TOMSK POLYTECHNIC UNIVERSITY

PROFESSIONAL COURSE IN ENGLISH

"PROCESS TECHNOLOGY. EQUIPMENT AND SYSTEMS"

Unit 3. Furnaces

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Outline

1. Heat Transfer
2. Combustion
3. Basic Components of a Furnace
4. Furnace Types
5. Common furnace problems and solutions

Introduction

A furnace (fired heater) is a device used to heat up chemicals or chemical mixtures.

Fired heaters transfer heat generated by the combustion of natural gas, ethane, propane, or fuel oil. Furnaces consist essentially of a battery of pipes or tubes that pass through a firebox. These tubes run along the inside walls and roof of a furnace. The heat released by the burners is transferred through the tubes and into the process fluid. The fluid remains in the furnace just long enough to reach operating conditions before exiting and being pumped to the processing unit.

Furnaces are used in crude processing, cracking, olefins production, and many other processes. Furnaces heat up raw materials so that they can produce products such as gasoline, oil, kerosene, chemicals, plastic, and rubber.

Heat Transfer

The primary means of **heat transfer** in a fired heater are

- radiant heat transfer
- convection

However, heat must pass through the walls by conduction to be absorbed by the flowing fluid.

In the fired furnace, the flame on the burner is the radiant heat source. Radiant heat transfer takes place primarily in the firebox. Tubes located in the firebox are referred to as radiant coils or tubes. The tubes transfer heat to the fluid by conduction. In a fired furnace, radiant heat is emitted from the combustion of natural gas or light oil. As the radiant heat travels from the bottom of the furnace, contacting the tubes or passing in the furnace, and then continues to the top, heat is transferred to the surrounding air. This process initiates the convective heat transfer process that causes the lighter air and hot combustion gases to rise above the radiant heat source. The top of the furnace is referred to as the convection section because most of the heat it receives is by convection.

Combustion

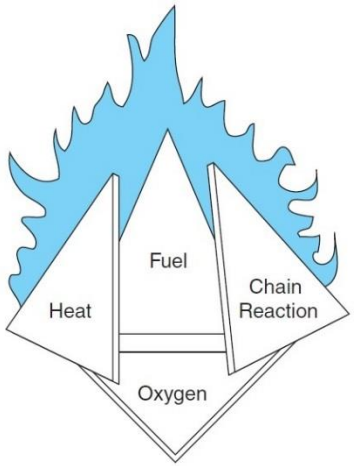
Combustion is a rapid chemical reaction that occurs when the proper amounts of fuel and oxygen (O_2) come into contact with an ignition source and release heat and light. Furnaces use this principle to provide heat.

Complete combustion occurs when reactants are ignited in the correct proportions. Incomplete combustion occurs in a fired furnace when not enough oxygen exists to completely convert all of the fuel to water and carbon dioxide.

Many furnaces use natural gas or methane (CH_4) as fuel for the burners. Methane (CH_4) reacts with O_2 to form carbon dioxide (CO_2) and water (H_2O):

$$\mathbf{CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O}$$

Incomplete combustion may result in the production of carbon monoxide. The chemical processing industry also uses ethane, propane, and light oils for fuel. Figure illustrates the basic components of the fire triangle or fire tetrahedron.



Another common combustion reaction with oxygen is

$$\mathbf{C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O}$$

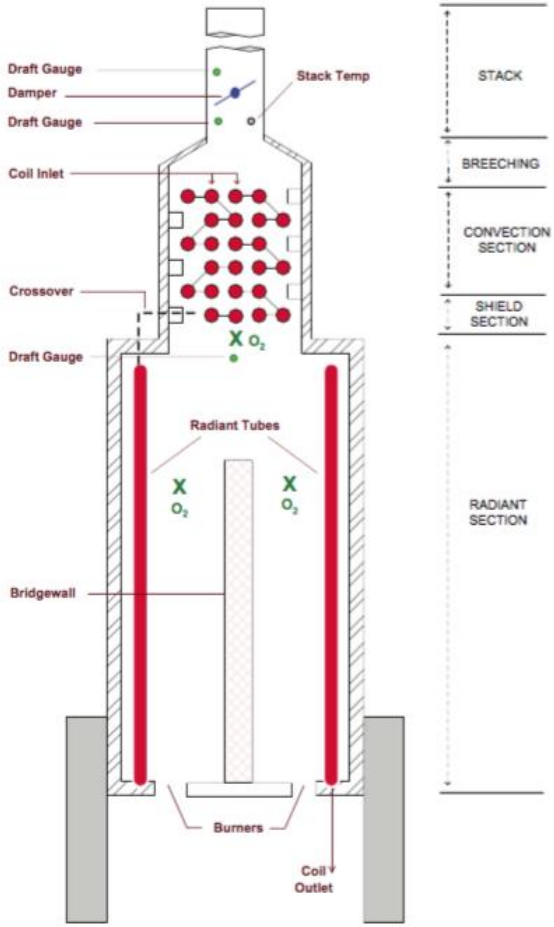
Propane and oxygen form similar products to methane and oxygen.

Basic Components of a Furnace

Fired heaters come in a variety of shapes and sizes. They have different tube arrangements and feed inlets and burn different types of fuels and have different burner designs.

All furnaces do, however, have certain things in common:

- firebox
- radiant tubes or coils
- convection tubes
- stack and damper
- refractory lining
- burners and air registers
- fuel system
- instruments
- induced- or forced-draft fans.



Basic Components of a Furnace

Firebox and Refractory Layer

The section in a furnace that contains the burners and open flames is called the firebox. The firebox is lined with a refractory layer, a brick lining that reflects heat back into the furnace. The refractory brick is classified as firebrick or insulating brick, both of which are specially designed to withstand and reflect heat.

Radiant and Convection Tubes

The tubes located along the walls of the firebox are called the **radiant tubes** or **coils**. Radiant tubes receive direct heat from the burners. These tubes operate at high temperatures and are constructed of high-alloy steels.

Radiant tubes may be mounted parallel or perpendicular to the furnace wall. Radiant heat transfer accounts for 60 to 70% of the total heat energy picked up by the charge in the furnace.

Basic Components of a Furnace

Convection tubes are located in the roof of the furnace and are not in direct contact with burner flames. Hot gases transfer heat through the metal tubes and into the charge. Convection tubes usually are horizontal and are equipped with fins to increase efficiency. Convective heat transfer to the process charge accounts for about 30 to 40% of the total heat energy picked up in the furnace.

This area is often referred to as the convection section. It is best described as the upper area of a furnace in which heat transfer is primarily through convection. Feed is introduced into the furnace through these tubes and exits out the radiant tubes. Tubes in this area are referred to as convection tubes.

Air preheaters are often used to heat air before it enters a furnace at the burners. Air tubes are typically located in the stack or convection section that allow outside air to be brought in by a compressor or blower and gradually warmed up before mixing with fuel at the burner.

Basic Components of a Furnace

Soot blowers are devices found in the convection section of process heaters. Soot blowing is required when the efficiency of the convection section decreases. This can be calculated by looking at the temperature change from the crossover piping and at the convection section discharge. Soot blowers utilize a transfer media such as nitrogen, water, air, or steam to remove deposits from the tubes.

Stack and Damper

Combustion gases leave the furnace through the stack and are dispersed into the atmosphere at a height to ensure against any immediate deleterious effect such as carbon monoxide poisoning. As the hot air rises in the stack, it entrains combustion by-products and carries them out of the stack. This natural draft creates a lower pressure inside the furnace that is essential to good operation. Draft is defined as the difference between atmospheric pressure and the lower pressure inside the fired heater.

A damper in the stack permits adjustment of stack drafts. The damper can be positioned to increase or decrease airflow. Controlling excess oxygen in the furnace is the single most important variable affecting efficiency. For heat transfer in the firebox or radiant section, the greatest efficiency is obtained when maximum furnace temperatures are achieved. Decreasing excess air in the furnace maximizes radiant heat transfer.

Basic Components of a Furnace

Burners

There are several **types of burners:**

- Oil burners
- Premix steam-atomizing burners
- Combination burners
- Low nitrogen oxide (NO_x) burners
- Raw gas burners
- Premix burners

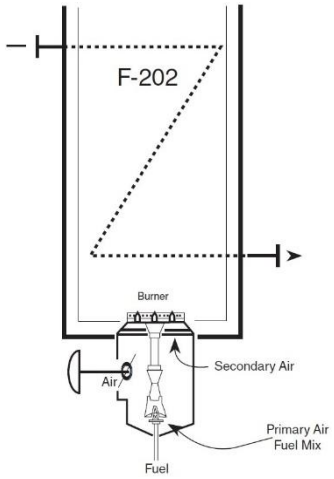


Figure 1. Gas Burner

Burner alarms are located on each burner and will immediately alert a technician when a burner goes out or is functioning outside normal parameters.

Fuel System

Located under or on the side of the furnace is a complex network of lines that provides fuel gas and air to the burners. The fuel is stored in a tank located a safe distance from the furnace. In an oil-burning system, atomizing steam and an oil preheating system are added to the network of pipes.

Furnace Types

Furnaces can be classified by several features

- type of draft
- number of fireboxes
- number of passes
- volume occupied by combustion gases
- shape

Draft

Furnace draft can be

- natural
- forced
- induced
- balanced

Furnace Types

In a **natural-draft furnace**, buoyancy forces induce draft as the hot air rises through the stack and creates a negative pressure inside the firebox. This pressure is lower than normal atmospheric pressure.

Forced-draft furnaces use a fan to push fresh air to burners for combustion. Forced draft is used in furnaces that preheat the combustion air to reduce fuel requirements.

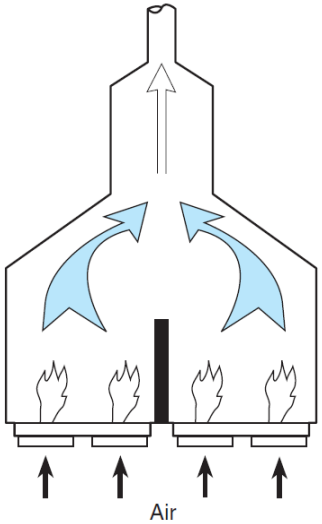


Figure 2. Natural-Draft Furnace

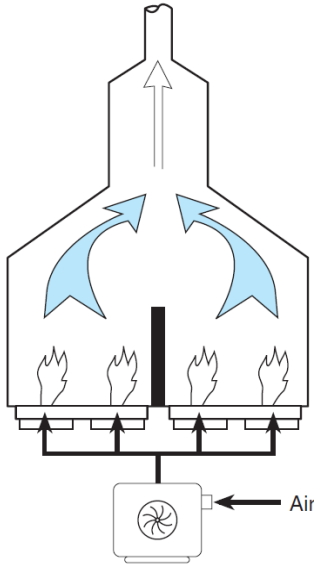


Figure 3. Forced-Draft Furnace

Furnace Types

In an **induced-draft furnace**, a fan located below the stack pulls air up through the firebox and out the stack.

Balanced-draft furnaces require two fans: one inducing flow out the stack and one providing positive pressure to the burners.

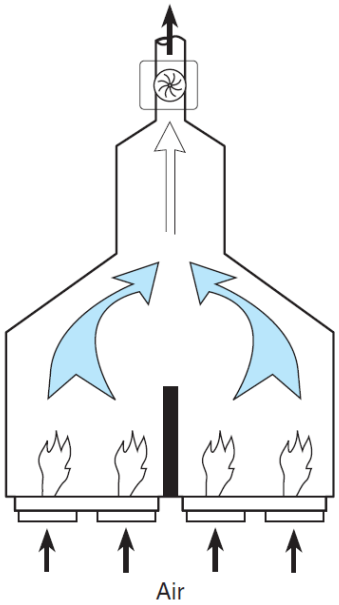


Figure 4. Natural-Draft Furnace

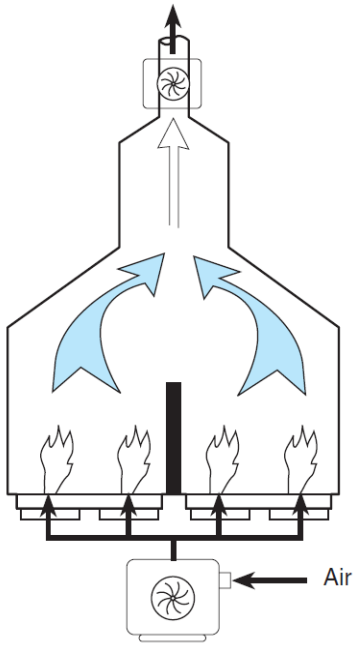


Figure 5. Forced-Draft Furnace

Furnace Types

Number of Fireboxes

A furnace can have one or two fireboxes. A double-firebox furnace has a center wall that divides two combustion chambers. Hot gases leaving the two chambers meet in a common convection section.

Number of Passes

The charge – that is, flow – entering a furnace is often split into two or more flows called passes. These passes usually are referred to as the east, west, north, or south pass. As the names suggest, each goes to a specific section of the furnace before they all enter a common discharge header.

Furnace Types

Direct Fired and Indirect Fired

Furnaces are classified as

- direct fired
- indirect fired

The class is based on the volume occupied by combustion gases. In **direct-fired furnaces**, the combustion gases typically fill the interior. Direct-fired furnaces heat process streams such as heavy hydrocarbons, glycol, water, and molten salts. Cabin, cylindrical, box, and A-frame furnaces are direct fired.

Fire-tube heaters are **indirect fired**. They contain the combustion gases in tubes that occupy a small percentage of the overall volume of the heater. The heated tubes run through a shell that contains the heated medium. A fire-tube heater resembles a multipass, shell-and-tube heat exchanger. This type of heater is composed of a shell and a series of steel tubes designed to transfer heat through the combustion chamber (tube) and into the horizontal fire tubes.

Furnace Types

Cabin Furnace

The cabin furnace is a very popular direct-fired heater used in the chemical processing industry for large commercial operations. Most cabin furnaces are located above the ground, making it possible to drain the tubes and provide easy access to the burners, which can be located on the bottom, sides, or ends. Radiant tubes may be configured in a helical or serpentine layout. The radiant section in a cabin furnace is designed to contain the flames while avoiding direct contact with the tubes.

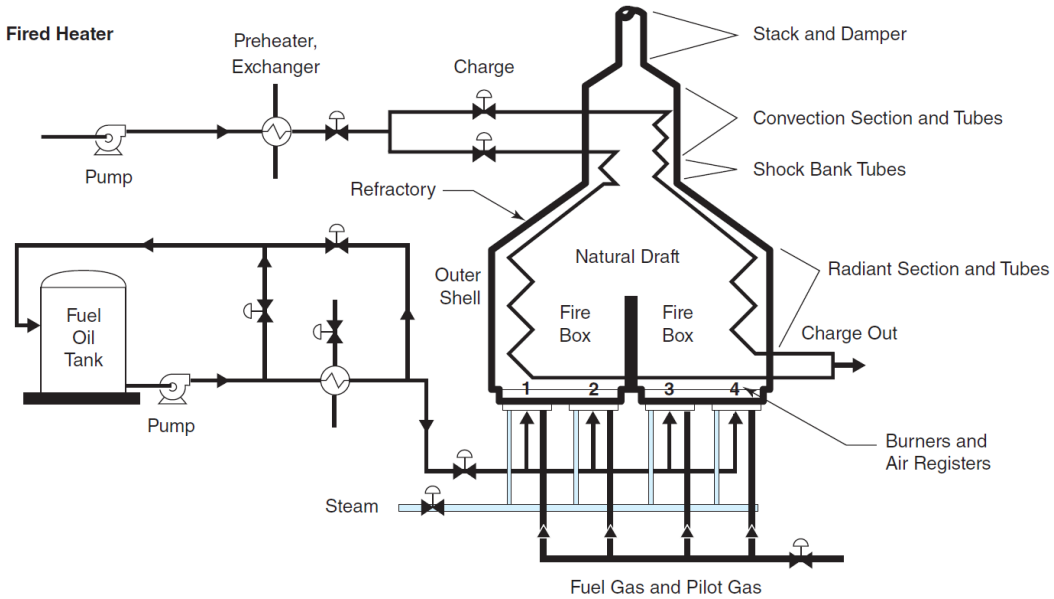


Figure 6. Cabin Furnace

Furnace Types

Cylindrical Furnace

Another very popular direct-fired heater design used by industry is the cylindrical furnace. The simple cylindrical furnace is engineered to utilize the radiant heat that emits from the burner in the bottom center of the furnace.

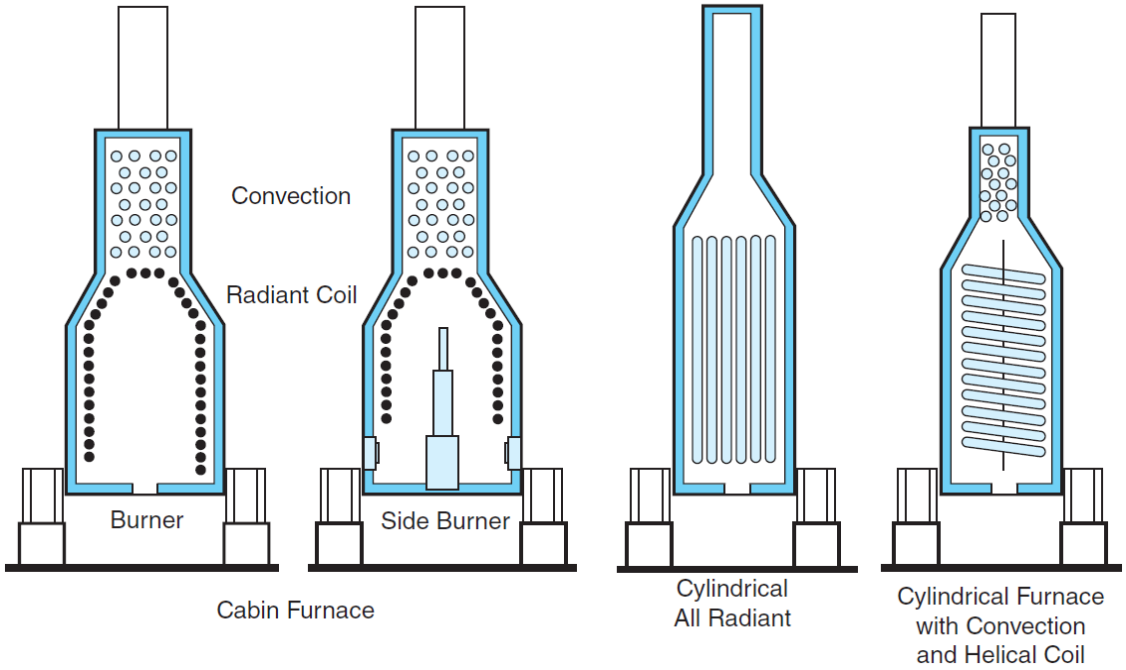


Figure 7. Cylindrical Furnace Designs

Furnace Types

Box Furnace

A box furnace takes its name from the square or rectangular design of the heating unit. This kind of furnace is best suited for oil firing. Burners can be on the sides or ends of the furnac. The firebox and radiant section use the roof, walls, and floor to reflect heat back into the firebox.

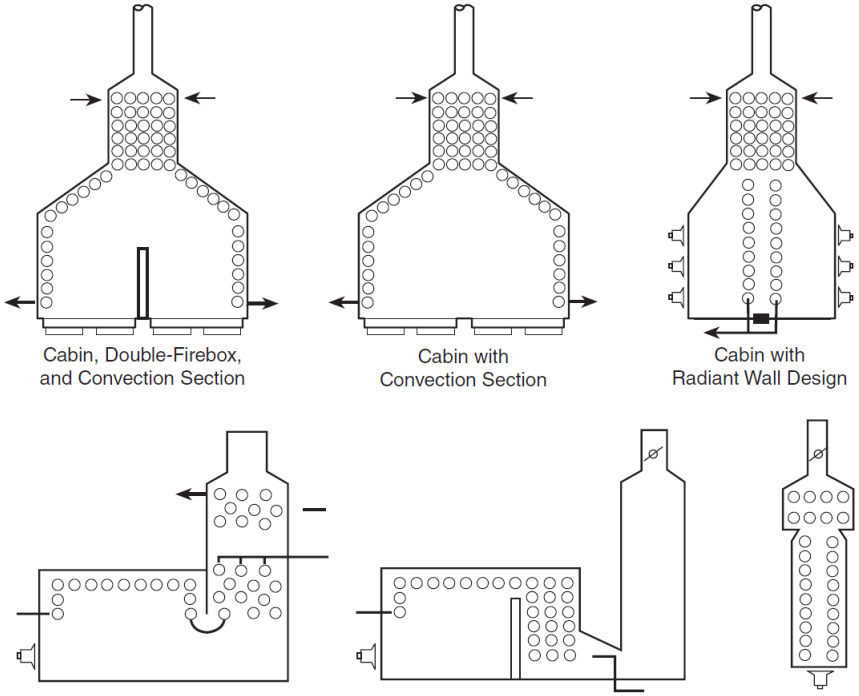
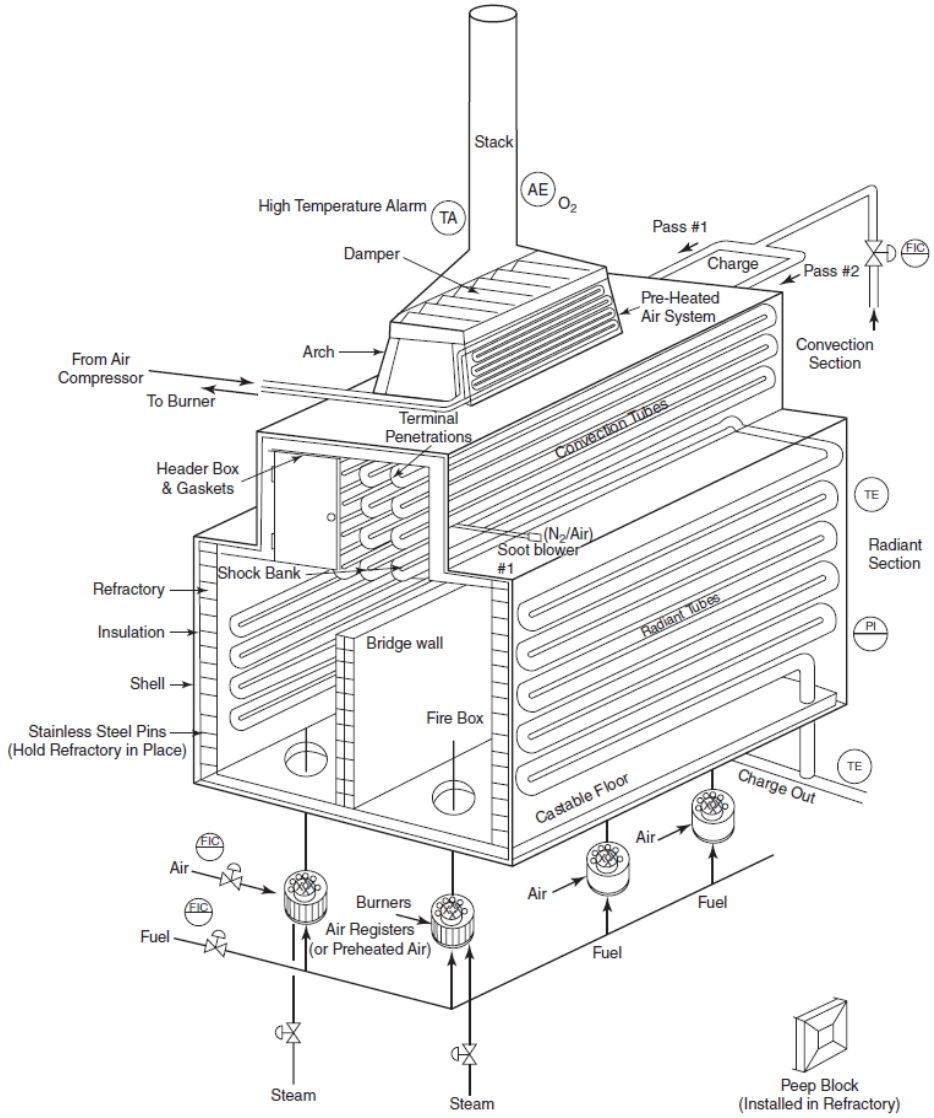


Figure 8. Furnace Designs

Furnace


Stack
AE
O_2
High Temperature Alarm
TA
Damper
Pass #1
Charge
Pass #2
FIC
Pre-Heated
Air System
Convection
Section
Arch
From Air
Compressor
To Burner
Terminal
Penetrations
Convection Tubes
Header Box
& Gaskets
TE
(N_2/Air)
Soot blower
#1
Radiant
Section
Shock Bank
Refractory
Insulation
Radiant Tubes
PI
Bridge wall
Shell
Fire Box
Stainless Steel Pins
(Hold Refractory in Place)
TE
Castable Floor
Charge Out
Air
FIC
Air
Burners
Air Registers
(or Preheated Air)
FIC
Fuel
Air
Fuel
Fuel
Steam
Steam
Peep Block
(Installed in Refractory)

Revision

1. What types of heat transfer exist in furnaces?
2. What section of the furnace has the highest temperature?
3. Where are the convection tubes located in a furnace?
4. Where are the radiant tubes located in a furnace?
5. List the basic components of a furnace.
6. List types of furnaces.
7. How are carbon deposits in the tubes of a furnace called?