Flame safety

C. Filoon, Coen, USA and C. Baukal, John Zink Co. LLC, USA, report on flame safety technology.

Many industries burn large quantities of hydrocarbon fuels to heat a wide range of materials. There are numerous types of combustors used in these processes such as process heaters, furnaces, ovens, kilns, dryers, roasters, calciners, boilers, and thermal oxidisers.[1] The most important consideration during the operation of these combustors is safety.[2] Failure to safely operate a combustor burning large quantities of fuels can result in serious personnel injuries and equipment damage.

There are two primary areas of safety concern when operating fuel burning equipment. The first is starting up the combustion system where the fuel must be properly ignited. A variety of techniques are used including spark ignitors, torches, and pilots.[3] The ignition device must be activated on or before introducing any fuel into the combustor. Normally there will be some trial for ignition time to limit how much fuel can be introduced before ignition is detected. If the fuel fails to light in that time, the fuel flow is stopped. A serious explosion could occur if a large quantity of a flammable mixture is introduced into the combustor before ignition occurs.

The second primary area of safety concern is the loss of flame during operation. There are many possible causes for a flame out such as improper operation, changes in operating conditions, and failure to properly install and maintain the combustion equipment.

The main objective during a flame out is to detect the loss of flame as soon as possible so the fuel flow can be stopped. Continuing to supply fuel and air into a hot combustion chamber after the flame has been lost can lead to a dangerous explosion.

One of the keys then to safe combustion operation is the ability to detect the presence and absence of a flame as quickly and reliably as possible. There are many codes and standards that relate to flame safety. One example is the National Fire Protection Association (NFPA) standard 86 which requires flame detection for combustor temperatures up to 1400 ˚F.[4] Above that temperature, no flame detection is required because this is well above the auto ignition temperature of common fuels. As long as the fuel/air mixture is flammable, it will burn above that temperature, so a thermocouple (T/C) that measures combustor temperature is sufficient for proving the presence of a flame.

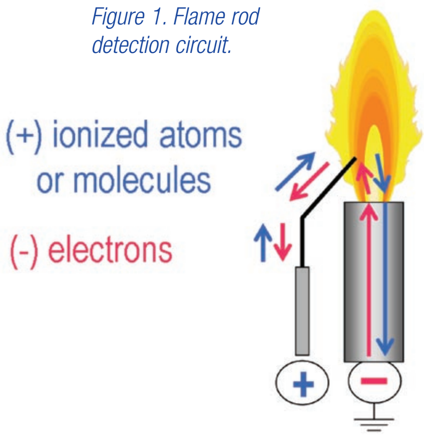
Flame detection

Physical

There are two general methods of flame detection referred to as physical and optical. In physical flame detection, the detector comes in physical contact with the flame. The most common physical flame detectors are T/Cs and flame rods. T/Cs measure flame temperature. Their response time in detecting the loss of flame is dependent on the design; however, the thermal inertia generally produces some lag time that may not be acceptable if a fast response is needed. Another consideration for T/Cs is the high temperature oxidising conditions in a flame that can reduce the life of this type of sensor.

Flames naturally generate charged particles called ions that can be used in flame detection. Flame rods can be used to detect the flow of current through an electrical circuit, which occurs when a flame is present and a voltage is applied to the circuit (Figure 1). Flame rods are in direct contact with the flame and respond immediately to the presence or absence of the flame, but generally have limited application due to temperature limitations of the metal rods. Figure 2 shows an example of a flame rod on a pilot ignitor.

Figure 1. Flame rod detection circuit.



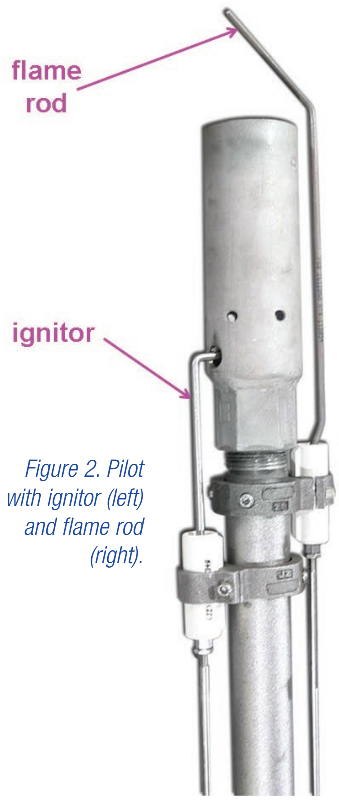


Figure 2. Pilot with ignitor (left) and flame rod (right).

Optical

Optical flame detectors measure the electromagnetic emissions from a flame. The two most common types of optical flame detectors are ultraviolet (UV) and infrared (IR), which measure the UV and IR emissions, respectively from the flame. A major limitation of IR flame detectors is that they also detect the IR emission from hot combustion chamber walls. Unless the IR from the flame is much greater than from the walls, such as for oil and coal flames, IR scanners often have trouble distinguishing between the flames and hot refractory walls. The more common type of optical flame detector used in most common gas fired industrial combustion applications is UV. Flames generate a significant amount of UV radiation that can be easily and quickly detected. Hot refractory walls in the combustion chamber generate essentially no UV radiation so UV detectors only see the flames. Scanners must be properly designed for the appropriate area electrical classification.

UV scanners use UV tubes that react to the radiation emitted from a flame. These tubes have been commonly used since the 1950s and are known to fail over time. They can fail in an unsafe manner, often referred to as a ‘run away’ tube. Electromechanical shutters are used to block the UV radiation to the tube and allow the amplifier to check for a ‘run away’ condition. Even with an electromechanical shutter, x-rays from weld inspection equipment being operated near these tubes can cause the tubes to saturate. This causes the scanner to falsely detect a flame out, which shuts down the combustion system causing a nuisance trip. These self checking UV scanners are required on burners that continuously fire without shutdown for more than 24 hours. For burners that cycle at least once in 24 hours, a UV tube scanner without the electromechanical shutter can be used. Once every 24 hours is a long time for fuel to build in the vessel if the flame has extinguished for whatever reason.

Other light sources can trick a UV scanner into thinking a flame is present. For example, light bulbs and sunlight can both generate enough UV radiation to look like flames to a UV scanner that may see these sources directly or from reflections. Electromagnetic interference (EMI) generated from improper grounding can cause a shutdown due to a false signal. Radio frequency interference (RFI) can also cause detector problems.

Advanced optical scanner

Years of troubleshooting optical scanner problems lead to the design of a new flame scanner that actually differentiates real flame signals from simulated flame signals. This advanced scanner, called the iScan (Figure 3) combines the amplifier with the sensor, which eliminates the special signal cable previously required to run between the scanner and amplifier. Combining the amplifier and the sensor eliminates issues with EMI and RFI, and allows for a more pure flame signal to be processed. Combining the sensor and amplifier also allows the iScan to use 24 VDC, eliminating the high voltage running through cables, jeopardising hazardous location areas, and putting service technicians at risk of being severely shocked.

The iScan uses a single solid state sensor to detect both UV and IR radiation from a flame. In the chemical and hydrocarbon processing industries, this is important since a single scanner can be used in place of using one IR scanner and one UV scanner to monitor a single burner's flame (Figure 4). Because waste gases change heating values without notice, having a fuel flexible sensor monitoring the flame is a real benefit. The use of a solid state sensor also eliminates the need for an electromechanical shutter since self checking is done electronically. The solid state sensor does not over saturate in the presence of x-ray testing of welds in the vicinity of the scanner.

Combining the sensor and amplifier into one housing and using solid state sensors eliminates many risks that can cause a conventional flame scanner to be unsafe. However, it is the signal processing that is truly revolutionary. The sun, the operator, and the hot refractory can all still trick a flame scanner into indicating a flame is present when it is actually not.

The iScan monitors the rate of combustion by analysing the flicker frequency, or the fingerprint, of the flame.

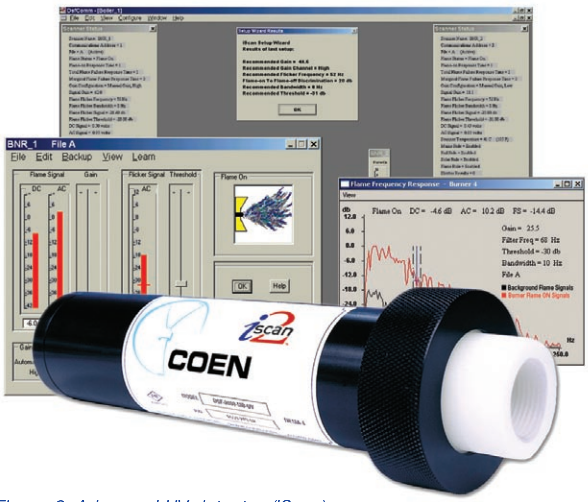


Figure 3. Advanced UV detector (iScan).

Figure 4. iScan mounted on the back of a burner.

Peak flame intensity is typically at or near stoichiometric conditions and drops off in a bell curve fashion at richer and leaner conditions. As the fuel and air mix and combust under the right amount of heat, heat and radiation are emitted in proportion to the fuel/air ratio. Since the flame burns back toward the fuel source, the flame is always in motion. This motion allows the intensity of the flame to vary across a flame flicker frequency spectrum. The iScan analyses the flame flicker frequency spectrum to determine the fingerprint of the flame. It then compares the flame fingerprint with any other signals, whether real or simulated, to safely determine if the flame is actually present or not.

There are four rules that work in combination with the flame fingerprint. The first one is the 'mains rule' and ensures ground loops or improper grounding cannot simulate a flame signal, since the line voltage frequency is concentrated at either 50 or 60 Hz. The second rule is the 'flame rule' and this ensures that only flame signals, which are linear (starting at a high intensity, low frequency and ending at a low intensity, high frequency), are recognised as a flame signal. The third rule is the 'solar rule,' which assures the radiation from the sun will not be detected by the sensor as a flame signal. The 'rail rule' safeguards against operator error so that a high gain setting in combination with the high intensity from the flame will not falsely indicate a flame-on. This combination of safety measures is a unique method to enhance flame detection.

There are some installation considerations when using optical scanners. Premature failure due to excessive temperatures is one of the more costly maintenance issues. Optical scanners are commonly mounted in the back of burners to minimise the heat load seen by the sensors (Figure 4). The iScan has an internal scanner temperature sensor, so the cooling air effectiveness can be monitored and corrective action taken before the scanner is damaged by excessive temperatures. This scanner can be used in a wide range of area electrical classifications. Remote communications permit combustion system analysis for troubleshooting ignition problems, stuck dampers, fouled nozzles, and other combustion related issues.

Conclusion

Flame safety is critical to safe plant operation. Flame rods and UV scanners are the most common physical and optical flame detection methods, respectively. Flame rods are more commonly used on pilots and UV scanners are more commonly used to detect flames from burners. There are some important issues to be considered in the proper operation of UV scanners. Certain conditions can trick the scanner into thinking a flame is present even if it is not. Other conditions may cause a scanner to falsely think the flame has gone out even when it is present. An advanced UV flame scanner has been developed to handle these conditions and enhance the safety of the combustion system.

References

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