Clean Rooms & Associated Controlled Environments

SecuriSmoke ASD

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1 Introduction

A single fire event in a cleanroom can cause millions of dollars in damage long before flames become visible. In highly controlled environments such as semiconductor fabrication plants (FABs), pharmaceutical facilities, biotechnology laboratories, hospitals, and medical device manufacturing plants, even small fires can be devastating and dangerous. Early detection is crucial, but the nature of the controlled airflow in these environments, alongside restrictions to access, provide challenges that require specific consideration.

In some cases, the greatest danger is the need to evacuate people with reduced mobility; but for many manufacturing sector cleanrooms, smoke contamination, production disruption, and operational downtime are the key drivers of the need for early detection. As these industries continue to expand, the need for highly reliable and early fire detection has never been greater.

The global growth of cleanroom-dependent industries is driving unprecedented investment in controlled environments: Semiconductor manufacturing, fuelled by artificial intelligence, automation, electrification, and renewable energy technologies, is experiencing particularly rapid expansion. The global cleanroom technology market size was around US$ 7.69 bn in 2024 and is expected to grow at a CAGR of 5.9% from 2025 to 2030 (US$ 10.82 bn) across main end-user segments of pharmaceutical, medical device, biotechnology, hospitals and diagnostic centres. Every new facility, retrofit, modular cleanroom, or controlled storage area introduces unique fire risks that must be addressed without compromising stringent environmental requirements.

Unlike conventional buildings, cleanrooms present complex challenges for fire detection. High air-change rates, directional airflow patterns, pressure differentials, and extensive HVAC systems are designed to remove contaminants rapidly. Unfortunately, these same characteristics can dilute, disperse, or redirect smoke, making conventional smoke detection less effective. In semiconductor facilities, large open production areas, sub-floor cable spaces, process equipment enclosures, hazardous gas systems, chemical storage, and restricted maintenance access further complicate detector placement and system maintenance. 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), resulting in an air change rate of 600/hour or more.

The fire risk itself can be significant. Industrial and manufacturing facilities frequently contain electrical equipment, high-temperature processes, flammable liquids, solvents, oxidising agents, pyrophoric gases, and other hazardous materials. Hospitals and healthcare facilities face additional risks from oxygen-enriched environments, alcohol-based preparation products, and critical life-safety operations such as surgical procedures. Even small incidents can escalate rapidly or result in extensive contamination and costly business interruption. In semiconductor manufacturing, a minor overheating event or smoke release can contaminate production tools and cleanroom environments, potentially causing losses that far exceed direct fire damage.

For these reasons, Early Warning Fire Detection (EWFD) has become a critical component of modern cleanroom fire protection strategies. High-sensitivity aspirating smoke detection systems can identify incipient-stage combustion before visible smoke develops, providing valuable time for investigation, intervention, equipment shutdown, evacuation, or suppression system activation. Early detection also supports reliable operation of pre-action sprinklers, gaseous suppression systems, water mist installations, and other fire protection measures.

A well-designed fire detection system must do more than satisfy code compliance: It must address operational risk, protect high-value assets, minimise false alarms, and support business continuity. By combining risk-based design with advanced detection technologies, facilities can achieve earlier intervention, improved life safety, reduce downtime, and enhance protection of critical processes. In cleanrooms and associated controlled environments, early and reliable fire detection is not simply a regulatory requirement – it is an essential safeguard for people, property, and uninterrupted operations.

The purpose of this Design Guide is to provide fire safety and protection consultants, qualified fire system specifiers, design engineers or technicians with recommendations for the application and use of SecuriSmoke ASD to provide Early Warning Fire Detection in a variety of cleanroom facilities. In particular, Securiton's ASD 2000, with its unprecedented aspiration power and sensitivity, allows both large open spaces and areas with high airflow to be covered effectively and to a high standard both of early warning and reliability.

This Design Guide focuses on the following types of cleanroom and related facilities:
- Controlled environments and modular cleanrooms
- Semiconductor Fabrication Facilities (FAB)
- Ambient-controlled manufacturing

Although the food manufacturing industry also uses cleanrooms, these typically ISO 6 and ISO 7 classified facilities are covered in detail in Securiton's Food Processing Facilities Design Guide, which offers a combination of ASD and linear heat solutions due to the need for food-grade materials to withstand vigorous cleaning. They are therefore not included here. Similarly, hospital operating theatres and isolation wards share many characteristics with cleanrooms, but these are covered by the Design Guide to Hospitals and Large Clinics.

The guide sets out relevant codes and standards but seeks to go beyond these, using risk-based methodology in order to facilitate the design of detection systems aimed at maximising egress times and allowing for a timely, staged response that minimises the risk of a fire causing significant damage, disruption or injury.

The Design Guide also provides key requirements on Inspection, Testing and Maintenance (ITM) of SecuriSmoke ASD; and 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.

2 Aspects of fire safety and prevention

A cleanroom is defined by ISO 14644-1 as a room in which the concentration of airborne particles is controlled, constructed and used in a manner to minimise the introduction, generation and retention of particles inside the room and in which other relevant parameters such as temperature, humidity, and pressure, are controlled as necessary.

More specific definitions and standards are provided by the different industries hat commonly use cleanrooms. In a pharmaceutical context, for example, cleanrooms are those rooms that meet the code of GMP[1] 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.

A wide range of manufacturing, warehousing and similar business operations also 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 optical components, hospital operating theatres and ISO 8 for production of ball bearings.

For historical reference, Table 1 also shows the former USA Federal Standard 209E cleanroom classes. FS-209E was withdrawn in 2001 and has been superseded in practice by ISO 14644-1, which is now the internationally recognised standard for classifying cleanrooms by airborne particle concentration.

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

Table 1 ISO 14644-1 classes vs. USA Federal Standard FS-209E

For easy reference throughout this Design Guide, Table 2 below shows a comparison between ISO Classifications and typical ACR (in ACH, air-change per hour)[2], room airflow velocity (in m/s or fpm and FFU[3] coverage (% of ceiling area). It is important to notice that these values are not ISO 14644-1 requirements but typical design/engineering guidance values that are commonly associated with cleanroom classes. The impact of the high airflow resulting from FFU ceiling coverage, air velocity for designated cleanroom class must be considered when designing the fire detection system.

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1 GMP: Good Manufacturing Practices

2 ACR: Air Change Rate (in Air-Change per Hour (ACH)), ACR range depends on the activities and equipment within the room (e.g. less obstructions, lower airflow).

3 FFU: Fan Filter Unit

ISO 14644-1 Class[4]	Air change rate, airflow and FFU ceiling coverage ACR (ACH)	Average airflow velocity m/s (fpm)	FFU ceiling coverage %
ISO 1	Up to 750 unidirectional	0.36-0.66 (70-130)	90-100%
ISO 2	360-600 unidirectional	0.31-0.51 (60-100)	80-100%
ISO 3	360-540 unidirectional	0.31-0.46 (60-90)	60-100%
ISO 4	300-540 unidirectional	0.25-0.46 (50-90)	50-90%
ISO 5	240-480 non-unidirectional	0.20-0.41 (40-80)	35-70%
ISO 6	150-240 non-unidirectional	0.13-0.20 (25-40)	25-40%
ISO 7	60-90 non-unidirectional	0.05-0.08 (10 -15)	15-20%
ISO 8	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%

Table 2 Typical air change rate, airflow and FFU ceiling coverage [1], [2], [3]

2.1 Cleanrooms and operation characteristics

Cleanrooms – or otherwise controlled environments – are used across a wide range of industries, including aerospace, chemical, manufacturing, semiconductor, research laboratories, biotech, pharmaceuticals, 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.

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 pre-action sprinkler system 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.

Typically, these controlled environments are required because strict and often highly sensitive manufacturing processes are in place. 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 cleanroom 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].

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[5] or ULPA[6] filters with filtration efficiency of up to 99.999% down to 0.12 microns.
- Room pressurization with the cleanroom is positively pressurized (to 12.5 Pa (0.05 in WC[7])) with respect to the adjacent areas [3].

[4] GMP EU Cleanroom Classifications (Grades) A B C D 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.

[5] HEPA (High-Efficiency Particulate Air), rated 99.99% efficient at removing particles ⩾ 0.3 μm

[6] ULPA (Ultra-Low Penetration Air), rated 99.999% efficient at removing particles ⩾ 0.12 μm

[7] WC: Water Column (1 in WC = 249 Pa)

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. 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.

The use of 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. Finally, 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.

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 3 categories of cleanroom-type facilities are the focus of this Design Guide:

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

2.1.1 Controlled environments and modular cleanrooms

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 European Union 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).

The benchmark of air cleanliness is particle concentration. Hence, air change rate (ACR) is a prime variable in determining ISO cleanness standards (according to Table 2). Other unique building design components include clean room ceilings, partitions, floor systems, placements of fan filter units (FFU), light fixtures and return air grills. 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.

Stringent cleanrooms for sterile or aseptic processes with a classification rating of ISO 5 or Grade A per EU GMP guidelines (FS-209E 100) 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 grills, especially in large cleanrooms, the airflow is also found to be unidirectional.

Generally, a 12.5 Pa (0.05 in WC) 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 5.0 Pa (0.02 in WC) 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.

Figure 1 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 installed within a warehouse-type facility

Figure 1 Controlled environments and modular cleanrooms

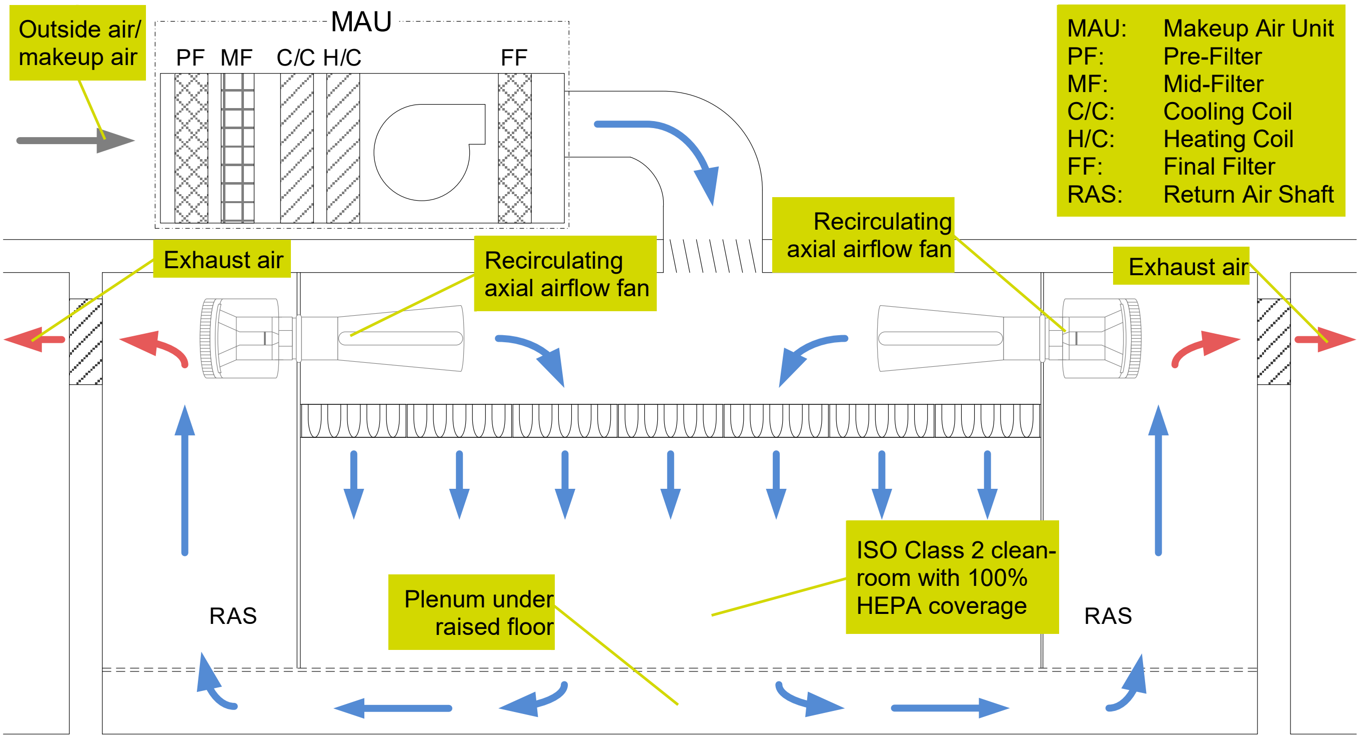
Apart from airflow and ventilation issues, goods sensitive to ambient conditions need to be stored and handled in an ambient-controlled environment. For example, European Good Distribution Practice Guidelines [4] and WHO require vaccines must typically be stored and handled in a range of 2 to 8°C (35.6 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). Fire detection for these refrigerated storages is the subject of separate Securiton design literature and are therefore not covered in detail in this guide. See the Case Studies on Refrigerated Storages and Ultra-Low Temperature Storage, available from Securiton.com.

2.1.2 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 2, 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), lower airflow cleanrooms are commonly designed as non-unidirectional (turbulent) airflow in a single-pass or recirculating pattern ([5]).

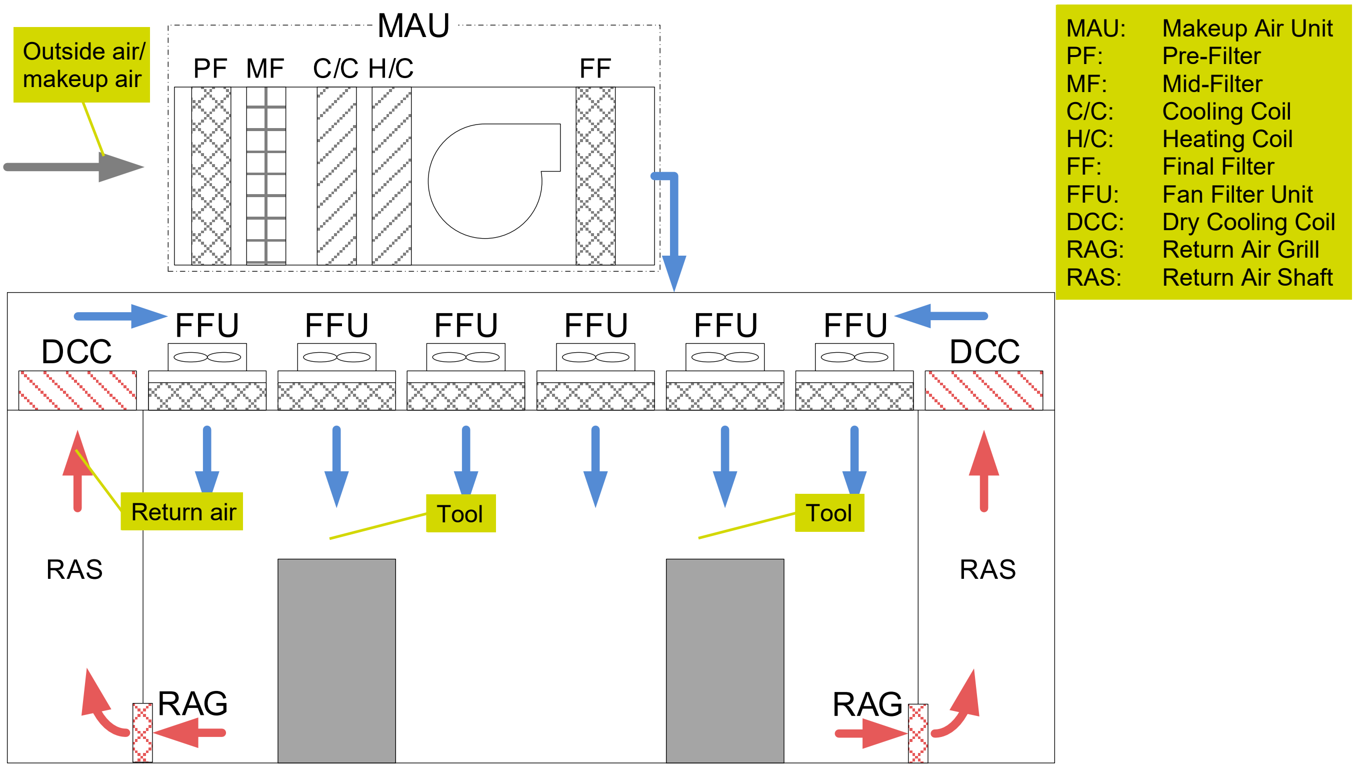
The space air velocity in a typical ISO Class 1 cleanroom or spaces within a cleanroom can be in the range of 0.35-0.66 m/s (70-130 fpm). Return air grills are always located lower near the floor and made as long as possible to increase the collection of dust particles over a larger area. Return air risers behind the grills 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 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) [3] at the top of the shafts before exhaust/exit or recirculation via filtration elements.

Figure 2 illustrates air circulation to exhaust ventilation cleanroom with raised floor or wall RAS[8] in the form of (a) single-pass or recirculating HVAC system and (b) Wall-return or (c) FDCU[9]-return ventilation scheme.

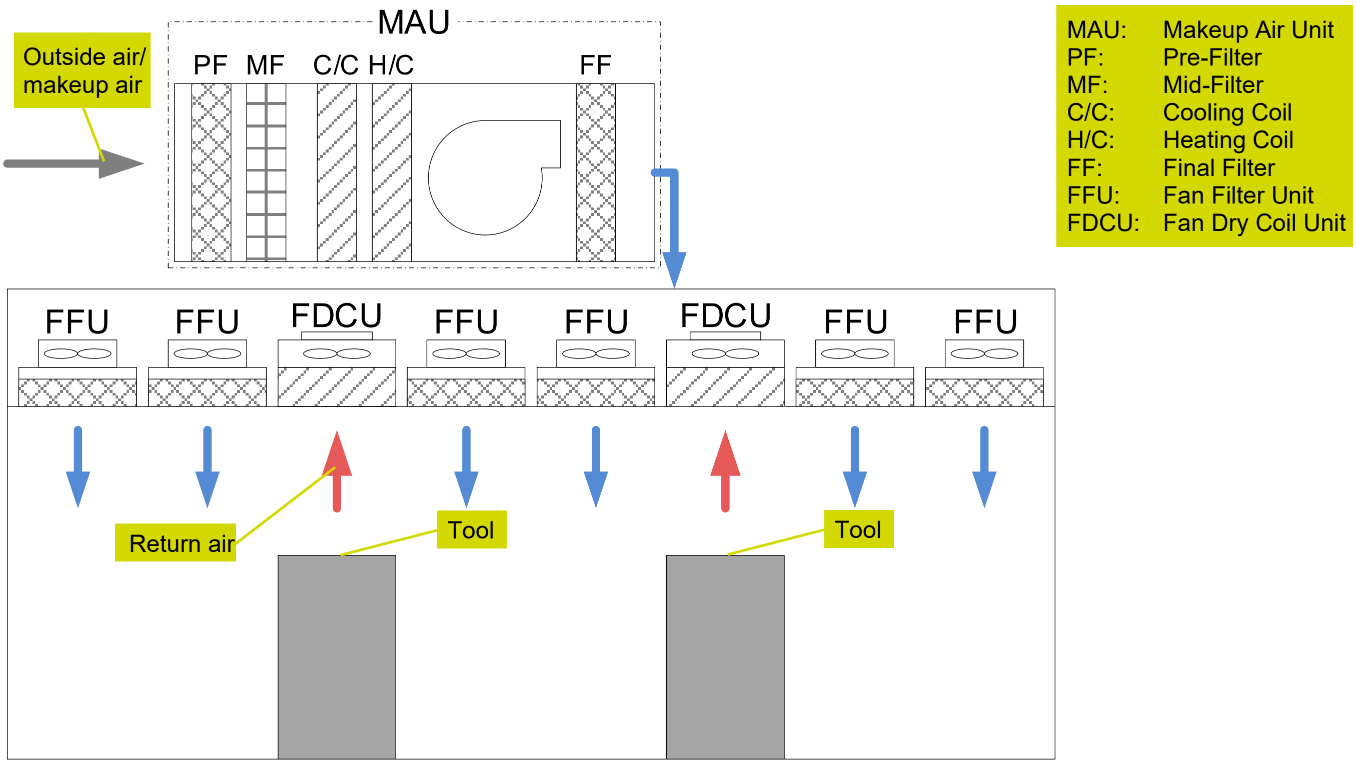


(a) Single Pass (red arrows air exhaust out) or recirculating (blue arrows internal) HVAC system

8 RAS: Return Air Shaft
9 FDCU: Fan Dry Coil Unit



(b) Wall-return ventilation cleanroom (red arrows return air) or recirculating (blue arrows internal)



(c) FDCU-return ventilation cleanroom

Figure 2: Air circulation/exhaust ventilation cleanroom with raised floor, wall RAS or FDCU

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 5.0 Pa (0.02 in WC) between each level of spaces are maintained.

Special design considerations are required for an Early Warning Fire Detection system for large FAB due to 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.

2.1.3 Ambient-controlled manufacturing

In addition to the buildings with controlled environments and large FAB described in chapters 2.1.1 and 2.1.2 that require a high level of cleanness (hence lower ISO Classes), other ambient-controlled manufacturing can be found, with unique hazards and challenges. For example, 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 [6]. 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 3 illustrates examples of ambient-controlled manufacturing (e.g. solar panels).

Figure 3 Ambient-controlled manufacturing

2.1.4 Operating theatres and sterile healthcare facilities

Hospital and healthcare facilities require a high standard of sterile, aseptic and constant accurate pressurisation to contain or isolate sensitive areas. These areas can be classified as cleanrooms and require reliable and early fire detection. They are covered in detail in the Securiton Design Guide to Hospitals and Large Clinics, and are therefore omitted from this document, which concentrates on industrial facilities.

2.2 Fire risk, consequence and safety

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.

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, electrical bus bars and electrical panels throughout the plant have a high combined peak power load [7].

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 inside cleanrooms and similar controlled environments are generally assessed in line with the classification of occupancy as well as commodities (for example NFPA 1 [8] and FM Global DS 8-1 [9]), 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 [10] 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.

To enhance risk management, fire prevention and fire protection further, large insurers such as FM Global and industry peak body SEMI[10] 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 [11], SEMI Safety Guideline for Fire Risk Assessment and Mitigation Process [12] and Industrial Risk Insurers (known as AXA SA nowadays) Guiding Principles for the Protection of Semiconductor Manufacturing Facilities [13] [14].

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 [15] and Health Care Facilities [16] and Cleveland Clinic (USA) mandated facilities conforming to its Fire Protection and Life Safety Design Standards.

Most, if not all cleanrooms 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.

Figure 4 illustrates key aspects and advantages of using a reliable EWFD system[11]:

- How the intensity and destructive power of a blaze grow exponentially, from an incipient stage, through a growth period and into a fully-fledged fire which will rapidly cause a total loss as well as being extremely dangerous to persons.
- How business operation interruptions and potential losses due to fire damage may be minimised by EWFD, compared to standard detection and the even greater damages when only sprinklers are used, with no prior detection.
- Suitable points for a staged response where EWFD is coupled with multiple stages of alert and alarm.
- Increase of available safe egress times as result of the use of EWFD.

With an Early Warning Fire Detection system, fire incidents or small fire situations can be managed during their incipient stage to avoid operational interruption and damages or avoidable site-wide evacuation and power shut-downs, or at least keep such incidents to an absolute minimum. 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 cleanrooms, EWFD helps ensure the effectiveness of ceiling level sprinkler operation.

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[10] SEMI: Semiconductor Equipment and Materials Institute www.semi.org

[11] 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 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.

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 plant operation occurs, resulting in minimal interruption to the operation and consequential impact to the entire supply chain.

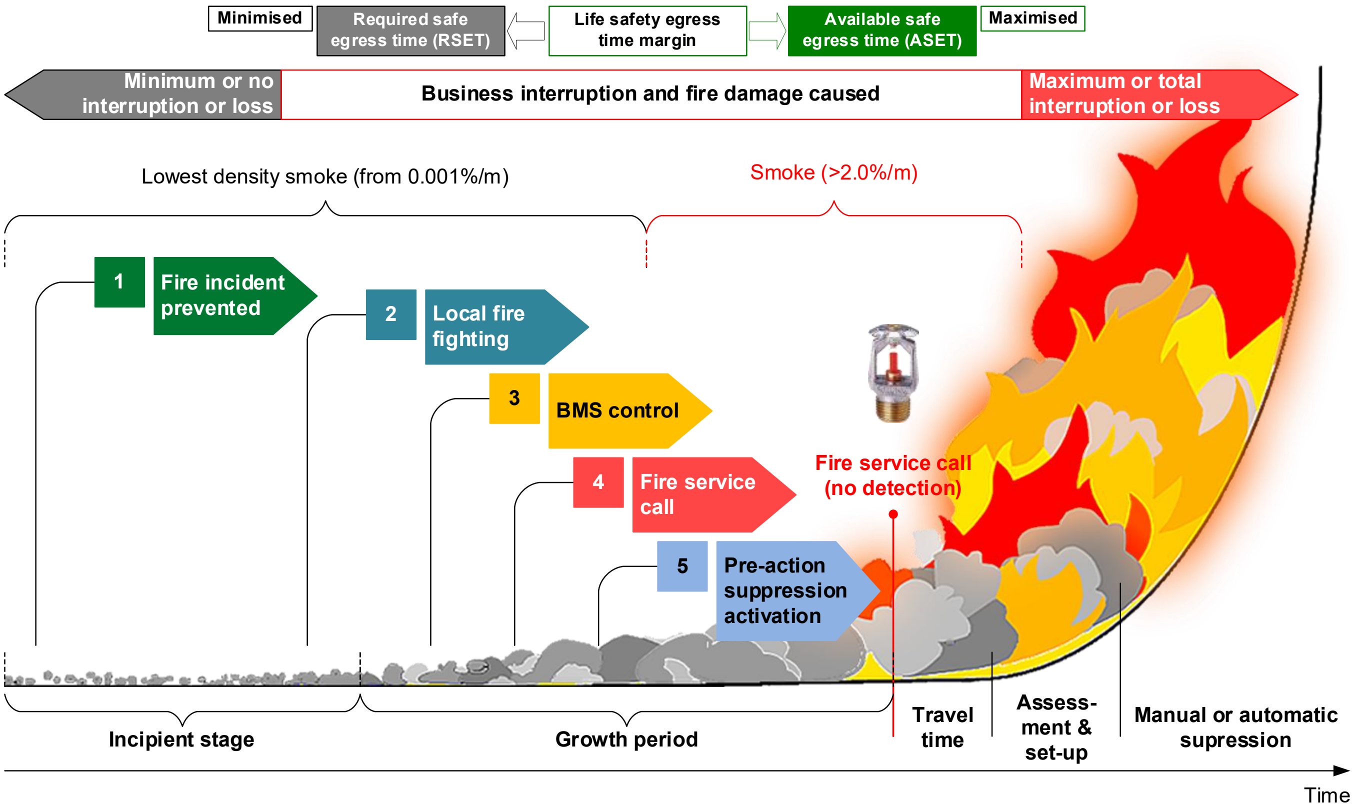


Figure 4 Impact of a detection system on life safety and loss due to fire damages

2.3 Challenges to Early Warning Fire Detection

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 and associated controlled environments that cover diverse building occupancies like industrial, manufacturing, storage, healthcare and pharmaceuticals. These buildings often come with 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.

The use of an Early Warning Fire Detection system presents 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. SecuriSmoke ASD Early Warning Fire Detection systems address all the key challenges to deliver early and reliable fire detection in cleanrooms and associated facilities (see Table 3).

Challenge	SecuriSmoke ASD
Large Open Space	Active aspirating sampling with powerful fans and global approval listings.
Natural ventilation, high air velocity	Powerful aspiration and high sensitivity detection chamber – especially in the ASD 2000 – can offer reliable and early warning in high airflow. Flexible placement of sampling points and spacing between them.
Rapidly diluted smoke and stratification	Very high, consistent detection sensitivity for incipient fires; position of sampling holes at various levels closer to the potential sources of fire risk. ASD 2000 offers unprecedented pipe layout options thanks to 1000 pa aspiration engine.
Wide ambient temperature range and high humidity	Practically no limitation to detector installation location. Operating temperature range is -30°C to 60°C (-22°F to 140°F).
Risk-based detection with complex design considerations	Unique features include option of dual detection chambers, maximum number of sampling holes for required level of sensitivity. Add-on intelligent pinpoint detection REK for better addressability and control. Capable of integrating with gas, off-gas or flame detectors; designed to work with gaseous suppression, water mist and pre-action sprinkler systems. Flexible sampling pipe and sampling hole placement using Securiton design tools for large scale project design for detection at multilevel, compartments, vertical riser type, in-cabinet or vault-like concealed spaces. Detector units in SecuriSmoke ASD 2000 product line come with more pipe channels, dual alarm zones, wide sensitivity range, much longer pipe run with powerful aspirator and sufficient sampling holes; Large coverage from one single detector delivering Class A and Class B VEWFD and EWFD protection throughout cleanrooms. Flexible design with to caters for pressure differentials across adjacent spaces.
Obstructed or difficult access	Active sampling technology with detectors and testing points often located in areas easy to access or outside the protected areas. Positioned at locations such as the return air grills in large containment areas to best supplement general open space protection. Active sampling technology with detectors and testing points located in areas easy to access or outside the protected areas, or positioned at locations such as inside the return air shafts 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 535HD and SecuriSmoke ASD 2002/2004 with two detectors, designed to cover one single protected zone).
Low TCO and easy access for maintenance	SecuriSmoke ASD main detector units are installed remotely in an easy access area with only sampling pipes run into the protected areas. Routine ITM services are done from the main detector unit with no interruption to business operation.

Table 3 Challenges and solutions (Early Warning Fire Detection)

2.4 Code compliance and Performance-based Design

Fire protection professionals work within the prescriptive constraints of the applicable building codes and standards such as NFPA 101 [8] and The International Building Code [17] while applying the best engineering practices to address industry and building occupancies specific needs[12]. In particular, the risks and uninterrupted business operation requirements in cleanrooms and associated facilities must 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 [16] or local government agency directive (e.g. [18]).

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 [19]. A PBD approach is commonly adopted for either of the following:

- As a means to determine equivalency to a prescriptive code or standard
- 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 [15] and SEMI [12].

Special note to the current latest edition of NFPA 101 and NFPA 99 in regards fire safety in healthcare and healthcare occupancies, changes were made mainly based on lessons learned during the COVID-19 pandemic in early 2020s. NFPA 101 also expanded the scope of the code's reference to NFPA 241 [20] where alteration of healthcare bundling uses need to adhere to strict processes to assess and evaluate the impact on existing fire and building safety systems.

Table 4 illustrates how Early Warning Fire Detection system performance, as well as the fire safety goals and objectives are defined.

Sensitivity	BS/EN 54-20 [21][13]	NFPA 76 [22]
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 [23].	Systems that use fire detection-initiating devices to achieve certain life safety and property protection, in accordance with applicable standards such as NFPA 72 [24].

Table 4 Similarity in Early Warning Fire Detection definitions

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 [24], BS 5839-1 [25] or VdS 2095 [26] 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 [27], BS 6266 [28]) and risk management orientated FM Global Data Sheets related to cleanrooms or cleanroom-type buildings such as DS 7-7 [11] and DS 1-56 [29].

[12] 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.
[13] ISO 7240-20 [30] and AS 7240-20 [31] are derived from BS/EN 54-20.

3 Early Warning Fire Detection Design

This chapter describes the use of aspirated smoke detection to combine the prescriptive and risk-based approaches to design a fit-for-purpose fire detection system for cleanrooms and associated controlled environments. 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. In particular, the new SecuriSmoke ASD 2000 range offers unprecedented power and sensitivity, while being one of the quietest such devices on the market.

3.1 Securiton detection product portfolio

This Design Guide focuses on Securiton aspirating smoke detection systems, used for EWFD in cleanrooms and otherwise controlled environments. Key performance parameters of the SecuriSmoke range are shown in

Model	Key performance parameters								
Sampling holes, pipe length, spacing/sensitivity									
	Max. # of holes (Class)/Sensitivity/Zone					**Max. aggregated pipe length**	**Max. distance to furthest hole**		
Class	A	B	C	Alarm Sensitivity % obs/m	Alarm zones		A	B	C
SecuriSmoke ASD 2001	31	80	120	0.01 - 30	1	400 m	90	110	150
SecuriSmoke ASD 2002	62	160	240	0.01 - 30	2	700 m	80	100	115
SecuriSmoke ASD 2004	62	160	240	0.01 - 30	2	700 m	70	90	90
Supplement product selection									
SecuriSmoke ASD 531	6	8	12	0.02 - 10	1	75 m	40 m		
SecuriSmoke ASD 532	8	12	16	0.02 - 10	1	120 m	70 m		
SecuriSmoke ASD 533 1/2	32	100	100	0.02 - 10	2	400 m	2x80 m		
SecuriSmoke ASD 535-3/4	36	112	240	0.02 - 10	2	600 m	2x110 m		
Rating and operational data									
SecuriSmoke ASD	IP54 (IP66 for SecuriSmoke ASD 535-3/4 HD)								
	Operating temperature					**# of Relays: Built-in + (Expanded – Module)**			
SecuriSmoke ASD 531	-10 to +55°C (14 to 131°F)					2 + (5)			
SecuriSmoke ASD 532/533	-20 to +60°C (-4 to 140°F)					2 + (10) or 3 + (10)			
SecuriSmoke ASD 535/535HD	-30 to +60°C (-22 to +140°F)					3 + (10)			
SecuriSmoke ASD 2001	-30 to +60°C (-22 to +140°F)					3 + (10)			
SecuriSmoke ASD 2002	-30 to +60°C (-22 to +140°F)					5 + (10)			
SecuriSmoke ASD 2004	-30 to +60°C (-22 to +140°F)					5 + (10)			
REK	0 to +50°C (32 to 122°F)					1 (NA)			

Table 5 below.

Model	Key performance parameters[14]								
Sampling holes, pipe length, spacing/sensitivity									
	Max. # of holes (Class)/Sensitivity/Zone					**Max. aggregated pipe length**	**Max. distance to furthest hole**		
Class	A	B	C	Alarm Sensitivity % obs/m	Alarm zones		A	B	C
SecuriSmoke ASD 2001	31	80	120	0.01 - 30	1	400 m	90	110	150
SecuriSmoke ASD 2002	62	160	240	0.01 - 30	2	700 m	80	100	115
SecuriSmoke ASD 2004	62	160	240	0.01 - 30	2	700 m	70	90	90
Supplement product selection									
SecuriSmoke ASD 531	6	8	12	0.02 - 10	1	75 m	40 m		
SecuriSmoke ASD 532	8	12	16	0.02 - 10	1	120 m	70 m		
SecuriSmoke ASD 533 1/2	32	100	100	0.02 - 10	2	400 m	2x80 m		
SecuriSmoke ASD 535-3/4	36	112	240	0.02 - 10	2	600 m	2x110 m		
Rating and operational data									
SecuriSmoke ASD	IP54 (IP66 for SecuriSmoke ASD 535-3/4 HD)								
	Operating temperature					**# of Relays: Built-in + (Expanded – Module)**			
SecuriSmoke ASD 531	-10 to +55°C (14 to 131°F)					2 + (5)			
SecuriSmoke ASD 532/533	-20 to +60°C (-4 to 140°F)					2 + (10) or 3 + (10)			
SecuriSmoke ASD 535/535HD	-30 to +60°C (-22 to +140°F)					3 + (10)			
SecuriSmoke ASD 2001[15]	-30 to +60°C (-22 to +140°F)					3 + (10)			
SecuriSmoke ASD 2002	-30 to +60°C (-22 to +140°F)					5 + (10)			
SecuriSmoke ASD 2004	-30 to +60°C (-22 to +140°F)					5 + (10)			
REK	0 to +50°C (32 to 122°F)					1 (NA)			

Table 5 SecuriSmoke ASD products

3.2 SecuriSmoke ASD design criteria

Airflow and detection sensitivity are two main factors that affect SecuriSmoke ASD sampling hole spacing. Table 6 summarises some key design criteria for deploying Early Warning Fire Detection to protect cleanrooms.

To provide clarity, below are some key terminologies:

- **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., End-of-test EOT condition) and the notification of their presence at the ASD detector

Pipe network layout and length of single or aggregated pipe length, and the fan type and fan speed setting 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 the SecuriSmoke ASD PipeFlow design tool. For ASD 2000 installations, the enhanced PipeFlow 3D is available. PipeFlow offers to calculate a pipe layout in three modes:

[14] Highlight performance parameters as per EN54-20 (ASD), and REK point-type detector sensitivity per EN54-7. SecuriSmoke ASD sampling hole class sensitivity and corresponding hole coverage are as shown in Table 6.
[15] Operating parameters for ASD 2000 to be confirmed September 2026

1 EN 54-20 (also its derivatives ISO 7240-20 [30] and AS 7240.20 [31]): 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 [21] 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 72 and NFPA 76[16]: PipeFlow optimises its calculation for the required transport time for VEWFD, EWFD or SFD.
3 GB 50116[16]: PipeFlow additionally takes the reduced maximum pipe length into consideration.

Design recommendations described in this chapter assume the transport time meets the respective sampling hole or detector unit sensitivity level in Table 6 for target Class A (VEWFD), Class B (EWFD) or Class C (SFD) design.

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

Table 7 and Table 8 illustrate the design parameters commonly referred to when designing Early Warning Fire Detection with SecuriSmoke ASD in accordance with the codes such as FIA Code of Practice [27]. Smoke detector spacing based on air change rate (ACH[17]) per NFPA 72 or FM DS 5-48 [32].

Model	Key design criteria		
NFPA/FM Global	**VEWFD**	**EWFD**	**SFD[18]**
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
EN/AS/ISO/BS	**Class A**	**Class B**	**Class C#1**
Hole sensitivity[19]	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[20]	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[21]	<60 sec	<90 sec	<120 sec
Reaction time[22]	<60 sec	<60 sec	<60 sec

Table 6 Key design criteria (SecuriSmoke ASD)

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 [23] or [33])	Smoke is visible and sufficient to be detected by point or beam technologies (per [23]or [33])
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

[16] NFPA 76 and GB 50116 calculation is only available in PipeFlow 3D
[17] ACH: Air Change per Hour
[18] SFD/Class C refers to point type detectors, usually tested to an alarm sensitivity of 2.0 dB/m (36.9% obs/m (11.247% obs/ft)).
[19] For Securiton ASD products. Individual hole sensitivity can be determined using SecuriSmoke ASD PipeFlow design tool.
[20] 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.
[21] Transport Time of AS7240-20 conformed Class A, B and C are 60 sec, 90 sec and 120 sec respectively in AS1670-1.
[22] Reaction Time of 60 sec after EOT refers to EN 54-20 test requirements for relevant tests to Class A, B or C sensitivity.
[23] LOS: Large Open Space

Parameters	Key design considerations		
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 7 Sensitivity requirements vs. detection requirements (FIA Code of Practice [27])

Air changes/hr (ACH)	Spacing [m² (ft²)]
60	12 (125)
30	23 (250)
20	35 (375)
15	46 (500)
12	58 (625)
10	69 (750)
8.6	81 (875)
7.5	84 (900)
6.7	84 (900)
6	84 (900)

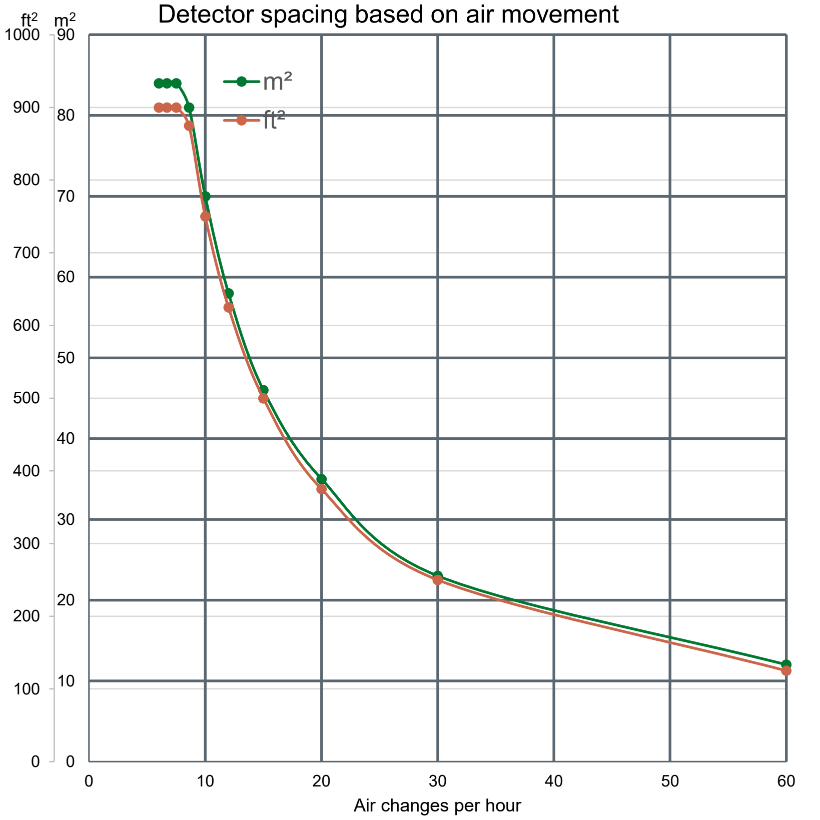


Table 8 Smoke detector spacing based on air change rate (NFPA 72 [24]/FM DS 5-48 [32]

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:

- Sampling hole spacing
- Sampling hole placement
- Sampling hole orientation (in general perpendicular downwards to the floor unless mentioned otherwise)

3.3 Detection design: Cleanrooms in general

Chapter 3.3 sets out the general SecuriSmoke ASD design approach for cleanrooms and controlled environments. It links sampling hole spacing, placement and orientation to airflow, pressure conditions, access constraints and the required detection performance class, providing the basis for the more risk-specific design methods that follow:

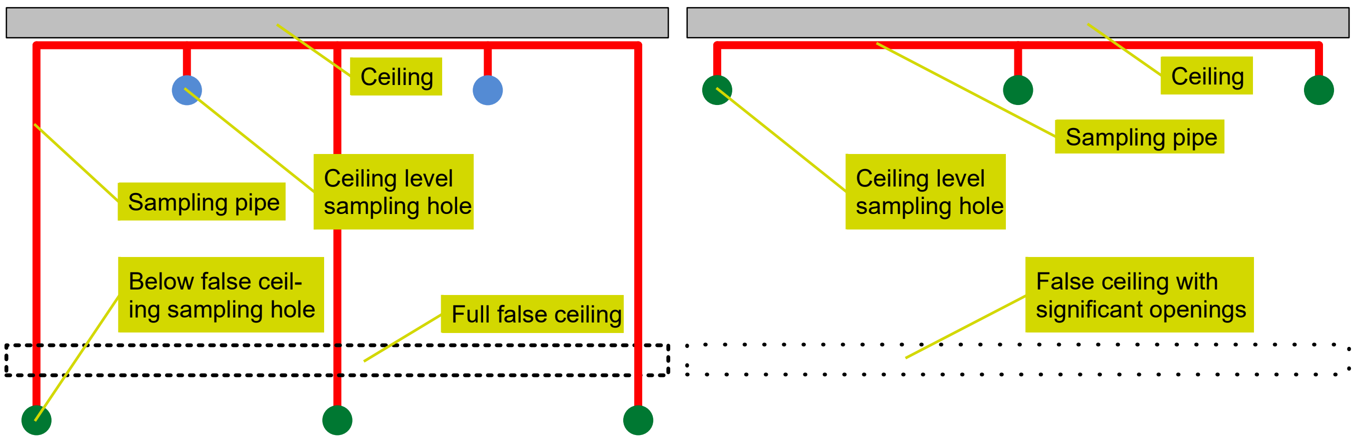
- General open space
- Underside ceilings with beams/joists
- Underside raised floors
- Pressurised environments
- Return air grills and duct detection

3.3.1 General open space

SecuriSmoke ASD Early Warning Fire Detection systems are generally installed at ceiling level 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. The shape of the ceiling must be taken into consideration, alongside system parameters and detection category limitations, with reference to airflow and pressure differential issues.

Figure 5 illustrates how SecuriSmoke ASD sampling holes are located underside a flat ceiling in a typical production area. As well as considerations for specific cleanroom environments – such as FAB or operating theatres – discussed in detail further in this chapter, consideration must be given to the ceiling structure. False ceilings are common in cleanroom environments, and are ideal for concealing ASD pipes:

- With a full suspended ceiling (≪50% openings), pipes extend down so that air can be sampled from above and below the false ceiling (Figure 5 (a)).
- For suspended ceilings with significant openings of 50% or more, sampling can take place in the space above to protect the room below (Figure 5 (b)).



(a) Full false ceiling (b) False ceiling with significant openings

Figure 5: Under ceiling ASD pipe layouts

Variable	Design recommendation
Spacing	For general design with regard to sensitivity class and ceiling height, refer to Table 7. For airflow <60 ACH: From 84 m² (900 ft²) @6 ACH down to 12 m² (125 ft²) @60 ACH, refer to refer to NFPA 72 or FM DS 5-48 [32]. Where a higher detection sensitivity is required, refer to for recommendations for Class A (VEWFD) and Class B (EWFD).
Placement	Underside the ceiling for exposed ceiling or ceiling with solid (Figure 5). Pipe network runs may not have to be straight to go around areas where individual detection systems may be provided, or large machine tools are located. SecuriSmoke ASD 2000 product line supports extra-long pipe runs to cater for such a design requirement. ASD pipes always run inside the suspended ceiling space (underneath the ceiling). Capillary sampling points may be used for below full false ceiling sampling points. For irregular or architecturally designed ceiling structures, Performance-based Design (PBD) is usually implemented where ASD pipe network and sampling point locations may be designed in such way that the detection performance meets the performance requirements. Often the physical structures of the buildings are used for pipe installation [34]. Always run sampling pipes away from busy operation areas and consider a blind end-cap to be located at a lower level or outside the busy production areas with easy access. It serves as a commissioning and ongoing ITM[24] test point for easy access [35].[25]
Orientation	Perpendicular downwards.

3.3.2 Underside ceilings with beams/joists

Figure 6 illustrates how SecuriSmoke ASD sampling pipes and sampling holes are located underside the beams/joists or inside deep beam pockets[26].

[24] ITM: Inspection, Testing and Maintenance

[25] For the initial commissioning and ongoing ITM (Inspection, Testing and Maintenance), 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 [27].

[26] 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 chapter 3.2.

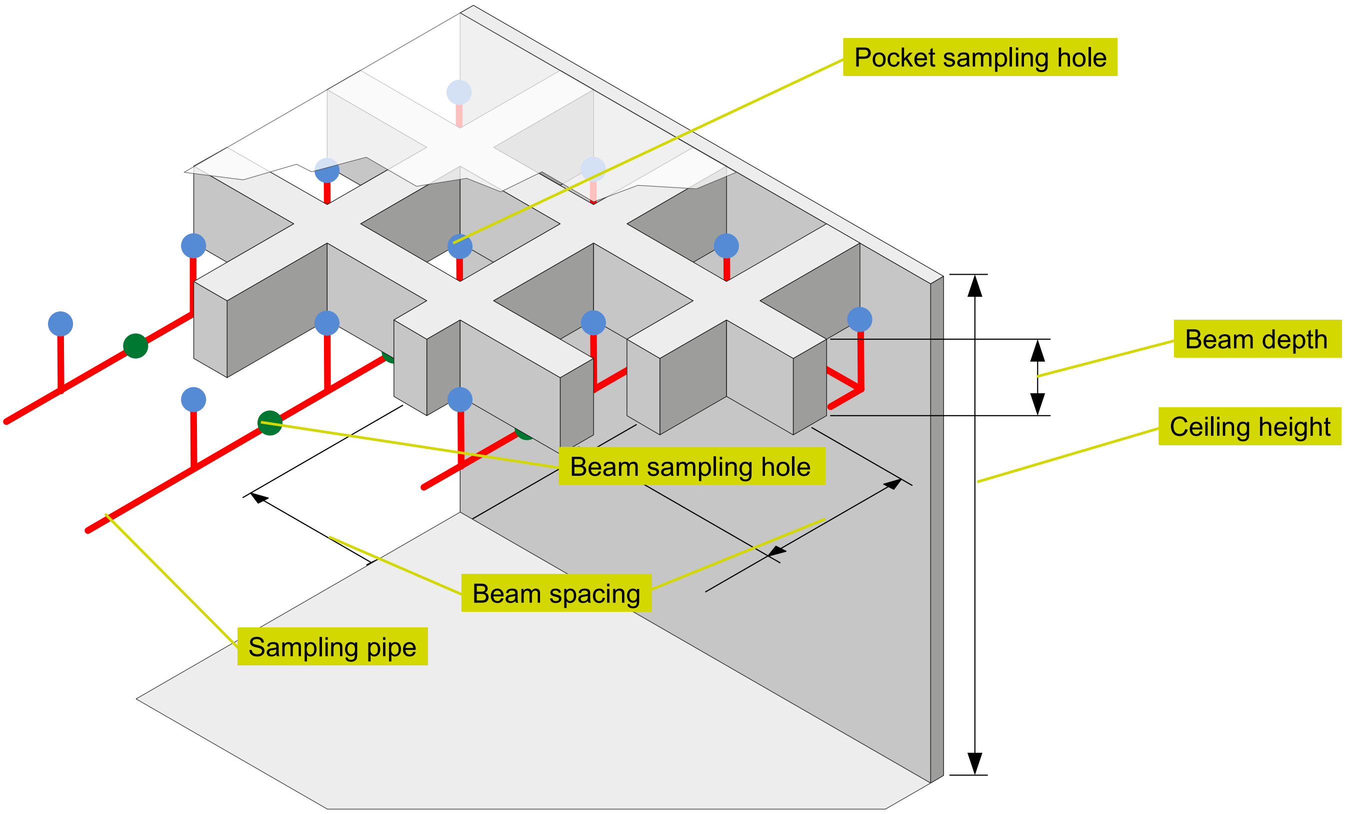


Figure 6: ASD pipe layout under ceiling with beams/joists

Variable	Design Recommendation
Spacing	In relation to airflow, refer to chapter 3.2 above. Sub-surface areas under a building or re-enforced floors for heavy loadings can have a ceiling resembling a beamed structure (Figure 6). ASD sampling pipes are generally installed under the beams according to the following. 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 green) ii. Beam spacing ≥ 40% of ceiling height: a sampling hole shall be placed on the ceiling within each beam pocket (see alternative sampling hole in blue). Note that more than one sampling hole may be required to cover a given beam pocket. 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 NFPA 72 [24] or FM DS 5-48 [32]. If a higher detection sensitivity is required, refer to Table 6 for recommendations for Class A (VEWFD) and Class B (EWFD).
Placement	Refer to PBD design approach [36] or prescriptive codes (e.g., NFPA 72 [24], summarised above)
Orientation	Perpendicular downwards (ceiling level)

3.3.3 Air plenum (underside raised floors and above ceilings)

Figure 7 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.

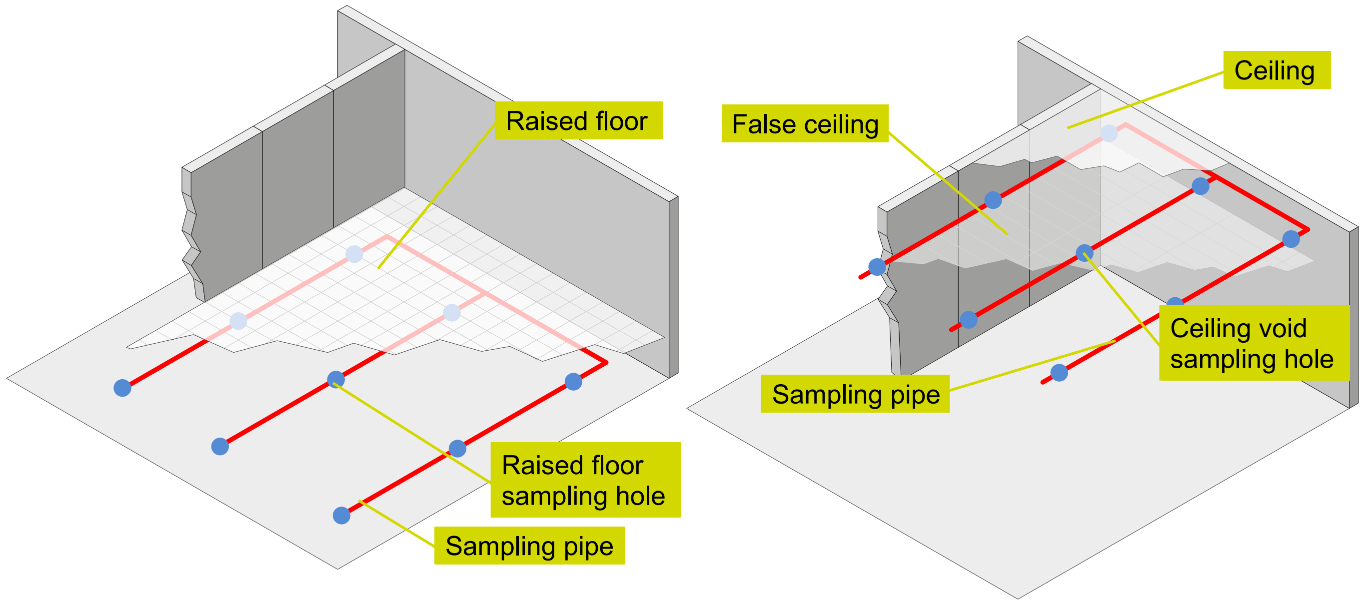


Figure 7 Fire detection placement (raised floor or ceiling plenum)

Varia-ble	Design Recommendation
Spac-ing	In relation to airflow, refer to chapter 3.2 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. SecuriSmoke ASD 2000 product line allows for significant amount of Class A and Class B sampling holes as well as extra-long pipe runs (see

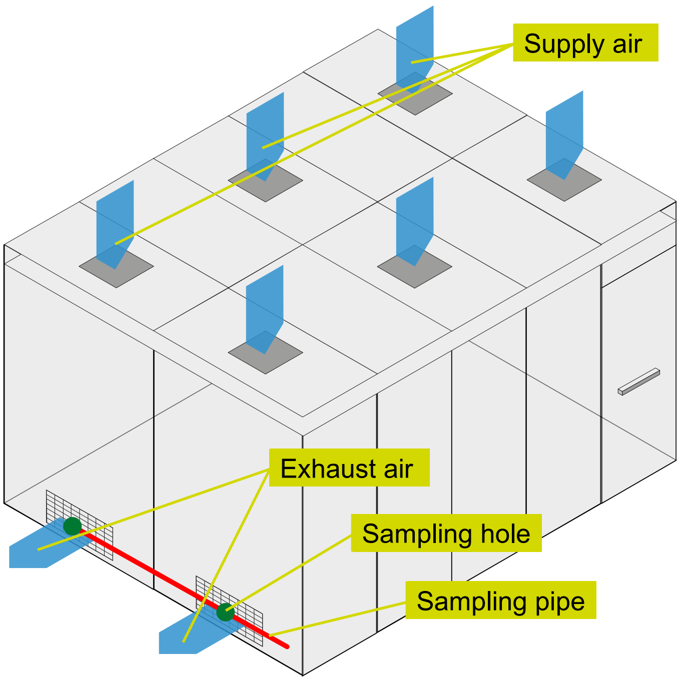
Model	Key performance parameters								
Sampling holes, pipe length, spacing/sensitivity									
	Max. # of holes (Class)/Sensitivity/Zone					**Max. aggregated pipe length**	**Max. distance to furthest hole**		
Class	A	B	C	Alarm Sensitivity % obs/m	Alarm zones		A	B	C
SecuriSmoke ASD 2001	31	80	120	0.01 - 30	1	400 m	90	110	150
SecuriSmoke ASD 2002	62	160	240	0.01 - 30	2	700 m	80	100	115
SecuriSmoke ASD 2004	62	160	240	0.01 - 30	2	700 m	70	90	90
Supplement product selection									
SecuriSmoke ASD 531	6	8	12	0.02 - 10	1	75 m	40 m		
SecuriSmoke ASD 532	8	12	16	0.02 - 10	1	120 m	70 m		
SecuriSmoke ASD 533 1/2	32	100	100	0.02 - 10	2	400 m	2x80 m		
SecuriSmoke ASD 535-3/4	36	112	240	0.02 - 10	2	600 m	2x110 m		
Rating and operational data									
SecuriSmoke ASD	IP54 (IP66 for SecuriSmoke ASD 535-3/4 HD)								
	Operating temperature					**# of Relays: Built-in + (Expanded – Module)**			
SecuriSmoke ASD 531	-10 to +55°C (14 to 131°F)					2 + (5)			

	SecuriSmoke ASD 532/533	-20 to +60°C (-4 to 140°F)	2 + (10) or 3 + (10)
	SecuriSmoke ASD 535/535HD	-30 to +60°C (-22 to +140°F)	3 + (10)
	SecuriSmoke ASD 2001	-30 to +60°C (-22 to +140°F)	3 + (10)
	SecuriSmoke ASD 2002	-30 to +60°C (-22 to +140°F)	5 + (10)
	SecuriSmoke ASD 2004	-30 to +60°C (-22 to +140°F)	5 + (10)
	REK	0 to +50°C (32 to 122°F)	1 (NA)
	Table 5)		
Placement	Inside the raised floor at the top of the raised floor or underneath the ceiling in the ceiling void 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.		

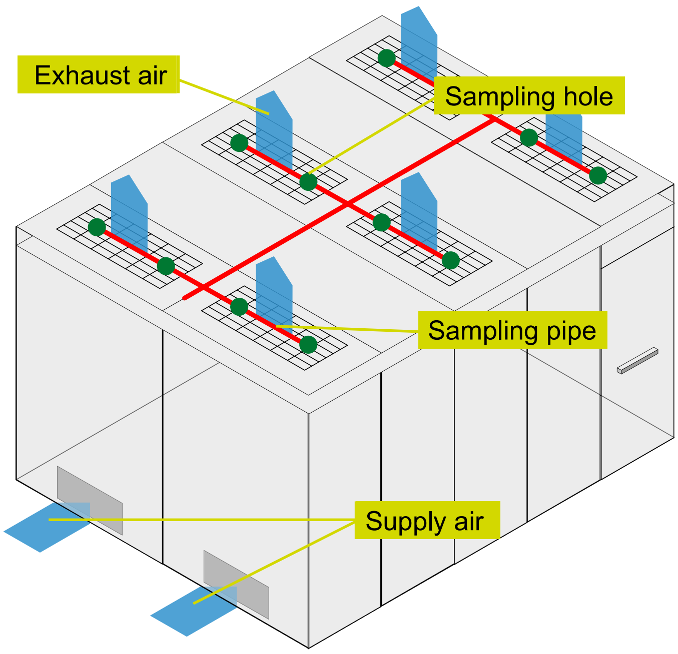
3.3.4 Pressurised environments

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 8 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 8: Pressurised rooms for isolation or containment

Variable	Design Recommendation (pressurised environments)
Spacing	See chapter 3.3.5 for sampling point spacing.
Placement	At the exhaust air grill see chapter 3.3.5 for sampling point placing.

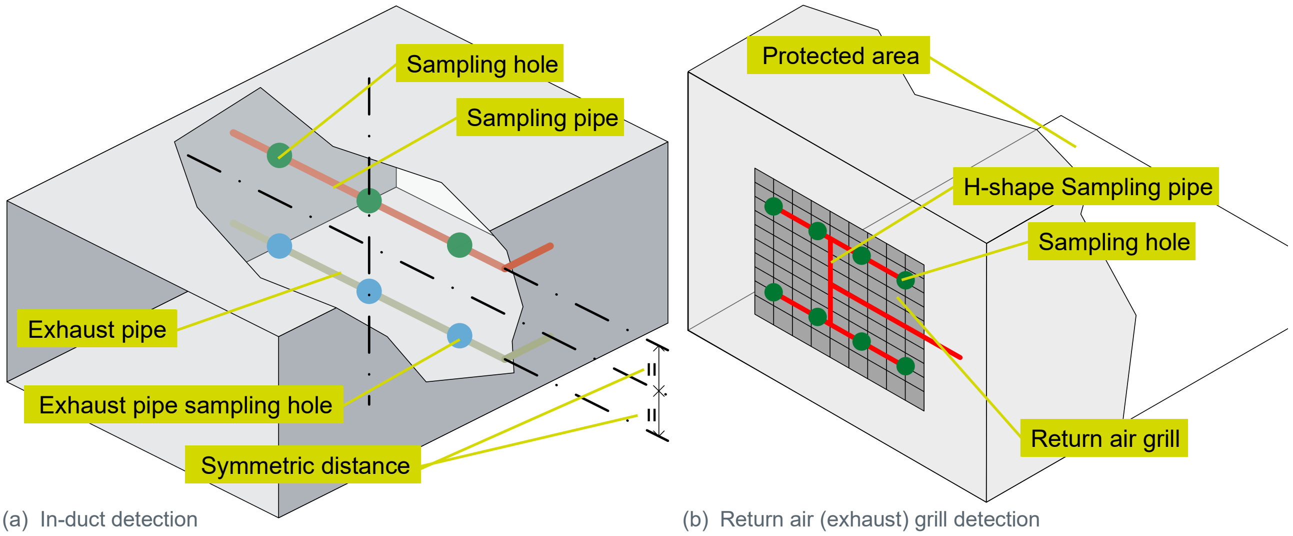
Orientation	Facing the incoming airflow; where possible, consider using Securiton sampling funnel SF ABS.
Special considerations	
	Place the detector unit as well as a blank end cap outside of the protected area, thus there is no need to access the protected space for service and maintenance purposes. If the sampling point are located within the protected area and the detector unit is mounted outside the protected area, the ASD detector exhaust air must be fed back to the protected area through an air-tight pipe network. 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 Return air grills and duct detection

NFPA 72 specifically requires that a smoke detector should not be used in airflow environments above 1.52 m/s (300 ft/min), unless it is recognised for use in specific airflow environments. Both BS 6266 [28] and NFPA 72 recognise the challenges of detecting smoke in high-airflow environments and stipulate reductions in spacing of detection points in such conditions. Special applications such as detection of smoke inside air ducts, in front of return air grills or large exhaust fans for open space areas are strictly limited to the types of detection technology approved as suitable for high-airflow environments.

SecuriSmoke ASD can be used for high airflow duct detection (approved to UL268A [37] with a maximum airflow of up to 20.3 m/s (4,000 ft/min). Figure 9 (a) is a cross-section view of a duct with the sampling pipe and pipe from the exhaust port inside the duct. SecuriSmoke ASD 532 model [35] is generally recommended as a cost-effective solution for in-duct detection. For such application, the total length of the sampling pipe and exhaust port pipe should be no more than 20 m (~65 ft).

Figure 9 (b) illustrates how ASD sampling points are positioned in front of a return air grill in an open space area.



(a) In-duct detection

(b) Return air (exhaust) grill detection

(c) SecuriSmoke ASD pipes covering large return air grill in FAB facility
Figure 9 Fire detection placement (duct or exhaust detection)

Variable	Design recommendation
In-Duct sampling pipe	
Spacing	In-duct detection: 2 to 4 or more sampling holes are used, hole spacing ranges from 10 to 80 cm (~4 to 30 in).
Placement	In-duct detection: Inside the duct, perpendicular and symmetric to the central line of the duct in relation to the pipe from exhaust port below. It is recommended (per NFPA 72) that duct smoke detectors/sampling points be located in a duct section that is between 6 and 10 equivalent duct diameters from bends or openings.
Orientation	Facing the incoming airflow using Securiton sampling funnel SF ABS.
In-Duct exhaust 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.
Return air (exhaust) grills	
Spacing	Maximum area coverage of 0.4 m^2 (4.3 ft^2) of the air grille (or exhaust fan) cross section area per sampling hole. When two or more rows of sampling pipes are needed for larger grills or fan cross-section area, sampling pipes are designed to form an 'H' shape.

Variable	Design recommendation
Placement	Installed across with pipe stand-off to the surface of the grill (fan) cross section area at ~250 mm (~10.0 in).
Orientation	Facing the incoming airflow using Securiton sampling funnel SF ABS.

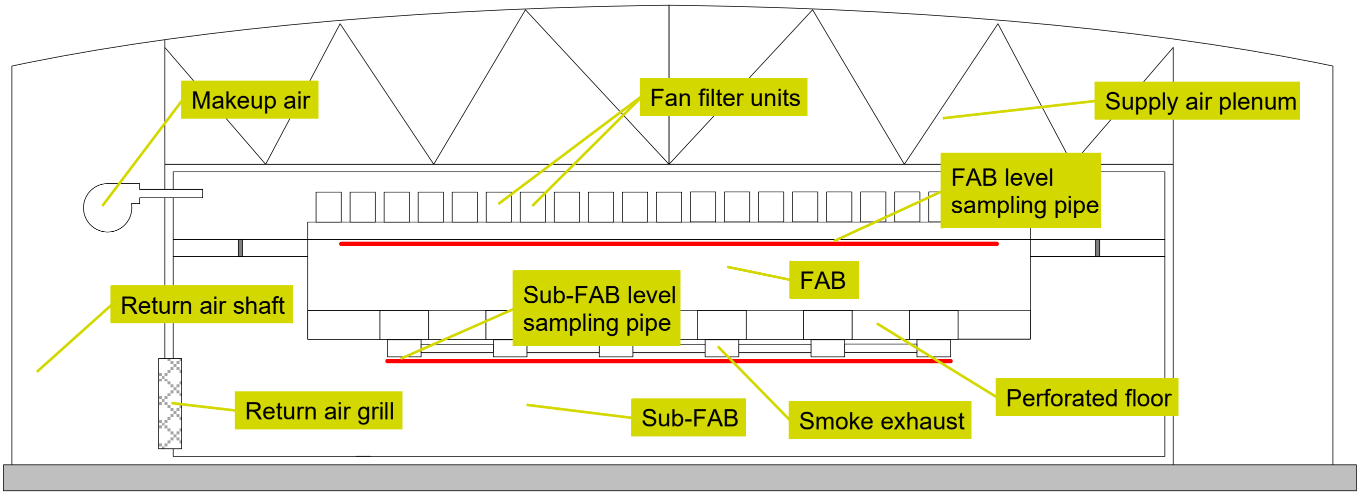
3.4 Detection design: Semiconductor fabrication (FAB)

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 ASD Early Warning Fire Detection to address the needs for:
- General FAB and sub-FAB open space protection
- Supply to return air path protection in FAB

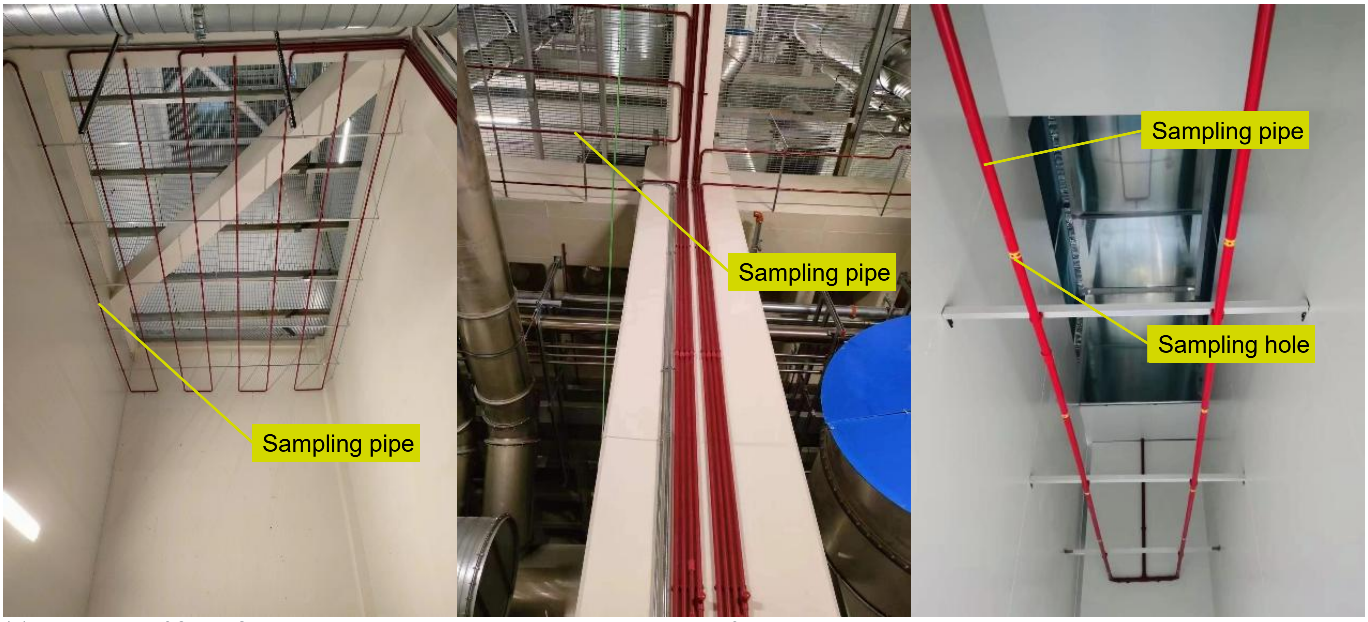
3.4.1 FAB and Sub-FAB open space

Figure 10 illustrates how SecuriSmoke ASD sampling pipe network are positioned at the ceiling level of FAB and sub-FAB facilities.



(a) Overview of ASD pipe network for FAB and sub-FAB open area protection[27]

[27] RAG: Return Air Grills (also known as Dry Coils in FAB)



(b) Examples of SecuriSmoke pipe networks installed in FAB and sub-FAB facilities

Figure 10: Fire detection placement (FAB and Sub-FAB open areas)

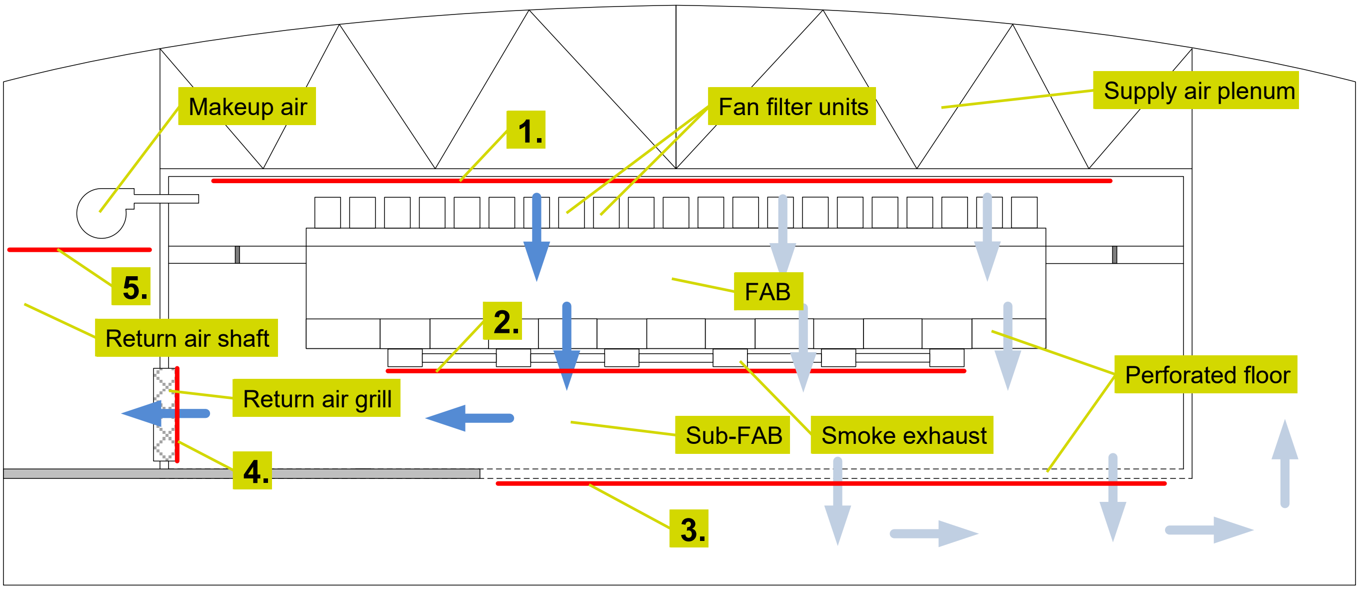
Variable	Design recommendation
Spacing	Refer to chapter 3.3 for ceiling level detection.
Placement	When risk-based detection methods are applied, the ceiling level smoke detection is often designed to meet local prescriptive code requirements.
Orientation	
Special considerations	
	When other risk-based ASD sampling methods and its placement are adopted per chapter 3.3, the ceiling level smoke detection spacing design can follow ACH rate up to the minimum coverage per sampling hole of 10-12 m^2 (108-125 ft^2)
	Pipe network runs may not have to be straight due to large FAB's interior complex machine tools and test bench enclosure layout. SecuriSmoke ASD 2000 products support extra-long pipe runs to cater for such a design requirement
	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

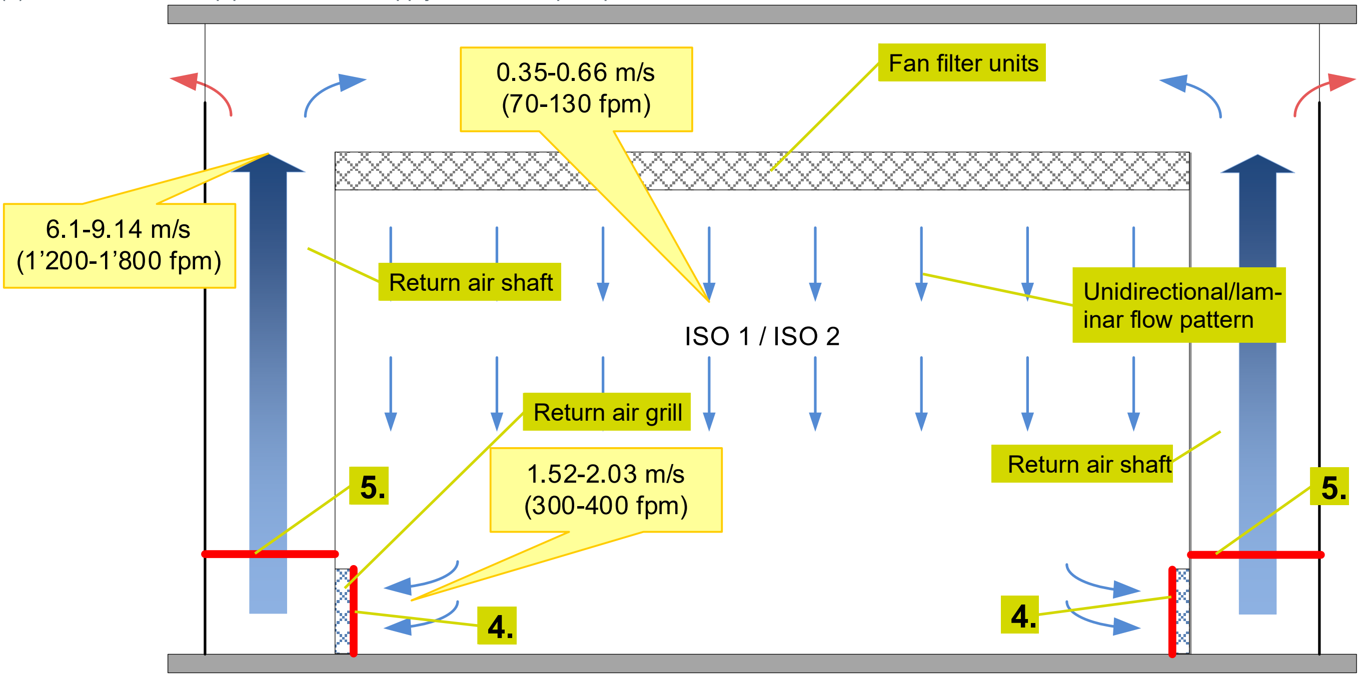
One of the key advantages resulting from the use of SecuriSmoke ASD Early Warning Fire Detection, is its ability to detect fire incidents early in high air flow environments where smoke can be diluted quickly before reaching the location where conventional smoke detectors would be installed. One common practice for large FAB facilities is to place 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 11 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.

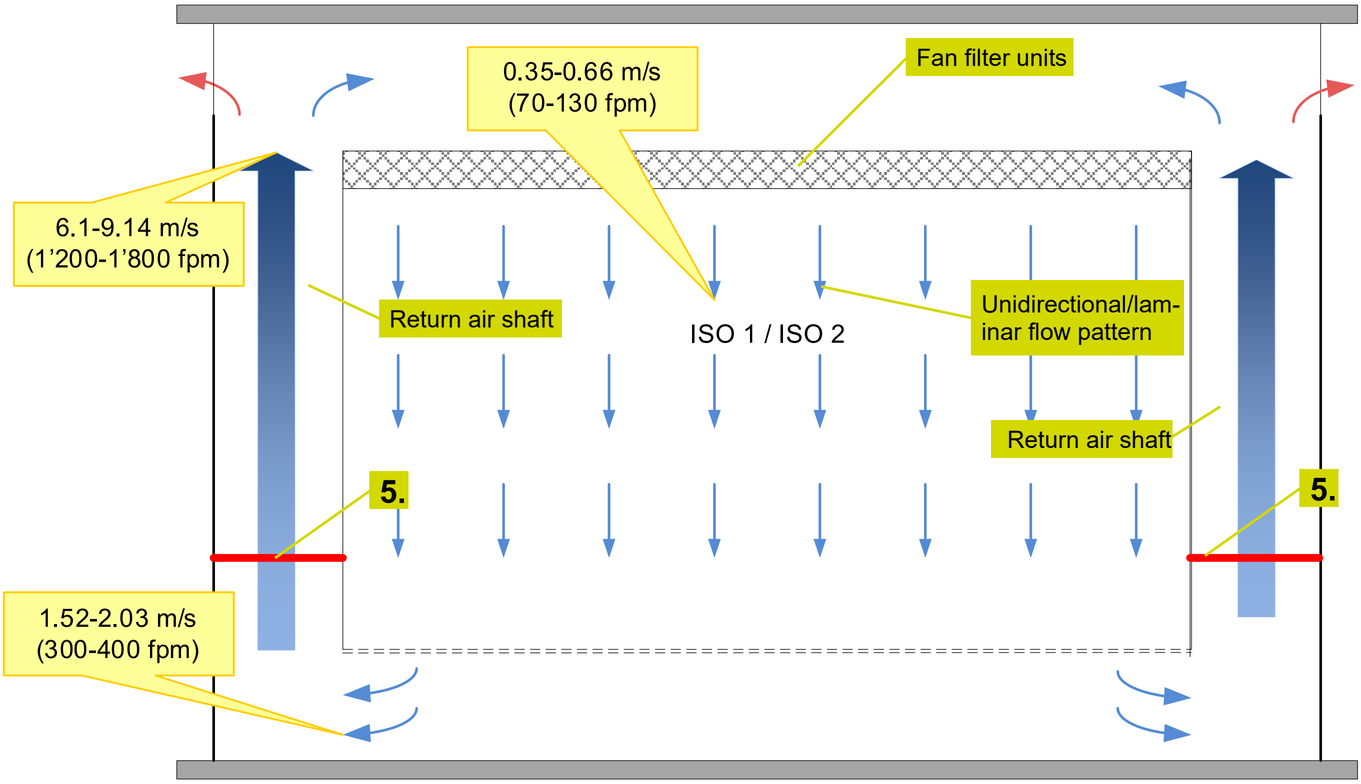
1. Design for FAB ceiling void (supply air plenum) for the protection of roof space where large number of FFUs and other electrical and mechanical equipment are located.
2. Underside the sub-FAB ceiling with sampling holes facing upcoming air flow for the purpose of protection FAB space.
3. Raised floor return air plenum (if large amount of electrical equipment and cable trays are present) or single level FAB without using the return air grills (RAG) design.
4. In front of return air grills at the sub-FAB wall air return vents.
5. Inside the return air shafts (RAS) behind the vents to supplement 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

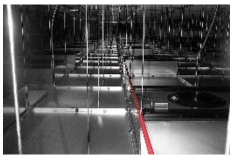


(c) Location of sampling pipe network in RAS on a FAB with a raised floor plenum

Figure 11: Fire detection at supply to return air path and plenum

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

Special considerations



FAB Ceiling Void (supply air plenum)

Refer to chapter 3.3.3.

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

This method is used when the fire detection in FAB above is deemed insufficient.

Refer to chapter 3.4.1 but take into account the location of perforated floorboards and areas blocked by machine tools and equipment.

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

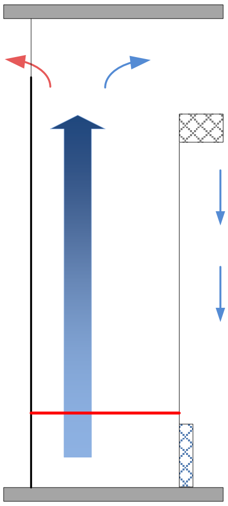
Raised floor return air plenum

Refer to chapter 3.3.3.

Return air grills at sub-FAB dry coils vents

Refer to chapter 3.3.5, the sampling hole 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).

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.



Return air shafts behind dry coils

To supplement Return air grills vents detection above, sampling pipes may be installed inside the Return Air Shaft, horizontal to the floor, approx. 300 mm (1 ft) above the upper edge of the dry coil vents.

Refer to chapters above for sampling hole spacing and orientation.

3.5 Localised and supplementary protection

Within large cleanrooms or cleanroom-like buildings or hospitals and healthcare facilities, there are plant rooms and other sensitive areas that also 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, ambient-controlled storages, electrical cabinets, computer server rooms or plant control centres. The table below summarises relevant Securiton Design literature for protecting these areas to a high standard.

Area or function within facility	Securiton guide
Electrical cabinets	CDG Electrical IT Cabinet Protection 092022 CS HT Electrical Control Panels 032026
Cable trays and pathways	CDG Cable Pathway Spaces 092022
Ceiling voids and raised floors	CDG Ceiling Voids Raised Floors 062021
Partially enclosed storage and maintenance sheds	CS Partially Enclosed Buildings 052025
Logistics/storage areas	DG Logistics & Distribution Warehousing 2026
Refrigerated/ambient controlled storage	DG Refrigerated Storages 092021 CS Ultra-low temperature storage 122025
Loading Docks	CS Loading Docks 202302

Table 9: Relevant Securiton Design Guides and Case Studies

4 Securiton 360° fire protection solution

Securiton 360° Fire Protection Solution (illustrated in Figure 12 below) 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.

SecuriSmoke ASD detectors are connected to the detection loop or 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.

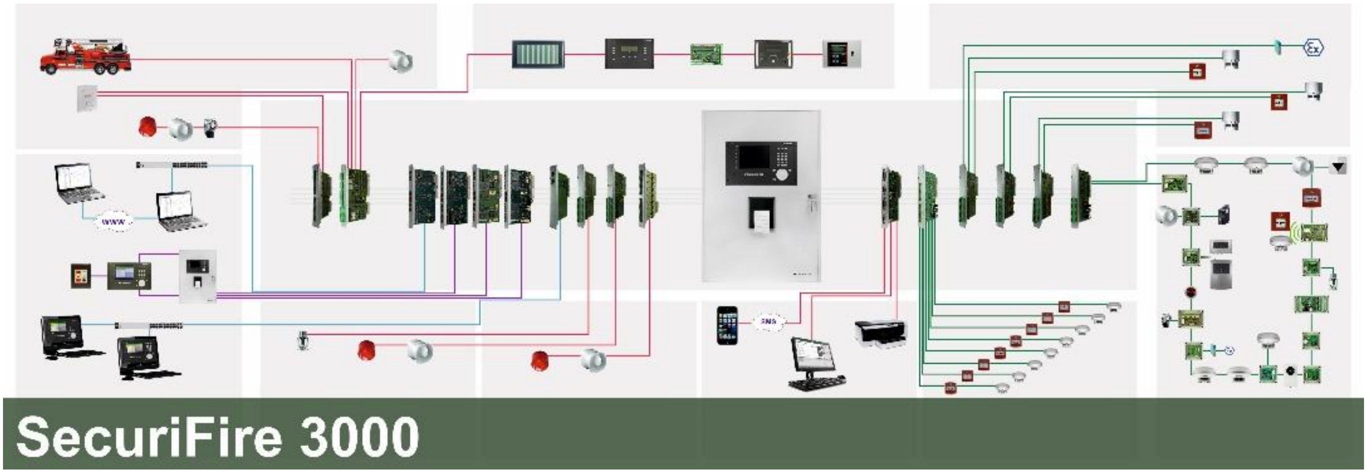


Figure 12 Securiton 360° fire protection solution (FACP and connections)

4.1 Features and benefits

Developed in Switzerland and manufactured in Germany, Securiton AG as a whole is certified in accordance with ISO standards 9001, 14001 and 45001 and thus meets globally applicable standards with regard to quality management, environmental management, and occupational health and safety management systems.

The following table is a summary of the benefits of Securiton SecuriSmoke ASD detection products.

Features	Benefits
Early and reliable smoke detection	Ensure safe egress for life safety.
ASD unit away from sampling pipes	Easy access for services while ensuring operation continuity; Simplify intrinsically safe design.
Automatic on-demand fault alarms	Minimal service required, hence low Total Cost of Ownership (TCO).
5-level of alerts and alarms	Enable fully integrated and orderly verify, control and response.
Optimal alarm settings supported with design tool for code compliance	Eliminate false alarms in challenging environments.
Dynamic use of aspirating technology to address unique operating conditions	Consistent detection performance in areas with pressure difference (e.g., in-duct sampling vs. room detection), high or low temperature or humidity.
Seamlessly integrated with fire alarm system (FAS) and building management system (BMS) components	SecuriSmoke ASD is designed as a key component of a total fire prevention and protection solution.
Use for applications with challenging environments	Aspects of SecuriSmoke ASD product design for use in applications with challenging ambient environments include high IP enclosure and wide temperature range suitable for natural ventilated build environment installation; complete sealed sampling air path, separated sampled air from detector electronics; conformal coatings of PCBs and special coating treatments to connectors and contacts. Use of suitable accessories to manage dusty or high humidity where condensation could occur.
ASD 2000 – The click-mount field replaceable parts	Keep product life cycle costs low with simple and field servable parts such as smoke sensors, airflow sensors, fan unit, main board and coarse filters.
ASD 2000 – Coarse filter accessible without having to open the device	Means filters can be changed and cleaned very regularly at little to no cost.

4.2 Integrated verify, control and respond

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’). These alarm signals can be used for power-down and building system control, detection to suppression actuation.

Table 10 below shows the typical use of SecuriSmoke ASD multilevel alarms. Table 11 illustrates various suppression actuation schemes with SecuriSmoke ASD or the combination of SecuriSmoke ASD with other Securiton detection systems such as Optical Smoke Switches ORS and SecuriHeat Line Type Heat Detection.

Level	Signal	Typical use
1	Pre-signal1	Verify and control (manual extinguishing as needed).
2	Pre-signal2	Manual control or shutdown of HVAC and operation to affected areas if required. Call emergency team.
3	Pre-signal3	Auto control or shutdown of HVAC and related BMS. Initiate smoke and fire management and other related processes Evacuate the site.
4	Alarm	Actuate clean agent suppression where applicable. Initiate fire alarm. Call fire brigade.
5	Alarm2	Actuate pre-action sprinkler.

Table 10 Alert and alarm levels and their typical use for SecuriSmoke ASD

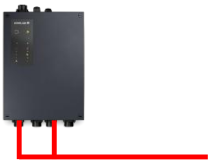
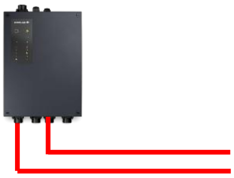
Scheme	Illustration	Remarks
A		2 x SecuriSmoke ASD 531, 532, 533 or ASD 2001 for full redundancy or cross zone coincidence design
B		Single SecuriSmoke ASD 535-3/4 or ASD 2001 with one set of pipe network, each smoke sensor set to different sensitivity
C		Single SecuriSmoke ASD 535-3/4 or ASD 2002 or ASD 2004 with two independent pipe networks, each smoke sensor set to different sensitivity
D		Use REK in place of 2nd ASD in Scheme A, or localised suppression
E	Scheme A, B or C plus 	Any of SecuriSmoke ASD with REK

Table 11 SecuriSmoke ASD and REK for control and suppression actuation

4.3 Non-intrusive system access for ITM

Another advantage of using SecuriSmoke ASD detectors is the non-intrusive access to the system while the protected areas, in this case Large Logistics & Distribution Warehouses with high density of stored goods, machine movement and long operating hours, remain in full operation. Examples of relevant codes and standards for fire detection and alarm systems Inspection, Testing and Maintenance (ITM) include ISO 7240-14 [38], NFPA 72, BS 5839 [25] and AS1851 [39]. 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. Testing methods refer to NFPA 76 [22] FIA CoP [27], or local applicable requirements.

Table 12 below is a simplified ITM schedule for SecuriSmoke ASD product services. Note that SecuriSmoke ASD 2000 models do not require the replacement of the interior dust filter, as they use an advanced centrifugal filter system. The coarse filter on the ASD 2000 is situated at an externally accessible point, while the ultrasonic airflow filter is largely maintenance free. Refer to Securiton product manuals for more details.

Service Item	Fault/Alarm	Trimestrial	Yearly
Cleaning the detector housing exterior (air outlet)	(✓)[28]	?	✓
Cleaning of sampling pipe tube network, accessory parts, airflow sensors	(✓)	?	✓
Clean/replace coarse filters	(✓)	✓[29]	✓
Cleaning of air flow sensor (not applicable to SecuriSmoke ASD 2000)	(✓)	✓	✓
Check correct seating (no leakage)	(✓)	?	✓
Check of fault and alarm release	✓	?	✓
Update maintenance protocol	✓	?	✓
Analyse event memory	✓	?	✓
Analyse airflow issues (caused by operational changes)	✓	?	✓

Table 12 Typical Inspection, Testing and Maintenance (ITM) Schedule for SecuriSmoke ASD

4.4 Support with peace of mind

SecuriSmoke ASD products are supported with a range of software tools to facilitate design, installation, commissioning, trouble shooting and maintenance.

Tool	Usage
Design	ASD PipeFlow (for the ASD 53x family) allows the design and planning of aspirating smoke detection systems at a very early stage. ASD PipeFlow 3D is a much enhanced version for the ASD 2000 family for designing and planning aspirating smoke detection systems at a very early stage.
Install and service	EasyConfig for simple systems directly on the device. The ASD Config software tool is used for more complex systems and application-specific adaptations when using devices from the ASD 53x family. The SecuriSmoke MobileConfig App for the ASD 2000 family is used to commission, maintain and trouble shoot an ASD 2000 installation.
Monitor and manage	All tools offer extensive analysis functions and setting options to ensure safe, cost-effective operation of the aspirating smoke detection system.

Applications and design support includes mainly:
- Partner accreditation program
- Application design and field engineering support
- Worldwide reach through a network of partners as well as subsidiaries and investment companies, with branch offices or local employees around the world.

[28] ✓ indicates 'shall do'; (✓) indicates 'as needed'; ? indicates 'only if required by local codes and standards'
[29] As per manufacturer recommendation for protected areas with high level of dust present or natural ventilated areas subject to dusty air particulates.

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