Technologies for Clean and Renewable Energy Production
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Lecture-15
Tutorial 3

Hi friends, now we will have one tutorial session and this is based on the last four classes we will see the problem number one, which says.

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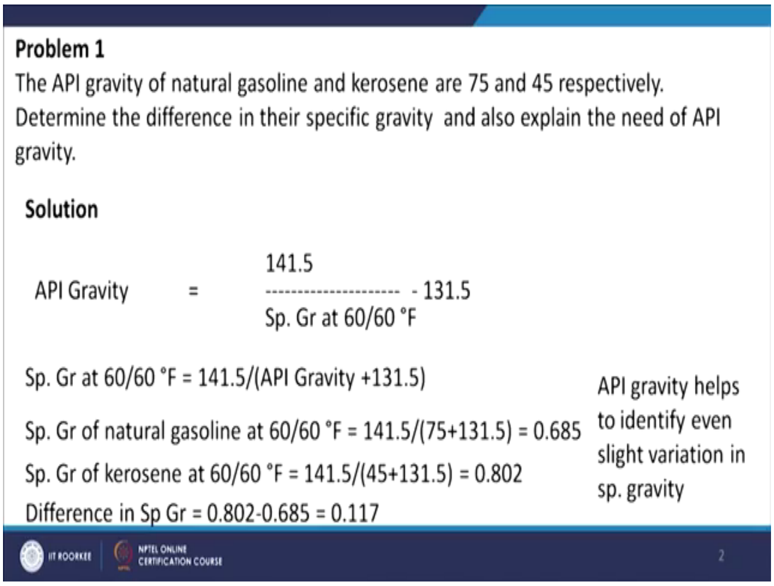

The API gravity of natural gasoline and kerosene are 75 and 45 respectively. Determine the difference in their specific gravity and also explained the need of API gravity. Now, we will solve it. So, we have discussed in our previous class that API gravity = 141.5 / specific gravity - 131.5. And this is proposed by American Petroleum Institute. Now, in this case, we have API 75 for natural gas and 45 for kerosene.

So from these relationship, if we can get specific gravity equal 141.5 by API gravity + 131.5 Why just will take this way. So, this part, if we take left side, the API + 131.5 so this is coming here. So, for one case, for natural gasoline, we have the degree API 75. So we will put it the 75 So, 141.5 divided by 75 + 131.5. So we are getting 0.685. But in case of kerosene, we have the same formula will put the API as 45 has given and then 131.5 it is becoming 0.802.

Then what is the difference? This minus this so you will get 0.117. So, this is the difference in the specific gravity of these two. Now the last part is what is the need of API gravity. So, we have a specific gravity definition then what is the use of this API gravity. Now, you see the difference in API gravity is 30, 75 - 45 for this very small difference in the specific gravity so .117 So, if there is some other liquid fuel having in between, say this is .802 it is .685 between 7.07.

So, this difference will also be less, so, smaller the scale it is difficult to identify the different components. So, once we can increase this in terms of degree API, that is 30 difference where 0.117 so we will be having better chance to isolate and to identify different fuel properties, which are important for certain operations. So that is the use of API gravity unit.

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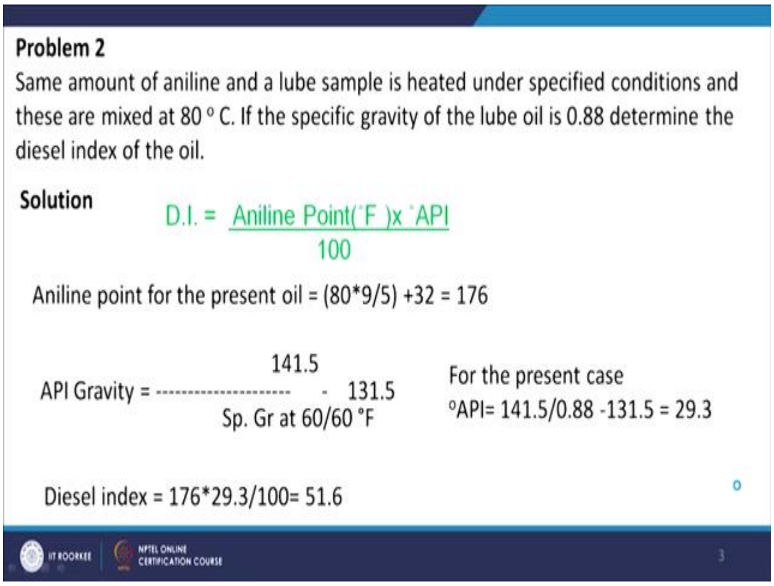

Now, in the next problem, the statement says same amount of aniline and a lube sample is heated under specified conditions and these are mixed at 80 degree centigrade. So to same amount it is mixed in the laboratory in a particular arrangement then it is giving us 80 degree centigrade. If the specific gravity of the lube oil is 0.88, so determine the diesel index of the oil. So we have the diesel index of that lube oil, which is having specific gravity .88.

And then it is also given that same amount of this oil and aniline mixes at 80 degrees centigrade. So we have already discussed the diesel index (D.I.) = (Aniline point (Fahrenheit degree) x degree API) / 100. So this is the formula. So here aniline point of the present value is equal to what the temperature at which equal amount of aniline and oil mixes. So, this 80 degree centigrade it is converted to Fahrenheit.

So this plus this 176 Fahrenheit, so we will be putting these one as aniline point and degree API we have to calculate, the specific gravity is given, we have to calculate the API. So what is the API gravity, this is a formula we already have. So, now we will put it so 141.5 by 0.88 – 131.5 so 29.3 we are getting here (141.5/0.88-131.5 = 29.3). So we will put this one in this expression, so it is coming 176 aniline points into 29.3 API and divided by 100 (176 x 29.3/100 = 51.6), so, it is coming 51.6.

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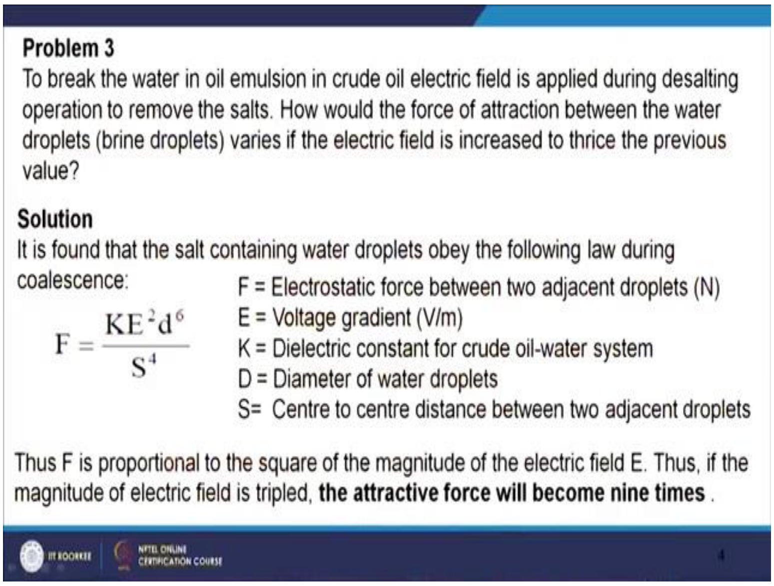

Our next problem says to break the water in oil emulsion the crude oil electric field, to break the water in oil emulsion in crude oil electric field is applied during desalting operation to remove the salts, how would the force of attraction between the water droplets varies if the electric field is increased to thrice the previous value. So, this deals with a desalting problem so we have to predict now what will be the force of attraction will change that we have to calculate, force of attraction between the water particles or emulsified water droplets.

We can say water droplets will feel experience that okay. So, we have already discussed in our previous classes that this force of attraction can be represented by this formula $F = KE^2d^6/S^4$. So, where F is the electrostatic force between to adjacent droplets and E is voltage gradient and K is the dielectric constant and d is the diameter of water droplets, this is d in the diameter of water droplets. This is the centre to centre, distance between two adjacent droplets. So, this is known to us we have already discussed.

Now, the problem statement says that if the electric field is increased, to thrice the power electric field what is this, voltage gradient. So, voltage variant is tripled. So, 3 times increase.

So, if it is 3 times increase the F will be 9 times increase, because this is proportional to E square. So that is why the attractive force will be, will become 9 times than the existing one okay.

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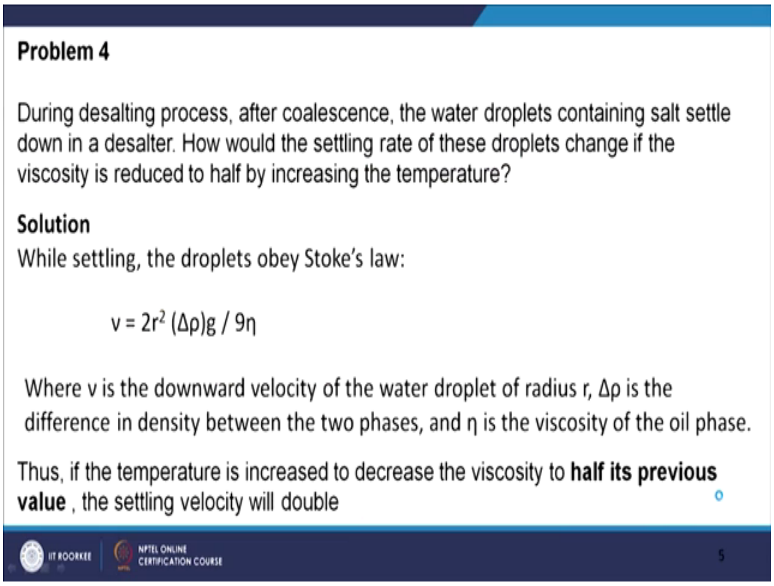

So, next problem 4 it says that during desalting process, after coalescence, the water droplets containing salt settle down in a desalter. How would the settling rate of these droplets change if the viscosity is reduced to half by increasing the temperature? So, when this desalting operation is taking place, if we increase the temperature viscosity will be reduced and it is given in this case that it is reduced by half 50% is reduced.

So, then in this case, how the settling velocity will change. So, we can assume this as a laminar flow and then Stokes law will be applicable. And this is the formula of stokes law. So, this v is the terminal settling velocity which is 2 into r square del Rho the density difference and then viscosity of the media ($v=2r^2(\Delta\rho)g/9\eta$). So, now, what is happening this is inversely proportional to viscosity. So, what will happen in this case? The viscosity is reduced to half, so viscosity is reduced so, if its reduced then this will increase the temperature increase to decrease the viscosity of half its reverse value the settling velocity will be doubled.

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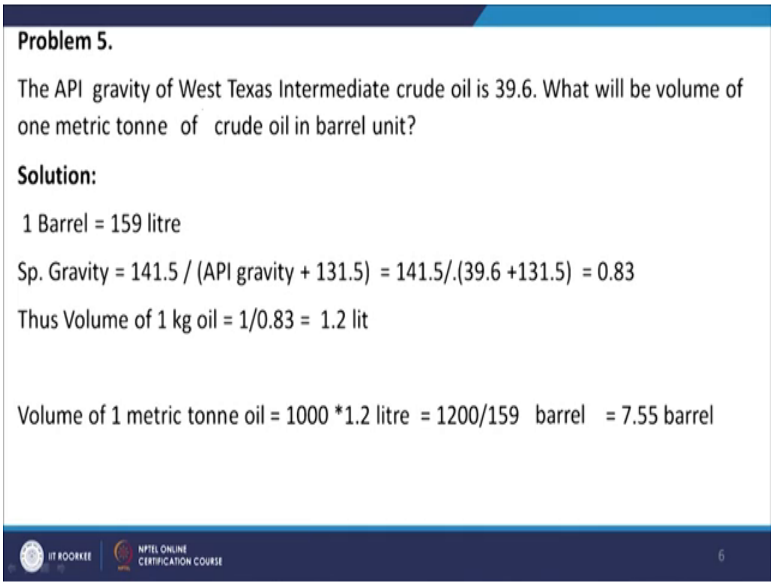

Next problem says that the API gravity of West Texas Intermediate crude oil is 39.6. What will be the volume of 1 metric tonne of this crude oil in barrel unit? So, we know that 1 barrel is equal to 159 litre then, specific gravity we have this formula 141.5 divided by specific API gravity + 131.5 (141.5/API Gravity+131.5) already we have discussed in a previous problem. So, we will put this formula here. So, getting .83 so, this is a specific gravity of this.

Specific gravity once we get that means that volume of 1 kg oil = 1/0.83 = 1.2 litre that you known so, then we have 1 metric tonne So, 1 metric tonne means = 1000 kg, so 1000 x 1.2 litre, so, that will be these much of litre. So, 1200 litre. So, if it is 1200 litre then what will we get; what will the value in barrel value divided by 159 so, we are getting 7.55 barrel.

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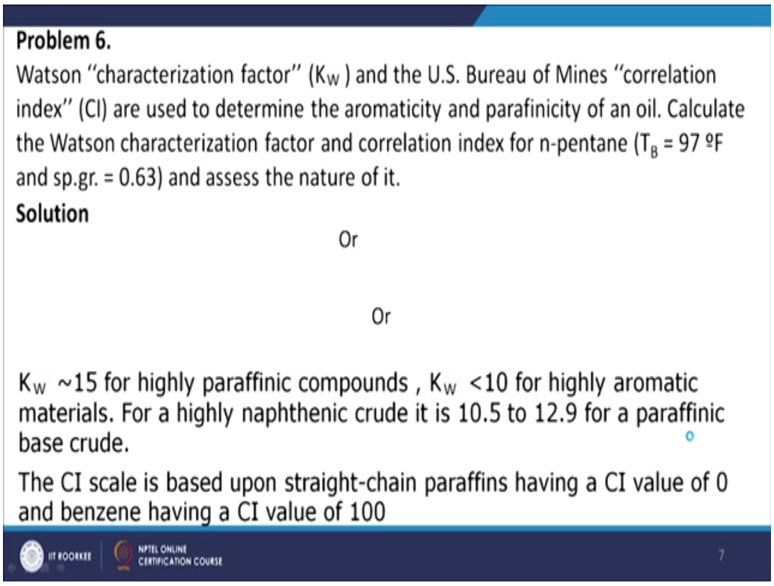

Next volume says Watson characterization factor and the US Bureau of Mines correlation index CI are used to determine the aromaticity and parafinicity of an oil. Calculate the Watson characterization factor and correlation index of n-pentane that is T_B is 97 degrees Fahrenheit T_B is equal to true boiling point and specific gravity is equal to 0.63 and asses the nature of it. So, what type of compound it is that is n-pentane?

On the basis of the values which we will calculate that is K_w and CI we can predict it, okay. So, to solve this problem, we have to determine the K_w value, we have to determine the CI value. And we have to compare these values we the standard one or with the literature value, then we will predict what type of compound it is. Now, we will see what K_w and CI is, so, K_w is the characterization factor that is defined by or developed by UOP and this is CI that is correlation index is developed by US Bureau of mines.

The objective was to measure now, what is a aromaticity and parafinicity of any oil and K_w is determined by this formula that is equal to T_B to power one third and specific gravity by specific gravity at 60 Fahrenheit and CI is defined by US Bureau of mines that is 87552 divided by T_B + 473.7 into specific gravity - 456.8. So, these are two formula and it is also provided in literature, the K_w w value is around 15 then it is highly parafinic compounds and if it is less than 10 highly aromatic compound.

And for a highly Naphthenic crude it is 10.5 to 12.9 for a parafinic crude base if it is; and CI index that is a correlation index CI that CI scale is based upon straight chain paraffin's having CI value of 0 if it is straight value of paraffin's then CI value will be 0. And if it is benzene then it will have CI value of 100. So, these are the literature available. So, our objective will be to determine the K_w and CI value first and to compare these values with this literature value.

So, for the case, what is K_w? K_w is this, so, what is T_B true boiling point and it is given 97 degrees Fahrenheit. So, this T_B not in degree centigrade or Fahrenheit it is in rankine. So, that is you have to add 96 + 460 so, this is rankine to the power one third divided by 0.63 that is specific gravity it is given. So, we are getting 13.06. So, K_w is 13.06 already just to have discussed that around 13 or 15 it is paraffinic compounds.

And 10.5 to 12.9 for a paraffinic crude base so; it is paraffin one in n-heptanes. And if we consider the CI value, then this is the expression CI value is 87552 divided by T_B that means 97

+ 460 + 473.7 into .63 and minus this one it is becoming 0. So, once it is becoming 0 that means, it indicates that it is straight chain paraffin and now we compare n-pentane it is a normal straight chain and pentane is paraffin. So, now did salt and by the value of the CI and K_w we can predict whatever compound it is.

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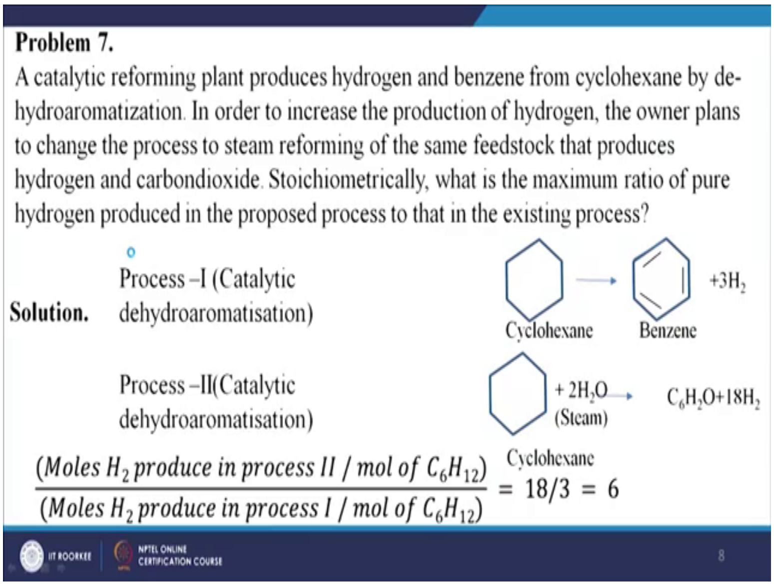

Next problem says that a catalytic reforming plant produces hydrogen and benzene from cyclohexane by dehydroaromatization. In order to increase the production of hydrogen the owner plans to change the process to steam reforming of the same feedstock that produces hydrogen and carbon dioxide. Stoichiometrically what is the maximum ratio of pure hydrogen produced in the proposed process to that in the existing process?

So, what we have to do in this problem, we have to see what will be the ratio of hydrogen production of the proposed process and the existing process. Existing process is the dehydro aromatisation and proposed is your steam reforming. So, this process Cyclohexane we have, this is the existing process dehydroaromatisation and this is the second process, which the owner is proposing to reform it in presence of steam in this form.

So, one mole of cyclohexane if we consider, then it is giving 3 mole of hydrogen the existing process whereas, the proposed method is giving 18 mole hydrogen. So, what will be the ratio 18 divided by 3 (18/3 = 6) that is equal to 6.

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Problem 8

A gasoline mixture is formed by mixing different types of compounds as provided in the following table. Determine the requirement of n-butane to make this gasoline with Reid vapour pressure (RVP) of 10. The RVP and molecular weight of n-butane are 52 and 58 respectively.

Base stock	BPD	Lb/hr	MW	Mol/hr	Mol%	RVP, psi	PVP, psi
LSR gasoline	4000	39320	86	457	21.0	11.1	2.32
Reformate	6000	69900	115	617	28.4	2.8	0.80
Alkylate	3000	30690	104	295	13.4	4.6	0.62
FCC gasoline	8000	87520	108	810	37.2	4.4	1.64

Next problem says a gasoline mixer is formed by mixing different types of compounds as provided in the following table. Determine the requirement of n-butane to make this gasoline with Reid vapour pressure RVP of 10. The RVP and molecular weight of n-butane are 52 and 58 respectively. So, this table, show us some data that is our base stock this is a blend gasoline blend which is having LSR gasoline and then reformate and then alkylate and FCC gasoline.

So, straight run gasoline and then reformate, alkylate then FCC. So, we are mixing with this is barrel per day so it is 4000, 6000, 3000, 8000 so, these are the production will mix it and then we will get some mixed gasoline. So, in this BPD it is this is pound per hour, these are the pound per hour, mole per hour is this one you converted and mole percentage is given. So, Reid vapour pressure for each component is given here also okay.

Now, we have to decide what amount of n-butane we can add with this mixture, so that overall RVP we can get 10. So, this is the problem statement and we have to determine what ratio what will be the ratio or what will be the mole per hour here, what will the mole per hour of this n-butane. So, that will give us the 10 RVP, so, that is the statement.

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Solution:

The desired RVP of a gasoline is obtained by blending n-butane with (C5-193°C) naphtha.

The amount of n-butane required to give the needed RVP is calculated by:

$$M_t(RVP)_t = \sum_{i=1}^{n} M_i(RVP)_i$$

Where

M_t = total moles blended product

$(RVP)_t$ = specification RVP for product, psi

M_i = moles of component i

$(RVP)_i$ = RVP of component i, psi

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So, now, in this case, we can assume that the after mixing, what is the mass of this we are getting the total moles of this how much total moles of the blend we are getting and what is the RVP of the total blend. So, that is equal to individual components which are getting their moles and their RVP if we sum it up the moles and RVP of those the components that will be equal to the total mass total moles of the blended product into RVP of the blended products ($M_t\,(RVP)_t$ = summation of $M_i\,(RVP)_i$ where i = 1 to n). So, this is the formula we will be using.

We have in this case 3, 4 components and we will be adding these 5 now will be having 5 components. So that way we can get so this is the formula that is M_t is a total moles blended or blended products, RVP_t is the specification and RVP for the products psi and M_i is the moles of component i and RVP_i will be the RVP of component i.

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Butane requirement:

The RVP of the original gasoline mixture = (457 *11.1+ 617 *2.8+ 295 *4.6+ 810 *4.4)/21000 = 5.38

Let the n-butanol requirement is M mole/h

$$(2{,}179)\,(5.38) + M\,(52.0) = (2{,}179 + M)\,(10)$$
$$11{,}723 + 52.0M = 21{,}790 + 10.0M$$
$$42.0M = 10{,}067$$
$$M = 240 \text{ moles } nC_4 \text{ required}$$

	BPD	lb/hr	MW	mol/hr
n-Butane	1640	13920	58	240

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So in this case the RVP of the gasoline original gasoline mixture will be how much, original gasoline mixture we have without adding this n-butane this is your original we are considering so what will be the RVP so we can get mole per hour. If we take one hour basis so this will be mole and this will be the RVP. So this into this + this into this + this into this + this into this sum it up then divided by the sum of this.

So by adding these we are getting 2179 and then what we are getting here divided by 2179 this is not 2179 so we will be getting 5.38. So, 5.38 we are getting so that is the RVP of the original gasoline mixture. Now, let the n-butanol requirement is M mole per hour. So, what do we this M into RVP of M that is n-butane that is 52 it is given in the problem statement plus this, the other one now 2, one is the original mixture now butane two we are mixing.

So that will be this into this and after mixing what will be the total moles of this, this + M so that is 2179 + M and what is the requirement of RVP of this product 10 as per the statement. So, this is equal to 10. So this expression we are getting so from these expressions by summarising we are getting this plus this equal to this plus this by rearranging this M, we are getting 42M is equal to 10,067.

So M is this divided by 42. So 240 moles of normal butane is required, so now we are getting 240 moles of normal butane is required. So, then we can make this table. So, what do we get the normal butane per hour is 240 mole per hour, what is the molecular weight 58. So, pound per hour 13920 and then BPD is 1647 barrel per day. So, this is a requirement of n-butane to make the blend, which will be having RVP of 10.

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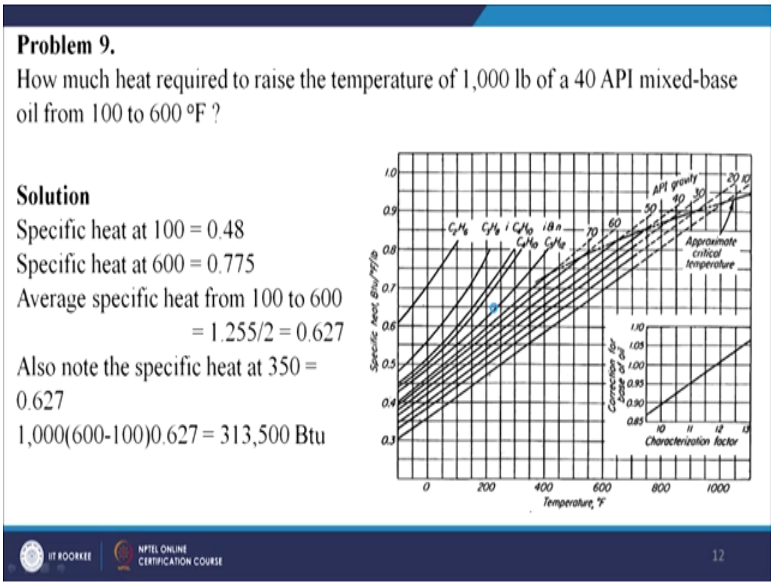

So, now we have solved the problem. Next problem says that how much heat required to raise the temperature of 1000 pound of a 40 API mixed based oil from 100 to 600 degrees Fahrenheit. So, we have to determine here how much heat is required to raise the temperature of 1000 barrel of a 40 API mixed based oil from 100 to 600 degree Fahrenheit. So, how can solve it? We have to define the average specific heat.

So average specific heat we have to determine within this temperature. If we can do it, then we will use it. So mCpdt that formula will be using mass x Cp x temperature difference. So temperature difference in this case 100 to 600 degree so 600 - 100 will get and then Cp we have to calculate and mass is given 1000 lb. So, how can we get the average Cp that is the most important part and that can be determined in a graphical method; some graphs are available as shown here.

This specific heat Btu per degree Fahrenheit per pound and here temperature with respect to Fahrenheit. So, if we see in this case, we have 2 temperatures 100 and another is 600 Fahrenheit and our oil is 40 API. In this graph, we see different API are shown so 10, 20, 30, 40, 50, 60, 70 like this. So our case is 40 so, we will consider this case this 40 case and we have temperature one is 100. So, this is our 100 and we have another 600.

So, if we go up and we take this one this line, so it is coming here. So, this value is almost coming below .5, so, it is around .48. So specific heat at 100 degree Fahrenheit, it is coming .48 Btu per degree Fahrenheit per pound. And specific heat at 600 degrees centigrade, it is coming here. This is below .8 and above .7 so .75, so, it is coming .775. So, from this graph, we are getting this .775.

Then what will be the average? So we will be getting the average by this + this divided by 2 that is equal to .627. So, the average Cp value is .627, other way we can also get that 100 and 600. So in between is 350. So, if we take 350 curve and 40 degree specific gravity, then also it is coming the same value that is your 0.627. So, now we are able to get the average specific heat. So then we will apply this formula mCpdt.

So m, dT and Cp so we are getting this 313,500 Btu. So now the problem is solved. So in this session, we have solved 9 numerical problems on this topic. So thank you very much for your patience.