7.8 Flame, Fire, and Smoke Detectors

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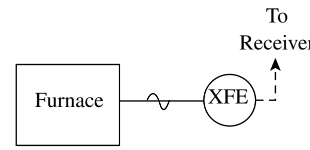

Flow Sheet Symbol

Types:	A. Flame (pilot and main flame detectors in combustion processes) B. Fire (fire safety devices) C. Smoke (detect smoldering and the incipient of fires)
Smoke Sensitivity:	2%/ft (303 mm) obscuration ±0.6%/ft (UL)
Costs:	Battery-operated household smoke detectors are available from around $10. Addressable, intrinsically safe smoke detectors with software programmable test option and with both smoke and temperature sensors cost about $100. Flame rod or thermocouple-type pilot flame safeguard detectors cost about $500. Optical flame safeguards for burner management cost from $800 to $3000, with the higher priced units having explosion proof packaging and intelligent electronics.
Partial List of Suppliers:	Ansul Co. (B, C) (www.ansul.com) Apollo (C) (www.apollo-fire.co.uk) ASCO (B) (solenoids valves) (www.ascovalve.com) Autronica (B, C) (fire panels) (www.autronica.no) Badger (B) (extinguishants) (www.badgerfire.com) Chemetron (B) (extinguishants) (www.chemetron.com) Detector Electronics Corp. (A, B) Systems Optical Flame and Gas Detection (www.detronics.com) Digital Security Controls (C) (www.dscgrp.com) Dwyer Instruments Inc. (C) (test equipment [smoke generators and test equipment for burners]) (www.dwyer-inst.com) Electronic Development Labs Inc. (A) (temperature measurement [resistance temperature detectors] pyrometers) (www.edl-inc.com) E-One (B) (fire pumps/trucks) (www.eone.com) Faraday LLC (fire panels and smoke detectors) (B, C) (www.faradayllc.com) Fike Corp. Fike Metal Products Div. (B) (www.fike.com) Fire-End & Croker Corp. (B, C) (www.fire-end.com) Fireye (A) (flame scanners) (www.fireye.com) Fire Lite (B) (fire panels) (www.firelite.com) Fire Sentry (B, C) (optical fire detectors) (www.firesentry.com) Flame Gard Inc. (kitchen spark and grease flame arrestors) (A, B) (www.flamegard.com) Forney Corp. (www.anarad.com) General Monitors Inc. (A, B) (flame detectors) (www.gmi.com) Hochiki (B, C) (smokes and panels) (www.hochiki.co.jp) Honeywell (B) (fire panels and smoke and heats) (www.honeywell.com) Horiba Instruments (C) (infrared thermometer) (www.hii.horiba.com) International Safety Instr. (B) (www.intsafety.com) Intronics (A) (www.intronics.co.uk) Ircon Inc., Subsidiary of Square D Co. (A) (thermal imaging) (www.ircon.com)

Kidde-Fenwal Inc. (B, C) (fire panels smokes and heats, extinguishants) (www.kidde-fenwal.com)
Life Safety Associates Inc. (B, C) (training organization) (www.lifesafety.com)
MSA Instrument Div. (B) (flame and gas detectors) (www.msanet.com)
Notifier (B) (fire panels) (www.notifier.com)
Pyronics Inc. (A) (flame scanners) (www.pyronics.com)
Pyrotronics (B) (fire panels) (www.sbt.siemens.com)
Reliable Fire Equipment (A, C) (www.forneycorp.com)
Sierra Monitors (A, B, C) (optical fire detectors) (www.sierramonitor.com)
SimplexGrinnell (B, C) (fire panels) (www.simplexgrinnell.com)
Spectrex (B) (optical flame detectors) (www.spectrex.com)
TSI Inc. (C) (www.tsi.com)
Wajax Pacific Fire Equipment Inc. (B, C) (fire pumps) (www.wajax.com)
Western Fire Equipment Co. (suppliers to fire brigades of clothing and engines) (B) (www.western-fire.com)

INTRODUCTION

This section covers both the types of instruments that guarantee the maintaining of combustion and the instruments that serve to warn the occupants of a building when a fire starts. The devices used for these purposes operate on similar principles and therefore can be discussed in the same section of the handbook. The fire and smoke detectors will be discussed first. This will be followed by a discussion of optical fire detectors, concluding with a description of fire safeguarding devices used in burner management.

FIRE AND SMOKE DETECTORS

A fire occurs in four distinct phases. In the first, or incipient, phase, warming causes the emission of invisible but detectable gases. In the second phase, smoldering, smoke is formed, so smoke detectors can be used. In the third phase, when the ignition temperature has been reached, flames are present and therefore their emitted radiation (infrared [IR] and ultraviolet [UV]) can be detected. In the fourth and last stage of the fire, heat is released; the temperature of the space starts to rise, and the use of thermal sensors becomes feasible. Obviously, the sooner the evolution of a fire is detected, the less damage it is likely to cause. Therefore, fire and smoke detectors are discussed here in the order of their applicability to the four stages of fires.

Smoke Detectors

Ionization Chamber Sensors In the early warming and incipient stage of fire, combustion products are emitted without visible smoke, flame, or heat release. Ionization chamber type sensors are used to detect the presence of these gases by analyzing the composition of the atmosphere through the measurement of conductance. The ionization chamber contains two electrodes held at different potentials and a radioactive alpha particle source that ionizes the air in the chamber. The ionization current that results reflects the composition of the air and rises as the invisible combustion gas concentration rises.

Photoelectric Sensors Once the fire starts to smolder and smoke is present, photoelectric sensors can be used to activate alarms. Most smoke detectors use a light beam and a photoelectric cell or transistor. As the smoke density rises, less light passes from the source to the receiver and an alarm is activated. Smoke detectors must be maintained so that dust and dirt accumulation will not cause false alarms. In most fires the casualties are not caused by the heat of the fire, but by the toxicity of the combustion gases and by asphyxiation from smoke. Therefore, early warning systems, such as photoelectric smoke detectors, are very important.

Thermal Sensors

There are two types of thermal sensors that are used in fire protection application. One is the rate-of-rise sensor, and the other is the absolute temperature sensor. Rate-of-rise alarms are usually set at 15 to 20°F (8.3 to 11.1°C) per minute. This rate of rise can be detected by either bimetallic pneumatic tube sensors or thermoelectric sensors. The fixed temperature sensors actuate an alarm when the space temperature reaches a present limit. They are usually either bimetallic or fusible link devices. In the fusible link devices, the melting of a low-melting-point solder activates the operation of sprinklers or other extinguishing devices.

Flame Sensors

Once there is a flame, it emits a flickering radiation, which is mostly in the IR wavelength. Therefore, IR sensors can be used to detect the presence of flames. The flickering frequency of open flames (5 to 25 cps) allows the discrimination of flames from infrared radiation generated by light bulbs (at 120 cps) or from unmodulated ambient light sources. False alarms can still be caused by sunlight reflections from windows or rippling water surfaces, or by flickering neon signs. Therefore, the mounting location of the sensor should be carefully selected. Flame detectors should be used when combustible gases or flammable liquids are present, where the ignition is almost instantaneous and has practically no incipient or smoldering stage.

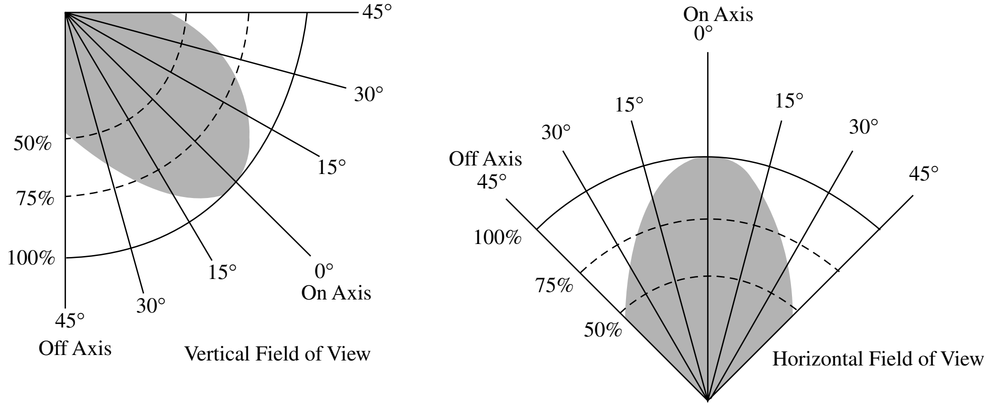

FIG. 7.8a
Cone of vision for a 90° with 50% off axis sensitivity.

Types of Optical Flame Sensors There are basically five types of optical detectors in addition to closed-circuit television (CCTV):

1. UV
2. IR
3. UV/IR
4. Dual IR
5. Multi-IR

Flame detectors are specified by their cone of vision, which is defined by the field of view and the on axis detection distance to the fire (Figure 7.8a). The angle of the field of view is defined by the 50% of the on axis detection capability of the detector. Typically these are about 90° (horizontally) although there are some detectors with fields of view of up to 120°, or with 100% off axis detection capability. A distance to a specified size fuel source (typically 1 ft^2) is also specified. This fuel source is generally *n*-heptane although other fuels are often listed (e.g., gasoline, methane plume, etc.). The manufacturer's data sheet should indicate the off axis detection distance, generally graphically (or as a percentage of the on-axis distance).

When selecting a flame detector, the specifying engineer must take into consideration the fuel source and the cone of vision of the selected detector to ensure adequate coverage of the potential hazard. Because these are optical devices, it is important to ensure that the detector has an unobstructed view to the hazard, and that the selected detector automatically verifies the cleanliness of its lens. Several manufacturers offer an optical integrity check and therefore the ability of the detector to see a fire. The failure of the optical check should generate a fault alarm.

The flame detection algorithms within the flame detectors are highly specific, and often their response and capability to detect a fire will vary from manufacturer to manufacturer. Tables 7.8b and 7.8c provide data on the flame detection distance and the false alarm sources, respectively, of the various optical fire sensors discussed below.

TABLE 7.8b
Typical Optical Flame Detection Distances (Feet)

Type	*UV*	*IR*	*Dual IR*	*UV/IR*	*Multi-IR*
Gasoline	90	85	100	100	210
Diesel	65	65	50	40	150
Methanol	50	50	20	55	150
Methane	80	45	25	90	100
Hydrogen	50	NR	15	NR	NR
Metal fires	15	NR	15	NR	NR
Black powder	15	40	40	NR	NR

Note: NR – no response

TABLE 7.8c
False Alarm Source Impact

Type	*UV*	*IR*	*Dual IR*	*UV/IR*	*Multi-IR*
Arc welding	■	▲	▲	▲	▲
Modulated IR radiation	●	▲	▲	●	●
Electrical arcs	■	▲	●	●	●
Radiation (nuclear)	■	●	●	●	●
Lightning	■	●	●	●	●
Grinding (metal)	■	●	●	●	●
Artificial lighting	■	●	●	●	●
Sunlight	▲	●	●	●	●

Note: ■ Severe effect, ▲ Some effect, ● No effect

Ultraviolet Detectors This optical technology was developed in the early 1970s using UV detection with Geiger Muller tubes. These were the first optical flame detectors and are based upon a Geiger Muller tube. The UV detectors count the number of pulses in the tube and give a total number of counts per second. The detector then alarms when a predetermined threshold has been exceeded. The UV detector is very good for flame detection in enclosed spaces. It is not so good for outdoor applications as there are too many potential sources for false alarms.

UV detectors are good for sensing hydrogen and methanol fueled fires (fires that emit predominantly in the UV spectrum) because these materials burn with a blue flame (i.e., strong UV source). These detectors are generally the fastest responding typically 30 ms. The drawback is that they are prone to false alarming from strong UV sources such as arc welding and lightning. Even if not directly in the field of view, UV reflections will trigger an alarm. UV is attenuated by oil films and is obscured by smoke. Because of the sensitivity of UV detectors to lightning, it is generally not recommended for outdoor applications. Another potential cause of false alarms is static discharges that can be detected by some UV detectors.

Infrared Detectors In general, IR detectors are good for detecting hydrocarbon based fires (i.e., fires that have strong IR emissions). IR detectors are generally not as fast as UV detectors to respond to a fire. A disadvantage of IR is that ice buildup can desensitize the detector (lessen its ability to detect a fire), but this can be overcome with heated optics. IR does not respond to electric arc welding unless the welding is very close to the detector, in which case the detector may alarm due to seeing the burning from the welding process. Some IR detectors have flicker and statistical analysis algorithms to minimize the effects of black body sources, a false alarm source.

UV/IR Detectors These detectors combine the best of both the UV and IR and result in fewer false alarms than UV or IR detectors alone. Depending on how the individual manufacturers use the two signals also affects their performance. Some UV/IR detectors "AND" both signals such that in order to generate an alarm, both UV "AND" IR sources must be present and exceeding their threshold levels. Other designs might "OR" the two sources such that only UV or IR will alarm. Yet others may ratio the two signals; in order to generate an alarm, both sources of UV and IR must not only be present, but also must exceed a certain ratio.

One disadvantage is that the loss of one (either UV or IR) will prevent alarming except in the "OR" design. High background IR (engine body) may meet the IR condition in an "AND"-ed detector such that an arc or lightning would cause a false alarm. Also, it is possible to saturate the UV portion in a ratio-based detector, if it is so designed that the corresponding IR would have to be excessively large to signal a fire alarm.

Dual IR These detectors have two IR sensors. The dual IR sensors seem to be falling behind the more favored multispectrum (triple IR) detectors. These types of detectors generally have longer detection ranges than UV or IR sensors and are more fuel specific in their applications. Dual IRs can be desensitized by high background levels of IR, reducing their ability to detect a fire.

Multispectrum IR These detectors have three IR detectors. Each manufacturer's multispectrum detector is somewhat different. These differences are due to the differing (patented) flame detection algorithms used by the manufacturers (i.e., how the three optical IR signals are processed). In general, these detectors offer greater detection ranges and give fewer false alarms. They are currently the best performing flame detectors available.

Closed Circuit Television This is an emerging technology and there are only a few products to choose from. These types of detectors come either as black and white or color images that are human viewable. As they are only sensitive to the red-green-blue spectrum they are not suitable for blue/translucent flames from such fuels as hydrogen and methanol. The advantage of CCTV detectors is that the user is able to verify the presence of a fire before taking any action. Since this is an emerging technology, there is little information on their performance.

FLAME SAFEGUARDS (BURNER MANAGEMENT)

In this section, a brief description of the more widely used means of flame detection will be presented. After some basic theoretical discussions, the various devices will be described. The feature tabulation given in Table 7.8i will enable the reader to select the most desirable sensor for the application at hand. Functions of flame sensors as part of burner control systems will be discussed later.

Among the many characteristics of flame, the following have been successfully used to detect the presence flame:

1. Heat generated
2. Ability to conduct electricity (ionization)
3. Radiation at various wavelengths, such as
   a. Visible
   b. IR
   c. UV

Methods of detecting these characteristics are described below.

Heat Sensors

The earliest flame sensors utilized the most obvious characteristics of the flame—namely, the heat generated. These devices were thermocouples, bimetallic elements, etc. For small installations and domestic burners these devices were satisfactory and are still used. Their relatively slow response (2 to 3 min) renders them unsuitable, and indeed dangerous, for larger installations.

Let us take a large reforming furnace as an example. If it requires 1000 SCFM (0.47 m^3/s) of fuel gas, and flame failure is detected only after 2 to 3 min, the 2000 to 3000 ft^3 (56 to 84 m^3) of unburned fuel gas admitted to the furnace will create an explosion hazard. A detector with a response of 4 to 6 s or less will not permit sufficient amounts of gas to enter the furnace to cause an explosion. Another obvious disadvantage of these sensors is that since they only sense heat, they will be unable to distinguish between heat generated by flame or that radiated by the hot refractory.

Conduction-Type Detectors

The first major breakthrough toward fast (but unreliable) detection of the flame was the discovery that flame is capable of conducting electricity. This is true because the flame, being a chemical reaction between a fuel and oxygen, liberates a large number of electrons. Because of ionization, the flame can conduct both DC and AC currents, which are utilized to establish an electrical circuit. A rod immersed in the flame (flame rod) acts as one electrode, the burner as the other. This proved to be fast but unreliable in that a high-resistance electrical short caused by, for example, faulty insulation, could simulate the presence of flame.

Rectification

Any electrical device that offers a low resistance to the current in one direction but a high resistance to the current in the opposite direction is called a rectifier. An ideal rectifier is one with zero resistance in one direction and infinite resistance in the opposite direction.

When AC is passed through a rectifier, the current obtained will be rectified current. It will consist of only that portion of the input current to which the rectifier presented low resistance.

By making the area of one of the electrodes (the burner in this case) much larger than the other, conduction will essentially take place only in one direction (Figure 7.8d).

The Rectification Phenomenon The explanation for the above phenomenon is that when ionization takes place, electrons are liberated from the gas molecules and are free to move about, constituting electric current. In addition to the freed electrons, the negative electrode contains many surplus electrons acquired through the negative side of the external circuit that makes the electrode negative. These surplus electrons repel each other, and, given enough positive ions to attract them, will leave the negative electrode. The number of electrons leaving the negative electrode and entering the positive electrode determines the rate of current flow. It is apparent that the current flow depends on the number of positive ions that get near enough to the negative electrode. Suppose the area of one electrode is made several times large than the other and that electrode is negative. This will increase the flow of electrons to the other (positive) electrode.

If AC is applied, the current through the flame will be rectified. Indeed, using this arrangement and thereby obtaining a *half-wave rectified* current, the lack of safety due to simulated flame was eliminated, as the circuitry associated responded only to a half-wave rectified signal. Unrectified alternating current or direct current input to the detecting circuit will result in a safe shutdown. Because flame rods are in direct contact with the flame, they have to be cleaned or replaced often. Above approximately 2000°F (1100°C), very few metals can be used and even these become brittle. Fuels with high sulfur content burn with flames having low resistance, resulting in low flame rod output and leads to nuisance shutdowns.

To avoid direct contact with the flame and the maintenance problems arising from it, another obvious characteristic of the flame—its ability to radiate energy—was used.

Radiation Types

Radiation emitted by the flame covers the energy spectrum for wavelengths corresponding to UV, visible, and IR range (Figure 7.8e).

Visible Radiation Visible radiation occupies about 8% of the total bond of wavelengths radiated by the flame. To detect this position of the radiation, a rectifying phototube is used. It consists of a light-sensitive coated cathode of large surface and an anode encapsulated in a vacuum (Figure 7.8f).

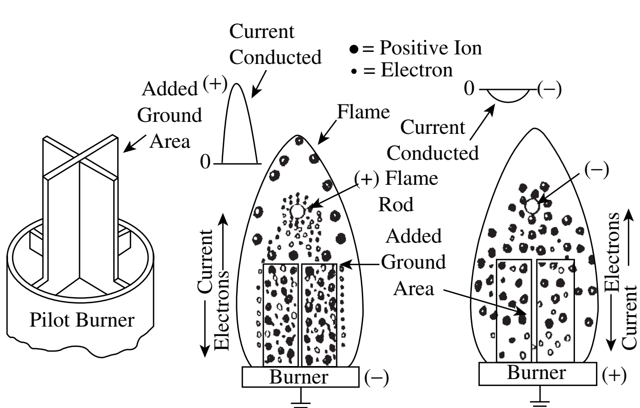

FIG. 7.8d
Rectification by flame.

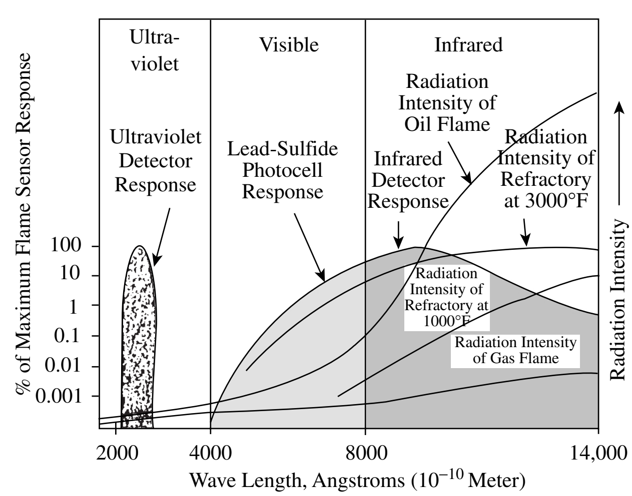

FIG. 7.8e
Applicable ranges of selected flame sensors and the range of hot refractors effect.

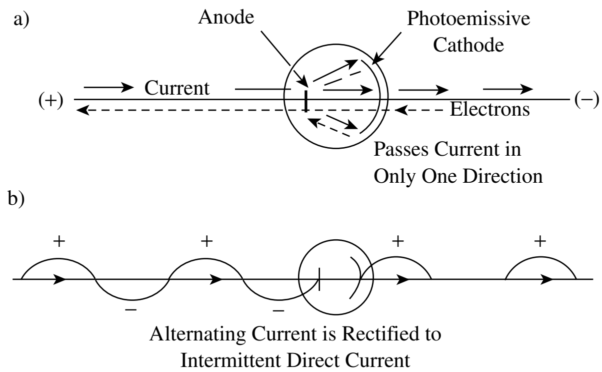

FIG. 7.8f
Rectifying phototube.

The number of electrons emitted by the cathode is approximately proportional to the light intensity. Conduction will take place only when the anode is positive.

If AC is applied, the phototube will act as a half-wave rectifier. The associated electronic circuit will respond only to such a rectified signal, and high-resistance shorts will not simulate flame. At high temperatures, the refractory (noncombustible insulator used to line interiors of furnaces) emits visible radiation. The detector might not be able to distinguish this radiation from the visible radiation emitted by flames; therefore, caution must be exercised in installing the detector in such a position that it will not be able to sight hot refractory. Use of rectifying photocells is limited to oil-fired burners, because visible radiation emitted by gas flame is insufficient to be detected by this type of flame sensor.

Cadmium-Sulfide Photocell The single element of this type of photocell is coated with cadmium sulfide, which is sensitive to radiation in the visible spectrum only. In darkness cadmium sulfide has high electrical resistance. When exposed to light, it conducts freely and almost instantaneously. The electrical resistance of cadmium sulfide decreases directly with increasing intensity of light. Like lead sulfide, it acts as a variable resistor and conducts current equally well in either direction.

This photocell is used in series with the coil of a low voltage relay in an AC circuit. When the cell sees sufficient light to pass a given current, the relay "pulls in." The sensitive region of the cadmium-sulfide cell is such that it will not respond to gas flames and can, therefore, be used with oil flames only. The performance of this cell will not be affected by the "shimmering" effects of hot refractory.

Infrared Radiation IR radiation covers the largest portion, approximately 90%, of the band of wavelengths emitted by the flame. Its intensity is by far the strongest of all radiation forms emitted. The IR radiation emitted is a more reliable means of detection than the visible radiation. It is emitted by gas as well as oil flames, and the intensity never drops to zero.

Lead-Sulfide Photocell This cell is sensitive to IR radiation and is the most widely used device for such detection. Similar to the principle of the cadmium-sulfide photocell, the principle of the lead-sulfide photocell is to change its resistance inversely to the IR radiation it is subjected to. It is a variable resistor and conducts electricity equally well in both directions without rectification. The current flow is a measure of flame strength.

The signal-sensing circuit responds only to so-called flame frequencies. When looking at a flame, it seems to burn steadily. But if the eyes were sensitive enough to very rapid changes, it could be seen that the flame burns brightly at one instant and less brightly the next. The flame really flickers or pulsates, but much too rapidly for this to be detected by the human eye. The frequency of the flicker is very irregular, but may be detected by an electronic circuit designed to accept only a proper band of frequencies. Such a tuned circuit is selective and will not be affected by IR radiation emitted by hot refractory, nor can a high-resistance short simulate a flame.

Experiments show that a shimmering effect caused by movement of hot gases between the refractory and photocell can fool the circuit and flame simulation can occur. This so-called shimmering can be demonstrated by viewing objects through the heated air over a candle.

Ultraviolet Radiation Seemingly, UV is the least significant portion of radiation. It represents only about 1% of the total radiation and covers 10% of the emitted band of wavelengths. UV radiation is emitted by gas as well as oil flames. The device popularly known as a UV detector is a gas-filled tube with voltage applied between its two electrodes (anode and cathode).

The tube is conductive only if voltage is applied at its terminals, and it is subjected to UV radiation.

It is readily seen that a high-resistance short cannot simulate flame, nor can it be affected by the hot refractory. This is because no UV radiation will be emitted by refractories below approximately 2500°F (1370°C). Compared to the detectors so far mentioned, the UV cell is foolproof.

In addition to all these attributes, some UV detectors have an additional built-in safety feature. This consists of a shutter arrangement that blocks the view of the cell for a fraction of a second about 20 times each second, interrupting the circuit that can reestablish current flow again only if UV radiation still exists. This arrangement makes the detector responsive to flame failure within a fraction of a second, because it has to convince itself 20 times a second that flame exists.

Installation

Proper installation of flame sensors is essential to safe operation. Installations of these sensors fall into three categories:

1. Pilot and main flames supervised simultaneously—Checking the pilot and main flames simultaneously is the most desirable method of flame supervision. When

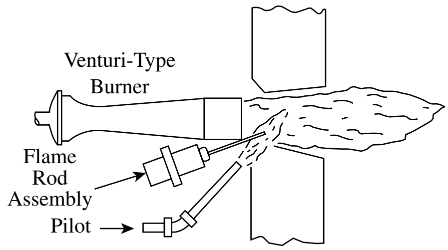

FIG. 7.8g
Pilot and main flame monitored by flame rod.

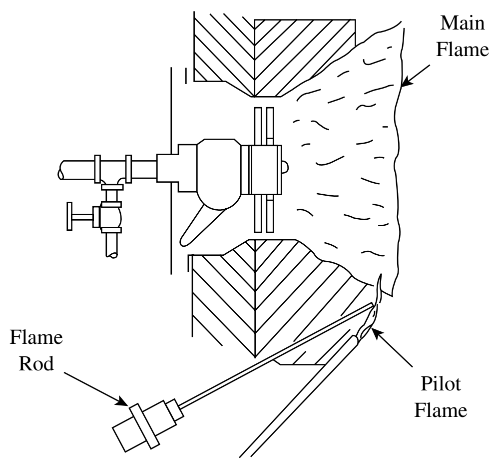

FIG. 7.8h
Mechanical fan-type burner. Pilot flame only is proved.

this arrangement is used, the pilot is capable of safely igniting the main flame (Figure 7.8g). The flame rod in this case is located in the path of both the main flame and the pilot flame.

2. Only pilot and flame supervised—On some installations it may be impossible to prove the pilot and main flames simultaneously because variations of the main flame envelope at different firing rates. This condition prevails, for example, in mechanical fan-type burners. The recommended practice of installation in this case is to supervise the pilot flame (Figure 7.8h).
3. Only main flame supervised—In application where the pilot flame is not lit continuously but only on light-off, the main flame is supervised. It is essential that the sensor be installed in such a way that it will be able to feel or see the flame during all variations in firing rates and draft adjustments.

The above considerations are applicable for flame rods as well as for the different viewing devices. Additional care must be exercised in the installation of rectifying phototubes and lead-sulfide photocells to ensure that incandescence of hot refractory or shimmering of hot air will not simulate the flame. This is accomplished by limiting the view of the devices through a restriction orifice.

Portholes for viewing devices must be cleaned regularly to ensure an unobstructed view and thus prevent nuisance shutdowns.

CONCLUSIONS

The order of presentation for the different types of sensors was intended to show how the limitations of each design have been eliminated.

Flame Guards

Starting with the heat sensors, it was seen that their response time rendered them unsuitable for industrial applications. The flame rods provided for fast response, however, their direct contact with the flame and the consequences, such as brittleness or oil and carbon deposits on the rod, limited their usefulness. Photocells utilizing the visible range of radiation were limited by their inability to reject radiation from the refractory, and their useful range covered only oil flames.

The infrared detector eliminated most of the above shortcomings, but shimmering of hot air could still fool the detecting circuit. It is safe to say that UV detectors can be used reliably in any application. Their relatively high cost demands that the situation be carefully investigated for possible application of other sensors.

In an oil-fired furnace, the cadmium-sulfide cell can be safely used if it is installed so that it will not see the hot refractory. For combination oil and gas furnaces, the lead-sulfide cell will work satisfactorily if it is installed with its view pointed toward the flame through a restricting orifice so that it will not see shimmering hot air.

All devices except the flame rods share the common advantage of not being in contact with the fuel and the flame. The temperature limitations imposed on them are easily satisfied because the temperature outside of the furnace is unlikely to reach 150°F (66°C). The purpose of these installations is safety, and, therefore, cost consideration can be only secondary.

For a summary of flame guard sensor features, see Table 7.8i.

Optical Fire Detectors

In selecting the right fire detection system, the user must analyze the potential hazard and false alarm sources and select the detector that can signal an identified fire with the highest immunity from false alarms (Tables 7.8b and 7.8c). The specific cone of vision of the selected flame detector should be evaluated to make sure that it will give adequate coverage to the particular fire hazard (Figure 7.8a). These detectors must also have an unobstructed view to the fire hazard.

TABLE 7.8i
Comparison of Flame Safeguards

Principle of Flame Detection	*Rectification*		*Infrared*	*Visible Light*	*Ultraviolet*
Type of Detector	*Rectifying Flame Rod*	*Visible Light Rectifying Photo Tube*	*Lead-Sulfide Photocell*	*Cadmium-Sulfide Photocell*	*Ultraviolet Detector Tube*
			ADVANTAGES		
Same detector for gas or oil flame			✓		✓
Can pinpoint flame in three dimensions	✓				
Viewing angle can be orificed to pinpoint flame in two dimensions		✓	✓	✓	✓
Not affected by hot refractory	✓			✓	✓
Checks own components prior to each start	✓	✓	✓	✓	✓
Can use ordinary thermoplastic covered wire for general applications, no shielding needed	✓	✓			✓
No installation problem because of size			✓	✓	
			DISADVANTAGES		
Difficult to sight at best ignition point			✓		
Exposure to hot refractory may reduce sensitivity to flame flicker and require orificing			✓		
Flame rod subject to rapid deterioration and warping under high temperatures	✓				
Not sensitive to extremely hot premixed gas flame			✓	✓	
Temperature limit too low for some applications	✓	✓	✓	✓	
Shimmering of hot gases in front of hot refractory may simulate flame			✓		
Hot refractory background may cause flame simulation		✓			
Electric ignition spark may simulate flame					✓

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