Lecture 5: Evaluation of Oil Stocks: Vaporization Characteristics

Hello, and welcome to the 5th lecture on Petroleum Technology. In this lecture, I will cover the rest part of the evaluation of oil stocks under which we will talk about the vaporization characteristics of petroleum stocks. Vaporization characteristics of oil stocks are characterized by different batch distillation processes. Batch distillation curves are those where the percentage distilled or recovered is plotted against the temperature at which they are distilled. So, here, the first coming the true boiling point TBP distillation, which is theoretically a perfect fractionation or perfect separation process. Here it is said that the fractions are having complex mixtures of different hydrocarbons.

And those hydrocarbons are separated exactly at their boiling points with exactly the same amount contained in the mixture. So, here in this graph, you see, it is said, this is a mixture of only two components, a binary mixture of A and B. T_A is the boiling point of A, and T_B is the boiling point of B. And A is 30 percent, and B is 70 percent in a 100 percent mixture.

For a theoretical TBP curve, if we start heating the mixture for distillation, we will see that the temperature will rise in the distillation till up to T_A. And whenever the temperature reaches T_A, A starts to come. And A will come up to 30 percent point when all A is exhausted. And then as there is no A, the temperature will rise up to T_B. And after it is risen up to T_B, B starts to come as T_B is the boiling point of B, and it will go up to 100 percent.

So, it is a step curve, but practically it does not happen. You know that there is always some overlap of one component with another. Whenever A starts to come at T_A, after some time, the temperature will rise to some extent, and then we will find there is a mixture of A and B distilled out. And again when A is completely finished, then only B will come purely. So, obviously, there is an overlap in the distillation curve. Although we can do the true boiling point distillation by a distillation column having an infinite number of trays with a very high recycle ratio, and reflux ratio.

Now coming to another type of batch distillation, which is done in the laboratory, ASTM distillation. The full form of ASTM is the American Society for Testing and Materials. ASTM D158 is the standard of atmospheric ASTM distillation. It is non-fractionating, which means, the separation is very poor. Look at picture A, where the percentage of distilled is plotted against the temperature. The stepwise curve is the TBP curve, it is denoted the TBP curve, and the dotted line is the ASTM curve.

So, ASTM is showing an imperfect fractionation, but TBP is better than ASTM. So, we do not get this type of step curve in TBP. If you look at picture B, you see that the TBP curve is steeper than the ASTM curve. Usually, we see that the TBP slope is more than ASTM, and ASTM is flatter. Now coming to another type of batch distillation, which is called equilibrium flash vaporization, EFV.

It is also a non-fractionating separation. What is done in this type of distillation, the mixture of hydrocarbon is taken at a particular temperature, and that mixture is flashed at a lower pressure. So, this way, the same material can be heated at different temperatures, and flashed at the same pressure and same low pressure. So, all these experiments at different temperatures will give us different amounts of vapor flashed in the separator. Hence we can get different distilled percentages.

This vapor and liquid in the separator remain in the equilibrium state. So, its name is equilibrium flash vaporization. This way we get different points in the EFV curve, and this curve shows the comparison of the slopes of the TBP, ASTM, and EFV curves. So, the TBP curve is the steepest one, then coming to the ASTM curve which is coming next, and the EFV curve is flat. Usually we take a 10 to 70 percent slope of all the curves, and it is seen that the 10 to 70 percent slope of TBP is greater than that of ASTM than that of EFV.

Now, coming to the discussion of mid percent curve. The petroleum property varies throughout the fraction as we gradually go down from one compound to another compound. And distillation is a means to arrange these compounds in terms of their boiling points. And it is seen that as we go down, the property also changes. So, the rate of change of a physical property of a petroleum fraction drop by drop is represented by mid percent curve.

A petroleum engineer may have a query to determine the physical property of a commercial width of petroleum fraction. It is seen that some of the properties they vary in such a way that whenever we distill that petroleum fraction, the difference in the physical properties of one drop with its preceding drop and the succeeding drop is equal. Hence for a short range of fractions, the physical property of that range is lying exactly at the middle point of that range. So, this is called the mid-percent curve. Look at this figure, this is crude oil distilled and its percentage distilled is plotted against the specific gravity of different cuts.

So, here the whole curve is divided into 19 fractions, 1 to 18 are divided into 5 segments and 19 is 10. 19 is 10 whereas, others are 5. Now, how can we determine the property, any property? here, it is specific gravity, how can we determine the specific gravity of the whole cut? Actually, for determining a mid-percent curve, the curve should be straight, but obviously, a curve is not straight all the time, but it is substantially straight at a short range. So, if we look at this curve, we see that from 20 to 90 percent, the curve is almost straight and the specific gravity of this cut is determined by several horizontal lines drawn in the curve and the corresponding specific gravity is determined from the curve. And you see that from this point to this point, the curve is almost the straight and the horizontal line passes exactly at the middle of this curve. This section where the curve is straight, but for the other other part 1 to 4 and 19 for them the curve is not straight.

So, what is done is the straight line, the horizontal line is arranged in such a way that the triangle formed at the top and bottom of this line has an equal area. So, this cut, this 19 cut has the specific gravity according to this straight line. So, what is the specific gravity of this whole petroleum cut? That is, the 5 into this 18 cut specific gravity plus 10 into this 19 cut divided by 100. This will give the full range of specific gravity of the petroleum cut, which we have plotted over here. The mid-percent curve cannot be used for the properties of the oils which are not additive because we are doing the arithmetic mean, we are calculating the properties from the mid-percent curve by arithmetic mean.

So, the properties should be additive. Several examples of additive properties of oil are specific gravity, boiling points taken from a TBP curve, percentage sulfur, and hydrogen to hydrocarbon ratio in the oil. Some non-additive properties of oils are viscosity, API gravity, color, flash point etcetera. Although viscosity is non-additive property, sometimes it is seen that, for a narrow range of fractions, viscosity is additive. So, sometimes viscosity is also drawn in the mid-percent curve. For the properties that are not additive, we draw the yield curve.

The yield curve is determined experimentally by blending fractions together and plotting the property value so obtained. Here what is done, there are two types of yield curves drawn, one is the residue yield curve, and the other is the distillate yield curve. The residue yield curve is drawn by blending different mixtures of residues and their viscosity is determined and plot of the viscosity of residue product versus the percentage of residue gives the viscosity yield curve. Distillate yield curve, one example is the flash yield curve, where the plot of temperature versus percentage distilled. Here the flash vaporization is practiced where we get the different percentages recovered or distilled by the plot of temperature versus percentage distilled. So, this will construct the flash yield curve, which is the distillate yield curve.

These are the references. Thank you for your attention.