Fired Heaters

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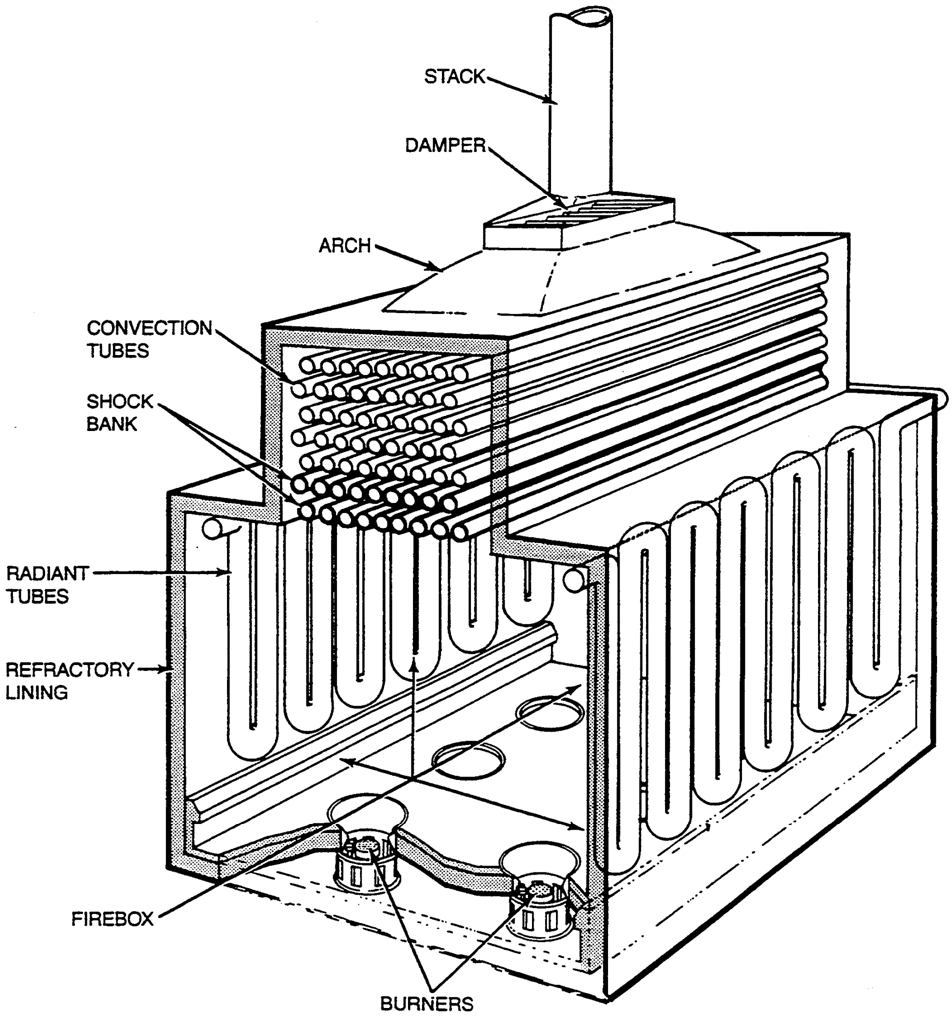
Fired Heaters

FIRED HEATER DESIGN

Fired heaters are normally custom designed for a particular application. As a result, there are many different furnace designs.

Furnace Equipment

Figure 3.4 shows the components of a typical furnace. The burners are located in the floor of the furnace. Heat is produced by combustion of fuel at the burners. The open area above the burners is called the firebox. The tubes along the walls of the firebox receive direct rays of radiant heat. These are called the radiant tubes. The hot gases formed by burning fuel and air are called **flue gases.** These gases move up the furnace and are funneled through the arch into the stack.



Furnace Components

The tubes at the top of the furnace absorb heat from the hot flue gasses passing over them. These tubes are called the convection tubes.

The section of tubes located between the radiant section and the convection section is called the shock bank. The shock bank receives both convection and radiant heat.

The furnace walls, floor, and ceiling are lined with a material that reduces heat losses and reflects heat back to the tubes. This material is called a refractory lining.

Inside the stack is a damper which controls the flow of flue gases out of the furnace. By adjusting the damper, you can control the furnace draft.

The tubes

The tubes carry the process fluid, or flow through the furnace. The fluid ordinarily comes to the furnace from other sources that have already raised its temperature to some extent. It leaves the furnace at a higher temperature.

The furnace tubes are made of metal. The metal tubes absorb heat by both radiation and convection. The heat passes through the tube walls by conduction. The tube ends must be joined together to allow for continuous flow through the tubes.

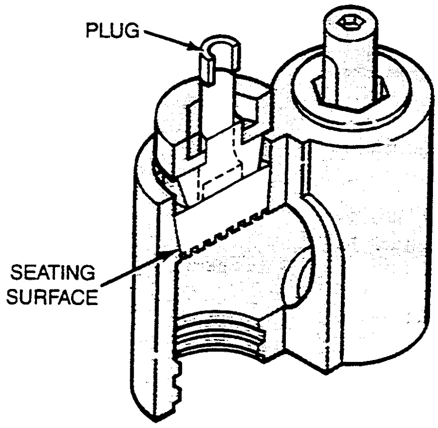
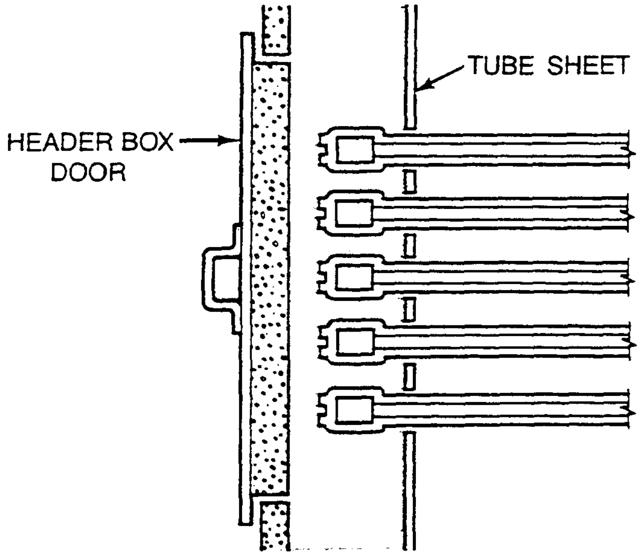


Figure 3.1 Rolled Headers

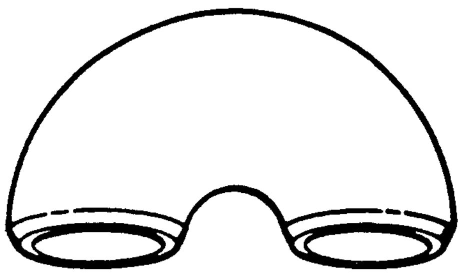
One way to join the tube ends is with a rolled header (Figure 3.1). The headers are attached to the tube by expanding the tube ends against the header openings.

To provide access for tube inspection and mechanical cleaning, the headers have removable plugs. The diagram below shows how the headers are mounted in the furnace.



You can see that the headers are enclosed in what is called the header box. The header box helps to cut down on heat losses from the headers and tube ends. Sometimes leaks occur in the headers or the tubes. When the leaking fluid contacts hot surfaces in the furnace, it can ignite and burn. The header box serves to isolate and contain any leaks or fires. Most header boxes are equipped with a steam line for smothering fires.

This drawing shows another way that the tube ends can be joined together. This design is called a return bend. Return bends are **normally used where heat levels are low and no coking or corrosion problems are likely, or expected**. Since there are no removable plugs, return bends are less likely to leak than rolled headers.



RETURN BEND

Draft Systems

Draft is the buoyant energy created by hot gases as they rise through the furnace. Hot air rises because it is less dense than cool air. Figure 3.8 shows four different types of draft systems.

A. Natural Draft:
Draft is maintained by the natural, upward flow of hot gases. Cool air is drawn in at the burners to replace the flue gases leaving the stack. The draft is controlled by adjusting the position of the damper in the stack. The other types of furnaces rely on fans to assist in maintaining a draft.

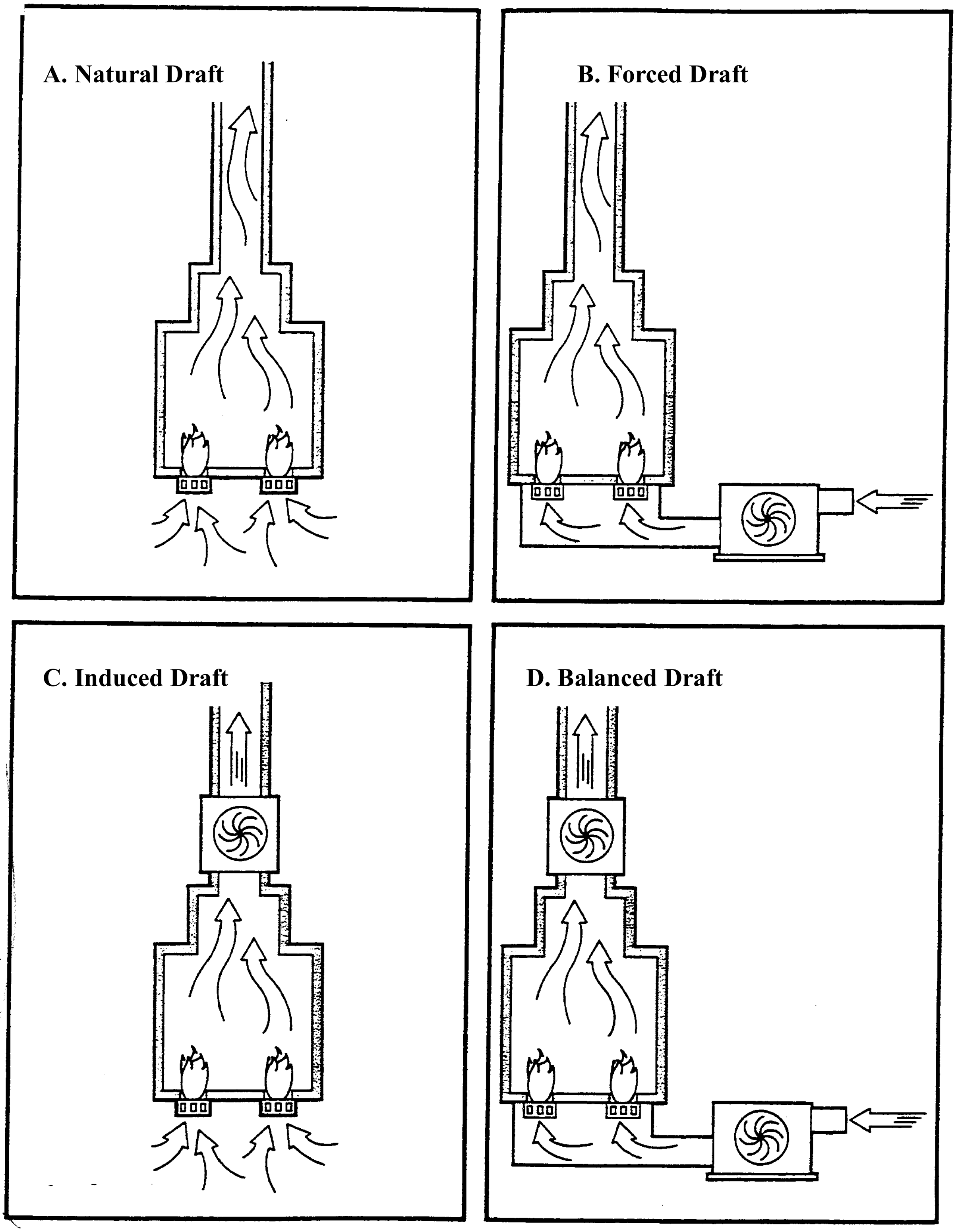
B. Forced Draft:
The fan supplies combustion air to the burners. Forced draft permits steady control of the air at the burners.

C. Induced Draft:
Is a draft produced by discharging the flue gas out of the furnace with a fan located between the convection section and the stack.

D. Balanced Draft:
The furnace uses two fans. One fan supplies air to the burners while the other discharges flue gas from the furnace. The use of two fans allows greater control over the factors that affect complete and efficient combustion.

As the flue gases move up through the furnace and around the tube banks, they loose energy due to friction. The draft must supply enough energy to overcome this friction and maintain the flow of the flue gases. When this flow is adequate, safe and efficient firing conditions will be maintained in the furnace. Fuel and maintenance costs are increased by too much or too little draft.

Figure 3.2 Draft Systems



Air Preheaters

An air preheater is a device which uses some of the heat in the flue gas to raise the temperature of the air supply to the burners. The higher air supply temperature means that less heat is absorbed by the air inside the furnace. By recovering heat that would otherwise be lost out the stack, an air preheater saves energy, or money.

There are several different types of air preheaters.

A. Recuperative Preheater

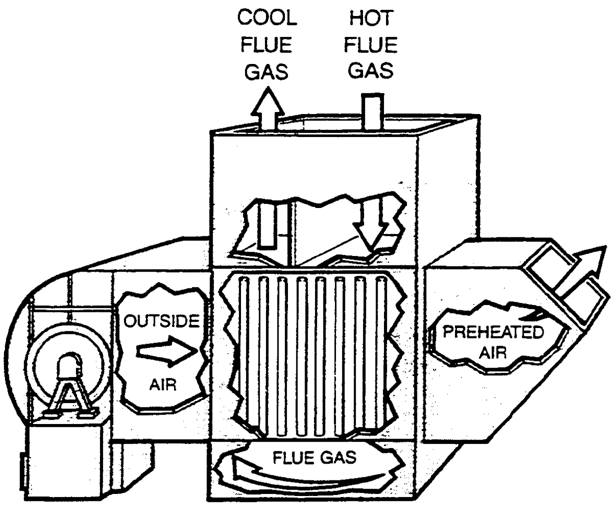


Figure 3.9 Recuperative Preheater

In a recuperative preheater (Figure 3.9), hot flue gases are circulated through a series of tubes. The outside air is heated as it passes over the tubes. The preheated air is then sent to the burners and the cooled flue gas is returned to the stack. Furnaces with air preheaters are normally equipped with fans which move the air and flue gases through the heat exchange equipment.

B. Regenerative Preheater

Figure 3.10 shows a regenerative air preheater.

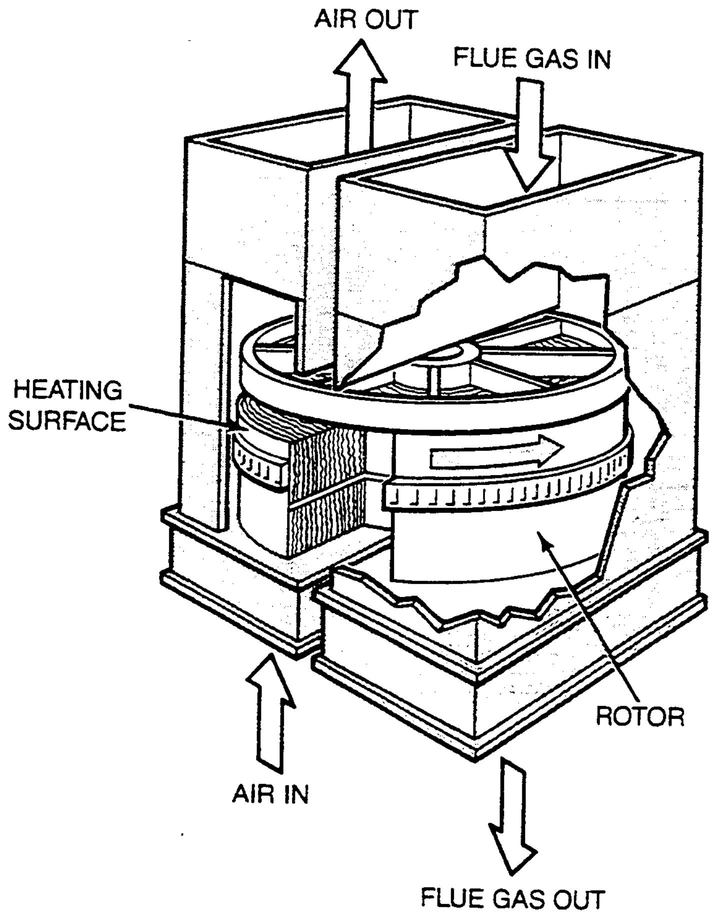


Figure 3.10 Regenerative Preheater

This type of preheater contains a rotor across the streams of air and flue gas. The rotor contains many tiny metal blades or heating elements that are used to absorb and release heat. As the flue gas passes through the preheater, some of its heat is absorbed by the heating elements. The heating elements then rotate into the incoming air stream and release heat to the incoming air. The heated air is sent to the burners and the cooled flue gas returns to the stack. If the flue gases are allowed to get too cool, water vapor condenses and can form corrosive acids. To protect the metal stack and heat recovery equipment, you must maintain a stack temperature above the temperature at which corrosive vapors condense.

C. Heat Medium Air Preheater

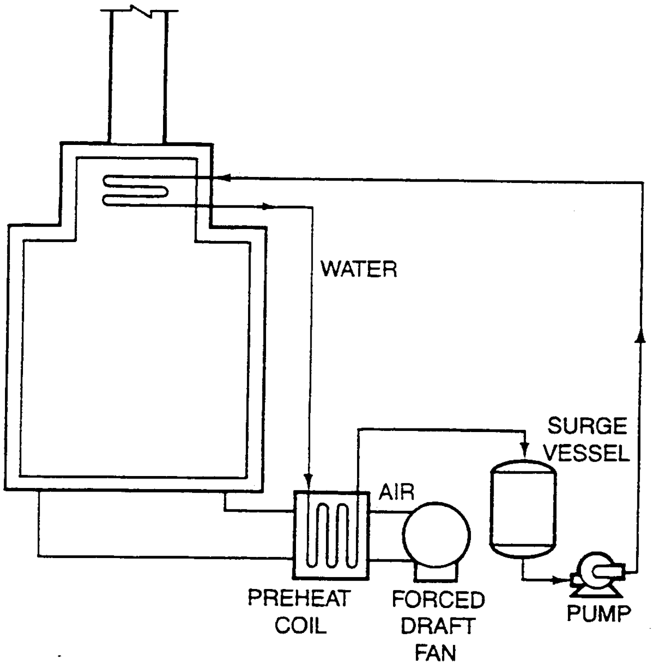


Figure 3.11 Heat Medium Air Preheater

This types of preheater (Figure 3.11) uses an intermediate fluid (water) to transfer heat from the flue gas to the incoming combustion air. The water is heated by pumping it through tubes in the convection section of the furnace. The heated water is then circulated through tubes in the preheat coil. Air for combustion is passed over these tubes and absorbs heat from the hot water. The water is then pumped back through the convection section for reheating.

In this type of system there is a continuous circulation and transfer of heat between the water, the flue gas, and air.

D. Process Fluid Air Preheater.

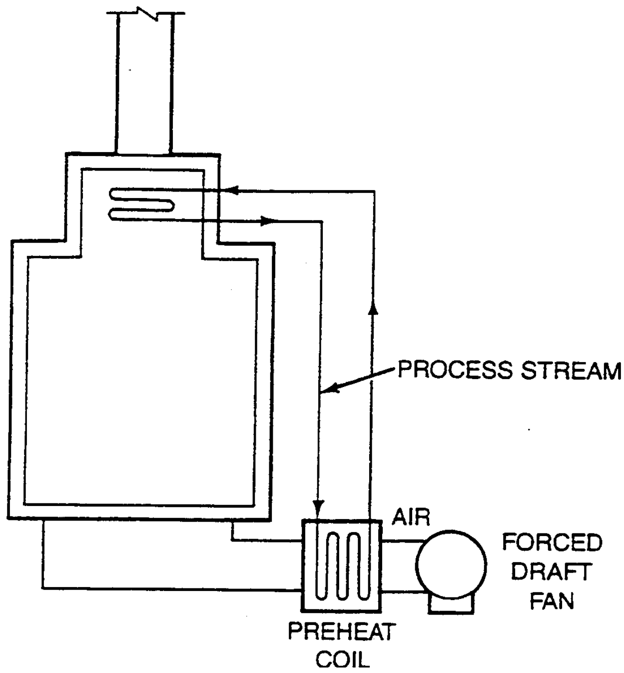


Figure 3.12 Process Fluid Air Preheater

In this system (Figure 3.12), a portion of the heated process fluid is diverted through the preheat coil. The combustion air absorbs heat from the fluid as it passes over the coil tubes. The cooled process fluid is then returned to the convection section where it is reheated and rejoined with the main process stream.

Burners

Combustion in a fired heater occurs at the burners. The burners are designed to mix fuel with air in a manner that will maintain stable and continuous burning, or combustion. Furnaces may burn fuel gas, fuel oil, or both oil and gas at the same time.

A fuel gas burner is designed to mix the gas evenly with air. The proper mixture is needed to ensure stable combustion.

A fuel oil burner breaks the liquid oil into a fine mist and mixes it evenly with a large quantity of air. Steam or air pressure is used to break the liquid oil into a fine mist. Different burner designs have been worked out to produce the proper mixture for stable combustion.

A. Gas-Fired Burners

A simple fuel gas burner is the **raw gas** burner. (Figure 3.13)

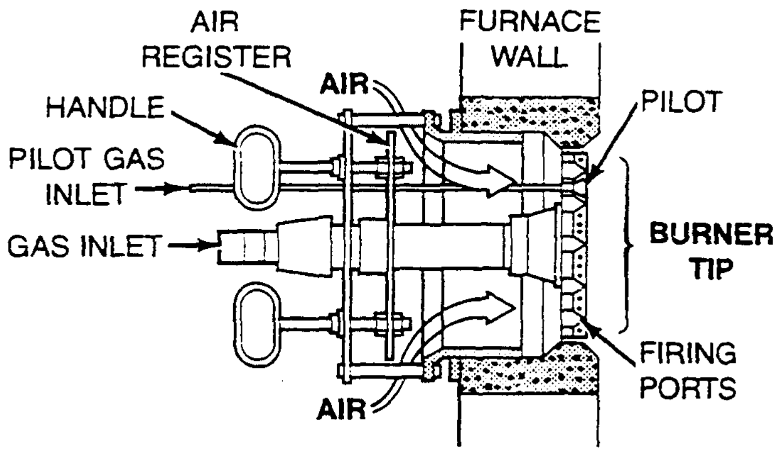


Figure 3.13 Raw Gas Burners

The gas is piped into the burner through a gas inlet pipe. Air is let into the burner through an air register. The air register can be opened or closed by moving it back and forth with the handles.

In a raw gas burner, the air and gas are mixed together and burn at the firing ports in the burner tip. The gas is channeled through the firing ports to break it down into finer streams which ensure thorough mixing of air and gas. This burner is also equipped with a pilot which serves as a source of ignition for the burner. During start-up operations, the pilot is lit before the main burner.

Figure 3.14 shows a premix gas burner. With this design, air enters the burner at two places. The primary air is drawn into a venture mixing chamber. A jet of incoming gas creates a suction which pulls air into the mixing chamber. This air is thoroughly mixed with the gas before it reaches the burner tip. The rest of the air needed for combustion enters through the secondary air register.

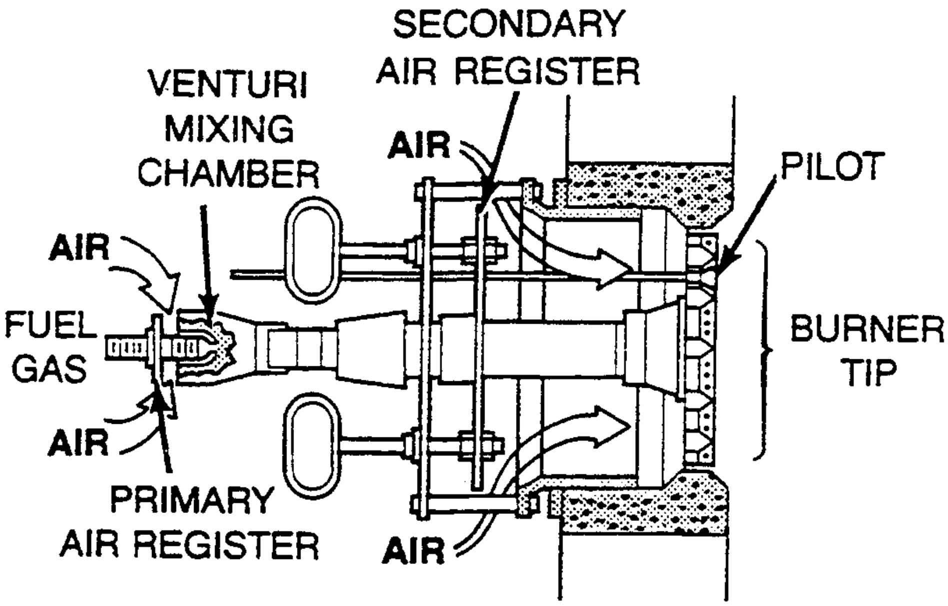


Figure 3.14 Premix Gas Burners

Combustion occurs at the burner tip. The primary and secondary air registers are adjustable so that the operator can control the amount of air entering the burner. An advantage of the premix burner is that it allows for better control and a more thorough mixing of gas and air.

The function of the pilot is to serve as a source of ignition for the main burner.

B. Oil-Fired Burners

When oil is used as fuel, it must be changed from a liquid to a fine mist by atomization before being mixed with air.

Figure 3.15 shows a typical oil burner. It uses steam to break up the oil. The oil and steam are carried through the burner in the oil gun. The steam meets the oil with great force at the throat and atomizes it into a fine mist. As the oil is forced out of the throat through the tip, the particles of oil mix with air and burn. For complete combustion to occur, the fuel oil must be thoroughly atomized by the steam.

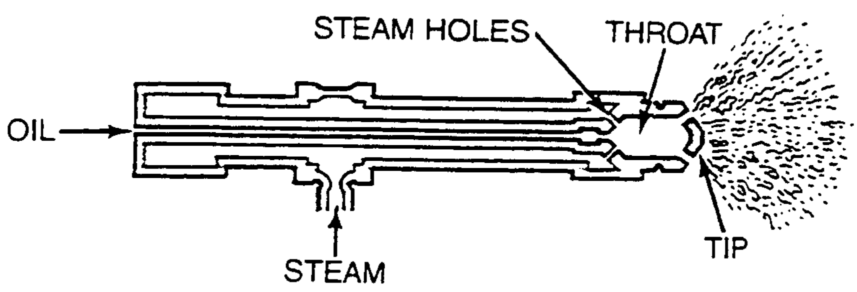


Figure 3.15 Oil Gun

C. Combination Burners

Combination burners can burn fuel oil, fuel gas, or both at the same time. Figure 3.16 shows a combination burner.

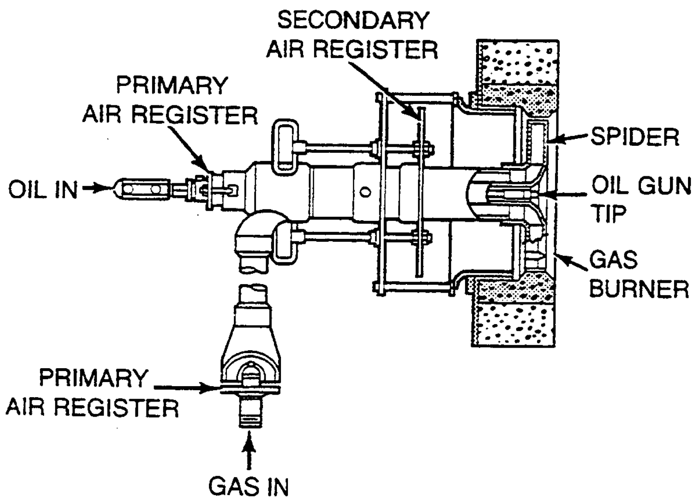


Figure 3.16 Combination Burners

You can see there is a separate burner for oil and another for gas. The gas burner has a primary air register so it operates like a premix burner. The oil gun is set in a tube down the center, or middle of the burner. The oil gun can be moved back and forth inside the tube so it's called a retractable oil gun. When oil is being burned, the tip of the oil gun is set into the burner. When the fuel is gas alone, the oil gun is retracted, or taken out of the combustion zone.

In operating a fired heater, the objective is to ensure complete combustion of the fuel while minimizing excess air, or oxygen. The air that is mixed with the fuel before it reaches the combustion zone enters through the primary air register. The rest of the air needed for complete combustion enters through the secondary air register. The amount of air entering the burners is controlled by adjusting the air registers.

D. Staged Fuel Burner

Nitrogen oxides (NO_X) are pollutants that are formed during high temperature combustion. Since the release of these pollutants is strictly regulated, it is necessary to limit the amount of NO_X produced by the burners, or furnace.

NO_X production can be reduced by using a staged fuel burner (Figure 3.17) with this type of burner, combustion occurs in two different stages, or zones. Staging out the combustion process allows us to reduce the high flame temperatures which produce NO_X.

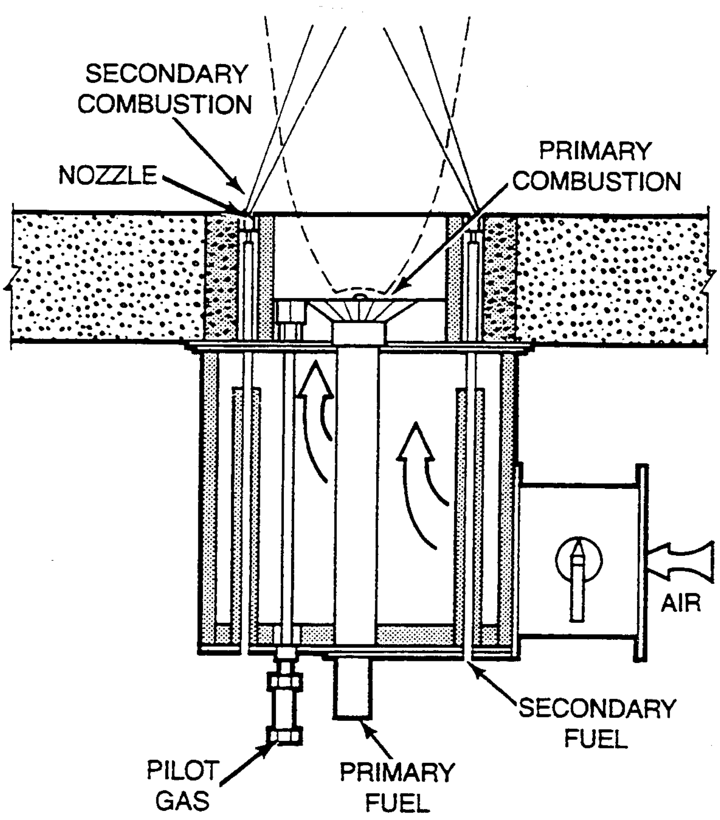


Figure 3.17 Staged Fuel Burners

In the primary stage of combustion, a high air to fuel ratio is intentionally maintained so that the mixture in the burner is initially oxygen rich. This excess oxygen reduces the flame temperature which inhibits the production of NO_X. In the secondary combustion zone, high pressure fuel is injected through a series of nozzles positioned around the burner. Because of its high speed, the fuel for secondary combustion rapidly combines with the combustion products from the first or primary stage. This reduces the temperature in the secondary **zone.** The lower temperature in the secondary combustion zone further restricts the production of NO_X.

Fuel Systems

The fuel for a fired heater must be stored, processed, and distributed to the burners. This is the job of the fuel system.

The fuel system must supply a steady, clean supply of combustible fuel. The fuel being supplied may be oil or gas.

A. Fuel Gas System

Figure 3.18 shows a typical fuel gas system.

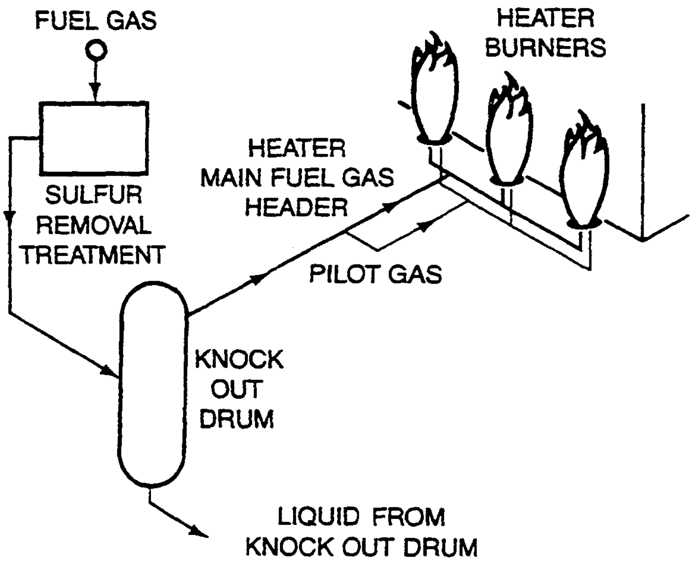


Figure 3.18 Typical Fuel Gas Systems

The supply gas is first treated to remove sulfur. This is done in many plants to keep the sulfur dioxide emissions below the required standard, or level. Next, the fuel gas passes through a knockout drum. The knockout drum removes any liquid from the gas. Finally the gas is sent to the furnace pilots and the burners.

Typical Problems

Some typical problems with fuel gas systems are high and low pressure variations, liquid in the gas, and changes in fuel composition.

Pressure Variation

To some extent, you can compensate for pressure variations by adjusting the flow of fuel.

Liquid in the Gas

Liquid in the gas can usually be controlled by adjusting the operation of the knockout drum.

Change in Fuel Gas Composition

Fuel composition changes can often be identified with a fuel gas analyzer. If the composition changes, you will need to adjust the fuel flow rate and the air to the burners.

B. Fuel Oil System

Figure 3.19 shows a fuel oil system. The fuel oil starts from a storage tank. Pumps are used to move, or circulate the oil throughout the system. If a pump failed, there would be no pressure, or energy to supply fuel to the burners. For this reason, most fuel oil systems are equipped with a backup pump that can maintain circulation.

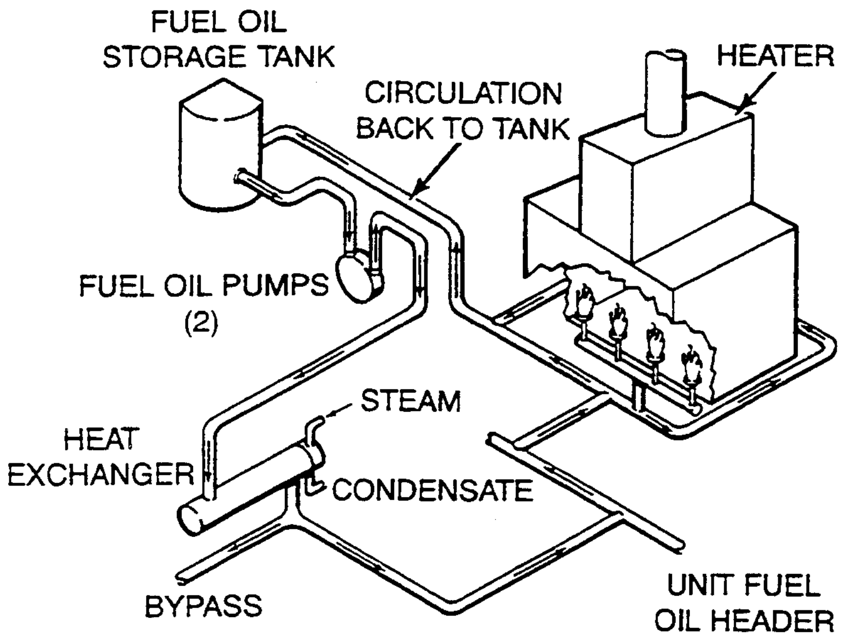


Figure 3.19 Typical Fuel Oil Systems

Before going to the burners, the fuel oil is pumped through a heat exchanger. The heat exchanger warms up the oil which thins it out and increases its ability to flow. The warmer oil is also easier to atomize which makes it easier to burn.

The fuel lines are often heated when a heavy fuel oil must be circulated through the system. The heat helps to keep the heavy oil flowing.

PERFORMANCE MONITORING

The operation of a fired heater is a complex process. There are many different variables on both the combustion and process side of the furnace that must be monitored and controlled.

An operator needs to know what these variables are and how they affect one another. For example, when you increase the process flow, more fuel must be burned to maintain the desired outlet temperature. And when you burn more fuel, more air, or oxygen is needed to complete the combustion process. To bring in more oxygen, the air registers have to be opened. And after you open the air registers, it may be necessary to adjust the stack damper to maintain the correct draft.

An operator who understands how changes in one furnace variable affect other furnace variables is in a much better position to monitor, or control the operation. And, better control usually means safer and more efficient furnace operations.

Excess Oxygen (O_2)

The key variable to control for safe and efficient operations is the amount of air, or oxygen in the furnace. Excess oxygen is the amount of oxygen admitted in addition to the oxygen needed for complete combustion. While some excess oxygen is necessary to operate the furnace safely, too much excess oxygen wastes fuel, energy, or heat.

The oxygen for combustion is supplied by air. The chemical makeup of air is approximately 21% oxygen and 79% nitrogen. This means that the percentage of excess air and excess oxygen in the furnace are different.

Figure 3.20 compares excess oxygen with excess air. At any point along the chart the percentage of excess oxygen is much less than the percentage of excess air. Most fired heaters are operated with excess oxygen between one and five percent in the flue gas. This figures out to be approximately five to thirty percent excess air.

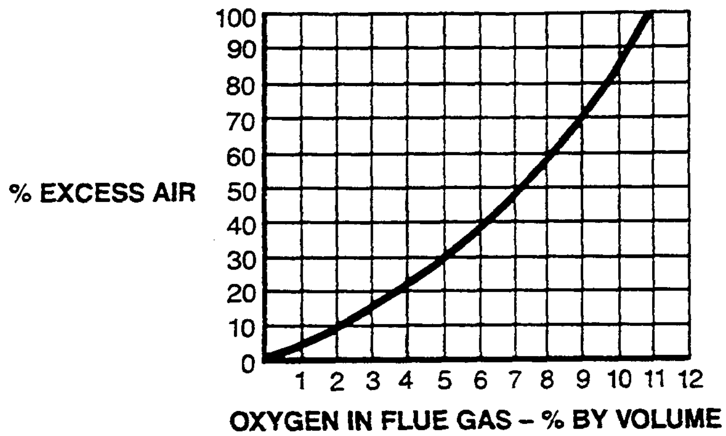


Figure 3.20 Excess Oxygen with Excess Air

The major component in this excess air is nitrogen. When more air enters the furnace than is needed, the excess oxygen and nitrogen absorb heat that would otherwise be transferred to the process flow in the tubes. The heated air becomes part of the flue gas that is discharged out the stack.

We can monitor excess oxygen by analyzing a sample of the flue gas. This is done with an instrument called an oxygen analyzer. When the excess oxygen is above 5%, fuel is probably being wasted. A reading below 1% indicates that you are nearing a point where not enough oxygen will be available to support complete combustion.

Some analyzers can measure the amount of carbon monoxide in the flue gas. Large amounts of carbon monoxide are an indication of incomplete combustion. Other analyzers can detect carbon dioxide. Carbon dioxide is a product of complete combustion.

The amount of air entering the furnace is controlled by adjusting the air registers. The registers at each burner should be adjusted so that there is just enough oxygen, or air to assure complete combustion.

On most burners, it is desirable to use as much primary air as possible and minimize secondary air. This is because the primary air is thoroughly mixed with the fuel before combustion. And, better mixing means better combustion.

Air can also enter the furnace through open peep doors or open air registers on out-of-service burners. This air does not mix with the fuel so it does not help with combustion. Instead, it absorbs heat that should be transferred to the process flow.

The flue gas is normally analyzed in both the radiant and convection sections of the furnace. High excess oxygen reading in the radiant section usually means that too much air is entering through the registers. If a high reading only occurs in the convection section, air is probably leaking into this part of the furnace. Once the air registers are adjusted for proper combustion, the damper should be adjusted for proper draft. In a large furnace with several burners, each section of the furnace should be checked for excess oxygen before adjusting the stack damper. If the excess oxygen in each section of the furnace is not the same, one group of burners may be starved while another has too much oxygen. Excess oxygen can be made equal for all sections of the furnace by adjusting the air registers on each burner and then analyzing the flue gas for that section. If the flue gas is not analyzed section by section, it is possible to show the right amount of air at the stack while some burners are starved for air.

Draft

Draft is negative air pressure generated by the buoyancy of hot gases inside the furnaces. The pressure inside the furnace is negative because the hot gases are less dense than the outside air. These hot gases weigh less than the cooler air so they are buoyant inside the furnace. This buoyancy causes the hot gases to rise upward out of the stack, creating a slight vacuum inside the furnace. The vacuum causes the outside air to flow, or draft the air registers.

The pressure in the atmosphere is 14.7 psi. A negative pressure is any pressure below 14.7 psi. The pressure inside the furnace is maintained just slightly below 14.7psi. This is called a negative pressure. The difference between the outside pressure and this negative pressure is what creates the draft.

Figure 3.21 shows the draft measurements for a typical fired heater. Draft is usually measured in three places: at the firebox floor, below the convection section, and below the stack.

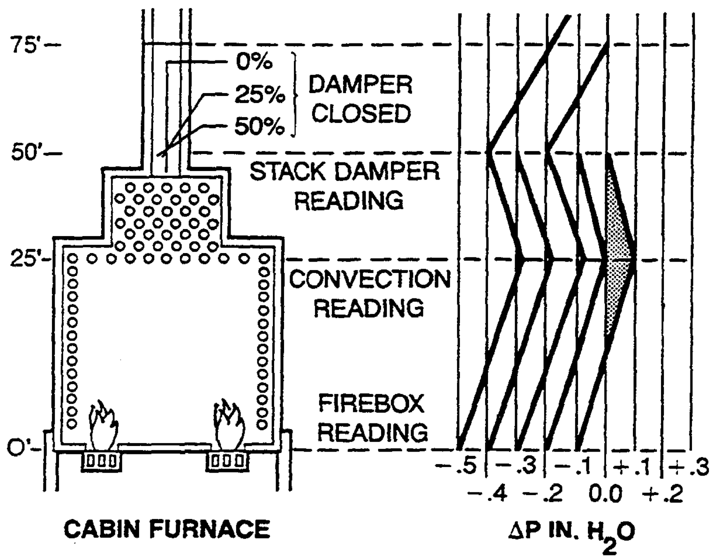


Figure 3.21 Draft Measurements for a Typical Fired Heater

The most important draft reading is below the convection section because the negative pressure is smallest here. The small negative pressure is due to the tubes in the convection section which obstruct the flow of the upward moving gases. This resistance to flow can cause the pressure in the convection section to shift from slightly negative to slightly positive. When the pressure shifts positive, there is a loss of draft.

With no draft, heat builds up just under the furnace arch and roof which can damage the structure of the furnace. A loss of draft also means that no air is pulled into the furnace so the burners will eventually go out.

The furnace draft is usually controlled by positioning a damper in the stack. Opening the damper allows more flue gas to flow out the stack which, in turn, increases the draft throughout the entire furnace.

The increase in draft is measured as an increase in negative pressure. When the damper is closed, the draft decreases. This is measured as a decrease in negative pressure.

It's important to maintain the correct furnace draft. Too little draft can damage the metal structure and snuff out the burners, or flames. Too much draft can pull excessive amounts of air into the furnace which wastes fuel, or energy.

Product Outlet Temperature

The product outlet temperature is the temperature of the process fluid as it leaves the furnace. The product outlet temperature is measured after the passes are rejoined. The desired temperature is maintained by adjusting the flow of fuel to the burners.

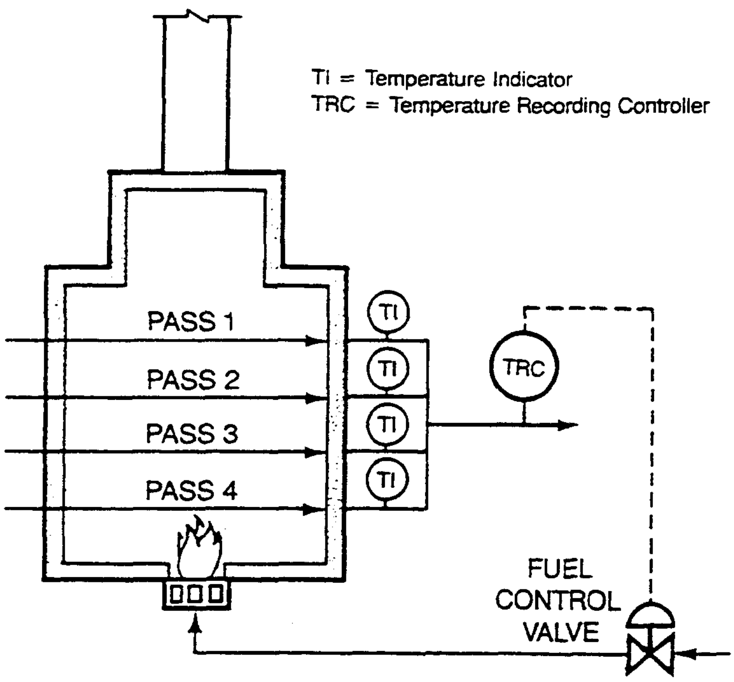


Figure 3.22 Typical Product Outlet Temperature Control

A temperature indicator is used to monitor the temperature of each of the passes, or coils. If the pass flows are equal and the furnace is firing evenly, the pass temperatures should be essentially the same. You should avoid overheating any of the passes because this increases the formation of coke. The flows to the passes can usually be adjusted so that each one is heated to nearly the same temperature.

Process Flow Rates

The process flow rates tell you how much feed is being heated over a given period of time (Figure 3.23). Each of the passes is equipped with a flow controller that regulates the position of a valve. For balanced flow through the passes, each of these valves should be positioned equally. Equal valve positions are attained by setting the controllers for equal flows. If it becomes necessary to change the total flow through the furnace, each controller must be readjusted to maintain equal pass flows.

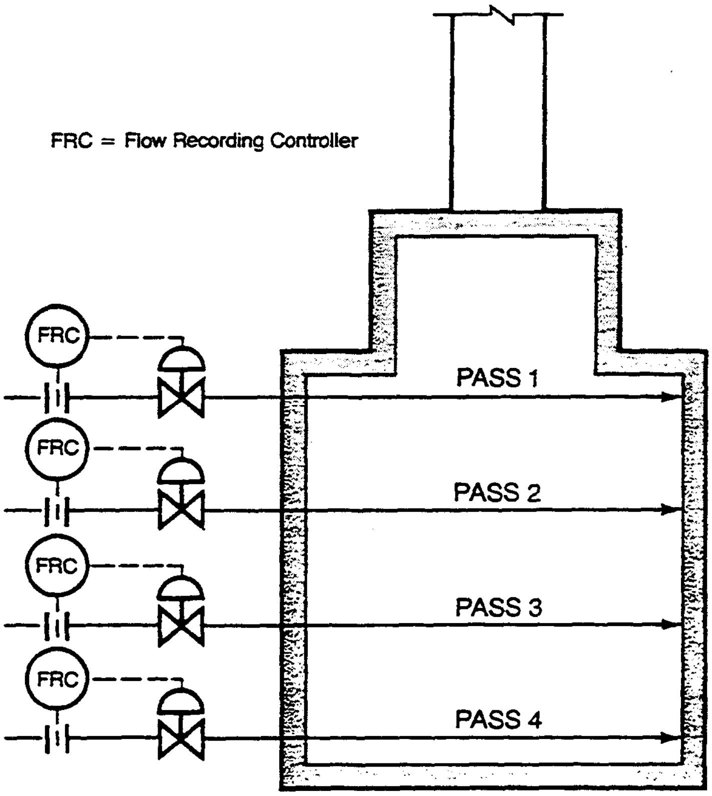


Figure 3.23 A Typical Process Flow Rates Control

Some furnaces are equipped with ratio or bias flow controllers (Figure 3.24) that automatically keep the passes balanced when there is a change in the process load. For example, if the feed to a furnace increases by 800 barrels per day, a ratio flow controller will automatically increase each pass flow by 200 bbl /day. With a ratio flow controller, the operator does not have to adjust individual pass flows when there is a process load change.

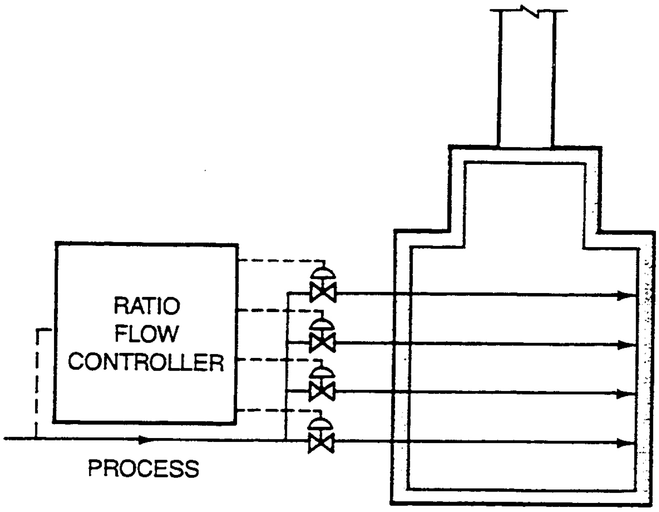


Figure 3.24 Ratio (Bias) Flow Controllers

Sometimes an uneven heat distribution in the furnace will cause one of the passes to overheat even though the pass flows are equal. In this situation, you can intentionally increase the flow through the hot pass to carry away some of the heat. But normally, you want to keep the passes balanced.

Fuel Flow

The flow of fuel to the burners is usually controlled by the product outlet temperature (Figure 3.22). The product outlet temperature is monitored with a temperature indicating controller. If the outlet temperature falls below the desired range, the controller signals the fuel control valve to open. This allows more fuel to flow to the burners which raises the product outlet temperature. If the outlet temperature rises above the desired range, the controller decreases the flow of fuel.

When the amount of fuel to the burners changes significantly, the supply of air, or oxygen must also be adjusted to assure safe and efficient combustion. If the fuel to the burners increases, the supply of air should be increased. To make sure there is enough oxygen to support combustion, the air supply should be increased before the fuel increase. If you increase the fuel first, there may not be enough oxygen present to burn the additional fuel. When the fuel to the burners is decreased, you need to decrease the air supply. To maintain enough oxygen for combustion, the air supply should be decreased after the fuel decrease.

Remember

- When you increase fuel, you should increase the air first.
- And when you decrease fuel, you decrease the fuel first.

Some furnaces are equipped with automatic control systems called cross-limiting or lead-lag controllers. These systems automatically adjust the air registers when there is a fuel flow change to keep the right amount of air, or oxygen in the furnace. If the furnace is not equipped with a cross-limiting controller, the operator must make the adjustment.

Stack Temperature

Stack temperature is the temperature of the flue gas as it leaves the furnace. This temperature is a measure of how much heat is being lost from the furnace. A high stack temperature may be an indication that the furnace is over firing. When, the furnace is over firing, BTU's are being wasted out the stack.

A sudden increase in the stack temperature usually indicates a problem in the furnace such as a leaking tube. Leaking tube results in uncontrolled combustion inside the furnace, often calling for an immediate shutdown.

Header Boxes

A header box is an enclosure for the tube-end fittings outside the main furnace casing. Smoke coming from a header box may indicate a leak and fire. Sometimes the flames and smoke from a header box fire are sucked into the furnace. When this happens, the leak may be detected by looking inside the furnace.

A smoky stack or an unusual rise in the stack temperature is other common symptoms of a header box fire. If you notice these symptoms, you need to locate the leaking header and extinguish the fire. The header boxes are usually equipped with smothering steam connections. These allow you to extinguish fires by adding steam to the header box. You should never open a leaking header box while the furnace is operating. This could result in a flash fire and injury, or burns to yourself or your co-workers.

Pilots

To prevent gas from accumulating inside the furnace, the pilots should be lit at all times while the burners are firing. The pilots can be visually checked from the outside of the furnace. You should do this on a regular or routine basis. If a pilot is not burning, it should be checked out and repaired, or relit. The problem is often caused by plugging in the fuel supply lines.

Burners/Flame Patterns

You can determine if the burners are firing properly by visually checking the burner flame patterns. The flames should never be allowed to touch or ***impinge*** on the tubes because this will overheat, or damage them. We call this flame impingement. Flame impingement causes coking and if not corrected can eventually rupture a tube.

The Following lists the normal and abnormal flame patterns for oil and gas burners.

Oil Burners

1. Clean yellow flame with no smoke	- Proper flame for oil burner.
2. Long smokey flame	- Insufficient combustion air, or insufficient atomizing steam.
3. Reddish dusty flame with smoke over part of flame	- Insufficient oxygen for complete combustion.
4. Dazzling white short flame	- Too much excess oxygen or too much atomizing steam.
5. Thin fluttery oil flame	- Too much atomizing steam, insufficient oil flow or low fuel oil pressure.
6. Sparks in flame	- Dirty oil burner tip, wet steam, solids in fuel, or water in fuel.

Gas Burners

1. Blue compact flame	- Proper flame for gas burner.
2. Long flame	- Too much secondary air and / or not enough primary air
3. Short flame	- Too much primary air and / or not enough secondary air.
4. Blow back of flame into burner	- Low gas pressure or lighter fuel gas such as hydrogen in the fuel
5. Flame lifts off burner	- High gas pressure.

Oil and Gas Burners

1. Uneven flame	- Dirty burner tip.
2. Pulsating flame or puffing or woofing noise	- Loss of draft and insufficient oxygen to correct the situation, adjust the air registers, and the stack damper. May also be caused by burner damage or high fuel pressure

It's important for an operator to monitor and correct abnormal flame patterns because they create an irregular release of heat in the firebox. This, in turn, results in an uneven distribution of heat to the process flow.

FIRED HEATER OPERATION

Furnace Start-Up

Furnace start-up is always a potentially dangerous time. It's a time when equipment that's been sitting idle is put back into operation. This equipment must be checked and monitored prior to and during the start-up to make sure that it's working, or functioning. It's also a time when a source of ignition is introduced into a "cold" furnace.

If fuel vapors have accumulated in the idle furnace, this ignition source can set off an explosion, or fire. To prevent this from happening, we always purge the furnace of vapors before lighting the burners.

Every plant has written start-up procedures that are designed to make furnace start-up as safe as possible. It's important that you follow these procedures and do every step in the correct sequence or order. We will review the main steps in lighting a furnace as a general reference to the procedure. When starting up your furnace, however, you will need to refer to your company's specific procedures.

The following outlines the general procedures for start-up. The five major steps in furnace start-up are:

1. Inspection
2. Purge
3. Light off pilots
4. Light off burners
5. Normal operations

A. Inspection

The furnace and the area around it should always be clean. This means that tools, rags, and other debris in or around the furnace should be removed. Oil spills inside the furnace should be cleaned up because they can release flammable vapors. These vapors make it impossible to purge the furnace of flammables.

Also check the furnace for any obvious physical defects such as refractory damage or burner obstructions. To assure that no fuel is leaking into the furnace, the main fuel header blind should be closed, or installed.

You should also verify that all individual pilot and burner valves are closed.

The stack damper and secondary air registers should be checked for proper operation and then be opened. The damper and registers are opened so that air or steam can freely flow through the furnace during purging.

Finally, you establish circulation of the process flow through the tubes and visually check for any tube leaks. The process stream must be flowing before you light the burners to avoid overheating the tubes.

B. Purging the Furnace

A furnace must always be purged before the burners are lit. Purging removes any flammable vapors which may be present in the furnace.

A furnace can be purged with air or steam depending on its design. Steam is used in natural draft furnaces because the steam provides heat to start a draft.

The draft, in turn, pulls fresh air through the furnace which cleans out any vapors. Air can be used to purge a forced, induced, or balanced draft furnace because these furnace designs can produce an artificial draft with fans.

The purpose of purging is to create a draft and remove all flammable vapors from the furnace.

C. Light off Pilots

Before lighting the pilots, put on your light off safety gear. In the event of a minor flashback, this equipment will protect you from being burned. Next, remove the blind in the pilot fuel header. This allows fuel to flow to the pilots.

The pilots are lit before the burners. Once lit, the pilots serve as a steady source of ignition for the burners. You may use either a hand-held lighting device or an electric ignition device to light the pilots.

The order of lighting pilots is important since you want to distribute a source of ignition throughout the furnace as quickly as possible. This means that you should not light all the pilots on one end of the furnace before moving to the other end. Instead, you should light a pilot on one end of the furnace and then light a pilot on the other end. Next, you light a pilot near the middle. The rest of the pilots are lit in a similar distributed pattern. This is the fastest way to spread a source of ignition throughout the furnace, which reduces the chances of flammable vapors accumulating in the firebox.

D. Light off Burners

When all the pilots are lit and burning stable, you are ready to light the burners. The burners should be lit in the same order as the pilots. First, you remove the blind in the main fuel header. Then slowly open the fuel gas valve to ignite the burner. If the first burner does not light within a few seconds, you should turn off the fuel to prevent vapors from accumulating in the furnace. Some unbumed fuel will already be in the furnace so you may need to repeat the purging operation to clear it out.

As you light the burners, you should maintain a stable fuel gas pressure. This is because the burner flame may flash back or go out if the fuel pressure gets too low.

You will also need to establish the correct draft by adjusting the stack damper. After all the burners are lit and the damper is adjusted for draft, you adjust the air registers for the correct flame pattern. Normally, you will have to adjust the air registers and damper several times to achieve the correct amount of excess oxygen draft.

E. Normal Operations

Once the burners are lit and the furnace operation is stable, you can begin increasing the temperature and flow of the process stream. To avoid heat stressing the equipment, this should be done very gradually. At this time, you will also need to balance the flow through the passes and check that the pass outlet temperatures are equal.

During start-up you will be in manual control, so these adjustments will be made by the operator. When the temperatures and flows get within the control range of the automatic instruments, you can switch over to automatic, or instrument control. Once on automatic, the furnace is considered to be in normal operation.

Furnace Shutdown

Shutdown of a furnace is usually part of the shutdown of an entire unit for inspection and repairs. During a routine shutdown, the process flow rate and the temperature of the furnace are gradually reduced together.

When the minimum firing rate is reached, the burners are shut off. At this time, the stack damper and the air registers should be opened fully so that the furnace can be purged with air or steam. The purge removes any flammable vapor.

The main and pilot fuel headers are blinded and the burners are isolated to prevent any accidental release of fuel into the furnace.

For gradual cooling, the process flow is circulated through the furnace tubes for several hours. When the furnace is cool, the process flow is blocked off and the tubes are purged with steam.

These general procedures don't cover all the details of a furnace shutdown. When you shut down a furnace, you should refer to your company's specific shutdown procedures.

Emergency Shutdown

An emergency shutdown is called for when the furnace operation becomes seriously abnormal. Abnormal conditions in the unit or the furnace may demand the rapid removal of both the process flow and the fuel from the furnace.

In any furnace emergency:

- You must act to protect yourself and your co-workers from injury.
- You must act quickly but cautiously to minimize danger or damage.
- You want to limit, as much as possible, the effect of the emergency, or shutdown on the whole operation of the plant.

To deal effectively with an emergency, you should plan your actions in advance and be ready to carry them out. This requires

- You to study your equipment and the unit operating procedures.
- You should know the maximum allowable temperature for the tubes, firebox, arch and stack.
- You should be ready to stop combustion by removing fuel from the burners.
- You may also need to remove the process flow from the tubes, depending on the emergency and your unit.
- You should know in advance how to reach emergency block and blow down valves.

These emergency controls are located in protected areas where they can be reached with minimum risk.

Emergency Operations

Fuel enters the furnace through the fuel oil and fuel gas lines. You can usually keep fuel out of the firebox by closing the burner valves. In some situations, you may have to go back to the fuel header valves. These valves stop the flow of fuel to all burners.

During normal operations, you don't consider the process flow as a fuel. But if a tube ruptures, this stream enters the firebox and can burn. Since the process stream is under pressure, a tube rupture may dump large amounts of flammables into the firebox. Shutting off the process flow and dumping it from the furnace does not get rid of what is already in the firebox. This fluid is best disposed of by burning it where it is, since the firebox is designed to support the heat of burning. To keep the temperatures from running too high, you need to control the air supply or use snuffing steam.

If the maximum tube and metal temperatures are threatened, trim down on the stack damper. If more air is needed, carefully open the air registers. You can restrict air entering the furnace by closing off on the stack damper. As the damper is closed, air entering the furnace is decreased, combustion is reduced and the heat release is limited.

A continuous large flow of snuffing steam restricts air by pushing it out. A header box fire can usually be snuffed out with steam from the header box steam line. You can put more steam in with a steam lance if the regular snuffing lines do not provide enough steam. In a hot firebox, steam has a cooling effect. So in addition to removing air, steam reduces the furnace temperature

If you lose your feed to the furnace for some reason, there is no flow to carry the heat away. If you can't get the flow started immediately, you need to stop the input of heat by closing the fuel valves. There may still be enough heat retained in the furnace to damage the tubes and other metal structures. If so, block off the furnace and dump the process stream. Then cool the tubes and firebox by purging with steam.

A tube rupture may suddenly admit a large amount of fuel into the firebox. Your actions will depend on how serious the situation is and how well you can control temperatures. If the leak is small, the process flow may be left in the tubes while the unit is circulated down. If burning continues and temperatures are excessive, restrict the input of air by adjusting the stack damper.

The furnace must be isolated and depressured if the rupture is large. Shut off the burner fires. Dump the process flow and cool the tubes with steam. Then purge the firebox with steam.

Improper operation of oil burners can lead to large amounts of oil burning on the floor of the furnace. Correct the burner operation. If temperatures become excessive, restrict the input of air by adjusting the stack damper.

Flammable liquid in the fuel gas line may fill the firebox with uncontrolled flames. Drain the fuel gas knockout drum. If temperatures become excessive, adjust the stack damper to restrict the input of air.

Trouble in the fuel system may cut off the fuel entirely. The burners go out. But there is enough heat left to ignite any fuel with explosive force. Shut off the fuel immediately. Then purge the firebox with steam.

The key to dealing with any furnace emergency is a thorough understanding of the combustion process and equipment limitations. This knowledge allows you to control combustion and minimize equipment damage.

TROUBLESHOOTING

Some furnace problems require a shutdown. Other problems can be corrected if they are detected early. In order to detect problems, you need to know the signs, or symptoms of abnormal operations. And you need to know what these signs and symptoms indicate, or mean. This requires troubleshooting skills on the part of the operator.

Some furnace problems can be detected with instruments in the control room. Other problems require you to physically check, or inspect the furnace. Once you have identified a problem, you need to take action to correct it. The action you take will depend on the severity of the problem. If a minor adjustment will keep the unit running and not compromise safety, you would normally make that adjustment. If there is immediate danger to people or equipment, you would normally shutdown the furnace.

By understanding the operation of the furnace and knowing the limitations of the equipment, you will be able to diagnose the problem and take the appropriate action.

Flame Impingement

Flame impingement occurs when a flame touches equipment inside the furnace, usually a tube. This contact causes overheating which promotes the formation of coke inside the tubes. If the problem is not corrected, the metal will weaken and eventually rupture.

Flame impingement can sometimes be corrected by adjusting the burner. Or, by cutting back the fuel supply. If these adjustments will not correct the problem, it may be necessary to remove the burner for cleaning or repair.

Hot Spots

A hot spot is an area of the furnace that has become overheated. The overheating may be caused by flame impingement or by the improper distribution of heat throughout the furnace. Hot spots are a problem because they form coke deposits inside the tubes and can weaken metal structures. Hot spots can occur anywhere in the furnace, but are most common on the tubes.

Since they often appear as a glowing red spot on the metal, hot spots can sometimes be detected by visual inspection. Another way to detect hot spots is with a special optical thermometer. This device is called a **pyrometer.** The pyrometer can measure the temperature of the metal.

Sometimes hot spots on the tubes can be corrected by increasing the process flow through the hotter pass. The increased flow carries more heat away from the hot tubes. In other situations, it may be necessary to adjust a burner or remove it from service for repair.

Coking and Decoking

Coking is the buildup of deposits inside the tubes. The coke acts as an insulator reducing the heat transfer to the process flow. It also reduces the rate of flow so less heat is carried away by the process stream.

Since less heat is transferred to and carried away by the process flow, there is a build up of heat in the tube metal. This heat build up can often be seen as a hot spot. Another way to detect coking is to monitor the tube skin temperatures. If nothing is done to correct a coking problem, the tube may eventually rupture.

A furnace can be decoked by injecting superheated steam and air through the tubes. This operation bums off the coke and cleans it out of the tubes. Before you can decoke the tubes, the process flow must be removed.

In some furnaces, different sections of the heater can be decoked without interrupting the flows through other sections. With this design, you can continue processing while the tubes are decoked. In other furnaces, all flows must be stopped which means a shutdown of the processing operation.

Soot blowing

The fuel oil burned in furnaces leaves a layer of ash on the outside of the tubes which may reduce heat transfer. To remove these deposits, oil burning furnaces are usually equipped with soot blowers. The soot blower uses steam to remove the ash deposit.

Soot blowing does not interfere with the process or fuel flows so the operation can be performed without a furnace shutdown. Figure 3.25 shows a rotating-element soot blower.

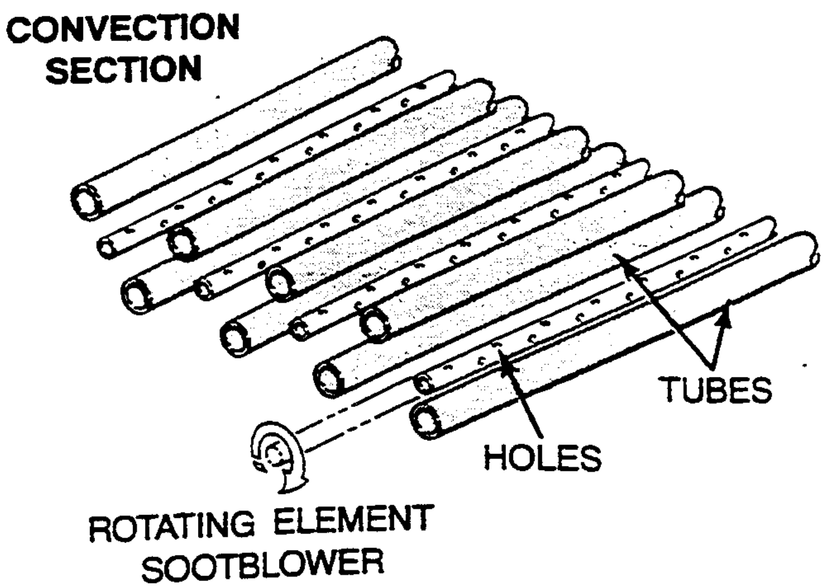


Figure 3.25 Rotating Element Soot blower

The soot blower consists of a number of long tubes that run through the convection section of the furnace. The soot blower tubes are filled with holes for discharging steam. During the soot blowing operation, the tubes rotate for better dispersement of steam. The jets of steam clean the ash off the tubes. When not in operation, the soot blower tubes remain inside the furnace.

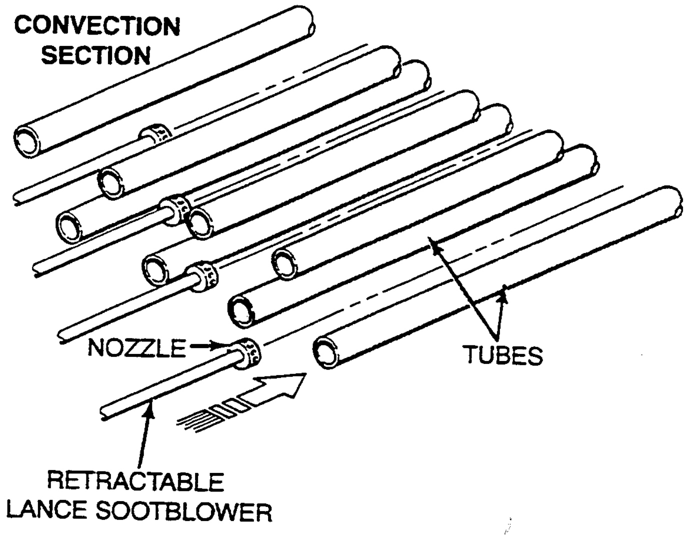


Figure 3.26 Retractable Lance Soot blowers

This soot blower is motor-driven so that it can be moved in and out of the convection section. Since it can move back and forth across the length of the furnace tubes, it is equipped with a cleaning nozzle only at the end.

During the cleaning operation, the soot blower moves between the furnace tubes discharging high pressure steam to remove the ash. When the tubes are clean, the soot blower is retracted, or removed from the furnace. In any type of soot blowing operation, the draft and excess oxygen should be closely monitored to prevent the steam and soot from snuffing out the burner flames. The frequency of soot blowing will depend on the particular furnace and the type of fuel that is being burned. If the ash deposits are allowed to buildup, there will be a decrease in heat transfer efficiency. This may be indicated by an increase in stack temperature.

Feed Pump Failure

The process flow is normally circulated through the furnace with a pump. If this pump fails, the circulation will stop, causing the furnace to overheat

Your first reaction to a pump failure should be to restart the pump, if possible, or switch to a backup pump. By restoring circulation, you can again remove heat from the furnace.

If you can't get the circulation started immediately, you need:

- To cut off the flow of fuel to the burners.
- The damper should be opened fully to allow maximum heat removal out the stack and.
- Steam should be added to the firebox which will have a cooling effect on the furnace.

The loss of the process flow means an emergency furnace shutdown.

Fan Failure

A fan failure in a balanced or induced draft furnace will cause a loss of draft. The draft is needed to supply air to the burners and remove heat out the stack. This means that if the furnace is not equipped with some type of backup system, it will have to be shutdown.

Some furnaces are equipped with natural draft air doors that automatically trip open in the event of a fan failure. The air doors admit enough air, or oxygen to allow continued operation at a reduced load. Other furnaces are equipped with steam rings that discharge steam into the furnace stack if a fan fails. The hot steam rises and creates enough of a draft for continued furnace operation at a reduced load.

Valve Failure

A valve failure means you lose your ability to control flow. A valve can fail in the fully open or closed position or become stuck somewhere in between.

If the valve is controlling the process flow, it will usually fail open or become stuck in one position. In either case, you won't be able to adjust, or change the process flow. If a by-pass valve is available, you may be able to regain control by routing, or sending the flow around the failed valve.

When a valve in the fuel system fails, it usually fails closed as a safety precaution. This will usually cause the automatic safety system to "trip off or stop the flow of fuel to all the burners. If the furnace is tripped off, it will be necessary to purge the firebox to get rid of any uncombusted fuel.

Burner Failure

A burner failure causes the flames, or fire to go out. The most common cause of burner failure is plugging, or fouling in the burner tip. If this happens, it will be necessary to remove the burner for cleaning, or repair. If all the furnace burners go out at the same time, this usually indicates a problem in the fuel system.

Instrument Failure

Instrument failures are sometimes difficult to detect. This is because in any automatic control scheme there are several different elements that can fail. And if one element fails, it can affect the operation of other instruments, or elements.

An operator may need to determine if an instrument reading is correct by comparing it with other readings. This is because a faulty reading can cause the automatic controls to try to correct a situation that doesn't exist. Since you can't depend on the automatic system when one of the components fails, you should put the controls on manual.

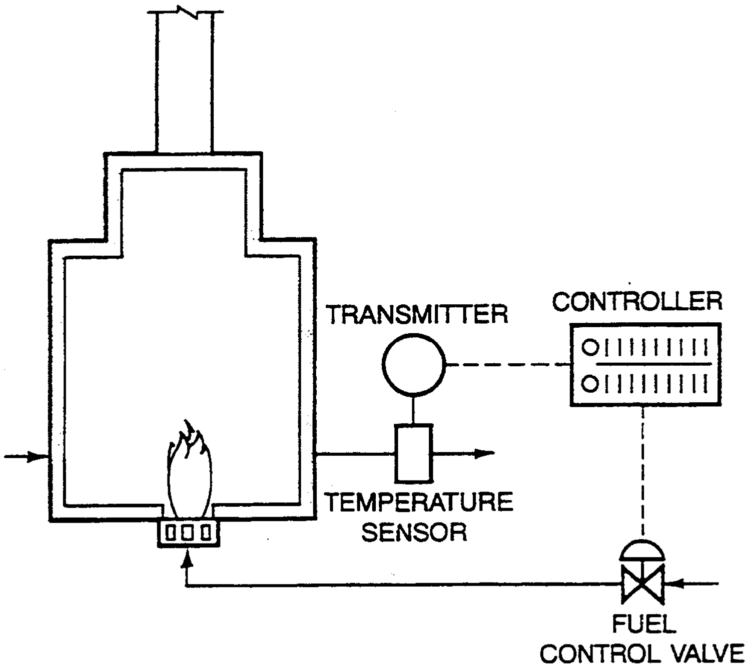


Figure 3.27 Temperature Control Loop

Figure 3.27 shows how instruments work together to control the process outlet temperature. The temperature of the process flow is determined by a sensor, or measuring instrument. This temperature measurement is then sent to a controller by a transmitting device. The controller compares the measurement value to a desired value called set point. If the temperature is not at the desired value, the controller signals the fuel control valve to open or close. This changes the flow of fuel to the burners and brings the process flow temperature back to set point.

Consider what happens if the measuring or transmitting device sends a faulty high temperature reading to the controller. The controller is not able to detect that the high reading is faulty. To compensate for the apparent high temperature, the controller reduces the flow of fuel to the burners. This causes the furnace to under fire which results in a low process outlet temperature.

If you suspected this was happening, you could check the individual pass outlet temperatures and compare them to the combined process outlet temperature. If the pass temperatures are below normal, you know that the measuring or transmitting device has failed. To maintain the correct outlet temperature, you would need to manually control the flow of fuel to the burners.

Flame Out

A very dangerous situation occurs when the burner flames go out and fuel is still entering the burner. This is called a flame out. Flame out results in an accumulation of uncombusted fuel inside the furnace. While automatic safety systems can often prevent a flame out, you should be ready, or prepared to identify and correct the problem.

In many instances, a flame out is a gradual progression that starts with a flame starved for oxygen. The shortage of oxygen results in incomplete combustion and the release of less heat. As the furnace temperature decreases, the automatic controls send more fuel to the burners. But since there is not enough oxygen to bum the fuel, the furnace temperature continues to fall, or drop. The controller, in turn, keeps sending more and more fuel in a futile attempt to raise the temperature. If the process is allowed to continue unchecked, the burner flames will eventually be snuffed out, leaving a supply of raw fuel entering the furnace. If air is then admitted into the hot furnace with raw unburned fuel in it, the mixture may ignite, or explode.

The symptoms of an impending flame out are a drop in the furnace temperature and an increase in fuel usage.

If you notice these symptoms early enough, it may be possible to correct the problem before a flame out occurs:

- First, you would reduce the flow of fuel to the burners.
- And then you would open the stack damper and the air registers to increase the draft and the amount of oxygen, or air entering the furnace.
- However, if you are uncertain how much uncombusted fuel is in the furnace, the safe thing is to shutdown and purges the furnace.

Remember:

The objective of furnace is to burn the required fuel with the minimum quantity of air without overheating of tubes.

Given 50-percent excess air, even a chimpanzee can fire a furnace.

Doing the job with 10-percent excess air requires skill. Without an automatic method of controlling combustion air, 10-percent excess air is a practical minimum.