Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

IIT Madras

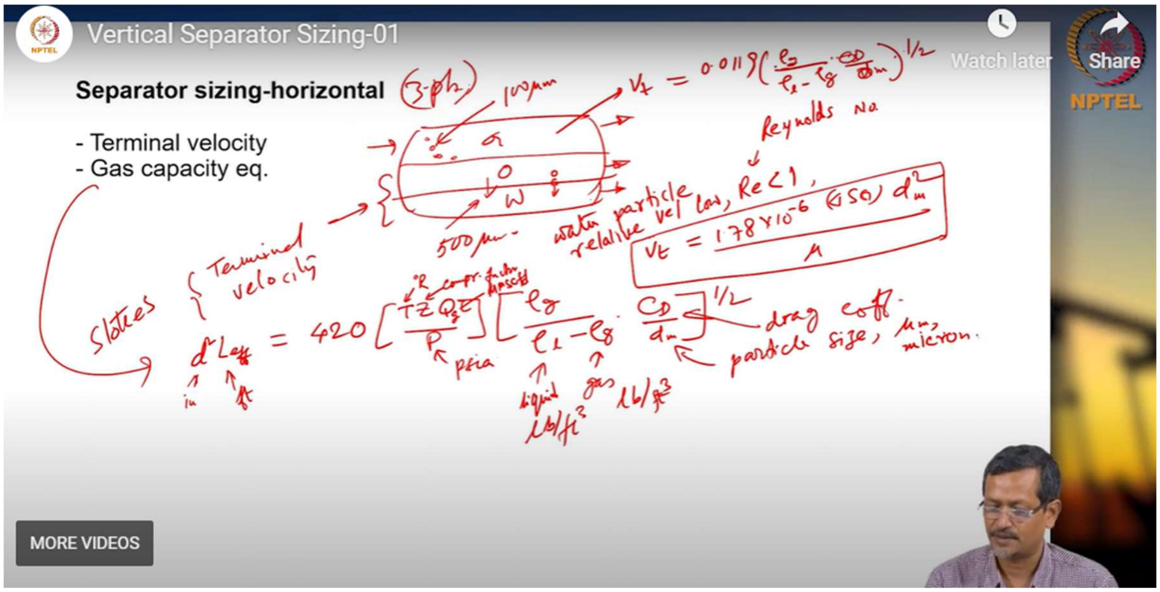
Vertical Separator Sizing-01

Good morning everybody. Today, we will try to size separator horizontal vertical three phase three phase separator, three phase horizontal vertical. So, previously we have discussed two phase separator, two phase again horizontal vertical we have discussed, we have discussed about settlement. So, we have discussed about particle size, we have discussed about internal component. So, internal component for three phase also we have discussed, internal component. And more theoretical part we have done.

Now, we will go towards more mathematical and we will try to solve some problem also using the formula whatever we derive or we get from the lecture. And this lecture is taken from the Arnold and Stewart book surface production operation volume 1 chapter 5. Separator sizing for horizontal and again three phase, you should not confuse get, should not get confused with two phase separator. So, three phase sum formula will be extra, sum will be relatively modified.

So, whenever you are talking about three phase actually fluid entry, then it is creating three layers, one will be gas layer, oil layer and water layer, oil means oil plus emulsion. Now, when fluid liquid is falling on this liquid surface, so this particle diameter about 100 micron or micrometer we take. And when water droplet getting separated from oil, we assume particle diameter 500 micrometer. This is approximate value. So, if something not given, sometimes we ask the student just take some guessed value which will be feasible.

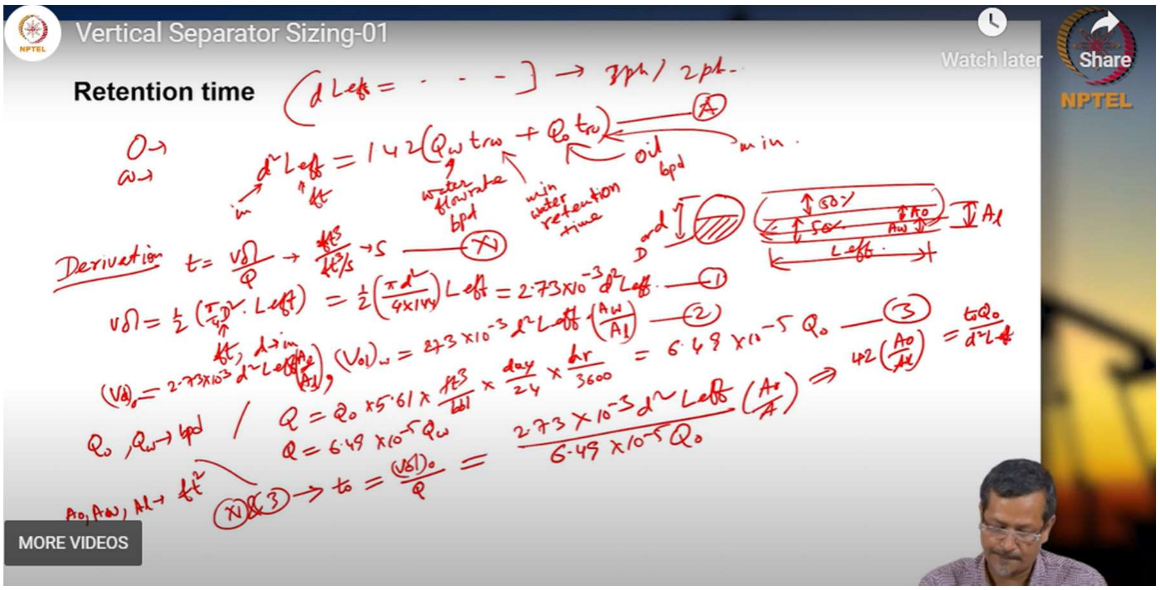
So, if you are guessing 100 micrometer liquid particle or oil particle falling, there is okay and 500 micrometer or microns water particle is getting separated from oil that will be okay for approximation. But if some other data is given and you may have to calculate the particle size or particle size will be given, maybe it may not be 100 or 500, maybe something like 90 or 600. So, in that case, you have to use that given data. So, terminal velocity, so when oil particle is falling through gas, oil or water also, because we are assuming higher amount of oil is there, so let us calculate for water. So, in that case gas capacity equation whatever you calculate for two phase separator, same equation will be holding here.



So, terminal velocity, terminal velocity here, oil particle is, now water particle is falling or sliding down from oil layer. So, terminal velocity, terminal velocity will be like Stokes law because very slowly oil, water particle will be coming down and will creating oil, water layer. So, this water particle, what we can say water particle relative velocity low. So, normally Reynolds number will be less than 1. So, in that case the formula will be Vt terminal velocity 1.

78, if I remember into 10 power minus 6 del Sg dm square divided by viscosity. So, when you are considering relative Reynolds number, this is Reynolds number, Reynolds number, Reynolds number is less than 1 or particle velocity low. So, in that case you can use this formula, but if you have Reynolds number higher in this case Vt will be different. So, Vt in this case you can use 0.0119 that formula because here particle size also 100 micron and some other component I am not writing here, I will see later.

So, Vt equal 0.011 and here the terms will be like rho g, rho L minus rho g, then dm by Cd, dm I will write like this dm by Cd, I will write clearly rho g by rho L minus rho g into Cd dm power half. So, this will be your terminal velocity when Stokes law is not holding. Now, after terminal velocity calculation you have to go to gas capacity based calculation because as in two phase separator you have seen first you calculate gas capacity formula based solution then you go to liquid capacity based solution. So, first you will go to gas capacity based solution and gas capacity based solution it will be as same as your two phase separator.

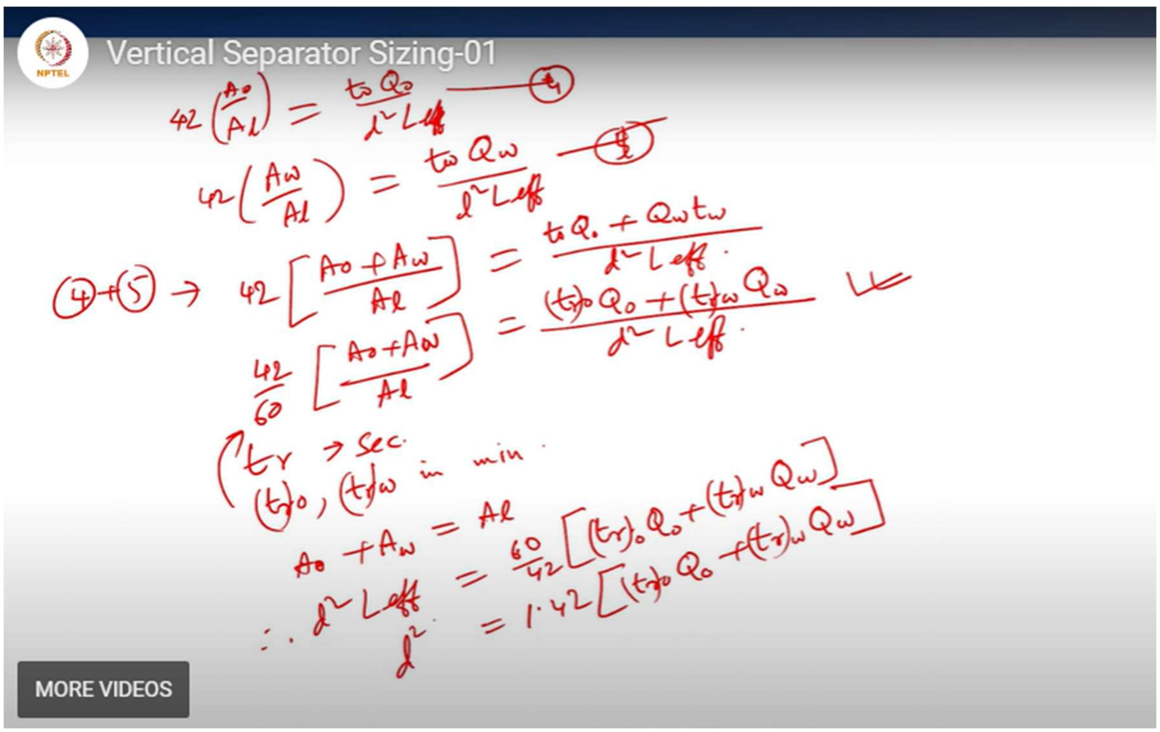


So, d square effective length equals 420 T ZQ gas P rho g rho liquid minus rho g into Cd by dm. So, now the units are d in inch, so here one catch is there, d will be inch but L in feet. Then T will be Rankine temperature, Z is compressibility factor, so compressibility factor, Qg gas flow rate, Qg Mscfd gas flow rate, P is psi a operating pressure. So, T and P is operating pressure condition. And rho g gas density, gas density this is liquid and unit will be Lb per cubic feet, Ft.

Cd is your drag coefficient and dm is particle size. Again this is micrometer or micron micron C r o micron M i C r o m. So, particle size if you take around 100, 150, so it will be, but if you are changing particle size too much there may be some issue. Now from two phase separator you got the formula for d square into L eff formula. You got the formula from two phase equation same as two phase, so three phase to phase does not matter.

So, three phase or two phase you can use the formula. Now retention time, retention time here actually you have oil plus water. So, oil will have separate retention time, water will have separate retention time, oil may be 5 minute or water may be 10 minutes. So, the formula is that d square L eff equals 1.42 Q w T rw plus Q o T ro.

This is the formula you have to use and how to derive this formula? Let us say this formula is A. So, first you see the units, units is internal diameter of the vessel. So, inch this is again feet and Q water, water flow rate, water flow rate. So, water flow rate is BPD, capital BPD, small b p d whatever you want to write you can write. T rw is minute, unit is minute, it is water retention time, water retention time, retention time.



Q oil, oil flow rate, so this is again BPD and T rw again this is minute, this is water, oil retention time. So, you should remember the formula, so derivation. How to derive the formula? So, first you have to start with T time equals volume per flow rate, flow rate you can see unit, unit is let us say cubic feet, cubic feet per second. So, finally, it will be second. Volume this is horizontal separator usually like this.

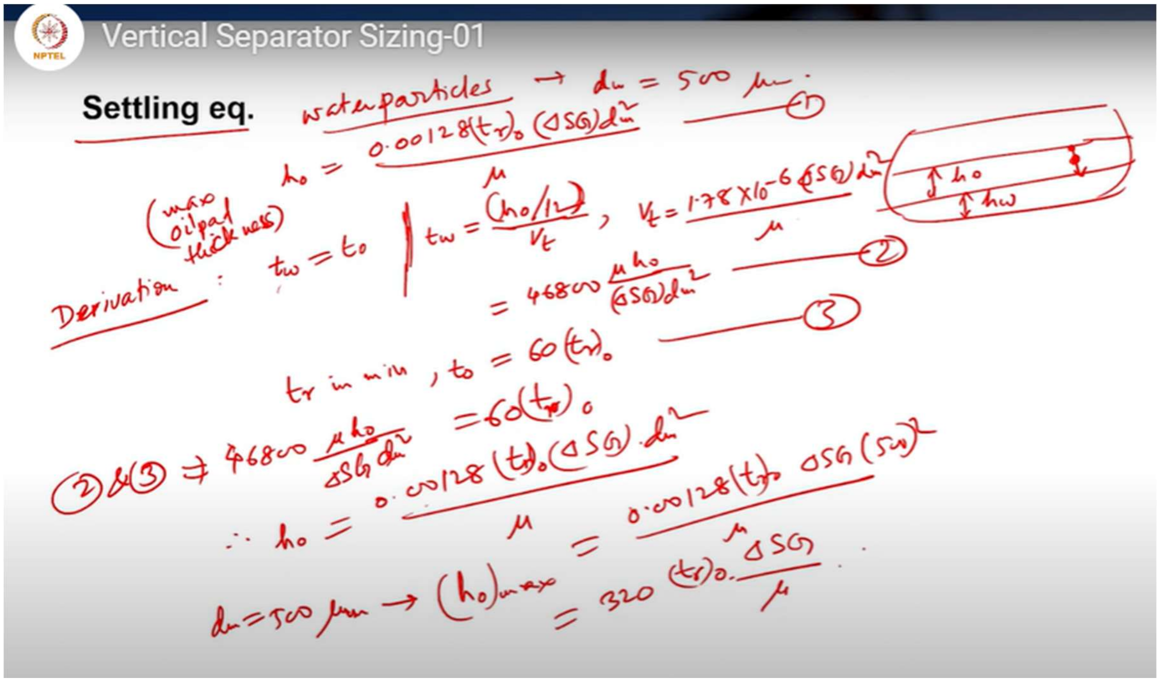
So, volume is equals half, half field separator this is 50 percent, this is 50 percent. So, half into pi by 4 d square total circle, this volume, this area. So, pi by 4 d square into effective length, this is d or capital D. So, unit is here, capital D is actually feet and if I write small d that will be in inch. So, we should not get confused there.

Then it will be like half pi small d square 4 small d converted into feet. So, it will be 144 will be coming here and effective length already in feet. So, if we simplify it, it will be like 2.73 into 10 power minus 3 d square L effective length. Now, volume of water, volume of first let us say oil, I am putting one symbol O, O means oil.

So, 2.73 into 10 power minus 3 d square L e f f. So, volume of water also same formula 2.73, 2.73 into 10 power minus 3 d square L e f f. One more term will be coming here.

So, volume V o l O is with the volume fraction. So, it will be A oil by A L, L means total liquid area, this is this area A L. So, this area A water, this area A oil. So, here also you will get A water total volume. So, this way you get a volume fraction.

So, Q o and Q w in BPD, again somewhere I am writing small capital. So, small right small here, so it will be uniform. Now, Q equals Q o into 5.61 that unit conversion into cubic feet per barrel into day 24 hours per day and hour 3600 hour, 3600 minute a second is 1 hour.



So, this is giving 6.49 into 10 power minus 5 Q oil. So, similarly you can find Q water 6.49 into 10 power minus 5 Q water and A o, A w, A l these are in feet square. So, I have to put one number, this is volume 1 is 1, what is that 2.73 this is 1 and this is 2, this is 3.

So, I am getting, I can put this one X 1. So, X 1 if I do like this X 1 and Q values, Q values here 3. So, it will give like this T water equals volume, volume of oil fraction by total volume. So, 2.73 into 10 power minus 3 D square effective length divided by 6.

49 into 10 power minus 5 Q naught and A naught by A will come. So, finally, this is this will bring 42 A o by A l equals T o Q o by D square effective length. So, this is equation number 5. So, I have to create another slide. Now, we have seen the 42 A naught by A l equals T oil Q oil D square effective length.

So, this is equation number 4. Now, we can get for water also 42 A water A l equals T water Q water D square effective length. Now, if we add these 2 4 and 5, 4 plus 5 this equation if we add 42 A w plus A oil A l equals the right side also will be added T o Q o plus Q water T water D square effective length. So, finally, this will give 42 by 60 A w plus A oil A l equals T ro Q o plus T rw Q w divided by D square effective length. So, here T r in minute T r in second T ro or T rw in minute. So, just that is why this 60 term is coming.

So, this is your formula to calculate retention time to link retention time flow rate and your percentage of how much thickness is there for oil and water. Now, A water A oil plus A water equals A l. So, this will give D square effective length equals 1.4 60 divided by 42 and A l is this side it is going like this then it will be like T ro Q o plus T rw Q w.

So, this will be 1.42 T ro Q o plus T rw Q w. So, this is your equation. So, this is equation for retention time calculation. Now, settling equation for water particle settling. Particles water particle will be falling down and we will be assuming D diameter 500 micrometer or micron and oil pad thickness h o maximum pad thickness h o equals 0.

00128 T ro del S g d m square divided by mu. So, this is your oil pad thickness. Now, derivation how to derive? Derivation. So, how to derive? So, we have to start T water retention time we assume T oil retention time inside separator. So, T water equals h you have to draw this one.

So, we h oil h oil h water T water equals h oil oil particle is flowing crossing this water particle crossing this oil pad. So, you assume oil pad from top portion one particle is moving down to oil water layer from oil to oil. When it is moving it is crossing h distance h o distance h o if it is in inch. So, inch divided by 12 h o divided by 12. So, that much of distance is crossing and if it is having velocity V t then distance divided by V t equals retention time of water how much time it is taking.

So, that much of time it should take it should be staying inside water area and what is the V t. So, V t in this case will take 1.78 into 10 power minus 6 del S g d m square divided by mu. We are assuming this stroke length is holding here so Reynolds number less than 1. So, T water if we simplify this one it will come like this 4 6 8 0 0 mu h o del S g d m square.

Now, T R in minutes T R in minute. So, T o equals 60 T R o. So, now we can see 2 and 3, 2 and 3 it can imply like this 4 6 8 0 0 mu h o del S g d m square equals 60 T R o retention time of oil. So, h o equals 0.00128 T R o del S g d m square mu. So, how h o oil pad thickness is linked that is it linked with your retention time of oil specific gravity particle diameter and viscosity.

Is the maximum thickness of oil pad that can still be allowing water droplet to settle out of in time T R o. Here we are assuming this retention type of oil and water is same. So, if we calculate for what oil calculate retention of our water the same is the same time we are assuming for oil also. And if we assume let us say d m equals 500 micrometer or micron then in that case h o will be like this whole equation 0 0 1 2 8 T R o del S g 500 square where mu which will be giving 0 not 0 3 2 0 T R o del S g divided by mu. So, if you know already particle diameter you can calculate like this or if you are assuming d m for water particle size.

So, just assume 500 and you can solve the problem. Thank you.