Lecture 09: Products and Process Utilities in Primary Processing, Pipe Still Heater

Hello and welcome to the 9th lecture on Petroleum Technology. In this lecture, I will cover several products and some process utilities that are used in the primary processing as well and we will learn about the pipe still heater. Here, in the very first time, we will talk about the major commercial fuel products, several fuel products we have compiled in this table. You will see the leftmost column shows the generic types of those products. The first one is liquefied gases. There are several liquefied gases obtained in the refinery.

In them, liquefied petroleum gas, which is LPG, which is very common to all of us, is one of the most important products obtained in this general. This is actually liquefied petroleum gas, which is a mixture of C3 and C4 hydrocarbons, that is a propane and butane mixture. As it is a mixture of C3 and C4 hydrocarbons, you understand that its density is very low, 0.5 to 0.55. These gas mixtures are compressed in the cylinder under pressure, and it is distributed to the industry or domestic heating purpose and also the automotive engines. So, according to the mixture components if the ratio of C3 and C4 differs, then obviously the pressure within the cylinder differs. If butane is more than propane, obviously, the pressure will be lower. And if propane is more than the butane, then pressure is higher. And it is completely dependent on what will be the composition of the LPG, is completely dependent on the demand of industry as well as for the domestic purpose. Next, coming to the gasoline. Gasoline is the first liquid product obtained from the atmospheric distillation unit. Gasoline is divided into two streams: one is motor gasoline, and the other is aviation gasoline. Motor gasoline, you know, motor gasoline is very much popular in the name of petrol. Petrol is the commercial name that we use. And it is obvious, you know, the petrol is used in different motor vehicles in the four-stroke and two-stroke engines, mostly the spark ignition engines and many other uses are there. And its density is quite high compared to the LPG, it is quite obvious. Aviation gasoline is one special kind of gasoline that is prepared for aviation use, maybe for civil aviation or military use. And also it can be used in different spark ignition engines. Both of these motor gasolines, petrol and aviation gasoline, both of these two streams have to meet the industry standard or have to meet the standard specification fixed by the country. Next, coming to the kerosene. Kerosene is coming just after the gasoline cut in the atmospheric distillation unit. Commercial kerosene is aviation turbine fuel, ATF, which is also a precision cut that is used for aviation purposes. It is mostly used in the military jet engine, but it can also be used for civil purposes. The stringent specification is maintained for this aviation turbine fuel before it is used for aviation purposes. We know that kerosene is in our country, a poor country like ours, we use kerosene for illumination purposes, but that is not accepted as a commercial product. The commercial product is the ATF. The next one is the automotive gas oil. Automotive gas oil is actually the cut we get from the atmospheric distillation unit, which is just coming

before the atmospheric residue that we draw from the bottom of the atmospheric distillation column.

Not only is the gas oil obtained from the atmospheric distillation column as the straight run cut, but we also get the gas oil from various secondary processing units. The fraction of the secondary processing unit may be the cracking, visbreaking, coking, reforming, etcetera. All those gas oil cuts are collected together, they are blended at different portions or proportions, and the marketable diesel fuel is prepared. So, diesel is actually a blended product; it is not a direct product coming from any unit of the refinery. Obviously, its density is higher than that of kerosene and all others. Diesel fuel is used in different motor vehicles, mostly compression ignition engines and it has applications in light duty as well as heavy duty.

For light duty, whatever diesel fuel is used is called light diesel oil, LDO. The heavy-duty diesel fuel is called HSD, high-speed diesel. Their properties are also different. You know diesel fuel has the most important property, cetane number. The cetane number is different in whatever is in there, in LDO and HSD. Now, coming to the last one, distillate and residual fuels, this cut mostly we consider coming from the vacuum distillation column. Distillate fuel, which we get as a side stream from the vacuum distillation column, can be used in marine engine power generation and also for different domestic heating purposes and its density is higher.

Now, coming to the lubricating oil. Lubricating oil is one of the most important cuts coming from the vacuum distillation column which comes from the lube-bearing crude oil. Whenever we process lube-bearing crude oil in the vacuum distillation column from the atmospheric residue of the atmospheric distillation column, we get the lubricating oil. Lubricating oil is not a fraction that is used for the purpose of fueling; it is not a fuel oil. It is used in the industry and different instruments where two moving parts are there where there is friction between the two moving parts, say gears, and we use the lubricating oil to avoid the wear and tear of these two moving parts as well as whatever heat generated by the friction of the moving parts can be dissipated by this lubricating oil, is absorbed by the lubricating oil.

Now, coming to the residual fuel oil, this is also a heavy cut obtained from the vacuum distillation unit. So, you understand that the density is quite higher than the lubricating oil and it is used in boiler steam heat for industrial heating and drying. And also, you will see this fuel oil is used in some big burners used in the different furnaces in the refinery. Now, let us talk about the utilities we use in the refinery. I will cover several utilities, not all. There are many types of utilities used in the refinery and whenever we design a refinery, then those utility production and their consumption, utilization points are to be taken care of.

So, utilities are coming within the refinery configuration. The utility systems in a refinery require significant investment because they occupy a significant part of the refinery. It is very important that the utility systems here, several utility systems are mentioned: steam, cooling water, air, electrical power etcetera. Except these, there are many others also, are reliable and available in sufficient capacity at all times. So, there should be a provision that at all the time, 100 percent availability of these utilities is required at any point of time in the refinery, without which it may happen that some part or whole of the refinery work will be disrupted. So, a failure of any one of the utilities at any time will cause a major refinery upset, or sometimes the total refinery shut down, without which the refinery cannot run.

So, this is the importance of the utilities. Hence, refinery utility systems are an integral part of the refinery configuration. Now, here, let us see how utility consumption varies with the type of crude oil and the specifications of the product. Obviously, it is so because depending on the type of crude oil whether it is a light crude oil or heavy crude oil, the utility consumptions vary. Just an example, if we take the steam as one of the utilities here. So, if the crude oil is lighter, then you know that, we introduce steam at the bottom of the atmospheric distillation column as well as at the bottom of the steam strippers. Steam takes out the lighter boiling fractions from the heavier cut of the oil. It strips out and makes the distillation operable as well as takes out the lighter boiling cut from the steam stripper units and makes the side streams stabilized. So, depending on the type of crude oil, if it is lighter crude, the amount of steam required is something else than if we use the heavier crude. And also it depends on the specification of the products. If we have to fix the specification of the product, accordingly we have to fix whatever vapor pressure is needed for a definite cut and depending on that we can utilize the steam.

There are several others here. You see the table for 100,000 barrels per day of atmospheric distillation unit and 50,000 barrels per day of vacuum distillation unit. What are the different kinds of utilities that may be used, like fuel, electricity, steam, cooling water etcetera are tabulated. This table is prepared for processing a mixture of middle distillate, Middle East crude oil. Here, I have compiled some of the utilities, their production points, and their utilization points. These are the basic refinery utility systems.

First one coming is the steam. Steam is produced in waste boilers throughout the refinery because it is one of the indispensable utilities and it is used for process heating, distillation, steam stripping, steam turbine etcetera. There are various other uses of steam at many points of the systems of the whole refinery. And then coming to the cooling air or water. Let us talk about cooling water, which is mostly used. And cooling water is obtained from the cooling tower. And if you go to the refinery you will see there are many cooling towers here and there located. And so from there, we get the cooling water and cooling water is used for the process of cooling, condensing steam. In the refinery mostly in the distillation towers, you know that the overhead vapors are to be condensed

and cooled and then stored in a reflux drum from which we can take out the product liquid stream as well as we can reflux some cut into the distillation tower back. So, for those systems, we require the cooling water or cooling air as well. Next, fuel gas or fuel oil is obtained from the waste gas from crude refining. From the overhead, we get the refinery off gases and refinery off gases are treated in the gas treatment section from where we can take out the valuable gas cuts. And then the excess amount of the gas which is not used as such is used as the fuel gas. As well as natural gas that is methane, methane is the natural gas that can also be collected and combusted in different boilers furnaces etcetera, and gas turbines. So, fuel gas, oil, etcetera, fuel oil, is obtained from the heavy cut of the distillation towers, and all these gases and oils are used in process furnace, boilers, gas turbines etcetera. Electrical power is also one of the most important utilities, which is obtained from the local grid. This is the driver of various types of machinery lighting throughout the refinery, as well as electric tracing.

The usual normal water that we get from the local municipality, lake, artisans well is used for boiler feed water, wash water, cooling water make-up etcetera. So, this is a small discussion on basic refinery utility units.

Here I will talk about several small units which are important in refinery, but not much discussed. One is the vacuum-producing system. You know that a vacuum distillation unit requires a vacuum-producing system. Without that vacuum, distillation cannot run. Here, one of the important components is the steam jet ejector system where we use steam as well as the non-condensable gases coming out from the tower top. It has investment costs lower, but the utility cost is higher, which means, steam is one of the utilities used over here. The cost includes the steam cost and then the vacuum pump. Vacuum pumps can also be used whose initial investment cost is higher, but its utility cost is much lower. So, a combination of the two systems can be used. Instead of these two, you know that in the vacuum-producing system, we need surface condensers. Surface condensers are used between the two steam jet ejector systems.

Usually steam jet ejector systems are used in different stages. The stages may extend from one stage to six stages depending on the amount of vacuum required in the vacuum distillation column. So, accordingly, the vacuum-producing system is designed.

Now, coming to the emission and waste products management. This is also an important section of the refinery. H_2S in overhead gas goes to the gas sweetening process. If the crude oil which we are processing in the atmospheric distillation column has dissolved H_2S gas in it, that gas comes out from the tower top along with the refinery gases. Whenever we try to process those refinery gases in the gas processing unit, this H_2S gas creates corrosion and disturbance and quality becomes low, and the ultimate product quality becomes low. So, we have to remove this H_2S gas from the refinery off gases.

Hence, after collecting the overhead gas before it goes to the gas processing unit, the H_2S is removed in a gas sweetening process.

Sweetening means the removal of sulfur components from the gas and making the ultimate gas sweet. And next one is the overhead sour water and desalter effluent water which are processed by a sour water stripping unit. The condensable gases are obtained from the tower top of the distillation tower as well as different fractionating towers of the various secondary processing units. Whenever we condense those condensable vapors in the condensers and coolers, we find that, along with the oil layer, we get a water layer at the bottom, which is the sour water. Also, the desalter produces effluent water that contains various types of impurities, so you know what the work of desalter is.

So, all these waters collected together and are processed in a sour water stripping unit. The sour water stripping unit strips out hydrogen sulfide and ammonia. If these are dissolved in the sour water, these are stripped off and the stripped water is then sent to the wastewater treatment facilities. So, otherwise, the wastewater treatment facility will also not run if those objectionable gases are present in the sour water.

Now, coming to the refinery equipment and in different types of refinery equipment one of the most important equipment is a pipe still heater. Do you know that pipe still heater we use before the crude oil or residue, atmospheric residue, goes to the distillation unit? Let us talk about the crude oil pipe still heater. The crude oils are heated up to about 350 degrees centigrade in a pipe still heater. This 350 degree centigrade is the general temperature. This temperature is fixed by the property of the crude oil that we are handling before entering into the atmospheric distillation column. So, crude oil is first heated in the pipe still heater, it generates the required amount of vapor and then the crude oil is flashed in the feed tray of the distillation column.

Next is this heater, which is a special type of furnace with a large number of tubes connected through bends in multiple rows. There are several tubes there, which are connected by bends and they are situated around the walls of the pipe still heater. The walls produce the heat transfer area and maybe these tubes may be situated either horizontally or vertically whatever and crude oil is flown through these pipes or tubes at a high velocity, so that it can capture the heat of the tubes in very high efficiency. The still is built with two distinct heating sections, radiant section and a convection section. So, these are the radiation section and convection section, these are the two important sections of the pipe still heater.

Let us come to this picture. This is a box type pipe still heater. You can see the shape of this pipe still heater, it is rectangular shape. The box-type pipe still heater may be rectangular or square type and you see this is the convection section. This part is the convection section, then coming to the shield section or shock section, and then coming

to the radiation section. So, this part is the radiation section. Both the sections and burners, open burners are located either on the floor or may be located at the wall where there is no pipe or tubes. And radiation section gets direct heat from the flame of the burners and the convection section gets heat from the flue gas generated by the burners. This shield section or shock section is that where there are two to three rows of tubes situated at this stack position. This is stack and this shield section separates the convection section and radiation section. Radiation section tubes get direct heat from the flame of the burner, the shield section gets heat from the flame of the burner as well as the flue gas and the convection section gets the heat from the flue gas only. Oil enters the convection section and gets heated. Maybe, the temperature may rise up to 260 degrees centigrade in the convection section. Then, crossing the shield section, the crude oil comes into the radiation section where it gets the direct heat and the temperature increases up to 350 degrees centigrade. After that, the oil goes out and goes to the atmospheric distillation column feed tray. Now, there are types of pipe steel heaters. The box type, I have already shown, the box type with the radiation section, which usually is of a square or rectangular cross-section that we have seen. And tubes are arranged horizontally or vertically along the heater walls, either horizontally or vertically and burners are located on the floor or on the lower part of the longest side wall and are mainly used where large capacities or large heat duties are required when we handle a large amount of crude oil. The vertical cylindrical type heaters are those which have a cylindrical shape and have a vertical axis. Burners are situated on the floor, on the base of the cylinder and tubes may be arranged in a circular pattern around the walls of the furnace or sometimes it is seen they are in an octagonal pattern also ok. So, this is the vertical cylindrical type heaters. Whenever we go for the pipe still heater design we have to keep in mind several points and the points are compiled over here. The computation of the flash vaporization curve of the feedstock is required to determine the vaporization temperature of the crude oil.

This is very important, we have to see at what temperature the crude oil gets vaporized, and it forms vapors within the tubes of the furnace. Sensible and latent heat duty up to the vaporizer temperature is required, but as well as we also have to determine whether cracking occurs. If cracking occurs then what is the decomposition temperature? So, we have to be careful about this temperature. We should not go up to this; otherwise cracking will occur within the furnace tube which produce lots of coke deposition and we will lose valuable cuts.

Next is the radiant absorption rate suitable for the operation or the stack. Tube length and stack gas temperature, this is for economic analysis. We have to see what is the tube length required and also the what is the stack gas temperature up to which we can reach. And radiant and radiant section area and tube length and convection section area and tube length are also important for designing the tubes, tube still heater or pipe still heater. How

many numbers of tubes are required? What will be the length of the tube and also what is, how much area will be kept for the radiation tube and how much area will be kept for the convection tube depending on the type of crude oil and the amount of crude oil that we are handling? For sweet crude, the radiant tubes and lower rows of the convection tubes are typically of 5 percent chrome with carbon steel. This is the material of construction for sweet crude. If it is sour crude obviously, the MOC will be different because of the corrosion. Now, pipe still outlet temperature is important. The outlet temperature of the still is usually higher than the vaporizer temperature, but if steam is injected into the vaporizer that causes a further decrease in temperature because steam lowers the vapor pressure of the oil. So, at the same time, it decreases the temperature. The vaporization that occurs in pipe still tubes is complicated by the constantly changing pressure throughout the entire length of the pipe still tubing. Throughout the pipe still tubing as the crude oil is flowing through it, is continuously getting heated and vaporized at different locations. So, at different locations the vaporization is different and vapor formation is different. So, at the same time, the pressure drop is also different at various points throughout the entire length of the pipe still heater, pipe still tubing. A large part of the pressure drop through pipe still occurs in the transfer line from the still to the fractionating tower. This is the pipe still and from here it goes to the feed tray of the atmospheric distillation unit. Say, this is the atmospheric distillation unit feed tray. This is a pipe still heater. So, in this part, there is no heating. So, obviously, a sudden decrease in temperature occurs, and obviously, pressure drop increases over here. So, this transfer line should be kept as small as possible to avoid the temperature decrease as well as to avoid the pressure drop.

Vaporization of pipe stills the amount of vaporization is related to many processing operations. If the liquid contains high boiling parts, that are sensible, sensitive to the heat, then vaporization should be suppressed. Obviously, if the high boiling part which is sensitive to the heat is facing the high heat then there is a chance of cracking within the furnace tubes. So, accordingly, the vaporization should be controlled. Another thing is coke formation may be initiated if the liquid phase becomes very small in amount with reactive materials in it.

If the crude oil is lighter and it produces a large amount of vapor within the furnace tube, then the liquid phase remaining will be very small compared to the vapor phase produced. And if that liquid phase contains reactive materials in it, reactive materials here means the coke precursors or coke forming materials, then at that little amount of liquid phase the coke formation will start which should be avoided. These are the references. Thank you for your attention.