Surface Facilities for Oil and Gas Handling

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Horizontal Separator And Sizing: Numerical

So, we will start Horizontal Separator Sizing. So, how to size it? Ok. Initially we will assume your separate is 50 percent filled ok. This is separate inlet, this is gassed outlet, this is liquid outlet ok? And gas oil plus water and you are using 50 percent filled ok. We have to calculate seam to seam length, dia effective length and we are assuming dm because 100 micrometer ok.

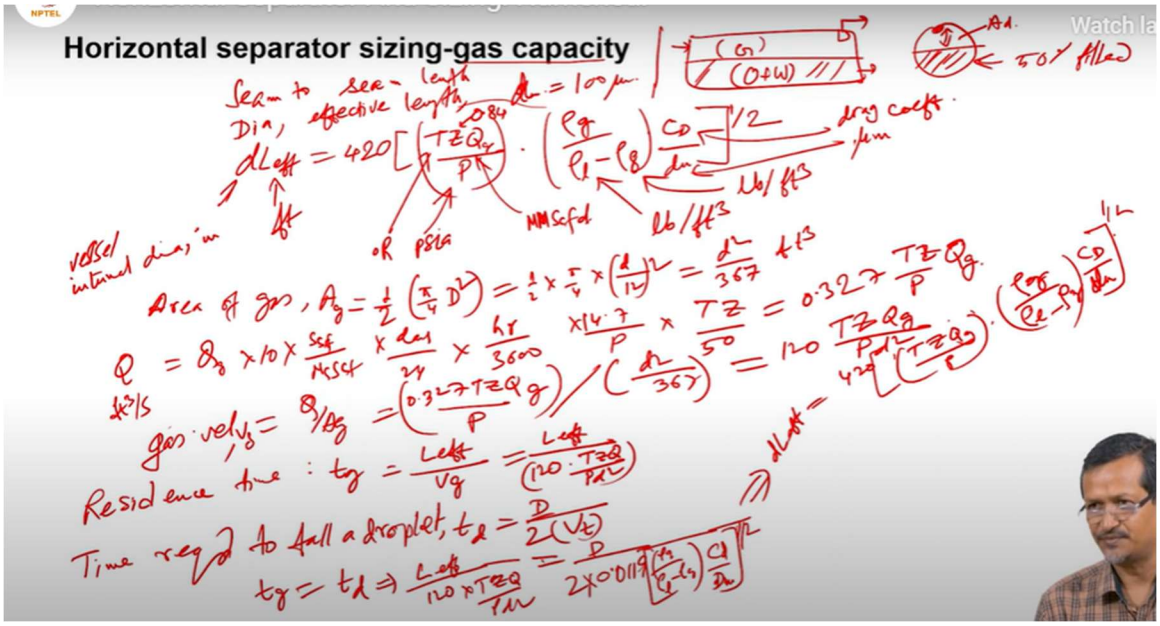
And separate is 50 percent filled ok, already I told you 50 percent filled. So, one formula is that dlef420, this digit also very unique you can remember IPC420 right. So, you can remember T z q gas p into rho g rho L minus rho g C C D dm ok. So, this will be standard formula from for gas capacity ok, you should remember this is gas capacity.

So, we have to calculate based on gas capacity, based on liquid capacity. So, presently I am focusing on gas capacity ok, learn how it how to do it. So, D is the vessel internal. So, lots of units will be there. So, D is the vessel internal area, vessel internal area vessel not external because middle with thickness will be certain thickness will be there.

So, you are taking internal area. So, internal not area this is called dia and this is inch. So, you should remember this one L effective, effective length of the vessel where separation occurs. So, vessel can be let us say 10 meter long, but actual separation length will be lower ok, because of certain other fittings will be there. So, actual separation will be lower and this unit is fit ok, this unit is fit effective length of vessel and T operating temperature ok, inside separator what are the temperature.

So, that temperature p again operating pressure ok, Z your gas compressivity factor ok. So, in my problem normally I take 0.84, compressive factor it may be different also you

can find from chart. Many cases I will be giving the value Z. So, you should not you may not need to remember, but you should know how to find the value ok.

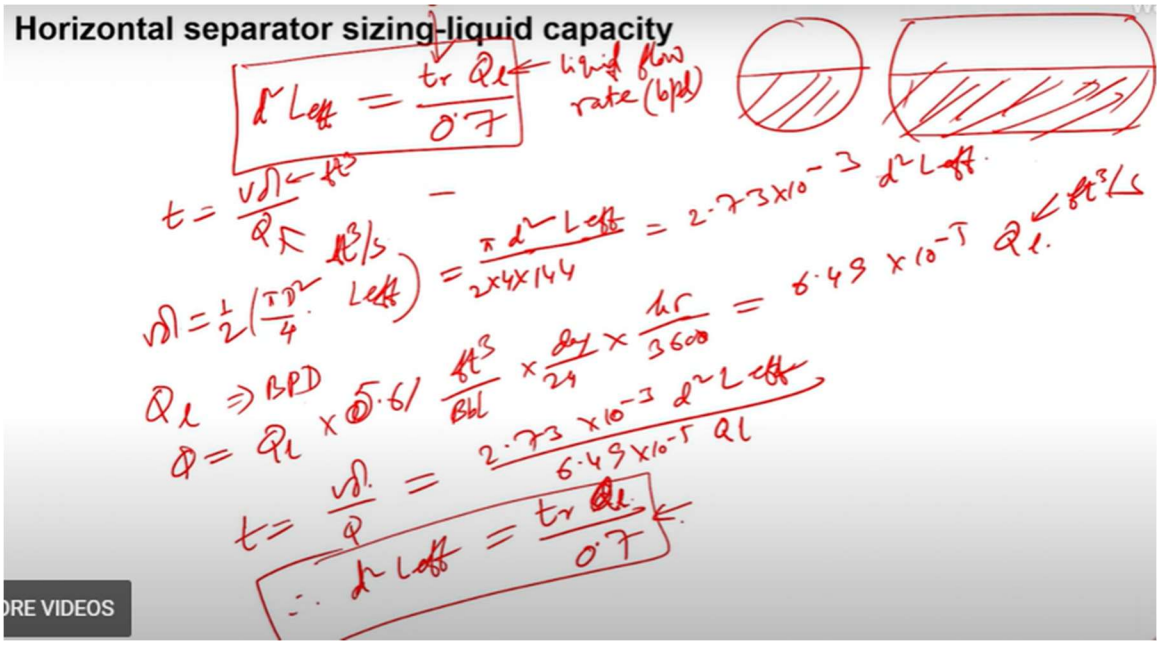


And Q g gas flow rate. So, gas flow rate will be m m s c f d, million standard cubic feet per day ok. Then rho g rho L ok, rho L is a density of liquid, liquid density this is pound cubic feet andrho gas again same ok, pound per cubic feet. And d m is your micron particle diameter micrometer or micron right and c d discharge coefficient sorry drag coefficient ok. You should remember the units drag coefficient is the ratio.

So, it will not have any unit, but density will have unit pound per cubic feet, your gas flow rate, your pressure, your temperature, your Z, your effective length it. So, all the all are having different units actually you see the d and L e f inch and feet is multiplied. So, not same unit and again another d m is there micrometer. So, lengths are in different unit itself in in the same problem ok. So, you should remember.

Now, first you convert area, area of gas A g ok. What what is the area of gas flow? So, if you see this one ok. So, then a half of this area pi by 4 d square total cross sectional area divided by 2 that is 50 percent field that is why it is coming half ok. Now, half into pi by

4 into d by 12 square you are converting into feet ok. So, this will be giving d square divided by 367 ok.



Now, gas flow rate you have to convert into cubic feet per second, but your data is given m m s c f ok. So, Q g into 10 into s c f m m s c f into day 24 into H r 3600 second then 14.7 then P into T z by 520. So, this is conversion ok. So, finally, you are getting 0.

327 T z P Q g. So, from standard condition you are converting to operating condition ok. So, velocity of gas, gas velocity. So, gas velocity will be V g Q by A g ok. So, Q how much you got 0.327 not 3, 3 2 7 0.

327 T z Q g by P divided by d square 367. So, this will be giving 120 T z Q g by P d square ok, gas velocity you got this one. Now, residence time residence time T g equals effective length divided by gas velocity. You see the unit effective length in feet and V g also feet per second then finally, you are getting second feet by feet cancel. So, you are getting second ok.

So, L effective and V g value we can put 120 120 into T z Q P d square and time required liquid droplet to fall. So, gas how much time is taking and time required to gas liquid time to droplet to fall droplet ok. You say from top it is falling down on the liquid surface T d

d by 2 this total circular area divided by 2 that amount of falling we are assuming that particle is on the top and is falling ok d by 2 divided by V t terminal velocity ok that velocity it is getting right. So, now, T g and T d if we equate we are assuming that residence time equal to droplet falling time. So, same amount of time it is taking gas going out and liquid falling down ok.

So, this will give for T d what is T d L effective 120 into T z Q P d square equals d divided by 2 into V t. V t what is V t? V t previously we have seen 0.0119 rho g by rho L minus rho g C d by d m not here here power half ok. So, finally, this will be giving the formula if you equate balance left side right side the things then you will get d L effective equals 420 T z Q G P rho g rho L minus rho g C d by d m power half here ok. I think I should not put this brace I will put other ok.

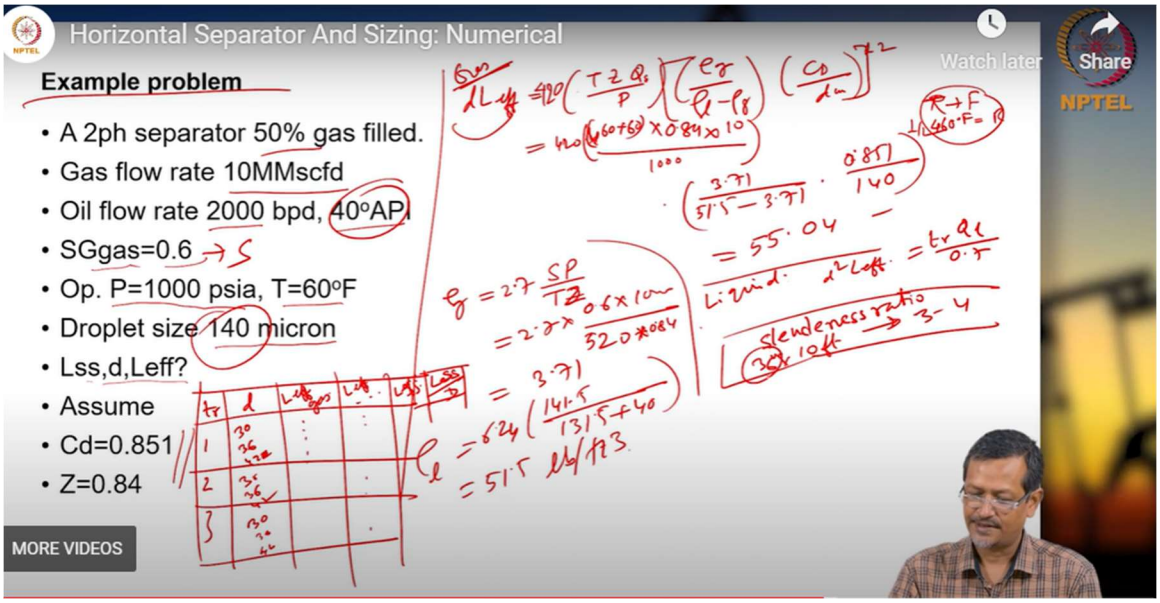
So, this way you are deriving gas capacity equation. So, the constant term remembering is I said already I P c 420 you can remember right T z Q G P rho gas divided by rho L minus rho g C d d m power half ok. So, in exam I may not give directly formula based thing I may give like step wise ok. What is the gas velocity of this one? What is the fluid velocity this one? So, actually step by step I can ask you to calculate. So, if you want to apply directly then again is finally, you have to move to this step by step ok.

Instead of asking directly final question I will be asking step by step ok. Then maybe you can remember for final equation or you can remember the step by step. So, better it is it is suggested to remember steps ok. Final equation also you remember there is no issue, but steps must be remembered.

Now, ok. So, we said like 50 percent gas and 50 percent liquid is there inside our separator. So, retention time will be calculated here liquid retention time. So, here d square L effective length this is the formula actually T r Q L liquid coming 0.7 this is the formula we will derive ok. So, liquid flow rate liquid flow rate B pd capital B pd B d whatever you want to write you can write and T r retention time this will be in minute ok.

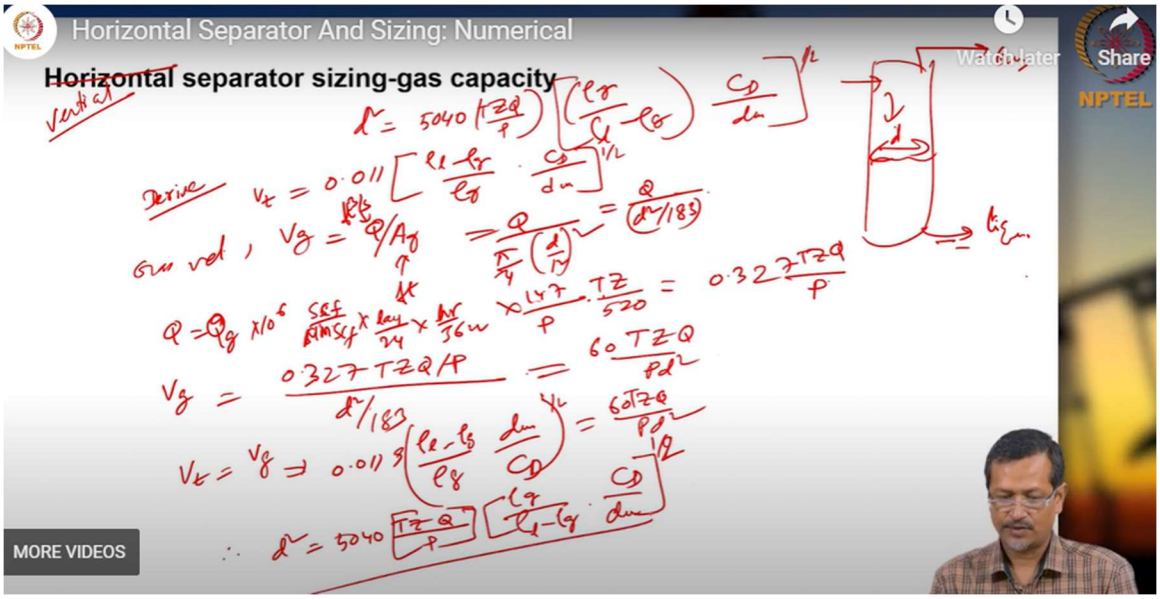
And d already you know the diameter L is effective length and unit is different ok. So, to

derive this one first check T volume per flow rate ok. Volume cubic feet flow rate ok. We know the time this volume per flow rate right. So, we can get how much time it is remaining inside fluid.



So, volume equals half pi d square by 2 L effective. So, volume will be like how much fluid is there. So, that is pi by pi d square 4 total volume divided by 2 into L effective length ok. So, there is your volume and so, pi d square 2 into 4 into 144 because you are converting unit small capital D to small d and L effective length you are in feet.

So, it will be coming 2.73 into 10 power minus 3 d square L L e f f ok. Now, flow rate u liquid flow rate in B pd equals q L this is cubic feet q L q wait what is the unit q L in B pd q in cubic feet a second ok. So, flow rate q in q L in B pd q in wait wait wait. So, flow rate q L in B pd.



So, q equals q L into 5.61 cubic feet barrel B b L or barrel you can write full day 24 into hour 3600 by your second. So, you are getting 42.0 d square L effective you are you are getting 6.49 into 10 power minus 5 q L ok q L is cubic feet. Now, T equals 42 now a from beginning of this right now T equals volume divided by q.

So, this will be giving 2.73 10 power minus 3 d square L effective divided by q L q L means 6.49 into 10 power minus 5 q L. So, this will give finally, d square L effective equals T R d L 0.

7 T R q L in 0.7. So, flow rate and attention time separated diameter and effective length is related like this ok. This is called liquid capacity equation this is called liquid capacity equation ok. Sim to sim length L s s and slenderness ratio ok L s s by d. Now, L s s is related to L s s effective this is some empirical relationship d by 12 for gas capacity equals 4 by 3 L e f anyone you can use for liquid capacity ok. Anyone you can use based on your gas capacity a liquid capacity and for liquid ok.

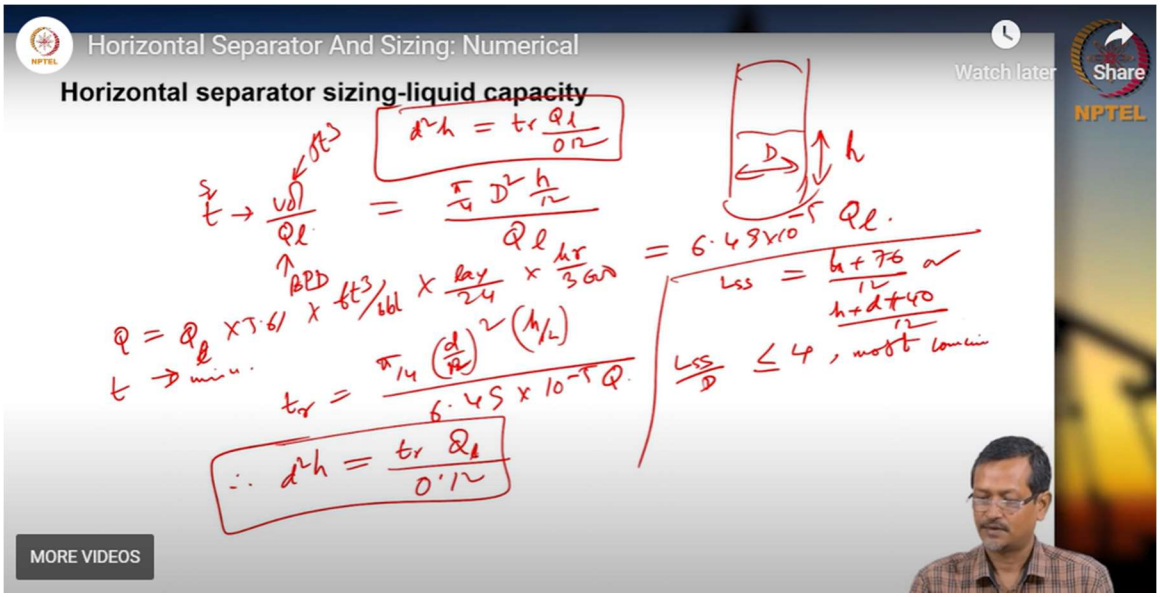
So, L s s divided by d must be greater than equals 1 ok. So, horizontal separator for most common L s s by d will be 3 by 3 to 4 most common ok. So, length will be 3 to 4 times then diameter. So, if I ask you to calculate sim to sim length d effective length or diameter.

So, you have to follow certain steps. First you have to calculate d and L e f f ok, diameter

and effective length and then to do this one you have to use a formula d L e f f equals 4 2 0 and you have the formula ok. Then calculate d square T R Q L 0.7 from liquid capacity. First you calculate from gas capacity then you calculate from liquid capacity ok. Then you calculate L s s sim to sim length ok.

So, we will show how this steps will be going on and then slender slenderness ratio you have to calculate slenderness ratio L s s by d like you keep 3 to 4 and you select your values for diameter total length effective length and sim to sim length ok. So, this will be the procedure. So, it is looking like very simple, but it is very it can be very long question also let us see ah. So, this problem actually given in your Arnold and Morris book a 2 phase separator 50 percent gas field and this can be different percentage also, but for simplicity I am using only 50 percent ok. Gas flow rate 10 mm c f d, oil flow rate 2000 barrel per day 40 degree API.

So, this mean light oil, the specific gravity of gas 0.6 operating pressure 1000 psi, temperature 60 degree Fahrenheit, droplet 140 micron, L s s d L e f f you have to calculate and these 2 values actually C d can be iteratively calculate calculated and z value can be taken from your chart. Presently for simplicity I am just asking you just fix it and try to calculate ok. So, first you have to calculate d effective length d L e f f. So, the formula T z Q by P rho g rho L minus rho g here also you will not do any mistake this rho L high density high gravity will be there.



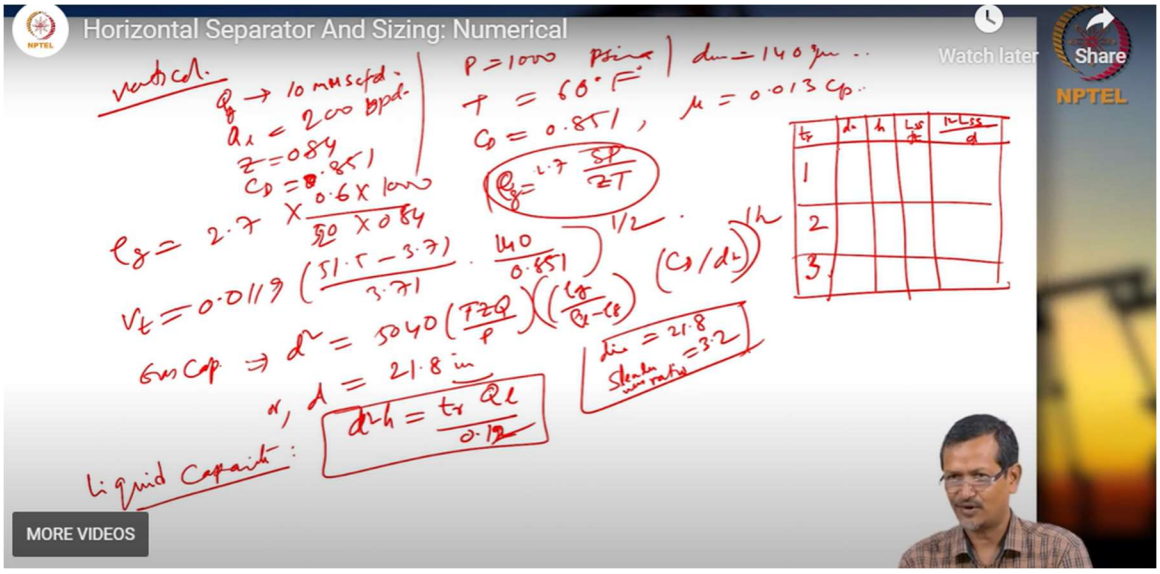
So, rho L minus rho g otherwise it will create a negative symbol ok. And then C d by d m and whole thing will be half ok and one constant I forgot ok. Now, you put all the data 4 to 0, T 5 to 0 which is 460 T and f conversion 460 degree Fahrenheit equals Rankine right. So, you have to add this this value directly 4 to 0 plus T value means 460 plus 60 into z value I have given 0.84 Q g Q g already given directly 10 and P value already given 1000 psi ok.

So, you got this one next is rho g rho g value also given. Now, rho g rho L you have to calculate actually rho rho g equals 2.7 S P T z this is the formula.

So, you can calculate 2.7 S means 0.6 specific this one S they are writing P is your pressure 1000 T 5 to 0 already 460 plus 60 plus z 0.84. So, this is giving 3.

71 and whatever rho L rho L is 62.4 141.5 divided 131.5 divided by plus 40, 40 means 40 degree AP already given ok. So, this is giving 5 1.5 pound per cubic feet ok.

So, those values I will be putting here. So, 3.71 rho L value I have got 51.5 minus 3.71 into C D value 0.851 140 micron is given there in problem ok and power is half.



So, finally, we are getting 55.04 ok D and L EFF multiplication. Now, you have to calculate based on liquid capacity this is from gas capacity ok. First you have to calculate gas capacity one then you have to go to liquid capacity. Liquid capacity formula is that D square L EFF T R Q L divided by 0.

7 ok. Now, Q L value you know T R you have to assume 1 2 3 ok. So, how to here. So, T R value you take 1 2 3 ok. Now, you calculate gas capacity L EFF ok. First you take D value D D you can assume let us say 30, 36, 42.

So, 30, 36, 42 ok. Now, from D then you calculate gas capacity L EFF L EFF from gas capacity ok. From gas capacity L EFF if you calculate from here using this formula you can calculate this D value already got. So, you can get calculate L EFF ok. So, for then you fill the table ok for 1 minute, 2 minute, 3 minute.

So, for gas capacity anyway T term is not there. So, just directly you can calculate you can fill L EFF ok. Now, liquid capacity L EFF from liquid capacity you can you calculate ok. Then you can calculate L ESS seam to seam length ok. Then once you get seam to seam length then you can calculate cylinder length ratio L L L ESS L SS divided by D ok, seam to seam length calculation. Now, when you get your L L L ESS divided by D or cylinder length ratio 3 to 4.

So, that value you have to take ok. So, first you have to assume different retention time 1, 2, 3, 4 then you take different D values ok. Now, you calculate L EFF for gas L EFF for liquid liquid capacity gas capacity. Then you can calculate ah the seam to seam length then cylinder length ratio L ESS by D. From there you calculate cylinder length ratio you try to maintain this.

You try to maintain cylinder length ratio about 3 to 4 ok. And because it is 40 degree API. So, you can take directly T R equals 1 ok. If I I do not give any criteria then maybe you have to calculate 1 or 2 T R. If I give if I say take only T R 1 then take T R 1 and you calculate ok. But if I in many cases I keep it open to student take a suitable value.

So, in that case you can justify I am taking 1 because it is 40 degree API ok. Some author says 40 degree API means T R 1 is ok. It is low light oil so, low T R value for that I am calculating ok. So, when we are solving problem you see how much max is given.

If max is 5 then maybe it will be 1 per solution. So, in that case maybe T R 1 is ok. So, if max is 20. So, in that case I will assume that you will be calculating 1, 2, 3 also you will be calculating several and it will be longer question right. If I must question means you have in 1 page solution when you are giving which will be more simplified form. So, you can justify like I am taking T R 1 because of this reason and I am not calculating so, many data because of this this reason and I am making simplified.

But if it is 20 that means, you have to give detailed solution ok. So, and again when you are solving you give step by steps. So, in this case the diameter they found 36 into 10 feet 36 length and 10 feet diameter 36 inch 36 inch diameter and 10 feet length ok inch 36 inch means 3 feet diameter and 10 feet length ok, same to same ok. So, if we want to go to solve vertical separator issues. So, first you have to remember the formula d square 5040 T z q p rho g rho l minus rho g C d dm ok.

Now, let us start deriving this one ok. V T formula you have seen 0.011 constant rho l minus rho g rho g into C d dm power half ok. Gas velocity so, vertical separator first you draw on inlet is there and gas liquid is going down gas is there and liquid is out ok. So, gas velocity V g equals q by A g ok. So, q by A g means pi by 4 d by 12 square d means diameter right.

So, you are converting unit also you are making feet. So, it is going q making q d square by 183 they calculated like this ok. A in feet q in feet q per second ok. Now, q formula for gas q g into 10 power 6 s c f as mm s c f into day 24 into hour 3600 into 14.7 that is from standard condition to operating condition you are converting that is why this 14.

7 coming divided by p T z by 520 ok. We are assuming same 60 degree temperature. So, this will be giving 0.327 T z q T z q by p. Now, V g equals 0.327 T z q by p divided by d square ok, 183 then right ok.

So, now, this is giving 60 T z q p d square. So, V t equals V g. So, this implies 0.0119 rho L minus rho g by rho g d m c d half equals 60 T z q p d square. So, this gives d square equals 5040 T z q by p rho g by rho L minus rho g c d by d m half ok. So, this is the formula for gas capacity equation for vertical separator ok. For liquid capacity for horizontal separator your formula is d square h equals T R q L divided by 0.

12 ok. So, this is your separator ok. So, T in sec. So, T in second is volume divided by q L this is B p d volume in cubic feet. So, it will be giving volume is pi by 4 d square h by 12 q L ok. What is d? d is this one h means this one ok. So, total volume we are calculating pi by 4 c d square h by q by L ok.

Now, q again q q liquid into 5.61 cubic feet barrel into day per 24 into hour 3600. So, it will be giving 6.49 10 power minus 5 q L ok. So, T R in minute. So, now, T R equals pi by 4 d by 12 square h by 12 q L q L 6.

49 into 10 power minus 5 q L. So, that will be giving d square h equals T R q L divided by 0.12 ok. So, this is your formula for liquid capacity equation and for seam to seam length L s s equals h plus 76 by 12 or you can use any one formula h plus d plus 40 divided by 12 ok. Cylindronic ratio you should keep less than 4 L s s by d less than 4 less 4 or less ok.

Most common 3 to 4 most common common 3 to 4 ok. Take a similar problem as horizontal separator is for vertical ok. So, vertical separator same flow rate you are taking 10 mm s c f s c f d your gas flow rate your liquid flow rate equals 2000 b p d ok, z value 0.84 your C d value 0.851 ok. So, all the parameter whatever you have taken for horizontal separator same parameter you take for vertical separator.

Now, you will try to calculate for d L s s cylinder cylinder ratio ok. Operating pressure is given 1000 psia and temperature is 60 degree Fahrenheit 60 degree Fahrenheit and your diameter 140 as it is whatever micrometer or micron. So, initially assume C d value 0.

851 ok already written ok. Viscosity is 0.013 C p that is viscosity. So, rho g 2.7 into 0.6 S p, p means 1000 ok temperature 520 and your z value 0.

84. So, formula is that 2.7 S p T z is rho g. So, this is a formula ok. d m is given 140. So, V t equals 0.0119 51.

5 minus 3.71. In previous question if you see horizontal separator we have converted already. So, same thing I am putting here I am not calculating again 3.71 140 your micron diameter given 8 point C d C d value is given 0.851 ok and then it is power half. So, gas capacity equation d square equals 5040 T z Q p rho g rho L minus rho g C d by d m half alright.

So, this value will be coming d 21.8 inch ok directly we got diameter. Now you have to go to liquid capacity. Liquid capacity will give like d square h equals T r retention time Q liquid 0.

12. So, here the constant term is changed actually 0.12 previously it was 0.7 in your horizontal separator ok. So, again you try to calculate T r you take 1 2 3 ok different retention time and then you can calculate d inch ok d inch already you have h you calculate

LSS feet then 12 LSS divided by small d or LSS divided by capital d ok. So, if you can calculate then actually diameter we are getting 8 and cylinderness ratio equals 3.

2 ok. So, around 3 cylinderness ratio means your design is ok ok. So, I am not showing all the values. So, it is a book solved problem. So, please go through the book because there are several calculation they have done. For exam purpose I cannot ask you to do all the calculation manual work I will ask maybe to calculate 1 or 2 point and you show this these things ok. Because my intention will be to know that you understood things and you know the steps how to solve how to design a separator not to do manual calculation too many things ok. So, thank you very much for this lecture.