pipe layout in two modes:

1. EN 54-20: PipeFlow optimises its calculation for transport time, balance (same air volume at each sampling hole) and takes the characteristic curves of all EN 54-20 test fires [23] into consideration. Pipeflow then indicates the sensitivity to which the detector must be set in order to allow for each sampling hole to reach the required sensitivity according to the selected Class.
2. NFPA: PipeFlow optimises its calculation for the required transport time for VEWFD, EWFD or SFD.

Design recommendations described in this chapter assume the transport time meets the respective sampling hole or detector unit sensitivity level in Table 8 above for target Class A (VEWFD), Class B (EWFD) or Class C (SFD) design.

In general, simply follow the relevant codes and standards for the design of smoke detection systems to meet prescriptive requirements. Two key considerations in design are (a) sensitivity requirements versus detection requirements in relation to the height of the ceiling and (b) the smoke detector spacing (or ASD sampling hole spacing as equivalent) in relation to the airflow.

Table 9, Table 10 and Table 11 below illustrate the design parameters commonly referred to when designing Early Warning Fire Detection with SecuriFire ASD in accordance with the codes NFPA 72 [19] and FIA Code of Practice [50].

However, individual countries may have different provisions regarding height limits or multilayer detection prescribed as Deemed-to-Satisfy (DtS) requirements. For example, the maximum height for the use of ASD in Germany is 20 m (65.5 ft) (DIN VDE 0833-2), in the Netherland it is 45 m (147.6 ft) (NEN2525-C1) and in France it is 12 m (39.4°ft) (R7) [52]. When the ceiling heights exceed the respective maximum limit, the use of ASD is considered a PBD engineering design which often requires proof with a successful fire test during the commissioning and acceptance.

Table 9 Sensitivity requirements vs. detection requirements (FIA Code of Practice [50])

Parameters	Key design considerations		
EN 54-20 Class	Class A	Class B	Class C
ASD Sampling Type and Smoke Characteristics	Smoke is not visible due to low quantity of smoke and/or high dilution caused by air movement or LOS[23]	Smoke is visible but insufficient to be detected by point or beam technologies (per [45] or [53])	Smoke visible and sufficient to be detected by point or beam technologies (per [45] or [53])
Primary Detection: sampling where smoke is likely to travel			
	Best	Appropriate (small areas only)	Not appropriate
Secondary Detection: positioning sampling holes per the codes for point detectors			
	For Early warning applications	For challenging applications	Appropriate
Localised Sampling: custom protection of specific equipment			
	Appropriate for high risk	Appropriate for low risk	Not appropriate
In-cabinet Sampling: Localised sampling			
	Appropriate for high risk	Appropriate for low risk	Not appropriate
Duct Sampling			
	Appropriate for high risk	Appropriate for low risk	Not appropriate

Table 10 Recommended ceiling heights

Recommended ceiling height limits for ASD#1			
ASD Type#2 **1**	**ASD Type 2**	**ASD Type 3**	**ASD Type 4**
10.5-18.0 m (34.4-60.0 ft)	15.0-26.0 m (49.2–85.0 ft)	25.0-43.0 m (82.0-141.0 ft)	40.0-43.0 m (131.3-141.0 ft)

#1: Recommended ceiling height for ASD varies from generally applicable (Low Limit) to ceiling with design for property protection with rapid fire service attendance time of 5 min. Include sloped ceiling no greater than 10% of ceiling height (High Limit).

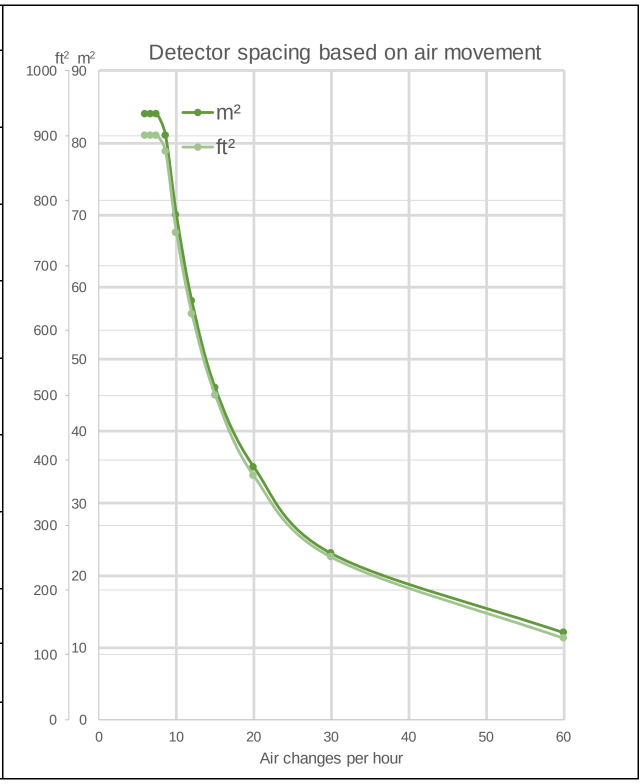
#2: ASD Type include:

Type 1: Any ASD system approved to EN 54-20
Type 2: ASD system with: at least 5 Class C holes or at least 2 Class B holes
Type 3: ASD system with: at least 15 Class C holes or at least 5 Class B holes
Type 4: ASD system with: at least 15 Class B holes

[23] LOS: Large Open Space

Table 11 Smoke detector spacing based on air changes (NFPA 72[19]/FM DS 5-48 [54])

ACH	Spacing [m² (ft²)]
60.0	12 (125)
30.0	23 (250)
20.0	35 (375)
15.0	46 (500)
12.0	58 (625)
10.0	69 (750)
8.6	81 (875)
7.5	84 (900)
6.7	84 (900)
6.0	84 (900)



Key design variables

Because each ASD sampling hole in effect represents a single point type smoke detector, the key criteria or variables included in this chapter focus on SecuriSmoke ASD design with regards to:

1. Sampling hole spacing
2. Sampling hole placement
3. Sampling hole orientation (in general perpendicular downwards to the floor unless mentioned otherwise)

3.3 Detection Design: General Open Space

Design for open areas

For large open spaces such as production and storage processing areas in a Cleanrooms & Associated Controlled Environments facility, a SecuriSmoke ASD Early Warning Fire Detection system is used for ceiling level detection to meet prescriptive code requirements as well as enhanced detection performance designs to meet risk-based fire safety objectives and to avoid losses due to fire damages and ensure business continuity.

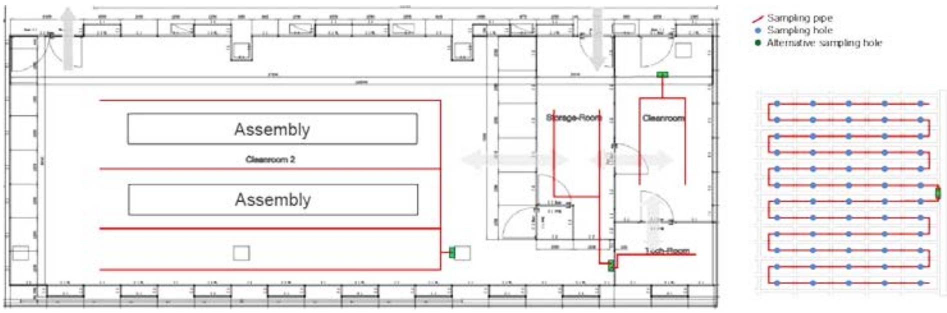
This chapter describes the following three detection methods:

1. Underside Ceiling (Pitched, Sloped or Flat)
2. Underside Ceiling with Beam/Joist
3. Air Plenum (Raised Floor and Above Ceiling)
4. Detection in Pressurised Environments
5. High-bay Racking and In-Rack Detection in Sterilised Storage

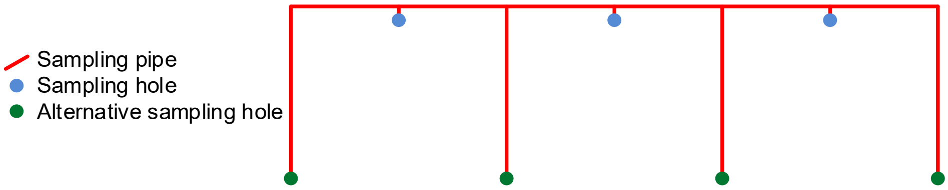
In the context of this Design Guide the term 'ceiling' refers to the upper limit of each level in a building structure. For instance, in large FAB, ceiling of FAB and sub-FAB refer to the ceiling for the respective space.

3.3.1 *Underside Ceiling (Pitched, Sloped or Flat)*

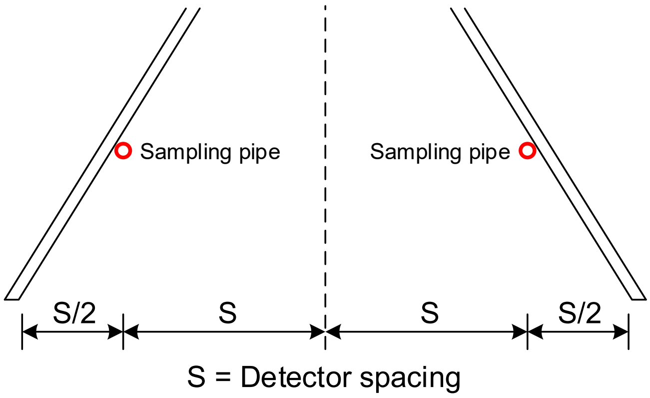
Figure 7 illustrates how SecuriSmoke ASD sampling holes are located underside a flat ceiling.



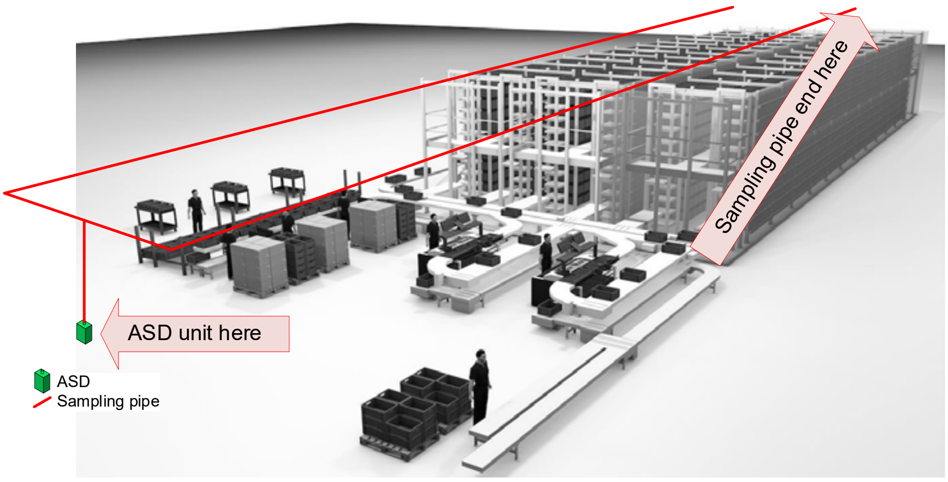
(a) Plan view ADS pipe layout at ceiling level (Example of pipe layout in FAB & sub-FAB)



(b) Elevation view of 2-layer or alternate sampling (only when needed)



(c) Pitched ceiling with additional sampling points located inside



(d) Example of ASD Detector Unit location and sampling pipe run away from operation area

Figure 7 Fire detection placement (underside ceiling – pitched, sloped or flat)

Sampling holes

Variable	Design recommendation (ceiling in general open space)
Spacing	For general design with regard to sensitivity class and ceiling height, refer to Table 9 and Table 10. For airflow < 60 ACH: From 84 m^2 (900 ft^2) @6 ACH down to 12 m^2 (125 ft^2) @60 ACH, refer to Table 11. If a higher detection sensitivity is required, refer to Table 8 for recommendations for Class A (VEWFD) and Class B (EWFD). *Reducing the hole spacing along the pipe can be considered to cater for high ceilings when Class C or Class B sensitivity is used.*
Placement	(i) Underside the ceiling; Additional sampling hole(s) may be considered on the vertical pipe run from the detector to the ceiling if local codes require or to enhance detection coverage (ii) Pipe network runs may not have to be straight in order to go around areas where individual detection system may be provided or large machine tools are located (Figure 7 (a)). SecuriSmoke ASD detectors support long pipe run to cater for such a design requirement. (iii) Always consider a blind end-cap to be located at a lower level, away from all the production handling or processing equipment. It serves as a commissioning and maintenance test point for easy access#1 (iv) In automated ambient-controlled high-bay warehouses or large FAB, always take into account operating spaces required for equipment (e.g. warehouse AS-RS) or machine tools and operation processes, and position the ASD detector unit and the run of the pipes away from these areas. Example is shown in Figure 7 (d).
Orientation	Perpendicular downwards (ceiling level), outwards (vertical)
2-Level detection or alternate level sampling holes	When 2-level detection is required by code or to address the concern of stratification, one way to achieve that is to apply alternate sampling at two different levels by extending every second sampling hole down from the ceiling (Figure 7 (b)). The other way is to incorporate the second layer with in-rack detection (chapter 3.3.5). Taken into account the minimum clearance between the top of the storage to ceiling sprinkler deflectors plus the top tier maximum storage height recommended come to approximately 1.5 m (5 ft) [9] when designing alternate level sampling holes positions, always keep the sampling pipes within the safety clearance area of the production operation.
Sloped ceilings	Generally, sloped ceilings with a slope no greater than 10% of the ceiling height are treated as flat ceilings. Large cleanroom-like facilities typically feature a flat ceiling.
Pitched ceilings	Pitched ceilings are very rare in large Cleanrooms & Associated Controlled Environments facilities. If the width at the bottom of the pitched ceiling is wider than the sampling hole spacing, then additional sampling holes are to be placed inside the pitched area [19] (Figure 7 (c)).

#1: For the initial commissioning and ongoing ITM[24], the blind end-cap is replaced temporary with an end-cap with a predefined sampling hole.

Measurements of transport time from the dedicated maintenance test point during maintenance should be confirmed to be within + 15% or + 3 seconds, whichever is the greater, of the same measurement taken at commissioning [50].

[24] ITM: Inspection, Testing and Maintenance

3.3.2 Underside Ceiling with Beam/Joist

Figure 8 illustrates how SecuriSmoke ASD sampling holes are located underside the beams/joist or inside deep beam pockets.

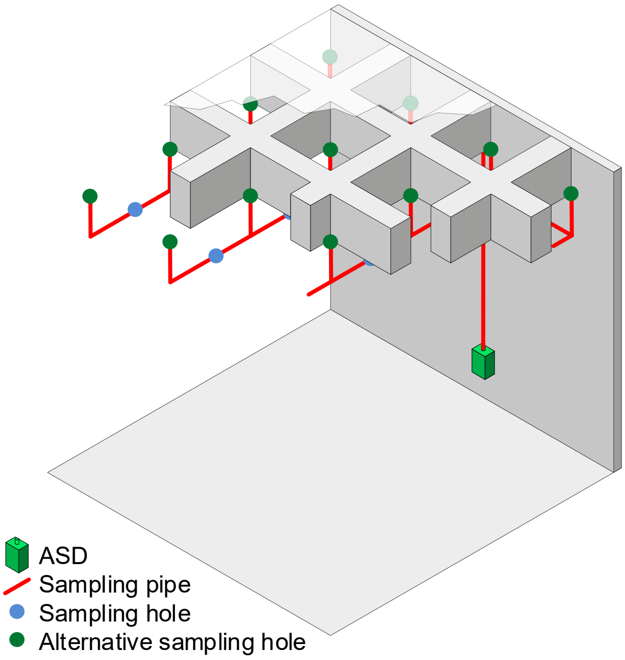


Figure 8 Fire detection placement (underside ceiling – deep beam/joist)

The airflow velocity shall be taken into consideration when designing the spacing and the placement of the sampling holes. It is recommended to choose the spacing and placement recommendations fitting the provisions of chapters 3.3.1 and 3.3.2 closest.

Sampling holes

Variable	Design recommendation (ceiling with beam/joist)
Spacing	In relation to airflow, refer to chapter 3.3.1 above. Ambient-controlled cleanroom-like facilities and large FAB can have a ceiling with a beamed structure. ASD sampling pipes are generally installed under the beams according to the following: Beam depth < 10% of ceiling height: smooth ceiling spacing is applied, on the bottom of the beams (see sampling holes in blue) Beam depth ≥ 10% of ceiling height: (i) Beam spacing < 40% of ceiling height: use smooth ceiling spacing ***parallel*** to the beams and half the spacing ***perpendicular*** to the beams, on the bottom of the beams (see sampling holes in blue) (ii) Beam spacing ≥ 40% of ceiling height: a sampling hole shall be placed on the ceiling within each beam pocket (see alternative sampling holes in green). Note that more than one sampling hole may be required to cover a given beam pocket
Placement	Refer to PBD design approach per [55] or prescriptive codes such as NFPA 72 [19], summarised above
Orientation	Perpendicular downwards

3.3.3 Air Plenum (Raised Floor and Above Ceiling)

Figure 9 illustrates how SecuriSmoke ASD sampling holes are positioned at the top of the raised floor or above the ceiling void when there are cablings and electronic control devices installed within these spaces.

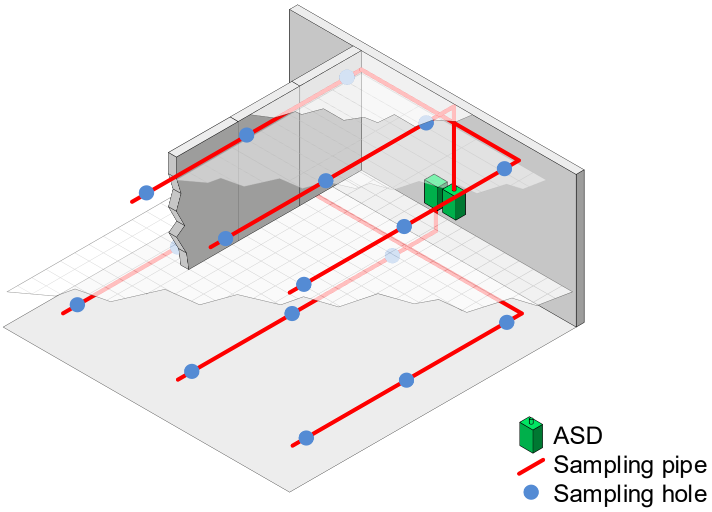


Figure 9 Fire detection placement (raised floor or ceiling plenum)

Sampling holes

Variable	Design recommendation (air plenum)
Spacing	In relation to airflow, refer to chapter 3.3.1 above It is recommended to design SecuriSmoke ASD for VEWFD (Class A), especially if it is the only smoke detection system installed without other forms of detection, e.g. related duct, air vent or return air shaft (RAS) protection.
Placement	Inside the raised floor or above the ceiling plenum with detector units in the main room space. A blind end-cap also located in the main room space serves as a commissioning and maintenance test point for easy access.
Orientation	Facing the incoming airflow; where possible, consider using Securiton sampling funnel SF ABS.

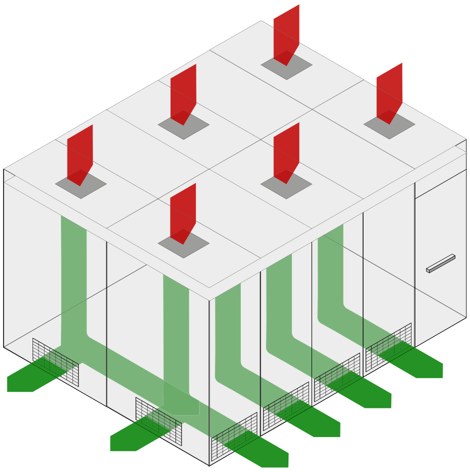
Refer to chapter 3.3.1 for provision of a blind end-cap for the purpose of testing and maintenance.

3.3.4 Detection in Pressurised Environments

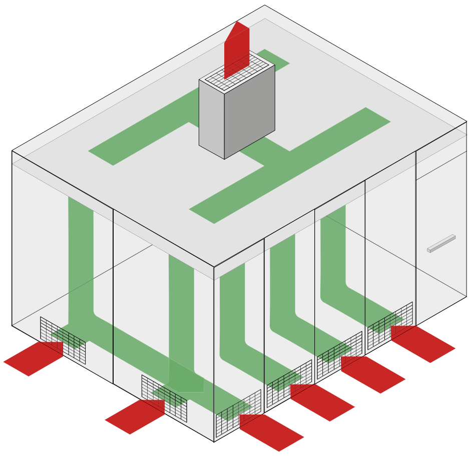
Positive and negative air pressure

From a room pressurisation perspective, positive air pressure is to ensure the sum of the return, exhaust and leakage air must be less than the supply (which has a fixed minimum). Negative air pressure is the opposite where the sum of the mechanically exhausted air must exceed the sum of the mechanically supplied air. Due to different ISO Classes for different areas within a typical cleanroom-type facility, cleaner areas are always maintaining a positive pressure to other areas. Airborne infectious disease prevention in hospitals, medical and bio laboratories often involve the proper environmental management when planning control of airborne infectious disease outbreaks (natural or intentional) through HVAC operation to the designated areas/rooms.

Figure 10 illustrates typical airflow patterns for spaces classified as isolation (where the pressure inside the room is positive to the surroundings) and containment (where the pressure inside the room is negative to the surroundings).



(a) Isolation – positive room pressure



(b) Containment – negative room pressure

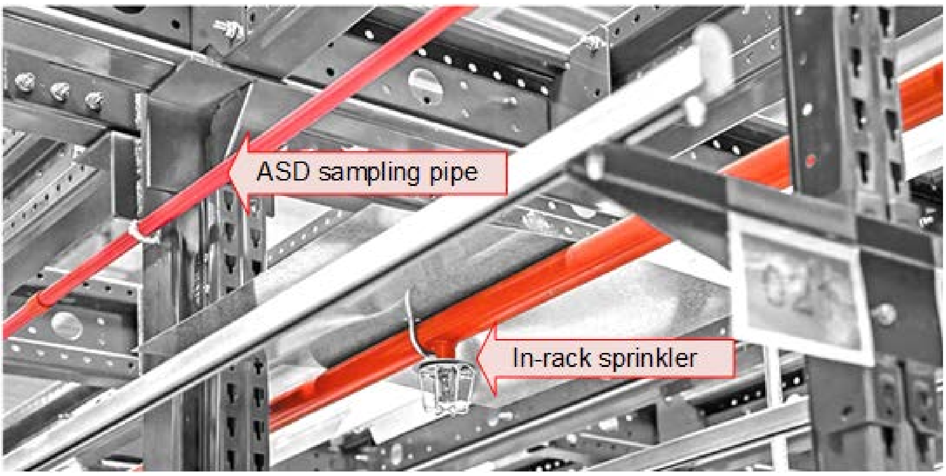
Figure 10 Pressurised rooms for isolation or containment

Sampling holes

Variable	**Design recommendation (pressurised environments)**
Spacing Placement Orientation	Refer to chapter 3.3.1 for ceiling level detection and chapter 3.6 when risk-based detection is considered, such as return air grille or duct detection
Special considerations	(i) ASD Detector exhaust air must be fed back to the protected space through an air-tight pipe network (ii) Place the detector unit as well as a blank end cap outside of the protected area, thus there is no need to access the protected space for service and maintenance purposes (iii) Establish a documented procedure in consultation with the property operators (e.g. a hospital) when any parts or detectors as a whole need to be removed/replaced from the site

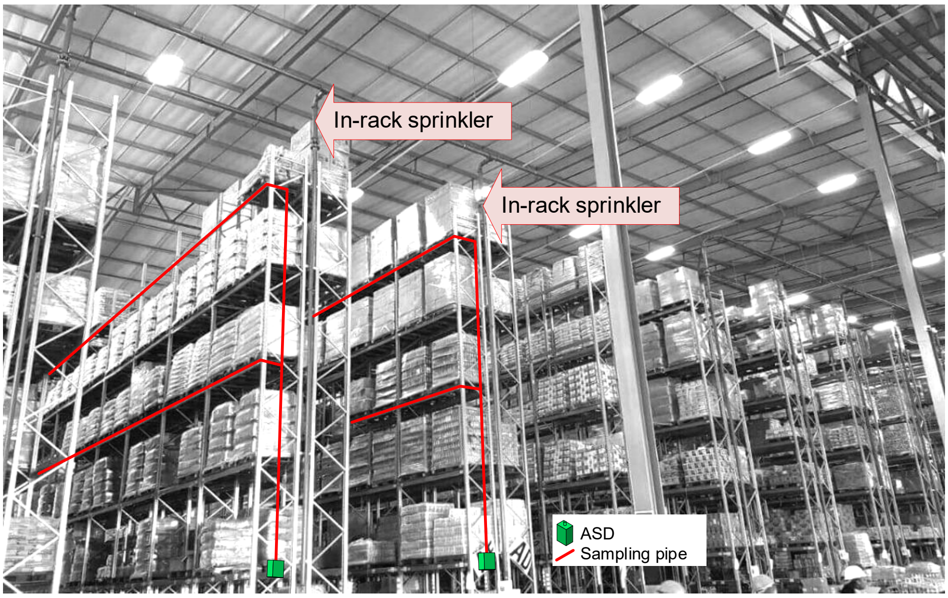
3.3.5 High-bay Racking, In-Rack Detection in Sterilised Storage

Figure 11 and Figure 12 illustrate how SecuriSmoke ASD sampling pipes are positioned for high-bay racking and in-rack detection, in reference to where in-rack sprinkler systems are commonly deployed.

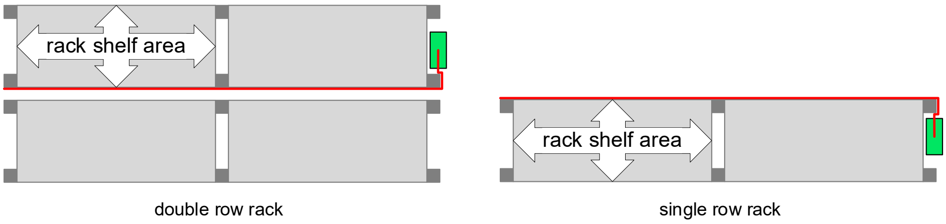


(a) In-rack ASD sampling pipes installed on the side of in-rack sprinkler pipes

Figure 11 Fire detection placement (high-bay in-rack detection)



(b) In-rack ASD sampling pipe spaced at every second in-rack sprinkler pipe



(c) Position of ASD sampling pipe (single and double row rack)

Figure 12 Cont'd: Fire detection placement (high-bay in-rack detection)

Sampling holes

Variable	Design recommendation (high-bay warehouses)
Spacing	Vertical sampling pipe spacing: (i) Take into account in-rack sprinkler vertical spacing, space the sampling pipes from 4.5 m (15 ft) to 12.0 m (40 ft) (Figure 12 (b)). Exception for reduced spacing may be given in case of solid shelf storing high value or storing sensitive commodities[#1] (ii) The very top of ASD sampling pipe may be aligned with the top of the in-rack sprinkler pipe, or at a height that meets local code requirement for 2-level smoke detector installation when ceiling height exceeds prescriptive code provisions Horizontal (transverse) sampling hole spacing: (i) It is recommended to design SecuriSmoke ASD for VEWFD (Class A) or EWFD (Class B) (ii) Sampling hole spacing should not be greater than 4.5 m (15 ft); spacing may be reduced if sampling pipe vertical spacing is wider; for example, if vertical spacing is the maximum of 12 m (40 ft), the sampling hole spacing could be reduced to 3.0 m (10 ft) for better coverage
Placement	Only a single sampling pipe is needed at each level for double-row or single-row rack configuration (Figure 12 (c)). When placing the sampling pipe for a double-row rack, consideration shall be given for possible access to the pipes or sampling holes for ITM purposes
Orientation	Facing to the aisle with the sampling hole angle slightly offset downwards (e.g. 15° to 30°).

#1: Per FM Global DS 8-9 [29] and NFPA 13 [27], max. 9.0 m (30 ft) for cartoned expanded plastics/non-cartoned plastics; max. 12 m (40 ft) for Class 1 through 4 and cartoned unexpanded plastics

3.4 Detection Design: Semiconductor Fabrication (FAB)

Semiconductor fabrication facilities (FAB)

Large semiconductor fabrication plants (FAB) are custom-built manufacturing facilities to host highly complex processes of crystal production, mask manufacturing, chip fabrication and packaging/assembly. Raw materials and work in processing goods as well as finished inventories all could be potential sources of fire ignition. Due to large scale production, the highest possible ISO class of cleanness is required. The building construction method is commonly involved a single level FAB or a combination of FAB and sub-FAB level. A combination of FAB and sub-FAB building layout can generally cover the air circulation patterns of a single level FAB, therefore only FAB with a sub-FAB configuration is used in this Design Guide.

This chapter describes the design of SecuriSmoke Early Warning Fire Detection systems to address the needs for:

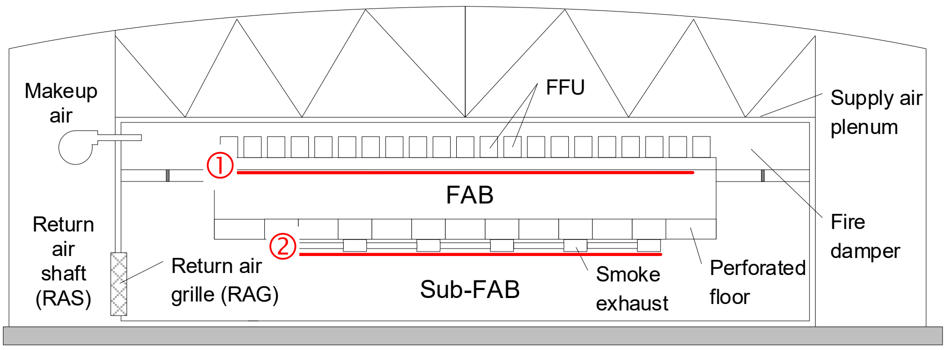
1. General FAB and sub-FAB open space protection
2. Supply to return air path protection in FAB

3.4.1 FAB and Sub-FAB Open Space

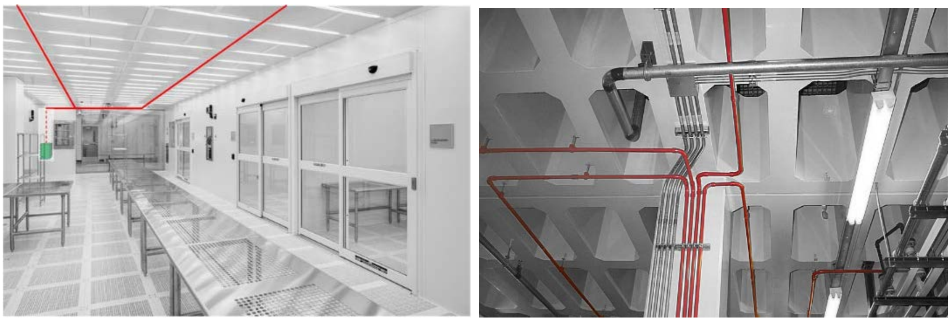
Figure 13 illustrates how SecuriSmoke ASD sampling pipe network are positioned at the ceiling level of

① FAB and

② sub-FAB



(a) Overview of ASD pipe network for FAB and sub-FAB open area protection[25]



(b) Usually straight pipes in FAB and pipe network run from a suitable detector location in sub-FAB

Figure 13 Fire detection placement (FAB and Sub-FAB open areas)

[25] RAG: Return Air Grilles (also known as Dry Coils in FAB)

Sampling holes

Variable	Design recommendation (FAB and sub-FAB open space)
Spacing Placement Orientation	Refer to chapter 3.3.1 for ceiling level detection. When risk-based detection methods are applied as per chapter 3.4.2 below, the ceiling level smoke detection is often designed to meet local pre-scriptive code requirements.
Special considerations	(i) When other risk-based ASD sampling methods and its place-ment are adopted per chapter 3.4.2, the ceiling level smoke detection spacing design can follow ACH rate up to the mini-mum coverage per sampling hole of 10-12 m^2 (108-125 ft^2) (chapter 3.3.1) (ii) Pipe network runs may not have to be straight due to large FAB's interior complex machine tools and test bench enclo-sure layout. SecuriSmoke ASD detectors support long pipe runs to cater for such a design requirement (iii) When there are compartmentations to be considered, provide at least two sampling holes inside each compartment or to use REK detectors for location addressability

3.4.2 Supply to Return Air Path Protection in FAB

Supply and return air path and air plenum detection

One of the key advantages resulting from the use of SecuriSmoke ASD Early Warning Fire Detection, is its ability to detect fire incidents early in high air flow environments where smoke can be diluted quickly before reaching the location where conventional smoke detectors would be installed. One common practice for large FAB facilities is to place the SecuriSmoke ASD sampling pipes at the locations where smoke is detected at the downstream (return air) air flow path or air plenum from the supply air, before reaching the filtration elements (FFUs) where air is recirculated.

Figure 14 illustrates an overview of SecuriSmoke ASD pipe network placements for the selected supply to return air path protection methods. SecuriSmoke ASD can be used for FAB roof space where air supply is to follow the supply to return air path, back from the Return Air Shaft (RAS). The design may include one or a combination of the followings depending on the actual FAB and Sub-FAB return air structure and the level of risk mitigation required.

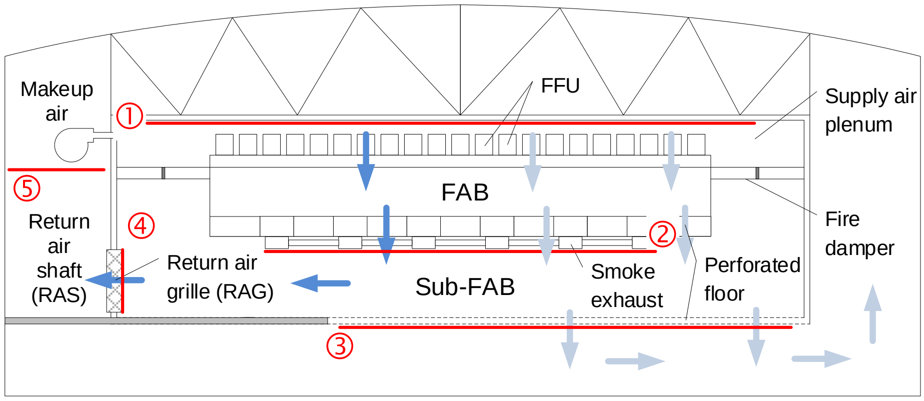
① Design for FAB ceiling void (supply air plenum) for the protection of roof space where large number of FFUs and other electrical and mechanical equipment are located

② Underside the sub-FAB ceiling with sampling holes facing upcoming air flow for the purpose of protection FAB space

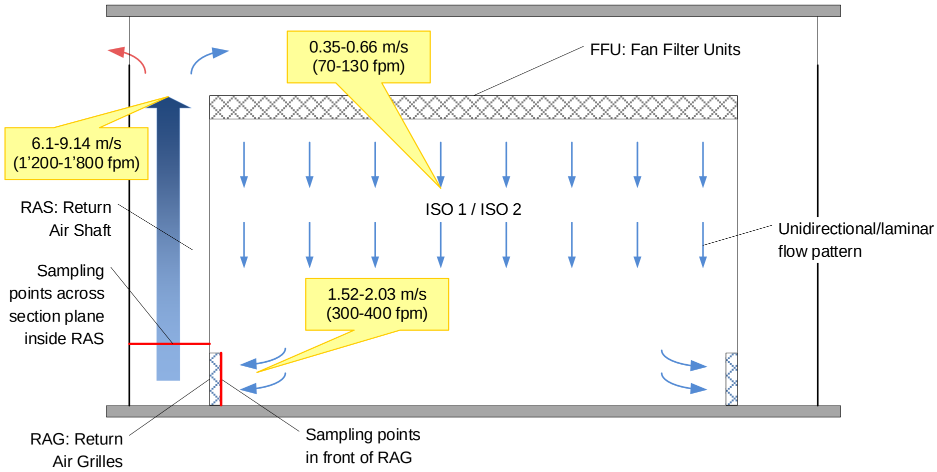
③ Raised floor return air plenum (if large amount of electrical equipment and cable trays are present) or single level FAB without using the return air grilles (RAG) design

④ In front of Return Air Grilles (Dry coils) at the sub-FAB wall air return vents

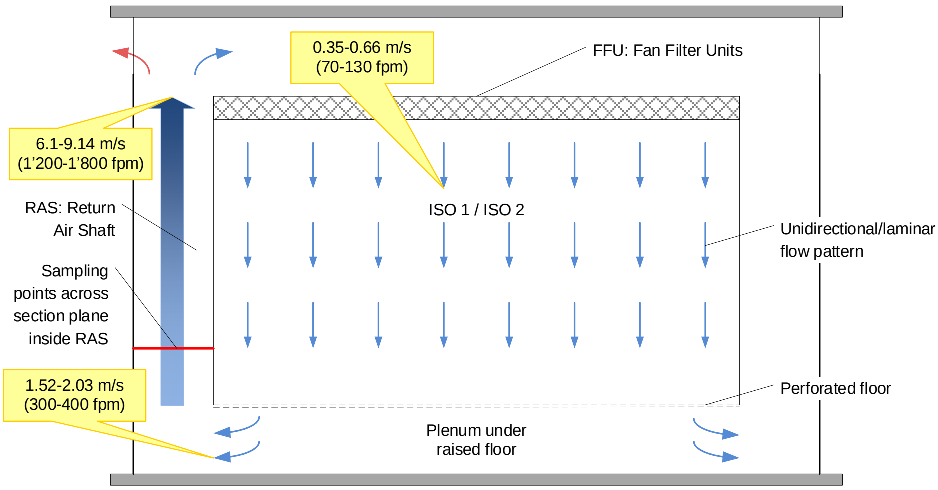
⑤ Inside the return air shafts (RAS) behind the dry coil vents as alternative to method 3 above



(a) Overview of ASD pipe network for supply to return air path protection



(b) Location of pipe network when placed either in front of RAG vents or inside the RAS



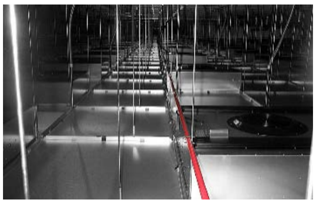
(c) Location of sampling pipe network in RAS on a FAB with a raised floor plenum

Figure 14 Fire detection at supply to return air path and plenum

Sampling holes

Variable	Design recommendation (supply to return air path)
Spacing Placement Orientation	Refer to chapter 3.3 for ceiling level and open space detection. Refer to chapter 3.6 when risk-based detection is considered, such as return air grille or duct detection

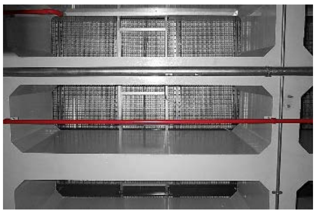
Special considerations



FAB Ceiling Void (supply air plenum)

(i) Refer to chapter 3.3.3

(ii) Sampling pipes may be installed underside the roof or middle of the plenum supported with suitable roof structure



Underside sub-FAB ceiling for FAB protection

(i) This method is used when the fire detection in FAB above is deemed insufficient

(ii) Refer to chapter 3.4.1 but take into account the location of perforated floor boards and areas blocked by machine tools and equipment

(iii) Sampling holes orientation is facing up to downward airflow. Consider using Securiton sampling funnel SF ABS where higher and turbulent airflow is present,

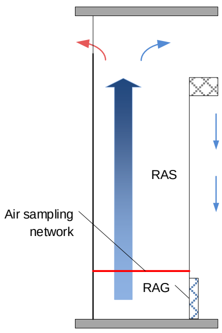
Raised floor return air plenum

Refer to chapter 3.3.3

Return Air Grilles at sub-FAB dry coils vents

(i) Refer to chapter 3.6.1, the sampling holes spacing may be wider than the recommended 0.36-0.4 m^2 (3.88-4.3 ft^2) for high airflow return air vents because the airflow at large FAB dry coils vents is typically slower at 1.5-2.0 m/s (300-400 fpm)

(ii) All large FAB are operating at highest ISO class with unidirectional/laminar flow within the FAB. Hence the smoke, although highly diluted, is generally mixed well before reaching the dry coils. The closely spaced adjacent sampling holes can sample the same already diluted smoke outside. The effect of dilution at the detector is therefore minimised. This effect allows to double the number of sampling holes without affecting the detection sensitivity[#1]



Return air shafts behind dry coils

(i) As an alternative to Return Air Grilles vents detection above, sampling pipes may be installed inside the Return Air Shaft, horizontal to the floor, approx. 300mm (1 ft) above the upper edge of the dry coil vents

(ii) Refer to chapters 3.6.1 for sampling hole spacing and orientation.

#1: Use the Securiton ASD PipeFlow design software (chapter 7.2.1) to design pipe and sampling hole configurations with the required sampling holes but taking into account the sensitivity could be doubled when two adjacent sampling holes have the same amount of smoke reading.

3.5 Detection Design: Hospital and Healthcare

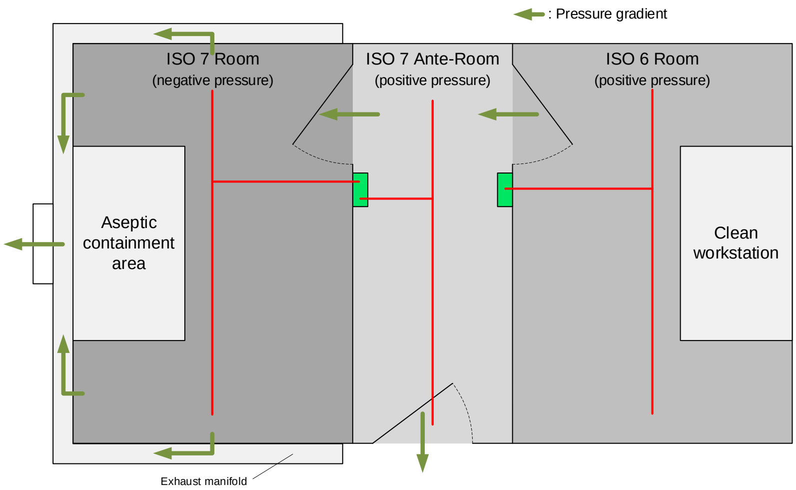
Hospitals and healthcare

While the general design of SecuriSmoke ASD Early Warning Fire Detection system for hospital and healthcare facilities can follow the applicable recommendations described in chapters 3.3 and 3.6, there are special considerations regarding certain aspects of the ASD design that should be taken into account. This chapter describes the design of SecuriSmoke Early Warning Fire Detection systems to address the needs of the following in the hospital and healthcare facilities.

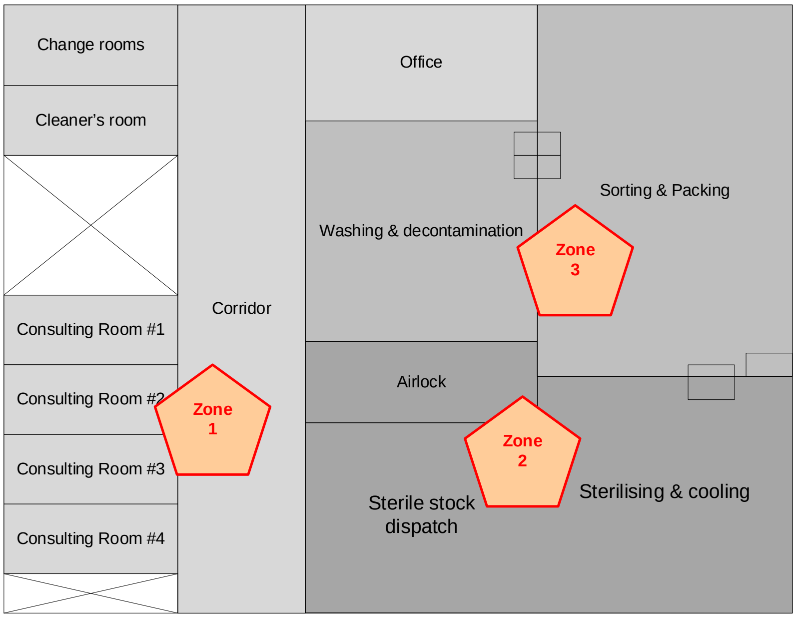
1. Mix of Sterilised Aseptic and General Areas
2. High Risk and Enclosed Rooms

3.5.1 Mix of Sterilised Aseptic and General Areas

Figure 15 illustrates how SecuriSmoke ASD sampling pipe networks are positioned taking into account (a) sterilised aseptic rooms and their adjacent areas where there is room air pressure differential, and (b) the optimisation of detection zone grouping (hence reduce number of ASD detectors required) in mixed use areas where ISO class rooms are part of other areas for hazardous materials handling, administration offices and public access spaces.



(a) Sterilised aseptic rooms and their adjacent areas (pressure difference)



(b) Illustration of detection zone allocation in mixed use areas

Figure 15 Fire detection placement (sterilised aseptic rooms and surrounding general areas)

Sampling holes

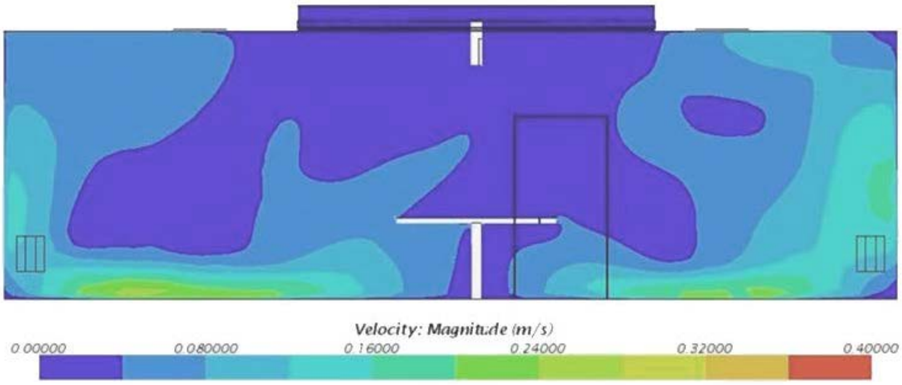
Variable	Design recommendation (mix of sterilised and general areas)
Spacing Placement Orientation	Refer to chapter 3.3 for general ceiling level and open space detection. Refer to chapter 3.6 when risk-based detection is considered, such as return air grille or duct detection, or localised protection.
Special considerations	(i) When designing SecuriSmoke ASD to protect areas of multiple rooms with different ISO class (Figure 15 (a)), same ISO class rooms may be protected by one ASD unit so long as the use and activities in these rooms are compatible, i.e. any possible cross contamination is not an issue (ii) Higher grade ISO class rooms are always operating on positive pressure in relation to its adjacent areas (iii) The detector unit is commonly installed outside the sterilised rooms in a relative negative pressure space and with easy access for service technicians. A good practice is to feed the detector exhaust port back to their respective protected rooms or areas (iv) When designing a large area with SecuriSmoke ASD (e.g. a whole floor in a hospital as shown in Figure 15 (b)), carefully group these with identical operation activities area and sterilised aseptic rooms into individual detection zones. Separate detectors shall be used to cover each zone while also taking into account fire alarm zone requirements as per the local codes and standards (v) When there are compartmentations or small rooms to be considered, provide at least two sampling holes inside each compartment or room, alternatively use SecuriSmoke REK detectors for location addressability

3.5.2 High Risk and Restricted Access Areas

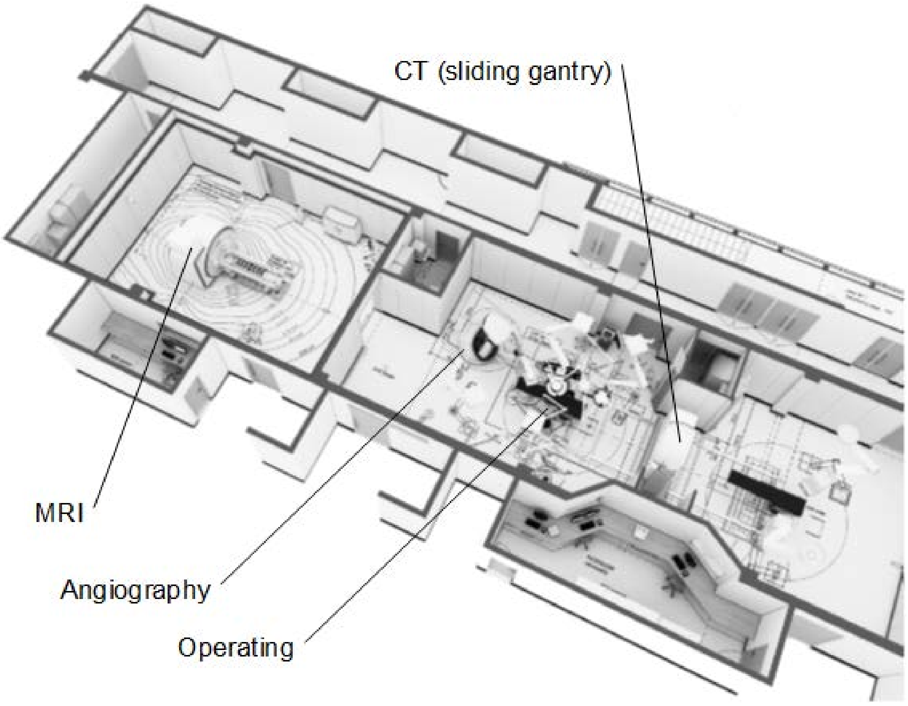
SecuriSmoke ASD Early Warning Fire Detection system are commonly used in these areas within the hospital and healthcare facilities with high risk of fire hazards, coupled with restricted access and patient treatments that require additional time to evacuate in the event of an emergency.

Early detection and early alerting

Figure 16 illustrates (a) typical air flow pattern in an operating theatre where placement of SecuriSmoke ASD sampling holes are important for early detection of a fire incident, and (b) the use of ASD detectors in other areas with restricted access, such as CT scan, MRI or angiography rooms where an early alerting for emergency evacuation is paramount.



(a) Illustration of air velocity distribution in operating theatre (DIN 1946-4 [38])



(b) High risk and restricted areas such as MRI, angiography and CT scan rooms

Figure 16 Fire detection in hospital areas with high risk and restricted access

Sampling holes

Variable	Design recommendation (high-risk or restricted access)
Spacing Placement Orientation	Refer to chapter 3.3 for general ceiling level and open space detection. Refer to chapter 3.6 when risk-based detection is considered, such as return air grille or duct detection, or localised protection.
Special considerations	(i) Localised protection method (3.6.2) is ideal for isolated areas such as an operating theatre where one SecuriSmoke ASD system may be used to protect both open space and return air grilles in the space, taken into account air flow dynamics (Figure 16 (a) as an example) (ii) When considering using one SecuriSmoke ASD to protect multiple small rooms or compartmentations within a larger area, provide at least two sampling holes inside each compartment or room, alternatively use SecuriSmoke REK detectors for location addressability (iii) Remote access from outside restricted areas for the service of the detection system is equally important consideration to prevent undesirable interruption to patient care

3.6 Detection Design: Risk-Based

Risk-based detection

Apart from cleanroom-type facilities' open space protection and protection of areas with specific risk hazard considerations in large FAB, hospitals and healthcare facilities, other risk-based detection methods may be relevant depending on the site. The concept of the risk-based protection method is to detect smoke where it originates and propagates or where the protected areas pose very challenging environmental or hazardous conditions.

This chapter describes the following detection methods that are relevant to some of the cleanroom-like structure buildings, namely:

1. Return air grills
2. Localised protection includes electrical and plant rooms, modular cleanrooms, cable trays, equipment tunnels, etc.
3. Duct detection
4. Detection in challenging environment

3.6.1 Return Air Grills

Figure 17 illustrates how SecuriSmoke ASD sampling points are positioned in front of return air grills.

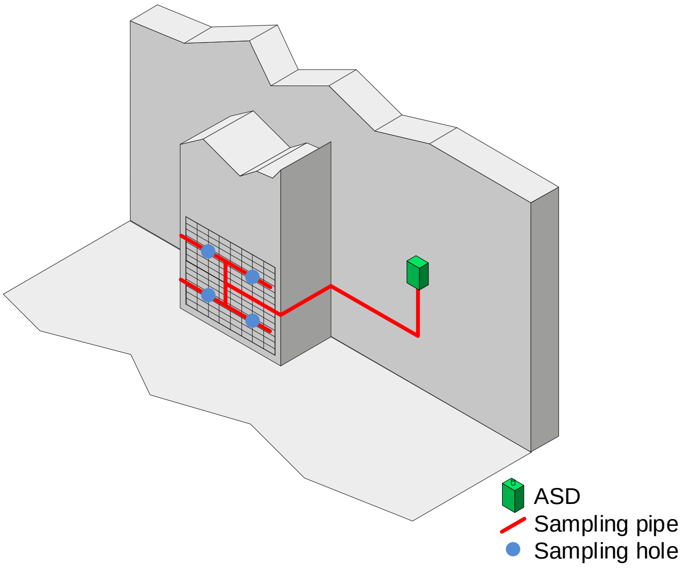


Figure 17 Fire detection placement (return air grills)

Sampling holes

Variable	**Design recommendation (return air grills)**
Spacing	Maximum area coverage of 0.4 m^2 (4.3 ft^2) of the air grille per sampling hole. Typically, 2 to 4 sampling holes are used to cover a single air intake [50]. When two or more rows of sampling pipes are needed for larger grills, sampling pipes are designed to form an 'H' shape
Placement	Installed across the grille with pipe stand-off of ~2.5 cm (~1.0 in)
Orientation	Facing the incoming airflow; where possible, consider using Securiton sampling funnel SF ABS

3.6.2 Localised Protection: Plant Rooms, Modular Cleanrooms

Localised detection

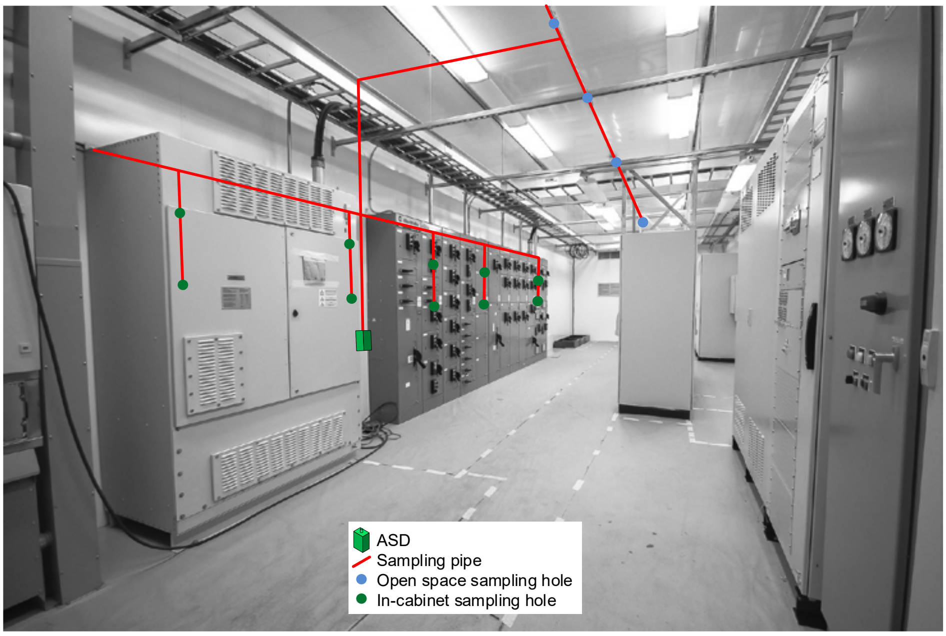
Within large cleanrooms or cleanroom-like buildings or hospitals and healthcare facilities, there are plant rooms and other sensitive areas that require Early Warning Fire Detection to ensure continuous operation or allow for protecting sensitive areas in an otherwise standard structure. Examples are power and mechanical rooms, modular clean rooms, ambient-controlled storages, computer server rooms or plant control centres.

Figure 18 illustrates how (a) SecuriSmoke ASD sampling points are positioned for both room open space and in-cabinet (electrical) detection or (b) room protection for a standalone, de-centralised modular cleanrooms or ambient-controlled enclosure or inside a plant room where detection of open space and return air grilles may be combined.

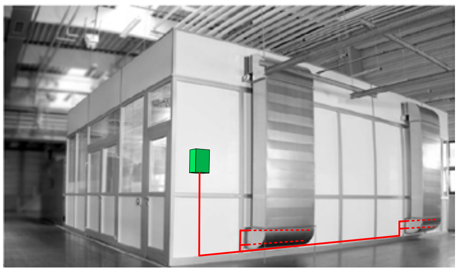
If detection addressability to individual cabinets is required or desired, simply add on REK 511, one for each zone for alarm notification purposes.

Protecting cable trays

Cable trays or equipment tunnels are best protected using SecuriHeat d-LIST Line Type Heat Detection (LTHD). The individual temperature sensors within the cable allow for both monitoring of temperature changes in the cable tray and localisation of the heat source alongside the tray.



(a) Example of one ASD for combined room and in-cabinet sampling



(b) Examples of ASD protecting modular cleanroom and critical operation support area

Figure 18 Fire detection placement (localised protection)

Sampling Holes	Variable	Design recommendation (localised protection)
	Spacing	(i) Refer to chapter 3.3 above for general open space (ii) In-cabinet: Nominal 100 cm (40 in), 2 or more sampling holes per inside cabinet
	Placement	(i) Ceiling level, Refer to chapter 3.3.1 above for placement (ii) Inside at the rear of cabinet where applicable (iii) Additional sampling holes in or near the hazardous area within the room as needed (iv) Refer to chapter 3.6.1 above for Return air grilles detection
	Orientation	Perpendicular to the run of the sampling pipes

3.6.3 Duct Detection

Challenges in high-airflow conditions

NFPA 72 [19] specifically requires that, unless a smoke detector is recognised for use in specific airflow environments, it should not be used in airflow environments above 1.52 m/s (300 ft/min). Both BS 6266 [51] and NFPA 72 recognise the challenges of detecting smoke in high-airflow environments and stipulate reductions in spacing of detection points in such high-airflow conditions.

Use SecuriSmoke ASD for in-duct smoke detection

SecuriSmoke ASD can be used for high airflow duct detection (approved to UL268A [56] with maximum airflow of up to 20.32 m/s (4’000 ft/min). Figure 19 is a cross-section view of a duct with the sampling pipe and pipe from the exhaust port inside the duct, when using SecuriSmoke ASD for in-duct smoke detection.

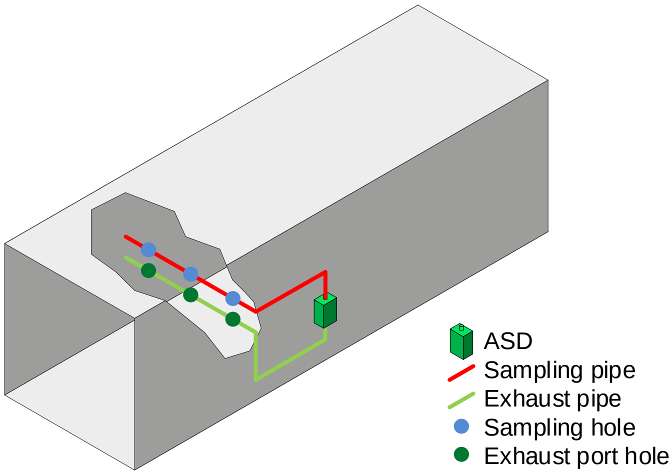


Figure 19 Fire detection placement (duct detection)

Sampling holes (sampling pipe)	Variable	Design recommendation (duct detection: sampling pipe)
	Spacing	2 to 4 or more sampling holes are used, hole spacing ranges from 10 to 80 cm (~4 to 30 in)
	Placement	Inside the duct, perpendicular and symmetric to the central line of the duct in relation to the pipe from exhaust port below
	Orientation	Facing the incoming airflow using Securiton sampling funnel SF ABS
Pressure balance holes (exhaust port pipe)	**Variable**	**Design recommendation (duct detection: exhaust port pipe)**
	Spacing	Exact same number of holes and identical spacing as in the sampling pipe above
	Placement	In parallel and symmetric to the central line of the duct in relation to the sampling pipe, spacing is no less than 10 cm (4 in)
	Orientation	Facing the incoming airflow using Securiton sampling funnel SF ABS

Refer to selected Securiton Aspirating Smoke Detector Technical Description manual for design details. As an example, SecuriSmoke 532 model Technical Description is shown in [57].

It is recommended per NFPA 72 [19] that duct smoke detectors be located in a duct section that is between 6 and 10 equivalent duct diameters from bends or openings.

The total length of the sampling pipe and exhaust port pipe should be no more than 20 m (~65 ft).

3.6.4 Detection in Challenging Environments

Detection in hazardous areas

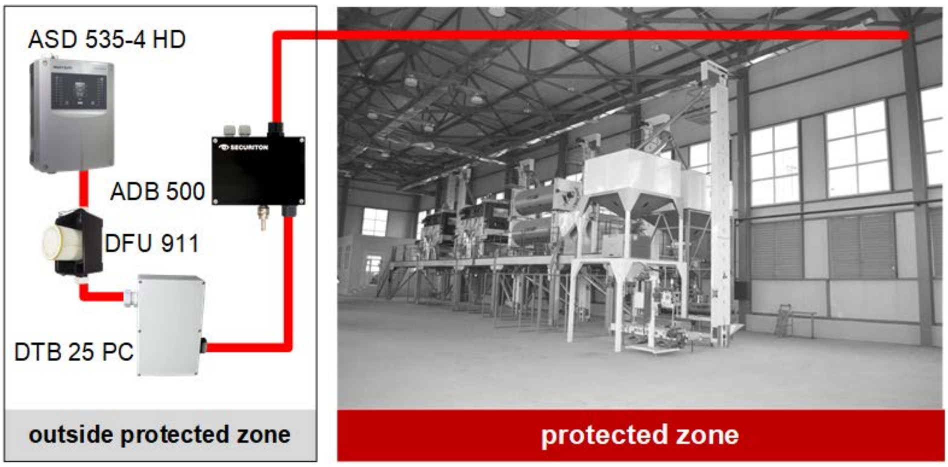
Although Securiton SecuriSmoke products currently do not have flame or explosion-proof or intrinsic safety certificates for the products to be installed in these hazardous areas, all products do come with FM Global approvals which allow for the products to be installed inside the protected areas with certain hazardous classifications [58]. Due to the differences in classifying hazardous areas between IEC[26] [59] (Zone), NFPA 70 [60] and FM Global (Class/Division or Zone where IEC standards are adopted), the actual hazardous conditions and requirements for detection equipment can vary from project to project. The assessment of suitability of SecuriSmoke Early Warning Fire Detection systems shall take into account respective site conditions.

Detection in challenging and harsh conditions

Apart from sites that are deemed as high hazardous areas, many low-level hazardous areas may actually present very challenging environmental conditions to fire or smoke detection, such as very high or turbulent airflow, dust, extremely hot or cold temperatures and high humidity. The SecuriSmoke ASD 535 HD (Heavy Duty), for example, is IP66 rated and can be installed in a location where high enclosure IP rating is required. While many conventional fire or smoke detectors fail in these environments, SecuriSmoke ASD detectors are proven as fit-for-purpose in early and reliable fire detection due to their unique air sampling technology, high quality components and Securiton's application know-how.

In many cleanrooms, hospitals or laboratories, often significant amounts of chemicals and hazardous materials are used or stored. With the "NFPA hazard diamond" marking scheme ([61]), it provides an immediate general sense of the hazards of a material and the severity of these hazards as they relate to emergency response. However, these areas (such as wet benches in large FAB) often contain toxic or corrosive off gases that must be dealt with quickly in part through exhaust systems. SecuriSmoke ASD becomes an ideal solution for early detection of a fire in these challenging operational environments.

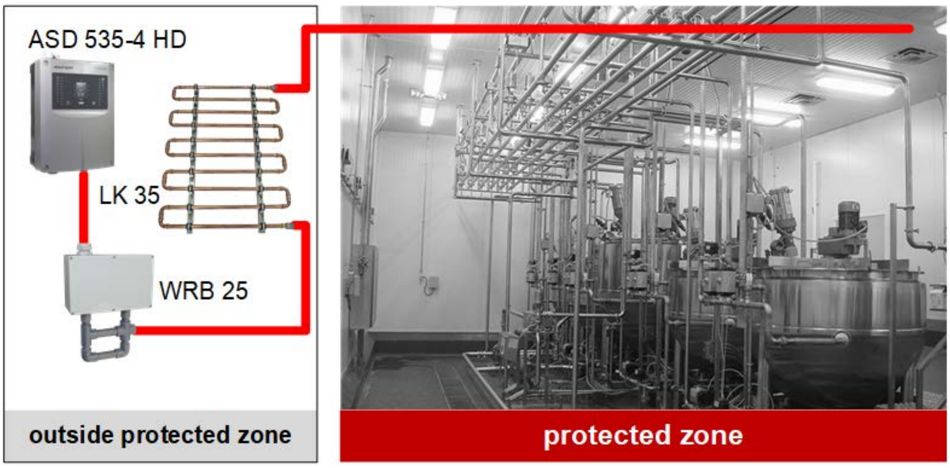
Figure 20 illustrates examples of SecuriSmoke ASD detector use in some challenging environments and how to select Securiton approved accessories to ensure a reliable installation and performance.



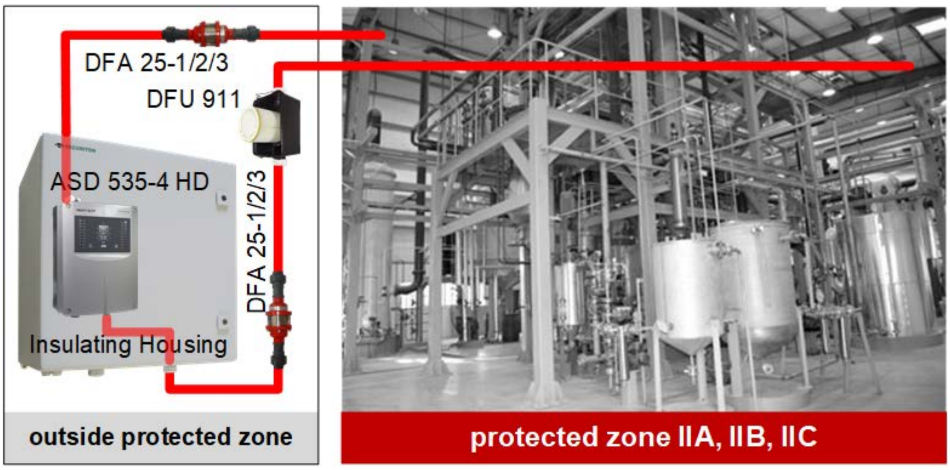
(a) High IP rating enclosure and very dusty environment (e.g. grain storage)

Figure 20 Fire detection placement (example use for harsh environment protection)

[26] IEC: International Electrotechnical Commission



(b) Extremely high temperature and/or humidity



(c) Work with certified flame arrestors

(d) Work in environments with corrosive airborne particulates

Figure 20 Cont'd: Fire detection placement (example use for harsh environment protection)

In case of a pressure differential and/or a higher temperature differential between the protected zone and where the ASD is mounted outside the protected zone, it is strongly recommended to return the sampled air to the protected zone via the exhaust port of the ASD.

In case high hazardous areas (zones IIA, IIB or IIC), the use of a filter unit DFU 911, installed ***before*** *the flame arrester, is recommended to prevent clogging up of the flame arrester. In addition, a second flame arrester is required when the exhaust air is returned to the protected zone (see Figure 20 (c)).*

Variable	Design recommendation (challenging environments)
Spacing Placement Orientation	Refer to chapters 3.3, 3.4 and 3.6 for SecuriSmoke products design recommendations in terms of detector sampling pipe layout and sampling hole locations.

Sampling holes

Accessory	**Description** (see Appendix C: for more details)
DFU 911	Dust filter unit
DTB 25 PC	Dirt trap box
ADB 500	Automatic blow-out device
WRB 25 PVC/ABS	Water retaining box
LK 35 PVC/ABS	High temperature air cooler
DFA 25 1/2/3	Flame arresters
ASD Housing Ex	IP54 steel enclosure

Use of SecuriSmoke accessories

Refer to selected Securiton Aspirating Smoke Detector Technical Description manual for accessory selection and application design details [57].

4 Optimising Level of Protection

Fit-for-Purpose

Optimising the level of protection for Cleanrooms & Associated Controlled Environments facilities, when using advanced SecuriSmoke ASD-based Early Warning Fire Detection solutions, consists of the following three key design considerations:

1. Where to use SecuriSmoke ASD
2. How other detection technologies could complement for a fit-for-purpose detection solution
3. How SecuriSmoke ASD works seamlessly and reliably with the control of certain BMS components (such as HVAC, mechanical ventilation and smoke management system), power-down processes and suppression actuation

4.1 General Areas

Detection products for general areas

A summary of Securiton detection products for general areas in or around Cleanrooms & Associated Controlled Environments facilities, is shown in Table 12 below.

Table 12 Detection design considerations (general areas)

General Area	Design considerations
Administration (offices and hallways) Loading docks General operation support rooms	• SecuriStar point type multi-criteria detectors for other areas and high nuisance or false alarm areas such as kitchen areas • SecuriBeam projected-beam detectors for high ceiling areas • SecuriSens Line-Type Heat Detection for loading docks and underground parking lots

4.2 Cleanrooms, Controlled and Sterilised Environments

Detection products for critical operation areas

Table 13 is a summary of Securiton detection products for critical operation areas within Cleanrooms & Associated Controlled Environments facilities.

Table 13 Detection design considerations (critical areas)

Critical Area	Design considerations
Cleanrooms & large FAB Ambient-controlled distribution, processing & storage Sensitive areas in healthcare, hospital or laboratory Areas where egress & life safety requires early warning Sensitive operation support rooms Areas with challenging environmental conditions Hazardous areas #1 Mobile facilities & modular cleanrooms	• Mainly use SecuriSmoke ASD Early Warning Fire Detection system • SecuriHeat Line Type Heat Detection (LTHD) systems considered for in-rack detection, cable trays, loading docks, hazardous areas and where heat detection is required • May be installed where coincidence/cross-zone[27] smoke detection is required for suppression systems (pre-actuation sprinkler, water mist or clean agent gaseous suppression) • For high-sensitive areas (e.g. plant rooms, on-site records storage and computer server rooms) • Where local fire/building codes require smoke or heat detection for building safety, point type smoke and heat detectors are used in conjunction with Early Warning Fire Detection for early warning and property protection

#1: Examples of challenging environments and hazardous areas include refregirate storage, corrosive processing (e.g. wet benches, wet chemical etching), high humidity washing-down (e.g. food processing), high temperature (e.g. furnances in FAB), high hazard classification (e.g. chemical storage & handling in laboratories).

4.3 Controls and Integration

SecuriSmoke ASD offers five alarm levels

One of the advantages of using SecuriSmoke ASD detectors is the five levels of alerts ('Pre-signal1', 'Pre-signal2', 'Pre-signal3') and alarm signals ('Alarm', 'Alarm2'). Staged alerts escalating to alarms from an overheating incident provide the early warning needed to prevent the situation from developing into a real fire event. Table 14 below shows a typical use of these alarm signals. Level 1 to 5 in the sequence from the time when the incident is initially originated.

Table 14 Typical use of SecuriSmoke ASD multilevel alarms

Level	Signal	Typical use
1	Pre-signal1	Verify and control (manual extinguishing as needed)
2	Pre-signal2	Manual shutdown of HVAC and power-down if required; call emergency team
3	Pre-signal3	Auto shutdown of HVAC, local ventilation or smoke vents and related BMS; evacuate the site
4	Alarm	Actuate clean agent suppression; initiate fire alarm; call fire brigade
5	Alarm2	Actuate pre-action sprinkler

The main objective: gain time

The objective of early detection is to provide personnel with the opportunity to investigate and intervene as soon as possible in the event of a fire so that smoke damage or damage resulting from automatic power-down or actuation of fire extinguishing system can be avoided.

[27] A.k.a. 'double knock' or interlock or double-interlocked

On the other hand, activation of automatic fire suppression systems or other BMS components (such as power-down to computer equipment, the control of fire doors, smoke ventilation, HVAC, etc.) require a reliable fire detection system.

In general, SecuriSmoke Early Warning Detection Systems are considered to be adequate to detect smouldering overheating or fire at its incipient stage for the prevention of the majority of fire outbreaks.

There may be slightly different requirements on how smoke detection is used in the emergency response and automatic actuation of various suppression systems (see Appendix A:).

4.3.1 Early Warning Incident Response

Staged response plans for incidents and emergencies

SecuriSmoke Early Warning 'Pre-signal1' and 'Pre-signal2' signals can be used in a logistics warehousing facility's Incident and Emergency Response Plan to effectively facilitate site security personnel to investigate, intervene and prevent a fire outbreak from developing.

Supported with the 'Pre-signal3' alert, 'Alarm' and 'Alarm2' fire alarm signals, a simple yet reliable interaction of manual and fully automatic control of fire detection and protection systems in the emergence response procedure can be executed in an early, timely and orderly fashion, together with both internal response teams and external fire services.

4.3.2 Power-Down and Building System Control

Power-down schemes

SecuriSmoke ASD 'Pre-signal2' and 'Pre-signal3' alerts can be designed for manual HVAC or other BMS components power-down or automatic process-related controls. SecuriSmoke 'Pre-signal3' alert and 'Alarm' can be used for automatic power-down.

Table 15 is a summary of typical detection and automatic power-down schemes using SecuriSmoke 'Pre-signal3' alert or 'Alarm'.

Table 15 Typical detection and power down schemes

Suppression	Automatic power-down (SecuriSmoke 'Pre-signal3' or 'Alarm')
Clean agent only	Initiation of a power-down sequence of equipment or machine tools, either automatic or automatic with time delay
Automatic sprinkler system only	Initiation of an automatic power-down sequence of equipment or machine tools, from either detection alarm or water flow alarm from a pre-action type sprinkler system
Both clean agent and automatic sprinkler system	Initiation of an automatic or automatic with time delay power-down sequence at 'Pre-signal3' alert for discharge of the clean agent system; use the 'Alarm' signal with or without time delay for automatic sprinkler system related power-down sequence
Water mist system	Initiation of an automatic power-down sequence

For discharge of clean agent suppression system, HVAC power-down will be subject to the system design for incoming air, which may dilute the concentration of extinguishing agent.

Examples for controlling other BMS components

Other BMS components, for instance mechanical/forced ventilation or large HVAC in cleanrooms type buildings, may be controlled through these SecuriSmoke alarm signals depending on the sequence and purpose of the control. One practical example is upon detection of a fire incident in an early stage, to turn off the selected ventilation system so their operation does not impede the effectiveness of ceiling level sprinkler operation. Another example is when in-rack SecuriSmoke ASD alerts are signalled, to control the surrounding or building HVAC to reduce or stop the air flow in order to ensure an effective suppression system operation and to avoid or delay fire spread before the incident can be brought under control.

Good practice In addition, when incorporating SecuriSmoke 'Pre-signal2', 'Pre-signal3' alerts and 'Alarm' with the manual or automatic power-down procedure, consider the following:

- Work with EPO[28] switch/button, remote manual, ventilation switch/button, etc. for powering down in affected zone(s)
- Use manual remote override to disconnect control for pre-determined automatic power-down scheme
- When site security investigation is available upon SecuriSmoke 'Pre-signal1' and 'Pre-signal2' alerts, the manual control points should be located in such a way that an immediate action to effect or override power-down is possible
- For automatic power-down with time delay associated with clean agent systems, manual power-down will be completed in a maximum of 10 minutes as part of the orderly power switch-off process, at which time automatic power-down sequence is initiated.

4.3.3 Detection and Suppression Actuation

Clean agent suppression systems While sprinkler and pre-action sprinkler systems are common to protect Cleanrooms & Associated Controlled Environments facilities, a clean agent suppression system may be used in some areas or cleanroom-like structures as an addition to achieve full protection in order to accomplish both building safety objectives and protection of critical equipment for business continuity. Minimising the possibility of a full sprinkler discharge can also avoid water damage, thus minimising the cost of interruption and recovery.

Water mist systems Water mist systems are also considered in locations with confined space for installation. Where protection against additional hazards are inherent in fire-propagating cables, the use of water mist to control or suppress such a fire is accepted as a good practice due to much less water usage. However, the effectiveness of water mist relies on a timely reduction of airflow in the protected space. This can be achieved with a SecuriSmoke early warning alert or alarm signal to turn down or turn off the HVAC before the water mist system is activated.

Suppression and Detection Regardless where and what type of suppression systems are installed, a suitable (and recommended per relevant codes and standards such as [50]) smoke detection system such as SecuriSmoke ASD is required to either actuate the related suppression zones or allow for a timely intervention to prevent the need for suppression. In the use of detection equivalency to point type detectors for the purpose of co-incidence (or interlock, double interlocked) suppression actuation [62], SecuriSmoke ASD is an ideal solution.

Table 16 is a summary of typical detection and suppression actuation schemes using either SecuriSmoke 'Alarm' or 'Alarm2' alarm signals.

[28] EPO: Emergency Power Off

Table 16 Typical detection and suppression actuation schemes

Suppression	Suppression actuation (SecuriSmoke ‘Alarm’ or ‘Alarm2’)
Clean agent only	Initiation of an automatic power-down or automatic with time delay power-down sequence of the equipment or machine tools.
Automatic pre-action sprinkler only	Activate pre-action valve with smoke detectors and control panel in accordance with FM Global DS 5-48 [54]. When coincidence detection is required for a double-interlocked pre-action sprinkler system, select one SecuriSmoke ASD detector with two independent detection chambers or two independent detectors for cross-zone detection actuation design. In certain cases, such as a small room or a compartmented suppression zones, use of REK 511 with a SecuriSmoke ASD would be a cost-effective solution.
Both clean agent & automatic pre-action sprinkler	Provide two independent SecuriSmoke ASD detection systems to actuate pre-action sprinkler and clean agent system respectively.
Water mist system	Use SecuriSmoke ASD detection systems to power-down the HVAC to affected zone(s), upon reach of the next level alarm, activate the water mist system.

Detection actuation with sprinkler system refers to the initiation of interlocked pre-action sprinkler system or stage one on a double-interlock system.

4.4 Summary: Use of Securiton Fire Detection

Table 17 summarises the use of Securiton Early Warning Fire Detection systems in terms of the areas for which they are recommended and the placement of detection for the optimal level of protection.

Table 17 Summary (use of SecuriSmoke Early Warning Fire Detection)

	Detection design considerations		
Detection location	*Ceiling*	*In-rack*	*Localised*
General areas			
Admin (offices and hallways)	Point / LTSD	NA	NA
Loading docks	Point / LTHD	NA	NA
General operation support rooms	Point	NA	NA
Critical operation areas			
Cleanrooms & large FAB	ASD	ASD / LTHD	ASD
Ambient-controlled distribution, processing & storage	ASD / Point	ASD / LTHD	ASD
Sensitive areas in healthcare, hospital or laboratory	ASD	NA	ASD
Areas where egress & life safety requires early warning	ASD	NA	ASD
Sensitive operation support rooms	ASD / Point	NA	ASD
Areas with challenging environmental conditions	ASD / Point / LTHD	NA	ASD / LTHD
Hazardous areas	ASD / Point / LTHD	NA	ASD
Mobile facilities & modular cleanrooms	ASD + Point	NA	ASD

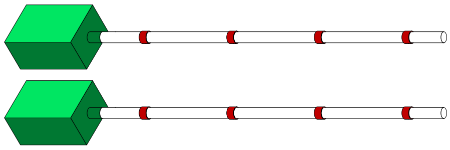
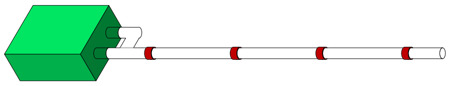
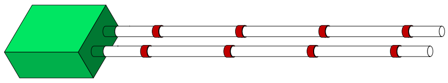
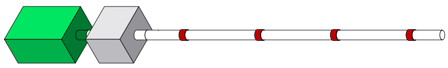
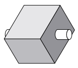
Point/LTSD (Linear Type Smoke Detector) (subject to ceiling height); ASD/Point (subject to hazard or sensitivity classification); ASD + Point (additional point type smoke or heat detectors subject to DtS code and suppression activation); NA (generally not required or not applicable); ASD (Early Warning Fire Detection is the best option where smoke detection is required).

SecuriSmoke ASD, REK and SecuriHeat Line Type Heat Detection (LTHD) are the optimal combination for fire detection design in Cleanrooms & Associated Controlled Environments facilities.

Suppression Schemes Table 18 is a summary of the use of SecuriSmoke ASD and REK for the purpose of control, power-down and actuation of suppression systems. Some of the suppression actuation schemes are referenced in the FIA Code of Practices [50].

Table 18 SecuriSmoke ASD and REK for control and suppression actuation

Suppression actuation schemes for pre-action sprinklers (interlocked, double-interlock), water mist and clean agent gaseous systems

Scheme	Illustration	Remark
A		2 x SecuriSmoke ASD 531, 532, 533 for full redundancy or cross zone coincidence design
B		Single SecuriSmoke ASD 535-2/4 with one set of pipe network
C		Single SecuriSmoke ASD 535-2/4 with two independent pipe network
D		Use REK in place of 2nd ASD in Scheme A, or localised suppression
E	Scheme A, B or C + 	Any of SecuriSmoke ASD with REK
F	 + 	Combination of Optical Smoke Switches ORS, localised suppression
G	Scheme A to F + SecuriHeat d-LIST	Combine with SecuriHeat Line Type Heat Detection

5 Securiton 360° Fire Protection Solution

Securiton 360° Fire Protection Solution is built on its advanced Securiton Fire Alarm Systems (FAS). SecuriFire is not just reliable in operation with its modular, decentralised system architecture, it is also versatile and expandable to cater for current and future needs to connect all approved fire safety devices such as signalling, alarming, display and control units.

SecuriFire Fire Alarm Systems (FAS)

Table 19 is a list of Securiton Fire Alarm Systems (FAS) with its baseline approvals. With any of these FASs, SecuriSmoke (Table 6) Early Warning ASD and REK detectors as well as all detection portfolios of products listed in Table 7, these can be used together with Cleanrooms & Associated Controlled Environments facility protection.

Table 19 Securiton Fire Alarm Systems (FAS)

Model	Key performance parameters	Approvals
SecuriFire 3000	FACP, ECP or FEP; SecuriLan network	VdS
SecuriFire 2000	FACP, ECP or FEP; SecuriLan network	VdS
SecuriFire 1000	FACP, Non-networked	VdS
SecuriFire 500	FACP, Non-networked	VdS

FACP (Fire Alarm Control Panel); ECP (extinguishing system control panel); FEP (fire detector/extinguishing system control panel).

Use of different SecuriFire models can design a main FAS with multiple Sub FAS and Mimic panel configurations which are commonly required for large Cleanrooms & Associated Controlled Environments facilities (see Figure 21 below). For small sites such as power and plant rooms or storage or vaults with high valuables, SecuriFire 500 would be a good fit.

Key attributes for total fire protection

SecuriFire centric total fire protection solution emcompasses the three key attributes below:

- Intelligence: Lightning-fast detection of incipient fires; fully redundant hardware and software design; modular and decentralised architecture; Up to 14 addressable loops with 3'500 elements per control unit; highest security standards
- Redundancy: 100% hot standby secondary system; maximum fail-safe design at all levels; secure data transmission via a redundant SecuriLan; tightly meshed diagonal SpiderNet networking technology; constant automatic system checks and remote diagnostics; device bus for external display and control devices connection
- Unique SpiderNet Technology: Up to 16 control units with a maximum of 250 loops; can be combined and networked between each other; covered over a maximum distance of 3'500 m (~2.17 mi)

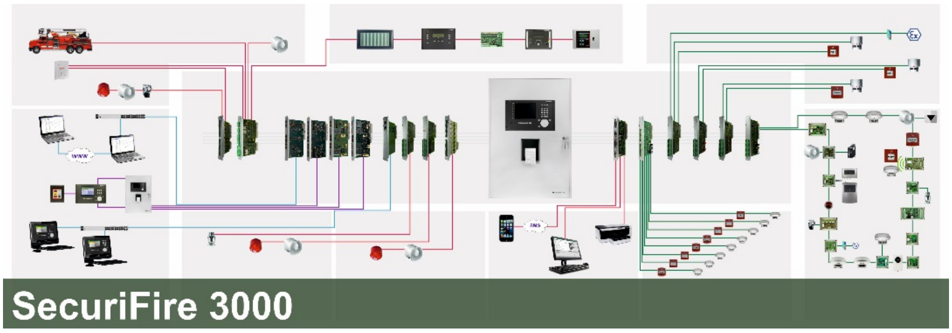


Figure 21 Securiton 360° Fire Protection Solution (FACP and Connections)

6 Inspection, Testing and Maintenance

Testing and services

Most, if not all Cleanrooms & Associated Controlled Environments facility operators are committed to regular maintenance service on site. Examples of relevant codes and standards for fire detection and alarm systems Inspection, Testing and Maintenance (ITM) include ISO 7240-14 [63], BS 5839 [48], AS1851 [64] and NFPA 72 [19]. In general, codes and standards also make references to the manufacturer's design, installation, and operation manual listed with relevant product-type approvals such as UL, EN or FM Approval.

Table 20 below is a simplified ITM schedule for SecuriSmoke ASD product services. Refer to Securiton product manuals for more details.

Table 20 Summary of Inspection, Testing and Maintenance (ITM) scheme

Service Item	Fault/ Alarm	Trimestrial	Yearly
Cleaning the detector housing exterior (air outlet)	(✓)	?	✓
Cleaning of sampling pipe tube network, accessory parts, airflow sensors	(✓)	?	✓
Replacement of dust filters	(✓)	?	✓
Cleaning of air flow sensor	(✓)	?	✓
Check correct seating (no leakage)	(✓)	?	✓
Check of fault and alarm release	✓	?	✓
Update maintenance protocol	✓	?	✓
Analyse event memory	✓	?	✓
Analyse airflow issues (caused by operational changes)	✓	?	✓

✓ indicates 'shall do'; (✓) indicates 'as needed';

? indicates 'only if required by local codes and standards'

Testing methods refer to FIA CoP [50], NFPA 76 [44] (similar to these described in FM Global DS 5-14 [65]) and any local applicable requirements. Refer to Appendix A.2 for test method extracts from FIA Code of Practices (suitable as reference for large open spaces such as these ISO Class or cleanroom-like facilities and manufacturing areas in a FAB) and NFPA 76 (suitable as reference for smaller rooms, confined spaces or compartments).

7 Operation Software & Application Support

Supporting design, configuration and remote monitoring

This chapter provides related software tools for design, configuration or remote monitoring and managing of SecuriSmoke ASD and related products. Securiton dedicated application support is ready to assist you with specific project needs.

7.1 Monitoring Software (Control Room)

Remote or local monitoring

SecuriSmoke ASD detectors are networked through RS485 or TCP/IP. The networked detectors from one or multiple sites can be centrally monitored and managed from a remote location, such as an on-site control room or any authorised off-site location or certified remote monitoring centre.

Manage with Securiton UMS

In general, one way to monitor and manage SecuriSmoke ASD detectors is to use Securiton UMS[29] software. In this scenario the SecuriSmoke ASD detectors are either

- independently networked and connected to the UMS, with simple alarm relays integrated to the on-site FAS for alarm and fault notifications, or
- connected via SecuriLine to a FAS of the SecuriFire family, which offers both notification and full control capabilities; the SecuriFire FAS in turn is connected to the UMS.

Manage with a BMS

Another way is to manage SecuriSmoke ASD detectors through an enterprise BMS software. In this scenario the ASD detectors are independently networked and connected to the BMS with help of a gateway. In this scenario, both alarm/fault notification and control are possible.

7.1.1 Rack-mount Standalone FidesNet RCU

Display and Control

Using Securiton FidesNet, multiple ASDs are connected to each other via a serial RS485 interface. The FidesPort NCU 900[30] acts also as a gateway for remote access, which supports standard interfaces (such as Modbus TCP or SNMP) to connect to a BMS.

No physical access required

FidesControl RCU 700[31] is a rack-mount, standalone networked SecuriSmoke ASD detectors display, control and management console. It comes with a 7" touch screen and offers access to all connected ASD for routine services and emergency response tasks. With the use of an RCU in most cases, it becomes obsolete to physically access the ASD devices themselves – often placed in highly secured areas – or bringing in personal laptop computers into such areas. This drastically improves the controlled access and contractors' activity tracking for the purpose of site security. Because the RCU device is designed for one-to-many or many-to-one topologies, more than one RCU to the same FidesNet networked SecuriSmoke ASD can be connected.

[29] UMS: Universal Management System
[30] NCU: Network Communication Unit
[31] RCU: Remote Control Unit

Figure 22 illustrates the RCU and NCU for display, control and management of networked SecuriSmoke ASD detectors remotely from the protected areas. Key features include:

- Device list: display all or a selection of the devices and the colour-coded status information of the individual networked devices
- Dashboard: display individual channels of a selected ASD with current measurement values (smoke and airflow), and current smoke value in relation to pre-determined alert and alarm thresholds
- Trending: display the measurement values of the airflow and smoke value in graphic charts with both real-time values and recorded values[32], against the pre-determined alerts and alarm thresholds (see Figure 22)
- Other views currently include an event memory and system settings

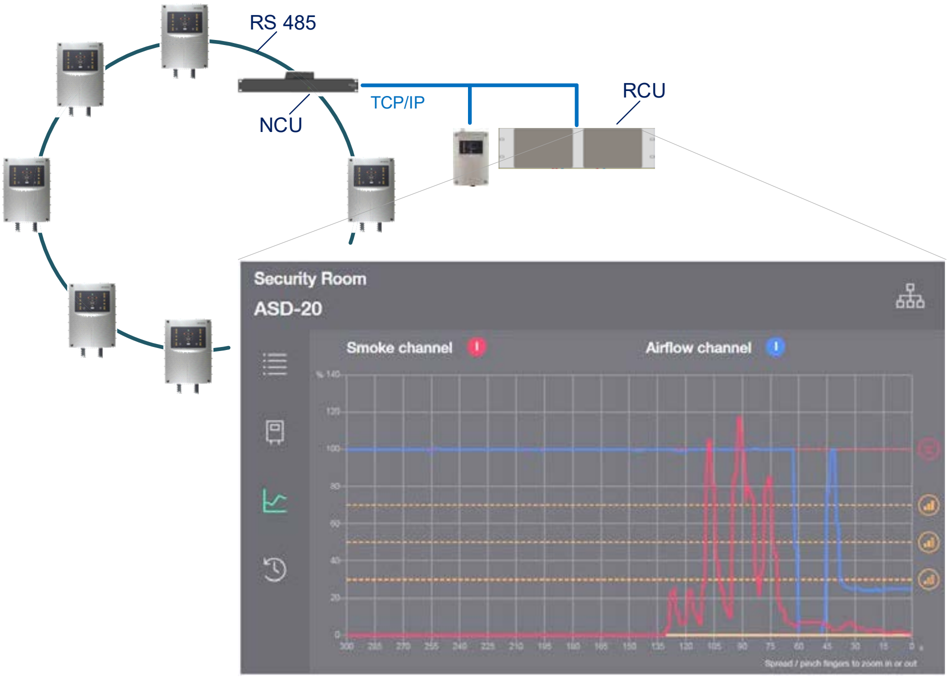


Figure 22 Rack-mount standalone FidesNet RCU display and control

[32] up to maximum of 300 seconds of recorded values

7.1.2 PC-based Universal Management System UMS

Managing all network devices

The UMS visualises live data from networked SecuriSmoke ASD. A comprehensive overview of the entire ASD population on one or more site(s) can be accessed from a central location, including the detectors current states. All data is visualised in form of lists, on a simple building layout plan or even a complex graphical view. UMS allows configuring and retrieving data from any of the detectors in the network through a user-friendly, intuitive graphical user interface.

Figure 23 illustrates two FidesNet networks of SecuriSmoke ASD devices, each connected to an RCU 700 for local display and control. Both networks are connected to a UMS for overall monitoring and control. The figure also illustrates the possible connection to a BMS as mentioned in chapter 7.1.

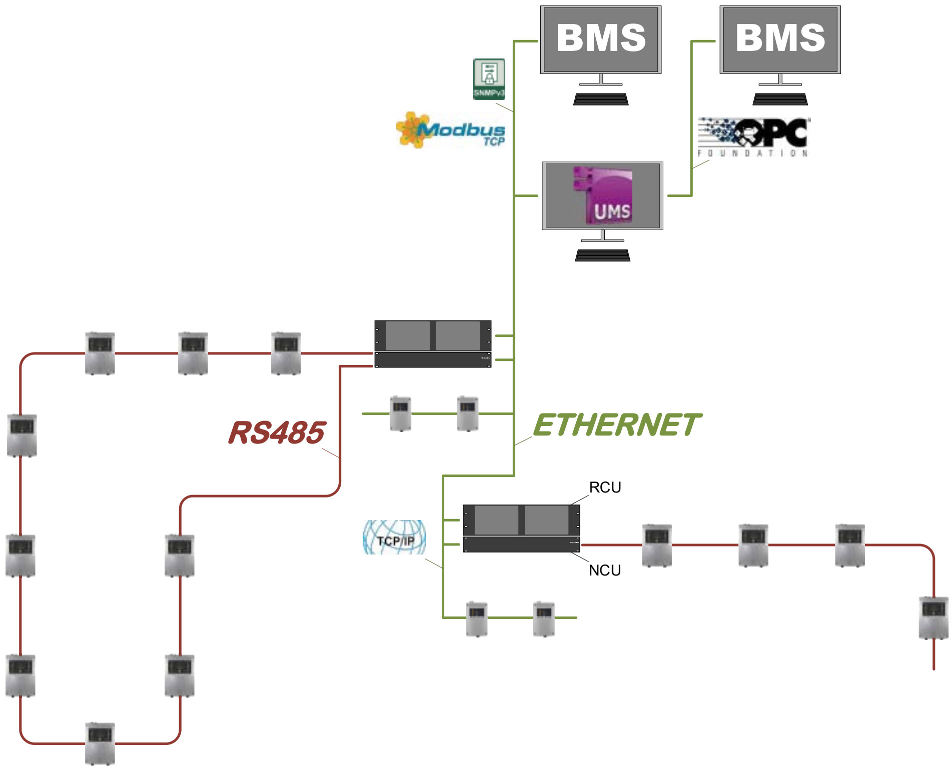


Figure 23 Networked SecuriSmoke ASD managed with UMS

7.2 Application Support

Application support includes mainly:

- Software tools for design, configuration, commissioning and ongoing ITM
- Partner accreditation program
- Application and field engineering support

7.2.1 Software Tools

Designing pipe networks with ASD PipeFlow

To design SecuriSmoke ASD detectors which meet the levels of protection required for an application (in terms of detection sensitivity, sampling hole placement/coverage, transport time limits, etc.), it is essential to use the SecuriSmoke ASD PipeFlow design software (Figure 24). This software helps in generating a design package, which is the basis of design, installation, commissioning and ongoing ITM throughout the product lifecycle.

The ASD PipeFlow software tool provides system designers the means and support to design a system in such a way, that SecuriSmoke ASDs are operating in accordance with either EN 54 or NFPA 72 provisions. It furthermore helps to optimise bills of material (BOM) supported with a 3D illustration of the entire pipe network.

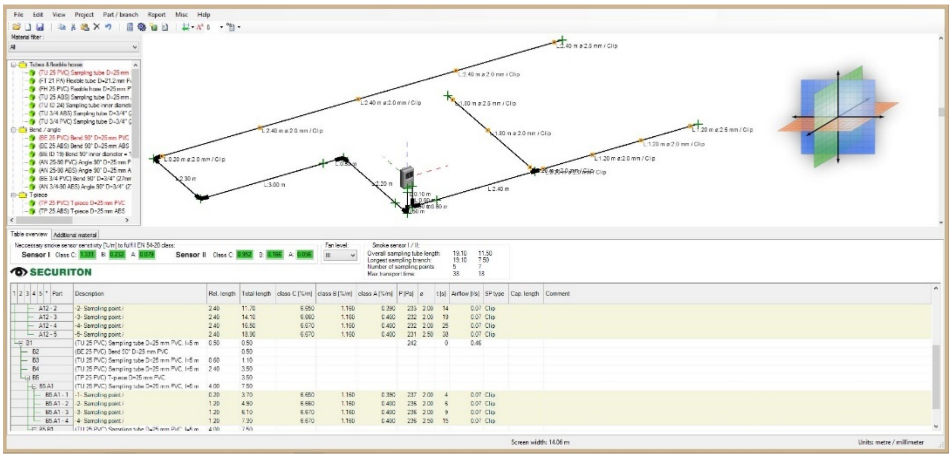


Figure 24 SecuriSmoke ASD design software: ASD PipeFlow

Configuration, commissioning and ongoing ITM for ASD with ASD Config

During installation, commissioning and ongoing ITM on site, SecuriSmoke ASD Config (Figure 25) is used for quick and easy set-up of individual or networked detectors from a single location, thus significantly improving the efficiency of all required fieldwork. When necessary, Securiton support teams can also connect to the detector network from a remote location for troubleshooting.

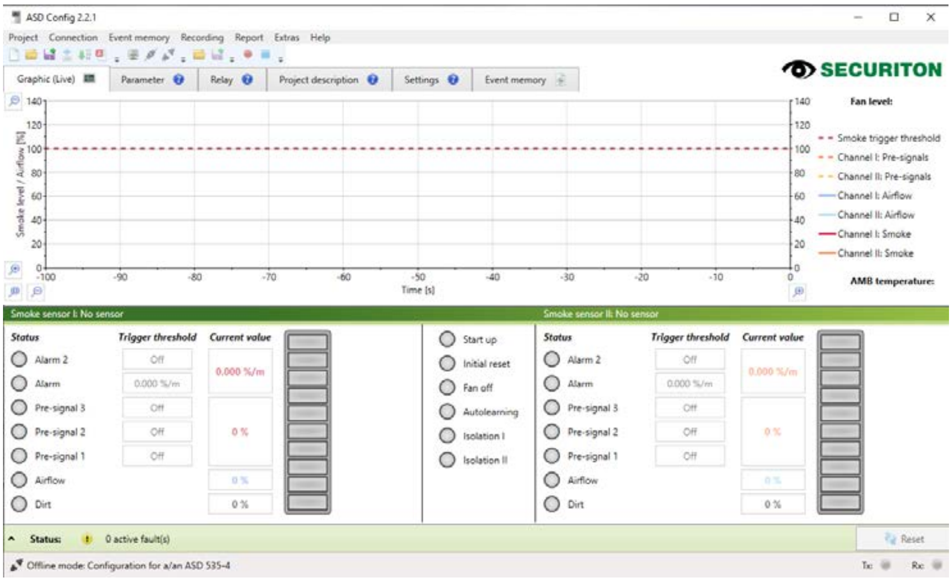


Figure 25 SecuriSmoke ASD configuration software: ASD Config

Configuration, commissioning and ongoing ITM for FAS with SecuriFire Studio

Securiton SecuriFire Studio (Figure 26) is a powerful and modern software tool supporting engineers during designing, installation, commissioning and ongoing ITM on site or remotely, of SecuriFire FAS installations. It allows for planning, configuring and troubleshooting of an entire networked FAS installation from a single location, consequently reducing significantly both time and manpower required for routine ITM tasks.

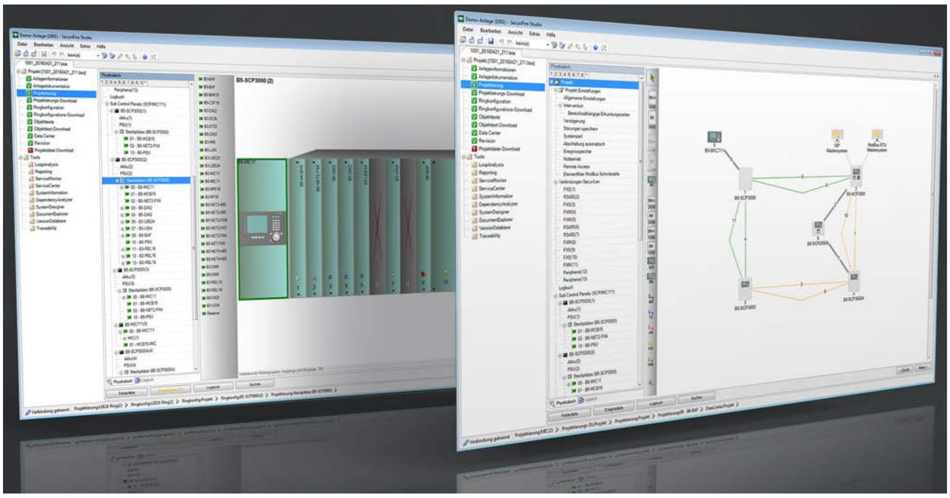


Figure 26 SecuriFire configuration software: SecuriFire Studio

7.2.2 Partner Accreditation Program

Training is a key element

Securiton is committed to providing service excellence through its worldwide partner network. A key element of the partner accreditation program is the training of the partner's staff in sales, engineering, troubleshooting and maintenance of Securiton products.

Online training platform and training courses

For this purpose, Securiton is operating a comprehensive online training platform in combination with in depth training courses, conducted either at Securiton headquarter or locally at the partner's premises.

Refresher courses are required for the partner to maintain or improve his accreditation level.

7.2.3 Application and Field Engineering Support

Application engineering support

Securiton application engineering support is always available to ensure a properly designed and implemented fire-engineered SecuriSmoke ASD Early Warning Fire Detection solution to protect mission critical infrastructure for life and building safety as well as maintain business operation continuity.

Field support

Field engineers and fully accredited product specialists from Securiton regional offices and its local distribution partners ensure a smooth installation and commission phase on site as well as supporting the client's maintenance force for ongoing ITM tasks.

Product support specialists and application engineers at Securiton European headquarter provide the next level of support to resort to. They in turn have access to the R&D department, thus ensuring adequate and effective support services on all levels.

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8.1 Additional Literature

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6. VdS Schadenverhütung GmbH, (2018) CEA 4001en - Sprinkler Systems, Planning and Installation, Cologne, Germany.
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Appendix A: Highlight of Fire Detection Codes

This Appendix provides information on related codes and standards for Early Warning Fire Detection systems as well as the typical site performance test methods for the purpose of commissioning and verification of system installation to the performance requirements of VEWFD and EWFD systems in Cleanrooms & Associated Controlled Environments facilities.

A.1 Summary of Codes and Standards

Table 21 is a summary of relevant codes and standards for Early Warning Fire detection system design and applications in the Cleanrooms & Associated Controlled Environments facilities.

Table 21 Summary of codes and standards (Early Warning Fire Detection)

Region	Product Approvals	Design for Use	Install/Commissioning, ITM[#1]
Global	UL 268; UL 268A	NFPA 1; NFPA 101, NFPA 70, NFPA 72, NFPA 76, NFPA 99/45/318 FM Global DS 1-56, DS 5-1, DS 5-14, DS 5-48, DS 8-1, DS 8-9, DS 7-7 ISO 7204-20	NFPA 72 FM Global DS 5-14 ISO 7240-14
EU/UK, MENA, SEA, India	EN 54-20; EN 54-7; EN 54-27	BS 6266; VdS 2095 Appendixes, R7 Rules, BS 5839-1, (UK) Fire Industry Association Code of Practice, etc.	FIA CoP, VdS 2095, BS 5839-1
China	GB 50116-2013	GB 50016, etc.	GB 50166
ANZ, Pacific, SEA, India	AS 1603-8, AS 1603.13	AS 1670-1; AS 7240-20/AS 1603-8	AS 1851

#1: ITM (Inspection, Testing and Maintenance) involves

(a) Install and commissioning

(b) System fault report and handling

(c) Periodic services and maintenance

Apart from these requirements from relevant codes and standards, you also need to refer to Securiton product manuals.

A.2 Testing Methods: Early Warning Fire Detection

Most commonly used test methods for Early Warning Fire Detection systems are these described in FIA CoP and NFPA 76 (see Table 22).

Table 22 Typical Early Warning Fire Detection performance test methods

FIA CoP 2012 Appendix A – ASD System Performance Tests

Type	Application	Response Class A	Response Class B	Response Class C
Primary	Clean room, Telco or computer facility (ceiling <3m)	2m PVC wire (E.2)	1m PVC wire (E.1)	7-9g pellet (B.1)
	Other (including open areas and high ceilings)	1m PVC wire (E.1)	7-9g pellet (B.1)	13-18g pellet (B.2)
Secondary	Low ceilings (<3m)	2m PVC wire (E.2)	1m PVC wire (E.1)	7-9g pellet (B.1) Paper Chimney (C.1) Poly' mat (G) Pot' Lactose (H)
	Normal ceilings (up to 20m unless otherwise stated)	7-9g pellet (B.1)	13-18g pellets (B.2) Paper Chimney (C.1) – 5m max	2x13-18g pellets (B.3) Paper Bin (C.2) Poly' mat (G) Pot' Lactose (H)
	High ceilings (>20m)	N/A	2x13-18g pellets (B.3)	Paper Bin (C.2) Pot' Lactose (H)
Localised	Ideally devise custom test to reflect risk – otherwise use...	2m PVC wire (E.2)	1m PVC wire (E.1)	7-9g pellet (B.1) Poly' mat (G) Pot' Lactose (H)
In-cabinet	Vented/cooled	2x12ohm for 80sec (F.3)	2m PVC wire (E.2)	1m PVC wire (E.1)
	Unvented >3m³	12 ohm for 70sec (F.2)	2x12ohm for 80sec (F.3)	2m PVC wire (E.2)
	Unvented <3m³	12ohm for 8 sec (F.1)	12 ohm for 70sec (F.2)	2x12ohm for 80sec (F.3)
Duct	For smoke generated in the duct	2m PVC wire (E.2)	1m PVC wire (E.1)	7-9g pellet (B.1)
	For smoke generated in the room, devise custom test to reflect volume and usage of space protected.	1m PVC wire (E.1)	7-9g pellet (B.1)	13-18g pellet (B.2)

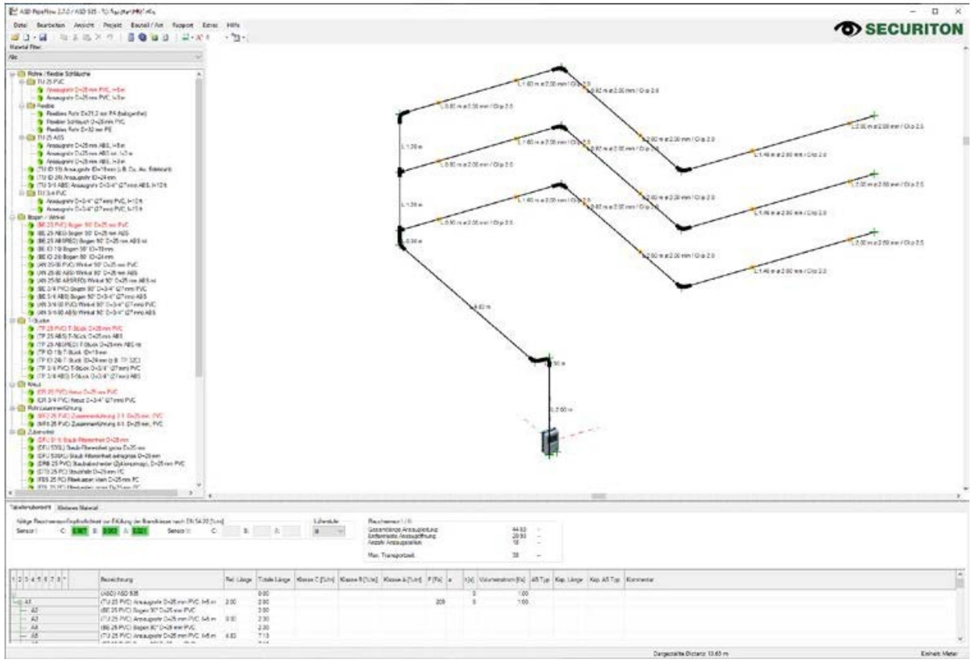
NFPA 76 Annex B Performance Test Procedures for VEWFD and EWFD Systems

Table B.2.1 Heated Wire Test Parameters

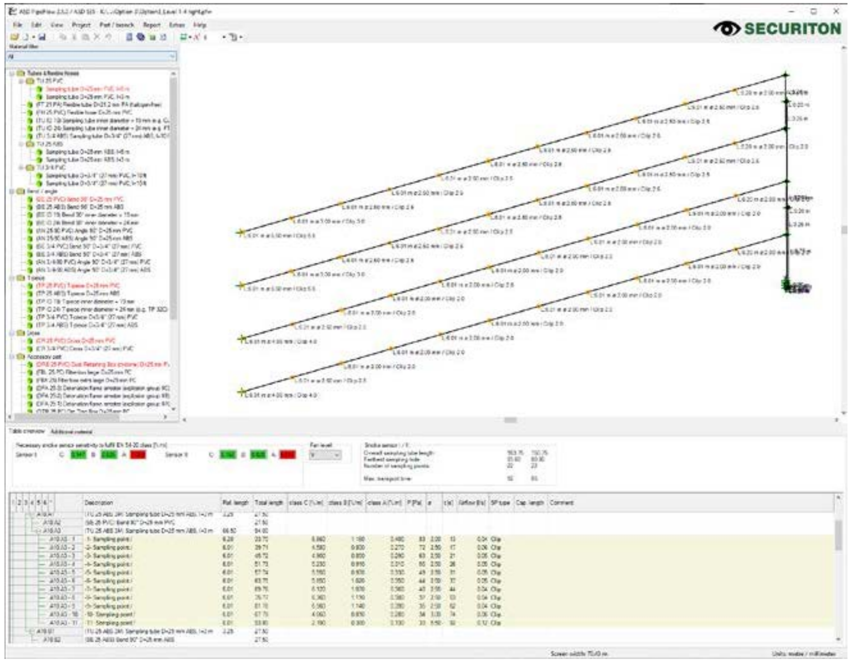
Parameter	BS 6266 Test (1992)		Modified BS 6266 Test: Two 1 m Wires in Parallel	North American Wire Test: North American Wire
	2 m Wire Test	1 m Wire Test		
Wire specs	10 strands of 0.1 mm diameter tinned copper wire.	Total cross-sectional area of conductor is 0.078 mm². Insulated with PVC to a radial thickness of 0.3 mm.	Wire is very flexible due to stranded construction and highly plasticized insulation.	A single strand of 22 AWG copper wire, insulated with PVC to a diameter of 1.1 mm (0.041 in.). This wire is stiffer than the BSI wire due to the single-strand construction and the minimally plasticized PVC insulation.
Smoke characterization	Smoke is very light (barely visible). HCl vapor is unlikely to be produced due to the low temperature achieved in the wire. The primary constituent of the smoke is plasticizer.	More visible smoke than the 2 m test, but still very light smoke. Due to the higher temperature in the wire, a very small amount of HCl vapor will be produced.	More visible smoke than the 2 m test or the single wire 1 m test but still very light smoke. Due to the higher temperature in the wires, a small amount of HCl vapor will be produced.	More visible smoke than the BSI wire tests but still very light. A minor amount of HCl is produced but for a shorter duration than the BSI wire tests.
Test period	180 seconds	60 seconds	60 seconds	30 seconds
Electrical load	Constant voltage — 6.0 volts dc, current varies from 0 to 15 A during the test due to changing resistance in the wire.	Constant voltage — 6.0 volts dc, current varies from 0 to 15 A during the test due to changing resistance in the wire.	Constant voltage — 6.0 volts dc, current varies from 0 to 30 A during the test due to changing resistance in the wire.	Constant current of 28 A. Voltage varies from 0 to 18 volts dc during test due to changing resistance in the wire.
Pass/fail criteria	Fire detection system should "respond" within 120 seconds of the end of the test period.		"Alert" or "pre-alarm" signal within 120 seconds of the end of the test period.	

Appendix B: Illustrations of Securiton ASD PipeFlow Design

This Appendix provide illustrations of typical SecuriFire ASD pipe network design using Securiton ASD PipeFlow software tool (see Figure 27 below).



(a) Cleanrooms (dry coil vents)



(b) Ambient-controlled High-bay Warehouse (4-level detection)

Figure 27 Illustration of Securiton ASD PipeFlow software tool (Cleanrooms & Associated Controlled Environments)

Appendix C: SecuriSmoke ASD Accessories

This Appendix provides a summary of SecuriSmoke ASD accessories (see Table 23) for challenging environments:

1. Dusty
2. High humidity or high air temperature
3. Intrinsic safety or potentially explosive
4. Deep Freezers

Table 23 Summary of SecuriSmoke ASD accessories for challenging environments

Challenging Environment	Illustration	Description
Dusty		**DFU 911** (large volume) or **FBS 25 PC (small volume)** dust filter unit increases the service life of the smoke sensors used in the ASD and greatly reduces the likelihood of false alarms
		**DTB 25 PC** Dirt trap box used in very dusty rooms. Inserted into the sampling pipe before dust filter
		**ADB 500** automatic blow-out device 1 sampling pipe is automatically blown out and cleaned, to prevent fault messages caused by clogged aspiration points and also to avoid false alarms.
		**MV 25 PVC or MV 25 ABS** Manual ball valve for revision and cleaning works with compressed air
High Humidity or High Air Temperature		**WRB 25 PVC or WRB 25 ABS** Water retaining box Used in rooms with high humidity
		**LK 35 – PVC or LK 35 – ABS** used as an air cooler when the sampling pipe is in a room >60°C. Can also be used as a water separator in rooms with high amount of air humidity and / or condensing water because of temperature differences
Potentially Explosive		**DFA 25-3 (**Equipment category IIC) or **DFA 25-2 (**Equipment category IIB) or **DFA 25-1 (**Equipment category IIA) Detonation flame arrester for explosion zones
		**ASD Housing Ex** IP54 Steel used as additional personal protection in explosive areas or serve as a mechanical protection measure
		**GC 25 Ex** Grounding Clamp for 25mm ASD pipes with ATEX certification. Copper or stainless-steel piping
Inside Deep Freezers		**HEAT 3.0/3.5/4.0/4.5/5.0 PVC HEAT 3.0/3.5/4.0/4.5/5.0 ABS** in deep-freeze rooms to prevent the freezing of the aspirating holes
		**WCU 535** Wiring connection unit introduction of the supply of the sampling point with heating into the aspirating tube, with internal clamps

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