Flame Detection Technology: Principles & Devices

One of the key elements in any combustion safety system is the flame monitor. Flame monitor controls and flame detection principles, are generally less understood than other parts of the system. The following is a general description of optical flame detection methods, together with some specific details of Eclipse Combustion Controls flame safeguard equipment.

An ideal flame detector would reliably sense a flame of interest, while totally ignoring all other flames or signal sources and would, in the process, be totally unaffected by ambient operating conditions. As is well known from experience, no completely ideal flame detector exists. The practical goal becomes one of approaching as closely as possible, as many of the ideal attributes as possible.

That characteristic of a flame most useful for its detection, is the electromagnetic radiation produced by it. This radiation covers the spectral range from infrared to far ultraviolet. Infrared and visible radiations, are functions of flame temperature and emissivity. Since furnace and burner parts become heated by the flame, they become potential secondary sources of infrared and visible radiation, which must be discriminated against.

This is accomplished with a reasonable degree of success by a signal processing apparatus, which ignores the averaged steady state radiations and utilizes for signal purposes, only the repetitive minute fluctuations in radiation intensity, within the region scanned by the sensor. This “flicker” characteristic is present in varying magnitude and frequency, in all radiating bodies in a furnace environment, but is sufficiently greater in most flames, to enable them to be distinguished from secondary sources. This does not ease the problem of distinguishing one flame from another in a multiple-burner furnace. Discrimination between flames strictly on the combined bases of flicker and directivity is made difficult, by the fact that the flame portions exhibiting the largest flicker component (the periphery of the flame envelope) are those most apt to intrude into the region scanned by an adjacent burner’s sensor. Improvements in this regard can be achieved by the use of spectral filters and by electronic filters designed to pass flicker frequencies which are predominantly stronger in some regions of the flame than in others. Because flame characteristics may vary considerably with burner adjustment, change in firing rate, fuel composition, etc., any critically selective system may randomly and unpredictably, either provide inadequate signal from the flame of interest, or unwanted signal from other flames. If there is no other available means which meet the combined detection goals as well, then a critically selective system with its know limitations may still be a considered choice.

Ultraviolet radiations of extremely small magnitude are also temperature-dependent emissions of ordinary fuel flames. With commercially feasible sensors and signal processors, this signal is too small for practical use. Other and stronger (though still very small) UV emissions are produced by the ionization which accompanies, and is a part of the oxidation of, fuel in a flame. The source of these emissions is strongest in the very early stages of combustion and therefore in an area relatively close to the nozzle. The outer portion of the flame, where combustion is mostly complete, emits substantially less UV. It will be evident that there is a flame characteristic which is not synthesized by heated furnace and burner parts and, being more localized, makes discrimination between adjacent flames more easily accomplished. The only non-flame source of UV in all but very high temperature furnace walls (2500° F. and up), is the spark from an electric igniter, which radiates very strongly in the ultraviolet and must be shielded from the sensor's view.

Detectors which will sense the small UV emission produced by the ionization process are of a type known as gas-avalanche detectors. These comprise very pure and extremely clean metal electrodes sealed in a UV-transmitting envelope along with a purge gas at a fraction of atmospheric pressure. When a suitable potential difference is applied between the electrodes, and when UV photons in sufficient quantity strike the negative electrode, an electron is released from the electrode and is attracted to the positive electrode. In its movement, this electron collides with a molecule of the gas and dislodges another electron. The two then collide with two molecules and dislodge two more electrons which collide with still other molecules. The resulting "avalanche" enables a substantial current flow. Once initiated, this flow will not cease unless and until either voltage or current is reduced below a critical threshold value. Various circuit means are used to "quench" the avalanche and restore conditions, to permit a new avalanche upon the arrival of additional photons. The natural sensitivity of the detector is enhanced by using it in circuitry which permits avalanching and quenching to occur at rates which permit "counting" frequencies considerably above 60 Hz. line frequency.

UV detectors are not without disadvantages. Their proper function requires ultimate purity and cleanliness of materials, and the best possible seal where the electrode connections pass through the envelope. Any lack of perfection in these areas may result in the detector "counting" with no flame present. It is therefore extremely important that they be used with a signal processing amplifier which repeatedly checks for unimpaired function of the detection system and which acts to trip the burner if improper function occurs. This self-checking function, in all cases, involves periodic blocking of the sensor's view of radiation, and an internal test for proper "no flame" response. The check must occur within a fraction of the nominal 3-second flame failure response time, which is prescribed for flame safety controls in order that the burner may not be tripped by the checking operation.

Another notable problem with UV detection relates to the fact that UV, in the spectral regions being utilized, is interdicted or severely attenuated by most media other than air. **Infrared will** penetrate smoke, dust, fuel particles and oil films; short wave **UV will not**. UV detection is effective with almost any clean fire. Any burner flame which will characteristically cause smoke or fuel particles to be present between the flame and the sensor makes satisfactory UV detection problematical. The better the burner design and adjustment, the less the change of UV detection problems. It is also important that purge air be continuously passed through the flame scanner's sighting tube, regardless of whether or not such air is needed for cooling or scavenging of smoke. It has been found that a stagnant heated air column in the sight tube may, due to diffraction, reduce flame signal by as much as 25 percent.

Following is a partial list of features which contribute to the performance and maintainability of Eclipse self-checking UV flame safeguards:

1. The UV detector has a composite envelope, of which the front half is UV-grade quartz. The quartz passes UV of shorter wavelength than does the high silica glass used for most detector envelopes. The scanner lens, which concentrates UV on the detector cathode, is a special grade of UV transmitting quartz which passes all the wavelengths to which the detector is receptive.

2. The circuit is arranged to enable a maximum "counting" rate of approximately 2000 counts (avalanches) per second. This rate could have been made higher, but higher rates offer little advantage over the rate chosen.

3. Materials in the scanner have been carefully chosen to avoid any materials, which when heated, give off gases which attenuate UV transmission.

4. Getting a good signal is one problem and delivering it intact and transient-free, is another. The relatively small signal produced by the sensor is, in the Eclipse-Dungs scanner, shaped, amplified and delivered to the associated control, at pulse levels of approximately 20 volts in a relatively low impedance circuit. As a result, no shielded signal cables are required. Scanner connecting circuits can usually be routed in the same conduit with other wires, although their routing in a separate conduit gives greatest surety against pick-up problems.

5. The Eclipse control is designed for simultaneous operation of two flame scanners at isolated inputs. This has several advantages, including the following:

   a. Flame patterns tend to fluctuate for various reasons. By simultaneously monitoring two different flame areas, there is a better chance for maintaining a strong flame signal.

   b. Even if both scanners target on the same area, the signal produced by two will be 50 to 75 percent greater than the signal from one alone, if in parallel.

   c. If each scanner by itself produces a strong stable signal, either may be removed for lens cleaning without affecting burner operation.

Two scanners operating into one amplifier does not constitute a true redundant system. If either scanner develops a false flame signal, the burner will be tripped as the fault is recognized by the self-checking circuits. A true redundant system may be designed, however, using two controls, and each of these may use one or two scanners as desired.

6. All active components in the Eclipse control and scanner are plug-in replaceable on a modular basis.

   A scanner that is suspected of being defective can be replaced in 15 seconds or less, without tools, by non-skilled personnel. Additionally, the detector tube can be replaced by use of a screwdriver. The detector is mounted on a small insulating board which insures the maintenance of precision alignment in the optical path if replacement is required. The screws which mount the board automatically make the electrical connections when installed.

7. Important features of amplifier design include the following:

   a. All voltages for both the amplifier and the scanner are supplied by an integral ferro-resonant voltage regulator.

   b. The amplifier has integral temperature compensation over the rated operating temperature range.

   c. All semiconductors and resistors are loaded to not more than 50 percent of rating.

   d. Specified resistors are selected at assembly to hold amplifier sensitivity to within 10 percent of design center.

   e. All electrolytic capacitors which are subject to repetitive charging and discharging are of the "energy storage" type. In units currently supplied for paper mills or chemical plants, these capacitors are sealed to prevent degradation by chlorine and other gases. In the near future these seals will be standard in all units.

The features just enumerated contribute to consistent, long term stability and predictable performance.