Prof. J Murali Krishnan
Department of Civil Engineering
Indian Institute of Technology Madras

Lecture-16
Asphalt Usage and Processing - Part 2

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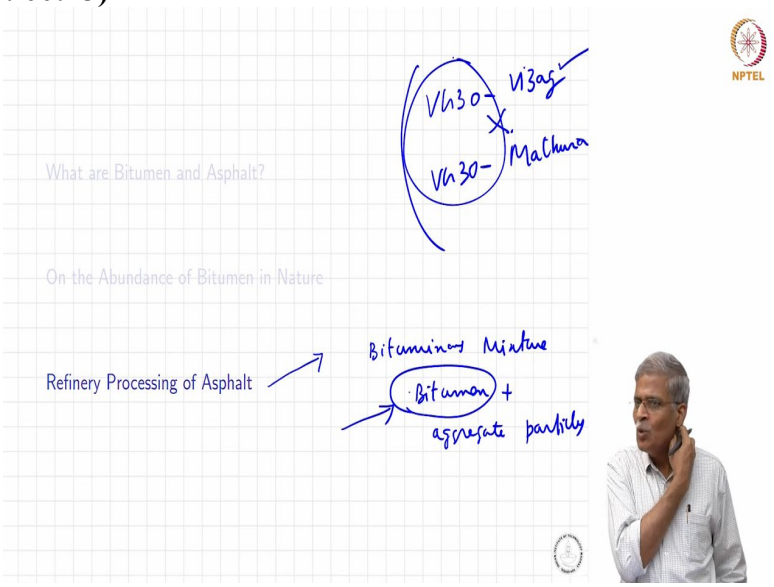

Let us know try and understand what the refinery processing of asphalt. Now why this is important because your bituminous mixture whatever be the name consist of bitumen, which I mean as binder plus aggregate particles. Now if you do not understand how bitumen is produced, manufactured, processed, different words can be used, we won't be in a position to understand the complexity related to this. To give you an example, if you are familiar with a VG kind of a specification.

A VG30 from Vizag refinery is not the same as the VG30 from Mathura refinery, they are not one and the same thing. So, what that means, the processing methods here will be different the raw material that is used may be different and while you will be meeting the spec, the actual rheological response of the material will not necessarily be the same. So, if I make this statement and if you have to understand it, we need to really get into the deeper aspect of the refinery processing.

So, but before we proceed further, I need to caution you that refinery processing or petroleum engineering is a 4 year undergraduate program at any of the higher universities. So, in the next 15 or 20 minutes, I will be discussing with you the refinery processing that needs to be understood from the perspective of a civil engineer and not more than that.

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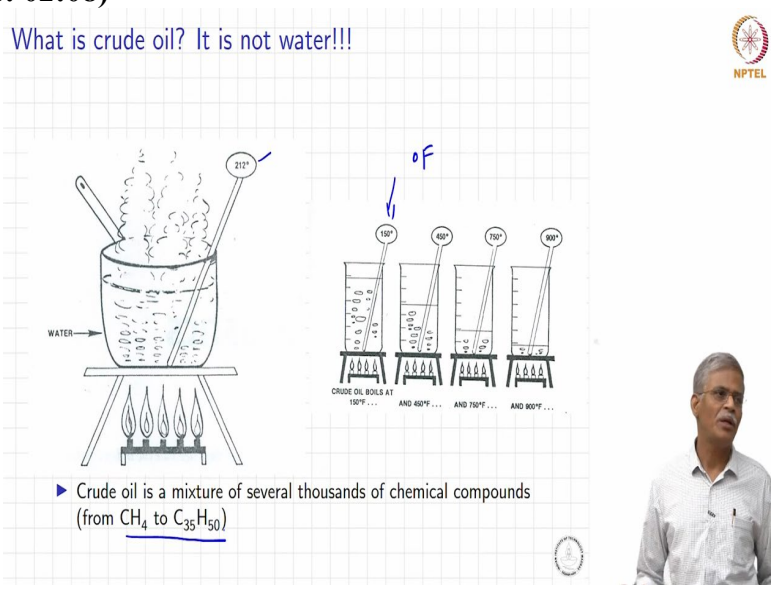

So, we will be sharing some of the lecture notes associated with this and so we will start with what is this crude oil. So, crude oil is definitely not water, these temperatures that are mentioned here are in degree Fahrenheit. So, if it is water 212 degrees Fahrenheit or 100 degrees centigrade, you are going to have boiling taking place, but when you are talking about crude.

It consists of mixtures and you can actually see from, this is the variability that we are talking and Dr. Nivitha in her later lectures will be talking to you about the chemistry and the chemical composition of it. So, as we keep heating it, we are going to see different components that are going to come out of them.

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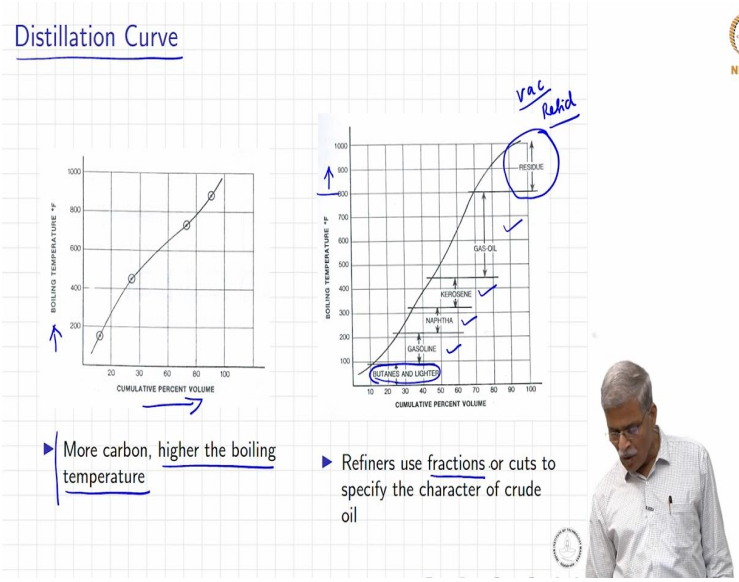

So, how to the refineries handle this scenario. So, they do what is really called as a, draw a distillation curve. So, what is a distillation curve, you can actually see on the Y axis the boiling temperature in Fahrenheit and on the X axis the cumulative percentage volume. So, what it means is if there is going to be more carbon, the boiling temperature is going to be much higher. So, let us take a look of the one sample of a crude oil.

So, when you start heating it. You are going to get as the first cut, butanes and lighter followed by gasoline followed by Naphtha followed by kerosene followed by a gas oil and finally, we end up with the residue and which is the residue which we are interested and in fact, the refinery terminology is vac residue that is the word that they will use here. So, around 800 Fahrenheit and above, you are going to get this vacuum residue here.

And normally the refiners will use this fraction, are most importantly the terminology that they will be using is called cut to tell you something about the character of the crude oil.

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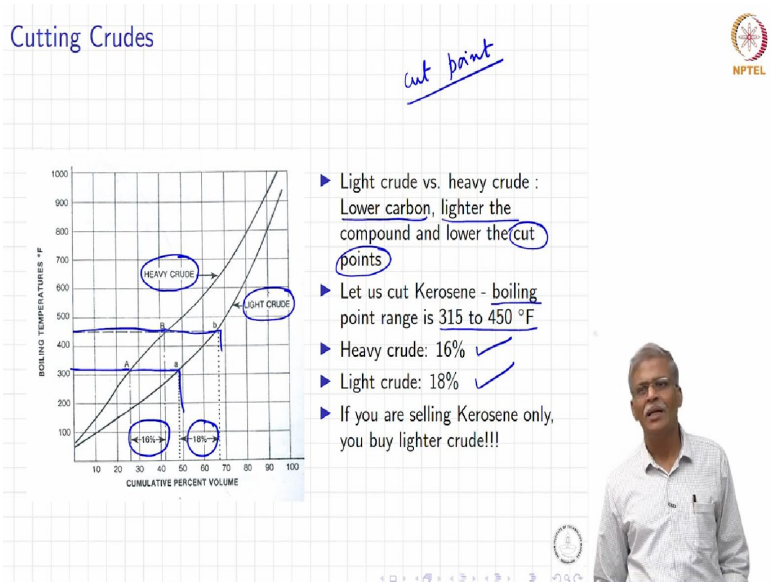

So, let us take two examples, there is the first example is a light crude. Second example is the heavy crude here. So, these are two different crudes and so, when we start boiling this and when we capture all the different constituents that are coming out of it and draw the distillation curve, you are going to get something different. So, as we discussed in the earlier slide, what did we say here? We mentioned that if there is more carbon the boiling temperature is going to be much higher. So, we look at the heavy crude, we look at the light crude.

So, if there is going to be a light crude there is going to be carbon is lower and lighter the compound and the refinery terminology needs to be understood what is really called as a cut point. So, let me write it here you may also want to write this carefully, cut point. So, now, let us take the simple case here, you have a light crude you have a heavy crude. So, let us cut kerosene, the kerosene boiling point basically ranges from 315 to 450-degree Fahrenheit and if you use the heavy crude.

So, let us go from 315 here to 450 here. You are going to see that there is going to be a heavy crude is going to give you something like 16%. But if you do the same thing with the light crude, you are going to get something like 18%. So, if for a hypothetical case you are interested in selling only kerosene and if you are given an option of buying a crude, obviously, you are going to get or buy a lighter crude because you could make more kerosene out of it and you can sell make more money, but that is not life is not going to be that simple here.

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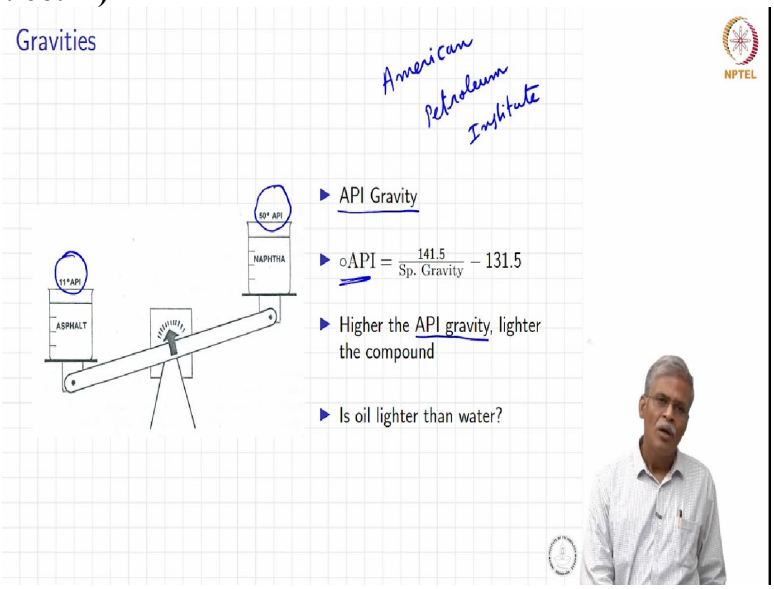

So, if we have to really understand what is this heavy, crude and light crude we also need to understand little bit about what is really called as the API gravity? API stands for American Petroleum Institute. So, this is a arbitrarily specific gravity definition that is given by the Americans and you may want to substitute the appropriate specific gravity for water here and figure out what will be the API gravity of water. So now you will have an idea about what this exactly is this API gravity.

So, if you are going to have API gravity of higher the API gravity, the component is going to be much light. And in fact, most of you if you know it, well if you recollect from your undergraduate experiments, you will know that the specific gravity of bitumen can be taken as close to 1. So, if the API gravity is going to be much higher, the component is going to be lighter. So, this is what you are going to get. So, if it is going to be asphalt, the API gravity is going to be close to 11.

But if it is going to be Naphtha, it is going to be close to 50. Now, how is this API gravity going to be used? In fact, if you look at it, when it is going to be a heavy crude it is going to be signified by API gravity if it is going to be a light crude, it is going to be signified with API gravity and depending on the API gravity, the crude oil prices will be fixed. So, from this simple picture you can actually understand that the price INR of light crude is going to be much higher than heavy crude because you can actually get more kerosene from it.

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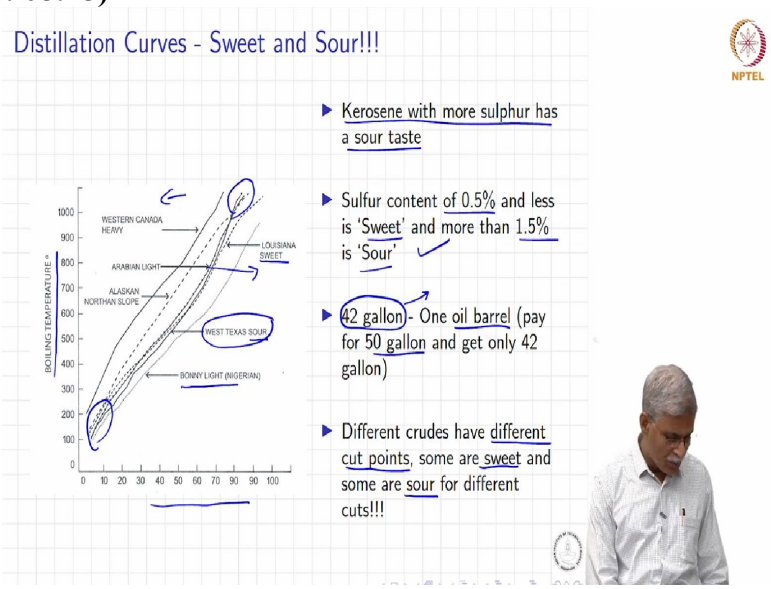

So, let us go to the next one. So, we will look at this distillation graph even more closer here. So, again you are going to see the boiling temperature here and the percentage volume here. There are few interesting terminologies are written here, what is called as a sweet crude, what is called sour crude. And in fact, in the olden days, I am talking about 1920s people used to taste the crude to find out how much is the sulphur content, say the sulphur content was less, the crude was sweet.

And if the sulphur content was more, it was sour, and based on it the API gravities also will change. So, if you in fact, if you look at the distillation graph, the heavy crudes will be aligned to this side, whereas the light crudes. In fact, you can see the Bonny light as well as the Arabian light is on the same, of course, the sour crude starts from this side and ends on the opposite side. So, it is not going to be very straight forward to clearly delineate which is a light crude, which is a heavy crude.

So normal definition is a kerosene with more sulphur has a sour taste and that is why it is called a sour crude. 0.5% and less is taken as sweet and 1.5% and more is taken as sour and we also need to understand that some of this terminology is related to barrel also comes from this. So, 42 gallon is actually taken us 1 barrel, again it was a 50 gallon. But when it was transported through a horse drawn vehicle used to be a lot of spill over, and at the end they will get only 42 gallon.

And so, 42 gallon was fixed as a unit volume of 1 barrel of crude oil. Nobody transports bitumen these days crude oil these days by a horse drawn vehicle and there are no wooden cask that are designed for it, but this terminology is as of now it is still being used. So different crudes will have, in fact you should understand different cut point some of them are sweet and some of them are sour for different cuts.

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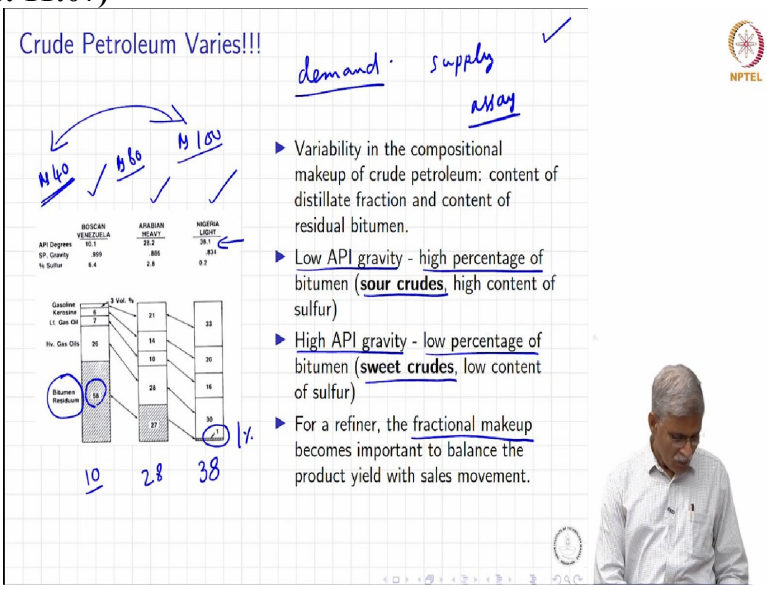

So, let us take a look at three types of crudes a Boscan Venezuela and Arabian heavy and a Nigerian light. Now, if you actually look at this picture, the first line says about something about the API degree, the API degree of this is 38 the Arabian heavy is 28 on the Boscan Venezuela is 10. The first thing that you will understand from this picture is as the API degree is close to 10, the amount of vacuum residue or the bitumen that is available is much higher here. And as you glow to the other side where the API is much higher, the material just has only 1% of bitumen in it.

So, if you are going to have a low API gravity, it is going to have high percentage of bitumen. And predominantly it will be a sour crude. If you are going to have high API gravity, the bitumen content is going to be low and it is going to be a sweet crude. Now, for a refiner, what is really meant is this fractional makeup is basically important. Now, we also need to understand that these days in fact these days meaning in the last 3, 4 decades, no refiner will process a single crude.

This will always be mixed and matched. Because it is really not gasoline on the one hand that you are really looking at or bitumen on the other side that you are looking at. So, what most of the refiners will do is since the prices are going to be. So, let us say this price is going to be 100 rupees, this may be 80 rupees and this may be 40 rupees. So, what you will do is per barrel, these are all hypothetical figures.

So, you will basically buy quite a bit of number of barrels from here million barrels of course, and then mix them together and try to find out what is the demand. In fact, we our refineries have a commitment to supply petrol, diesel, kerosene, fuel oil to the market. So, based on the demand and the supply different types of crudes will be purchased they will be mixed, the crude as they will be done from the mixer crude and the refinery process will be optimized so that they always meet the required demand of the industry.

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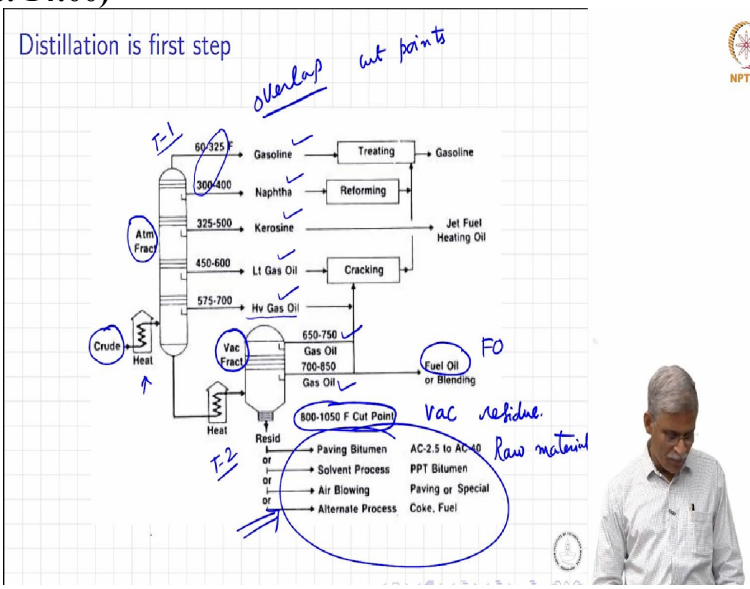

So, let us now take a little bit closer look at the refinery processing. So, the crude in fact, if you look at this very carefully, you are going to see that there are two towers, tower 1 and tower 2. The crude oil enters here it is heated and as you can see, as it gets heated here in the atmospheric tower here, you are going to get Gasoline, Naphtha, kerosene, light gas oil, heavy gas oil, you also have to understand that these end points are not the same.

So, you are going to have 60 to 325 you will get gasoline 300 to 400 you are going to get Naphtha. So, that means these are not precise cut points. There is always going to be overlap in

the cut points. So, as we increase the temperature, we get this heavy gas oil, but increasing the temperature in the atmospheric condition is not really a efficient way of running the refinery. So, what we will do is we will take it to the vacuum and then we start from start heating the process.

So, again we get the gas oil which will go as FO for fuel oil or for blending and around 800 to 1050-degree Fahrenheit is the cut point for vacuum residue and this is our raw material for bitumen. So now we will be spending some time talking about this production process here.

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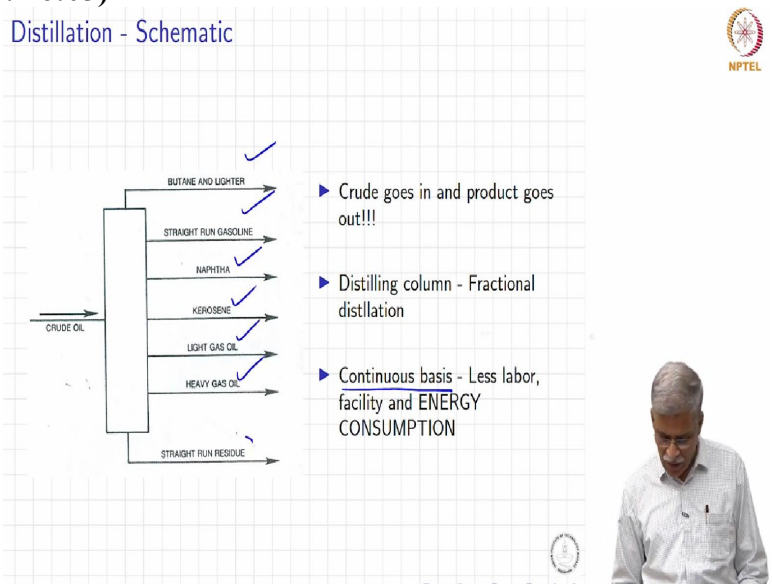

Before we spend some time, we need to understand that the process that is followed in refinery is continuous basis. So, that means the crude oil enters, Butane goes out, Gasoline goes out Naphtha kerosene light gas oil, heavy gas oil and finally the bitumen goes out and it is a continuous process.

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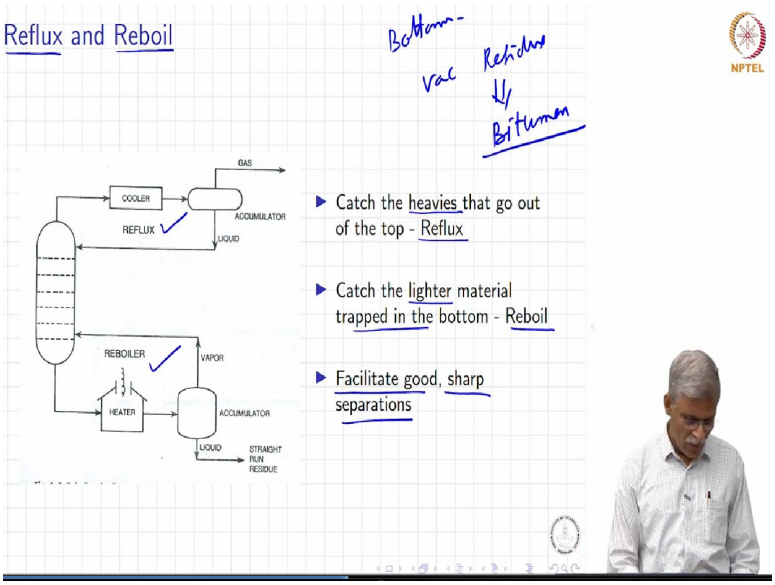

The next thing that we need to understand it no cuts or precise cuts, there is always a overlap. So, 2 terminologies are used what is really called us reflux and reboil. So, if you take a look at it, you can actually have some of the heavies that can go out of the top and that is called the reflux here. And some of the raw lighter material that can get trapped in the bottom is called reboil. So, this basically facilitates what are really called as good and sharp separations, this is very, important for us to understand because unless.

We get a precise and sharp cut points, the bottom that we are getting will also be influenced. So, when I say bottom, I am talking about vacuum residue, which again gives us bitumen that we use for our road construction.

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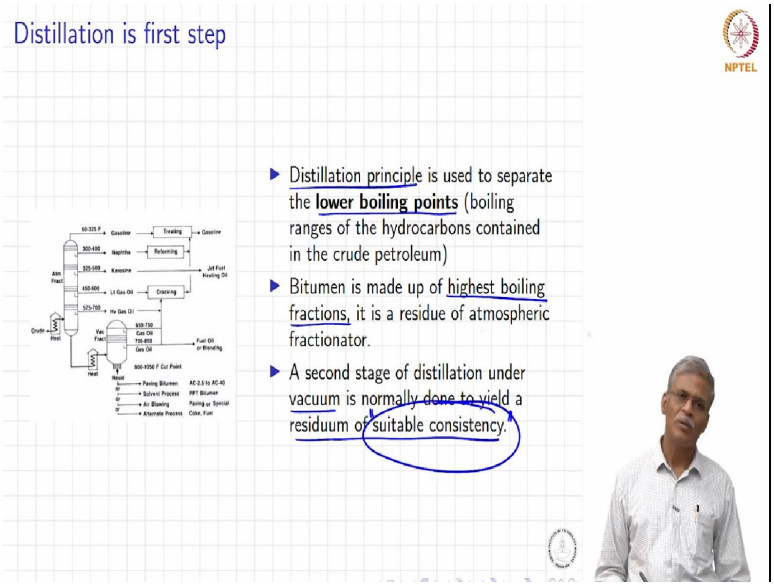

So, some of the details associated with this, this distillation is explained in this slide. And so, let me reemphasize again lower boiling point, this is the distillation principle is used and bitumen is made up of the highest boiling fractions and it is basically a residue that comes out of it and a second stage of distillation under vacuum is normally carried out to get a residuum of suitable consistency and in fact, this is the key word.

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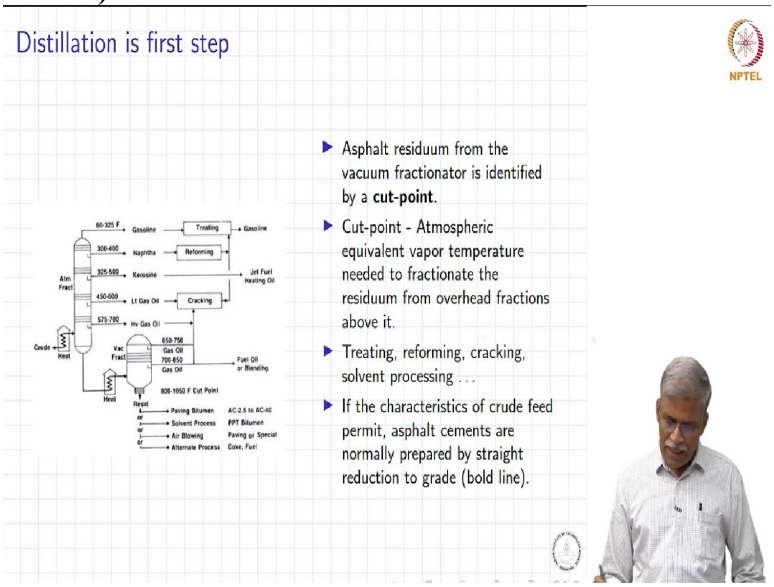

So, let us go here and also now understand some of the precise terminologies, what is a cut point? Cut point is the atmospheric equivalent vapor temperature needed to fractionate residuum from overhead fractions above it.

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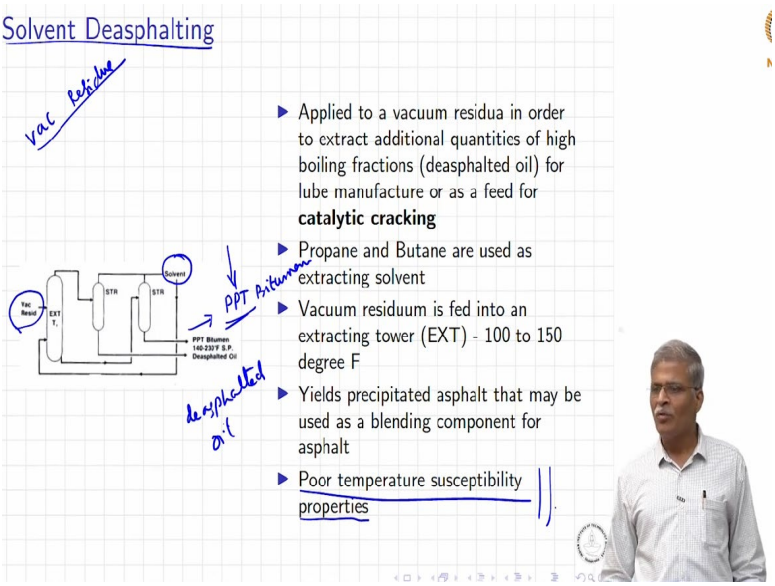

So, when we are really talking about the processing of vacuum residue, there are many processes that are involved and in fact, you can actually look at this particular thing. You are going to see that there is a solvent process that is mentioned here. There is an air blowing process that is mentioned here. So, let me write it here solvent process. Number 2. Number 2 is air blowing process. So, let us understand each one of them very carefully. So, what is this solvent process and in fact it is written as a solvent deasphaltene.

So, we take the vacuum residue here, we mix it with solvent, and we get two portions here. The first one is called as the PPT bitumen. The second is called as deasphalted oil. So, what is this PPT bitumen it is propane precipitated bitumen and this particular bitumen is bitumen manufactured from such process is known to have poor temperature susceptibility properties. This information is necessary for us to understand that when we get a bitumen from a refinery and

when it shows poor temperature susceptibility what exactly is temperature susceptibility that how the viscosity changes is it drastically varying or is it varying slowly. Now, if you have 2 bitumen and one of them is drastically showing viscosity change or a range of temperature compared to another bitumen, you can in a sense guess probably that this bitumen has come from a PPT process or propane precipitated bitumen process.

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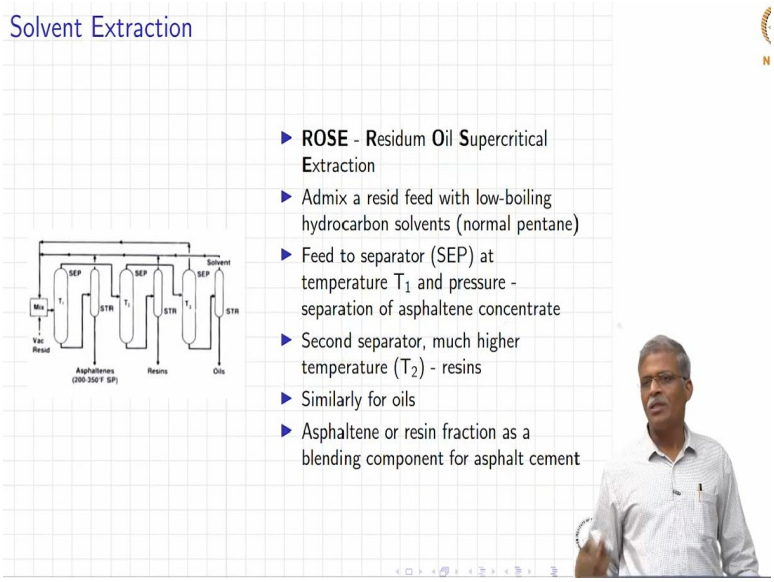

Unless a conscious effort is made it to correct it which is normally not done in that particular state. So, there is also, another process, which is in a sense similar to the PDA process, and this is what is really called as the residuum oil supercritical extraction. So, instead of removing the pitch and then using it for subsequent process here, we remove the asphaltane. Now, exactly what is asphaltane we will come to know about it in the latest discussions on chemistry of bitumen.

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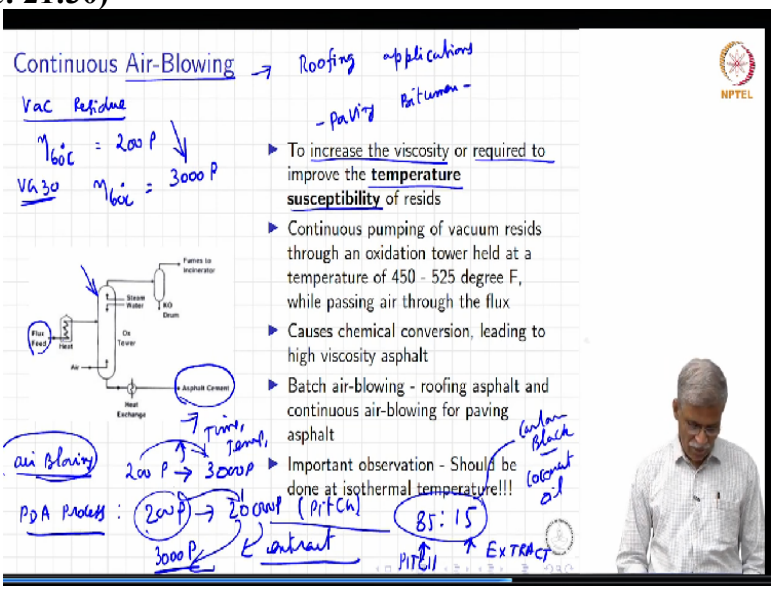

One more process is there which is really called as the continuous air blowing. These terminologies are have to be taken in a very general sense. So, there are many patented technologies for air blowing that are used here because, normally this air blowing bitumen is

used for roofing applications. But still we use the word air blowings when we are talking about paving bitumen. But the processes is slightly different and to and these are carried out to increase the viscosity or required to improve the temperature susceptibility of the residue.

So, as you can see there is a flux feed, there is a heat, and this is the tower in which this process is carried out and this is the binder that is coming out of it. So, now, let us take a small break here to understand what exactly or this process. So, I have vacuum residue and this vacuum residue let us say viscosity at 60 degrees centigrade it may be have something like 200 Poise. My customer wants a VG30 bitumen having a viscosity at 60 degrees centigrade of 3000 Poise.

Now, the question is how do I get this 2000 to 3000 poise, if I use air blowing I take this material from 200 Poise to 3000 Poise by appropriately optimizing the conditions that are explained here, the time duration, the temperature and the flow rate of oxygen. In the PDA based process what we normally do is we take this 200 Poise material, we make it into a pitch that might have a viscosity of 20,000 Poise, but what we wanted is only 3000 Poise. So, this will be the viscosity of the pitch So, I add many materials I am going to call them right now as extract.

So, when I add an extract of some proportion to it, I am going to get a 3000 Poise typical proportions are used in industry in India are 15% of extract, 85% of pitch. You can imagine them to have be more or less in the consistency of carbon black and coconut oil, that is the consistency you should imagine. So, when I make a bitumen with air blowing process in which a 200 Poise material goes to 3000 its properties are different compared to a PDA process in which the material goes from 200 to 20,000 and comes back to 3000 they are not one on the same.

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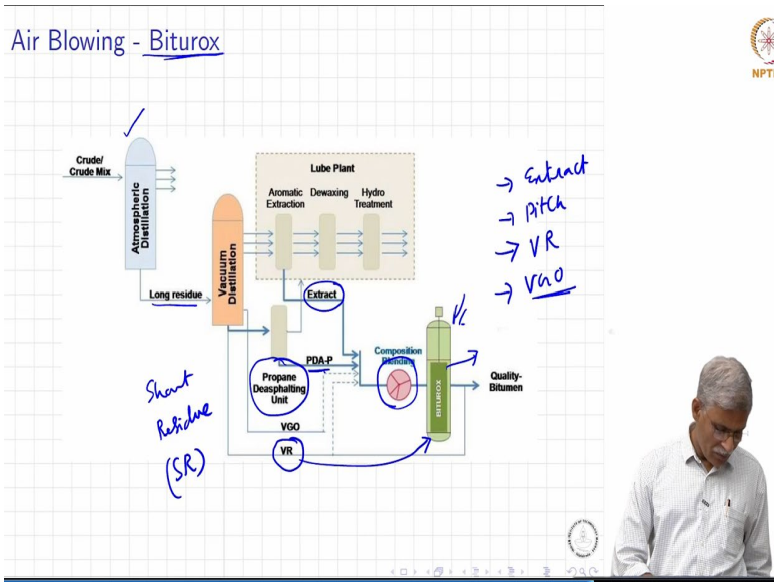

Now, let us take a look at one of the Biturox plant, which more or less uses this process and you will see that in real life a combination of blending and blowing PDA blending and blowing happens. So, you have the crude oil mix coming here atmospheric distillation, this is called us long residue and whatever comes out of it is called in refinery terminology as short residue or SR. So, you have a vacuum distillation unit and then it also has a PDA unit and you get a PDA pitch here this is the Biturox plant.

So, you have one input is the PDA pitch. Another input is the extract that comes out of it and these things in addition; some amount of vacuum residue is added. So, you are going to have extract which is your low viscous material, pitch which is high viscous material, vacuum residue which is nothing but our short residue, which comes here and that is something called as the vacuum gas oil. So, all of them are subjected to a composition blending and depending on the viscosity correction that is needed, some amount of air blowing is also carried out. So, this is the typical process that goes in one of these things.

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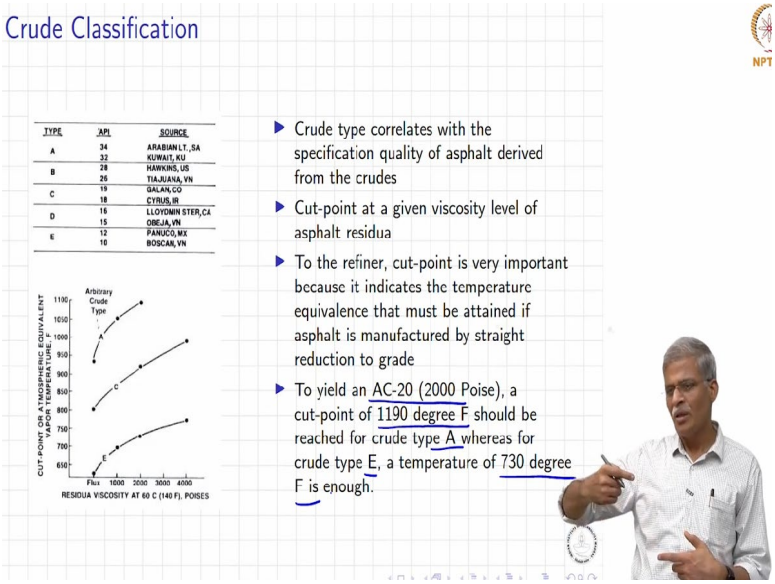

So, now, let us go back again to the classical A,C,E crude type that we saw here and you will be you will notice that A is of course, a high API material E is the low API material A is bitumen rich is a material that has hardly 1% of bitumen. So, as the carbon number keeps increasing the cut point that is needed also increases. So, you are going to see that a crude type such as E you can let us say you are interested in getting a viscosity at 60 degrees centigrade 2000 poise.

You could get it in this temperature range for a material crude source such as E which has an API of close to 10 whereas, if you are looking at the material such as, A you have to go all the way up to 1100 degree Fahrenheit roughly. So, you have to really cut it to that much temperature to really get here bitumen. Of course, both of them will have 2000 Poise, but one material has been cut a high temperature another material has been cut to a low temperature so we need to be aware of it.

So, the details are given here, and we understand that to yield an AC 20 a cut point of 1190 degrees Fahrenheit is needed for crude type A whereas for E it is enough if you do it in 730 degrees Fahrenheit. So, this difference of temperature during production that also will cause the changes in the theological behavior during the conditions, field conditions,

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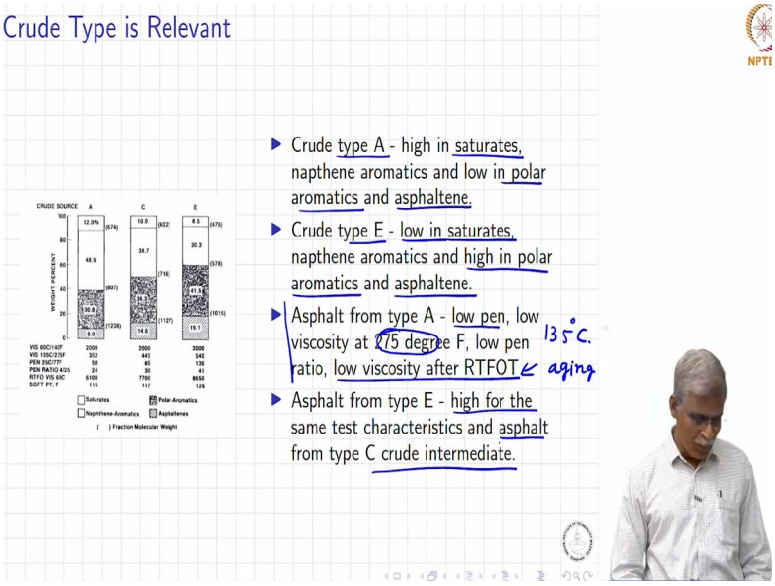

And now, one of the classic examples that we can actually see as to if you look in terms of the bitumen percentages, as well as the chemical composition. In fact, some of the terminologies that are listed here may or may not be appreciated by you at this point of time because we still have not introduced Asphaltenes, Polar aromatics, Naphthene aromatics and Saturates but Nevertheless, it will be useful for us to understand that the chemical composition of bitumen as well as the specification parameters, there is a big mismatch.

So, that means, you can actually look at crude Type E, let us say we produced it targeting 2000 Poise, and this is the chemical composition that you are going to see and the crude type A, which was also produced by S, for a targeted viscosity of 2000 the chemical compositions are, completely different, why, because, this comes from the lighter crude, this comes from the heavier crude and this is the analysis, chemical composition analysis that is carried out by the refiners they call it as the SARA analysis Saturates, Aromatics, Resins and Asphaltenes.

So, this is more or less the procedural combination that is used. So, when you look at the chemical composition and since the cut point of A and E are completely different, while you will get the same viscosity the chemical compositions are going to be different and the interesting point is you can actually look at the penetration values at 25 degrees centigrade. I am going to assume that all of you know what a penetration test at 25 degrees is centigrade, the penetration value of this material is 50 whereas, the penetration value of this material is 130.

Now, this is very very interesting and this will become later very clear when we are talking about the viscosity grade or the penetration grade. You will later come to know that bitumen that is processed from crude source A is a much better and superior material compared to bitumen that is processed from crude source E. So, that will become later as we clear as we go along. So, some of the information related to this particular chart is given here.

And you may want to really understand some of these things crude type A is high in saturates and low in polar aromatics and asphaltenes. Crude type E is low in saturates and high in polar aromatics and asphaltenes. So, when you are going to have an asphalt from type A you are going to have a low penetration and low viscosity at 275-degree Fahrenheit is nothing but 135 degrees centigrade. And you will also be interesting to see that the low pen ratio and low viscosity after age so, this is something we will talk later and asphalt from type E is the high for the same consistencies and asphalt from type C is somewhat intermediate.

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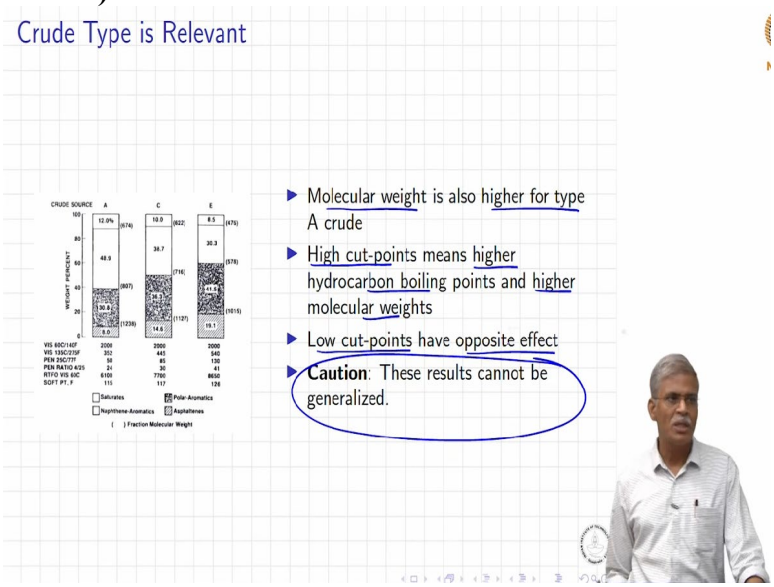

And you will also know that the molecular weight is also higher for type A crude and the lower cut point will actually have opposite effect in which means is if you have a very high cut point, you have very higher hydrocarbon boiling points and higher molecular weights. One needs to understand that if the crude type changes, these results will change, and they not necessarily be the same here.

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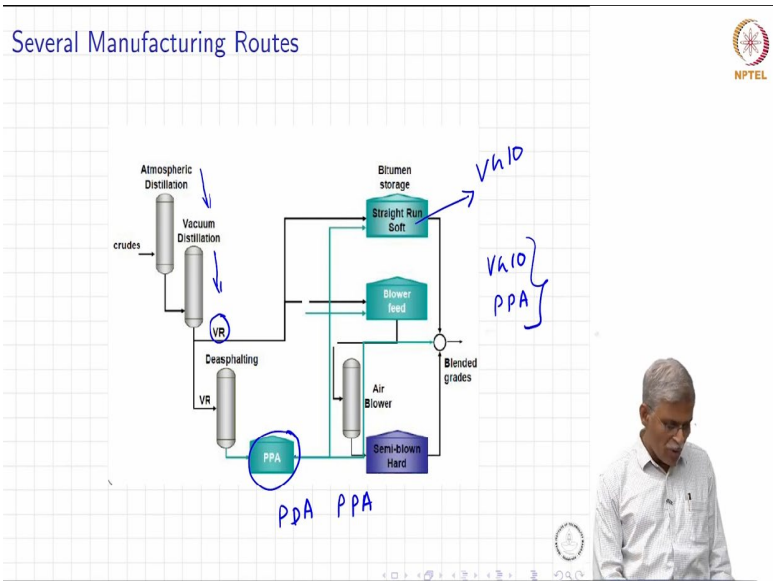

So, I am just going to show you some caricatures on how bitumen is processed, these are all commercial bitumen manufacturing routes. So, let us quickly go through each one of them. So, I get a crude I go to atmospheric distillation and from there come to vacuum distillation these are vacuum residue. So, one portion from the vacuum distillation goes to a soft bitumen. So, that means, if you really want a VG 10 material you can adjust your cut point in your vacuum tower to straightaway get here, let us say a VG 10 material.

Then when you get here, PPA and in fact PDA or PPA or one and the same this is propane precipitated asphaltene or propane deasphalted residue. So you get a PPA here and which basically goes to a blower feed here you can actually have a combination of a PPA that goes you can actually even use this to get your straight and soft or you could use a combination of VG 10, PPA and either blend them and send it or use them in a blowing condition. So, this is the combination of the process that is normally used.

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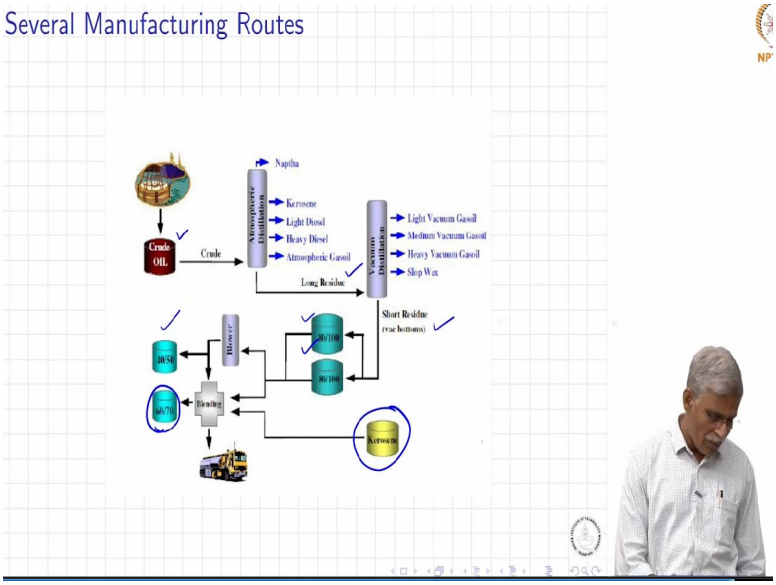

Again, this is a very interesting picture because you get a crude oil here, longer residue, and from there we get a shot residue straightaway you get your 80/100 bitumen and then you slightly blow it to get a 40/50 bitumen. But if you really want a 60/70 bitumen you take the material that comes from this 40/50 mix it with the 80 /10 add some little bit of kerosene here to correct to get your 60/70.

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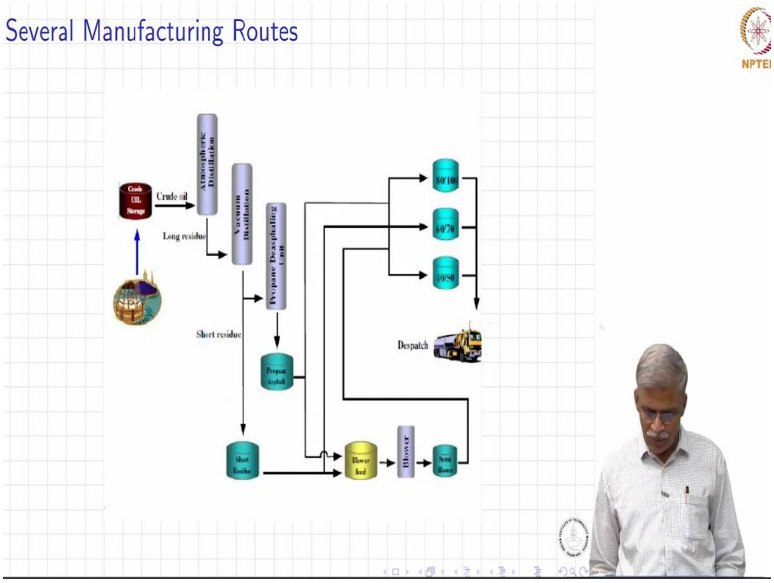

That is also another way of doing it. There is one more way that is shown here. You can actually take a look at it.

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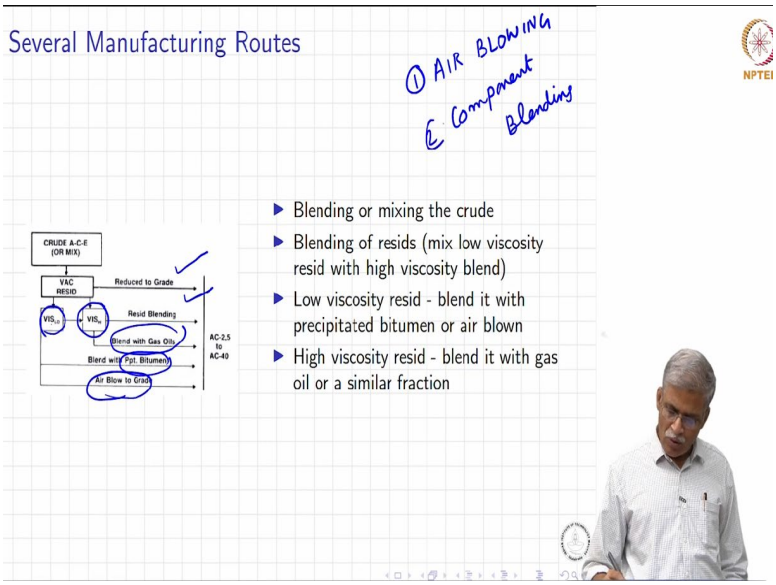

So finally, the idea is there are several manufacturing routes that are possible. You can reduce it to grade. You can get a low viscous material and a high viscous material and do residue blending, you can take a high viscous material and blend it with the gas oil, you can take a low viscous material and blend it with PPT bitumen or you could take this low viscous material and air blow to grid. So, in India, we are going to be talking only about 2 types of process what generically called as air blowing and component blending. So, these are the 2 processes that are followed here.

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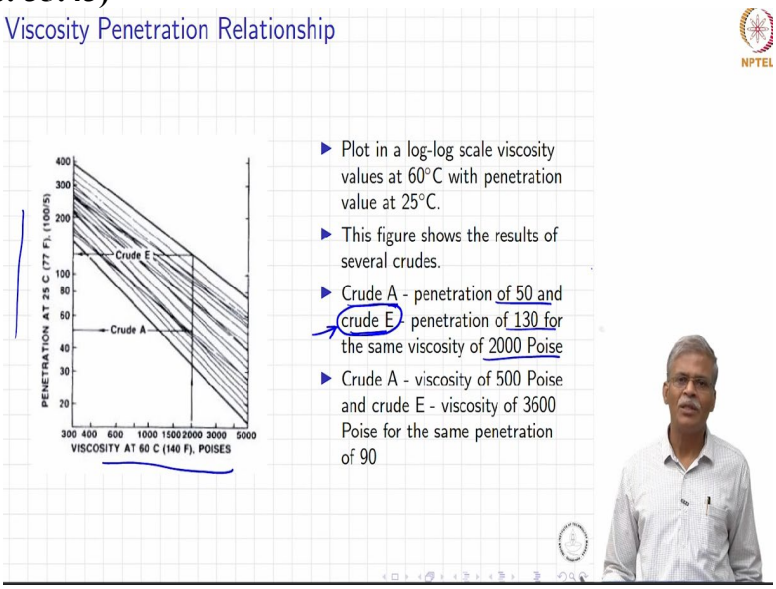

So, depending on the specifications that are available in place, one could get whatever grades that you want and it is also possible that you may not be actually get some of the desired bitumen

of the required specification and in fact, it is a big complaint from the refineries because some of the crudes cannot really produce bitumen of the required specification. So, normally this is a way in which it is done. So, you have viscosity at 60 degrees centigrade and penetration at 25 degrees centigrade.

You can actually see if you have a crude A you please refer to the earlier slides, the penetration of 50 and crude E having a penetration of 230 for the same viscosity of 2000 Poise. So, such things are possible. So, unless you do some process for crude E, you may not be able to match the required penetration that is needed from the specification.

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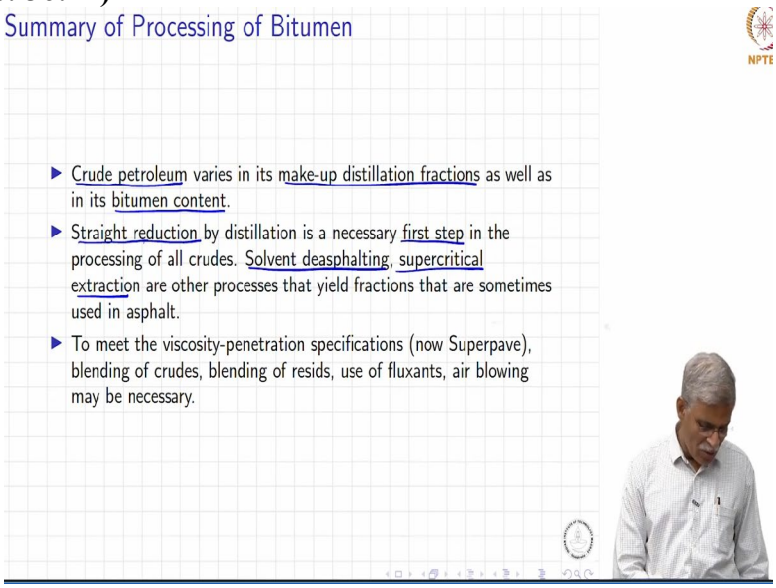

So, if you are looking at the summary of the processing of bitumen the crude petroleum these are some of the key words in its makeup distillation fraction, as well as in its bitumen content. Straight reduction is the first step by distillation, solvent deasphalting, supercritical extractions or other processes that are used. And if you really want to meet the specifications, you need to have a combination of blending, air blowing use of flux and many other processes are needed.

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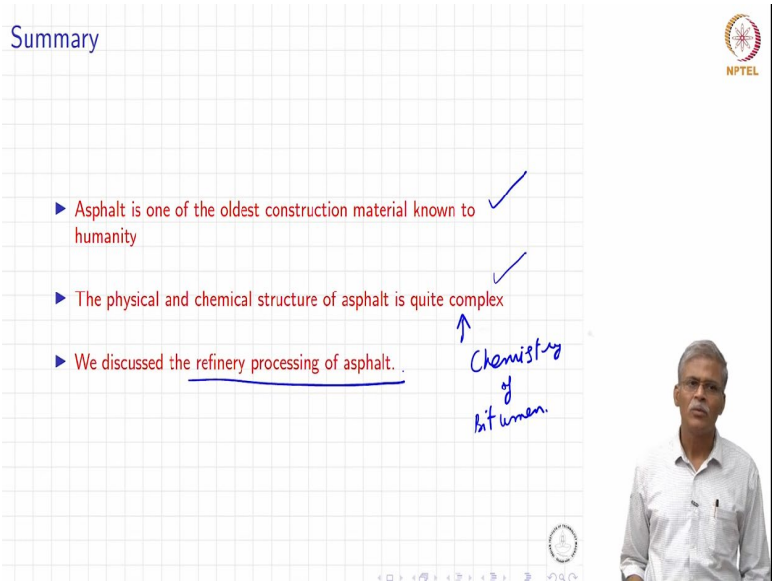

So, what we discussed in this lecture is, we understood that as Asphalt is one of the oldest construction material, we also know that the physical and chemical structure of asphalt can actually be quite complex. In fact, we will be discussing this in the lecture on chemistry of bitumen and we also discussed the refinery process. So, thank you very much for your time