pilot before the main fuel valve can be opened; (2) in the event of a failure to prove an adequate pilot, a safety shutdown should occur; and (3) in the event of a flame failure during the burner burning cycle, the fuel valve should be immediately de-energized and the pilot re-established or a safety shutdown should occur.

5. Commercial and industrial gas burners of the power type are normally provided with the spark-ignited pilot established on each burner cycle. These burners require a flame safeguard control whose functions normally include (1) pre-ignition purge, (2) establishing and proving the spark-ignited pilot, and if not proven, causing a safety shutdown, (3) on proof of pilot, opening the main fuel valve, (4) at the end of the timed ignition period, turning off the spark ignition only or both the spark ignition and pilot valve, (5) in the event of a flame failure, de-energizing the fuel valves within four seconds, (6) at the end of the burner operating cycle, closing the fuel valves and keeping the burner motor running for a post-purge period, and (7) in the event of a flame failure, obtaining a safety shutdown (requiring a manual reset prior to restart).

6. On combination gas-oil burners, because the programming sequence of the primary control varies only slightly from gas to oil, single and dual fuel units normally utilize the same flame safeguard controls with the addition of the added flame detector as required.

7. Mechanical and thermal flame sensing means are not considered adequate for these burners because the majority of local codes and approval bodies require a four second response timing following a flame failure on commercial and industrial burners.

Electronic means of flame sensing, responding within four seconds to the presence or absence of a flame, utilize either electrical characteristics or the spectral radiation of a flame as a signal source. Electronic flame detection units are classified by their means of flame sensing:

a. The *flame rod*, for checking a gas pilot or main flame, or both, utilizes the current carrying ability of a flame.

b. The *photocell* responds to the visible radiant energy of the luminous flame (oil).

c. The *lead sulphide cell* responds to the invisible (infra-red) radiant energy from either a luminous or non-luminous flame (gas or oil).

d. The *ultra-violet photocell* responds to the invisible (ultra-violet) radiant energy of the flame. Not affected by radiant energy from hot refractory (gas or oil).

Whenever the pilot is proven before the main fuel valve is opened, a pilot turndown test should be made on the burner installation to prove that the flame sensing means will always provide a pilot capable of safely igniting the main burner.

In addition to the controller, the limit control, and the primary of flame safeguard controls, the control system for the commercial and industrial burners may include additional controls to provide added sequence or safety interlock functions. The extent to which the control system will include these added functions will depend upon the size and type of burner involved, as well as upon local code and approval body requirements. The complete control system for the commercial-industrial burners could include the following control functions:

1. *Interlocks*. These provide a check to insure that the control devices are in proper position and that other conditions are satisfactory prior to burner start-up as well as during the firing cycle.

2. *Firing rate or combustion controls*. These regulate the burner firing rate.

3. *Valves*. These provide off-on control of pilot or main fuel supply or both.

4. *Water level controls*. These control the water level on steam boilers and guard against low water conditions.

5. *Draft control*. This regulates the draft in the combustion chamber for proper combustion.

6. *Electric overload releases and fuses*. These prevent electric overloads from endangering or damaging the burner or electric wiring.

A discussion of preceding items 1 to 6 follows.

Interlocks. Interlocks consist of electrical switches which indicate that a satisfactory starting and operating condition exists. The starting interlocks prove that the burner linkage is in the low fire position, the up-take damper is in the start burner position, the draft control interlock is in the start position, the oil is at the proper temperature to assure ignition or that air and fuel pressures are proper for burner operation. Operating interlocks prove that the fuel and air pressures are maintained within the burner operating limits and that proper draft conditions prevail. In the combination gas-oil burners, the fuel changeover switch may also perform an interlock function. The selection of interlocks for a burner control system depends largely on the size of the burner, the fuel involved, and the method of operation as well as approval body requirements.

Firing rate or combustion controls. Most of today's large commercial-industrial burners have a means of adjusting the firing rate to the load demand. This involves a change in the firing rate (both air and fuel simultaneously) either from high fire to low fire or to a modulation between these two points as the pressure or temperature of the controlled variable changes. This change in firing rate may be governed by either electric, hydraulic, or pneumatic control. Burners with firing rate controls are required to be started at a low firing rate. The firing rate controls may allow the burner to go to a high fire rate immediately after ignition as the main fuel valve opens, or may hold at the low firing rate until the burner stabilizes and the draft becomes established before permitting the firing rate control to operate. Regardless of the type of firing rate the control employed or the means used to accomplish it, the assured low-fire start provides a smoother ignition. The types of firing rates involved are low-fire start, high-fire run, high-low, or modulating. The type used depends upon the size and requirements of the burner.

Valves. Valves are required for final shutoff of both the gas pilot and main gas or oil valves in the supply line. The type of valve to be used would depend upon the service, fuel, and characteristics of the burner. Valves are classified by types as follows:

a. *Solenoid gas or oil valves*. These provide quick opening and quick closing. For gas, approved as safety shutoff valves in ¾-in. size and below are used normally only for pilot supply.

b. *Motor operated gas and oil valves* may be of geartrain or hydraulically operated types. They provide relatively slow opening and quick closing. Opening time is not adjustable. They have provision for either direct or reverse acting operating levers.

c. *Diaphragm valves for gas* are usually operated by gas pressure, although some types are steam- or air-operated. These valves make provision for adjustable opening timing which may be adjusted to the desired burner operating characteristics. They have provision for either direct or reverse acting lever arm.

d. *Manually opened safety shutoff valves for gas or oil* can be opened manually only when power is available. When power is interrupted they trip free for fast closure. They are normally used on semiautomatic and manually fired installations.

e. *Burner input control valves* are required for gas or oil by some approval bodies in addition to safety shutoff valves. These

may be of the slow-opening type or may provide for high-low or modulating operation. These valves may or may not have provision for final shutoff. Requirements of local codes and approval bodies should be followed to assure that valves selected are approved for the type of burner used and that maximum overall efficiency of the burner is obtained.

Water Level Control. On steam boilers it is necessary to provide low-water cut-offs to prevent burner operation if the water level should drop to an unsafe level. In addition, water level controls may be required in added sequence to protect against low-water conditions in the boiler and to avoid burner interruptions. Two basic types of water-level and low-water cut-offs are the float and probe types.

The float type water-level control consists of a switch operated by a float which is either in the boiler water or in a float chamber installed adjacent to the boiler. As the water level falls, the float drops and, through a linkage, operates a switch to start the feed-water pump, energize the electric feed-water valve for (low pressure water) or the float and linkage may open directly the mechanical feed-water valve (low pressure boilers only). If the boiler water continues to fall another switch is actuated by the linkage to shut off the burner before a hazardous low water level is reached.

Probe type controls provide the same function as float type controls. They operate on the principle of conduction of a small current from the probe through the water to hold the relay energized. As the water level falls, the contact between the probe and water is broken, the current flow stops, and the relay is de-energized. Contacts on the relay provide switching as required. Probe type controls cannot be used for direct operation of feed water valves.

Draft control. A draft control is normally used on commercial burners in place of a draft hood so as to maintain a constant fire-box draft to assure stable firing and to increase the overall efficiency of combustion. The two basic types are the barometric and the motorized damper positioners.

Barometric draft regulators are generally installed in the breeching between the boiler and the chimney. They are balanced and closed when the chimney draft is low and opened when the chimney draft is high. When the barometric draft regulator opens, it allows air from the boiler room to enter the breeching, thereby maintaining a constant draft in the breeching.

Motorized draft controls are generally used on larger installations to regulate the boiler uptake damper. They maintain balanced furnace drafts at the burner by sampling the actual overfire draft condition. The motorized draft control provides complete damper sequencing and safety electrical interlocks for automatic firing. They do not require boiler room air for control operation. Generally they are designed to hold the damper in the minimum position with the burner shutoff (thereby conserving combustion chamber heat), open the damper wide prior to ignition (to provide maximum draft) for purging and modulate the uptake damper when the burner is operating to maintain constant overfire draft. The system includes an integral switch to prevent burner operation unless the damper is open. The system may also include starting draft rate selection (for control of mechanical draft), and draft switch shutdown interlock (to protect against draft failure).

Electric overload releases and fuses. Electrical overload releases and fuses are a part of the overall control system to disconnect electric power in the event of short circuits or any electric overloads that could endanger or damage the equipment. Small burner motors generally have built-in overload releases. Large motors require external overload releases which are generally included in the magnetic starters for the motor. Fuses should be provided as specified by local electric codes.

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