International Association of Certified Practicing Engineers	**www.iacpe.com** **Knowledge, Certification, Networking**	**Page: 1 of 36** **Rev: 01** **April 2017**
IACPE **No 19, Jalan Bilal Mahmood** **80100 Johor Bahru** **Malaysia**	**FURNACE** **CERTIFIED PROCESS TECHNICIAN TRAINING MODULE**	

The International Association of Certified Practicing Engineers is providing the introduction to the Training Module for your review.

We believe you should consider joining our Association and becoming a Certified Process Technician. This would be a great option for engineering improvement, certification and networking.

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1. **Providing a standard of professional competence in the practicing engineering and management field**
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3. **Encourage practicing engineers and management professionals to participate in a continuing program of personal and professional development**

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INTRODUCTION

Scope

A furnace is a device used for high-temperature heating. The term furnace can also refer to a direct fired heater, mostly used in refinery units, providing heat to chemical reactions for processes like cat cracking, thermal cracking, reforming, coking, crude distillation, cat poly and vacuum units, or boiler applications in chemical industries.

Furnaces are used throughout the industry to provide the heat, using the combustion of fuels. In fact, furnace operation treats the three elements of combustion. They are fuel, air, and a source of ignition. These elements are combined by under controlled conditions in the furnace. Furnaces consist essentially of an insulated, refractory lined chamber containing tubes. Tubes carry the process fluid to be heated, and sizes are device for burning the fuel in air to generate hot gases.

Providing air for combustion in sufficient quantity for maximum release of heat is the normal day – to – day task of the operator. The operation is treated and air control equipment, the indicators and analyzers are used by this unit. These equipments make possible strict regulation of the air supply.

The consumption of fuel is minimized and the life of furnace equipment is extended by proper control of air. The process technician is better to have ability to regulate the air supply within narrow limits contributes to the economy of heat production and extended life of the equipment.

This training module provides an overview of the furnace and its parts along with practical combustion and air control. The knowledge and understanding of the basic principles and concepts of furnaces, combustion and air control are essential to deal with the way these parts function in the total process of making heat and transferring it to the petroleum materials being processed into useful products and important to analyze the furnace operation.

This module includes parts of the furnace, variations of funaces, drafts, burner designs, and factors that effect in furnace such as relationship draft and stack, and the tube. It also covers fuel and combustion, various of air preheaters that are used in according the requirement, heat indicators, draft gages, flue gas and oxygen analyzers, air control and stack damper. These descriptions are great basic knowledge based on efficiency and design which every process technician know.

The sciences of furnaces in this module provides a foundation in practical furnace which enable the process technician to solve furnace problem in industries. The student who

knows the furnace and how it works – whether or not he is actually engaged in furnace operation - is better prepared to understand the reasons for making the most of heat and wasting the least heat possible everywhere in the refinery. He is a more understanding workman and more valuable in any job.

This module also has figures and tables to illustrate the equipment and condition cases as example and reference. It is important to assist the students to understand and can be applied in industries practically.

General Consideration

I. Furnace

In terms of refining costs, the furnace is one of the most important pieces of equipment in the refinery. A large part of the heat used in refining is added directly to the charge as it passes through a furnace. From a dime to a quarter of every dollar spent on the whole refining process is for the fuel oil and fuel gas used in firing the furnaces.

To achieve the lowest possible heating cost, the furnace must operate at maximum efficiency. When the furnace operates below maximum efficiency, extra fuel is consumed. When the furnace operates properly, the furnace and its parts have a longer working life with minimum repairs. A properly run furnace is a safe furnace. By operating a furnace properly, the equipment is protected from damage.

A. Furnace Equipment

Furnaces are needed in refineries to release heat and transfer it to material being processed into petroleum products. Furnace is composed into several parts. There are burner, firebox, radiant tubes, shock bank, convection tubes, breeching, and stack. The parts of furnace can be given in figure 1.

Burners are installed on the floor of the furnace. Fuel mixed with air ignites at the burners and releases heat. The gases and vapors formed by burning fuel and air are called combustion products. Flue gases are combustion product and air not consumed in the burning reaction.

The firebox is the open area above the burners. The tubes along the walls of the firebox are radiant tubes. The tubes are the radiant tubes and the shock bank which receive rays of radiant heat from the direct light of the burners. The walls and roof are lined with a material that reduces heat losses and radiates heat back to the tubes. A refractory lining radiates heat back to the tubes to increase the amount of heat absorbed.

Whereas, the breeching is the duct which gathers the flue gases and discharges them to the stack. Flue gases flow from the firebox into the breeching and out of the stack.

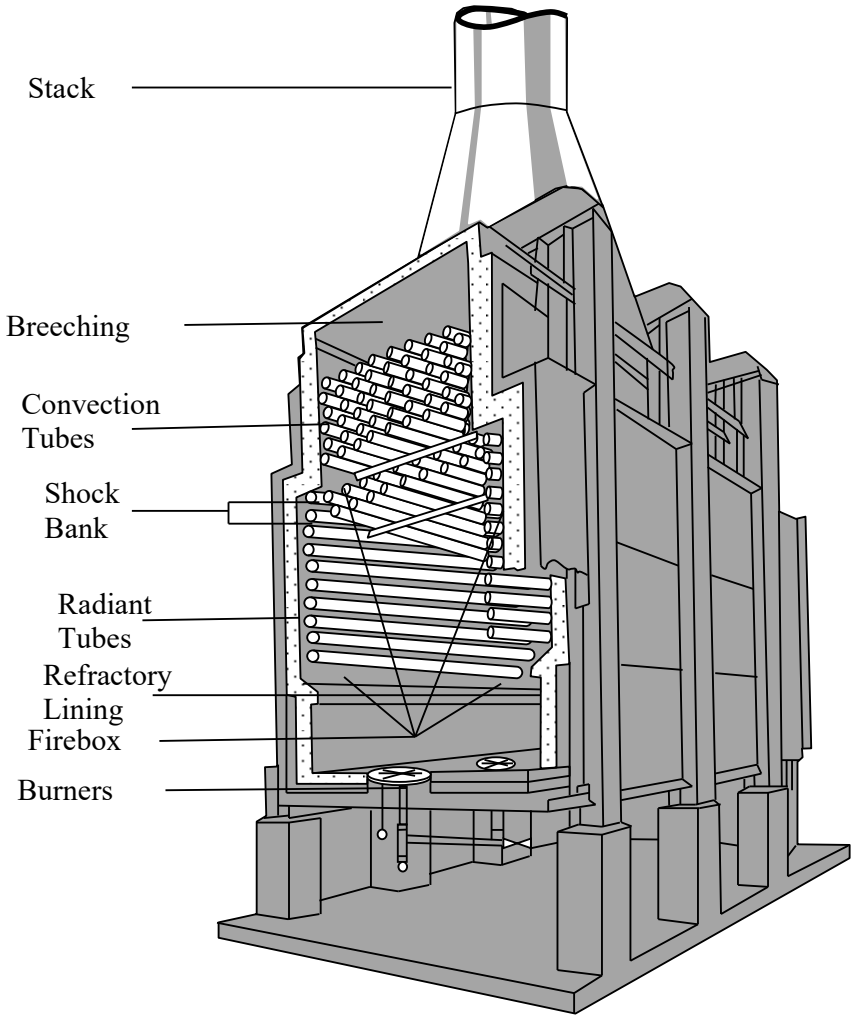
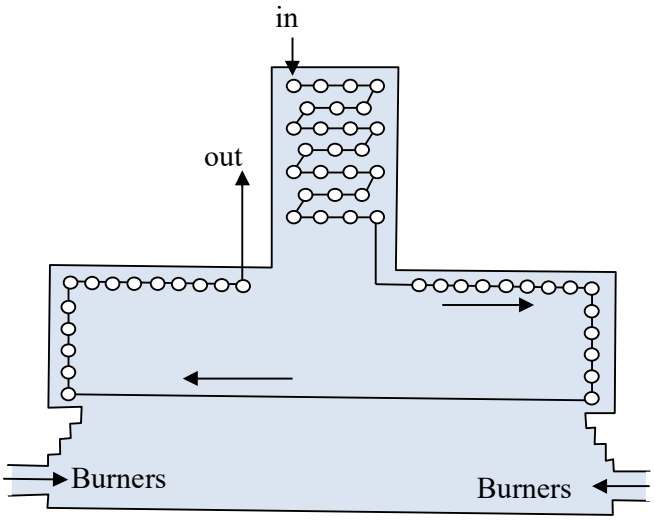


Figure 1 : rectangular furnace

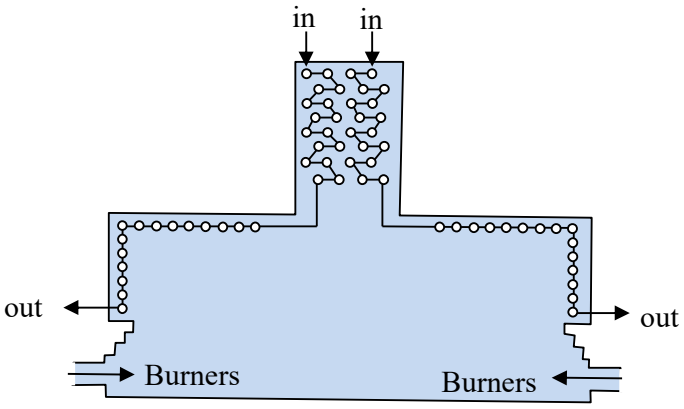
Heat released by the burners is absorbed by the tubes in two sections. The part of the furnace contained the radiant tubes is the radiant section. The part where the convection tubes are located, is called the convection section. The shock bank receives both convection and radiant heat. Tube banks differ in the kind of heat they absorb from the burner flame. The radiant tubes absorb radiant heat from the burners and the

refractory. The convection tubes absorb heat from the hot flue gases passing over them. Heat absorbed from the flow of hot gases is called convection heat.

The charge is normally fed into the convection tubes and drawn of at the radiant tubes. The oil charge to this furnace can flow in series and parallel through the tubes. Series flow happens when the total charge flows through every tube in the furnace. While, parallel flow happens when the charge is split into two or more streams and the separate streams flow through the furnace as shown in figure 2.



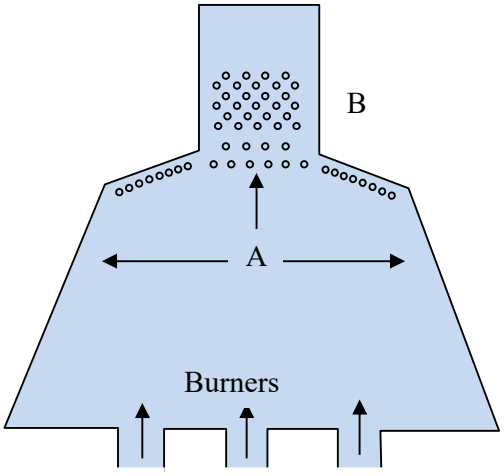
(a.) Series flow



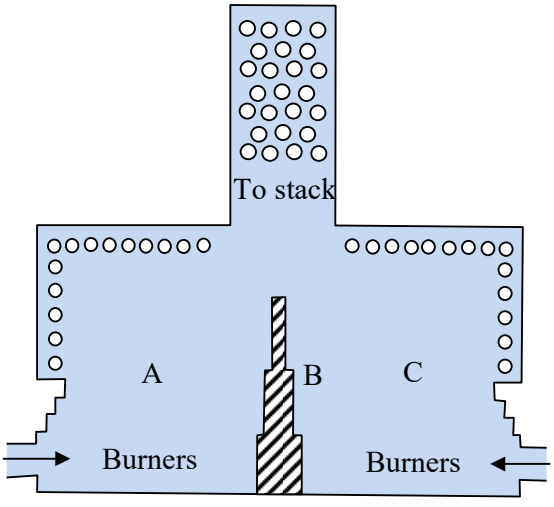
(b.) Parallel flow

Figure 2 : series and parallel flows

Actually, the rectangular furnace have many different shapes. Two of the variations are illustrated in figure 3 and 4. In furnace at figure 3a, the flue gases pass upward over the convection tubes on their way to the stack. The radiant tubes are at A. At figure 3b, a bridgewall made of refractory material divides the two combustion chambers. The bridgewall reflects radiant heat to the tubes in the radiant section. The bridgewall is at point B.



(a.)



(b.)

Figure 3 : shape variation of rectangular furnace

In addition to rectangular furnace, a cylindrical, vertical furnace is typically used in industry. For a given heat capacity, a vertical furnace occupies less ground area than a rectangular furnace. The radiant tubes are set vertically. Radiant heat is reflected to the tubes by the refractory lining. A steel radiating cone also reflects radiant heat to the tubes. Flue gases are directed to the convection section by a baffle sleeve. The construction can be given as shown in figure 4.

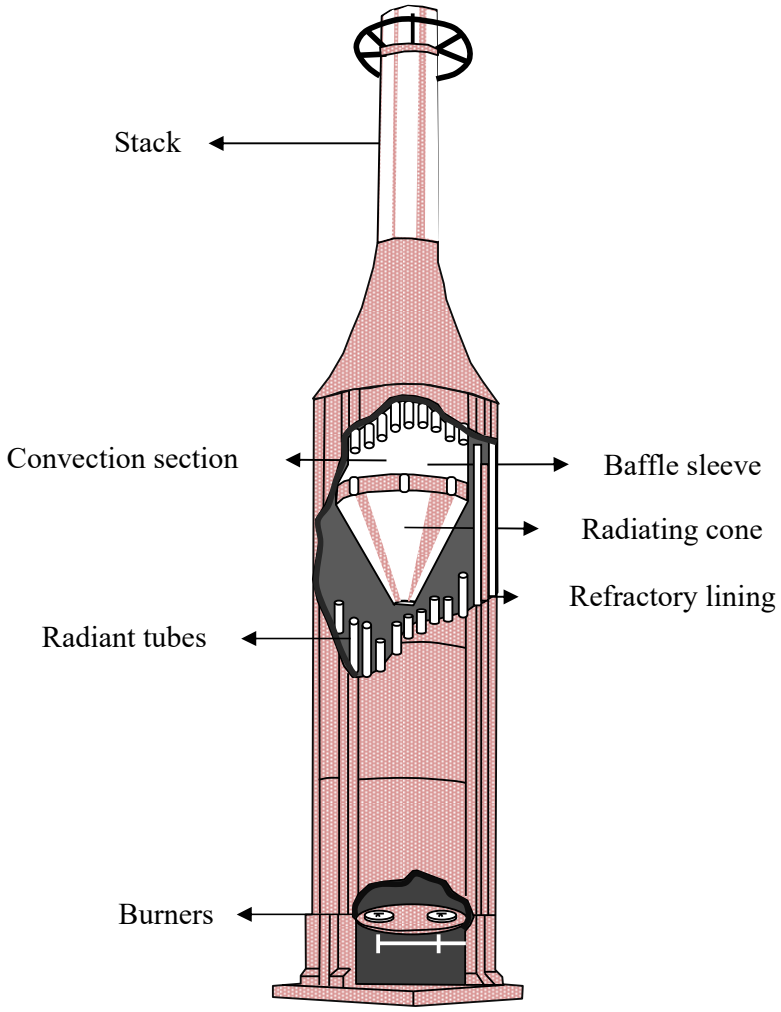


Figure 4 : vertical furnace

Another variation of the vertical furnace can be given as shown in figure 5.

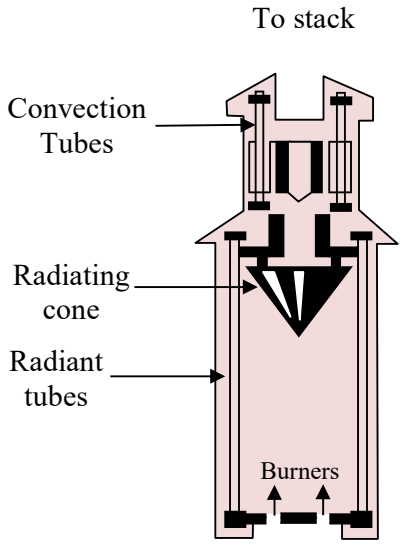


Figure 5 : another variation of the vertical furnace

The basic operation of refinery furnaces is the same, but they are different in size and design to meet the overall conditions of particular process installation. A furnace handling a large flow of material may be made up of a number of individual sections or cells. Each of these cells can then be controlled separately like a single smaller furnace.

Furnace differ in the size and placement of tubes, depending on the material being heated. Furnaces are designed for different temperature ranges. High temperatures demand more room for the tube metal to expand or ‘creep”. Because faster –moving liquid tends to “scrub” the inside of the tubes, a material which may leave coke deposits in the tubes is pumped through at a higher speed.

II. Combustion and Air Control

A. Temperature and Heat

Temperature does not measure the amount of heat in a substance. The temperature of charge increases in degrees as it goes through the furnace. In measuring heat absorbed, the charge uses the temperature difference. The amount of heat in a substance depends on both its temperature and its mass. It is measured in British Thermal Units, BTU. One BTU is the amount of heat required to raise the temperature of

one pound of water by 1 ^{o}F. One pound of carbon completely burned to carbon dioxide (CO_2) gives off 14100 BTU.

B. Fuel and Combustion

Burning or combustion of a mixture of air and fuel combines oxygen (O_2) with carbon (C) or hydrogen (H_2). The burning of air and fuel produces carbon dioxide (CO_2), water (H_2O), and heat. Carbon monoxide can be formed, instead of carbon dioxide, when there is not enough oxygen, some of the carbon atoms unite with one atom of oxygen in combustion.

Oxygen in furnace is obtained from air which normally is composed of about 4/5 nitrogen and 1/5 oxygen. The nitrogen remains unchanged, except that it is heated during combustion. The oxygen is diluted and the intensity of combustion is reduced by the nitrogen. All the nitrogen in the air goes out of the stack with the flue gases at the same temperature. Some excess air is needed to make sure that all the carbon and hydrogen atoms combine with oxygen. The excess nitrogen and oxygen absorb some of the heat that would normally go to the charge in the tubes.

Forming carbon monoxide instead of carbon dioxide releases only 28% as much heat. This incompleted combustion liberates about one pound of carbon only 4,000 BTU. A burner giving off carbon monoxide releases less heat. Less heat is then absorbed by the charge in the tubes.

When the charge comes cooler, more fuel is automatically fed to the burners. More fuel brings more carbon to combine with the oxygen. The carbon in great quantities will form carbon monoxide if more carbon combines with the same amount of oxygen. As the proportion of carbon monoxide rises, the amount of heat liberated goes down.

The burner flame will be quenched of lack of oxygen, leaving a supply of raw gas entering the furnace since the increasing carbon monoxide process goes too long. The mixture may be ignited if air is then allowed to the hot furnace with raw unburned fuel in it. This ignition can suddenly result in a violent and destructive explosion.

a. Combustion

Combustion must have a source of ignition. Once burning has started, the heat of the burning itself is a continuous source of ignition. Burners create turbulence to thoroughly mix the fuel and oxygen. In premix burner, the pressure brings the fuel to the point of combustion fast enough thus, the mixture burns in front of the burners. The flame may flash back into the burner if low pressure slows down the fuel.

b. Fuel Type

One element of combustion is fuel. The fuel is composed into gas and liquid. Fuel gas is burned without any other treatment than mixing with air. While fuel oil is a liquid which must be atomized before it is mixed with air. A jet of steam breaks the fuel oil into a mist.

The fuel oil achieves to the burner at a steady temperature to maintain constant and steady flow. In the oil, coke particles or impurities can partially clog the holes. Fuel oil requires a constant source of ignition. It is needed a gas pilot or the hot refractory in front of the burner to overcome it.

In fact, fuel oil is more difficult to keep burning than fuel gas. The gas flame provides a source of ignition for the oil. In entering fuel to the furnace, it should be under pressure condition, because it will quickly set conditions for a disastrous explosion if a flame is allowed to go out.

DEFINITION

Air preheater - a device which uses some of the heat in the flue gases to raise the temperature of the air supply to the burners.

Balanced draft - produced by discharging air into the firebox with one fan and discharging flue gases into the stack with another.

Breeching - the duct which gathers the flue gases and discharges them to the stack.

Burner - a device which is used to generate a flame, in order to heat up products using a gaseous or liquid fuel.

Combustion - the rapid chemical reaction between oxygen and a combustible material that releases heat and light.

Convection - heat transfer between a solid and an adjacent fluid which occurs by movement of the fluid molecules.

Convection section - the part where the convection tubes are located.

Draft - a slight pressure difference that produces the flow of gases through the furnace.

Draft gage - the draft inside the furnace that is measured in fractions of an inch of water.

Excess air - the amount of air requisited in addition to the air needed for combustion.

Firebox - the open area above the burners.

Force - the action of one body on another which will cause acceleration of the second body unless acted on by an equal and opposite action counteracting the effect of the first body.

Furnace - a device used for high – temperature heating.

Impingement - a burner flame touching a tube in the firebox.

Induced draft - a draft produced by discharging the flue gases out of the furnace with a fan located between the furnace and the stack.

One BTU - the amount of heat required to raise the temperature of one pound of water by 1 ^{o}F.

Orsat - a device which is used to test flue gas.

Pressure - the force exerted per unit of surface area.

Quenching - the cooling of a fluid by mixing it with another fluid of a lower temperature.

Radiant section - the part of the furnace that contains the radiant tubes.

Recuperative preheater - a heater that uses the air to recover the heat lost to the tubes by the flue gases.

Regenerative preheater - particularly used to assist to reduce danger chemical material input and output released to atmosphere.

Set pressure - the inlet gauge pressure at which the pressure relief valve is set to open under service conditions.

Stack - a type of chimney, a vertical pipe, channel or similar structure through which combustion product gases called flue gases are exhausted to the outside air.

Stack damper - the principal control of the draft.

Thermal radiation - electromagnetic radiation generated by the thermal motion of charged particles in matter.

Thermocouple - heat-sensing devices placed in different parts of the furnace.