White Paper

Flame Detectors: Key to an Effective Fire Suppression System

EMERSON

Flame Detectors: Key to an Effective Fire Suppression System

The first step to battling a blaze is recognizing when it is happening, best accomplished by selecting and applying the right detectors to spot flames while ignoring false alarm conditions.

Introduction

Many process plants and facilities have large quantities of flammable and even explosive liquids and gases as products, feedstocks, or fuels. Even when best practices are diligently followed, there are occasions when equipment failures or operator errors allow these products to escape their containment and mix with air, resulting in fires.

While most people have read about spectacular explosion and fire disasters, many potential incidents are snuffed out early on when a flame detector activates an automated fire suppression system. The system cuts off the source of fuel and extinguishes the fire, often using a special type of foam, to minimize equipment damage, personnel injury, and environmental impact. The flame detector also alerts first responder plant personnel, allowing them to quickly arrive at the scene.

Achieving such a positive outcome depends on effective safety systems and personnel training. Putting first things first, such systems must be able to detect when a fire has started as quickly as possible, triggering the correct sequence of remedial steps before the incident has a chance to escalate.

Plants of the past depended largely on human operators to sound alarms and launch fire-fighting efforts, often due to a lack of effective flame detectors. But with fewer workers in most plants, and greatly improved flame detectors, automated systems are a best practice for initiating efforts.

Fire detection technologies take many forms. Residential and commercial spaces have smoke detectors that look for specific combustion products or air opacity, but these depend on closed spaces to accumulate detectable levels, plus enough time elapsed to reach threshold concentrations. Heat detectors share the same problem. Since process plants are often open to the outdoors, smoke detectors may not be wholly suited to provide early warning of fires.

The fastest way to detect a fire is to recognize flames. They form immediately when gases or liquids combust, and there is no need to wait for accumulation of any specific combustion products or heat. While the concept is clear, the ability to positively recognize flames at fast response speeds is a challenge.

Detecting flames

Humans recognize fire by seeing the visible light it generates and feeling the heat radiated. But anyone who has studied the nature of fire realizes that different fuels can create much different kinds of fires. Burning alcohol is almost invisible compared to burning oil. Fortunately, instrumentation designed to detect flames (Figure 1) does not necessarily have the limitations of a human eye. Flame detectors can look for hot emissions of products of combustion, radicals, and other species in different parts of the electromagnetic spectrum, and when placed effectively, respond in a matter of seconds.

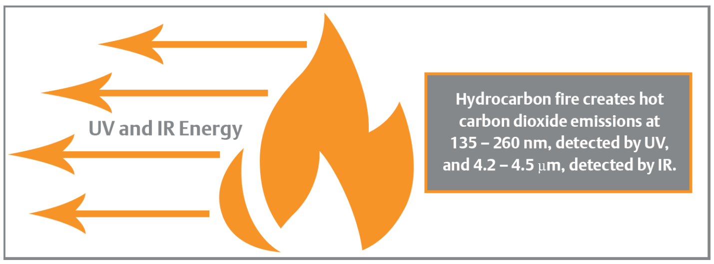

Figure 1: *Optical flame detectors look for specific types of electromagnetic radiation resulting from fires.*

Most products we think of as combustible contain carbon and therefore generate carbon dioxide as a primary effluent. However, carbon is not required to be a fuel as illustrated by inorganic products such as hydrogen, ammonia, metal oxides, silane, and others. Many of these contain hydrogen and therefore produce water vapor. Alcohols, hydrocarbons, and many other fuels include both hydrogen and carbon, and therefore generate both effluents.

Regardless of the fuel source, flames and the resulting hot gases generate electromagnetic radiation in a variety of wavelengths (Figure 2) from ultraviolet (UV), through the visible spectrum and into infrared (IR). How much and in what wavelength depends on the fuel source. Hot carbon dioxide has a strong peak at 4.2 – 4.5 µm (micrometers) with hot water vapor at 2.7 µm. Flame detectors are typically designed to detect light emission at those wavelengths with intensity patterns common to open flames.

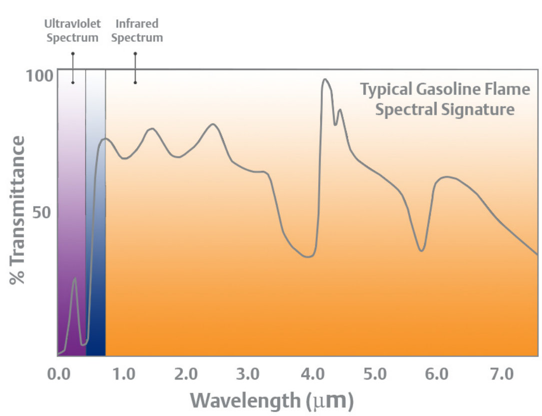

Figure 2: *Combustion creates electromagnetic emissions across a wide range of wavelengths. This spectrum is typical of hydrocarbon combustion.*

Avoiding false alarms

The conditions that flame detectors respond to are not always restricted to the kinds of fires facilities are concerned about. Hot carbon dioxide and water vapor can be created by the exhaust of a truck or stationary engine. Ultraviolet light can be produced by a welder or an odd flash of reflected sunlight. If the flame detector misinterprets these as an actual fire, leading to an alarm and automated control actions to suppress a fire, the response can be enormously costly and disruptive, likely creating a reportable incident.

Besides the cleanup, production will be lost, in many cases for a long period of time after all systems are ready to go due to a waiting period for root-cause investigations, regulatory reports, and other approvals issued prior to restart. Due to these and other requirements, a false alarm can be nearly as disruptive as an actual fire.

This reality has spurred the development of flame detectors able to recognize and reject false alarms, reducing the need for plant personnel to make well-intentioned but ill-advised adjustments. One of the most common, although an inadvisable practice, is simply detuning the flame detector to reduce its sensitivity. This reduces the potential for false alarm at the expense of detection coverage. During a developing incident, the fire will have to escalate to the point where it can trigger the detuned detector, which makes it harder to battle and extinguish.

A better but more instrument-intensive solution is to apply the tried-and-true method of using multiple flame detectors in a voting scheme. This is common in other types of critical safety instrumented systems, but can be costly to deploy and integrate. Nonetheless, deploying multiple detectors and supporting systems will usually be less expensive than dealing with a single false alarm.

The necessity to rely on either of these approaches has been reduced thanks to the growing sophistication of flame detector signal processing systems and their ability to distinguish between an actual fire and other potential sources.

For example, is the source of ultraviolet radiation detected coming from a flame or a welder? While the two may produce emissions in similar wavelength bands, the nature of the output in intensity and variability is quite different and a smart detector can identify which is which.

The quick response time possible with a sophisticated high-sensitivity flame detector can be the difference between a disastrous incident and a fire extinguished with minimal impact. These types of flame detectors can also ensure production uninterrupted by false alarms.

Flame detectors are rated by their ability to resist specific false alarm sources, so any product evaluation should review these in detail. Categories include items such as fluorescent lights, halogen lights, glowing heated coils, arc welders, sunlight, and so on. Most will specify an immunity distance from the subject event.

Tuned to specific hazards

As mentioned, sophisticated flame detectors are designed to look for the most specific wavelengths associated with the types of fires expected in a given facility. This strategy ensures high sensitivity to the anticipated hazard while minimizing the potential for false alarms.

Detector sensors can zero-in on individual or combinations of wavelengths optimized for specific types of combustion and applications (See the Understanding Flame Detector Technologies sidebar). The tradeoffs involved in a selection process touch on several topics, including:

- Fuel and type of combustion
- Sensitivity and response time requirements
- Expected sources of false alarms
- Environmental factors

When these are analyzed, usually one or two flame detector types will emerge as the appropriate choice for a given application. Given the high stakes related to failure, it is important to ensure there are enough selections under consideration to avoid getting stuck with a less-than-optimal choice.

Flame detector application and placement

The most sophisticated flame detectors cannot create an effective system by themselves, nor can they help if placed in ineffective locations. System design must begin with an analysis of the facility, with specific attention paid to where flammable products are stored, processed, or transported. In petroleum and chemical process plants, fire hazards tend to be concentrated in specific zones. The following are several examples:

- Large hydrocarbon liquid and gas storage tanks
- Clusters of control valves on transfer lines
- Pump and strainer installations
- Truck, railcar, and marine loading areas

Flame detectors are usually required to monitor these zones, known as Category H and N zones, due to their high risk for hazardous material releases, fires, and explosions (Figure 3).

Figure 3: *Flame detectors should be placed selectively around hazardous areas where there is potential for flammable products to escape.*

Flame detectors work much like cameras—they require a clear line of sight to the fire to see and detect it (Figure 4), so placement should follow the same basic concepts of surveillance cameras. For example, if a fire hazard exists on the front and back sides of a tank, two flame detectors are necessary.

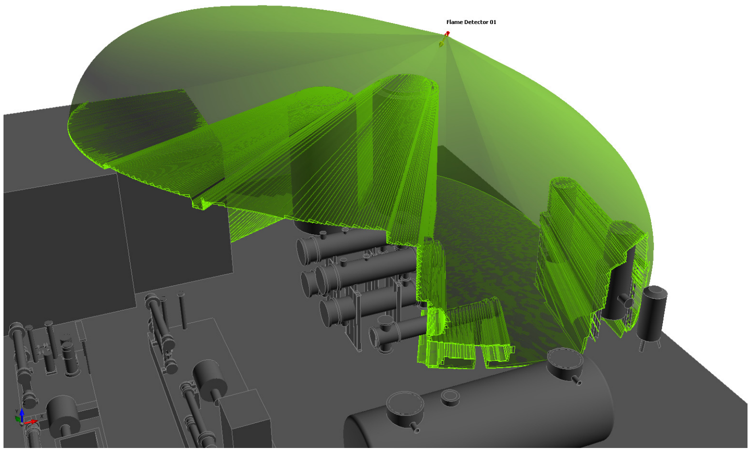

Figure 4: *Coverage by a flame detector depends on clear sight lines to "see" the fire developing. Physical obstructions are just as problematic as with a camera. Detect3D model, Insight Numerics. Used with permission.*

The distance between the detector and flame has a major effect on the ability to recognize a developing fire. Using the camera analogy, if a photographer is taking a photo of a scene with light source, doubling the distance between the camera and source results in one-fourth the radiation energy reaching the camera. Staying in the same location and switching to a wider-angle lens has a similar effect.

Since a flame detector works in much the same way, trying to cover a larger area with a wide-angle lens, or simply moving the detector back, results in less sensitivity. Moreover, since flame detectors have a defined detection coverage for a given sensitivity setting and size and type of fire, as shown in Figure 5, more detectors are required to provide adequate coverage as the target zone's size increases. To improve the odds of detection success, the devices are often placed so that their detection coverages overlap, as shown in Figure 6.

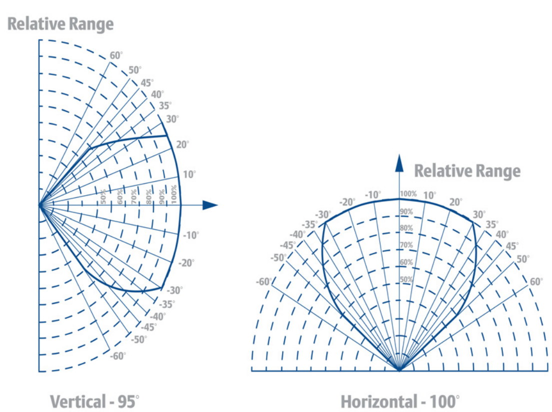

Figure 5: *As this diagram illustrates, coverage falls off from the outside edges as distance increases. This affects both the vertical and horizontal axes.*

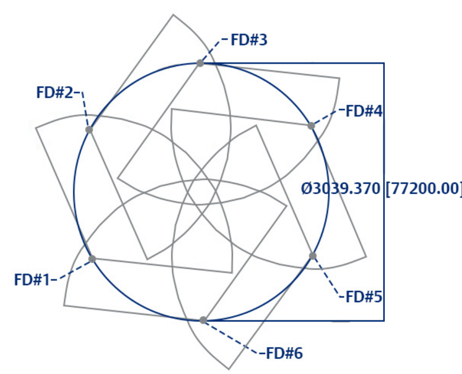

Figure 6: *Effective overlapping of multiple flame detectors around the rim of a crude oil storage tank provide complete coverage of a critical area. Flame detectors at the rim are denoted FD#1, FD#2, and so on.*

Flame detectors can be blinded, to some extent, by their environment:

- Dust can be deposited by wind and rain, obscuring the sensor element
- Clouds of steam, oil mist, rain, and fog can reduce sensitivity
- Sooty smoke from a nearby fire can obscure visibility in another area
- Careless maintenance people can clean windows and optics inappropriately, interfering with resolution and blocking specific wavelengths

Therefore, best practices for flame detection must not only include selection and installation of the right detectors, but also proper ongoing maintenance coupled with close observation of operating conditions.

Effective fire suppression systems

Once the right kind of flame detectors are placed in appropriate locations, they must be integrated with the right kind of suppression system. Design parameters must follow appropriate codes and standards for the types of hazards involved, which should be interpreted by experts to ensure effective implementations. For North America, FM 3260 is critical, as is EN 54-10 in Europe.

If the nature of the hazard is limited, a flame detector may be tied to a self-contained extinguisher system. In other cases, it may be part of a much larger integrated alarm and fire suppression system with automated valve closure and isolation protocols.

When applied correctly, flame detectors and associated systems are very effective in a variety of applications common to refineries, chemical plants, and wellsites. Here are five typical examples, including selection and installation recommendations.

Atmospheric storage tanks

Large tanks filled with hydrocarbon products are normally surrounded by bunds to minimize spreading of any liquid that leaks out or spills from vents during an overfilling incident. These result in rim fires at the top near the vents or pool fires where the flammable liquid spreads on the ground.

Flame detector type: MSIR multi-spectrum hydrocarbon flame detectors [Rosemount 975MR]

Placement: Detectors on the roof can spot rim fires while detectors on the bund walls spot pool fires

Battery rooms

Large battery installations providing uninterruptable power supplies for servers and other computer hardware are often located in remote spaces with poor ventilation combined with conventional electrical equipment. Hydrogen from malfunctioning batteries can accumulate until ignited by an arcing light switch.

Flame detector type: MSIR multi-spectrum hydrogen flame detectors [Rosemount 975HR]

Placement: Room corners overlooking the cells

Natural gas wells

Most wellsite fires are the result of a pipe break, poorly sealed joint, or inadequately closed valve, which allows pressurized gas to escape. If ignited, the gas forms a jet fire with relatively clean, soot-free combustion. However, it still generates carbon dioxide that can be detected.

Flame detector type: Ultraviolet infrared flame detectors [Rosemount 975UR]

Placement: On poles overlooking valve clusters and Christmas trees

Loading racks

Plants and terminals often have loading racks for trucks and railcars bringing flammable liquids in or transporting them out. These provide the potential for liquid spills and vapor plumes when equipment is not used correctly, hoses break, or connections are not properly sealed. These result in pool fires, which may be clean or very sooty depending on the situation.

Flame detector type: MSIR multi-spectrum hydrocarbon flame detectors [Rosemount 975MR]

Placement: Overlooking canopy, catwalks, and ground where pools may form

Pipeline compressor stations

Natural gas pipelines can suffer jet fires similar to wellsites and should be instrumented appropriately. Compressor units can also experience equipment failure, resulting in gas leakage and fires of lubrication systems. Most fires involve natural gas, sometimes mixed with lubricating oil. Lubricant fires can be very sooty.

Flame detector type: MSIR multi-spectrum hydrocarbon flame detectors [Rosemount 975MR]

Placement: Overlooking turbine/compressor installations and valve clusters

Figure 7: *The Rosemount 975 series of flame detectors consists of multi-spectrum infrared and ultraviolet infrared technologies.*

Emerson's Rosemount™ 975 Flame Detector family

Emerson offers a wide range of sophisticated flame detectors in the Rosemount 975 detector family, however it does not manufacture every type due to the ineffectiveness or limited applicability of some types. For example, straight UV detectors are difficult to implement effectively due to their susceptibility to false alarms.

Here are the main types of Rosemount flame detectors, along with common uses:

Rosemount 975MR Multi-Spectrum Infrared

Detects hydrocarbon fuel and gas fires at long distances and provides the highest immunity to false alarms with its multi-spectrum infrared design.

Rosemount 975HR Multi-Spectrum Infrared for Hydrogen

Offers combined capability to detect hydrocarbon and hydrogen fires simultaneously with all the benefits of multi-spectrum infrared technology.

Rosemount 975UR Ultraviolet Infrared

Dual UV and IR detector with sensors tuned to 0.185 – 0.260 μm and 4.4 – 4.6 μm respectively, suitable for the detection of flames produced by clean burning hydrocarbon fuels.

Rosemount 975UF Ultra-Fast Ultraviolet Infrared

Detects hydrocarbon fires plus hydroxyl, hydrogen, metals and other inorganic fuels.

Conclusion

The flame detector is arguably the most critical element of a fire suppression system. It must be sensitive enough to quickly respond to an incident while able to avoid triggering a false alarm. Fortunately, such detectors are available in a range

Understanding Flame Detector Technologies

There are four primary optical flame detector technologies which depend on line-of-sight radiation:

- Ultraviolet (UV)
- Ultraviolet/infrared (UV/IR)
- Multi-spectrum infrared (MSIR)
- Visual flame imaging

Within the major categories there are variations for specific types of applications.

UV detectors respond to radiation in the 0.18 – 0.26 μm range. They offer the fastest response and good sensitivity at comparatively short ranges (0 – 15 m for a 0.1 square meter heptane pool fire). The downside is their susceptibility to arc welding, halogen lamps and electrical discharges like lightning. Consequently, they tend to be used indoors, but thick, sooty smoke can cause failures due to attenuation of the incident UV radiation.

UV/IR hydrogen detectors combine a UV optical sensor (0.18 – 0.26 μm range) with an IR sensor (2.7 – 3.0 μm range) designed to detect water vapor from hydrogen and hydrocarbon combustion. The combined UV/IR flame detector mitigates the drawbacks of a straight UV detector so it can be used outdoors, but with a slightly slower response time. As with UV detectors, detection range may be reduced by heavy smoke. [Rosemount 975UF]

MSIR multi-spectrum hydrogen detectors zero-in on infrared spectral regions at 2.7 – 3.0 μm and 4.2 – 4.7 μm to detect water and carbon dioxide emissions. The hot water band is particularly useful for detecting hydrogen fires, the flames of which are practically imperceptible in the visible light range. This type has a long range and high immunity to smoke and false alarms. [Rosemount 975HR]

MSIR multi-spectrum hydrocarbon detectors concentrate on a wide infrared band to detect carbon dioxide emissions produced by hydrocarbon fires, but with no sensitivity to water vapor. This type can detect fuel and gas fires at long range and has a high immunity to false alarms, but cannot recognize hydrogen fires. [Rosemount 975MR]

Visual flame detectors employ a charged couple device (CCD) image sensor and flame detection algorithms. The imaging algorithms process live video images from the CCD array, and then analyze the shape and progression to discriminate between flame and non-flame sources. Unlike IR or UV flame detectors, CCTV visual flame detectors do not depend on emissions from carbon dioxide, water and other products of combustion to detect fires, nor are they influenced by fires' radiant intensity. Despite their advantages, visual flame detectors cannot detect flames invisible to the naked eye such as those produced by hydrogen fires. Heavy smoke also impairs the detector's capacity to detect fire.

of options able to cover the most complex and demanding applications. These can help ensure minimum damage in the event of an incident, while protecting profitability through uninterrupted production.

More information can be found at Emerson.com/FlameGasDetection

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