WHITE PAPER

Fire protection in hazardous locations:

Meeting NFPA standards for flame, smoke and gas detection

Fire is one of the most critical hazards in any built environment, and industrial processes and facilities that involve volatile and potentially flammable materials present special challenges for fire protection.

Hazardous conditions can occur in a range of settings, from automotive to munitions manufacturing and semiconductor to petrochemical facilities. Other applications where the risk of fire is high include turbine enclosures, aircraft hangars, and garages where buses fueled with liquefied natural gas (LNG) are stored. These high-risk locations and operations call for process-specific fire protection.

Fire protection requirements are legislated and subject to a myriad of international codes and standards, such as NFPA (National Fire Protection Association) 72, NFPA 70® *National Electrical Code*® (NEC®), EN (European Norms) 54 and ISO (International Organization for Standardization) 7240. Some of the codes apply to residential and commercial settings, where smoke and heat detection are commonly adequate. However, hazardous-area fire protection requires other detection technologies as well as equipment suitable for use in hazardous locations as required in the U.S. by OSHA (Occupational Safety and Health Administration) 1910 Subpart S.

But first, what attributes make a process or location "hazardous?"

Defining Hazardous Areas

The definition of hazardous locations is based on a number of factors. The National Fire Protection Association in the U.S. covers these topics in great detail. According to its website, NFPA has published more than 300 codes and standards that affect "virtually every building, process, service, design and installation" with the goal of minimizing the risk and effects of fire.

In particular, NFPA 70, Chapter 5 addresses "special occupancies." Within that chapter, Article 500 "Hazardous (Classified) Locations, Classes I, II and III, Divisions 1 and 2" stipulates that locations be classified based on the flammables that could be present, and their concentration

or quantity. Hazardous areas are broken down into these three classes:

- **Class I** — areas in which flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures
- **Class II** — locations in which combustible dust is present; dust is defined as solid material less than 420 microns (0.017 in.) or smaller in diameter
- **Class III** — locations in which easily ignitable fibers or flyings, such as rayon, cotton, jute, hemp and cocoa fiber are present

Within each class, there are divisions based on the concentration of flammable materials, the form of handling and the frequency with which the materials may be present. For example, in Class I:

- **Division 1** is a location where combustible materials are routinely present in ignitable concentrations.
- **Division 2** is one in which the same materials are handled, processed, or used, but in which the materials are normally confined and can escape only in case of accident or breakdown or failure of ventilation equipment.

Figure 1:

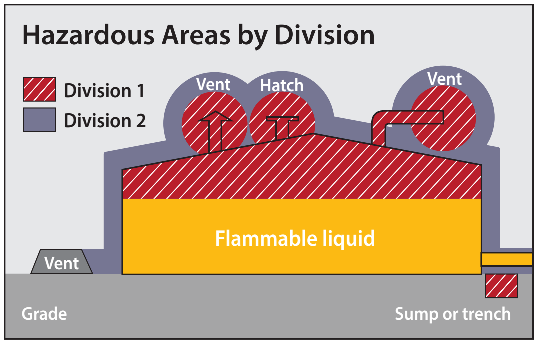
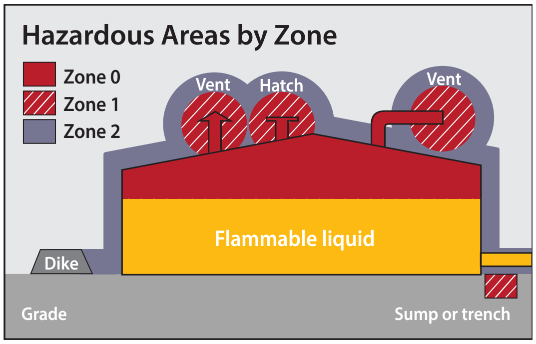


Figure 2:



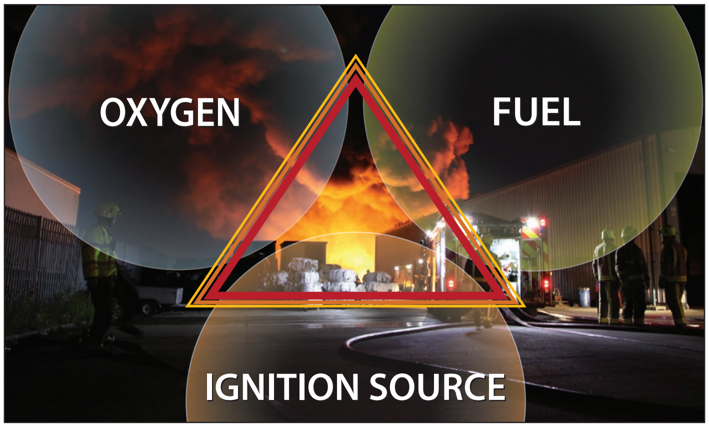


Figure 3: The fire triangle depicts the three elements a fire needs to ignite.

Within Class I, locations are also defined by Zones (0, 1 or 2) per Article 505 of NFPA 70. For example, in a Class I, Zone 0 location, ignitable concentrations of flammable gases or vapors are present continuously or for long periods of time. (See Figures 1 and 2.)

Classes II and III are similarly broken down into divisions. Hazardous areas tend to be confined spaces in which confinement turns the risk of fire into the risk of explosion.

How to Control Fire Risk in Hazardous Areas

Before thinking about controlling fire risk, it's important to understand the components needed for a fire to start. Commonly referred to as the "fire triangle," the essential elements are:

1. **Oxygen** — which can be a constituent or outcome of various industrial processes, though its primary source is the ambient air
2. **Fuel** — which is present in structures and used in processes of all kinds, but is of greater concern in locations defined as hazardous
3. **Ignition source (i.e., heat)** — which, depending on the fuel and conditions, can be as minimal as the spark of an electric switch or electric motor, or a hot surface

To control the risk of fire, one of the elements of the fire triangle must be eliminated. When possible, flammable materials must be contained and kept away from oxygen, as well as ignition sources such as sparks or hot surfaces. The primary goal should be containment of the fuel source, i.e., preventing leakage. The next step is to eliminate or minimize the risk of ignition. Because oxygen is ever-present in the atmosphere, it is difficult to eliminate this element from the fire triangle. Success in containing or reducing the concentration of fuel determines the Division level of a hazardous area.

Any hazardous area, by definition, has some degree of risk due to the presence of flammable materials at combustible levels.

Controlling ignition risk from equipment

Many industrial locations in which hazardous materials may be present are also areas where electronic and electrical equipment could provide sources of ignition. It is therefore necessary to control ignition sources, e.g., heat, arcing or sparking. Electrical equipment should be placed outside the hazardous area, although this is not always possible. If electrical equipment, including flame and gas detectors, must be located in a hazardous area, per NFPA they must be designed to limit or isolate potential sources of ignition — either by installation technique or enclosure design.

NFPA 70 Section 500.7 "Protection Techniques" lists several techniques for protecting electrical and electronic equipment used in hazardous (classified) locations. The three acceptable protection methods for Class I Division 1 are:

- **Explosion Proof (XP)** — sparks or explosions are contained within the housing
- **Purged and Pressurized** — combustible gases and vapors are denied entry into the enclosure
- **Intrinsically Safe (IS)** — the entire power of the system is limited

In addition to limiting electrical energy as an ignition source, the surface temperature of electrical equipment must also be controlled. Equipment is marked (T1 – T6) to show the environment for which it has been evaluated and is considered suitable.

The Fire Protection System

A fire protection system is comprised of several subsystems that can include but are not limited to: flame, smoke and gas detection, plus notification and/or suppression activation. A complete fire protection system includes a controller that receives the inputs from the detection devices, makes decisions and initiates appropriate action(s).

There is no single answer for fire detection in hazardous areas. Each solution is customized to the application's requirements. Effective protection is based on the materials and fuels present, the processes involved, the environment, and other controls measures present. Based on these variables, an effective detection and suppression system may require multiple technologies to effectively detect the hazards. Regardless of the application, many NFPA codes and standards for specific processes reference NFPA 72, *National Fire Alarm and Signaling Code*, including:

- NFPA 15 *Standard for Water Spray Fixed Systems for Fire Protection* — "The selection, location and spacing of automatic fire detectors for the actuation of fixed water spray systems shall meet or exceed the application requirements of NFPA 72..."
- NFPA 30 *Flammable and Combustible Liquids Code* references numerous NFPA codes, including NFPA 15, which in turn references NFPA 72.
- NFPA 59A *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)* says, "...the detection system shall be designed, installed and maintained in accordance with NFPA 72 *National Fire Alarm Code*."
- NFPA 70 *National Electrical Code* has multiple references to NFPA 72.
- NFPA 409 *Standard on Aircraft Hangars* says, "Listed detection systems shall be acceptable in lieu of heat detection if approved by the authority having jurisdiction and installed in accordance with NFPA 72."

Chapter 17 of NFPA 72 is titled "Initiating Devices" and it provides requirements for the use of various types of detectors — radiant energy-sensing (flame), smoke and gas — that can be used to discover or recognize potential indications of fire. Below is an overview of each detector type and some of the NFPA standards applicable to each.

Flame detectors

NFPA 72 describes a flame detector as "a radiant energy-sensing fire detector that detects the radiant energy emitted by a flame." Flame detectors are line-of-sight devices that can employ several sensing technologies: ultraviolet (UV), infrared (IR), ultraviolet/infrared (UV/IR) and multi-spectrum infrared (MIR).

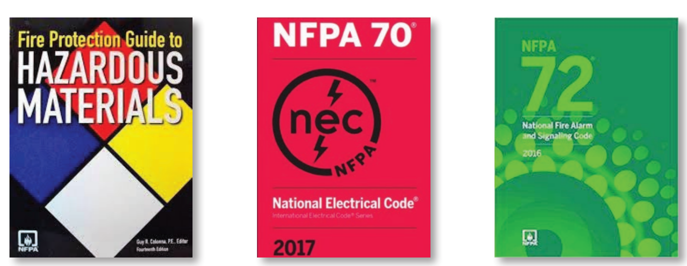


Figure 4: NFPA is a consensus-based developer of codes and standards, enlisting the help of over 9,000 volunteer committee members.

Radiant energy-sensing detectors are incorporated into hazardous-area fire protection systems particularly when either or both of two factors are present in the application: 1) when rapid-fire detection and actuation response times are critical; and 2) when the impact of false alarms is potentially disastrous in terms of damage, downtime or both. Flame detectors used in hazardous areas must be hazardous-location-rated and performance-certified.

There are many factors to consider when selecting the type, quantity, location, and spacing of flame detectors. These factors include:

- Matching the spectral response of the detector to the spectral emissions of the fire or fires to be detected.
- Minimizing the possibility of spurious nuisance alarms from non-fire sources inherent to the hazard area.

NFPA 72 addresses these selection factors in Chapter 17:

- **17.8.3.2.1** The location and spacing of detectors shall be the result of an engineering evaluation that includes the following:

1) Size of the fire that is to be detected
2) Fuel involved
3) Sensitivity of the detector
4) Field of view (FOV) of the detector
5) Distance between the fire and the detector
6) Radiant energy absorption of the atmosphere
7) Presence of extraneous sources of radiant emissions
8) Purpose of the detection system
9) Response time required

DETECTOR TYPES AND CONTROLLERS USED IN HAZARDOUS LOCATIONS

Multispectrum infrared (MIR) flame detectors

Multispectrum IR flame detectors are often preferred in industrial environments since background IR noise is quite common, and this interference tends to desensitize single-spectrum detectors that are set to detect one specific wavelength somewhere between one and five microns. MIR detectors use multiple-IR sensors, each set to detect a different wavelength, along with processing algorithms that can differentiate flames from background IR radiation. MIR detectors vary widely with respect to the sensitivity range and FOV they provide. For example, adequately covering a particular hazard zone using detectors with a range of 50 feet requires six times as many detectors as covering the same zone using detectors with a range of 200 feet.

Fixed-point toxic gas detectors

Fixed-point toxic gas detectors detect toxic gases using electrochemical, infrared or metal oxide semiconductor technology. They measure the concentration at the point where the detector is located and give readings as parts per million (PPM). Toxic gas detectors are placed anywhere there is a potential for a hydrogen sulfide leak hazard.

Fixed-point combustible gas detectors

Fixed-point combustible gas detectors detect combustible gases using catalytic or infrared technology. They measure the concentration at the point where the detector is located and give readings as the percentage of the lower flammable/explosive limit (LFL/LEL). Combustible gas detectors monitor for potential flammable gas leak conditions.

Line-of-sight (LOS) gas detectors

Line-of-sight gas detectors continuously monitor combustible gas levels between two points at ranges of up to 120 meters. Line-of-sight detectors are often deployed in and around open areas and harsh environments that are typical of an industrial site. This technology is perfect for perimeter monitoring for gas clouds, and it augments point detectors for optimal coverage in large open areas.

Acoustic gas leak detectors

Acoustic detectors are non-contact gas leak detectors that recognize unique acoustic "fingerprints," and are ideal for areas where there is risk for pressurized gas leaks. These detectors are suitable for harsh outdoor applications, unmanned operations and extreme temperatures. They are unaffected by fog, rain, and wind. The ideal acoustic detector accurately identifies the sound of a gas leak while ignoring other nuisance environmental sounds.

Certified systems for detection and suppression

Controllers for functional safety systems provide configurable and flexible operation for flame and/or gas detection, alarm signaling, notification, extinguishing agent release and/or deluge operation. It is important that the control platform is certified to all applicable standards by qualified certifying bodies.

To increase the probability of detection of a hydrocarbon gas leak, multiple gas detector technologies should be used. (See Figure 5.)

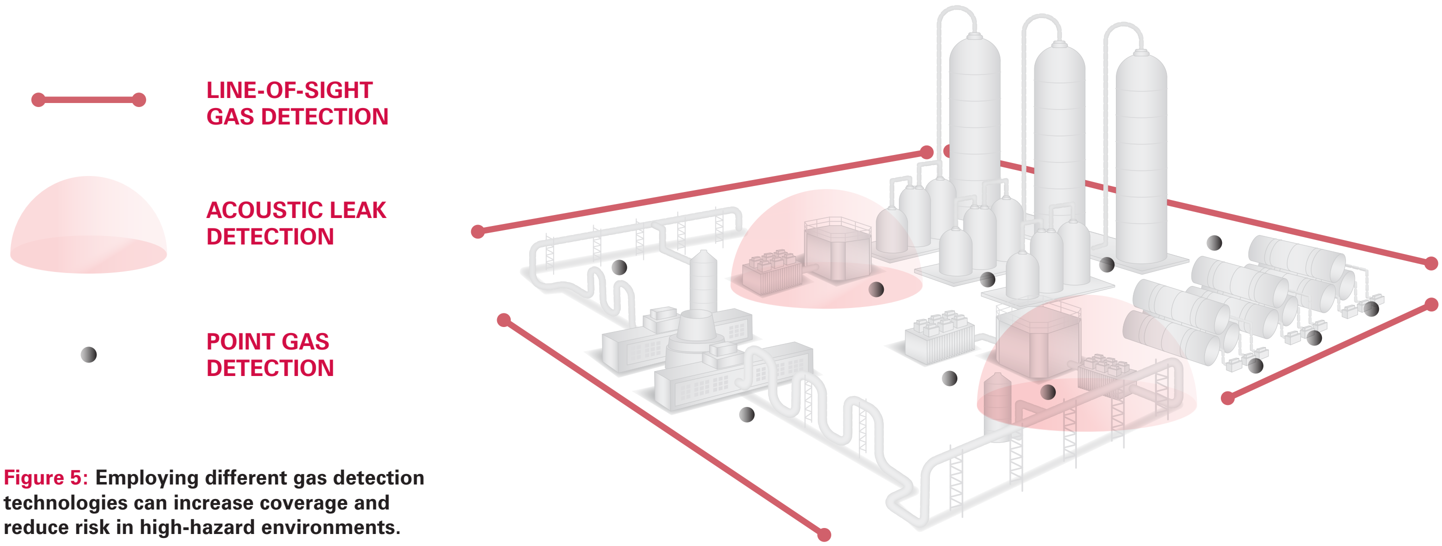


Figure 5: Employing different gas detection technologies can increase coverage and reduce risk in high-hazard environments.

Detecting fires outside the field of view of a detector, or detecting fuels not listed or approved may require changing detector distances and aiming, along with possibly adding detectors.

In addition, these line-of-sight detectors should not be obstructed by structural members or opaque materials or objects. It is also important to maintain window clarity on flame detectors as the sensitivity and detection capabilities can be compromised by particles, aerosols, oils or ice accumulation.

Smoke detectors

A smoke detector detects the particles produced by combustion using a variety of technologies. These can include ionization, cloud chamber, photoelectric light obscuration, photoelectric light scattering and video image detection. To be effective, smoke detectors should be located and spaced in anticipation of airflow from sources likely to present fire risks, but without resulting in unwarranted alarms. NFPA 72 describes the requirement this way:

- **17.7.1.9** The location of smoke detectors shall be based on an evaluation of potential ambient sources of smoke, moisture, dust, or fumes, and electrical or mechanical influences, to minimize nuisance alarms.

Smoke detectors used in hazardous locations can be designed either for detecting smoke in defined areas or within ductwork. As with other types of detectors used in high-risk locations, it is critical that smoke detectors have the necessary performance and hazardous location approvals to operate effectively and safely in the application.

Combustible gas detectors

NFPA 72 describes a gas detector as "a device that detects the presence of a specified gas concentration." Detectors are intended for specific types of gas or vapor and should be chosen accordingly, as specified in NFPA 72:

- **17.10.2.4** The selection and placement of the gas detectors shall be based on an engineering evaluation.

Gas leak detection technologies can include:

- Acoustic detection for gas leaks — ultrasonic sensors detect leaks based on noise patterns
- Infrared detection along a line of sight — detects gas along a path providing a large area of detection
- Point detection of a toxic or combustible gas by electrochemical, catalytic, or infrared technologies — gases come into contact with the detector, causing the detector to activate

A challenge relating to gas detection is that the origin of gas leaks can often be difficult to predict. Gas leak detection can also be challenging due to varying environmental conditions such as wind and rain, and application factors such as machinery and piping. These environmental and situational factors, as well as the many potential sources of gas leaks, play major roles in selecting the type(s) of combustible and toxic gas detection technology to use, and the placement of the devices.

Each of the three major types of combustible and toxic gas detection technologies (fixed point, line-of-sight and acoustic) has benefits and limitations depending on environmental and application factors, and an optimal solution may depend on implementing more than one type of technology. Combining various technologies and placing them in locations that maximize their effectiveness can mitigate the impact of a hazard.

Toxic Gas Detection

While not a contributor to fire risk, toxic gases can be extremely dangerous. For that reason, fast, accurate detection is essential — and toxic gas detection is often considered part of an overall safety system in hazardous locations. Toxic gases include hydrogen sulfide, carbon monoxide, nitrogen dioxide, ammonia, chlorine and sulfur dioxide.

Depending on the detection technology, contact with the gas is generally required. A widely accepted standard for toxic gas detectors is ISA 92.0.01, developed by the International Society of Automation. OSHA also has exposure limits for toxic gases. In addition to requirements for the detectors themselves, there are standards related to proper installation, calibration and maintenance, all of which are critical to effective toxic gas detection. A design analysis takes into consideration airflow in the affected area as well as factors like the density and anticipated source of the toxic gas.

The Brains of a Fire Protection System

A safety system controller (SSC) receives and interprets input from multiple detectors and makes executive decisions regarding notification and further activity including suppression. In some cases, in order to prevent nuisance alarms, the SSC may discount information from a single detector if it is not confirmed by other detectors in the area. As is the case for individual detectors, the SSC, if installed in a hazardous location, must be rated for the location. Alternatively, the SSC can be located outside the hazardous location.

Figure 6: **A fire safety system controller coordinates flame and/or gas detection, alarm signaling, notification, extinguishing agent release and/or deluge operation.**

Preventing Nuisance Alarms

The primary function of detectors is to detect a hazard and then signal to alert that an event has occurred. At the same time, it is essential that detectors are capable of maximizing false alarm rejection so they do not alarm to non-hazardous events, such as arc welding.

NFPA 72 defines a nuisance alarm this way: "An unwanted activation of a signaling system or an alarm initiating device in response to a stimulus or condition that is not the result of a potentially hazardous condition." Nuisance alarms can be inconvenient, costly in terms of equipment damage and cleanup labor, or even dangerous.

Other Safety Standards

The NFPA standards do not address specific performance of the detectors. Other standards organizations or Nationally Recognized Testing Laboratories (NRTLs) have metrological standards that support the NFPA. These include Factory Mutual (FM) 3010 for fire alarm systems and Underwriters Laboratories (UL) 864.

Although well-adopted outside of the U.S., there have been increasing requests for fire and gas detection systems to be designed in accordance with International Electrotechnical Commission (IEC) 61508 which defines the requirements for ensuring that systems are designed, implemented, operated and maintained to provide the required Safety Integrity Level (SIL). Refer to the Det-Tronics white paper "Why Functional Safety Product Certifiers Must Meet Highest Level of Accreditation" for further information on IEC 61508.

Beyond the Standards

As detailed and comprehensive as NFPA and other codes and standards are, they are a minimum for demonstrating the use of recognized and generally accepted good engineering practices (RAGAGEP). Local authorities having jurisdiction (AHJ) may have more stringent requirements. Also, standards may not consider the value of the assets being protected, or in some cases, insurance carriers may demand higher levels of protection. Process owners and facility managers need to consider the risks, balance the costs, and consult with experts to optimize the process-specific fire protection for high-risk locations and operations.

Disclaimer

Resources:

1. NFPA 70 *National Electrical Code*
   www.nfpa.org/70
2. NFPA 72 *National Fire Alarm and Signaling Code*
   www.nfpa.org/72
3. International Electrotechnical Commission
   www.iec.ch/functionalsafety/
4. Factory Mutual
   www.fmapprovals.com
5. European Norms
   www.cen.eu
6. ISO 7240 Fire detection and alarm systems
   www.iso.org
7. UL Standards (Underwriters Laboratories)
   ulstandards.ul.com

About Det-Tronics

Det-Tronics is a global leader in fire and gas safety systems, providing premium flame and gas detection and hazard mitigation systems for high-risk processes and industrial operations. The company designs, builds, tests and commissions SIL 2 Capable flame and gas safety products ranging from conventional panels to fault-tolerant, addressable systems that are globally certified. Det-Tronics is a part of Carrier, a leading global provider of innovative HVAC, refrigeration, fire, security and building automation technologies.

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DET-TRONICS

Corporate Office
6901 West 110th Street
Minneapolis, MN 55438 USA
det-tronics.com

Phone: +1 952.941.5665
Toll-free: +1 800.765.3473
Fax: +1 952.829.8750
det-tronics@carrier.com