Lecture 06: Primary Processing of Crude Oil: Desalting

Hello and welcome to the 6th lecture on Petroleum Technology. Today in this lecture, I will cover the primary processing of crude oil. Under which, in detail, we will talk about the Desalting process. The petroleum refining process, which is done in the petroleum refinery consists of physical processes as well as several chemical processes. In the physical process, the major process is crude oil distillation, which is done in two ways: atmospheric distillation and vacuum distillation. These are the two types of distillation processes which is done in the refinery. Except for the physical process, there are several chemical processes that are practiced in the refinery and among them, I have mentioned a few, cracking, reforming and hydrotreating. There are many.

So, now let us come to this introduction to crude distillation. Here, before going to the actual crude distillation unit, let us get acquainted with some of the essential equipment of the crude distillation unit. In that very first we will talk about the pipe still heater. A pipe still heater is a type of, it is a type of tube still heater. Also, we can say, it is used to heat crude petroleum before the petroleum crude is introduced into the atmospheric distillation tower.

Next coming to the fractionating tower, the fractionating tower is obviously, the crude distillation unit which is the distillation tower. Next are the steam stripping columns. Steam stripping columns are several columns, maybe some bubble cap tray columns which are used to remove the light ends or light fractions from a heavy fraction by using steam. Next the heat exchangers, the heat exchangers are obviously, the essential parts of the crude distillation unit. It is required to heat the crude or heat the different petroleum fractions as well as exchange heat with the cold stream and hot stream. Now coming to the condensers and coolers. These condensers and coolers are used in several parts of the crude distillation unit.

These are used to condense the vapor part of the crude distillation unit, which comes out from the topmost part of the crude distillation unit. Next coming to the pumps and connecting lines. Pumps and connecting lines are obviously, used for transportation of the crude oil as well as the petroleum fractions obtained from the distillation units. Next, the storage and accumulated tanks, are obviously necessary after we get different crude oil fractions from the crude oil distillation unit and the next one is instrumentation which is also a very necessary part. Now before adapting to the processing of a particular crude oil stock, the following factors must be considered.

So, before we go for an atmospheric distillation of crude oil we have to do a crude oil assay. What is that? We have to do the TBP distillation of that crude oil and get to know the boiling range of the oil stock, in which boiling range the crude oil is boiled. So, the

initial boiling and final boiling temperatures are determined, as well as what is the TBP slope. So, different types of crude oil have different types of TBP slope and accordingly, we can come to know what the boiling range of that crude petroleum is. This boiling range is also a determinant for determining or fixing the temperature of the pipe steel heater as well as the operating condition of the atmospheric distillation unit.

Next coming to the stability of the stock with respect to heat, this is the same thing as the previous one. As soon as we can determine the boiling range of a petroleum stock we can come to know within this temperature range the crude oil is stable. If we increase the temperature beyond the final boiling temperature of the crude oil, obviously, the crude oil will be highly sensitive to the heat and its stability will be questionable. So, we do not want any higher temperature, higher than the final boiling temperature of the crude oil. Because, if we go beyond that, then there will be a decomposition or cracking in the crude oil we will see that, and the whole distillation column will be totally filled up with vapor and fumes that is a highly undesirable condition. Next coming to the specifications of the products to be produced depending on the boiling range. Again, I have to talk about the boiling range. Depending on the boiling range of the stock we can come to know which type of crude it is, whether it is light boiling, lighter boiling crude. That means it contains lighter hydrocarbons, which means, light crude or heavy crude containing heavier molecular weight hydrocarbons as well as a higher boiling range.

So, depending on this boiling range of the petroleum oil stock we can come to know which type of product we are going to get from the atmospheric distillation unit as well as the vacuum distillation unit. So, accordingly, we have to fix the specification of the products that we will get as the distillate fractions and these distillate fractions are said to be ‘cut’. These fractions are said to be ‘cut’ and the cut which is obtained directly from the atmospheric distillation unit is called a straight run cut. Straight run cuts are those that come directly from the crude oil distillation unit without any processing again in the next step and all the countries have their own specifications for each type of crude petroleum cut or fractions which we get from the atmospheric distillation column as well as the vacuum distillation column. For example, having Indians have Indian standard specifications fixed and before we go to selling in the market of distillate products we have to bring the specifications of the distillate products according to the standard specification. Now, coming to the introduction of the crude petroleum distillation. Here flow diagram is shown. The crude oil is first sent to a desalter unit.

Desalter is the unit that is a necessary part of any atmospheric distillation crude distillation unit which separates or removes the salt and water content in the crude petroleum. After the desalting unit, the crude oil free of any salts or water is sent to a pipe still heater to raise the temperature of the crude oil before it goes to the atmospheric distillation column. It is done to raise the vapor in the crude petroleum so that it can be flashed in the feed tray of the atmospheric distillation unit. After the crude petroleum is

introduced into the atmospheric distillation feed tray, we get several fractions in that. The first on the topmost one is the off-gas. Off gases are those which consist of C1 to C4 hydrocarbons that means, from methane to butane, except that we may have hydrogen H_2S etcetera if they are dissolved in the crude petroleum.

So, off gases are taken out and from the next part of the distillation unit, we start to get the liquid products. In the liquid products, the first one is the light naphtha. Light naphtha is the fraction which is having the range of C5 to 90 degree centigrade cut. This is called C5 to 90-degree centigrade cut which means, it starts from pentane and the fraction which boils up to 90-degree centigrade is called light naphtha. Next comes the heavy naphtha, which is usually taken out from the side tray in the boiling range of 90 to 140 degrees centigrade. This is a 90 to 140-degree centigrade cut.

This 140-degree centigrade or 150-degree centigrade or 130-degree centigrade whatever cut we will take from the side tray of the distillation unit is dependent on the country's need or country's specification. Now, coming to the kerosene part. Kerosene is usually taken out in the boiling range of 140 to 240 degrees centigrade or it may be 230 or 250, again depending on the specification mentioned by the country. And the next cut is gas oil, gas oil boils in the range of 240. If we take out kerosene in up to 240 then obviously, gas oil will be taken out from 240 to 330 or 340 or 350 depending on the type of crude. If it is a light crude then obviously, the end temperature of the gas oil will be lesser than that for the heavy crude petroleum. Now, after the gas oil we do not get any more distillate fraction from the crude petroleum distillation because then we need to increase the temperature of the atmospheric distillation unit.

If we increase the distillation temperature, then obviously, there is a tendency to decompose the petroleum crude inside the column which makes a column full of fumes as well as the quality of the product will be degraded. So, we take out the atmospheric residue from the bottom of the column after we get the gas oil in the atmospheric column. This atmospheric residue is then put into the vacuum distillation unit. Obviously, the atmospheric residue that we have drawn from the bottom of the atmospheric distillation column contains many valuable distillates that were not possible to take out in the atmospheric distillation unit's parameter or condition. So, this residue is put into the vacuum distillation unit which operates at vacuum and under the vacuum we get several other important distillate fractions. In that, vacuum gas oil is there and from the bottom, we get vacuum residue.

Obviously, we get several other cuts from the vacuum distillation unit as per our need or as per market demand, but usually, we term vacuum gas oil combining all the cuts together. Now, the vacuum residue that we get from the bottom of the vacuum distillation unit almost does not have any valuable cut remaining in it. It mainly contains bitumen, wax etcetera which are very heavy cut and these are not fit for use for any fuel purpose.

Some atmospheric residue may be taken out before it goes into the vacuum distillation unit depending on the secondary processing units' needs as well as the nature of the atmospheric residue, which is obviously determined by the nature of the crude oil that we are processing. So, both these vacuum residue and atmospheric residue are sent to the various secondary processing units, which are actually upgradation processes because these residues are to be upgraded to get some more valuable fractions. Out of it, which are different types of units that are operated at high temperature as well as with catalyst etcetera which we will talk afterward.

Now, coming to the crude desalting operation. I said that before we introduce the crude into the atmospheric distillation unit, we have to put the crude into the desalting unit. What is desalting? When we extract the crude oil from the mines through wells, the crude oil is obviously associated with salts and water, brine water. In the water, there are several types of salts dissolved into that: sodium chloride, sodium chloride, calcium chloride, magnesium chloride and various others and soluble in the water associated with the crude. These salts and solids that come out with the crude petroleum are very undesirable because they cause corrosion, they cause fouling, plugging and catalyst deactivation in the next stage of operations, even into the atmospheric distillation unit.

They cause corrosion in the material of construction of the atmospheric distillation unit because this NaCl, calcium chloride, and magnesium chloride form HCl at the condition of the atmospheric distillation column and obviously, HCl is highly corroding in nature and fouling, plugging and catalyst deactivation also in the next stage of the operation when we will do the secondary processing operation. Now, the purpose of desalting is to remove such contaminants by water washing, followed by coalescing the contaminant-laden dirty water by the high electrostatic force and then separation from the oil. This is done in the electrostatic desalter. Now, usually what is done, the crude petroleum is washed with water, water wash is given and then it makes water-in-oil emulsion. It is difficult to settle the water in an oil emulsion and get the water separated out of the oil.

It takes highly time, is a time-consuming process and sometimes never happens. So, we introduce the electrostatic force to break this emulsion and get the oil separated along with the salts contained in it and oil is separated out from the water. This is the purpose of the desalting unit. Now usually most of the salts that we see in crude petroleum are NaCl sodium chloride. Other salts are there, but comparatively in a lesser quantity.

So, the total salt contained is expressed as the sum of the equivalent of sodium chloride. All the salt concentrations are expressed in the unit of ptb which is pounds of NaCl per 1000 barrels of crude. Usually, it is seen that in crude petroleum after it is mined from the well and then transported in the pipelines as well as transported in a large barge or tanks, the total content of oil may range from 10 to 500 ptb and on an average it is seen

that more than 100 ptb and water content is around 0.1 to 2 % percent. So, all these are to be removed by the desalting unit and the number of stages of desalting is determined by the next stage of operation in which the petroleum fractions or crude petroleum will be used. So, now let us come to the operation of desalting.

Crude oil is first water washed by about 5 to 7 percent. Water is added to the crude oil to dilute the salt content of the crude oil and a chemical that assists in breaking the emulsion. Water in the oil emulsion in which a demulsifier is added to the crude oil. This whole mixture is heated in a heat exchanger and then sent to a mixing valve. The mixing valve makes a good mixing between the water and oil and forms a stable water in oil emulsion. So, the water and oil phases come in very near contact with each other and whatever salt is present in the crude oil can come into the water phase. Now, after that, the whole mixture is sent to a desalter unit.

Here you see that the electrostatic force is applied to the water in the oil emulsion phase and usually the electrostatic force is applied in this kv kilovolt, 10 to 30 kilovolts and this way what happens is, the water in the oil emulsion breaks down. Water forms large drop and ultimately coalease together and give two phases. The bottom one is water with salts and the upper one is that oil, that means desalted oil. So, the water plus salt phase is taken out by gravity as effluent water and desalted crude oil is taken out from the top part of the desalter unit. Now, these are the conditions operating conditions of desalting the pressure is kept in such a way. So, that the crude oil as well as the water associated with it, should not get vaporized. The pressure is kept higher than the vapor pressure of crude oil and water and usually 500 to 1000 kilopascal pressure is applied depending on the type of crude oil as well as the amount of water present in that after water washing.

Next is the temperature, the temperature of the desalting unit is kept at around 100 to 150 degrees centigrade. The temperature is kept at this temperature to reduce the viscosity of the oil. So, that oil can mix with water easily and then get the salt transferred to the water phase. The wash water is kept in the range of 5 to 7 volume percent depending on the amount of salt present in the crude oil. If the amount of salt is lesser then less amount of water is needed.

If the salt content is more, obvious, we need more amount of wash water for the crude oil. Now, depending on the next use of the crude petroleum or maybe the content of the salt in the crude petroleum, the stages, number of stages of the desalting unit is fixed. For a single stage, it is seen that the efficiency is 85 to 95 percent and after the desalting the salt content of the desalted crude becomes 2 to 5 ptb. And when we go for the 2-stage operation, 97 to 99 percent salt removal is observed and the typical salt content of the desalted crude is coming as 0.3 to 0.5 ptb. Usually, a single-stage desalting unit, as we have discussed in the previous stage, is used in the refinery, but when the residue from

the crude petroleum is treated in the hydro desulfurization, residue hydro, then we need the 2-stage desalting process. These are the references. Thank you for your attention.