THE ULTIMATE GUIDE TO ADVANCED FIRE DETECTION IN WAREHOUSES: RISKS, REQUIREMENTS, DETECTION OPTIONS

LEARN MORE: XTRALIS.COM

Warehouses are a central part of logistics operations and are key to fulfilling time-critical deliveries, from e-commerce to mail distribution. These essential hubs often work around the clock to honor service level agreements (SLAs) and meet customer expectations. In recent months, they have been faced with unprecedented demand from online retail activity,[1] which has made the need to minimize disruption even more pressing. Preventing fires, a major risk in warehouses, is always vital. This guide will look at the most common fire-related risks and some specific challenges to fire detection in warehouses.

The guide will start by analyzing some of the main causes and consequences of fires in warehouses. It will then look at requirements and challenges that are associated with detecting smoke in warehouses, highlighting the importance of adopting a very-early-warning approach to fire detection.

The last section will look at the main detection options currently available, including key considerations when it comes to selecting, installing, and using smoke detection systems in warehouses. This section will draw upon Xtralis' research to compare the performance of different types of fire detection and suppression systems in a warehouse setting.[2]

WHY IS PREVENTING FIRES IN WAREHOUSING SO CRITICAL TODAY?

In recent years, there has been a move towards faster, time-critical deliveries, that has put unprecedented pressure on warehousing and logistics operators. The same-day delivery market, for example, is expected to continue growing at a compound annual growth rate of nearly 48% over the next five years.[3] One of the consequences of this growth is that most warehousing and logistics companies now must honor tighter SLAs with their customers. It is critical to maintain high levels of business productivity and minimize downtime.

The need for greater efficiency and productivity has also led many warehousing and logistics operations to adopt automation on a greater scale. According to McKinsey, the transportation and warehousing industry has the third-highest automation potential of any sector[4] and the autonomous mobile robots (AMRs) market is set to expand by 60% in 2020.[5] Besides AMRs, other examples of warehouse automation technologies include automated guided vehicles (AGVs), advanced automated storage/retrieval systems (AS/RSs), advanced conveyors, and drones.[6] Protecting these high-value assets against damage and disruption is fundamental.

The move towards automation also raises new challenges when it comes to protecting the workforce. Swarms of robots and AGVs are adding to already 'crowded' environments (forklifts, pallets, racks, etc.) where ensuring a fast and smooth evacuation may prove problematic. The current trend towards mega warehouses (also known as 'hubs') adds to this challenge.

These large distribution centers are often located outside major urban areas, which may present challenges in terms of access to reliable water supply (for fire suppression systems) and distance from the nearest fire brigades.

CAUSES AND CONSEQUENCES OF UNDETECTED FIRE THREATS

Fires are a real threat to warehouses. According to the National Fire Protection Association (NFPA), in 2018, 27 thousand fires were recorded in storage facilities across the USA.[7] But what is causing such a high number of incidents?

A comprehensive study conducted by the NFPA revealed that more than a quarter of all warehouse fires were caused by electrical, lighting or heating equipment.[8]

The same study found that electrical or mechanical failure was a contributing factor in 30% of all warehouse fires. Risks of this kind may become even more widespread as the trend towards automation introduces new potential fire hazards. For example, batteries and other electronic components powering robots and AGVs, as well mechanical parts in machinery such as conveyors, can generate a fire if they malfunction or fail.

What makes a typical warehouse particularly vulnerable to fires is its high fuel load, which may include large quantities of vertically-stored flammable goods such as furniture, rubber tyres, tobacco, alcohol, and textiles. These, together with packing materials such as carboard as well as wooden pallets and crates, create conditions for fast-spreading fires. This risk is exacerbated given that warehousing facilities tend to be large, undivided open spaces where fires can spread easily.[9]

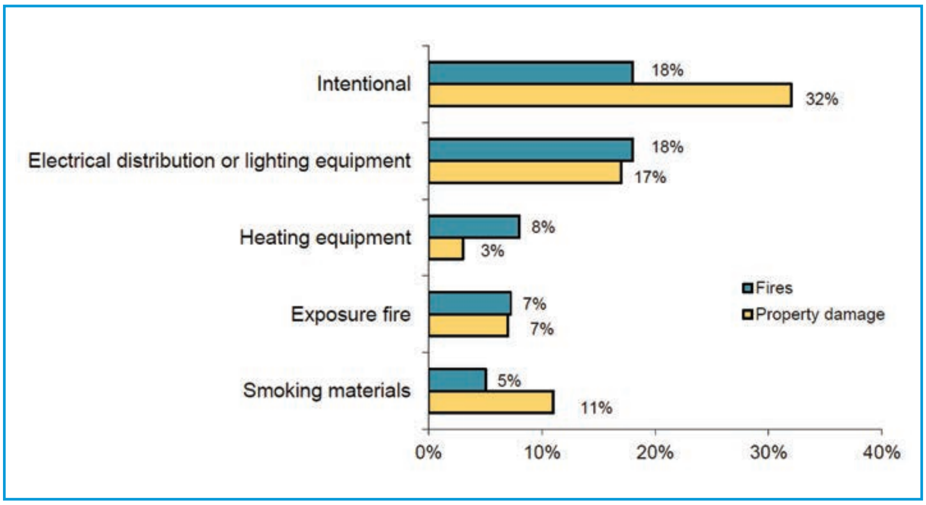


Table 1: Leading causes of warehouse fires in the USA, 2009-213 (source: NFPA)

Unless one of the earliest signatures of fire such as smoke is detected promptly, it can escalate quickly and the consequences can be dire. As the examples below suggest, the costs arising from damaged buildings and goods as well as downtime, injuries, insurance claims, and reputational damage, can be eye watering:

- A 2014 study commissioned by the UK Business Sprinkler Alliance found that, over the previous 5 years, the British economy had suffered losses in the region of £1 billion and 5,000 full-time jobs due to preventable warehouse fires.[10]
- According to the NFPA, in 2018, the cost of warehouse fires in the USA amounted to $833 million in property loss alone.[11]
- The fire that devasted a UK-based Ocado warehouse in 2019 was estimated to have cost £110m.[12]
- In 2019, a Jim Beam warehouse in Kentucky (USA) suffered a fire that destroyed 45,000 barrels of whiskey, costing an estimated $45 million in lost product alone.[13]

A fire can have significant environmental consequences that can be felt well beyond the warehouse walls. Soot, toxic fumes and runaway contaminated water are examples of the potential impact that fires can have on other buildings, infrastructure, and the public in the surrounding area. For example, a warehouse fire in Bremen, Germany, recently caused coin-sized pieces of burned asbestos to fall within a 300-meter radius.[14]

Even fire false alarms can cause disruption to critical operations, leading to unnecessary evacuations that can bring an entire warehouse to a halt. These occurrences are common, with false alarms accounting for more than 4 in 10 incidents attended by English fire and rescue services in 2019.[15] Around two thirds (67%) of these fire false alarms were linked to fire detection apparatus, either because of human error or malfunctioning.[16]

KEY CHALLENGES TO SMOKE DETECTION

We've seen how fires pose a significant threat to warehouses. This is largely due to structural and environmental conditions that make the early detection of fires particularly difficult. Typically, warehouse settings face four main challenges:

1. **Dilution:** many warehouses consist of huge, open spaces and high ceilings meaning smoke and gas tend to dilute easily, becoming more difficult to detect.
2. **Dispersion:** in large, open spaces airflow patterns can become erratic, often due to mechanical HVAC systems or natural ventilation that can divert smoke away from detection points.
3. **Stratification:** the combined effect of poor insulation and solar radiation can create warm layers of air that prevent smoke from reaching the ceiling, where detectors tend to be installed.
4. **Obstruction:** anything from racks to conveyors, and AS/RSs, can obstruct smoke moving towards detectors.

Due to these conditions, smoke detectors' response may be delayed thus allowing fires to grow to large sizes, potentially overwhelming the response from sprinklers. As Table 2 illustrates,[17] the higher the ceiling, the greater potential size of the fire by the time the fire suppression system initiates. If the ceiling is extremely high, the sprinklers may not activate at all.

Sprinkler distance over fire source (m) [ft]	Fire size (MW) at time of sprinkler activation
< 3.5 [11.5]	1.5
3.5 – 11 [11.5 – 36]	2.3 – 2.5
> 11 [> 36]	Risk of no sprinkler activation

Table 2: Estimated fire size at sprinkler activation (Source: Hughes Associates Inc)

Another key challenge warehouses face is the installation and maintenance of smoke detectors. Commissioning and regular testing are key to ensuring that detectors are always up and running. Installing and accessing these devices in hard-to-reach locations such as high ceilings and high racks can be risky, time consuming and require equipment such as cherry pickers, which may disrupt time-critical warehousing operations. Consequently, some warehouse operators may decide to only install a limited number of detectors or, worse, not install them at all. A 2017 study found that 58% of warehouse facilities that suffered a fire in the United States had neither smoke detectors nor sprinklers installed at the time of the incident.[18]

KEY REQUIREMENTS AND THE IMPORTANCE OF PBD

Fire safety regulations and standards tend to vary from region to region[19] so keeping up to date with the latest local codes is paramount; however, local standards may not necessarily be enough to protect a warehouse and the associated business operation from fire. The main reason for this is that warehouses often present unique structural features such as an unusual height and size that may fall outside of prescriptive codes. There may also be challenging environmental conditions that may challenge traditional passive fire detection and suppression methods.

An engineering-led, Performance Based Design (PBD) is recommended when designing a fire detection and suppression systems tailored to the specific requirements of the warehouse environment.[20] For example, the location of the detectors or the distance between sampling points, which is normally dictated by local codes, may need to be adapted to suit specific conditions.

PBD is now widely adopted internationally and there is a trend towards further standardization. For example, the International Fire Safety Standards Coalition is currently establishing "a common set of internationally-accepted PBD principles for fire safety aspects of design, engineering and construction, occupation and ongoing management".[21] Keeping up to date with the latest guidance in terms of PBD can help ensure that the design of a fire detection system is entirely fit for purpose.

HOW TO CORRECTLY CHOOSE AND DEPLOY SMOKE DETECTORS

A key element of an effective fire safety strategy is the selection of appropriate fire detection devices. There are three main smoke detection technologies available:

- **Optical spot:** possibly the most commonly-used type of detector, it is shaped like a cone, equipped with a sensor and mounted on the ceiling. It monitors levels of smoke by using an internal light source and sensor.
- **Optical beam:** it typically involves an infrared light beam that is generated by a transmitter and captured by a receiver. It is activated when smoke reduces the intensity of the light beam, triggering an alarm.
- **Aspirating:** this is an active system that draws air through a series of sampling holes, via a network of pipes, to detect smoke through a sophisticated detection chamber. Aspirating smoke detectors (ASDs) can be of two types: 1) based on a network of fixed pipes with sampling holes 2) based on a system of flexible tubes with a single sampling hole that can identify the location of the smoke (this technology is called 'addressable' aspirating detection).

Optical spot detectors are generally the most affordable and recommended for standard residential or office building applications. They measure smoke at a single point in space and require sufficient smoke to reach them for an alarm to be triggered. They may not be suitable for large open spaces where smoke can be highly diluted and dispersed. They also require direct access for mandatory maintenance, which can be challenging when placed in hard-to-reach locations.

Beam detectors provide standard detection where there is a clean line of sight, but can be vulnerable to false alarms. For example, dust build up on the receiver or an intruding object may reduce or block the light transmission.

ASDs allow for multiple sampling locations to be distributed across the building horizontally and sometimes vertically, and can detect smoke very early, even if it is diluted as they transport multiple samples back to a centralised detector. Their ability to actively draw air from the building HVAC system can also accommodate changing airflow conditions. In addition, ASDs can be installed in a convenient, accessible location for easy maintenance.

A consideration when specifying smoke detectors is their activation time. This largely depends on sensitivity, which is normally measured in %/meter (or %/foot) obscuration: the higher the sensitivity the lower the concentration of smoke that is needed to activate the detector.

ASDs are normally classified as:

1. Very-Early-Warning Fire Detection (VEWFD), or 'Class A', with 1.5%/m (0.457%/ft) obscuration
2. Early-Warning Fire Detection (EWFD), or 'Class B', with 4.5%/m (1.37%/ft) obscuration
3. Standard Fire Detection (SFD), or 'Class C', with 10%/m (3.05%/ft) obscuration

Sensitivity can vary significantly from one technology to another so specifying a detection system that is commensurate to the fire risk is paramount. To prove this point, Xtralis conducted Computational Fluid Dynamic (CFD) modelling to compare the activation times of different types of smoke detection as well as sprinkler technologies.[22] The modelling was based on a 1,500m^2 (16,000ft^2) warehouse with an 8m (26ft) ceiling height and 2.4m (7.8ft)-high storage racks. Assuming that the fuel source was located at floor level, between racks, the modelling estimated that the fire would reach a 4.2MW Heat Release Rate (HRR) in 10 minutes (with no incipient phase).

As illustrated in the table below, the CFD modelling found substantial differences in activation times, from less than one and a half minutes to over seven minutes. By the time the sprinklers were activated, the fire was up to 20 times bigger than when the VEWFD ASD had first detected it.

Fire protection System	Activation time (sec)	Fire size (kW) at activation	Ceiling smoke level (%/m) [%/ft]
VEWFD ASD	89s	100	1.3 [0.4]
EWFD ASD	109	140	2.7 [0.82]
Optical Beam	136	217	2.25 [0.69]
SFD ASD	142	236	3.1 [0.95]
Optical Spot	230	620	6 [1.8]
ESFR Sprinkler (RTI: 25)	344	1400	13 [4]
ESFR Sprinkler (RTI: 50)	363	1550	14.5 [4.4]
Standard Sprinkler (RTI: 200)	434	2200	19.8 [6]

Table 3: Detector and sprinkler activation times
(Source: Xtralis, "Benefits of Very Early Warning Fire Detection in Warehouses," 2017 [Doc 32795_00], https://xtralis.com/file/9495.)

The graph below provides a visual representation of the activation times in relation to fire size and smoke levels.

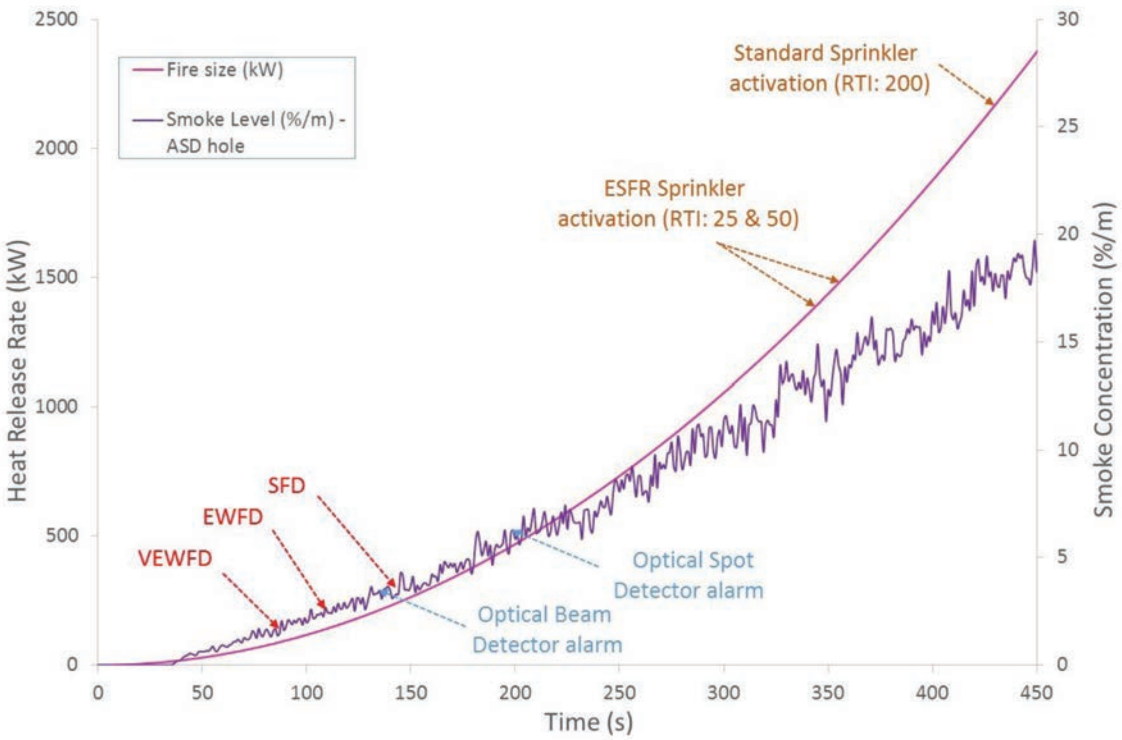


Table 4: Detector and sprinkler activation times (Source: Xtralis, "Benefits of Very Early Warning Fire Detection in Warehouses," 2017 [Doc 32795_00], https://xtralis.com/file/9495.)

This modelling demonstrates is that very early warning detection has the potential to alert personnel to a fire threat when they can still suppress it without causing any major disruption.

In situ testing conducted by BRE[23] corroborates the findings of the CFD modelling. The test took place in a 42m-high warehouse and involved ASDs and a range of fuels and fire stages. As the table below illustrates, VEWFD was the fastest (and in some cases the only) to activate.

Test No.		1	2	3	4	5	6
Fuel		Small crib	N-Heptane	Large crib	Paper bin	Pot-Lactose	Smoke pellet + heater
HRR (kW)		100	400	>500	40	<100	12
ASD response time (sec)	**VEWFD – Class A**	750	62	117	153	99	191
	EWFD – Class B	ND	118	132	191	102	ND
	SFD – Class C	ND	325	ND	202	106	ND

Table 5: Fuel sources and response times for different sensitivity classes (source: BRE)

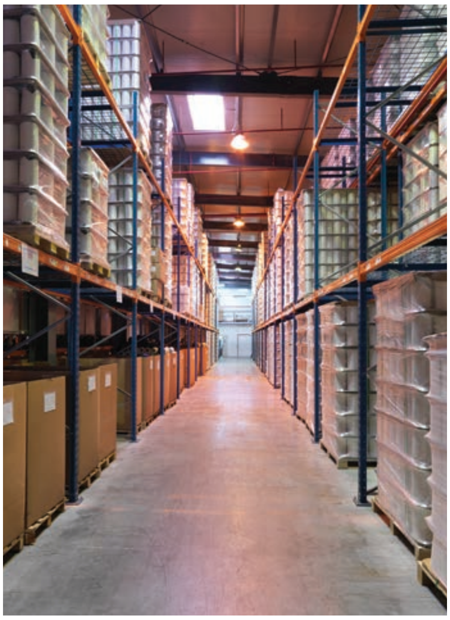
CONCLUSION

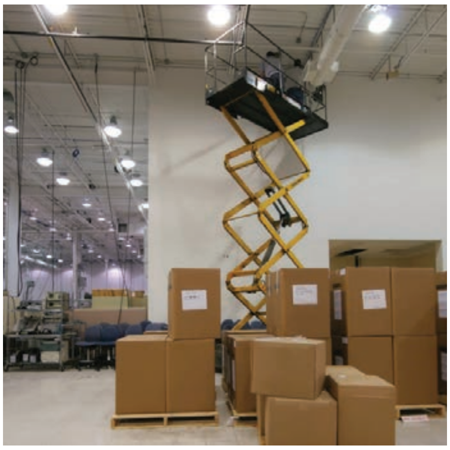
Warehouses around the globe are facing unprecedented pressure. They need to ensure high levels of productivity and efficiency to satisfy SLAs and customer expectations so uptime is critical.

This guide illustrated how fires are a significant threat to warehouses and can easily spread and escalate into disaster if they are not detected early enough. There are key challenges to detecting the signs of an impending fire, which is why having reliable smoke detection in place may help avoid downtime or even more damaging outcomes.

This guide also highlighted the importance of adopting a performance-based design that factors in the unique structural and environmental features of warehouses.

The final section of the guide focused on the different smoke detection technologies currently available and what to consider when specifying them. This theme will be addressed in more detail in our Warehouses Design Guide, which provides guidelines on the design and deployment of smoke detection systems in warehouse facilities. You can download the Guide here.





ABOUT THE AUTHOR

Richard Taylor is Global Director Advanced Fire Detection at Xtralis. He has been involved in the development and application of very-early-warning smoke detection technology for more than 25 years.

ABOUT XTRALIS

Xtralis is the leading global provider of powerful solutions for the very-early and reliable detection of smoke, fire, and gas threats. Our technologies prevent disasters by giving users time to respond before life, critical infrastructure or business continuity is compromised.

We protect highly valued assets and infrastructure belonging to the world's top governments and businesses.

To learn more, please visit us at www.xtralis.com

[1] *https://ccinsight.org/#global-outlook*
[2] *Xtralis, "Benefits of Very Early Warning Fire Detection in Warehouses", 2017 (Doc 32795_00): Source: https://xtralis.com/file/9495.*
[3] *https://www.marketstudyreport.com/reports/global-same-day-delivery-market-2020-by-company-regions-type-and-application-forecast-to-2025?gclid=EAIaIQobChMI2rfO8off6QIVVu3tCh0VBQRJEAMYASAAEgK5OPD_BwE*
[4] *https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/automation-in-logistics-big-opportunity-bigger-uncertainty*
[5] *https://www.interactanalysis.com/warehouse-automation-market-off-to-a-strong-start-in-2020/*
[6] *https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/automation-in-logistics-big-opportunity-bigger-uncertainty*
[7] *https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osFireLoss.pdf*
[8] *https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/oswarehouse.pdf*
[9] *https://www.firesafe.org.uk/fire-safety-in-factories-and-warehouses/*
[10] *https://cebr.com/reports/economic-impact-of-warehouse-fires/*
[11] *https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osFireLoss.pdf*
[12] *https://www.bbc.co.uk/news/business-48919285*
[13] *https://www.forbes.com/sites/emilycappiello/2019/07/03/jim-beam-may-face-45-million-loss-from-warehouse-fire/#514592c49ea3*
[14] *https://www.industrialfireworld.com/553984/warehouse-fire-in-germany-raises-concern-about-asbestos*
[15] *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/884271/fire-and-rescue-incident-dec19-hosb1120.pdf*
[16] *Home Office, "Fire statistics table 0104: fire false alarms by reason for false alarm, England", 2020. Source : https://www.gov.uk/government/statistical-data-sets/fire-statistics-data-tables#incidents-attended.*
[17] *Source: D.T. Gottuk and J. Dinaburg, "Fire Detection in Warehouse Facilities", Hughes Associates Inc. Jan. 2012, Report for The Fire Protection Research Foundation*
[18] *https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/OSWarehouseFires0615.ashx*
[19] *https://ifss-coalition.org/the-standards/*
[20] *https://firesafeeurope.eu/performance-based-design-prescriptive-methods/*
[21] *https://ifss-coalition.org/the-standards/*
[22] *Xtralis, "Benefits of Very Early Warning Fire Detection in Warehouses", 2017 (Doc 32795_00): Source: https://xtralis.com/file/9495.*
[23] *BRE, "Smoke Detection in High Spaces using ASD", Fire Industry Association, UK, 2011*