3. Pilots and ignition systems

Overview

Purpose

Initiating the combustion process requires the heating of a fuel-air mix to the point of ignition. This Chapter examines various methods that the gas industry uses for this purpose.

Objectives

At the end of this Chapter, you will be able to:

- explain pilot burners;
- explain ignition systems; and
- explain flame sensing devices.

Terminology

Term	Abbreviation (symbol)	Definition
Pilot burner		Provide adequate ignition flame for a main burner
Thermistor		Solid-state device whose electrical resistance decreases with temperature
Thermocouple		Powers combustion safety circuits that have constant pilots
Thermopile (power pile)		Consists of multiple thermocouples joined together at one end and connected in series to generate more voltage than a single thermocouple

Pilot burners

No one pilot burner can give adequate ignition flame for all types of main burners. Consequently, there are many different pilot burner designs with a wide selection of mounting styles and directional hoods.

Pilot burners have three main functions:

- to create a flame of the proper size and characteristics that can be proven by a flame detector to be a safe pilot flame;

8) Match the appropriate word(s) to best complete the following statements:

a) _____________ use a mechanical device to mix the required amounts of air and gas before ignition.	Aspirator type of burner
b) The _______________ uses air under pressure to entrain gas at atmospheric pressure.	Premix burners
c) The _______________ provides complete premixing with mechanical mixers.	Blower-mix burner

9) What type of burner has a fan located downstream of the combustion zone?
   a) Forced draft burner
   b) Induced draft burner
   c) Atmospheric burner

10) What device is used to regulate gas supply to an aspirator-type burner?
   a) Zero governor
   b) Orifice
   c) Blower mixer

11) Which atmospheric burners are most susceptible to flashback?
   a) Ribbon burners
   b) Ring burners
   c) Mono-port

12) What helps to keep the flame retained at the burner port of a mono-port burner?
   a) Gas pressure
   b) Flame spreader
   c) Crimped ring

13) What is a "multiport" burner susceptible to?
   a) Clogging with lint from the inside
   b) Delayed ignition
   c) Sooting

- to ignite the main burner flame safely and reliably; and
- to provide a mount for the igniter (if so equipped) and a flame detector.

The categories of pilot burners, like main burners, are according to whether they premix air with gas.

Consequently, the two basic types of pilot burners are:
- aerated pilots; and
- non-aerated pilots.

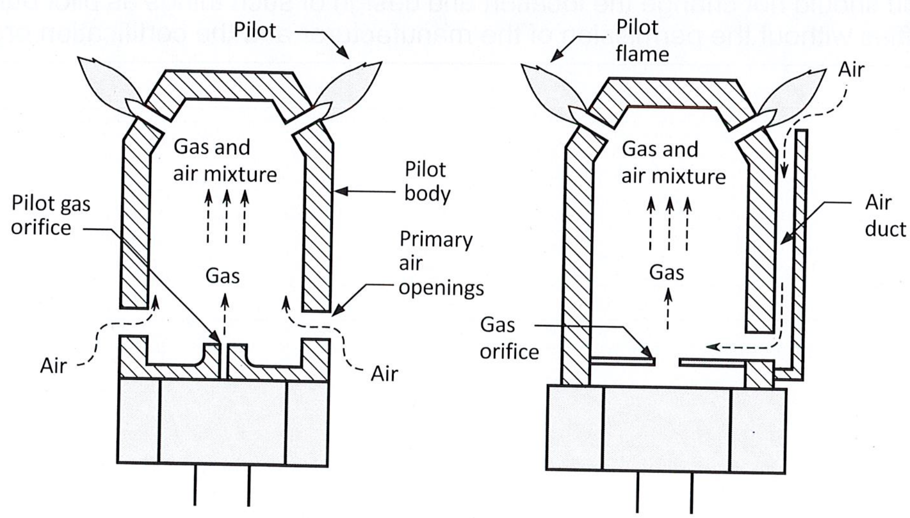
Aerated pilot burners

Aerated pilots (see Figure 3-1A and Figure 3-1B) premix air and gas and develop a sharp, intense blue flame. Draft and main flame variations do not greatly affect these pilots, which have a relatively stable flame.

Aerated pilots also provide a hot flame (due to primary air mixing) for good flame detector response. However, because of the hotter pilot flame, aerated pilots tend to give shorter thermocouple life.

The most common problem associated with aerated pilot burners is clogging due to dust and lint. This is especially true for burners that are near the floor, such as water heaters. The incinerating pilot (see Figure 3-1B), however, solves the dust problem. This type of pilot draws the primary air through a tube or air duct. This tube passes around the pilot flame, incinerating any lint or dust that could be in the primary air.

Figure 3-1
Aerating pilot burners



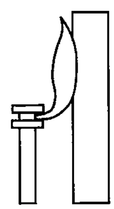
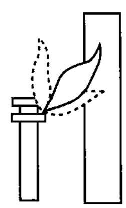
(a) Aerated pilot **(b) Incinerating pilot**

Troubleshooting aerated pilot problems

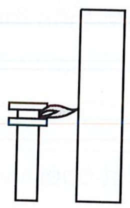
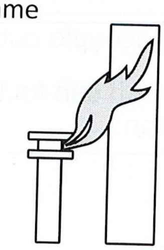
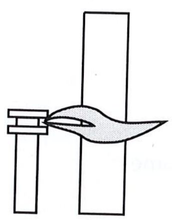
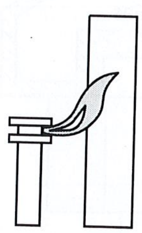
Table 3-1 lists common aerated pilot problems, causes, and possible remedies.

Use this guide when troubleshooting aerated pilot problems.

Table 3-1
Guide to troubleshooting aerated pilot burners*

Flame type	Causes	Remedy
Lazy yellow flame 	Dirty lint screen or primary air opening.	• clean pilot burner as required, removing lint screen
Waving blue flame 	Excessive draft at pilot location. Recirculating products of combustion.	• relocate pilot • install protecting baffle

* **Note** that you should not change the location and design of such things as pilot burners and protecting baffles without the permission of the manufacturer and the certification organization.

Flame type	Causes	Remedy
Small blue flame 	Low gas pressure Clogged pilot burner orifice Clogged pilot line filter Improper orifice (too small)	• increase pressure to normal • clean pilot burner orifice • clean filter • install correct orifice
Noisy lifting blowing flame 	High gas pressure	• reduce pressure to normal
Hard sharp flame 	Orifice too small	• install correct orifice inlet fitting
3/8 in to 1/2 in normal flame 	Proper installation	• none needed

Non-aerating and target pilot burners

Non-aerating pilots (see Figure 3-2a) have no primary air intake. They give a softer blue flame. Because their combustion air is solely secondary air, draft and main flame variations affect these pilots more than the aerated ones.

Target pilots (see Figure 3-2b) enable the gas issuing from a pilot orifice entrains air at this point. The resulting air-gas mixture burns against a target hood that directs the flame and protects it from drafts.

The non-aerating and target pilots do not have the same dust and lint problems as the aerated pilots. Also, they tend to promote longer thermocouple life since they produce less torching (the hard, sharp, hot flame from aerated pilots).

However, changes in pilot supply pressure can affect these pilots more than the aerated type.

If the supply pressure is...	**Then...**
Too high	The pilot flame will roar, giving a noisy pilot operation and lower thermocouple life. A lifting flame can also disrupt the operation of a flame rod flame detector.
Too low	There is insufficient heat, giving low thermocouple output voltage. A yellow, carbonizing flame may result, which can foul the flame rod or thermocouple and disrupt flame detection.

Figure 3-2
Non-aerating and target pilot burners

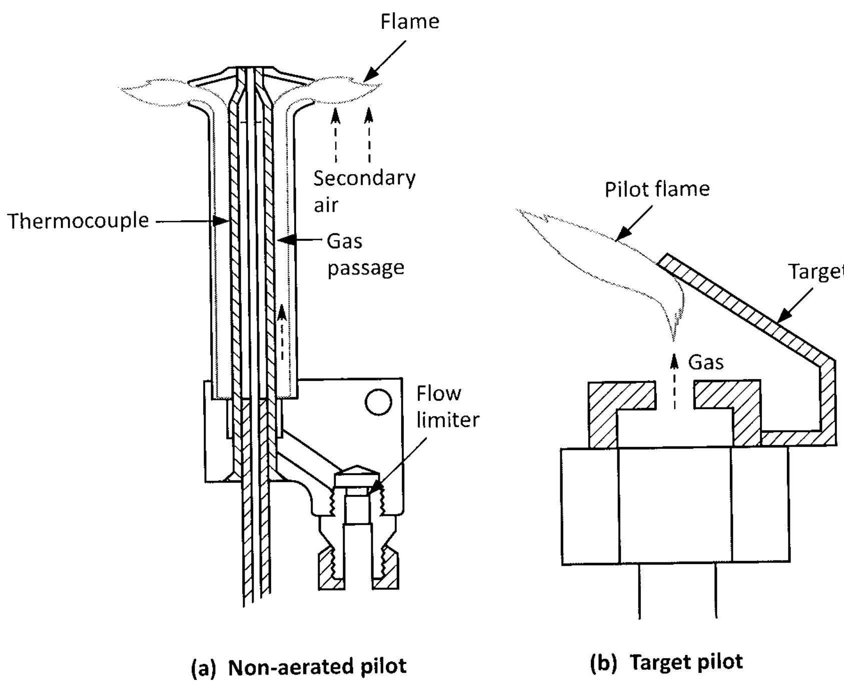
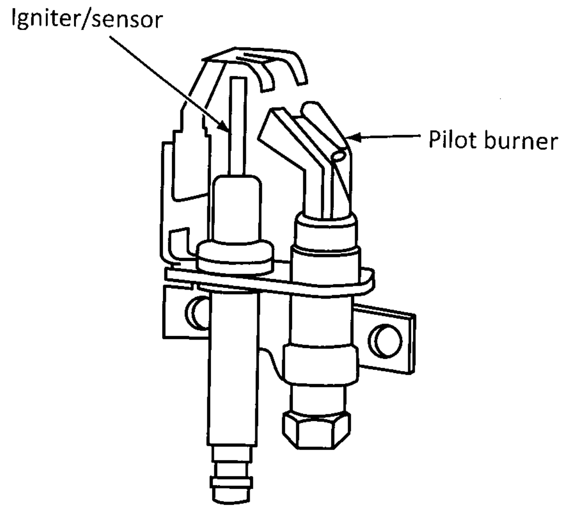


Figure 3-3 shows a typical application of a target pilot burner used in conjunction with an igniter/ sensor.

Figure 3-3
Typical target pilot burner

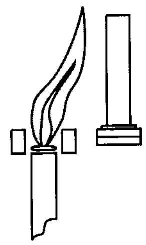
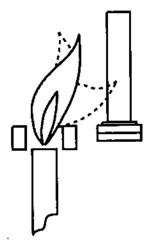
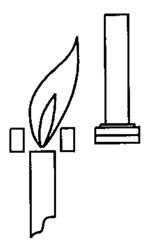
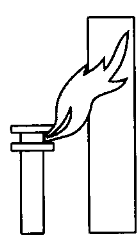


Troubleshooting non-aerating pilot burners

Table 3-2 lists common non-aerating pilot problems, causes, and possible remedies.

Use this guide when troubleshooting non-aerated pilot problems.

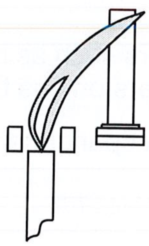
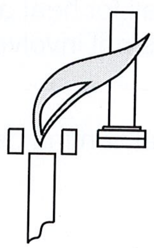
Table 3-2
Guide to troubleshooting non-aerating pilot burners*

Flame type	Causes	Remedy
Lazy yellow flame 	Orifice too large	• replace orifice spud
Waving blue flame 	Excessive draft at location Recirculating products of combustion	• replace pilot, or • install protecting baffle
Small blue flame 	Low gas pressure Clogged pilot-burner orifice Clogged pilot-line filter Improper orifice	• increase pressure to normal • clean pilot burner orifice • clean filter • install correct orifice
Noisy lifting blowing flame 	High gas pressure	• reduce pressure

***Note** that you should not change the location and design of such things as pilot burners and protecting baffles without the permission of the manufacturer and the certification organization.

(Continued)

Table 3-2 (Concluded)

Flame type	Causes	Remedy
Hard sharp flame 	Orifice too small	• install larger orifice
Normal flame 	Mostly blue, steady Envelops 3/8 in to 1/2 in of thermocouple	• none needed

Proved pilots

When a flame detector that acts to prevent gas from flowing to the main burner, unless a proper pilot flame is proven, monitors a pilot flame, you call this flame a *proved* pilot.

The flame detector may act upon a primary gas valve upstream of all burners—as in the case of a thermocouple flame detection system—or it may send an electric signal to a flame safeguard control that in turn acts upon the gas valve(s).

Ignition systems

Manual ignition

There are two general ways to use manual ignition on gas appliances :

- manually lighting the pilot, which, in turn, lights the main burner automatically as required; and
- manually lighting the main burner for every use.

Type	Description
Continuous pilot (standing pilot)	This burns throughout the entire time the burner assembly is in service, whether the main burner is firing or not. You manually light this type of pilot using a match.

Type	Description
Expanding pilot	Similar to the continuous pilot, this burns whether the main burner is firing or not. Upon a call for heat, however, this pilot flame automatically increases in size to reliably ignite the main burner. This pilot may also turn down automatically at the end of the main burner flame-establishing period.
Piezoelectric pilot	This helps ignite pilot burners or main burners such as main burners on gas barbecues or refrigerators, or pilot burners on gas fireplaces. This can generate a high voltage to supply a spark after the application of a mechanical force.

Automatic ignition

Automatic ignition of the pilot and/or main flame at the start of each call for heat avoids the problems associated with manual ignition systems. The off-cycle does not involve wasting of gas nor does it require venting (unlike with constant pilot systems).

High efficiency appliances—especially ones that employ a mechanical venting device—use one of two automatic ignition systems:

- intermittent ignition; and
- interrupted ignition.

Type	Description
Intermittent ignition	This involves the activation of an intermittent igniter or pilot at each call for heat in accordance with the sequence of operation of the burner control. The igniter or pilot continues to function during the entire period that the (call for heat is present) main flame is present.
Interrupted ignition	This also involves the activation of an interrupted igniter or pilot at each call for heat in accordance with the sequence of operation of the burner control, but ceases to function after the establishment of the main flame.

Energization of both automatic systems happens upon each call for heat, and monitoring of the flame occurs with the help of an electronic sensing device. The flame monitoring systems that you use with these automatic ignition systems must provide a much faster response to flame failure than a thermal device such as a thermocouple. The *Flame sensing devices* section discusses flame detectors.

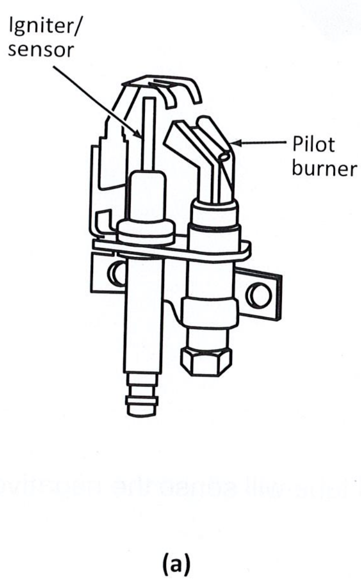
Types of initial ignition sources

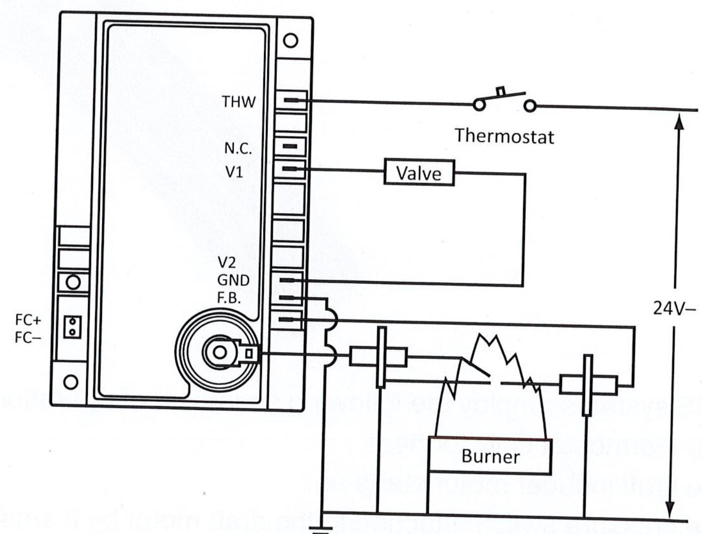
The initial ignition source for automatic ignition systems may be one of the three following types:

Source	Description
Spark ignition	Automatic ignition system that uses an ignition spark to light a pilot burner (See Figure 3-4a.)
Direct spark ignition	Automatic ignition system that uses an ignition spark to light the main burner Applies to burners not using a pilot (See Figure 3-4b.)
Hot surface ignition	Ignition system in which a hot surface (such as a glow bar) automatically ignites the pilot or main burner flame upon each call for heat (See Figure 3-5.).

Older systems were designed to provide a relight function for continuous pilots.

Figure 3-4
Spark ignition of a pilot burner (a) and direct spark ignition (DSI) of a main burner (b)





The hot surface igniter is, arguably, the most commonly used electronic ignition system today. They are reliable and inexpensive, and the electronic controls they require are also less expensive.

The hot surface igniter works like a light bulb filament. The hot surface igniter is usually made from a material like silicon carbide or nitride. As electricity (120v A/C) passes through the igniter, it glows white hot.

Figure 3-5
Hot surface igniter
Image courtesy of Terry Bell

Most HIS systems employ the following sequence of operation:

1) The thermostat calls for heat.
2) The draft inducer motor starts up.
3) The pressure switch attached to the draft motor by a small tube will sense the negative pressure created by the draft inducer.
4) The draft inducer motor runs for 30 to 60 seconds.
5) The flame sensor senses heat from the pilot or HSI and allows gas to flow to the burners.
6) The hot surface igniter or the intermittent pilot ignites the gas burner.

Chapter *4. Controls and safeties* covers the electronic control that regulates this sequence of operation.

Flame sensing devices

Flame detectors respond to the establishment of a flame during the trial for ignition of a pilot flame or main flame and to loss of an established flame—this is what you call flame failure response time. The standard to which the appliance received certification and the type of flame detection establish the maximum allowable time for this flame response.

The flame detector responds by shutting off the flow of gas of all burners—as in the case of a thermocouple flame detection system—or by sending an electric signal to a flame safeguard control that in turn acts upon the gas valve(s).

The seven most common types of flame sensing methods that residential or light commercial appliances employ are:

- constant supervision;
- bimetal heat sensors;
- bulb and bellows heat sensors;
- thermocouple or thermopile heat sensors;
- thermistor heat sensors;
- flame rod current rectification sensors;
- optical light sensors; and
- ultra Violet scanners and infrared scanners.

Constant supervision

The simplest and least reliable means of detecting the presence or absence of a flame is to have a knowledgeable person observe the flame and take the appropriate action during flame ignition and flame failure.

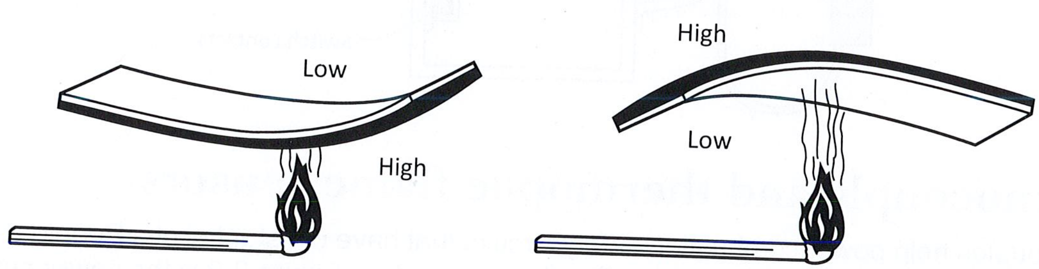
This is the flame detection method for the portable torches and barbecues. Constant supervision is as reliable and fast acting as the person tending the flame.

The most common example of this system is an outdoor barbecue. The manufacturer's instructions state how a person is to safely ignite the burner and warn the person to remain in constant attendance during operation. The requirements for outdoor location and distances to building openings and combustibles help ensure safe operation if constant supervision is provided.

Bimetal flame sensor

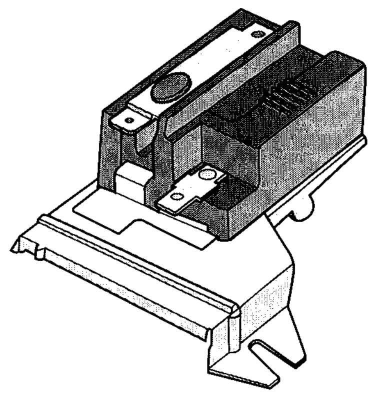
Two dissimilar metals welded together form the bimetal strip. Different temperature coefficients of expansion of the metals cause the strip to bevel or curve with changes in temperature (see Figure 3-6). You can use this principle to sense the heat radiation of a flame and act upon an electrical circuit.

Figure 3-6
Bimetal strip warps and bends with an increase in temperature



Some modern appliances such as clothes dryers employ highly sensitive bimetal flame sensors. See Figure 3-7.

Figure 3-7
Bimetal flame sensor used on a gas-fired clothes dryer

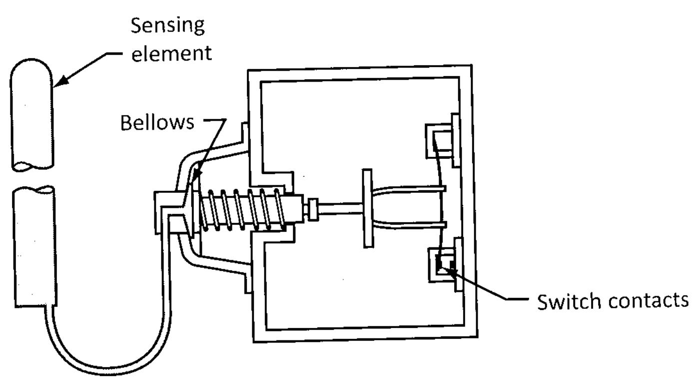


Bulb and bellows flame sensors

This type of flame sensor consists of a bulb, capillary tube, and bellows (see Figure 3-8) that contain a temperature expansive liquid such as mercury, toluene, silicone, or alkazine. When exposed to heat, the liquid expands causing a hydraulic action on the bellows which, in turn, acts upon a switch to complete an electrical circuit allowing current flow to the gas valve(s). If the flame fails, the liquid contracts and opens the circuit thereby closing the valve.

The size and appearance of the bulb and bellows flame detector is similar to that of a thermocouple flame detector but its response time is much quicker (usually less than 15 seconds). You can commonly find it on some residential gas fireplaces.

Figure 3-8
Bulb and bellows flame sensor



Thermocouple and thermopile flame sensors

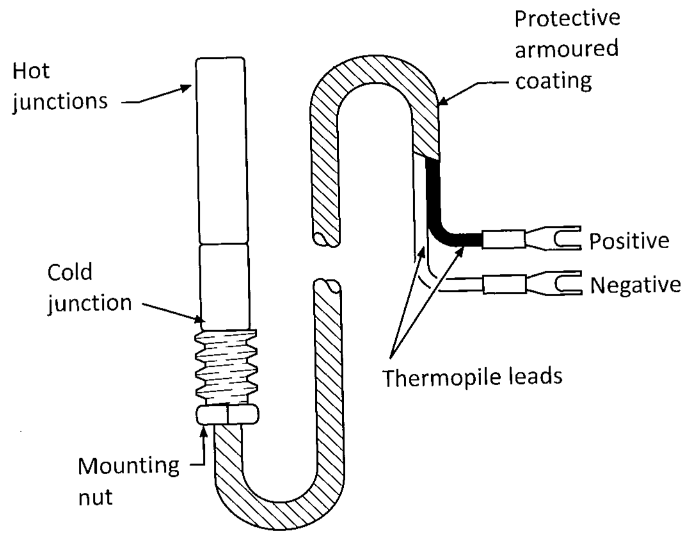
Thermocouples help power combustion safety circuits that have constant pilots. People use them on appliances with manual reset controls. The thermocouple in Figure 3-9 is the power supply for the combustion safety circuit of a gas furnace. The thermocouple assembly is attached with a threaded male fitting. See Figure 3-9.

When the pilot burner heats the hot junction, the thermocouple generates a voltage to power the electromagnet in the safety shutoff valve or safety switch. As long as the pilot remains lit, the shutoff valve will remain energized and open to allow the flow of gas to the main and pilot burners. If the pilot light goes out, the thermocouple will cool down, and the resulting drop in voltage will trip the safety switch to shut off the flow of gas.

Figure 3-9
Combustion safety circuit thermocouple
Image courtesy of Terry Bell

A thermopile, which you may also know as a power pile, consists of multiple thermocouples joined together at one end and connected in series to generate more voltage than a single thermocouple (see Figure 3-10). The higher voltage allows the power pile to power an appliance's combustion safety circuit and its control circuit. People use power pile generators (see Figure 3-10) on appliances with automatic-type controls.

Figure 3-10
Power pile generator

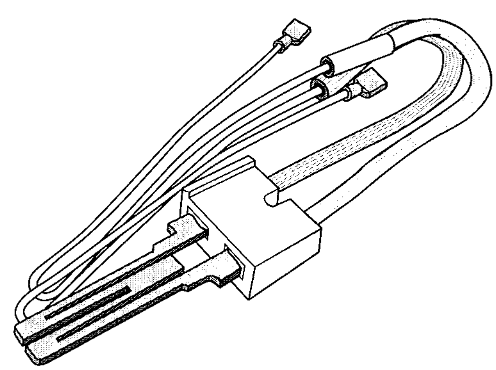


Thermistor flame sensors

A thermistor is a solid-state device whose electrical resistance decreases with temperature. You can use this reaction to monitor the flame status by immersing the thermistor in the pilot and/or main flame with a flame safeguard control monitoring the current flow through the thermistor.

You may also employ a hot surface igniter (see Figure 3-11) that you used to light a pilot or main burner to sense the presence or absence of the flame by employing the principles of a thermistor. If the establishment and maintenance of the flame occur after the HSI has completed its function as an igniter, the HIS remains hot and allows current to pass through the igniter.

Figure 3-11
Some hot surface igniters serve double duty as an igniter and flame sensor



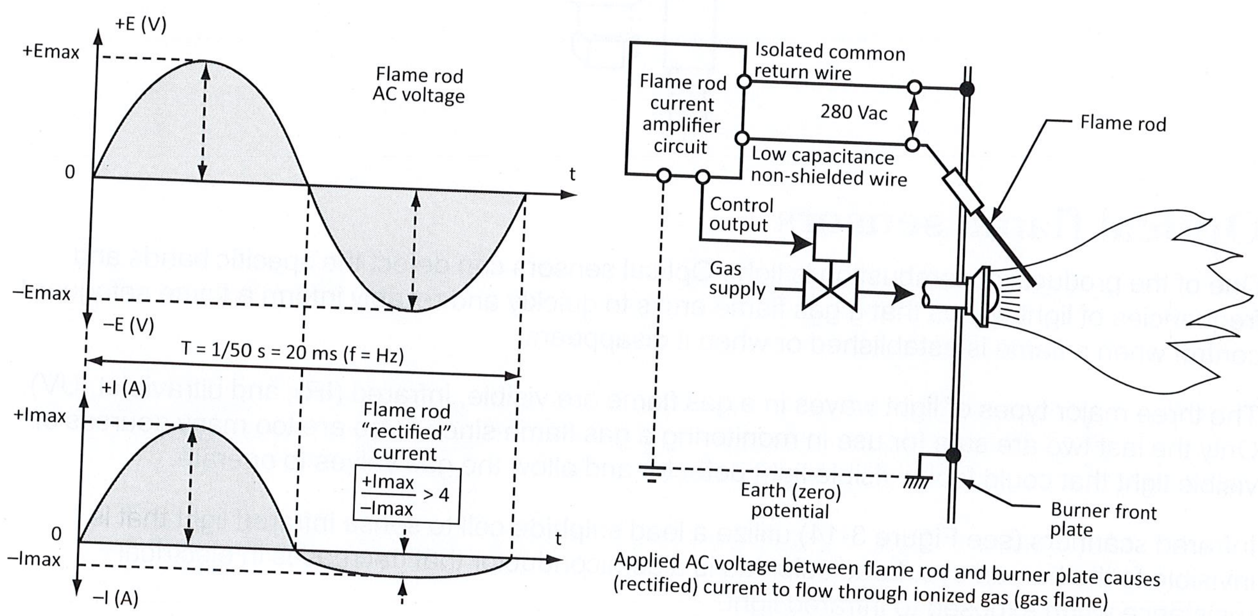
Flame rod sensors

Flame rods are the most common type of flame sensor that people use on modern gas-fired appliances. Flame rod systems depend on the ability of the flame to conduct current when a voltage is applied across two electrodes in the flame. Heat from the flame causes molecules between the electrodes to collide with each other so forcibly as to knock some electrons out of the atoms, producing ions. This is called ***flame ionization***.

The electric control applies an ac voltage to the flame rod. However, a pulsating dc current passes through the flame, since the flame rod is at least four times smaller than the grounding surface or electrode—the burner. See Figure 3-12.

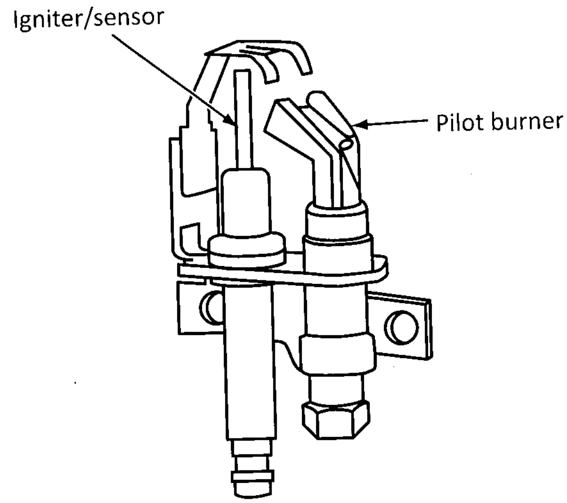
In some cases, the flame rod also serves as the spark igniter rod until a flame is established and then acts as a flame sensor. This system is often what you call a ***unirod***. See Figure 3-13.

Figure 3-12
Operating principles of flame rod rectification flame sensing systems



Applied AC voltage between flame rod and burner plate causes (rectified) current to flow through ionized gas (gas flame)

Figure 3-13
Unirod combination spark igniter and flame rod



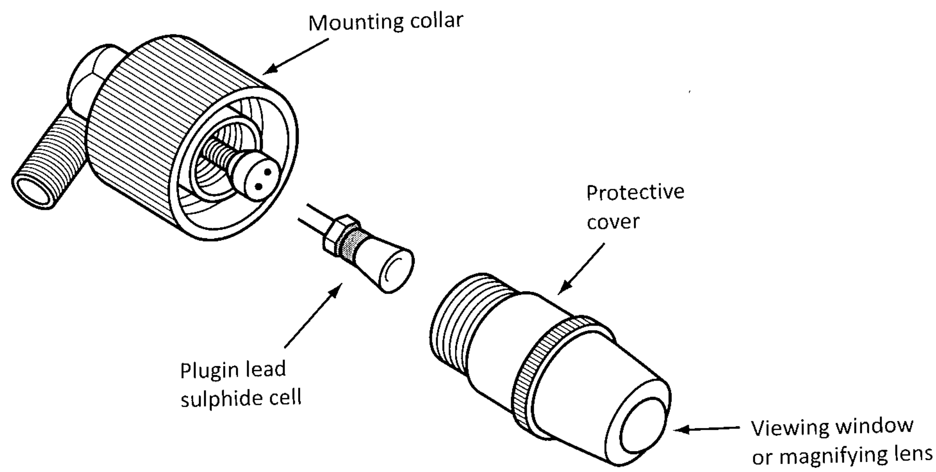
Optical flame sensors

One of the products of combustion is light. Optical sensors can detect the specific bands and frequencies of light waves that a gas flame emits to quickly and reliably inform a flame safeguard control when a flame is established or when it disappears.

The three major types of light waves in a gas flame are visible, infrared (IR), and ultraviolet (UV). Only the last two are safe for use in monitoring a gas flame since there are too many sources of visible light that could fool a visible light detector and allow the gas valves to operate.

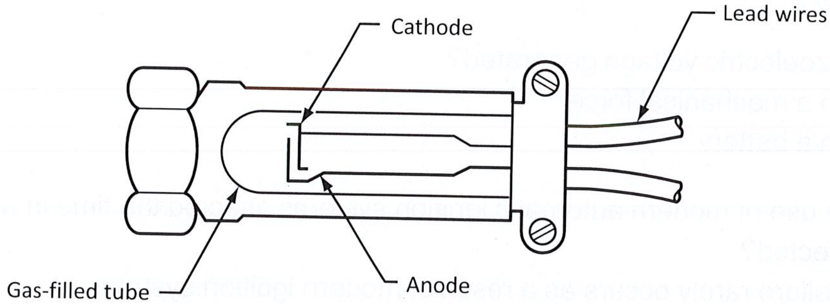
Infrared scanners (see Figure 3-14) utilize a lead sulphide cell to sense infrared light that is invisible to the human eye. Lead sulphide is a semiconductor that decreases in electrical resistance when exposed to infrared light.

Figure 3-14
Infrared (IR) scanner



Ultraviolet scanners (see Figure 3-15) consists of two electrodes sealed in a gas-filled quartz glass tube filled with a special gas. After the application of a high enough voltage across the electrodes and the exposure of the special gas to a UV source, the cathode emits electrons which ionize the special gas sealed in the tube. When the gas is ionized, the tube becomes conductive and current flows through the tube.

Figure 3-15
Ultraviolet (UV) scanner



You can usually find optical flame sensors on higher input appliances.

Assignment Questions – Chapter 3

1) Aerated and non-aerating are types of what?
   a) Ignition systems
   b) Flame sensing devices
   c) Pilot burners

2) What is the most common problem associated with aerated pilots?
   a) Clogging due to dust or lint
   b) Lifting or blowing
   c) Noisy

3) When you discover a noisy, lifting, blowing flame on a non-aerating pilot, what is the cause of the problem?
   a) High gas pressure
   b) Low gas pressure
   c) Blocked vent
   d) Orifice too large

4) When you discover a hard, sharp flame on an aerating pilot, what is the cause of the problem?
   a) High gas pressure
   b) Orifice too large
   c) Orifice too small
   d) Excessive draft at pilot location

5) Select the appropriate term to complete the following sentence:
When a flame detector that acts to prevent gas from flowing to the main burner, unless a proper pilot flame is proven, monitors a pilot flame, you call this flame a

______________________.

a) Proven pilot
b) Proved pilot
c) Intermittent pilot
d) Standing pilot

6) How is a piezoelectric voltage generated?
a) Through a mechanical force
b) Through a battery

7) How has the use of modern automatic ignition systems affected the time in which a flame failure is detected?
a) Flame failure rarely occurs as a result of modern ignition systems
b) Flame failure is detected much faster
c) There are fewer delayed ignitions

8) What causes the bimetal strip to curve with changes in temperature?
a) One side of the strip is shorter than the other side.
b) The welding temperature is too high
c) The two metals that are joined have different temperature coefficients of expansion

9) What causes the resistance of a thermistor to change?
a) A temperature change
b) Humidity
c) Time

10) Match the following terms to their corresponding definitions:

a) Remains on all the time:	Intermittent pilot
b) Remains on during the firing cycle: Intermittent	Interrupted pilot
c) Is turned on to light the main flame and is extinguished after the flame has been proved:	Constant pilot