Lecture 10: Refinery Units

Hello and welcome to the 10th lecture on Petroleum Technology. In this lecture, we will talk about various refinery units. We have already discussed the pipe still heater in our last class. Today, we will talk about some others. Among the various refinery units we see in the refinery heat exchanger is one of them and one of the important refinery units. It is required to heat, heating and cooling different streams of the refinery and there are various applications.

Here, several heat exchanger types are compiled. The vapor heat exchanger is that heat exchanger where the one vapor stream is there which is to be cooled, but much condensation is not needed. That type of heat exchanger is called a vapor heat exchanger. When the vapor is condensed in the heat exchanger due to the exchange of heat with the cooling stream, that type of heat exchanger is called a vapor denser heat exchanger.

After condensation, the liquid stream has to be cooled for the next utilization which is done in a cooler or after a cooler, which is another type of heat exchanger. Whenever the bottom stream of a fractionating tower is heated and refluxed back to the bottom of the fractionating tower that is called a reboiler. Double-pipe heat exchangers are very common in the refinery. It is seen that the double pipe heat exchangers are used for viscous streams or streams with low heat transfer rates. What is done in the double pipe heat exchangers, within the pipe, fins are installed and fins may be a spiral type or longitudinal plate type.

This increases the heat transfer area. So, double-pipe heat exchangers are used for those purposes. A jet-type heat exchanger is used in the vacuum distillation column to create a vacuum. Here, actually in the jet-type condenser, steam is condensed and this way it creates the vacuum in the distillation column. The working principle of this jet-type condenser is that, here, the product vapor and cooling medium are intimately mixed together and the heat exchange is done by the conduction process.

Now let us talk about how we can decide which material fluid or slurry whatever is to be passed through a tube. It is dependent on the nature of the fluid and which type of fluid we are handling. So, dirty streams usually are passed through the tubes because we can take out the tube with the tube bundle and clean the tubes. But whenever a stream has lots of cokes or debris in it, then that stream is passed through the shell and after some time, after some period of operation, the shell has to be disposed of. High-pressure fluids are flown through the tubes because tubes can withstand high pressure which shells cannot.

Corrosive fluids are usually flown through the tubes because corrosion-resistant tubes are comparatively cheaper than the shell. Water is flown through the tubes because of the reason, the water scaling can be cleaned by removing the tubes with the tube sheet and large volumes of liquids are usually directed through the shell. Here, the material of construction of heat exchangers is discussed and the metallurgy of the heat exchangers varies with temperature and the composition of the stream. Which stream has to be sent through the tube and which stream is to be sent through the shell is the determinant of choosing the material for construction. The majority of the heat exchangers are made up of 100 percent carbon steel and admiralty brass tubes have been used in freshwater-cooled exchangers because this type of tube can withstand water scaling.

Due to the high cost of brass tube bundles, many of those are replaced by carbon steel. Carbon steel is obviously cheaper than brass tubes, although brass tubes work very well in heat exchanging. As carbon steel is cheaper, we have to compensate for the cost and this working ability. In hot hydrocarbon service, 5 percent of chrome metal materials in heat exchangers are mostly used. This is one special type of material that can withstand corrosion due to the hot hydrocarbon stream. As the sulfur content in the crude oil increases, we have to go for a choice of using high chrome tubes and 12 percent chrome shell and channel linings are required to withstand the sulfur corrosion in the tubes and shells.

Now, we are coming to another very important refinery unit, which is the fractionating tower. The crude oil atmospheric distillation tower is the most important fractionating unit in the refinery. So, it has different types of design and we see that usually, the trays are of bubble cap trays, it is the most conventional and familiar design. These bubble cap trays we mostly seen in the atmospheric distillation unit. It is seen that small bubble caps are used for large liquid load and large bubble caps are used for large vapor load.

However many refiners choose a small bubble cap for small fractionating columns and a large bubble cap for large fractionating columns, may be 10 to 20 feet in diameter. Other types of trays, which are used as sieve trays, perforated trays, etc. are mostly seen in the vacuum distillation column. In the vacuum distillation column, this bubble cap tray is not very much used frequently, mostly sieve trays and perforated trays are the convention. Cast iron is largely used for bubble caps. Sometimes cast iron bubble caps may be the removable bubble caps, but the problem with removable bubble caps is that their bolts may catch rust.

Removing the bubble cap several times may break the bubble cap. This is one disadvantage, but several advantages are also associated with this removable type of bubble cap. In vacuum towers, pressed alloy steel caps are becoming important, because here, vacuum is operating and the streams contain high sulfur here in the vacuum towers. The atmospheric column is commonly lined more extensively than the flash column because the atmospheric column handles large amounts of crude oil which contains hydrogen sulfide gas dissolved in it. Also, the HCl may be formed because of the content of a small amount of NaCl in crude oil, which after getting in contact with the steam within the atmospheric column may be converted to HCl, which causes corrosion in the atmospheric distillation column. That is why, the atmospheric column, is the convention to line the atmospheric distillation column rather than the pre-flash column which we use to operate the lesser volume of the stream as well. The pre-flash column is not exposed for a long time in the crude distillation oil operation. Now, the top of the column is often lined with the metal Monel 400 which is 67 percent nickel and 23 percent copper to protect against condensing HCl in the top.

So, as the lighter products go up through the column, atmospheric distillation column, HCl, H_2S all go up along with the lighter products and as the temperature in the top of the column is much lower than the middle or bottom of the column, hence, HCl gets condensed in the liquid form and corrode the column top. So, the column top is usually lined with Monel metal, which can withstand this HCl corrosion. The lower two-thirds or three-fourths of the column is lined with 12 percent chrome cladding to protect against high-temperature sulfur corrosion. Here, in the lower part of the column, the heavier distillate fractions accumulate where there is a possibility to concentrate sulfur compounds in those fractions and there the temperature is much higher than at the top of the column.

So, here, the lower part of the column is exposed to a high-temperature sulfur environment, which is prone to sulfur corrosion. That is why the lower part is cladded with 12 percent chrome alloy. In the area of feed inlet or flash zone, 316 stainless steel may be required to protect against high naphthenic acid content in the crude. If the refiner handles crude oil that contains high naphthenic acid, this is also the reason for the corrosion in the feed plate. So, the feed plate or flash zone area is constructed out of 316 stainless steel.

Now, we are coming to another important refinery unit, which is a vacuum ejector and condenser. This system a combined system, vacuum ejector and condenser that produces a vacuum in the vacuum distillation unit. These two components act together, and condensers are normally situated between the ejector stages. Ejectors take out the overhead non-condensable gases from the top of the vacuum distillation column as well as steam and condense them to produce the vacuum in the vacuum distillation column. Surface condensers are used to condense the non-condensable gases.

This way the total system operates and this system reduces the vapor load handled by each successive ejector. So, some of the vapor load is handled by the surface condensers and some by the ejectors. So, as a whole, it makes the vacuum in the vacuum distillation column overhead top. The number of ejector stages in each design can range from 1 to 6, either 1, 2, 3, 4, 5. It is determined by the extent of or level of vacuum required in the vacuum distillation column. Ejectors use converging-diverging nozzle technology to convert potential energy into kinetic energy.

We will read afterward how the ejectors work. When the pressure energy of low-velocity steam flows through a nozzle, this ejector works in a converging-diverging nozzle technology, this is the working principle. The steam flows through a nozzle and it converts the steam into high-velocity, low-pressure steam. This is the drawing of a steam jet ejector. This is a static system. There is no movable part in the steam jet ejector.

The motive fluid is steam. It is a medium pressure or low-pressure steam, around less than 300 psig. Steam is used for this purpose. This motive fluid or steam, steam is expanded through this converging-diverging nozzle isentropically. And after this expansion the steam creates a low-pressure zone here and itself is converted with a supersonic velocity. The pressure at this region, the tip of the converging diverging nozzle is much lower than the overhead of the vacuum distillation column. This part is the connection between the vacuum distillation column and the vacuum column overhead.

As the pressure is lower in this area, the discharge from the vacuum column is pulled through this line, which is called the suction load. This suction load mixes with the steam together and flows through another converging-diverging nozzle, which is called a diffuser. And this is the diffuser throat. Again, this is expanded and the supersonic velocity is converted into pressure. This is the working principle of the steam jet ejector. Now, coming to pumps. Various types of pumps are used in the refinery. Among them, some examples are reciprocating steam-type pumps used to handle asphalts or semi-solid materials.

And that is because it handles very high-viscosity materials so, steam is used for pumping. Centrifugal pump is used for handling large amounts of medium viscosity oil. This is one use of a centrifugal pump and for highly viscous oils rotary pump is used. There are several other types of pumps, but these are the most common and highly used pumps in the refinery. Offsite facilities are those where we see that these are not exactly refinery operations, but these are highly necessary and indispensable parts of the refinery composition.

Under the offsite facility, we will learn about different segments; one is the intermediate storage tank. Intermediate storage tanks are those where, after the processing, the product streams are routed to this storage tanks where the streams are stored for say a few days and then they are routed to the blending or to another unit where they will go for meeting the final standard specifications. So, here it is an intermediate storage which is used for several days only. After that, the stream goes to a blending pump. Mostly, blending is done for gasoline and diesel to meet the specifications. So, blending pumps are used for that purpose.

Next coming to the final storage tank from the blending or from the point where the products meet the final standard specifications, they are directed towards the final storage. The products may be stored for a few weeks also and after that, they are transported for the end use. The transportation may be by tanks, barges or maybe Lorries or pipelines etcetera. Another offsite facility is the effluent treatment plant ETP. Here, all the products that do not have value are accumulated, in that mostly the waste waters are accumulated from where the oil is separated, the sour gases are stripped out, sulfur is removed and biological treatment is done to reduce the BOD of the water. So, this is the effluent water treatment so that the water we obtain after this treatment can be used for some purposes within the refinery or can be disposed off safely in the environment.

The next one is flare. Flare is an indication of a refinery. It is the flammable gases that are burned in a high long tower, tower top and this indicates the refinery. In the flare sometimes steam is injected at the flare top to reduce the black suit emission with the flame. A fire water system is highly required in the refinery to catch the fire hazard to fight against the fire at any point. So, fire water pumps, fire water rings, hydrants, etcetera are the accessories of this fire water system. A Blowdown system is where all the hydrocarbon discharge from the refineries is collected and manifolded to this collection unit. This is called the blow-down system.

The blow-down system provides the safe disposal of hydrocarbons, vapor, or liquid, whatever is discharged from pressure relief devices in the refinery at various points of operation. By using a series of flash drums and condensers arranged in decreasing pressure, blow-down material is separated into vapor and liquid curves. Whatever hydrocarbon materials are collected as the blow down are flashed in several pressure-reducing flash drums, one after another. And this way, the hydrocarbons are separated between these two phases, vapor and liquid. Liquids are taken out and vapor is again routed to another flash drum at a lower pressure than the previous one. Then again, some condensation occurs.

So, this way, at several stages of condensation and then flashing and then condensation flashing, this system gives us the separation of the condensable liquid and noncondensable gases. The noncondensable gases are routed in the flare. To obtain complete combustion or smokeless burning, steam is injected into the combustion zone of the flares. Steam reduces the hydrocarbon partial pressure there. So, it reduces the coke formation in the flare. So, obviously, as the coke formation is reduced, the soot formation at the tail of the flame is also reduced, and that has an environmental effect.

Steam injection also reduces emissions of nitrogen oxides that are also related to environmental pollution by lowering the flame temperature. This is another use. Oil movement and storage is one of the integral parts of the refinery and here, the functions are received and storage of crude in the tanks. First, crude oil is received by the refinery in tanks and it is stored for some time for next use. That is, it is then sent to the desalter and then to the atmospheric distillation tower, etcetera. Then transport of crude to different processing units, as I said, is sent to various processing units before it goes to the atmospheric distillation column.

Then, after receipt of intermediate feedstock and finished products, storage tanks are used in between when intermediate feedstock is collected and stored, even finished products are collected and stored and after that, those are transported. The blending of different components to prepare the finished product according to the specification. Here also, after blending storage is required before blending storage is required. So, here this is another step and delivery of finished products through oil tankers, lorries, barges, bullets, pipelines, etcetera. This is the transportation after the products are meeting their specification, that is, the finished products and they are transported to the point of use. There is equipment in oil movement and storage section, storage tanks are one of the most important of this.

There are several types of storage tanks and cone roofs. A cone roof is for nonvolatile materials; it is a fixed roof. You can say it is a fixed roof system when the oil, which is not that volatile, is stored within. So, it is safe for a safe liquid, for a safe product, which means, it will not generate dangerous gases at a moderate temperature. Next is a floating roof or floating head. You see this picture here, what is done in this cylindrical container, in a big container where liquid products are stored, that is volatile liquids, and the head or roof is floating on the surface of the liquid. So, what happens if the atmospheric temperature increases and the volatile liquids generate vapor? The floating roof is displaced and the vapor can be released.

There is a very thin space between the rim of the floating roof and the outside cylinder rim. So, from this thin section, the vapor can escape and hence the accident can be avoided. Another one is the pressure type, here big spheres or bullets are used, and it is mainly used to store the gases at high pressure. Floating comes with a cone roof, which is also used for storing volatile liquid at atmospheric pressure. What is done here? It is the floating head and on it, another cone roof is installed, it is situated over here. So, there is a space between this floating roof and the cone roof.

So, if at all the volatile liquid can emit any vapor, it can be within the cone roof. So, here, the accident can be restricted. There are several types of pipelines used for crude oil transportation, finished product transportation and pump suction and discharge. All these are very common in the refinery. These are the references. Thank you for your attention.