



**Flame Safeguard Controls**  
in  
**Multi-Burner Environments**

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WV-96, APRIL 1998



# FLAME SAFEGUARD CONTROLS IN MULTI-BURNER ENVIRONMENTS

## PREFACE

This booklet provides the basic principles of operation and application of Flame Detectors and their associated controllers in the multi-burner environment. The intent of this document is to develop an understanding and appreciation of those principles and applications.

The reader is guided through the principles of Burners and Safety Systems, the Combustion Process, Igniters, Burner Configurations, Flame Detection and Controllers.

The content outlines the Burner Management Systems (BMS) environment in multi-burner applications as well as the principles of operation, application, and installation of the various flame detectors and their associated controllers.

Field technicians preparing for a wider base of knowledge in the field of multi-burner flame detection equipment will find the greatest use for this document. Although it should prove beneficial at many levels, the content presupposes that the reader has an adequate background in the fundamentals of boiler room control equipment. The emphasis within is toward those flame safeguard control particulars directly associated within a multi-burner environment.

## BURNERS AND SAFETY SYSTEMS

Burners are simple devices that convert fossil fuels into heat energy. In order to achieve safe and reliable operation, each burner must be equipped with a monitoring and control system. The complexity of a safe and reliable system is relative to the complexity of the process at hand. This system can be as simple as a single burner using a single fuel, to a complex multi-

burner environment where many burners fire into a common combustion chamber where multiple fuels are burned simultaneously. Conditions affecting the complexity of control systems is not necessarily dependent upon large burner input, but IS dependent upon the following conditions:

- Type of process.
- Type of burner.
- Multi- or single burner environment.
- Multi or single fuel operation.
- Safety hazard of fuel burner.
- Local codes and standards.
- Redundancy and reliability factors.
- Continuous or intermittent burner operation.

Recent technological advances require knowledge of applications and systems and should be applied only by qualified technicians. Standards are set by local authorities and must be understood and properly operated in order to assure that safety requirements are met.

## BURNERS

The primary functions of burner systems are as follows:

- Controlled fuel delivery.
- Controlled combustion-air delivery.
- Controlled fuel and air mixing.
- Controlled and reliable ignition.
- Evacuation of combustion products.
- Controlled emissions.

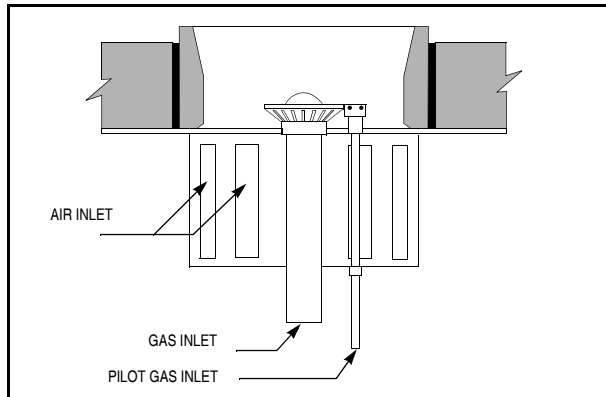
Regardless of fuels fired, the burner system must reliably perform all functions listed above. Choice of fuels burned and type of burner affects the ease of achieving optimal results.

### Gaseous fuel fired

- Natural draft burners.
- Balanced draft burners.
- Induced draft burners.
- Forced draft burners.

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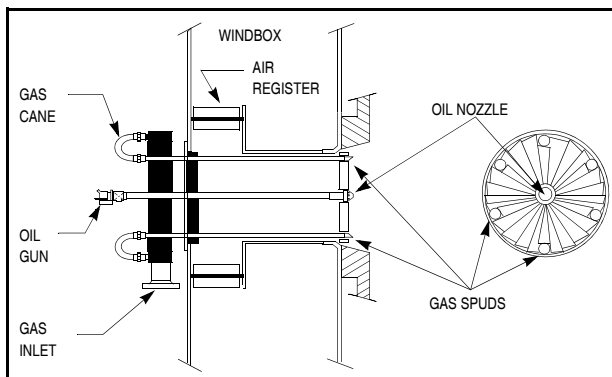
**Figure 1:** Vertically fired Atmospheric Gas Burner.



### Liquid fuel fired: (forced or balanced draft)

- Mechanically atomized.
- Air atomized.
- Steam atomized.

**Figure 2:** Cane burner, with center fired oil-gun.



### Solid Fuel Fired

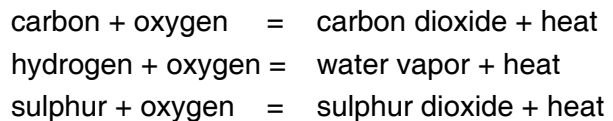
- Grate Burners.
- Fluidized bed burners.
- Powdered coal burners.

Final fuel delivery and combustion-air and fuel mixing varies, depending on the burner types listed below:

- Gun type.
- Cane (spud) type.
- Ring type.
- Rotary cup type.
- Bucket (coal).

## COMBUSTION

Combustion (or burning) is a rapid combination of oxygen with fuel, resulting in a release of heat. Air (the oxygen source) is about 21% oxygen and 78% nitrogen by volume. Most fuels contain carbon, hydrogen, and sometimes sulphur. A simplification of combustion could be listed in the following three processes.



These products of combustion are chemical compounds. They consist of molecules, combined in fixed proportions. Heat given off in any combustion process is excess energy which the molecules must release.

**Stoichiometric** combustion results when no fuel or air goes unused during the combustion process. Combustion with too much (excess) air is said to be **lean** or **oxidizing**. The excess air or oxygen plays no part in the combustion process. In fact, it reduces efficiency. Visually, excess air produces a short and clear flame.

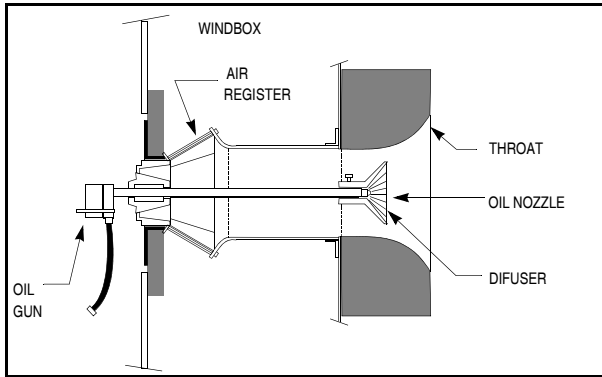
Combustion with too much fuel is called **rich** or **reducing**, producing incomplete combustion. This flame appears long and sometimes smoky. The oxygen supply for combustion generally comes from ambient air.

Because air contains primarily (78%) nitrogen, the required volume of air is generally larger than the required volume of fuel. **Primary air** is air mixed with the fuel before or within the burner's fuel delivery system. **Secondary air** is usually brought in around the burner's fuel delivery system and spun through a diffuser or turning vane system in order to optimize air-fuel mixing. **Tertiary air** is used to control the shape

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of the flame envelope or to control flame temperature on **low-NOx** burners. It is brought in downstream of the secondary air.

**Figure 3:** Oil register burner



**Table 1:** Comparative heating values for typical fuels

FUEL BURNED	Btu/lb (Btu/Gal)		Kcal/Kg (Kcal/L)	
	Gross	Net	Gross	Net
Blast furnace gas	1,179	1,079	665	599
Coke oven gas	18,595	16,634	10,331	9,242
Natural gas	21,830	19,695	12,129	10,943
Propane gas	21,573	19,885	11,986	11,049
#2 Oil	18,993 (137,080)	17,855 (128,869)	10,553 (9,130)	9,920 (8,583)
#6 Oil	18,126 (153,120)	17,277 (145,947)	10,071 (10,198)	9,599 (9,720)
Coal	14,030	12,900	3,500	3,100

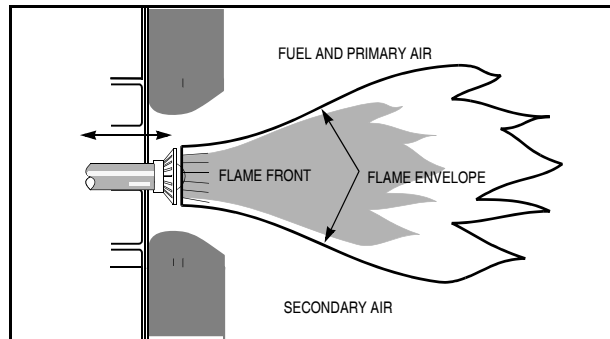
Most fuels are mixtures of chemical compounds called hydrocarbons. When these burn, the by-products are carbon dioxide and water vapor (unless a shortage of oxygen exists when carbon monoxide, hydrogen, unburned hydrocarbons and free carbon may be produced). Heat available from fuels is measured in Btu, Kilocalories, watt-seconds, or joules.

A **flame** is a zone within which the combustion reaction occurs at a rate that produces visible radiation. A **flame front** is the contour along which the combustion starts — the dividing line between the fuel-air mixture and the combus-

tion process. In stable flames, the flame front appears to be stationary. The flame moves toward the burner-nozzle(s) at the same speed that the fuel-air mixture leaves the burner. A variety of feed ranges exist in a wide range of burner designs. Common flame characteristics are as follows:

- Production of heat energy
- Expansion of gases
- By-product production.
- Radiation emission.
- Ionization within the flame envelope.

**Figure 4:** Flame, flame envelope



### FUELS

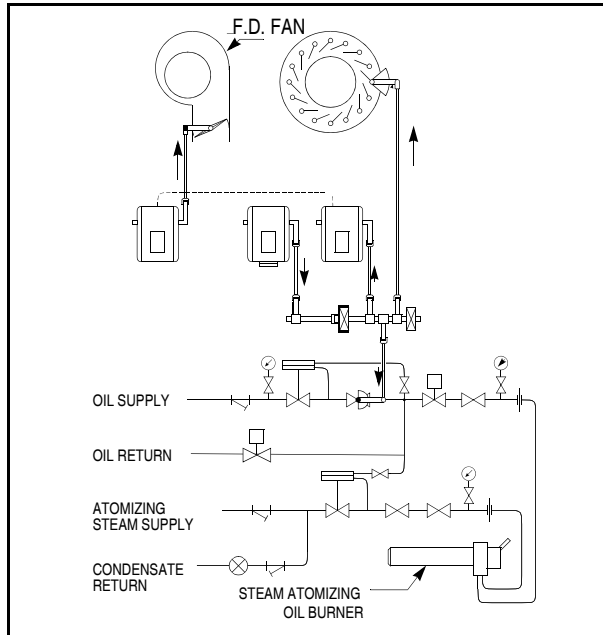
**Natural gas** fuel requires no special handling in filtering, drying, heating, etc. Efficiently using fuel oils largely depends upon the ability of the burner system to atomize the oil and mix it with air in the correct proportions. Heavy fuel oils are usually heated with steam. Tank heaters may raise the oil temperature sufficiently to reduce viscosity to facilitate pumping and straining.

**Steam atomization** occurs when steam is tangentially projected across jets of oil at the oil nozzle. This results in a conical spray of finely divided oil after the mixture leaves the nozzle.

**Air atomizing** occurs when air is used as the atomizing agent in a proportioning inside-mixing type oil burner using low pressure air.

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**Figure 5:** Schematic control diagram of automatic oil-fired unit, steam atomized

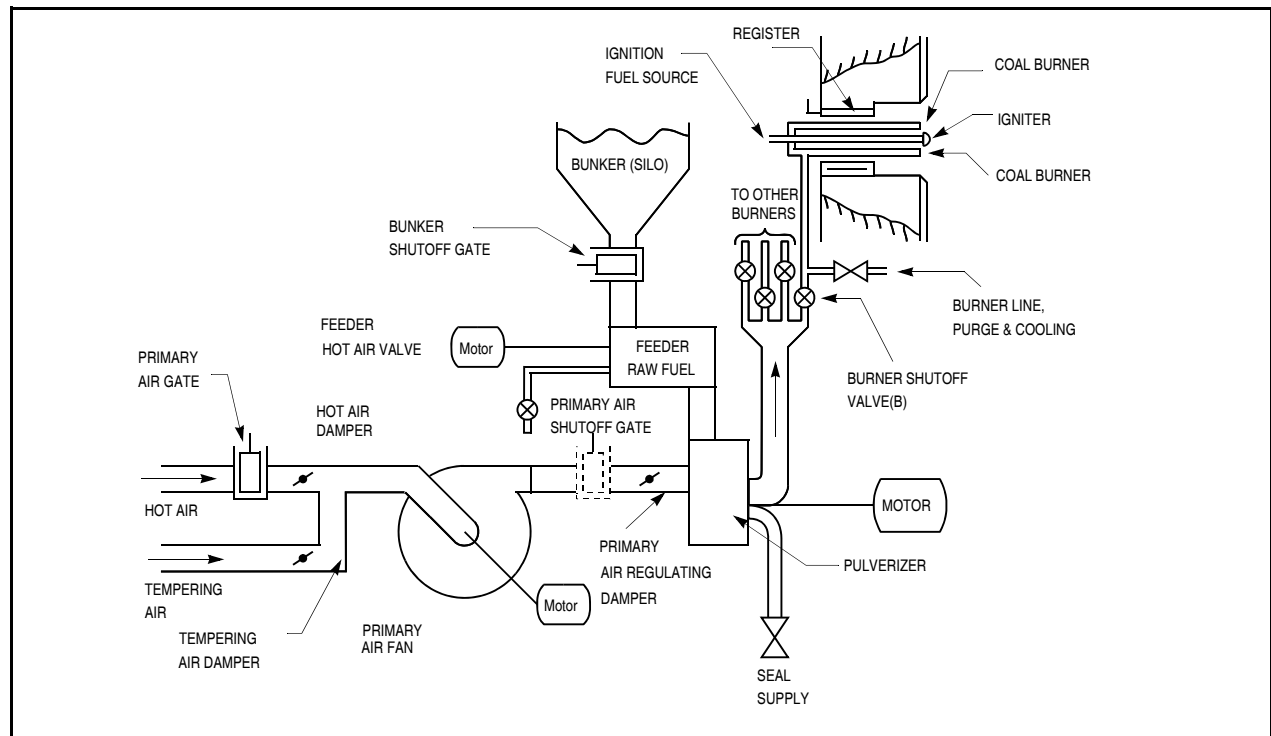


Large capacity oil burners use two steps to combust the oil — atomizing and vaporization. **Vaporization** converts oil from the liquid to

vapor by application of heat at the flame-front. By atomizing the oil into millions of tiny droplets, the exposed surface area is increased and the oil can vaporize at its highest rate. For good atomizing and vaporizing a large volume of air must be mixed initially with the oil particles.

**Mechanical atomization.** Atomization without the use of either air or steam is synonymous with pressure atomizing. The nozzle consists of a system of slots tangential to a small inner whirl chamber followed by a small orifice. When passing through the slots, the volume of liquid increases. The high velocity prevailing in the whirl chamber tangentially imparts a centrifugal effect that forces the oil against the walls of the nozzle. It passes through the orifices in the nozzle tip and into the combustion chamber, fanning out into a cone shaped spray of very small particles.

**Figure 6:** Typical direct fired pulverizing subsystem, individual external transport



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**Coal** burning in multi-burner applications uses **pulverized coal**. Boilers can be equipped with one or more pulverizing mills through which the coal passes on its way to the burners. Hot air from the preheater dries the pulverized coal and carries it through the burners and into the furnace (suspension firing). There are wide variations in fineness requirements. The lower the coal's volatile content, the finer it must be milled. Generally four to six burners are fed by one mill.

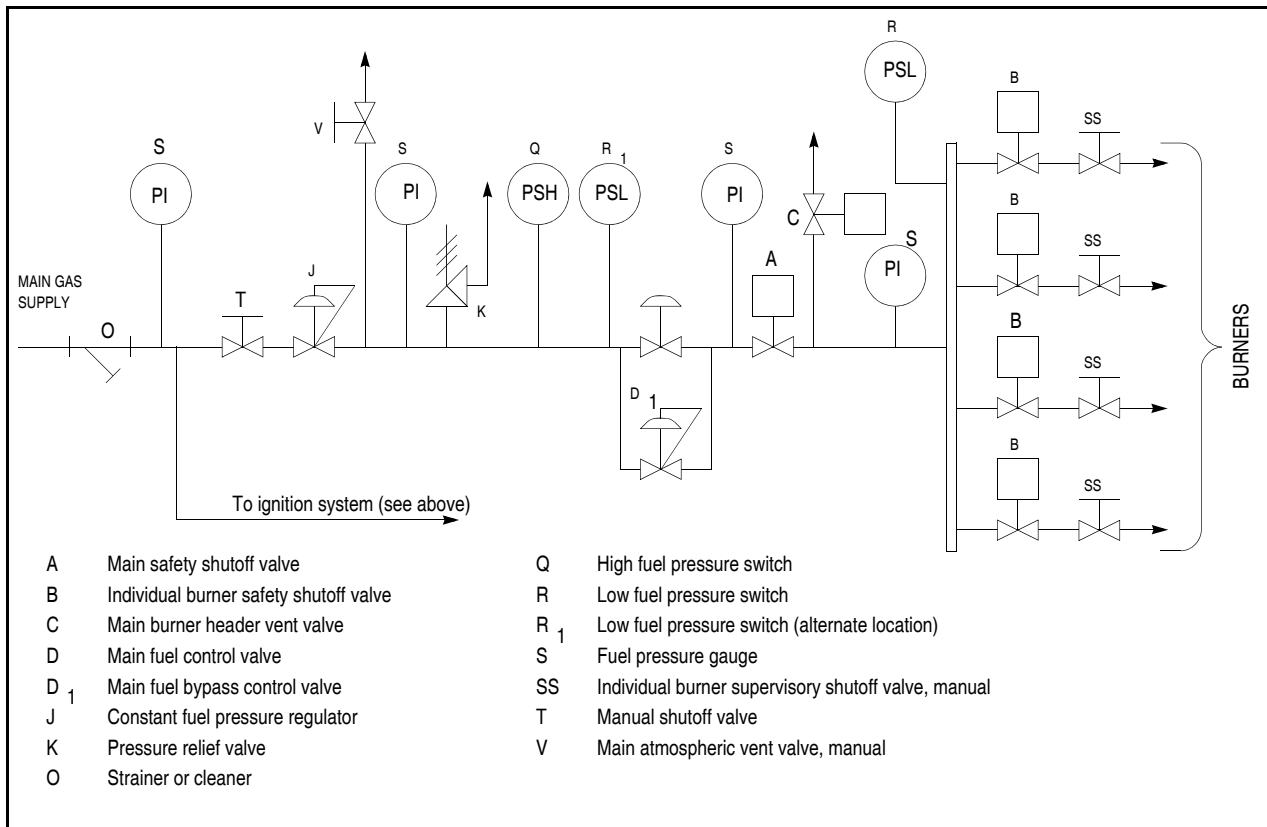
The **main fuel supply subsystem** (consisting of the piping and/or ducts and associated equipment to deliver the fuel to the burners) connects to the **main burner subsystem**. A fuel supply system needs to be sized and

designed to ensure continuous flow adequate for all operating requirements.

It needs to include the co-ordination of the main fuel control valve, burner safety shutoff valves, and associated piping volume to ensure against fuel pressure transients. This can result in exceeding burner limits for stable flame when burners are placed in and out of service.

Main burner subsystems (fuel trains) continuously supply burner inputs to the furnace with stable flame limits. Variations in the burning characteristics of a fuel introduce unreliability to the lower operating limits of a burner subsystem of any design. Class 1 or 2 igniters may be required to maintain stable flame.

**Figure 7:** Typical main burner fuel supply system for gas-fired, multi-burner boiler.



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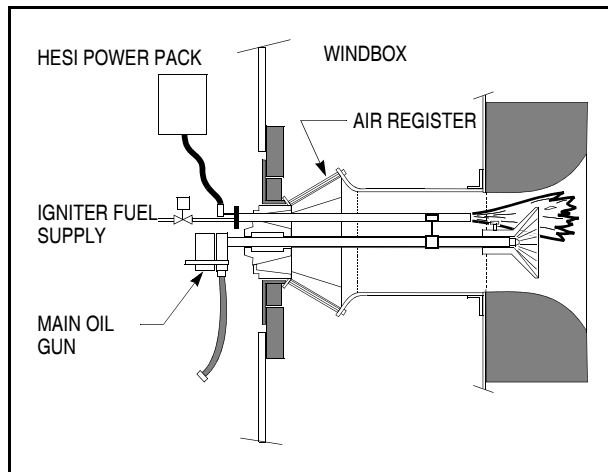
### IGNITERS

**Igniters** provide proven ignition energy to immediately light-off the burner. They are permanently installed. Igniters are classified as follows by NFPA:

**Class 3 special:** High energy igniter (HEI) capable of directly igniting the main burner fuel. Generally consists of a spark-rod, and power pack to deliver the high voltage pulse train, and required cabling. Operation time of igniter is no longer than required to light-off burner, within maximum allowed trial-for-ignition time.

**Class 3:** Low capacity igniter applied particularly to gas and oil burners. Ignites the fuel input to the burner under prescribed light-off conditions. The range of class 3 igniters generally do not exceed 4 percent of full load burner input. Operation time of igniter is not longer than required to light-off the burner, within the maximum allowed trial-for-ignition time.

**Figure 8:** Class 3 igniter installed on oil burner.



**Class 2:** Medium capability igniter applied particularly to gas and oil burners to ignite the fuel input to the burner under prescribed light-off conditions. The range of class 2 igniters generally is 4 to 10 percent of full-load burner input.

Class 2 igniters may remain in operation to support ignition under low-load or adverse operating conditions. Class 2 igniters cannot be used to extend main burner turn-down range.

**Class 1:** High capacity igniter used to ignite the fuel input through the burner. Supports ignition under any burner light-off or operating conditions. Its location and capacity provide sufficient ignition energy at its associated burner to raise any credible combination of burner inputs of both fuel and air above the minimum ignition temperature. Tests are to be performed with this ignition system in service to verify that the igniter furnished meets the requirement of this class as specified in its design. Class 1 igniters can be used to extend the main burner's turn-down, where they are in service and flame if proved.

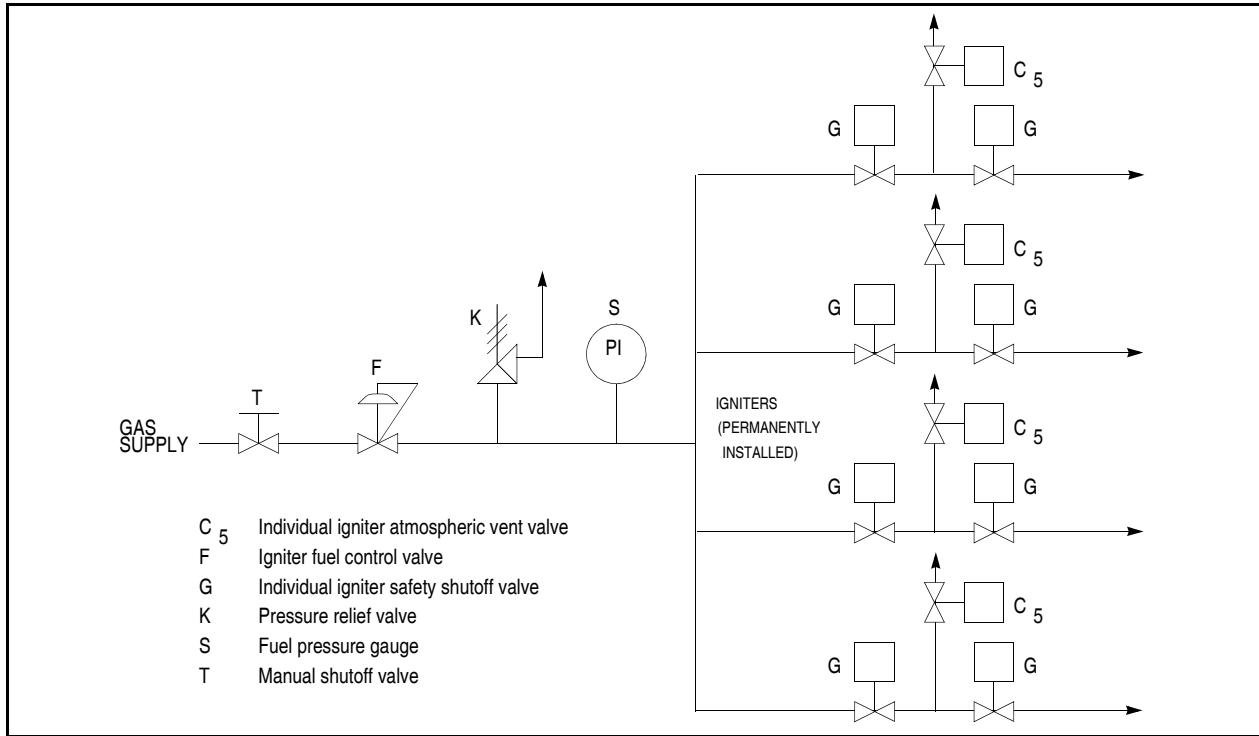
The **ignition subsystem** must be sized and arranged to ignite the main burner input within the limitation of the igniter classification. Many factors affect the classification and subsystem of igniters, including the characteristics of the main fuel, the furnace and burner design, and the igniter capacity and location relative to the main fuel burner.

**Burner configuration** is dependent on boiler furnace design and configuration. Some burner configurations in multi-burner boilers are:

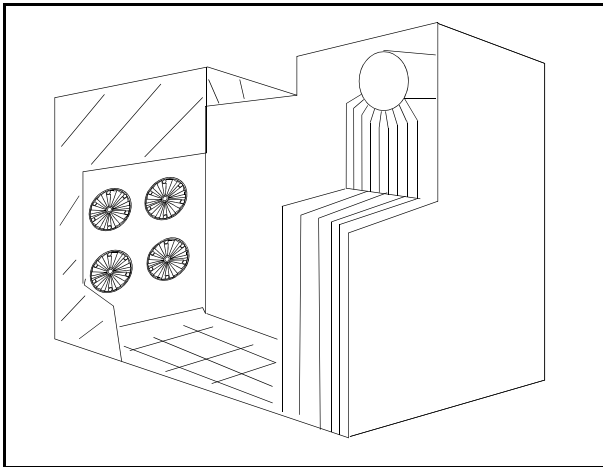
**Front fired.** Burners are located in only one of the furnace walls, nominally the front of the boiler. Variations in arrangements of front-fired applications can include a single row of burners at one level, to multi-burners per level at many levels. Four levels of three burners (3 over 4), or three levels of six burners (6 over 3), etc. would be common multi-burner configurations.

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**Figure 9:** Fuel supply system for gas fired, multi-burner boiler igniters.



**Figure 10:** Front-fired boiler.

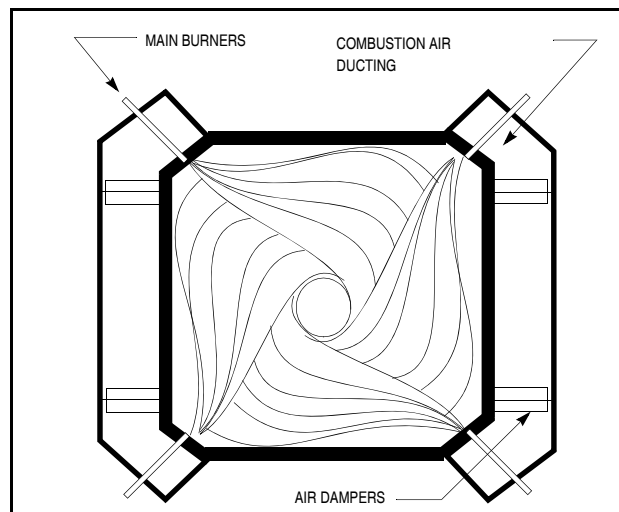


**Opposed fired.** Burners are located in two of the furnace walls, opposite each other, firing toward the center of the furnace. The same variations in burner arrangements as in front-fired may apply to opposed fired burners.

**Tangential fired.** Where burners are located in the corners of the furnace, firing tangentially into the furnace. This creates a large fireball in

the center of the of the furnace area. Tangentially fired boilers have four burners per level, and variations are in the burner decks.

**Figure 11:** Plan view of a tangentially fired boiler.



By law, boilers must be operated with the installation and check of a flame safeguard and instrumentation system. Boiler control is divided



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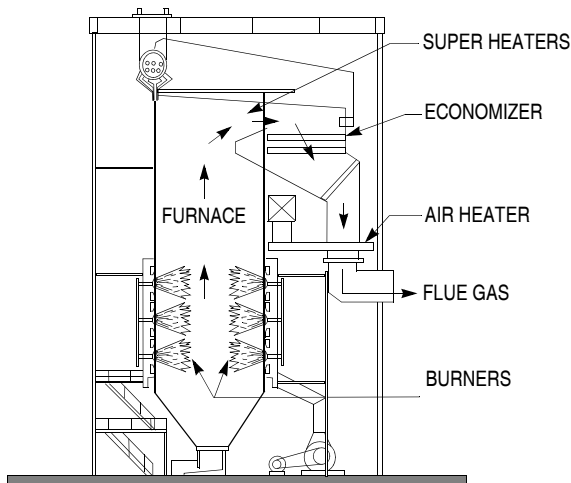
into two groups — the **combustion control system** and the **burner management system**.

The combustion control system regulates the furnace fuel and air inputs to maintain air-to-fuel ratio. This ratio must be within the limits required for continuous combustion and flame stability throughout the operating range.

The burner management system must be a stand-alone system dedicated to boiler safety. It assists the operator in safe starting and stopping of burners while preventing operator error. A burner management system (BMS) includes the following components.

- Interlock system.
- Fuel trip system.
- Master fuel trip system.
- Master fuel trip relay.
- Flame monitoring and trip system.
- Ignition subsystem.
- Main burner subsystem.

**Figure 12:** *Opposed fired boiler.*



### FURNACE EXPLOSIONS

The basic cause of furnace explosions is the ignition of an accumulated combustible mixture within the confined area of the furnace. Explo-

sions can also occur in associated boiler passes, and ducts that convey the combustible gases to the stack.

A number of conditions can arise in connection with the burner's operation to produce explosive conditions. The most common are:

1. Momentary loss of flame at the burner due to interrupted fuel or air supply, followed by delayed ignition of the accumulated fuel-air mixture.
2. Fuel leakage into an idle furnace followed by ignition of the accumulated combustible mixture by a spark (or other source of ignition).
3. Repeated unsuccessful attempts to light-off burner(s) without appropriate purging. This results in ignition of the accumulated combustible mixture.
4. The accumulation of an explosive mixture of fuel and air. This happens as a result of loss of flame or incomplete combustion at one or more burners during normal operation, or during lighting of additional burners.

According to NFPA, these examples are conditions that typically give rise to furnace explosions. An examination of numerous reports of furnace explosions suggests that small explosions, furnace puffs, or near misses is more frequent than commonly assumed. Improved instrumentation, safety interlocks, proper operating sequences, and a clearer understanding of the problems by both designers and operators can greatly reduce the risk and actual incidence of furnace explosions.

### FLAME SAFEGUARD CONTROLS

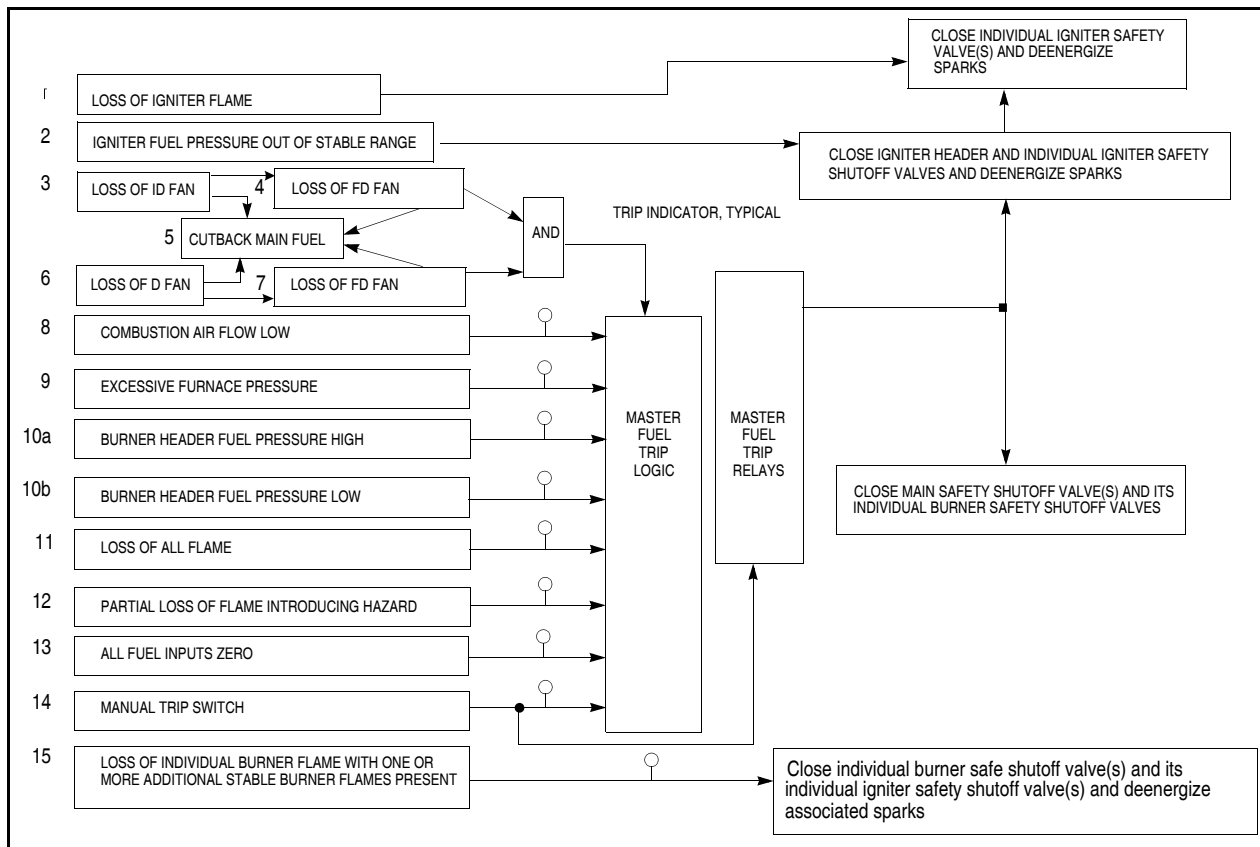
**Flame Safeguard (FSG)** controls are integral and essential components in the BMS system. These systems monitor individual burner

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flames and respond to the presence or absence of their targeted flame. This recognition occurs within a specified flame failure response time (FFRT) without being influenced by extraneous signals radiating from neighboring burners or furnace background. The detectors are connected to associated controllers. In industrial multi-burner environments, FSG detection may be located in extreme conditions of high ambient temperatures, vibrations, dirt, and moisture

from fuel oil and powdered coal, and burner front-area “hazardous area classification.” These situations require special attention to each type of application with attention to product specification and enclosure ratings. Each flame detection control is specifically designed to fulfill selected functions and the burner technician must customize to meet his particular application.

**Figure 13:** Burner Management System interlock and logic for natural gas fired, multi-burner boiler (NFPA 8502)



The most important criteria in hardware selection is determined by the application. Controls with the appropriate features must be selected. The control must be able to monitor its targeted flame, regardless of adjacent burners or furnace conditions. Awareness of different characteristics of flames can greatly assist

the technician in selection of the correct control.

The most basic flame characteristics are:

1. Production of heat energy.
2. Expansion of gases.
3. By-product production.
4. Radiation emission.
5. Ionization within the flame envelope.

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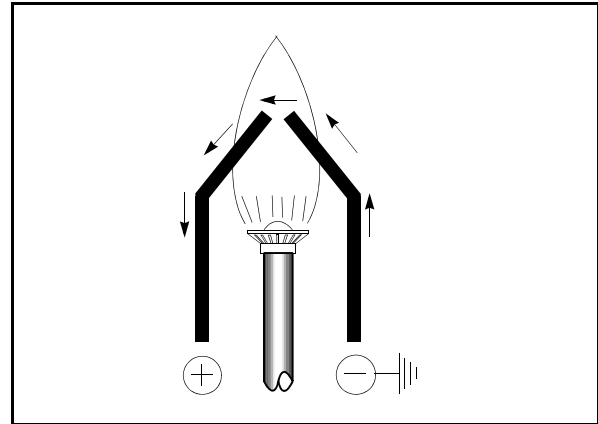
**Heat energy** from a flame is not a good method of flame detection. Sensors used to detect the presence or absence of heat respond too slowly. In addition, such a system requires directly inserting a sensing device into the flame. This method necessitates high maintenance costs.

**Expansion of gases** created by the combustion of fuel-air mixture can be detected and used as a flame detection method. However, it is not useful for main burner flame detection. Because this system requires the detection of minute changes in pressures at the burner nozzle, it requires tubing from the nozzle back to delicate pressure measuring devices. They require high-maintenance to keep operational.

**Production of by-products.** This is a reliable method of combustion detection, but, as with heat energy, response time is slow and detecting individual flames in multi-burner furnaces is unlikely.

**Emission or radiation and ionization within the flame** are the most commonly used flame characteristics measured with flame safeguard hardware. In multi-burner FSG systems, emission of radiation is the main flame detection method. Ionization, when used, is only appropriate for gas-igniter flame detection.

**Figure 14:** Electron flow through ionization within the flame envelope.



### FLAME IONIZATION PRINCIPLE

Heat in the flame causes the molecules in and around the flame envelope to collide with one another. The force of the collision frees some of the outer electrons of the atoms forming the molecules. This creates free electrons and positive ions, allowing a very small current to be conducted through the flame. The whole process is called Flame Ionization.

Within the flame there is very low conductivity and resistance can vary from 100,000 to 100,000,000 ohms. Current conducted through the flame (flame current) is generally in the range of 2-4 micro amps.

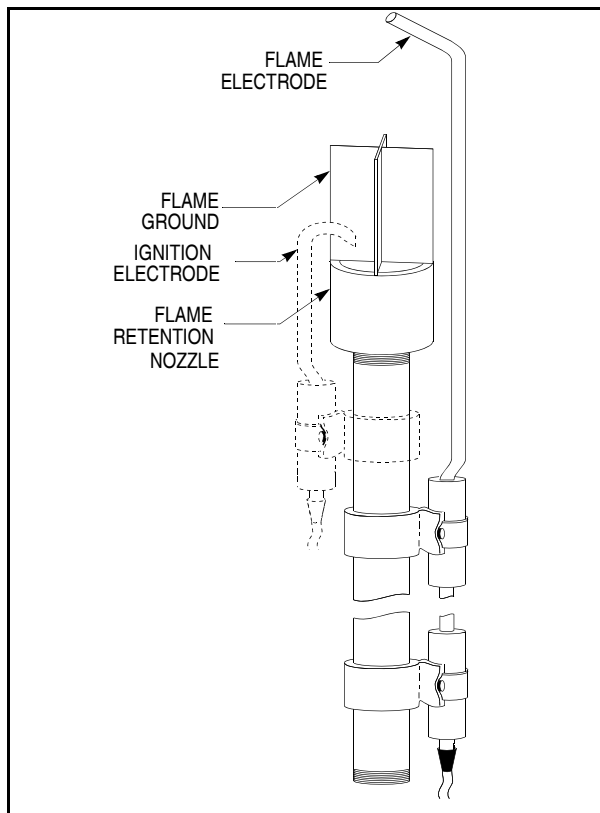
If two electrodes were placed in a flame as in Figure 14, and a voltage applied, a current could be conducted between the two rods (Flame Rods). Naturally the positively charged ions would flow to the negatively charged rod. In order to use this process to determine presence of flame and to prevent the potential hazard of a high resistance short to ground (effectively simulating flame signal), the flame current is rectified. Generally referred to as a **Flame Rectification System**, this is achieved by placing a grounding electrode in the flame

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which is several times (generally 4 times) larger than the flame rod or electrode. An AC supply voltage is applied across the electrodes. In the first half of the AC cycle, the flame rod is positive and the ground rod is negative. The positively charged ions will flow to the negatively charged grounding area.

The large grounding area increases the capacity to hold electrons. This results in a relative high flame current flowing through the flame during the first half cycle.

**Figure 15:** Typical ignition gas burner assembly using flame rectification detection system.



During the second half cycle, the reverse process will take place. This results in a much smaller flame current, rectifying the AC current through the flame. The only type of current accepted by the system is the rectified flame current. Any high resistance type short circuit

will result in an AC type flame current which is rejected by the FSG control. The large grounding electrode generally forms part of the burner fuel nozzle as shown in figure 15.

**Flame rods** are small diameter metal rods supported by an insulator. The tip-end of the rod can project into the flame. They typically are made of *Kanthal*, a high temperature alloy capable of operating in temperatures of up to 2400 F (1300C). Other materials with higher - temperature ratings, such as *Globar* (a ceramic material) are also available.

Applications for flame rod, rectification type flame detection in multi-burner applications are generally found in the supervision of gas fired igniter flames.

Requirements for successful applications include:

- Gas burners only (premixed where possible).
- Adequate flame rod to grounding area proportioning (4 to 1 minimum).
- Stable flame (no movement from flame(rod).
- Proper placement of flame rod in flame (short as possible, yet adequate contact).
- Proper rectifying flame current and associated circuitry.

### FLAME RADIATION PROPERTIES

**Radiation emission** from within a flame is the most typical media for flame detection systems in an industrial multi-burner environment.

The **radiation properties** of the flame operate electronic optical flame sensing devices. Electronic sensing is required to achieve the quick flame-failure-response-time (FFRT) demanded by the large input appliances. Depending on type(s) of fuel burned and rated input capacities, FFRT generally is from one

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second to four seconds.

Flames emit radiation along a wide band of the electromagnetic spectrum called the **flame spectrum**.

This spectrum consists of ultra-violet, visible, and infra-red radiation. Ultra-violet and infra-red radiation are at the opposite extremes of the flame spectrum and only wavelengths of

400 to 800 nanometers are visible to the human eye. The blue visible light is towards the ultra-violet, and the red visible lights is toward the infra-red portion of the flame spectrum. Flame detectors are sensitive within either ultra-violet, visible or infra-red radiation. Various aspects determine the proper selection of flame detector type.

**Figure 16:** Flame Rod, Flame rectification system operational diagram.

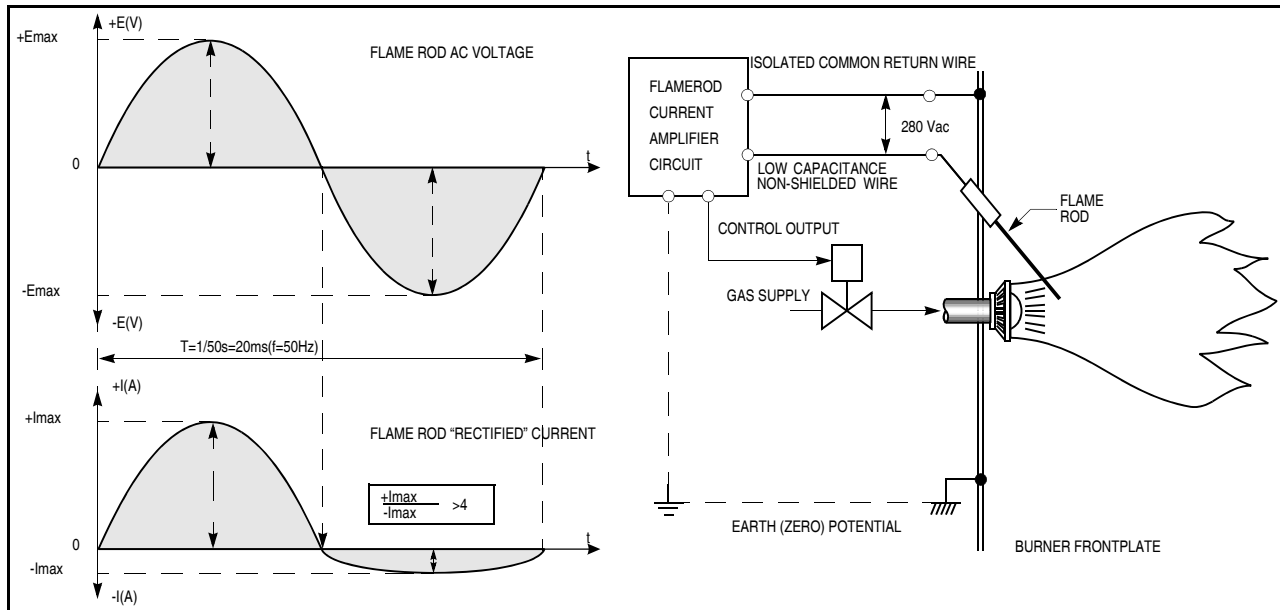


Figure 17 show the flame spectrum and each associated curve of commonly used fuels. Ultra-violet (at about one percent) is the least available of the three types of radiation from a flame. Generally, the first 1/3 of a burner flame is the main source of ultra-violet radiation. High temperature flames emit high amounts of UV radiation. Both oil and gas flames radiate sufficient UV for detection. Visible radiation amounts to ten percent of total radiation and is detectable by the human eye in the various colors:

- Blue with orange-yellow for gas flames
- Bright yellow for oil and powdered coal flames.

Infra red is emitted at about ninety percent of total radiation emitted by burner flames and is found mostly in the last 2/3 of the flame. Hot furnace parts (such as refractories) emit IR radiation when above 1000°F.

### ULTRA-VIOLET FLAME DETECTION

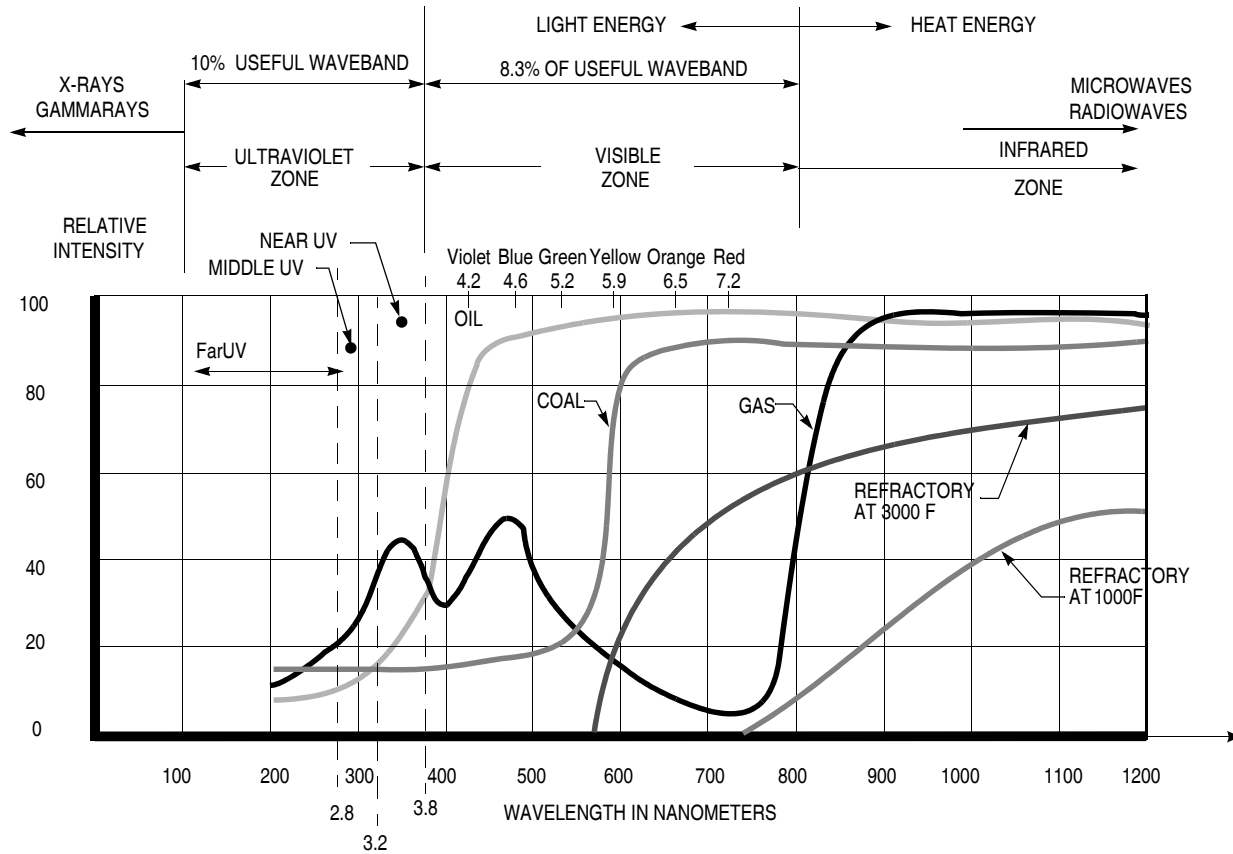
Flame scanners operating in UV wavelength use an ultra-violet detection tube. In this type of system the flame is considered present when UV radiation is detected. Differentiation or **discrimination** between the targeted flame and neighboring flames or background, is achieved by discriminatory scanner sighting. This sees as little as possible of the background

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and is then combined with **signal sensitivity adjust** or **threshold** settings to tune out unwanted signal at the detector's controllers. UV detection tubes should be sensitive only in the far UV wavelength range (200 to 300 nanometers) to be considered solar blind. Solar

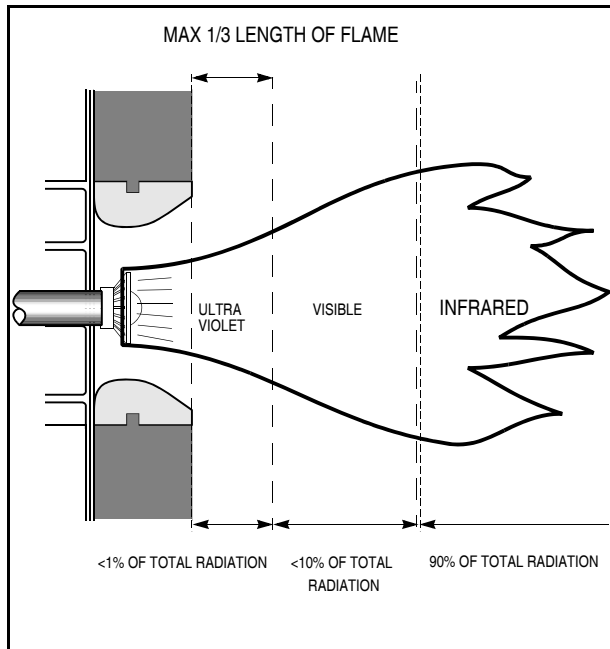
blindness is important to prevent stray light detection from sources other than the flame spectrum. UV detection tubes are made with quartz, the tube is then sealed and filled with gas. They contain two electrodes connected to a source of AC voltage.

**Figure 17:** Radiation intensity relative to wavelength as found in common fuels.



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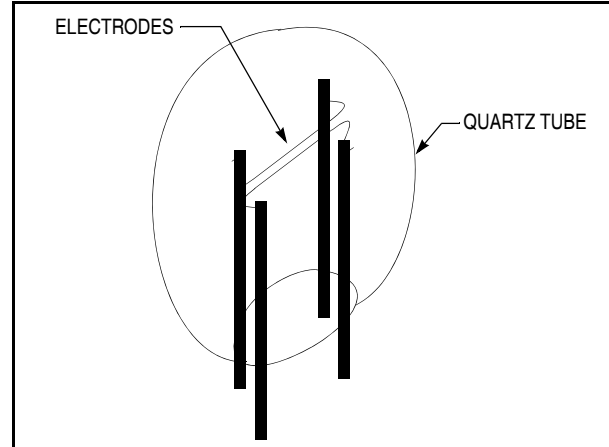
**Figure 18:** Radiation sources as emitted from a gas flame.



Electrons are released and gas within the tube becomes conductive through ionization. Then an electric current flow from one electrode to the other (cathode to anode) happens. This whole process is the result of strong ultra-violet radiation and with wave lengths within the response characteristics of the detection tube falls upon the electrodes.

A high AC voltage (400 to 1200 VAC) is applied to the electrodes. This causes the tube to produce an arc between the electrodes (provided sufficient UV radiation is present to produce the required ionization of the inter-electrode gas). The tube is said to be "Firing." In the tube design, this "arc" wanders back and forth along the electrodes, never staying in one place to prevent damage to the electrodes by over-heating. A quartz lens is needed to focus the UV radiation through the optical shutter window directly on the detector tube electrodes.

**Figure 19:** Ultra violet radiation detection tube.



Generally, the voltage supplied to the tube is AC. (DC voltage may also be used along with a square pulse generator). Voltage across the electrodes will zero for each half cycle of AC. This allows the tube to restore itself to a non-ionized or **quenched** state. On the next voltage half-cycle, the current is re-established across the electrodes in order to fire if UV radiation is present. The number of firings during each cycle is called the **count**. The maximum counts of firings during one second is the number of counts during one-half cycle, times twice the frequency of the supply voltage.

When flame is present and UV radiation enters the tube, the system begins to count. When flame disappears, the UV radiation stops and the system stops counting. The **flame control relay** is the part of the system with the electronic circuitry receiving the count signal from the detector. When the rate reaches pre-set levels of flame-on indication, the flame control relay pulls in the flame relay. The **flame relay** remains in as long as the pre-set threshold is satisfied. The count relates directly to the intensity of the UV radiation. A very intense source of UV radiation produces several thousand counts per second. The count is a measure of

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flame intensity. When the flame disappears, the count zeros, except for very infrequent firings inherent in this type of design to which the system does not respond.

UV flame detectors respond to UV sources in a flame. However, it is possible for the detector to respond to other sources of UV radiation such as:

- Hot refractory (well above 2000 F)
- Spark ignition
- Welding arcs
- Halogen light.

Care should be taken to avoid picking up unwanted signal from any of these sources at (or near) the burner front.

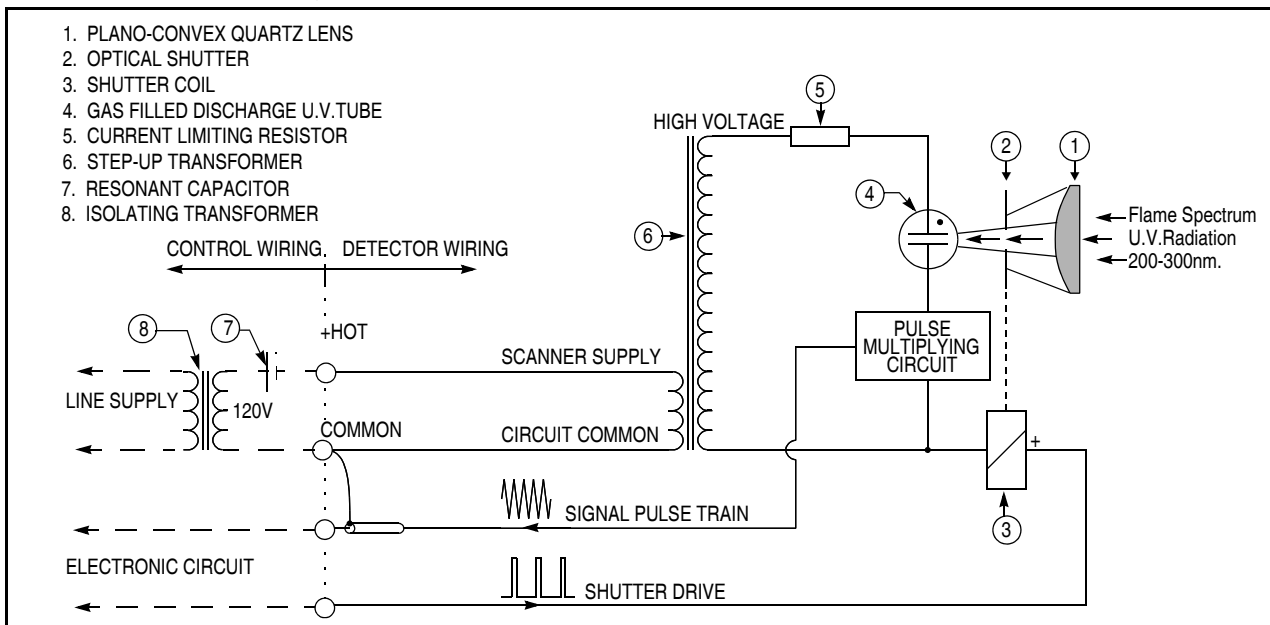
Ultra-violet detection tubes can deteriorate due to degeneration of the special gas inside

the tube. This can also result from over-heating the tube, subjecting it to excessive voltages, or subjecting it to excessive UV radiation for long periods of time.

Deteriorated tubes can operate in random failure mode — sometimes firing continuously after having started and failing to quench, or firing inconsistently and causing nuisance shut-downs. Tubes can also fail, causing the tube to fire as soon as the normal operating current is applied (regardless of the presence of UV radiation).

Flame safeguard systems will always pick-up faulty UV detecting tubes during start-up and no flame or signal should be present to cause system lockout if signal from a bad tube happens during flame-off conditions.

**Figure 20:** Ultra violet, tube type flame detector schematic.



If a tube starts to fail during normal operating flame-on conditions, the bad tube would not be recognized until a system re-start is initiated. To prevent this from happening, the scanner self-check systems were developed. A **self-**

**check** system for a UV tube-type flame detector, consists of an optical shutter placed directly in the path of the UV radiation from the tube. The shutter opens and closes continuously, effecting blocking the UV radiation for a brief



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period (0.25 to .75 seconds, depending on the design, but less than the FFRT).

The system drives the scanner self-check shutter mechanism and checks for the scanner's pulse count to stop during the shutter close period. (See Figure 20). Scanner pulse counts detected during the shutter close time causes the system to react in a safe manner through activation of its **fault relay** or through an immediate opening of its flame relay.

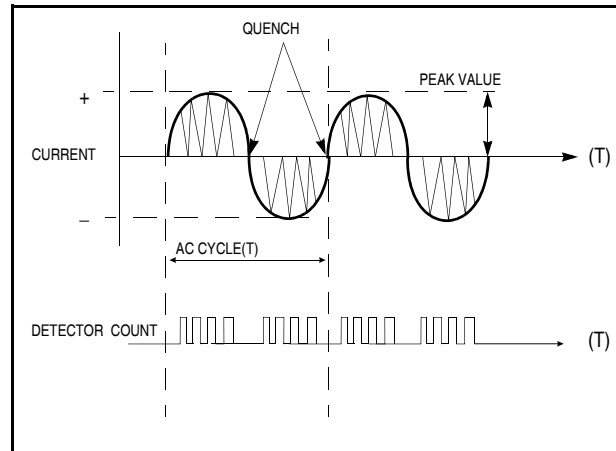
Activation of the fault relay indicates a scanner fault. In the BMS system's logic, this requires fixing within a set time-limit before a safety shutdown will occur. If the flame relay opens there is an indication at the control of scanner self-check failure.

When using UV, tube-type flame detectors, a scanner self-check feature is mandatory for burners or appliances designed for **continuous operation**.

Continuous operation (sometimes called permanent operation) is defined by the local authorities having jurisdiction over the appliance's safety regulations. This can vary from 1 to 24 hours. If the appliance operates continuously (firing for times longer than the classified time for continuous operation) UV tube-type flame detectors must be equipped with an approved self-check feature.

Besides the scanner self-check features, an FSG system designed for continuous operation must comply to **failure mode** stipulations for all of its system's components as set forth in the applicable norms and regulations.

**Figure 21:** Ultra-violet tube detector, AC current operation principle.



Ultra-violet radiation used in flame detection by means of a UV detection tube is limited in interpretation of the signal. When UV radiation is sensed, the flame is considered present. Only amplitude of the signal is available to interpret whether the signal received is from the targeted flame or from adjacent flames or from the background. Ultra-violet accounts for only about one percent of the flame spectrum. UV is weak and blocked by unburned fuel products of combustion, smoke, water vapor, and other substances found in and around flames. Accordingly, UV is picked up most easily by the sensor close to the root of the flame and UV radiation from background or adjacent flames tends to have a much weaker signal.

With proper scanner sighting and set-ups of associated controls, UV flame scanners remain a simple, well-trusted and acceptable option in multi-burner FSG systems.

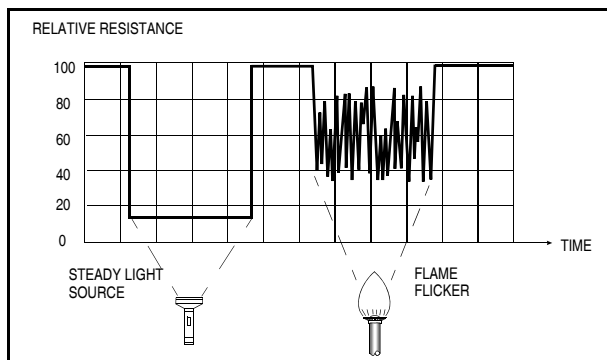
### FLAME DETECTORS IN THE VISIBLE AND INFRA-RED RANGE

Flame scanners operating in the visible and infra-red spectrum use a lens, photodetector and a solid-state frequency tuning circuit. Infra-

## FLAME SAFEGUARD CONTROLS IN MULTI-BURNER ENVIRONMENTS

red radiation, together with visible light, accounts for about 99 percent of total flame spectrum radiation (See Figure 18). IR and visible light (400 nanometer wavelength and upward) do not effectively detect the presence or absence of flame. A boiler with multiple burners and hot, glowing refractory contains an abundance of visible and IR radiation. Detecting the presence or absence of these would not be a reliable method to detect the condition of the targeted flame.

**Figure 22:** PbS cell response to radiation from steady light and from flame flicker.



Reliable detection of the targeted flame requires the IR detector to distinguish between the modulating frequency of the radiation it receives. IR radiates from a flame in many frequencies (**Flame Flicker**). As fuel ignites with oxygen during the burning process it initiates many small explosions. Each explosion emits light and IR radiation, giving the flame an appearance of comparatively steady shape and glow.

The flame constantly moves - changing shape and brightness. The function of the photodetector is to monitor flame flicker to distinguish between flame and other sources of radiation. The photodetector most commonly used is the PbS (lead sulfide) photo resistor. The PbS cell lowers its electrical resistance rel-

ative to amplitude of radiation >400 nm. visible infra-red region on the cell.

Figure 22 shows the response of the PbS cell to radiation from a steady light source such as a DC flash light, and a flame which provides a flickering type radiation. The cell responds by modulating, harmonized with the variations in radiation amplitudes given off by the combustion process.

Not only do flames flicker in this way, the flicker frequency is actually different within the zones of the flame.

Figure 18 shows the ultra-violet region of the flame, nearest the nozzle, the **ignition zone**, which has the least amplitude, but the highest flame frequency. Therefore, a photodetector mounted on the burner-front, looking parallel with the fuel flow, has the best possible view of the ignition zone of the targeted flame.

Should this targeted flame disappear, it would likely pick up radiation of lower frequency from either adjacent or opposed burner's flame envelopes.

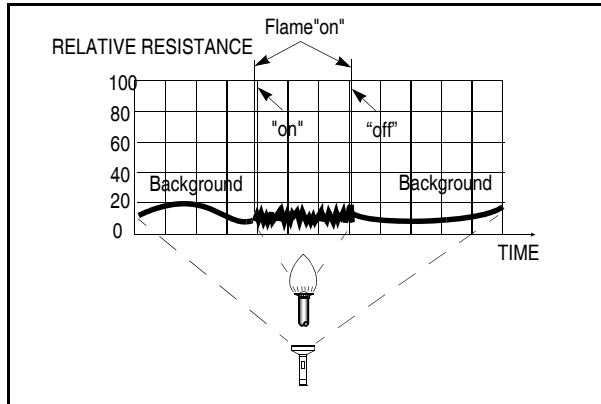
Flame flicker frequency is noted in Hertz. Flicker frequencies in flames can be found from 5 upwards to well over 200 Hz. Variations in higher or lower frequencies found in flames are dependent on a variety of functions in burner design and type of fuel burned. Designs such as gun-type or ring-type produce flames with a wide range of frequencies. However, spud-type (gas) and low NOx burners do not. Fuel oils and coal produce wide ranges of frequencies; gas (particularly low-NOx) burners do not.

The ability of the photodetector to detect flame flicker frequency can be adversely affected by overpowering, low-frequency radiation from furnace background light or heat.

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Strong sources of this low frequency radiation will have a **saturation** effect. Also called **washout**, saturation inhibits the cell's ability to maintain a high enough electrical resistance value. This renders it unable to monitor flame flicker.

**Figure 23:** PbS photodetector in saturation from abundant low frequency radiation.

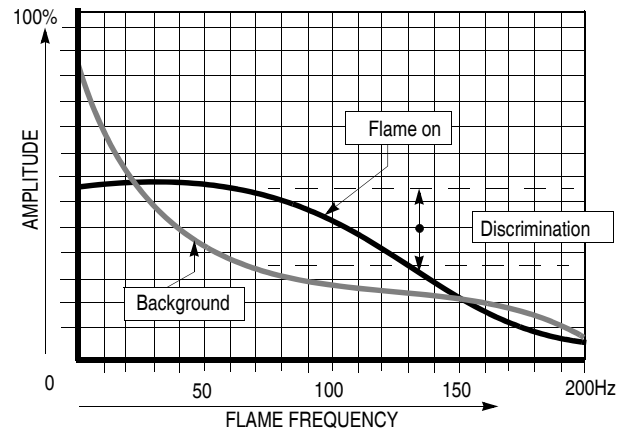


The flash-light in Figure 23 represents the lower frequency IR-visible light radiation from furnace background, made up of adjacent or opposed burner-flames, and the flame represents the ignition zone of the targeted flame. The furnace background radiation focused on the detector drastically reduces its electrical resistance. This leaves almost no room for the cell to respond to flame flicker modulation.

To minimize this saturation effect, sight the detector so that radiation from the ignition zone is maximized and radiation from furnace background is minimized. This is sometimes impossible because of burner design.

Oil and coal flames have strong radiation in the visible wavelength and gas flames do not. When looking through a burner's sight-glass it is easy to confirm that oil and coal burn brightly, whereas gas flames tend to be more transparent or dim. However, all fuels radiate profusely in the infra-red region of the flame spectrum.

**Figure 24:** Example of typical flame flicker analysis for flame "on" and flame "off" (background) condition.



The curves in Figure 24 indicate the relative amplitude of this radiation at the corresponding flame flicker frequency. The "flame on" curve shows a relatively high amplitude in the 50 to 120 Hz range received from the ignition zone of the flame.

The "flame off" (background) curve shows these 50 to 120 Hz frequencies at a much lower amplitude. The cause of this difference is that although the "flame off" condition receives nearly the same frequencies from adjacent flames in the background, they are further away from the detector. Therefore, there is less amplitude. This difference in amplitude at selected frequencies allows the flame detection system to discriminate.

In a set-up such as this, where the detector is sighted at the ignition zone of the targeted flame, it is not uncommon to find that the lowest frequencies increase dramatically in a "flame off" condition. This happens because the ignition zone of the targeted flame "masks" the bright background low-frequency radiation while the targeted flame is on. When the targeted flame disappears, the background radiation comes into full view is shown in the curve.

# FLAME SAFEGUARD CONTROLS IN MULTI-BURNER ENVIRONMENTS

## BACKGROUND GAIN CONTROL

Infra-red scanners may feature **Background Gain Control** or BGC. BGC inversely adjusts the Flame Signal Gain based on flame brightness as sighted by the scanner. As flame brightness increases, automatic gain (see Figure 25) is decreased, thereby diminishing the detector's flame signal.

Some older detectors use an optical shutter for verification of valid flame presence data, in later models this electromechanical shutter is replaced by an electronic self-check circuitry. This periodically bypasses the photo resistor cell and checks the system for false or corrupted flame signal.

## SENSITIVITY ADJUSTMENT OF GAIN CONTROL

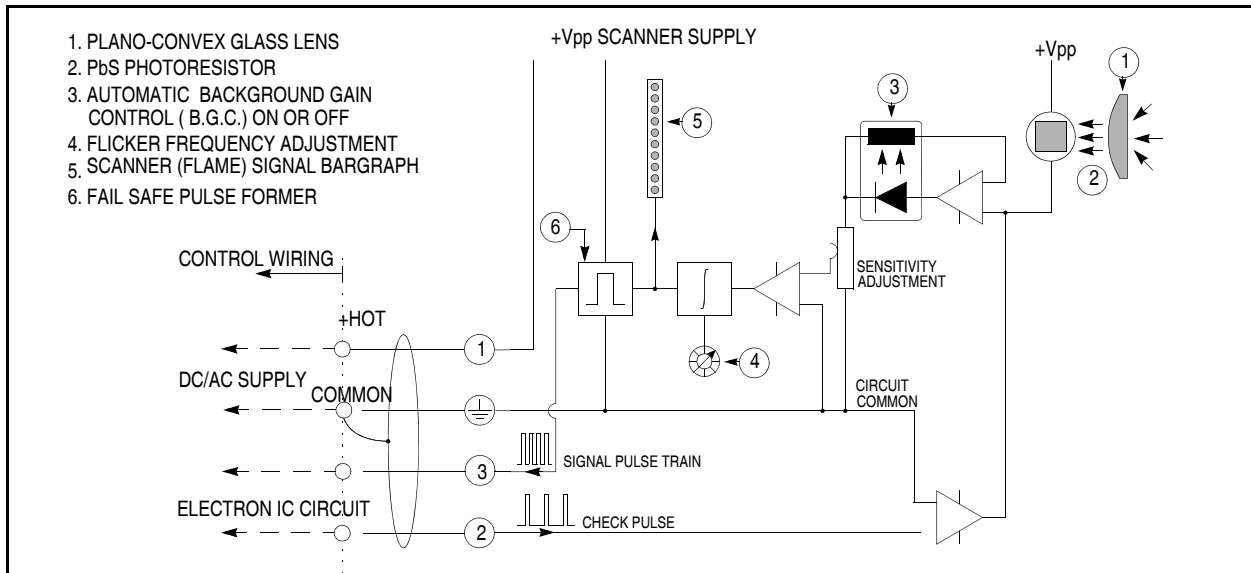
Most infra-red detectors incorporate some **sensitivity adjustment** or **gain control**. Both allow the user to adjust the sensitivity of the photodetector-to-flame-signal circuitry. The user can then tune background signal to a mini-

imum while maintaining sufficient signal for "flame on" detection, within the best possible "discrimination region." Optimal discrimination in Figure 24 belongs between the 50 to 80 Hz zone.

The ability to selectively discriminate varies by the design of the detector. Some have a fixed band-pass to modulation of flame frequencies, while others use multiple band-pass filtering, selectable to the appropriate flame flicker frequency of the application.

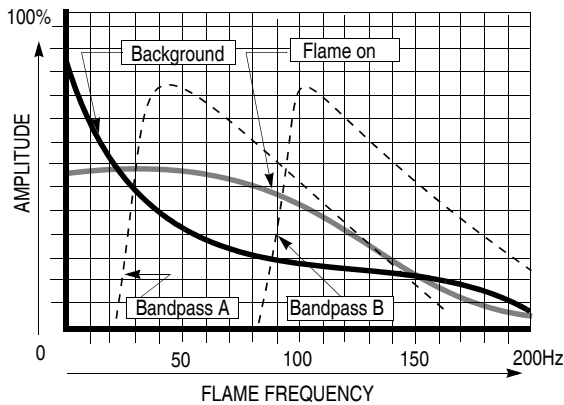
Figure 26 illustrates how selecting the appropriate bandpass helps the user to achieve optimum results. Bandpass A, peaks in sensitivity at 40Hz. This provides optimum discrimination in this example. Bandpass B, peaking in sensitivity at 100 Hz, remains sensitive in the higher frequency-range where both the "off" and "on" curves share the same amplitudes, compromising discrimination. Bandpass a would be the one to use.

Figure 25: Infra Red type flame detector schematic.



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**Figure 26:** Example of bandpass filter selectivity to flame flicker frequency, to achieve maximum discrimination.

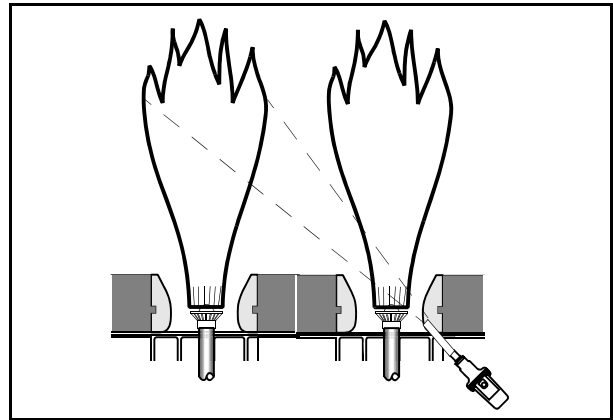


Selectivity of appropriate flame flicker frequency in infra-red flame detectors can be achieved in a several ways. These include fixed settings (no adjustment), to dipswitch selection (requiring consultation of charts to find the proper switch setting for the desired frequency), to a rotary type and marked selector switch. Detectors using selection switching of frequency response should have the selector switches placed so they can be manipulated

- without removing the detector
- so that the selection can happen while the scanner operates
- the result of the selection becomes immediately apparent (by means of signal strength meter at the detector).

Detectors without selectable frequency response ability must be sighted to optimize discrimination through sighting only. The difficulty in achieving this depends upon the application. If the scanner sees the adjacent flame too easily, it could be sighted more on axis with the targeted flame, avoiding the adjacent flame (Figure 27). If the situation in this figure of on an opposed fired burner, changing the angle to be more on axis may not have the desired results.

**Figure 27:** Example of detector receiving radiation from both targeted flame, and adjacent flame or background.



### SELECTABLE FREQUENCY RESPONSE

Detectors with selectable frequency response require careful set-up during system commissioning.

1. Carefully mount the scanner with the most advantageous angle-to-flame position. Best results are obtained by aiming the scanner's line of sight to intersect the burner center line at a slight ( $5^\circ$ ) angle. Remember to include the primary combustion zone (ignition zone) into the field of view when possible. Targeted burner should be on medium to maximum firing rate. Adjacent burners should be on highest possible firing rate during the setup, providing ample background radiation.
2. Find a strong flame signal at a high flame flicker frequency. Set the bandpass selector switch at the highest setting, gain adjust (sensitivity) set high, and work your way down the available frequency selectable settings until a steady and strong signal prevails. (Signal from either the scanner's indicator or the flame control's reading).
3. Back off the gain adjust to approximately mid-range of the signal output.

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4. Observe the flame-off condition by turning off the targeted burner and observe the change in signal.

It is not always the highest frequency that is most desirable (See Figures 24 and 26). In this graph, the peak signal strength for flame on is found at 30 Hz. But peak discrimination value is found at 65 Hz. It may take several attempts to find the frequency giving the highest discrimination ratio. Repeat the above steps and keep notes during each trial at flame-on and off sighting to create a graph for your own use. In this way you can select optimum frequency setting more easily.

The smaller the ratio in signal strength between flame-on and flame-off, the more your set-up will need to rely on exact duplication of those conditions during normal operation. In other words, you can not afford changes in flame flicker frequencies for both the flame-on or off conditions when your thresholds between on and off are very close. Stable fuels such as natural gas or #2 fuel oil, are not as subject to fluctuations in flicker frequencies and brightness. The detector may do well with a small discrimination ratio. Some fuels (such as powdered coal and heavy oil) are not as stable and may present the FSG system with fluctuations in their frequency-to-amplitude curve and also require larger discrimination ratios.

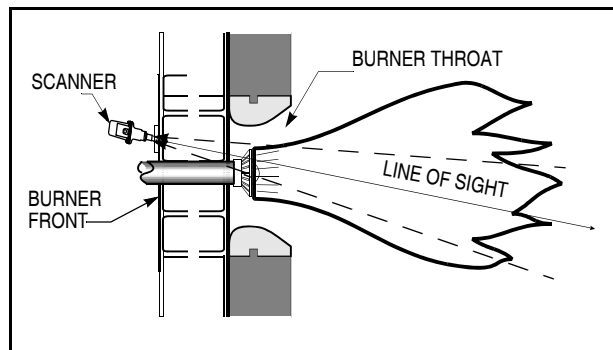
In setting up infra-red scanners, remember that the frequency-to-amplitude curve is affected by:

- Type of fuel(s) burned
- Type of burner(s)
- Type of fuel atomization.
- Flame temperature.
- Distance of detector from flame.
- Angle of view through flame.

- Portion of flame envelope viewed.
- Diameter of detector sight-tube.
- Length of sight tube.
- Obstructed or unobstructed view.
- Cleanliness of lenses.
- Type of photodetector used.

All of these factors, alone or combined, influence the frequency-to-amplitude curve of the targeted flame and background radiation. They have profound effect on the ability of the system to discriminate between the presence or absence of the targeted flame.

*Figure 28: Flame detector line of sight.*

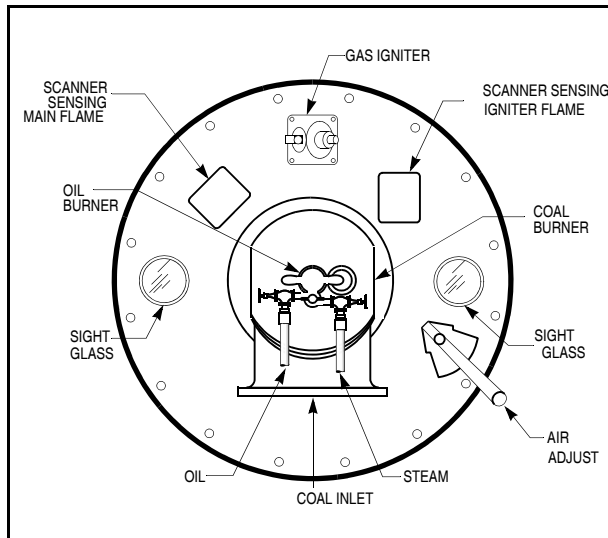


In some new detection devices (Fireye Signature Scanner), the conventional selected-frequency-to-amplitude approach, has been enhanced by incorporating the flame spectrum's complete frequency-to-amplitude curve (the Signature) in its flame on-to-off discrimination strategy. The heart of this style detector is a microcomputer built in the scanner. It continually monitors all flame flicker frequencies of its targeted flame, and compares it to the flame's "learned" flame-on **signature** that is stored in its memory. A programming procedure is used to "learn" the flame-on and -off conditions. Records of these conditions are stored in individual files. The scanner allows the user to review and program all setpoints and parameters, as well as up and download scanner files from a standard IBM compatible desktop or lap-

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top PC.

**Figure 29:** Burner front showing typical flame detector locations.



### INSTALLATION

**Installation** of flame detectors requires attention to detail. Many factors must be considered when mounting the scanner on a burner.

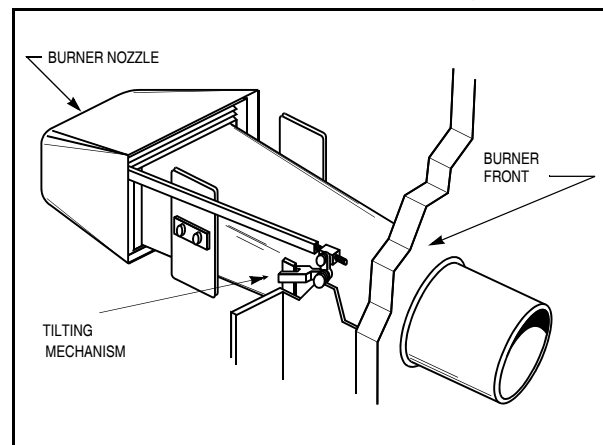
- A clear view of the targeted flame's primary combustion zone.
- Minimizing view of adjacent flames or background radiation.
- Ensuring pilot flame is detected only when in proper position to light-off main flame.
- Minimizing excessive heat radiation from burner front.
- Minimizing electrical noise from burner-front, particularly spark ignition sources.
- Protection from excessive furnace pressures.
- Hazardous area classification compliance.
- Materials and paint specifications.

**Providing a clear view of the primary combustion zone** is influenced by the design of the burner. Ideally, the detector is mounted in such a way that the line of sight intersects the primary combustion zone at a slight angle (5-10°).

Usually there are few locations appropriate for mounting flame detectors. They are often restricted by pre-designated positions on the burner front plate. Depending on burner design and variants in fuels burned, it can be difficult to find a location offering an unobstructed view of the primary combustion zone. Burners firing multiple fuels may have their internals cluttered with fuel delivery equipment, igniters, and air diffusers, all obstructing scanner sight.

Even though NFPA specifies detector placement in initial furnace design, little attention is generally given to detector location during burner construction. Some designs prevent clear view of the primary combustion zone, especially **tangential** furnaces, or where burners alter their angle of firing into the furnace (**tilting**).

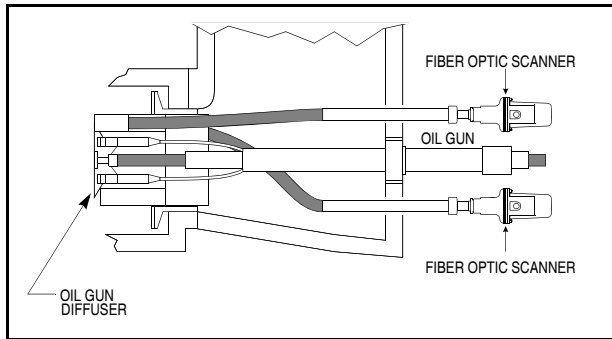
**Figure 30:** Tilting coal nozzle for tangentially fired boiler.



Tilting burners control superheater temperatures by directing fuel-flow upwards (towards the superheater), or downward (away from the superheater).

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**Figure 31:** Two fiber optic scanner assemblies installed on tilting oil burner.



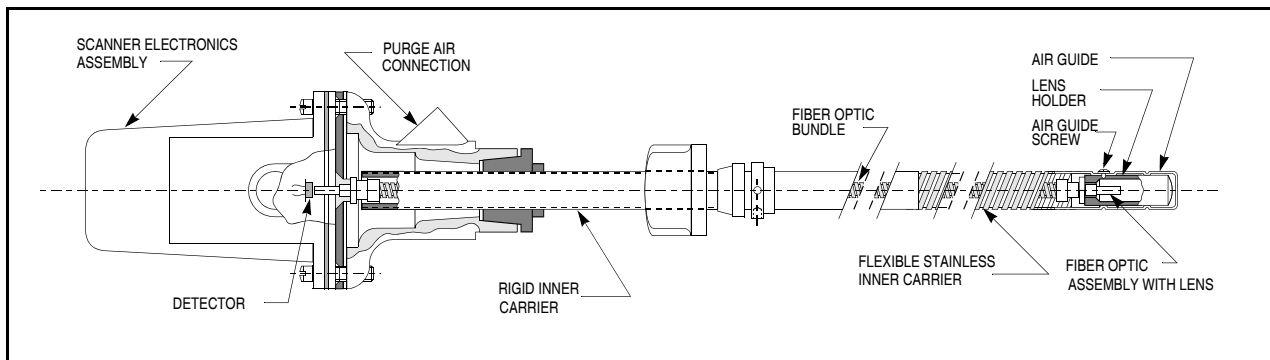
### FIBER OPTICS

**Fiber optic scanners** allow optimal viewing in burners where movable vanes, air compartments, or burner nozzles would obscure or move the target flame away from the line of sight. In tangentially fired boilers, where individual burner flames tend to form fireballs, a fiber-optic scanner can detect the presence of an

individual burner's flame (provided the fuel ignites before entering the fireball). A fiber optic scanner assembly includes an objective lens, mounted near the interface of the windbox and furnace area. The fiber optic bundle is enclosed within a series of flexible stainless steel tubes and brings the flame radiation to the detector within the scanner's assembly, located outside the windbox.

An inner carrier assembly containing the fiber optics is inserted into an outer carrier. The scanner electronics assembly is then attached. The outer carrier assembly is permanently fastened to the burner front. (See Figures 31 and 32). The extreme end of the outer carrier which holds the fiber optic lens, is usually made of stainless steel and welded to the burner front to allow the best possible viewing angle.

**Figure 32:** Cutaway view of fiber optic scanner assembly (shown without outer carrier).



The inner carrier assembly containing the fiber optic bundle and lens assembly, can be removed from the outer carrier for servicing.

Fiber optics and lens are made of high temperature glass for infra-red use, and quartz when used with UV detectors. The assembly requires protection from over-heating, and this is done with purge-air. Volume required for purge-air is from 4 to 15 SCFM (113 to 425 L/M), depending on the application. Fiber optics

and lens should be protected from temperatures in excess of 800F (430C). Optical field of view is 13 square inches at 3 feet. (110 sq. cm at 1.00 meter).

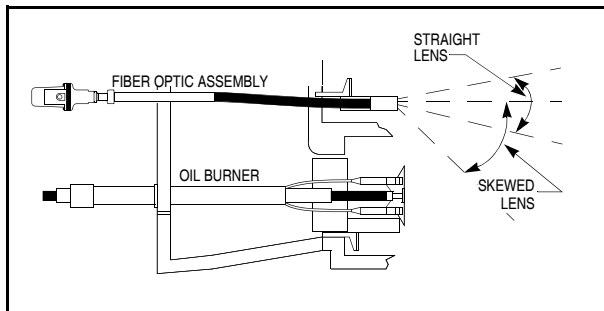
Lenses are available to assist the user in viewing the primary combustion zone when location of the lens-holder cannot be near enough to the burner nozzle. These lenses look at an angle (skew), allowing the primary combustion zone to be viewed as opposed to view-



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ing too far into the furnace area. If, due to mounting limitations of the outer-carrier's lens-holder, insufficient discrimination results, a 5 degree or 9 degree skewed lens can be installed. When using a skewed lens, the user can rotate the inner carrier assembly to find the primary combustion zone during commissioning of the system. As the inner carrier assembly is easily removable, the user can experiment with various degrees in skewed lenses until a suitable lens has been found.

**Figure 33:** Fiber optic scanner assembly using skewed lens to view primary combustion zone.



Fiber optic assemblies provide only “cold light” radiation to the detector. The saturation, or washout effect on a photodetector previously discussed, where excessive heat radiation may have an adverse effect on the system, is when using fiber optics, effectively filtered out.

Fiber optics may also protect the detector from excessive heat or vibration at the burner front by allowing the electronics assembly to be mounted away from this danger, while receiving flame radiation through the fiber optic assembly.

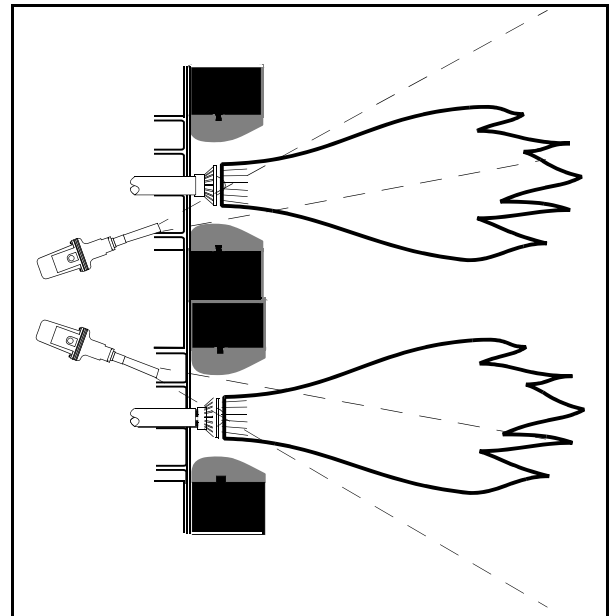
### DISCRIMINATION

Close attention to viewing angle during scanner mounting will **minimize view of adjacent flames or background radiation**. If possible, the scanner should be mounted to include as lit-

tle as possible of adjacent flame or background radiation in the field of view.

For example, if the situation shown in Figure 34 is a side-view of a multi-burner, six over six arrangement, then aiming the scanners as shown would help eliminate unwanted signal. The same viewing pattern would also be relevant to avoid unwanted signal from opposed burner arrangements. In multiple-burner-level arrangements, scanners mounted on the middle row of burners would not be able to view areas without background radiation. Many burners do not allow freedom to provide angle on the scanner's sight. The only available scanner mounting may be on the burner-front (Figure 29) with only a straight-ahead view into the furnace through the burner internals. In these situations only flame detection systems with the most advanced electronic discrimination capabilities should be used.

**Figure 34:** Typical discriminating scanner sighting positions.



Elimination of unwanted signal by mechanically limiting the scanner's view of adjacent

## FLAME SAFEGUARD CONTROLS IN MULTI-BURNER ENVIRONMENTS

flames can be achieved while concentrating on the flame's primary ignition zone. To do this, install either an orifice in front of the detector, or extend the detector's sight-tube. Since viewing adjacent flames or background radiation cannot be avoided, then it is best to view as little of it as possible.

**Figure 35:** Effects on field of view by extending scanner's sight tube.

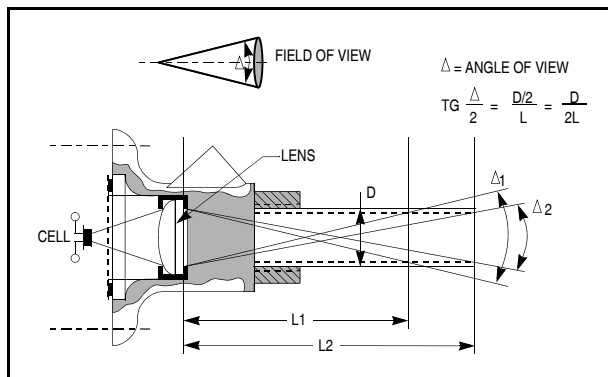


Figure 35 shows how to calculate the effect of extending the sight-tube. The use of an orifice to control dimension "D" would have a similar effect. Be sure to include the primary combustion zone into the detector's field of view. Both orifice size and extending the sight-tube restricts the amount of radiation to the detector. This makes it even more important to maximize view of the targeted flame.

Achieving the best result can be a matter of experimenting with various lengths and/or orifice sizes through trial and error.

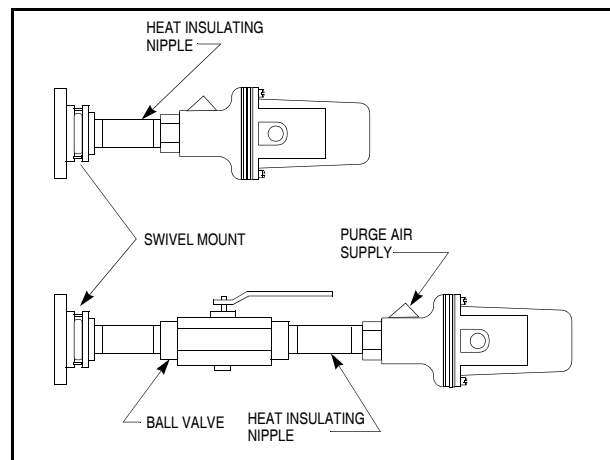
### PILOT BURNER DETECTION

When scanning pilot flames, insurance must be built into the system to detect the pilot flame only when it is in the proper position to light off the main flame. In multi-burner applications it is often difficult to reliably detect the relatively small pilot flame against the strong background radiation. In the process of commissioning the

system, steps must be taken to ensure that when the pilot is detected it will light off its main burner's flame under all conditions. For example, if an optical detector is used for pilot flame detection and the detector's view is on axis along the burner center, the system may detect the pilot even though the pilot flame is too far back from the main flame nozzle to light off the main flame. Using a flame rectification system (Figure 15) for the pilot burner (gas pilots only) would give greater control over the pilot flame's location when detected.

Alternately, and in the use of oil fired pilot burners, the way the pilot lights-off the main burner safely and reliably will be in the burner designs.

**Figure 36:** Flame detector mounting arrangements.



### HEAT RADIATION

**Minimizing effects of excessive heat radiation from burner-front to flame detector** when installing can be achieved by:

- Using a non-metallic material for the connection of the detector to the sight-tube (such as heat insulating pipe nipple) preventing heat transfer from the hot burner-front sight-pipe to the scanner head.
- Providing cooling air to the detector's cool-

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ing/purge air connection.

- When heat radiation from burner front area is extreme, other devices, such as water-cooled housings or additional heat-shields may be required.

See Figure 36 for common scanner mounting arrangements including common accessories.

### ELECTRICAL NOISE

Minimizing effects of electrical noise from the burner front area, particularly the spark ignition sources is an important consideration during installation of flame detectors. When using the non-metallic, heat insulating nipple (Figure 36), the detector will also be effectively isolated from the burner front. Electrical noise is a variation in frequency or voltage beyond the normally expected range. It exists in the industrial environment as RF (Radio Frequency) noise or a short duration transient voltage spike.

Noise can be carried by, or modified by AC or DC voltages. Therefore, any wire to a microprocessor-based instrument can potentially carry noise. The immunity to noise is controlled by the operating environment of the unit and the amount of noise suppression nearby. Even with noise suppression, an instrument cannot overcome noise unless it's environment (i.e. location, wiring, and power) meets minimum installation guidelines.

Listed below are some of the common sources of severe noise:

1. Ignition transformers
2. Arc welders
3. Mechanical contact relays
4. Solenoids
5. Motors

Earth ground must be attached to the unit's chassis. To verify that it is earth ground, make

an ohm check from unit chassis to the nearest proven earth ground. This reading should not exceed 1000 ohms. The chassis will be used to tie all suppression components to ground. This makes it essential that it be noise-free. Next, it is necessary to assure that neutral is at, or near, ground potential. Verify this with a voltmeter check between neutral and ground. On the AC range, it should not be more than 50 millivolts. If it is greater than this amount, the secondary of the AC transformer supplying the instrument should be checked by an electrician. All wires coming into or out of the microprocessor based instrument can be classified into three different categories.

1. Analog (i.e. 4-20 mA, T/C, RTD, V or mV DC).
2. Relay or SSR outputs.
3. AC.

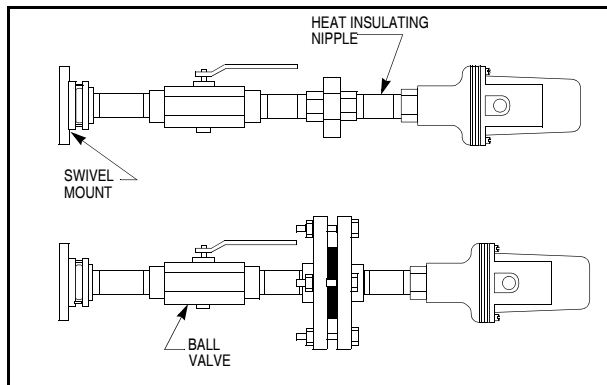
Each of these must be isolated from each other and from any wires coming from devices. If they need to be parallel with any other lines, then maintain a minimum 6-inch space between the wires. Remember that the only wires that can be run together in a bundle are those of the same category. If the wires must cross each other, do so at 90 degrees. This minimizes the contact with other wires and reduces cross talk. Cross talk is the EMF (Electro Magnetic Flux) emitted by a wire as current passes through it. This EMF can be picked up by other wires running in the same bundle. Shielded cable is a single or multi-pair of insulated wires; with each pair wrapped in an un-insulated wire (shield) wrapped with foil, and all inside a cover of plastic insulation.

Analog signals should be run with a shielded cable. Terminal lead length should be as short as possible, keeping them protected by

## FLAME SAFEGUARD CONTROLS IN MULTI-BURNER ENVIRONMENTS

the shielding. The shielding should be **grounded at one end only**. The preferred grounding location is the microprocessor based unit since its chassis should be at ground potential. Shielding helps eliminate RF and EMF noise the wires may be exposed to.

**Figure 37:** Installation details of flame detector installation for high furnace pressure applications.



### FURNACE PRESSURE

Protection from excessive furnace pressures is achieved through a viewing window, or protective lens installed between the detector and furnace opening. Be sure to use the lens with the appropriate material specification. Use high temperature glass for infra-red and quartz for ultra-violet radiation detectors.

The use of a full-bore shutoff valve between furnace and protective lens is required in order to be able to service the equipment while in service.

Figure 37 shows two examples of detectors installed on high pressure furnaces. The upper example, using the pipe union fitting with lens inside, is typical for the lowest pressures (max 1.5 PSIG or 0.1 BAR). The lower example has the lens mounted between flanges and is typical for higher pressures.

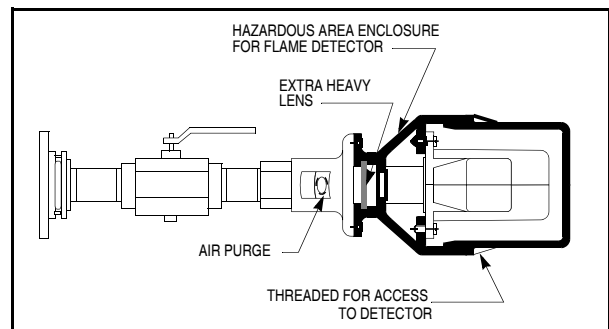
All fittings must be constructed with specified materials (ASME) according to the pressures involved. Purge or cooling air is generally not required in arrangements like these.

### HAZARDOUS AREA CLASSIFICATION

Detectors needing hazardous area classification compliance must be mounted inside an enclosure of the appropriate NEMA or CENELEC rating.

The enclosure in Figure 38 can be adapted for use with fiber optic detectors. Alternately, fiber optic assemblies can be used to locate the detector-head outside the hazardous classified area. Non-incendive detectors can be used in lieu of the requirement for special enclosures, when specifications allow.

**Figure 38:** Cut-away view of flame detector mounted in hazardous area enclosure.



### CONTROLLERS

Flame detectors operate in conjunction with an associated controller. The controller is the recipient of the flame detector's output signal and conditions its signal to operate the flame relay located within the controller. The normally open and normally closed contacts of the flame relay provide the input signal to the burner management system (BMS) for status of the targeted flame— on or off.

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**Figure 39:** Basic electrical connections to controller

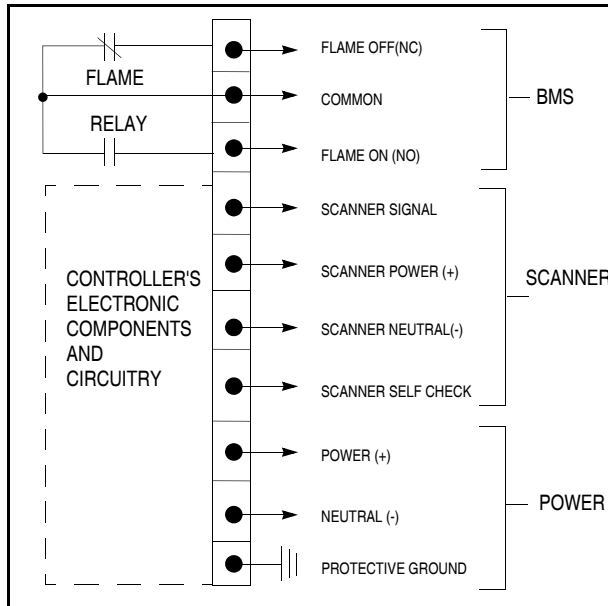


Figure 39 shows the most basic electrical connections to a simplified schematic of a single channel controller. The controller will operate the flame relay within a strategy based on its design. The most simple flame relay control strategy converts the flame detector's output signal into current. The current operates the flame relay and as long as this current is sufficient to hold-in the relay, the controller is signaling a flame-on condition. When the detector reduces its output signal based on flame radiation (targeted flame-off), the current to the flame relay is also reduced. If this occurs for a period longer than the **flame failure response time** (FFRT), the flame relay will drop out (flame-off condition).

### SENSITIVITY ADJUSTMENT OPTION

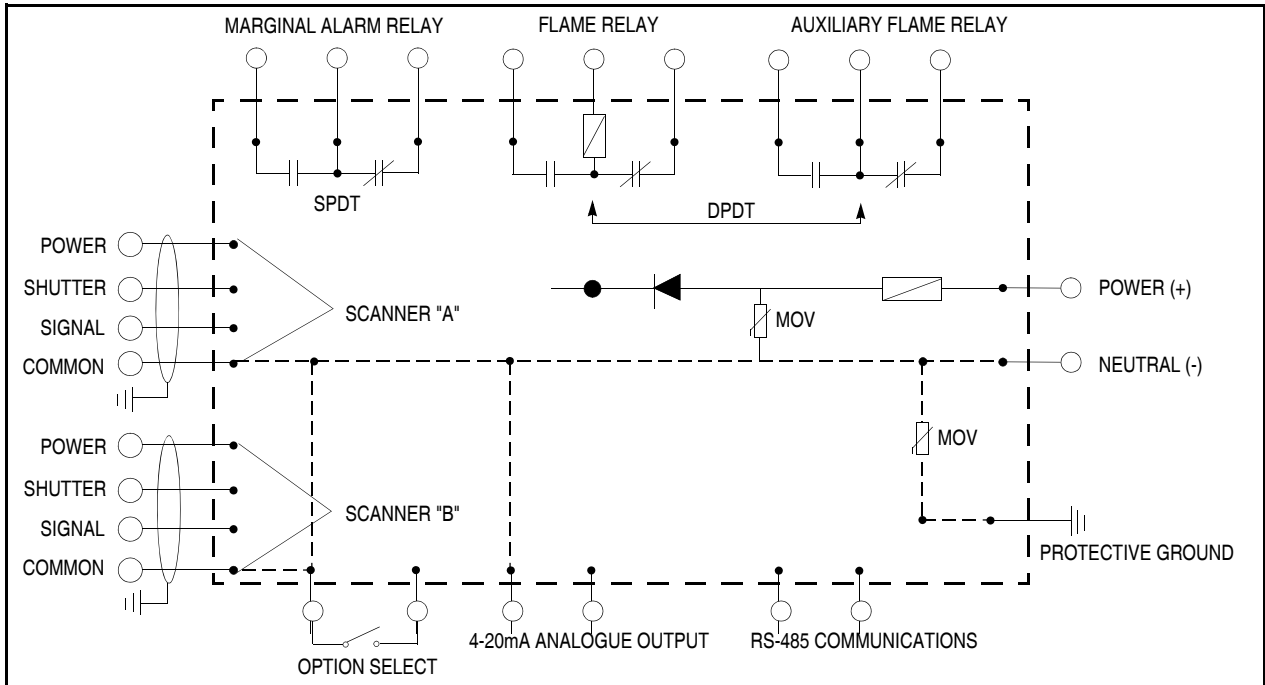
Controllers can also provide an operator **Sensitivity adjustment**. In this way, an adjustment is made to a sensitivity potentiometer. An increase in the sensitivity adjustment will provide an increase in the signal level to an output relay comparator. If the signal to the relay is

greater than the comparator's (fixed) threshold, the control will energize its flame relay. If the flame signal drops below the flame relay's threshold (or is absent) for a period longer than the FFRT, the flame relay will drop out. In the above method, the drop-in and pull-out threshold of the flame relay remains fixed and the adjustments allow the operator to manipulate the flame signal controlling the flame relay.

For example, with a flame detector mounted on the burner-front and connected to its appropriate controller and with the targeted flame-off, sensitivity set to maximum, the controller receives a detector output signal value of 45% as displayed on the control or with separate voltmeter connected. This would represent the signal value of the background radiation. The control's flame relay pull-in value is likely to be around a 30% value. The operator can now adjust the sensitivity dial (or screwdriver adjustment) to limit the detector output signal value to 0%, preventing the flame relay from switching on. When the targeted flame is turned on, the controller may display a detector output signal value of say 60%, ample to energize the flame relay. At this stage, the operator could select an even lower sensitivity setting of, for example, 50%, to assure discrimination between the presence of absence of the targeted flame.

## FLAME SAFEGUARD CONTROLS IN MULTI-BURNER ENVIRONMENTS

**Figure 40:** External connections to controller with dual detector inputs and option select feature.



### THRESHOLD ADJUSTMENT OPTION

An alternate, and generally more accurate method of operator adjustment is used in some controllers. This is available where the output signal from the flame detector remains unconditioned and the operator is allowed to adjust the controller's flame relay pull-in and drop-out threshold to determine the flame's presence or absence. The controller displays the value of its flame detector input signal. Via keypad or external device it allows the desired pull-in and drop-out threshold to be set.

For example, with a flame detector mounted on the burner-front and connected to its appropriate controller and with the targeted flame off, the controller displays a detector output signal value of 280 units. This represents the background radiation of a multi-burner furnace. When the targeted flame is turned on, the controller displays a detector output signal value of 750 units. The operator can now select a flame-

on threshold value of 500 units and a flame-off value of 350 units in order to assure discrimination between the presence or absence of the targeted flame.

### FLAME RELAY OPTIONS

Controllers generally have one double pole, double throw (DPDT) flame relay, allowing for an additional auxiliary set of potential free contacts. Usually, one set of contacts is fused, intended to be used for switching an electrical load. The other set can be used for general status purposes. When wiring to the controller's flame relay, attention must be paid to contact ratings, both maximum current as listed in the controller's specification.

### MARGINAL ALARM RELAY OPTION

Some controllers are equipped with a marginal alarm relay. The marginal alarm relay announces a deteriorating flame signal that could be caused by a dirty scanner lens, etc.

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When the flame signal becomes marginal, approaching the flame relay drop-out setpoint for longer than the allowable period, the marginal alarm relay will pull-in, activating an external alarm device. The pull-in threshold of the marginal alarm relay is adjustable and should be set above the flame relay drop-out threshold. It should be set high enough to allow corrective action, but not too high for nuisance trips.

### FAULT RELAY OPTION

Some controllers are equipped with a fault relay. The purpose of the fault relay is to announce when the system does not respond to the flame detector's or control amplifier self-check function properly. Controllers without a fault relay, directly open the flame relay when a self-check failure is determined. Controllers supplied with a fault relay, maintain the flame relay energized during a self-check failure, but its fault relay will trip, energizing a timed alarm function in the BMS before a burner trip. This allows the operator to remedy the fault before a burner trip is initiated. When this function is not desired, the flame and fault relay can be wired in series.

### ANALOG OUTPUT

Almost all controllers have an analog output for flame signal strength monitoring. The output may be a mA type (0-20 or 4-20) or voltage (0, -3, or 0-10). When connected to an appropriate service test-meter a continuous readout of flame signal strength is provided.

### OPTION SELECT

Controllers often have provision for the connection of two flame detectors. These detectors can be different types. For example, one could

be an ultra-violet and the other an infra-red type.

In more simplistic controllers, both input signals from the detectors (A + B) are used indiscriminately by the control. If strategy requires blocking one detector's signal, then the use of external relays would be required.

More sophisticated controllers with dual flame detector inputs, are provided with an option select feature (see figure 40). Using the option select lets the operator remotely select from a menu of scanner options: A only, B only, A and B, A or B, A xor B, and A plus B. Each of the scanner options are available during programming of the setpoints when commissioning the system. The operator programs in the scanner option into either of the control options. Then, switching between control options, the system selects the appropriate scanner option. With controllers such as this, the operator is also allowed to program two complete setpoint parameters into either option. This allows flexibility in scanner logic selection and also control parameters in both control options.

### TYPE OF CONTROLLER ENCLOSURE

Controllers are manufactured in various architectural designs; panel-mount, base-mount, DIN-rail, and rack-mount. Design selection is dependent upon the application.

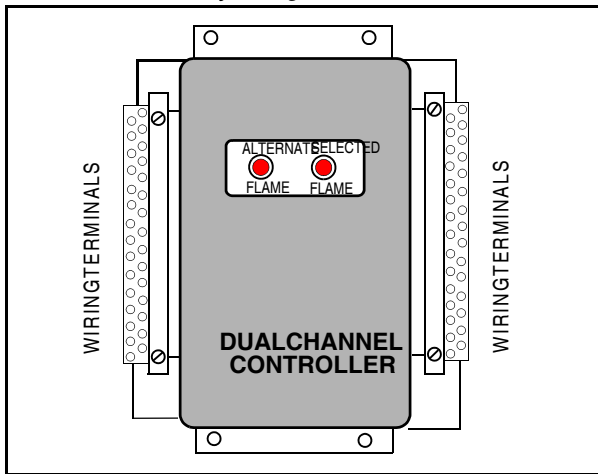
### PANEL MOUNT

**Panel mount** controllers (see Figure 41) mount directly in their control cabinet and are wired to the external wiring terminals. They are "one-piece" construction. Advantages of this design include relative ease of installation (no base, rack, or DIN rail required). Access to wiring terminals for servicing is easy. A disadvantage is the panel-mount's large footprint, especially

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when multiple controllers must be housed in the same cabinet. If, for example, twenty four controllers are required, cabinet space may be a problem. Panel mount controllers need to have all wiring undone and redone when replacing the control. A base, or rack-mount control requires less work at this stage.

**Figure 41:** Dual channel “panel mount” controller with side-entry wiring terminals.



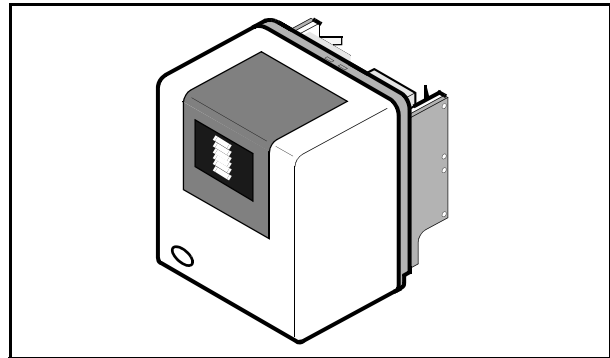
Simple panel mount applications might include burner-deck mounted operator control panels, one at each burner. With its relatively low profile, this installation in explosion-proof cabinets suits this style control.

### BASE MOUNT

**Base mount controllers** are similar in design strategy and subject to the same advantages (and disadvantages) as panel-mounted controls. The exception is the added wiring base. This allows quick removal and replacement in the field. The wiring is inside the wiring base with the control plugging into and out of the base. Obviously, the wiring terminals on base-mounted controllers are not external. This makes trouble shooting connections more difficult, unless the wiring has been terminated to a common, external wiring terminal-strip. This

base will also add to the controller’s total height dimension, possibly requiring a deeper cabinet for mounting the control. Base-mounted controllers (depending on their NEMA or IP rating), may also be mounted external to control cabinets.

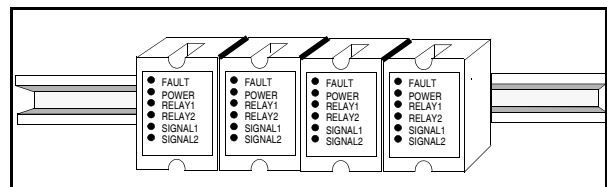
**Figure 42:** Single Channel “base mounted” controller with LED signal strength indication.



### DIN RAIL

Compact in design, **DIN rail** controllers are suitable when multiple units for a small space are needed. DIN-rail mounting allows flexibility in combining controllers and associated power supplies on the same rail.

**Figure 43:** DIN rail mounted controllers



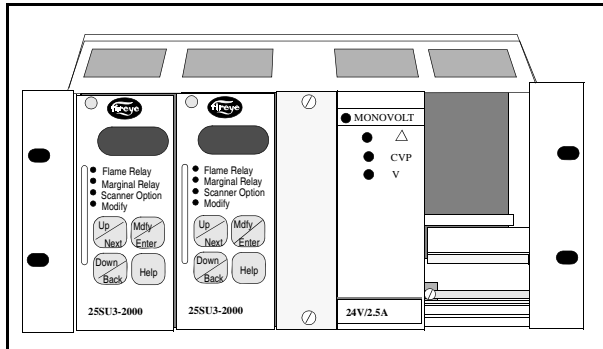
### RACK MOUNT

Ideally suited for mounting many units in small areas, rack-mounting is multipurpose and flexible. This style has been industry standard around the world.



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**Figure 44:** Programmable, single channel, "Rack Mounted" controllers in a half-rack.



### SUMMARY

Application of Flame Safeguard controls should only be undertaken by individuals with knowledge of the combustion process. A thorough knowledge of control and instrumentation is mandatory.

Understanding and solving application problems involves:

1. A full understanding of the problem. All objectives, including performance must be clear. Safety is paramount to any application. Difficulty in achieving strong and reliable flame signal cannot interfere with the ultimate goal of reliably detecting the targeted flame "on" and "off."
2. Determining various alternative solutions to the problem can present different advantages and disadvantages. On-site testing of equipment is often required, allowing the user to test various types of detectors and accessories.
3. Make the best selection based on the results of the tests and assure that they are implemented.

Flame Safeguard solutions require application knowledge. Economic justification may influence decisions, but should not interfere with appropriate solutions.

Today's microprocessor-based systems handle both modulating and digital logic functions. Future boilers, turbines, and furnaces will require the design and installation of progressively more sophisticated FSG controls. With the large installed base of controls and the need to upgrade equipment, this is an interesting and exciting time to be involved in this industry.