High Performance Industrial Flame Detection

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Optical flame detection has progressed to meet the ever-growing demands for maximum reliability, availability and minimal false alarm events and is widely employed in many high risk industries, such as those in oil & gas (onshore & offshore), petrochemicals, hazardous material handling and storage, etc., to protect both high-value plant and personnel.

Flame Detectors are the favored solution for high risk areas and outdoors where smoke and heat detectors are not effective. Unlike smoke and heat detectors, the fire/products of fire (smoke/heat) do not have to reach the optical detector to be recognised as it can 'see' the fire (flame) radiation from distances up to 65 meters, within a 100° 'cone of vision' in all directions – and raise an alarm within 5 seconds. Detection is taken to the fire rather than waiting for the fire to reach the detector.

Optical flame detectors provide the fastest detection of a fuel fire in the early ignition stage. This capability, adjustable field of view and programmability make them extremely well-suited for this critical duty

About Flames

Optical flame detection is based on detecting the unique characteristics of the electromagnetic energy emitted by a fire, including its 'spectral signature' and frequency pattern and distinguishing it from the other myriad of heat radiation emitters and black-body radiation spectral signatures in the surrounding atmosphere.

Flames emit electromagnetic radiation at a wide range of wavelengths, which vary depending on the fuel being burned and environmental conditions that affect the radiation transmission in the atmosphere. Optical flame detectors operate by sensing one or more of these wavelengths.

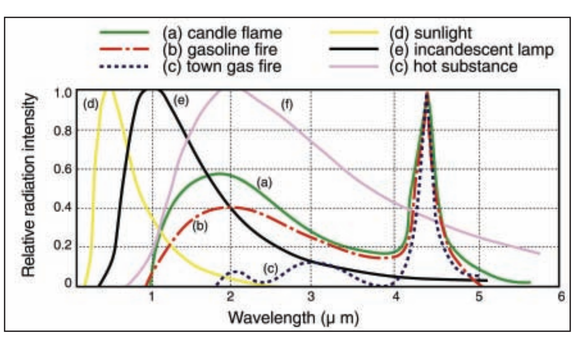

Figure 1: Flames Spectral Analysis

Many combustible materials include carbon, and combustion of such hydrocarbon fuels, typically generate hot carbon dioxide (CO_2) gas. Hot CO_2 has a characteristic infrared (IR) emission spectrum, with a relatively strong and well-defined peak at wavelengths from approximately 4.2 to 4.5 microns, and relatively little intensity at wavelengths immediately on either side of the peak. In the presence of an actual fire, the radiation intensity in the peak band is generally high, while little or no radiation is received in the side bands. Thus, high radiation intensity in the peak band as compared to that in the non-peak side bands is used to determine whether a flame is present.

Some other combustibles lack carbon, for example hydrogen, ammonia, metal oxides, silane and other non-organic fuels. In their combustion process, they generate a lot of hot water vapor that has a characteristic IR emission spectrum with a relatively strong peak around 2.7 microns.

In addition to these two major fire products (CO_2 and H_2O), other intermediate radicals, and ions and by-products created in the fire process (such as CO, CHOH, COOH, CH_3, OH, etc.), emit electromagnetic radiation that can be detected either in the ultraviolet (UV) solar blind spectrum or in the wide IR band 0.8 - 3 micron.

One of the problems in detecting fire conditions, particularly small fires or at long range, is the potential for a high false alarm rate. False alarms can be generated by other electromagnetic radiation sources which are "friendly fires"(like flares in the petrochemical industry) or by spurious radiation sources such as direct and reflected sunlight, artificial light, welding, electrical heaters, ovens, and other sources of noise. Such spurious radiation sources might not be large enough to activate short-range detectors, but may activate detectors whose sensitivity has been increased to maximise their detection distance. A false alarm may result in a costly discharge of the fire extinguisher and its replacement and/or plant shutdown.

Several generations of flame detectors have been developed over the years to address the various fire and explosion hazards, particularly in today's high-risk industries and on the ever-changing military battlefield where soldiers and their protective vehicles are faced with new incendiary weapons and explosives.

Flame Detection Technologies

Flame Detectors usually employ several optical sensors, working in specific spectral ranges (usually narrow bands) that detect simultaneously the incoming radiation at the selected wavelengths. The signals detected by each sensor are analysed according to a pre-determined technique that includes one or more of the following:

1. Comparator techniques (and-gate techniques).
2. Flickering frequency analysis.
3. Threshold energy signal comparison.
4. Mathematical ratios and correlations between various signals.
5. Correlation to memorized spectral analysis.

Modern Flame Detectors employ several of the above-mentioned techniques using multiple sensors to provide enhanced reliability and accuracy. The spectral bands selected for each type of detector determine the detector's sensitivity, detection range, speed of response and immunity to false alarms. The flame radiation spectral pattern, being unique, allows several spectral ranges to be employed simultaneously in the various detection devices.

The following, in chronological order, is a brief review of the technologies, their limitations and the solutions that have been developed and incorporated into modern flame detectors. All are still in use today although early types tend to be restricted to very specific applications.

UV Flame Detection – Single Sensor

The earliest flame detector utilised the UV spectral band. The UV spectral signature of some flames has a pattern that can be readily recognised over the background radiation. UV detectors based on this technology are detecting flames at high speed (3-4 milliseconds) due to the high-energy UV radiation emitted by fires and explosions at the instant of their ignition. However, this discernible UV radiation emitted by a flame from a distance (several meters) in outdoor applications can be attenuated by atmospheric pollutants, such as smoke, smog, hydrocarbon vapors, organic material accumulated on lenses or detector windows. In addition, the occurrence of random UV radiation from stimuli such as lighting, arc welding and radiation, X-rays, solar radiation (not absorbed by the atmosphere, due to holes in the ozone layer and solar bursts), cause false alarms in UV detectors.

A new generation of better performing and more reliable UV detectors now exist but are still susceptible to false alarms and limited to approx 15m detection distance. Today, they tend to be used indoors where other interfering radiation is not present and where very fast response is necessary, e.g. munitions manufacture.

IR Flame Detection – Single Sensor

IR radiation is present in most flames. The flame temperature and its mass of hot gases (fire products) emit a specific spectral pattern that can be easily recognized by IR sensor technology. However, flames are not the only source of IR radiation, in fact, any hot surface, e.g. ovens, incandescent lamps, halogen lamps, furnaces and solar radiation, emits IR radiation that coincides with flame IR radiation wavelengths.

Most single band IR detectors are based on pyroelectric sensors with a 4.4 micron (µ) optical filter and a low frequency (1-10 Hz) electronic band pass filter. This type of detector will recognise a 1 sq.ft. Gasoline pan fire from a distance of 15m.

However, these IR detectors are still subject to false alarms caused by blackbody radiation (heaters, incandescent lamps, halogen lamps, etc.).

Single frequency IR detectors respond only to a certain flicker and radiation intensity of 4.4µ. Under certain conditions, it is possible for flickering, caused by such things as shimmering water, rotating lights or interrupted thermal radiation, to be interpreted as fire by single frequency IR detectors.

In order to minimise or eliminate these false alarms in single UV and IR detectors, dual, triple and multiple wavelength technologies have been adopted for optical fire detection.

UV/IR Flame Detection – dual sensor

Dual spectrum UV/IR technology employs a solar blind UV sensor with a high signal-to-noise ratio and a narrow band IR sensor. The UV sensor itself is a good fire detector. However, it easily false alarms, thus the IR sensing channel was added, working at the 2.7µ or the 4.1µ-4.6µ spectral ranges and serve as a reliable detector for many mid-range applications.

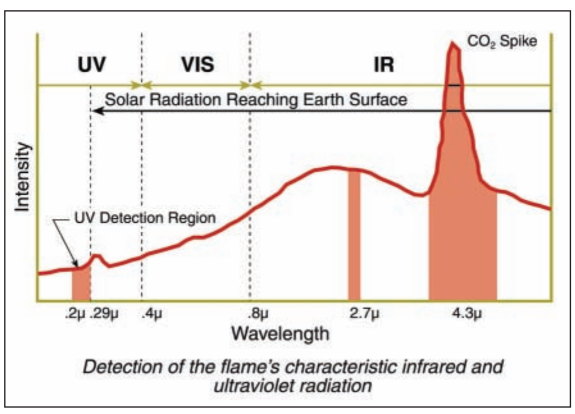

Figure 2: UV/IR Flame Detection

However, even this advanced technology has its limitations, since each type of fire has its own specific ratio of UV to IR output. For example, a hydrogen flame generates a lot of UV with very little IR (in the 2.7µ band), while a coal fire will generate little UV and a high amount of IR (in the 4.1µ-4.6µ bands). Hence, specific dual UV/IR detectors must combine both signals and compare them accordingly to distinguish a fire signature from false alarm stimuli.

To ensure the reliability, a discriminating circuit compares the UV and IR thresholds, their ratio as well as their flickering mode. Only when all parameters satisfy the detection algorithm is a fire signal alarm confirmed. However, UV radiating sources are sources for false alarms.

Since false alarms can affect both UV and IR channels, certain scenarios may occur when a fire is present. A serious problem may occur when a strong UV source (welding) is present and a fire ignites. Here, two UV signals are produced (one strong, the other weak) thus blocking the detector's logic from further comparison with the IR channel, and preventing fire detection.

Unwanted solar spikes in the UV (in the spectral band where fires emit most of their UV energy) combined with flickering IR sources (such as moving objects in front of hot sources) are liable to cause false alarms, even when a fire is not present.

Again, detection distance is limited to max 15m.

IR/IR Flame Detection – Dual Sensor

Common dual IR flame detectors employ two narrow bands (0.9µ and 4.3µ) for fire signal analysis or a combination of short wavelength 0.8-1.1µ and long wavelength 14-25µ IR channels. Some dual IR detectors include, in addition to one near IR channel for fire detection, a channel for the background detection in the 4.7-16µ IR band.

However, more recently, the fire's main spectral characteristic feature at 4.3µ - 4.5µ is analysed thoroughly. This "differential spectral" approach is where two spectral ranges are analysed: one emitted strongly by the fire, while the second is emitted weakly by the surroundings, thus the ratio gives a substantial mathematical tool for fire signal processing.

However, since most dual IR detectors use the 4.3µ sensor as their main channel for fire recognition, they suffer from atmospheric attenuation, especially at long range detection applications. Again, detection distance is limited to max 15m.

Triple Infrared (IR3) Flame Detection

TRIPLE IR (IR3) technology is a major breakthrough in fire detection, which detects by concurrently monitoring with three IR sensors.These signals are further analysed mathematically with respect to their ratios and correlations

IR3 detectors will not false alarm to any continuous, modulated or pulsating radiation sources other than fire (including sources like black or gray body radiation). The high sensitivity of the Triple IR technology, coupled with its inherent immunity to false alarms, enables another major benefit of this technology - substantially longer detection ranges than previously obtained with standard detectors – 65m compared to 15m for the same test fire.

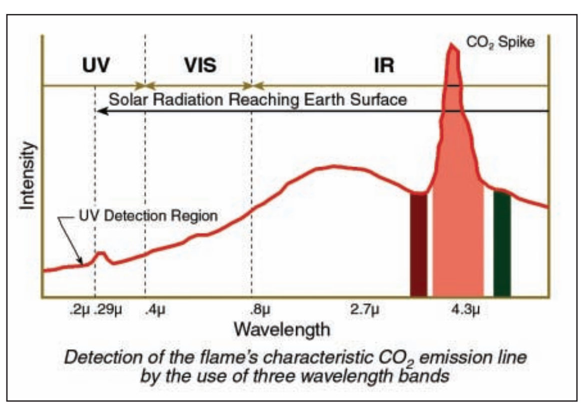

Figure 3: IR3 Flame Detection

Conventional IR3 flame detectors may have a limited ability for discriminating between distant fires and fires within the area they are tasked to protect. For example, petroleum drilling and processing facilities often have large flares that burn off hydrocarbon gas. Typically, flares emit IR radiation characteristic of hot CO_2. Stack flares typically represent known phenomena, and generally are not considered a legitimate alarm source. However, flares are often visible for miles. If within the field of view of a conventional triple IR flame detector, an alarm may be triggered.

To eliminate this, advanced IR3 detectors include special filters for the hot CO_2 peak that enable them to distinguish between near and far fires.

Multispectral Flame Detection

A major concern in optical flame detection is IR radiation with spectra, at least superficially, similar to those emitted by flames, which may be produced by many non-flame sources, including but not limited to warm objects (including, under some circumstances, people or animals), sunlight (direct or reflected) and various forms of artificial lighting. Such IR radiation may be misinterpreted as a flame. However, simply ignoring or filtering this radiation may result in actual flames being masked.

Analysing multiple spectral bands, identifying the absence of a strong peak or other well-defined marker, eliminating spectra resembling a blackbody curve, employing wide band and narrow band filters, are some of the modern 'tools' in flame detection.

The use of multiple IR sensors is the best technology, provided the selection of sensors and filters covers most of the flammables spectra (including hydrocarbons and hydrogen flames) and eliminate all the false alarm spectra in the monitored area. Such detectors can simultaneously detect a hydrocarbon fire at 65m and a hydrogen flame at 30m.

The increased activity in LNG and LPG processing and storage also requires the use of flame detectors, and recent improvements in the effective detection range for such gas type flames (e.g. methane, propane, etc.) means that fewer detectors are required to properly protect any given area than was previously the case.

Due to the increased reliability, durability, high quality and performance, SharpEye 40/40 Series Flame Detectors are approved to IEC 61508 - SIL2 (TUV) for safety integrity; performance approved to EN54-10, FM3260 and DNV Marine as well as Ex Zone 1 hazardous area approved by ATEX, IECEx, FM, CSA and GOST with a resultant extension in the warranty period to 5 years. This represents a major investment in the development, design and manufacture processes along with the high costs of these many 3rd party approvals. Most 3rd party approvals also entail an initial and continuing annual factory assessment to ensure that standards, processes and performance are being maintained.

Summary

Flame detection technologies have advanced significantly since the first UV detector, primarily 'pushed' by the ever-growing demands of modern industries for reliable and cost-effective detection equipment for their expensive high-risk, high-end facilities and processes. Smaller in size, larger in brains (with their miniature microprocessors), modern optical flame detectors provide enhanced flame detection reliability and longer detection ranges with minimal (or no) false alarms, backed by independent confirmation of their performance and integrity.

CCTV Flame Detector is Certified as SIL 2 Capable

Ideal for use in environments where functional safety is critical, the **Draeger** (Germany) Flame 5000 colour imaging based CCTV Flame Detector has been certified as SIL* 2 capable. Offering innovative, reliable flame detection technology for oil and gas installations as well as chemical and pharmaceutical plants, this explosion-proof system is easy to install in any industrial application where a potential fire source exists.

Believed to be unique, the Draeger Flame 5000 is different to traditional radiation, or combined radiation and CCTV cameras because it uses the camera to detect the flame. Designed as a stand-alone system and housed within a single unit, it combines colour imaging with advanced digital signal processing and software algorithms to process live video images and interpret the characteristics of a flame. As a result, it can eliminate false alarms caused by day-to-day workplace influences such as hot processes, flare reflections and hot CO_2 emissions.

The Draeger Flame 5000 can also be used to provide live video images, and can be fully integrated with a control system or fire panel to provide fault and fire signalling using normal 0-20mA or relay outputs. As well as the surveillance benefits, this capability removes the need to despatch operators to investigate alarms, reducing the risk of injury whilst improving response time to hazardous situations to around 4 seconds. Able to detect fires of 0.1m² or more at 44m within a 90° horizontal field of view, it can be operated in temperatures ranging from -60 to +85°C. Simple to install with a stainless steel mounting bracket that can be rotated to ensure optimum positioning, this accurate detector is also fitted with automatic optical verification. This advanced facility checks the window for contamination and ensures that the field of view is not compromised by obstructions placed immediately in front of the detector.

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