Aspen Plus Simulation Software - a Basic Course for Beginners

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Lecture - 04
Using Model Pallete – Mixers, Splitters, Separators

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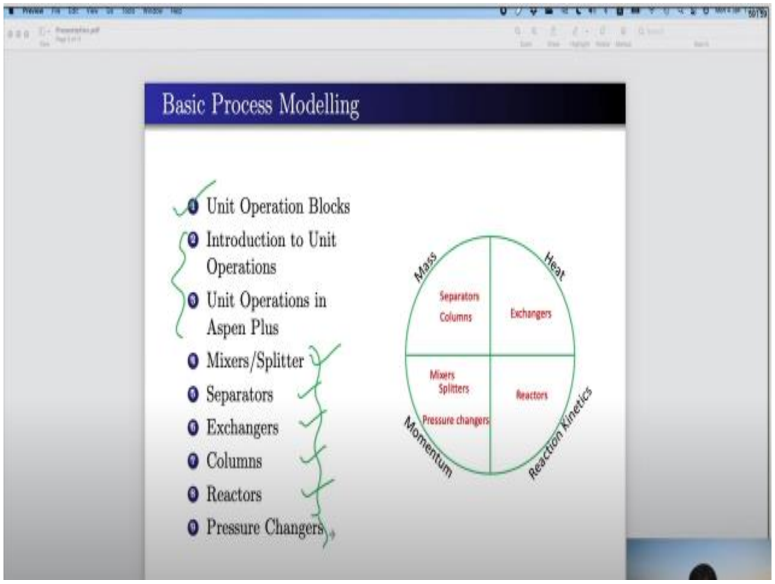

Welcome to the massive open online course on Aspen Plus. In today's lecture, we shall learn the basic process modelling. We will cover the portion of unit operation blocks. Actually, we will introduce the unit operations and unit operations in Aspen Plus, and we will cover these unit operations that are mixer splitter, separators, exchangers, columns, reactors, and pressure changes.

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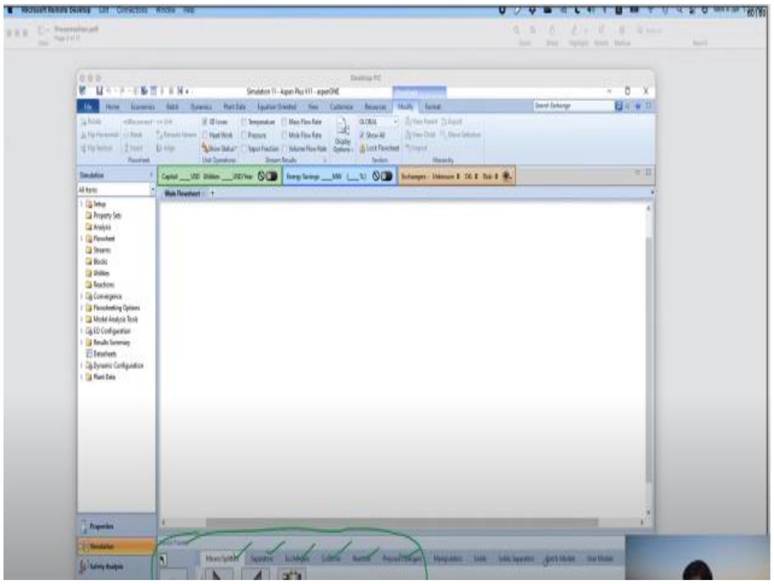

If you look at the Aspen Plus model pallet, then you will find them over here. So this is the portion that will cover the mixer splitter, separator, exchanger, column, reactor, and pressure changes. This portion is not within the scope of this lecture series.

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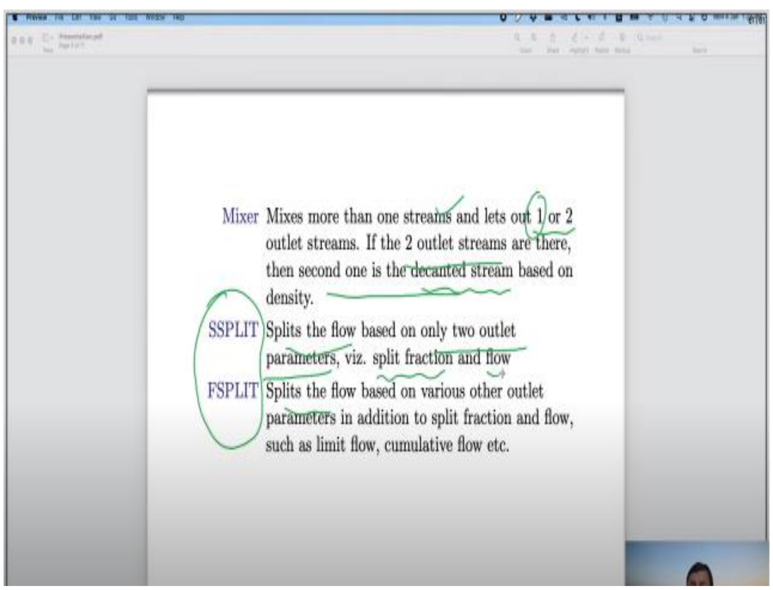

First, we will begin with the mixer. The mixer mixes more than one stream and lets us out one or two outlet streams. In most the cases, one outlet stream, sometimes a second outlet stream, is present. Now in case, the second one is present, then it would be the decanted stream based on the density. That means the fluid with higher density will flow through the bottom, whereas the fluid with lower density will flow through the top.

There are two types of splitters, SSPLIT that is string split and FSPLIT that is flow split. As the name suggests both of them splits the flow but SSPLIT it splits the flow based on only two outlet parameters, their split fraction and flow. On the other hand, FSPLIT splits the flow based on various other outlet parameters in addition to this split fraction and flow such as limit flow, cumulative flow etcetera. Now this mixer and splitter they are not any separate instrument.

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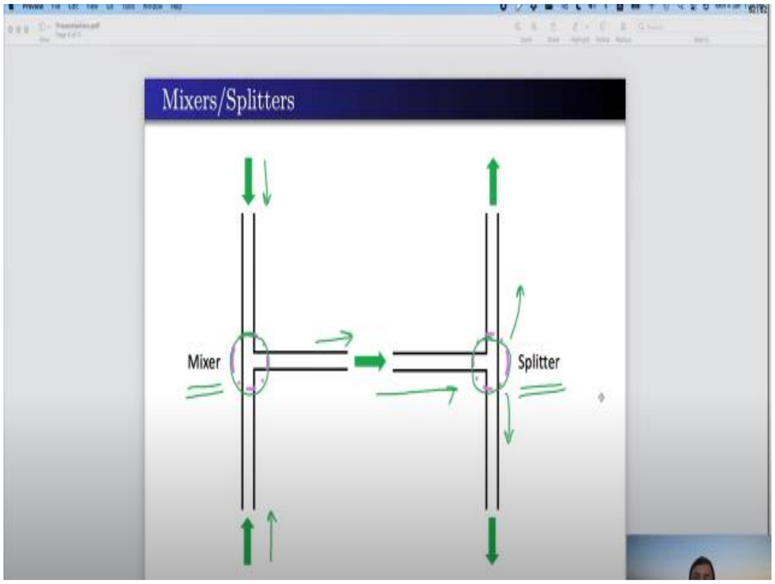

Whenever you find a pipeline where two inlet streams are coming from two directions and they are merged into one single stream which goes out through the outlet stream then the point of confluence can be regarded as a mixer. Similarly, when a single fluid enters through a pipeline and they are splatted into two or more streams then the point at which those streams they separate from each other that may be regarded as a splitter. Now let us take the example of mixer splitter.

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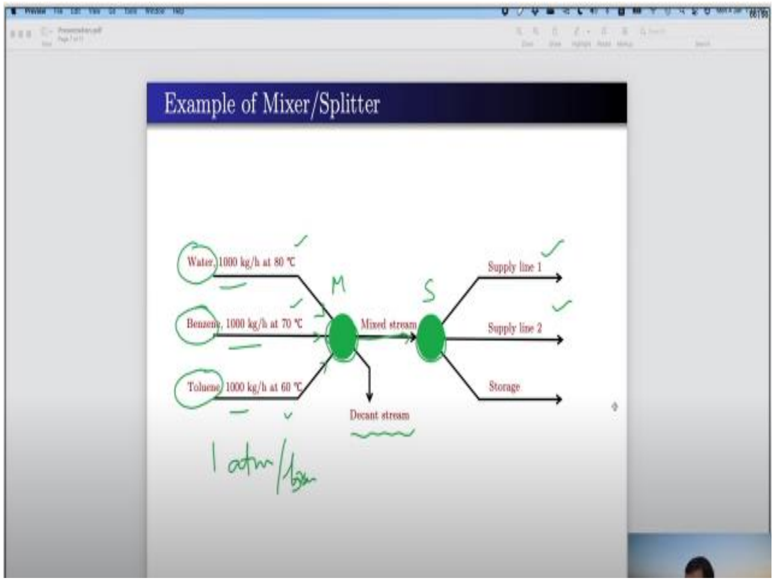

Here we find one mixer and one splitter. As you can notice that three streams are merging into this mixer, one is water, the benzene and toluene. For each one of them the flow rate is 1000 kg/hour and the temperatures are 80 degree centigrade, 70 degree centigrade and 60 degree centigrade respectively. The pressure has not been given in the problem but let us assume that the pressure is one atmosphere or one bar, whatever you use. So, they are mixed into this mixer.

The mixed stream is going into the splitter and we have taken a decant stream also. So we will solve the problem with or without the decant stream. This mixed stream is going into the splitter and the splitter splits this stream into three lines. Supply line one, supply line two and the third line is going into the storage. We have not specified in any split fraction. We will specify it when we do the problem in the Aspen Plus domain. So now let us go to the Aspen Plus domain and see how the things work.

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So, this is a fresh simulation. First, we have to go to the properties and fix up our components. So our components are water, benzene and toluene. Press next. Let us use Riley Quarks Wave model. For that we have to use a free water method steam, nbs. That is the norm. If you do not use it, it will not go forward. You can check the health file regarding the SRK model and the petroleum calculation options that is free water method.

Press next. Use estimate using UNIFAC and run. So the properties are available. Next go to simulation. Here let us bring a mixer and let us add the supply line. So this is the first inlet, this is second inlet and this is the third inlet. This is mixed stream and this is the decant stream. The decant stream is optional. But we give it here just to see how the things work. Let us rename it. Let us name it as water. This stream is benzene and this stream is toluene.

Let us use the name mixed and finally let us use decant. So, these are the streams that we have. Press next. So first it is asking for the inputs for benzene. So, benzene as you know it is 70 degree centigrade. So, water is 80, toluene 60, benzene 70. All of them are having 1000 kg/hour flow rate and one atmosphere pressure. So, 70, 1 bar pressure and mass flow of 1000 kg, it is completely benzene. So, the mass fraction is 1. Go to next asking for toluene.

Temperature 60, pressure 1 bar, mass flow rate 1000 kg/hour, mass fraction 1. Next is water. The temperature is 80 degree centigrade, so one bar pressure, mass flow rate 1000 kg, mass fraction 1. Now it is asking for simulation. Now let us go and check what are the options available for b1 mixer? Although everything is done, I mean the model equations are well balanced now. So, it is ready to run simulation.

But let us see if anything we can add as a value in b1. So here it is already showing vapor liquid and free water. So, three phases are here. So, we do not have to change anything just simply run. So, we have got the result. So let us go to the result summary streams. Here you can see what are the components. So, these are the two mixers that we are interested in decant and mixed. So here mass flow if you check mass flow see in the decant stream, we completely have water.

Nothing else, no benzene and no toluene. It is free water whereas in a mixed stream we have very little amount of water. And benzene and toluene total they are going into the mixed stream. The water being a heavier component it will go down the decant stream. So, you can check the density of water at 1 bar and 80 degree centigrade it is 0.9. Whereas the toluene 0.83 and benzene both benzene and toluene being 0.83 they are lighter than water.

So, water is going down. Now this one we have done with decant stream. Now let us forget about the decant stream. Let us delete it and the next problem that we will do about the splitter. So, we add a splitter over here. So, we bring in first FSPLIT. So FSPLIT connect the mix stream with this. Then there are three streams coming out from the mix stream coming out from the FSPLIT. These two are supply and the third one is storage.

So let us rename them, supply 1, supply 2 and storage. So, these are the three lines. Let us rename this also, splitter. Now press next. Now this portion has already been fixed. Now we have to fix splitter condition, splitter supply 1, supply 2. Anyway, press next. It will automatically go to splitter. Here the splitter input we have three options, supply 1, supply 2, storage. Now first supply 1 we have only two options, split fraction and flow.

Now let us assume that we will take 25% of the flow we will send it to supply 1. 50% flow will be sent to supply 2 and the rest of the flow will be given to the storage tank. So let us go by this strategy. So the split fraction of 0.25 will go to the supply 1. So supply 1 will get a split fraction value of 0.25 and supply 2 will get the value of 0.5. Till now the specification is half red. That is, it is looking for a data.

But the moment I give this data automatically storage will be fixed with the rest. That is 0.25. It will not ask for storage data. So, it will automatically take. So, the moment I press 0.5 it will be blue tint. See now it is blue tint. So, we have specified supply 1 and supply 2. Now it is ready to run. So, the moment I run, the streams will be here. You can see supply 1, supply 2 will get 50% of the total.

So here you can see 50% of 3000 is 1500 and 25% of 3000 is 750. They are going to supply line 1. Now if you see the mass fraction, they are also the same. Now here in the mixed flow water, benzene and toluene all of them are having equal proportion, 33.33% because all of them are 1000. So, the same proportion will be reflected in supply 1, supply 2 and storage as well. So, their fractions are different but the composition will be same as the inlet flow rate.

Composition cannot change. Similar thing can be done with flow. Instead of split fraction you can use flow data. For that you have to say mass flow rate. So out of 3000 how many kg/hour you want to give it into supply line 1? That is the specification that you have to give over here. Now let us remove the SSPLIT. Instead let us use FSPLIT. Connect this with this, this one with this, supply line 2 with this and storage with this.

Let us rename it as splitter here. Let us see what are the options they are asking for splitter, FSPLIT? So FSPLIT all the lines are together and they are asking for a lot more options other than split fractional flow. So, they have limit flow, volumetric limit flow, cumulative limit flow, cumulative volumetric limit flow and residual action. Now these two already you know. What is limit flow?

Suppose out of this 3000 kg/hour of feed into the splitter you want 1800 kg/hour to go to supply line 2 with a preference number 1. That means there might be situation in the process plant where the total flow rate may go below 3000 kg/hour. It may go to 2000, 2500. In that case you will not be able to feed all the challenge, supply 1, supply 2 and storage. You may not be able to feed into all the channels.

But your preference the first preference is to give 1800 kg/hour to supply line 2. You never would like to go supply line 2 go dry. So, you ensure 1800 over there. If there is a certain amount left you want 400 kg/hour to go to supply line 1 with a preference number 2 and the rest of the thing goes to the storage. So that is your strategy. You can use limit flow or cumulative limit flow.

So, you can say limit flow of supply line 2 with a mass flow rate of 1800 with a stream preference number 1 and cumulative limit flow of 1800 plus for 400. That means 2200 kg/hour. So that is cumulative. So that is done. Now here you have written cumulative flow you can give a limit flow also. In that case you have to give 400. Either one you can give. Either you can give cumulative flow or only limit flow. Choice is up to you. Now if you run the system just run and see the streams. See what happens.

So mass flow you see supply line 2 gets 1800, supply line 1 gets 400 and storage gets 1800. And mass fraction again they are the same. Now let us use some different strategy, say benzene we make it half. Let us take not 1000 kg/hour. Let us take 700 kg/hour of benzene, 700 kg/hour toluene and 700 kg/hour water. Now here we have a situation. Now we do not have 3000 kg/hour anymore.

Instead, we have 2100 kg/hour. But we have committed 1800 to supply line 2, 400 to supply line 1 and rest is the storage. But we do not have that much of water to flow. So here 1800 will be ensured to the supply line 1 and if 2100 minus 1800 so we will have 300. That 300 will go into supply line 1. Storage will go dry. So let us see whether this happens. So let us run and see the streams.

Here you see the streams. So, we have got 1800 ensure to the supply line 2 and then we no longer have 400 kg/hour left. So, we have only 300 kg/hour left because the total is 2100. So, supply line 1 gets only 300 kg/hour. The storage completely goes dry because it does not have any more flow left to feed into storage. So that is how you can use a mixer and splitter.

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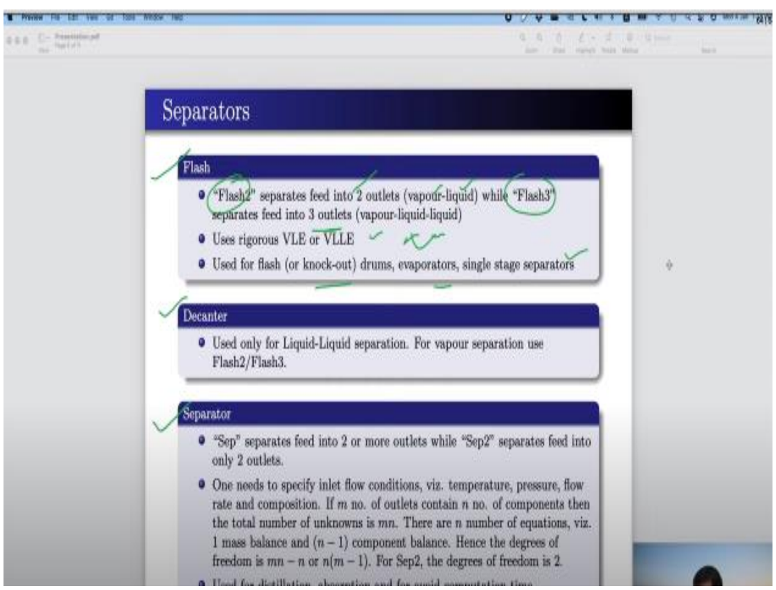

The next one is separators. There are three types of separators, flash, decanter and separator. In flash we have two types, flash 2 and flash 3. The flash 2 separates the feed into two outlets, one vapour, one liquid, while flash 3 separates the feed into three outlets, one vapour and two liquids. And they use rigorous VLE that is Vapour Liquid Equilibrium or Vapour Liquid Liquid equilibrium equations. Flash is used for flash drums or knockout drums, single step separator etcetera.

Now the next example is of flash. How we can use flash? Now I will use only flash 3. You can use flash 2 as a practice problem.

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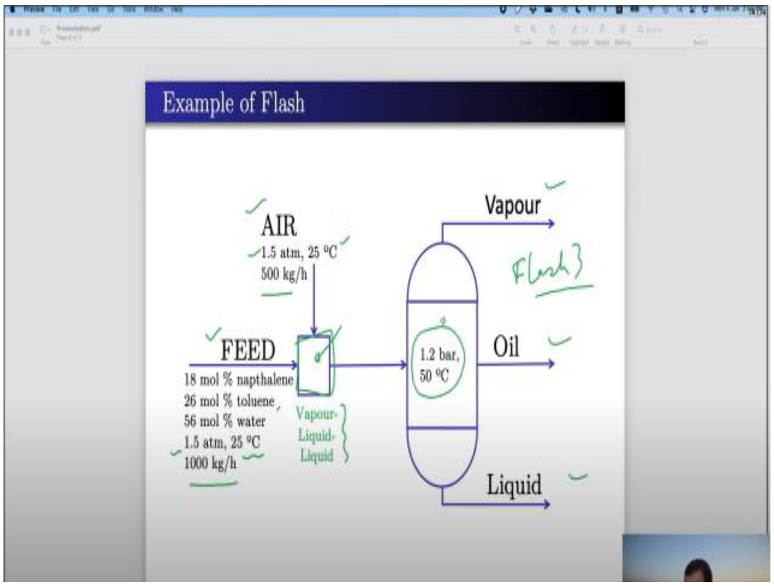

Now the flash problem we have a mixer over here. We have two feeds, one is a mixture of naphthalene, toluene, water at 25 degree centigrade and one at 1.5 atmosphere pressure, flow rate is 1000 kg/hour. We have a second feed of air with temperature 25 degree centigrade and pressure 1.5 atmosphere. It is flow rate is 500 kg/hour. They are mixed into a tank with vapour liquid liquid equilibria and that is fed into the flash.

And you can understand this is flash 3 because you have vapour, liquid and liquid. The flash condition is 1.2 bar and 50 degree centigrade. So let us do this problem in the Aspen Plus domain. So, for that let us open a new file blank simulation.

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Close it and do not save. Yes, so here we have three components, naphthalene, toluene, water and sorry four components, air, naphthalene, toluene, water. So first is air, water, toluene and naphthalene cannot be written full. So let us find it naphthalene. Find now. Here this is the one which you are looking for. So, add selected components and let us rename it naphthal. Now press next.

Let us use common one NRTL method. Next with UNIFAC estimation, run. So, you obtain the binary parameters. Let us go to a simulation. So, we need a mixer and flash 3. There are two material feeds, air and the other feed. This will go into the flash. It has a vapour, oil and liquid. So, this is air, this is other feed. This is the mixed feed, this is mixer, this is vapour, this is oil and finally this is liquid.

So, the heavier component will go down as a liquid. So here we have the options of toluene and naphthalene. So, we can expect toluene and naphthalene to go into the oil portion whereas water to go down to liquid. Let us see whether it happens. So, press next. It is asking for the input air. Now air 25 degree centigrade, 1.5 atmosphere. So, 25 degrees centigrade, one atmosphere. The one atmosphere and one bar they are the same thing.

But let us be true to the value and 500 kg/hour with mass fraction to be 1 for air. So we have air to be completely defined. Now we have to define feed with 18 mole % naphthalene, 26 toluene, 56 water. So, 18, 26, 56, for naphthalene, toluene, water. So, we have 18, 26 and 56 for and this is mole fraction not mass fraction. This is mole fraction total is 1. Temperature 25, 1.5 as before. This is 1.5 atmosphere and mass flow is 1000 kg/hour. So, this is defined.

We have done a small mistake with air. So let us correct that mistake. Actually, this is not 1.1 atmosphere it is 1.5 atmosphere. So, we make that correction. Now let us go to next. Now the flash input it is asking for flash. We know it is 1.2 bar and 50 degrees centigrade. Now it is ready to run because all the parameters are now fixed. But still, we want to go and see the condition in mixer.

Now it is showing vapour liquid but we know we do not have vapour liquid we have vapour, liquid, liquid because we have water and oil. So let us say vapour, liquid, liquid. So now run. Yes, so it has run and results are ready with us. So, these are the results. We have three things to see, liquid, oil and vapor. Now let us see the component. So, we have a total of 1500 kg/hour out of which the liquid contains 138.594 kg of which 138.518 is water.

The flow of air, toluene and naphthalene they are negligible in the liquid whereas water content is negligible in oil. So is air. The oil is full of naphthalene and toluene. Vapour obviously it will have more of air. Out of 500 kg/hour 499.737 it has gone into vapour and mostly water and toluene they will go into the vapour phase. Naphthalene mostly will remain in oil or to some extent vapour phase.

So that is the expected result that we get out of flash 3. The next one is decanter. Decanter is only used for liquid-liquid separation. The moment vapour separation comes you have to use flash 2 or flash 3.

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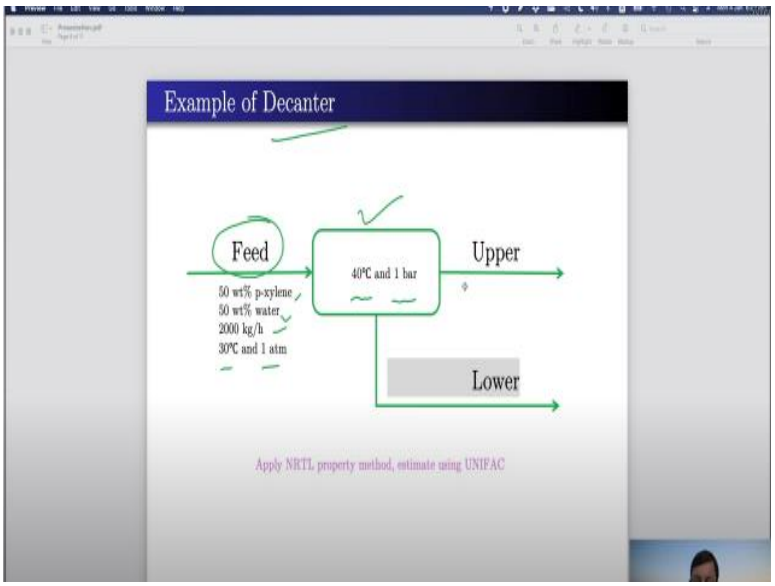

The next example is of a decanter. So as the name suggests the decanter always separates two liquids based on their density. That means the liquid with higher density will go through the bottom flow whereas the liquid with lower density will go through the top flow. So in this case we have a decanter over here we have a feed which contains 50% Para xylene, 50% water. Total flow rate is 2000 kg/hour and its temperature is 30 degree centigrade, pressure 1 atmosphere.

It will be passed through a decanter which will operate at 40 degree centigrade and one bar pressure. So, we will use NRTL property method and estimate using UNIFAC.

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Now let us go to the Aspen Plus window. So here let us open a new blank simulation. Close the current one, do not save it. So, we have two components, Para xylene and water. Press next. Use NRTL method. Next estimate using UNIFAC, run. So, the temperature dependent binary components are available. Go to the simulation. Here takes decanter then material. This is the feed; this is the first liquid and this is the second liquid.

Now the first liquid let us take it this side. It will look better. Change the name to feed, change the name to upper and this to lower. Press next. Now feed input. Temperature 30, pressure 1 atmosphere and flow rate 2000 kg/hour and 50% both of them. So, 0.5, 0.5. Press next. Yes, the decanter operates at 40 degree centigrade and 1 bar. Now here you have the option to choose the key component.

This is the key component to identify second phase liquid. Now we have two options, Para xylene and water. In the normal case if you do not choose anything if you do not select anything then the lighter component will go to the first phase liquid, heavier component will go to the second phase liquid. But if you prefer to choose the lighter component to come in the second phase liquid then you can choose over here.

In this case if you say Para xylene is the lighter component then if you can choose Para xylene to come over here for the second phase liquid. So that option is there with you. In this case we will not do something like that. We will go as the default condition exists. So, Para xylene is expected to go in the first-place liquid whereas water should go in the second phase liquid. So let us run it and see the result. Yes, so run is complete. So go to the result summary and streams.

Yes, so here upper and lower liquid mass flow total is 2000 kg/hour. You can see Para xylene is 999.766 in the upper liquid because it is the lighter one whereas water comes at the bottom because water is the heavier one. Now if you choose otherwise if you say that no, I want the Para xylene to be the key component for the second liquid phase then it will just toggle. So, if you run this way then you can again see the streams. And see your upper liquid will contain all the water and the lower liquid will contain Para xylene. So, the results will toggle because you have chosen the key components in that fashion.

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So that is how we operate a decanter. The third one is separator. There are two models in the separator section, one is Sep-1, another is Sep-2. The Sep separates feed into two or more outlets while Sep 2 separates the feed into only two outlets not more than two. Now in separator one needs to specify the inlet flow condition and that is true for any other model. The inlet for flow conditions is temperature, pressure, flow rate and composition.

Once you fix them then the outlet flow and outlet compositions are the ones which are unknown. For instance, if there are m number of outlets and there are n number of components then the total number of unknowns are m into n. Now we have n number of equations because we have one mass balance equation and n minus 1 component balance equation. So, the total number of equations we have 1 plus n minus 1, that is n.

So basically, we have m n minus n degrees of freedom. Now separators are used for distillation, absorption and for the cases where we have to avoid heavy computation time.

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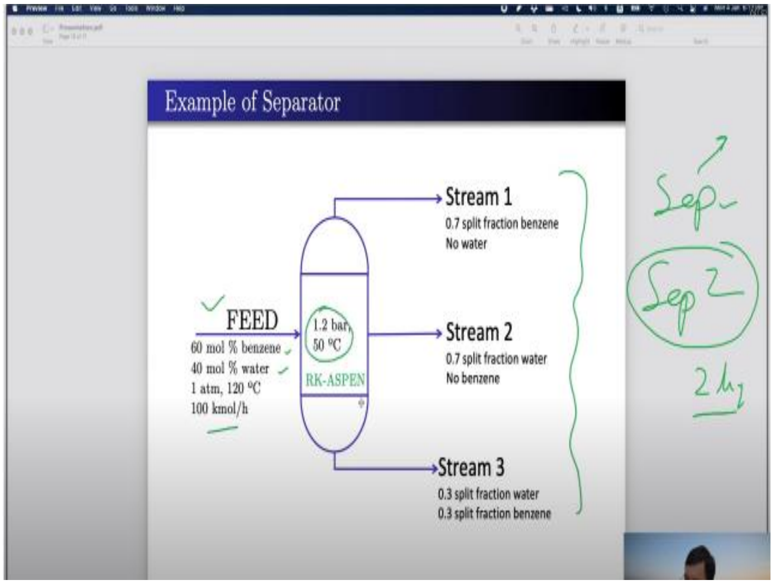

This example will have three outlet streams. So, we have only one feed and three outlet streams. The feed contains 60 mole % benzene, 40 mole % water and temperature and pressure given, the flow rate is also given. It will operate at this condition the separator. We will use RK-ASPEN. The stream one condition the split fractions are given. So, we want to operate this one. Now let us go to the Aspen Plus simulation window. Let us open a new simulation blank. Close the current one, do not save it.

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So, we have benzene and water. Next, we want RK-ASPEN. So RK-ASPEN will come here and run. Now go to the simulation. You choose Sep. You have the feed, stream 1, stream 2, stream 3. Rename it as feed, stream 1, stream 2, stream 3. Renaming is complete. Go to next asking for feed input. So, feed 120 degree centigrade, 1 atmosphere pressure, flow rate is 100 kilo mole/hour, 60 mole %, 40 mole %.

Next here again you have to give a split fraction. So, you might remember that sometime back we were talking about the degrees of freedom. So, the number of streams is 3 and the number of components 2, benzene and water. So, you have 3 into 2, m cross n. Now what are the degrees of freedom? Degrees of freedom is n into m - 1. So, it is 2 into 3 - 1. So, it is 4. That means we have to fix 4 components or four input data to define the entire system. So let us do it.

What are the other information that we have? Stream 1 we have 0.7 split fraction of benzene. So, stream 1 will have 0.7 split fraction of benzene and it should not have any water. So, I do not want any water to go into stream 1. Similarly, I do not want any benzene to go to stream 2. So, stream 2 should have no benzene all water. Now you can see if you define 0.7 split fraction benzene over here, 0.7 split fraction of water over here.

No water in stream 1 and no benzene in stream 2 then obviously 0.3 split fraction of benzene which is left from stream 1 and 0.3 split fraction of water which is left in stream 2 they will combine and go into stream 3. So out of these six components we have to choose any four. The other two will be fixed by itself. So that is what will happen. So we have got stream 1, let us choose stream 2.

Here we have no benzene and we have 0.7 of water. So, we can run the simulation now. Yes, so the simulation is complete. We can go to the result summary. See the condition of stream 1, stream 2 and stream 3. So, mole flow benzene 60. So, 0.7 of 70 %, 70% of 60 mole of benzene that means 42 kilo moles of benzene will go to stream 1. Whereas 70% of 40 that means 28 kilo mole/hour of water will go to stream 2.

And stream 3 will have a combination of 30% of benzene and toluene. So, 30% of 60 will be 18, 30% of 40 will be 12. So, this is the combination of stream 3. So that is how we can operate a separator.

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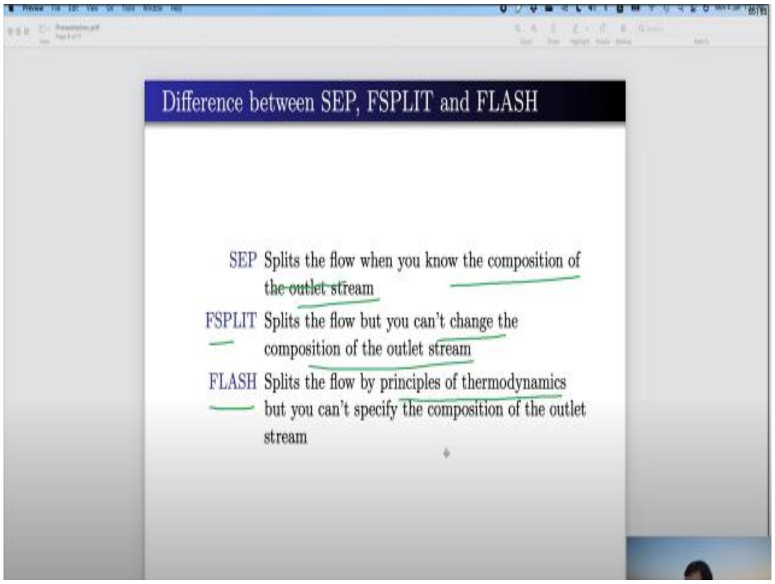

Now; one thing is common for Sep splitter and flash. All of them they FSPLIT the flow. But Sep splits the flow when you know the composition of the outlet stream. Not all but up to the degrees of freedom. While f split it also splits the flow but you cannot change the composition of the outlet flow. It is decided by the model equations. And flash this also splits the flow into vapour and liquid but it follows the principle of thermodynamics.

And here also you cannot specify the composition of the outlet stream. So today we have covered mixer and splitter, also we have covered separator. In the next few lectures, we will cover the rest that is exchangers, columns, reactors and pressure changers. Thank you.