2017

Heat Transfer Equipment

(HeatExchangers , FiredHeaters)

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Content

CHAPTER 1

Heat Transfer Basics

Heat Transfer Mechanisms

The heat produced by the combustion of the fuel is transferred to the process oil in 3 ways, by Radiation, convection and Conduction

Radiation

- Transfer of heat by direct waves “direct from heat source or reradiated from reflecting surface
- Driving force ΔT $Q = T^4_{hot} - T^4_{cold}$
- In Fired Heater about 60-70% of the heat transfers by radiation

Convection

- Transfer by flow of liquid or vapor
- Occurs when the hot gases flow from the firebox to the stack. the tubes @convection section absorbs heat
- contact required
- Driving force ΔT $Q = h A (T_{hot} - T_{cold})$

Conduction

- Transfer within a substance
- Occurs when the heat from the outside of the tube is transferred to the oil flowing on the inside of the tube
- Depends on thermal conductivity of material
- Driving force ΔT $Q = (k/l) \times A (T_{hot} - T_{cold})$

For heat exchangers the transfer of heat energy from the hot fluid to the cold fluid involves three steps.

- Convection

(1)The transfer of energy from the hot fluid to the exchanger tube and (2) the transfer of energy from the tube to the cold fluid is convective steps.

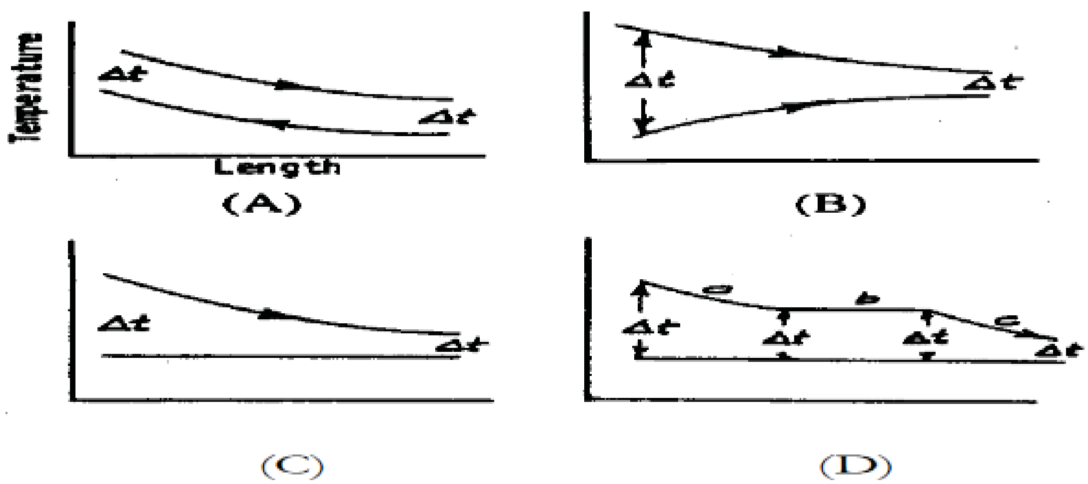
- Conduction

(3)The flow of the heat through the exchanger tube wall is a conductive step

Factors affecting heat transfer

1 Temperature difference   the greater the temperature difference between two materials the greater the driving force causing heat transfer
2 Thermal conductivity   every substance has a definite thermal conductivity which affects the amount of heat transferred. Metals are good conductors while wood and carbon are very poor conductors.
3 Area the cross-sectional area affects the heat transfer. The larger the area, the more heat can be transferred.
4 Velocity of the fluids in the tube affects the amount of heat transfer . An increase in the velocity of the fluids increases the heat transfer rate.
5 Direction of flow when using identical equipment with equal rates of flow, the one with counter-current flow and the other with parallel flow, the final temperature will be higher with counter current flow

Effective ΔT



(A) Two fluids flowing counter current, no phase change.

(B) Two fluids flowing concurrent, no phase change.

(C) One fluid flowing and one boiling (or condensing).

(D) Superheated vapors being cooled to saturation (a) condensing (b) and being subcooled as liquid (c). The other fluid is boiling or condensing.

The only temperatures that we can measure conveniently are at the inlet and outlet ends of the exchanger. Thus, we can measure two Δt's. The larger we will call Δt1, the smaller Δt2. Δt2 is also called the approach. It designates how close the temperatures of the two fluids approach each other in the exchanger. In concurrent flows the fluids flow in the same direction. In counter current flow they flow in opposite directions. Most exchangers use counter current flow or as close to it as possible since it is more efficient.

The basic equation for estimating Δtm is,

$$\Delta t_m = (F)\ \frac{\Delta t_1 - \Delta t_2}{\mathrm{Ln}\,(\Delta t_1 / \Delta t_2)}$$

Δt_m = log mean temperature difference (LMTD)
F = factor for heat exchanger
Δt_1 = largest Δt (at one end of the heat exchanger)
Δt_2 = smallest Δt (at one end of the heat exchanger)
Ln = logarithm to the base e
The value of **F** depends on the geometry of the fluid flow in the exchanger. **F = 1.0** for a concentric pipe-in-pipe exchanger.

CHAPTER 2

Heat Exchangers

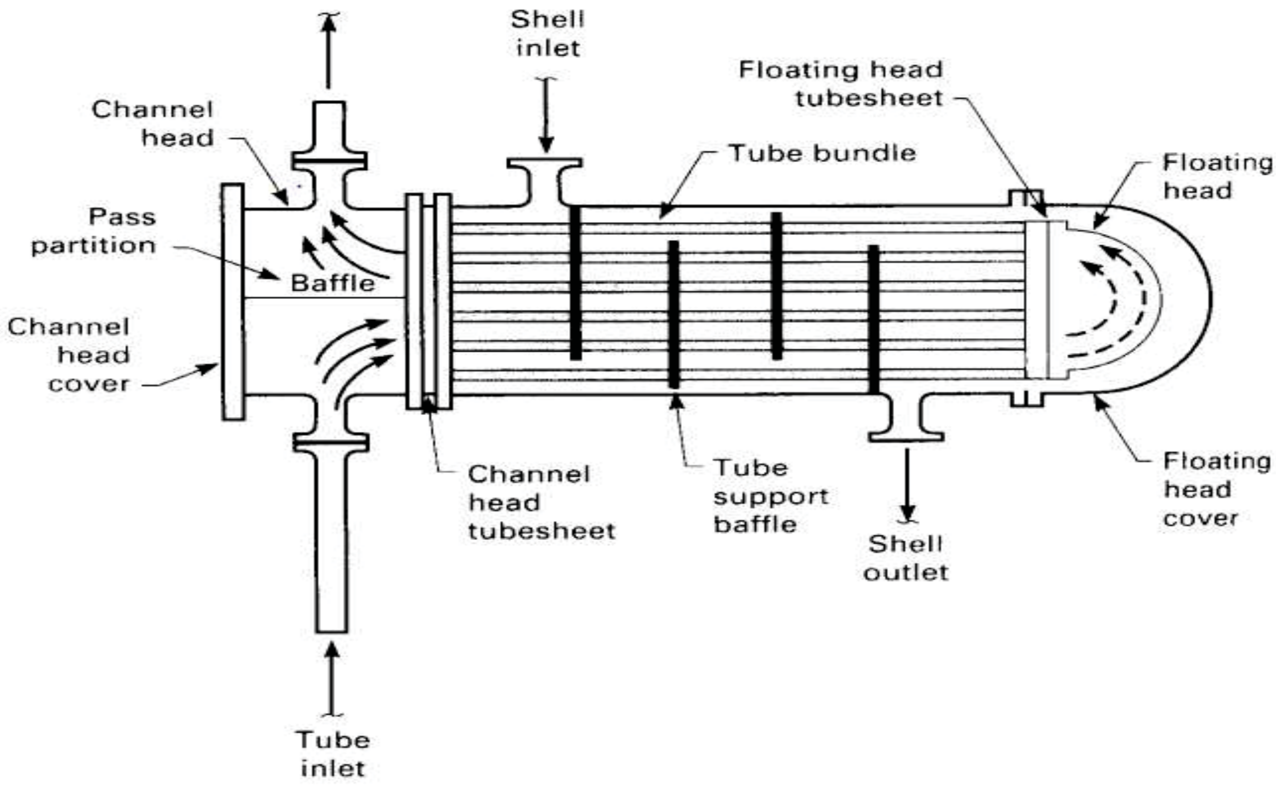
2.1 What is a Heat Exchanger?

A device built for efficient flow of thermal energy from one fluid to another at a different temperature, whether the fluids are separated by a solid wall so that they never mix, or the fluids are directly contacted.

2.2 Shell & Tube Heat Exchanger

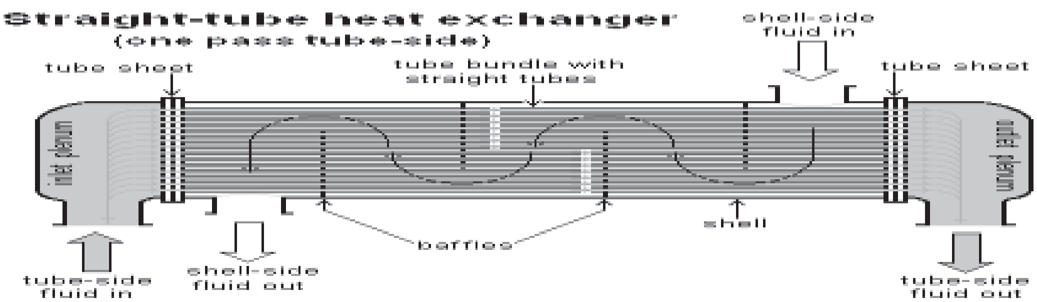
Consisting of a bundle of parallel tubes surrounded by an outer casing (shell). Both the tube bundle and the shell are designed as pressure containing elements in accordance with the pressure and temperature requirements of the fluids that flow through each of them

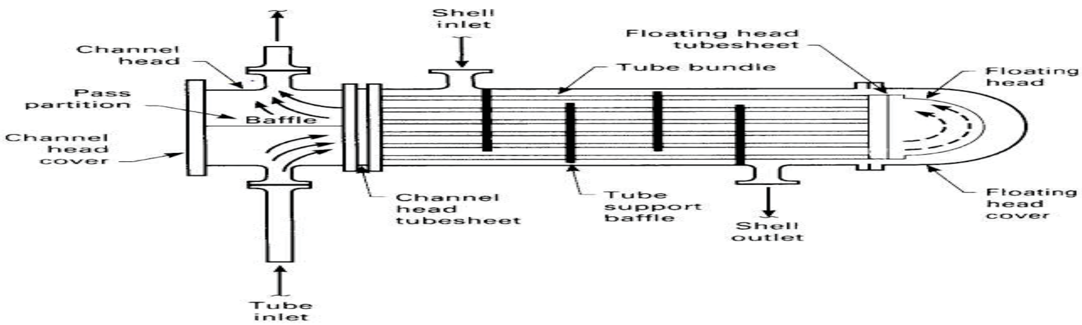
2.2.1 Shell-And-Tube Exchangers essential parts

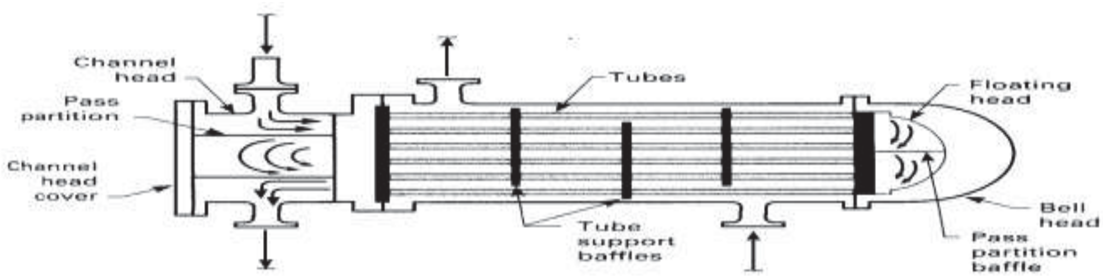


Tube passes

In order to maintain a high enough tube velocity to avoid laminar flow and to increase heat transfer, the design is modified so that the tube fluid passes through a fraction of the tubes in two or more successive “passes” from head to head



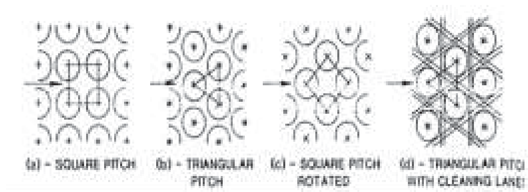




Tubes

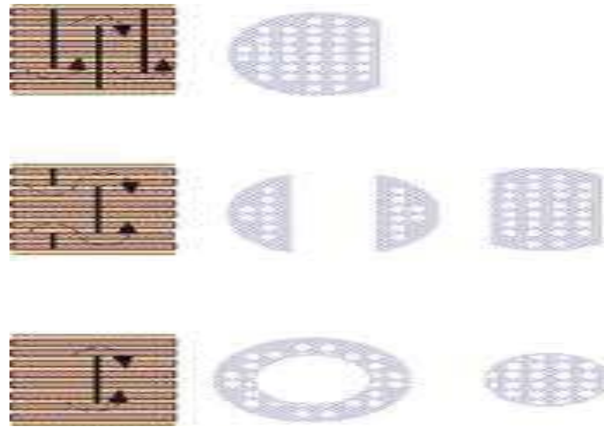
Heat-exchanger tubes are available in a variety of metals including steel, copper, brass, 70-30 copper-nickel, aluminum bronze, aluminum, and stainless steel

Tube holes cannot be drilled very close together, since this may structurally weaken the tube sheet. The shortest distance between two adjacent tube holes is called the “clearance.”



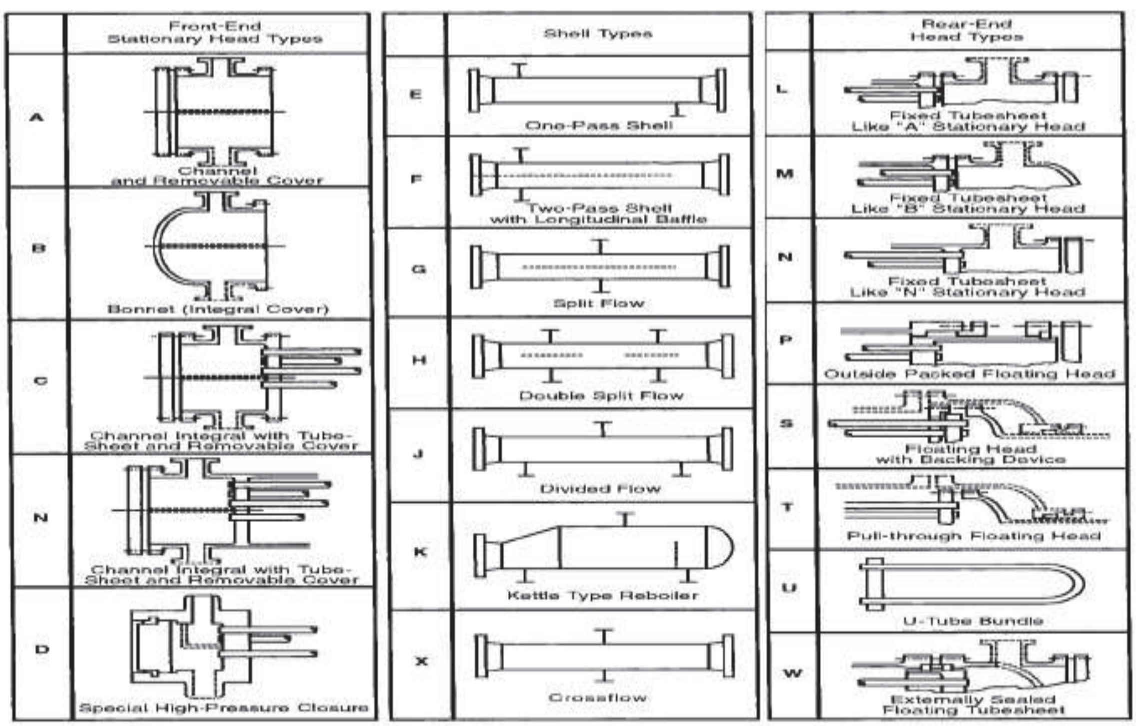
Baffles

Transverse baffles support the tubes that pass through holes in the baffle and also can help maintain greater turbulence for the shell side fluid, resulting in a higher rate of heat transfer



2.2.2 TEMA "Tubular Exchanger Manufacturers Association"

Shell-and-tube exchangers are named by the Tubular Exchanger Manufacturers Association TEMA (1988) . Letters are given to indicate the style of head (or front) end, shell, and rear end.



FRONT END

Removable covers Type A or N, are used when cleaning is required. Bonnets (B) are cheaper than removable covers and reduce leaks by eliminating one gasket.

Type B the bonnet (integral cover) is often used for hazardous (H2 or HF) in refineries, for high pressure service in gas plants, and for clean fluids.

SHELL

The one-pass shell, type E is most common

A two-pass shell, type F, has a much higher LMTD F factor but has a much higher pressure drop.

Divided flow shells (type J) reduce shell-side pressure drop to about one-eighth of a comparable E shell

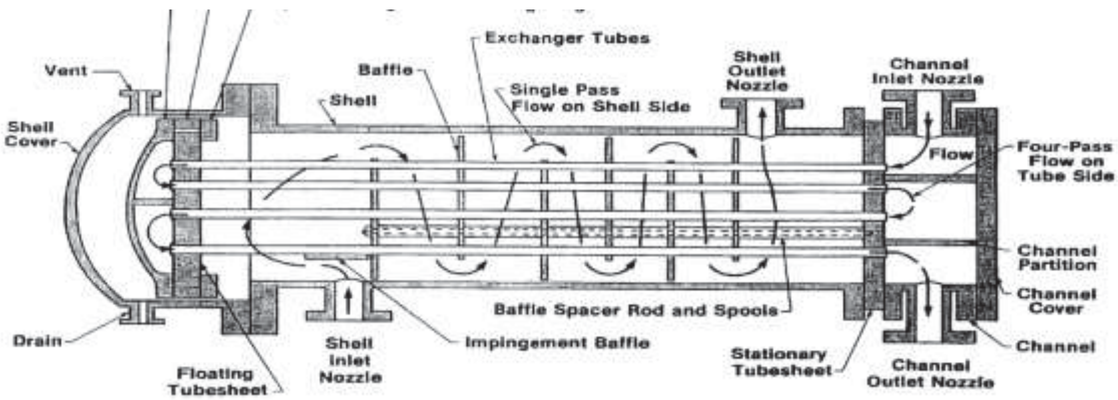
Kettle (type K) shells are used for reboiling or vaporizing, as in a chiller

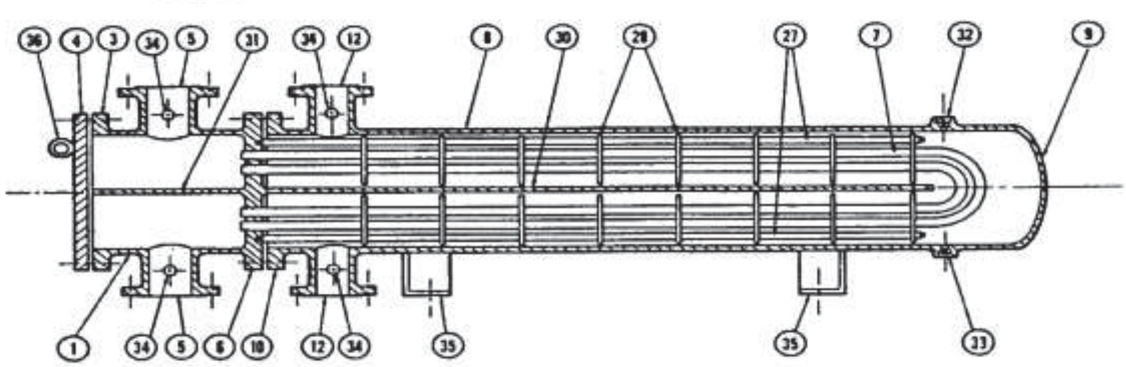
Rear

There are three types:
first is the fixed-tube-sheet exchanger. Fixed-tube sheets are relatively hard to remove or replace; therefore, they are used for clean streams and low temperature differences.

The second rear-end type is the floating-head exchanger. Manufacture is more expensive than for the fixed-tube sheet, but the channel head permits easier access for maintenance. Also, the floating head allows large temperature difference between ambient and operating conditions without excessive thermal stress on the equipment.

The third type is the U-tube. Like the floating-head, the U-tube is a removable bundle and has similar advantages. However, cleaning inside the tubes is extremely difficult





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2.2.3 Fluid Placement

The major consideration may be the character of the fluid itself. The following general guidelines are useful

Shell Side

- Fluid having the lowest flow rate
- Condensing or boiling fluid

Tube Side

- Toxic fluids to minimize leakage
- Corrosive fluids
- Fouling fluids
- High temperature fluids requiring alloy materials
- High pressure fluids to minimize cost

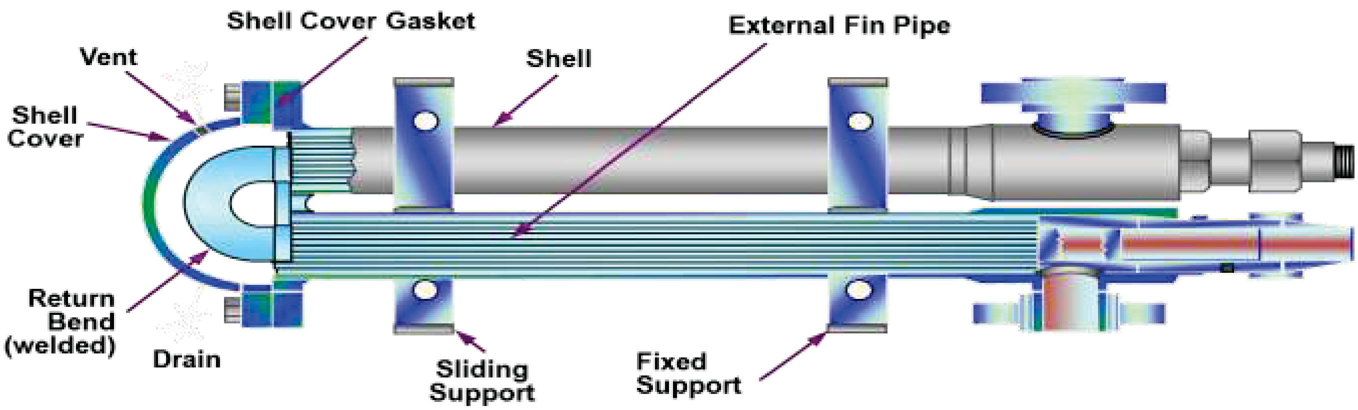
2.3 Other types of Heat Exchanger

2.3.1. DOUBLE-PIPE Exchanger

One fluid passes through the inside of the inner pipe and the second fluid flows through the annulus between the outside of the inner pipe and the inside of the outer pipe. The flow is countercurrent, so that the F factor is 1.0 for this type of exchanger.

Double-pipe exchangers have limited area and are used for services with small heat duties

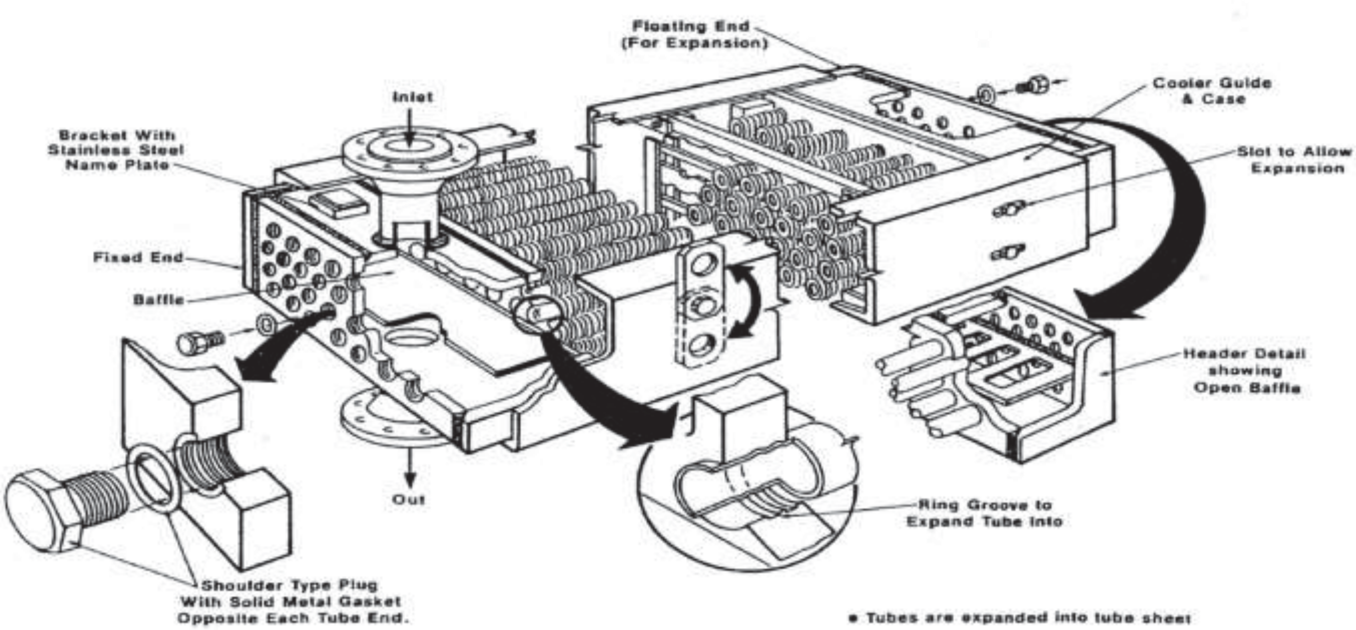
The advantages of double-pipe exchangers are that they are cheap and readily available, and because of the U-tube type of construction, thermal expansion is not a problem.



2.3.2. AIR-COOLED Exchanger

Air-cooled exchangers have the process fluid inside the tubes and ambient air on the outside, either moving by natural convection or blown by a fan.

Because of the low heat-transfer coefficient for atmospheric air, fins are used on the outside of the pipes



2.4. Shell & Tube Heat Exchanger Operation

2.4.1. Procedure to Take a Heat Exchanger out of Service

1. The hot fluid must be shut off before the cold fluid, This should be done slowly to allow the exchanger to cool down
2. After the temperature has cooled to that of the cold fluid, then the cold fluid can be shut off on both inlet and outlet valves
3. Both shell and tube side should now be pumped out to slop or drained down
4. Both inlet and outlet lines should be blanked off for safety

- If the exchanger is in sour oil service or any iron sulphide scale is expected, the exchanger should be water washed before opening to the atmosphere

2.4.2. Procedure to Place Heat exchanger in Service

1. Check the exchanger carefully to ensure that all plugs have been replaced and that all pipe work is ready for the exchanger to be placed in Note All valves should be in the shut position.
2. Purging and testing.
3. Open hot and cold fluid vent valves
4. Crack open cold fluid inlet valve vent all air when liquid full. Close cold fluid vent valve.
5. Crack open hot fluid outlet valve and vent all the air, then close hot fluid vent valve
6. At this stage, the exchanger is liquid full of both hot and cold flowing fluids - open cold fluid inlet and hot fluid outlet valves fully.
7. Both valves, the cold fluid outlet valve and the hot fluid inlet should be opened slowly until fully open

- All operations should be performed slowly and care must be taken not to cause sudden temperature changes.

2.4.3. Testing Heat Exchangers for Leaks

Heat Exchanger is normally tested at its place of manufacture. Sometimes, during operation, the products become contaminated and this could be due to a leaking heat exchanger tube

Hydrostatic test pressures at ambient temperature normally are 1.5 times the design pressure corrected. Always use a cold liquid for testing, because a hot liquid affects the expansion of tube and shell and can cause damage

The basic method for testing procedures:

- In a fixed tube sheet exchanger

1. after the end covers have been removed, a hydrostatic test pressure is applied to the shell
2. leaking tubes will be detected by water running out of the tube

3. The tube is sealed by driving in a tapered plug of suitable metal at each end of the tube and the test repeated until all the leaks have been cured.

- In a floating head exchanger

1. After the end covers are removed, a special test ring sized to fit the exchanger is fitted so as to seal the tubes and
2. The procedure then becomes the same as for a fixed tube sheet

2.5 Shell & Tube Heat Exchanger Problems

2.5.1. Heat Exchanger Fouling and Corrosion

The probability that fouling will occur in a heat exchanger is therefore normally taken into account at the design stage by the use of an assumed fouling resistance or fouling factor

Fouling in equipment involving boiling and evaporation is often more severe than in single phase heat exchangers and moreover, in aqueous systems, is frequently associated with corrosion

2.5.2. Types of Fouling

1. Scaling involve the crystallization of inverse solubility salts (such as CACO in water) onto a superheated heat transfer surface. This process can occur under either evaporating or non-evaporating conditions.
2. Particulate Fouling involves the deposition of particles suspended in the fluid stream onto the heat transfer surface This process includes sedimentation, i.e. settling under gravitational forces as well as other deposition mechanisms
3. Chemical Reaction Fouling involves deposits caused by some form of chemical reaction within the fluid stream itself (but not with the heat transfer surface). Polymerization, cracking and coking of hydrocarbon liquids at high temperature are prime examples
4. Corrosion Fouling involves a chemical reaction between the heat transfer surface and the fluid stream to produce corrosion products which, in turn, foul the surface
5. Bio fouling involves the accumulation of biological organisms at the heat transfer surface

Freezing Fouling occurs as a result of the crystallization of a pure liquid or one component from a liquid phase on to a sub cooled heat transfer surface

CHAPTER 3

Fired Heaters

3.1. What is fired Heater?

A device in which heat liberated by the combustion of fuel within an internally insulated enclosure is transferred to fluid contained in tubular coils

Fired Heater Size Is defined in terms of its design heat-absorption capability -DUTY- . Major Duty ranges 10-350 million Btu/hr

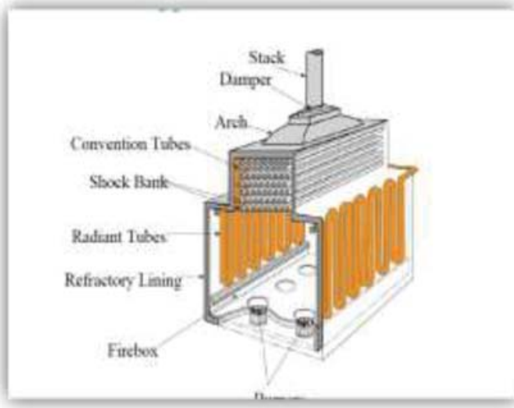
3.2. Process industries requirements for fired heaters

1. **Column Reboilers**
   Feed is a recirculating liquid from distillation column partially vaporized & the mixed vapor-liquid stream re-enter the colum, where the vapor condenses &releases the heat of vaporization. Outlet temp. 400-550 F 200-300 C
2. **fractionating-Colum feed preheater**
   Feed "usually all liquid" sent to the fired heaters following upstream preheated in unfired equipment fluid temperature raised enough to achieve partial vaporization 60%
3. **Reactor-feed heater**
   Raising charge-stock temperature to a level necessary for controlling a chemical reaction taking place in reactor vessel
4. **Heat supplied to viscous fluids**
   Fired heater employed to warm the oil to a temperature that will facilitate pumping
5. **fired-reactors**
   In which a chemical reaction occurs within the tube coils Ex. -Steam hydrocarbon reformer heaters-in which the tubes of the combustion chamber function individually as vertical vessels filled with nickel-bearing catalyst.in reformers that yield H_2

3.3. Heaters/Furnaces Categories

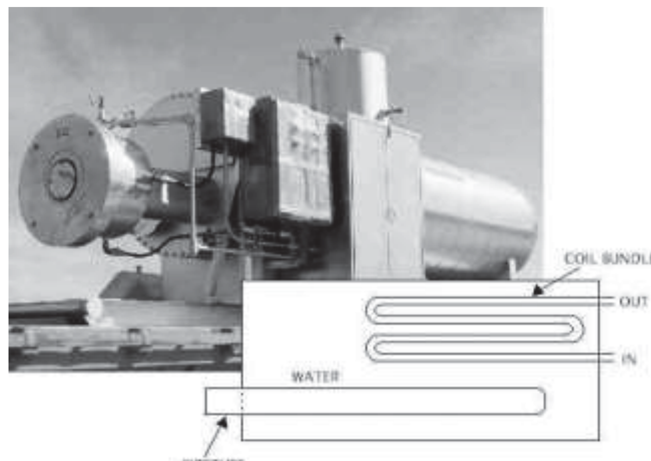
Direct fired heaters

Where the combustion gases occupy most of the heater volume and heat the process stream contained in pipes arranged in front of refractory walls



Fire tube heaters

Where the combustion gases are contained in a fire tube that is surrounded by a liquid that fills the heater shell. This liquid may be either the process stream or a heat transfer medium that surrounds the coil bundle containing the process stream



Different Types of direct fired heaters

Cylindrical

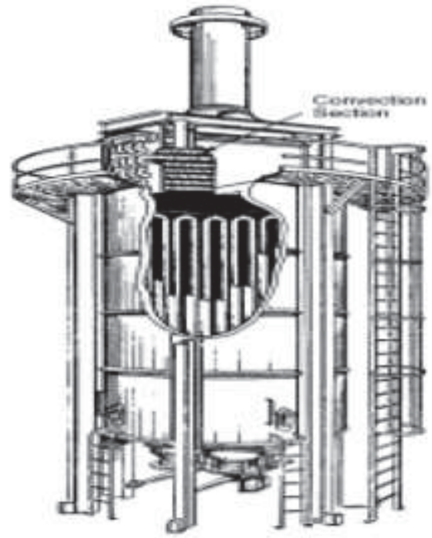
Require the smallest plot area for a given duty.

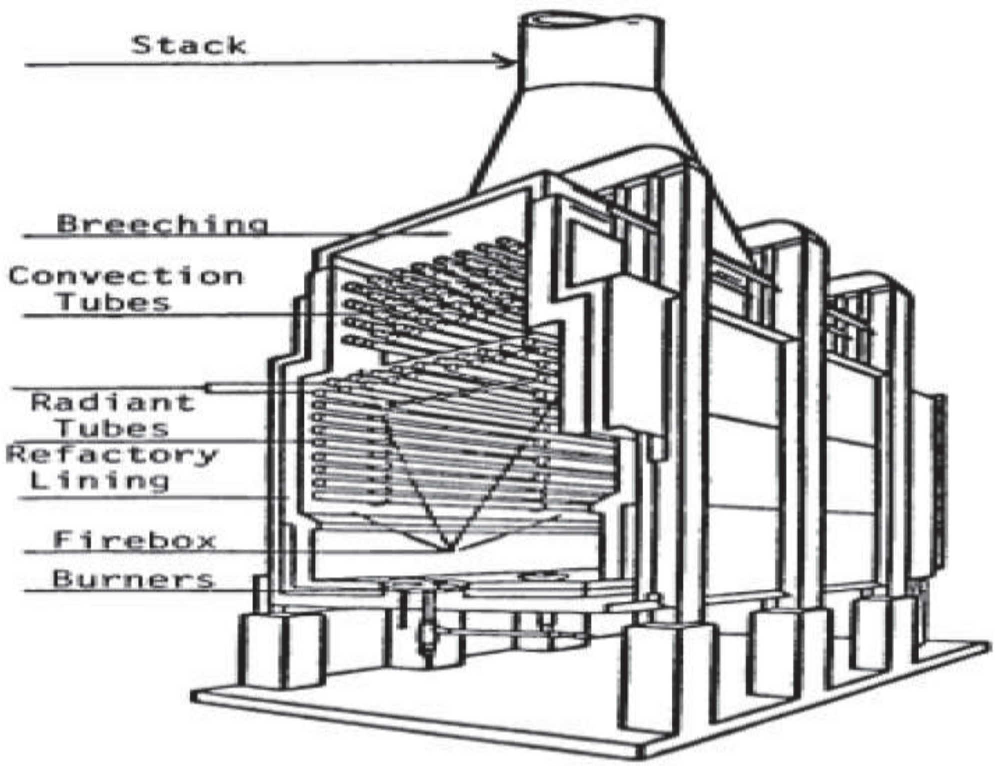
Cabin

Cabins can accommodate side-firing or end-firing burners instead of only vertically upward firing. This permits the floor of the heater to be closer to the ground. (Some burner manufacturers prefer to fire liquid fuels horizontally.)

Coil arrangements

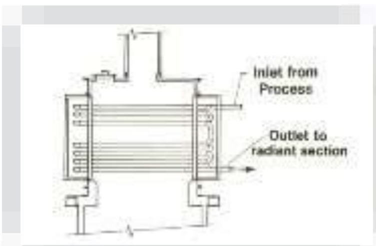
The principal classification of fired heaters, related to the orientation of the heating coil in the radiation section horizontal, vertical, helical

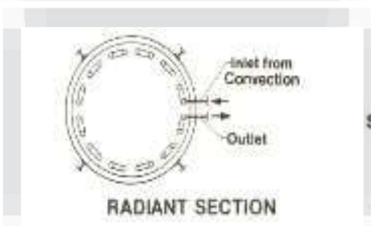

Convection Section

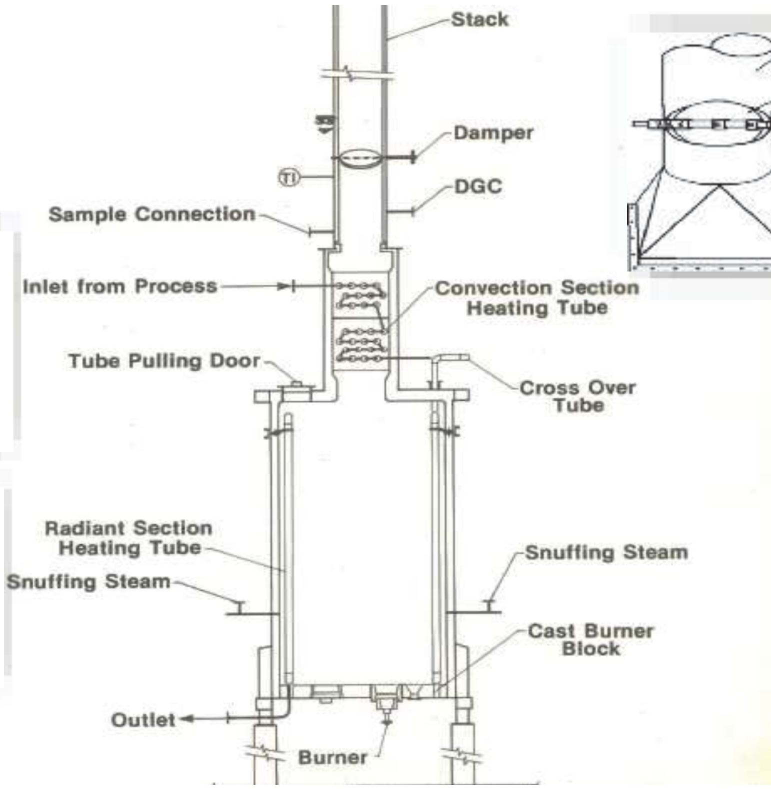

Stack
Breeching
Convection Tubes
Radiant Tubes
Refactory Lining
Firebox
Burners

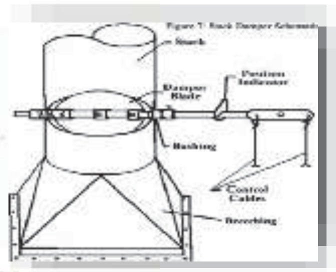
3.4. Fired Heater Components

The major components of a furnace are
the radiant section (firebox), convection section, stack, burner fuel system, and process fluid coil









- **Fire Box (Radiation Section)**

The radiant tubes, either horizontal or vertical, are located along the walls in the radiant section of the heater and receive radiant heat direct from the burners

The tube bank must be enclosed by a firebox to prevent the loss of heat from the burners to the atmosphere . Also it must prevent air leakage into the furnace

- **Convection Section**

The convection section is located in the path of the hot products of combustion , between the radiant section and the stack

The convection section removes heat from the flue gas to preheat the contents of the tubes and significantly reduces the temperature of the flue gas exiting the stack

- **Shield Section**

Just below the convection section is the shield (or shock tube) section, containing rows of tubing which shield the convection tubes from the direct radiant heat

- **Stack and Breeching**

The stack is connected to the furnace by a breaching or a flue gas duct

The height of the stack provides sufficient draft in a natural draft furnace for proper combustion of the fuel ,also releases the flue gas at a safe location

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The height of the stack provides sufficient draft in a natural draft furnace for proper combustion of the fuel ,also releases the flue gas at a safe location

Dampers are fitted into the stack , which are usually butterfly valves to give control of the draft within the firebox , and maintain a negative pressure within the firebox

- **Tubes**

They are necessary to direct the flow of oil through the heater

The type of steel used depends upon the process conditions and nature of process oil

As Chrome content increase , the tube heat resistance increase

Adding (nickel, molybdenum) to increase corrosion & heat resistance

.5% silicon content to increase oxidation resistance or exterior scaling resistance

- **Header Boxes**

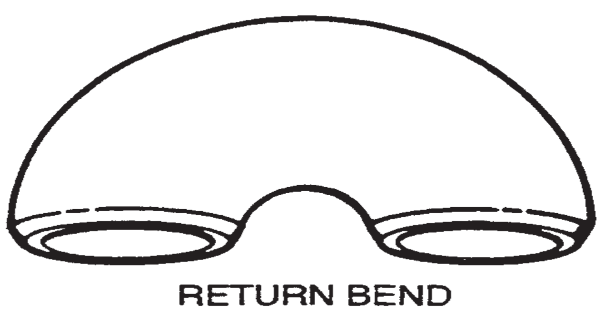
One way to join the tube ends is with a rolled header

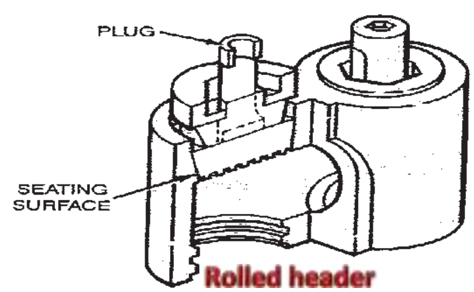
To provide access for tube inspection and mechanical cleaning, the headers have removable plugs.

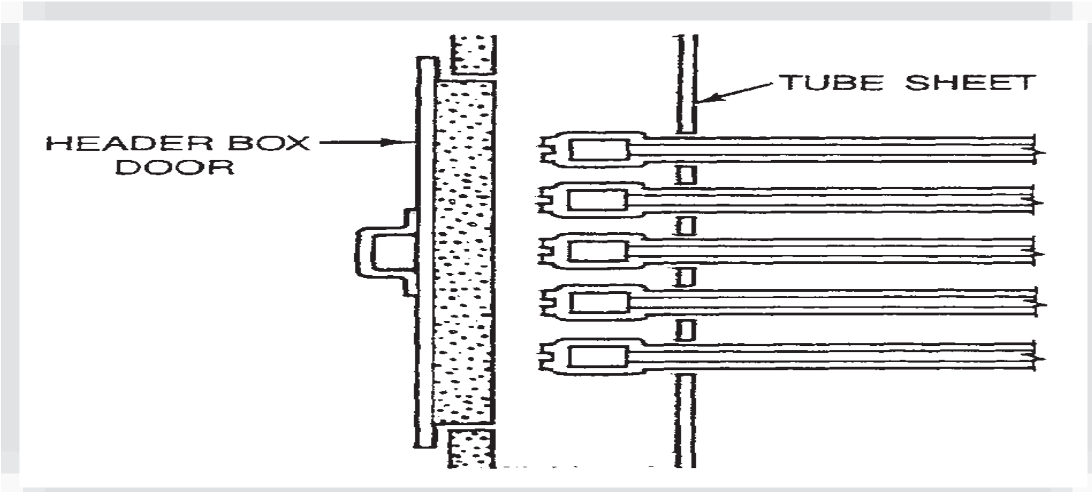
the headers are enclosed in what is called the header box

The header box helps to cut down on heat losses from the headers and tube ends

The header box serves to isolate and contain any leaks or fires. Most header boxes are equipped with a steam line for smothering fires. 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.







- **Explosion doors**

  Explosion doors are installed on the outside walls of some furnaces and in case of an explosion , these hinged doors will swing open and release the pressure. This helps to prevent damage in the firebox
- **Access Doors**

  Access doors are also on exterior walls to allow access to the furnace for inspection and maintenance during shutdowns. All doors should be closed and bricked-up to prevent leakage any air leakage into the firebox reduces the draft and affect the efficiency of the furnace
- **Peepholes**

  Peepholes have hinged or swinging covers and are installed on outside walls of the furnace to allow visual examination of the flames and tubes .They should be closed when not in use to prevent air leakage
- **Soot Blowers**

  Are to blow soot off the tubes in the convection section.
  - There are two types

    Fixed soot blower remains in the convection section all the time

    Retractable soot blower only enters the convection section when it is soot blowing

3.5. Draft systems

3.5.1. What is 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.

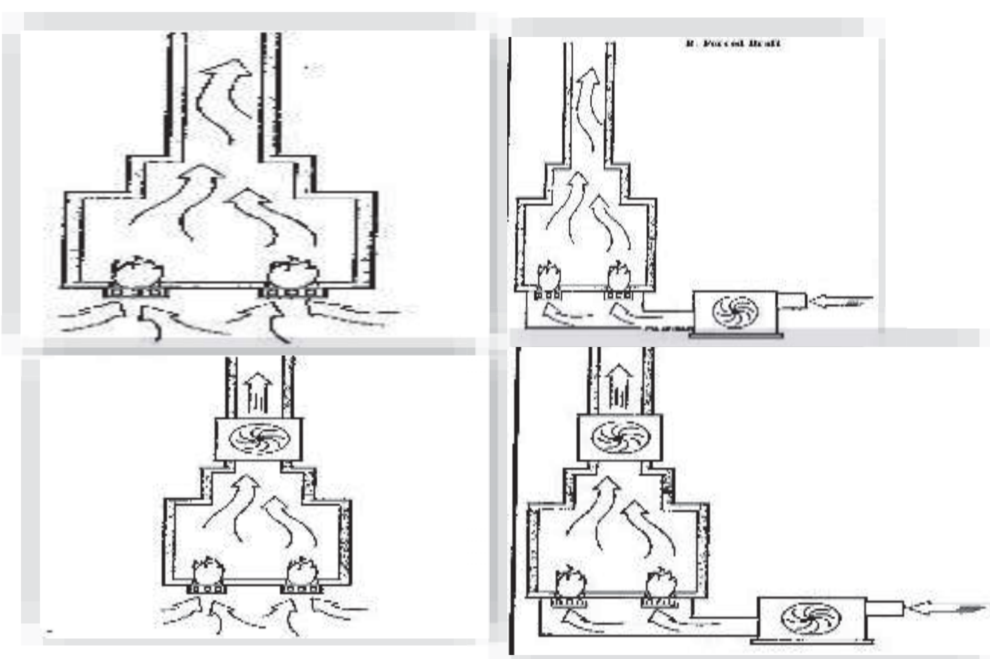
These hot gases weigh less than the cooler air so they are buoyant inside the furnace.

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

As the flue gases move up through the furnace and around the tube banks, they lose 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.

3.5.2. Types of draft systems

1. Natural Draft
2. Forced Draft
3. Induced Draft
4. Balanced Draft



1. **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.
   In designing a natural draft furnace the total available draft can be increased by increasing the stack height. The draft is controlled by adjusting the position of the damper in the stack and the burner registers. The other types of furnaces rely on fans to assist in maintaining a draft.
2. **Forced Draft**
   The fan supplies combustion air to the burners. Forced draft permits steady control of the air at the burners
3. **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
4. **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

3.5.3. Excessive Draft

Positive Pressure

The air registers are wide open and the damper mostly closed. This generates a positive pressure which forces flue gases outward through leaks in the convection section leading to serious structure damage, as well as heat loss.

Negative Pressure

The air registers are mostly closed and the stack damper is wide open leading to a high negative pressure in the convection section. Cold ambient air is sucked in through leaks in the convection section leading to erroneous oxygen readings, as well as heat loss. In addition the excessive draft causes tall flames which can reach the tubes resulting in serious damage.

3.6. Fuel & Combustion

Combustion is a chemical reaction that produces heat. Three things must be present for combustion to occur: fuel, oxygen, and a source of ignition.

3.6.1. Complete & Incomplete Combustion

Complete Combustion

The fuel and oxygen react to form carbon dioxide, water, and heat to form carbon dioxide each atom of carbon reacts with two atoms of oxygen.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + Heat$$

Incomplete Combustion

If there is not enough oxygen, some of the carbon atoms unite with one atom of oxygen to form carbon monoxide (CO) instead of carbon dioxide (CO2). Carbon monoxide comes from a flame starved for oxygen. This is known as incomplete combustion

The complete combustion of one pound of carbon releases 14,100 BTU The incomplete one pound of carbon releases only 4,000 BTU So incomplete combustion drastically reduces the production of heat, or BTU

3.6.2. Excess air

Combustion in a fired heater normally uses air as a source of O_2. Consequently ,there must be an excess air above stoichiometric requirements to ensure complete combustion of the fuel

But, if too much oxygen is present, it must also be heated to maintain the proper furnace temperature. This extra oxygen absorbs but does not generate any heat, so it actually wastes fuel, or energy

Excess-air requirements

- For natural draft fired heaters
  20% for gas firing
  25% for oil firing
- For forced draft fired heaters (a greater degree of air control is possible)
  15% for gas firing
  20% for oil firing

3.6.3. Heating values

For those fuels containing hydrogen , two sets of heating values are reported

- **HHV**
  The gross or higher heating value. Determine by assuming that all of the water vapor produced in the combustion process is condensed & cooled to 60^{o}F
  The actual heat released
- **LHV**
  The net or lower heating value. Assumes that the water vapor formed by combustion remains in the vapor phase
  The useful portion of the actual heat released

For those fuels that not contain hydrogen (CO) , only one heating value is reported

3.7. Operating & Troubleshooting

3.7.1. Start Up

Five major steps in furnace start-up

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

1. **Inspection**

   The furnace and the area around it should always be clean. 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 also verify that all individual pilot and burner valves are closed. The damper and registers are opened so that air or steam can freely flow through the furnace during purging. 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
2. **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. Air can be used to purge a forced, induced, or balanced draft furnace because these furnace designs can produce an artificial draft with fans.
3. **Light off Pilots**

   Use either a hand-held lighting device or an electric ignition device to light the pilots. The pilots are lit before the burners. Once lit, the pilots serve as a steady source of ignition for the burners. 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
4. **Light off Burners**

   The burners should be lit in the same order as the pilots
   Slowly open the fuel gas valve to ignite the burner
   As you light the burners, you should maintain a stable fuel gas pressure

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

5. **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.

   When the temperatures and flows get within the control range of the automatic instruments, you can switch over to automatic

3.7.2. Shutdown

1. The process flow rate and the temperature of the furnace are gradually reduced together
2. When the minimum firing rate is reached, the burners are shut off
3. Stack damper and the air registers should be opened fully
4. The furnace can be purged with air or steam
5. The main and pilot fuel headers are blinded and the burners are isolated to prevent any accidental release of fuel into the furnace
6. 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

3.7.3. Troubleshooting

1. **Flame impingement**

Flame impingement occurs when a flame touches tubes

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.

Caused by dirty burner tips , lack of combustion air , high burner tip pressure , improper draft

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

2. **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. 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

3. 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.

4. Loss of flow

This may caused because of Feed pump malfunction or surge or Instrumentation 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

5. Fuel system

Some typical problems with fuel gas systems are

- 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.