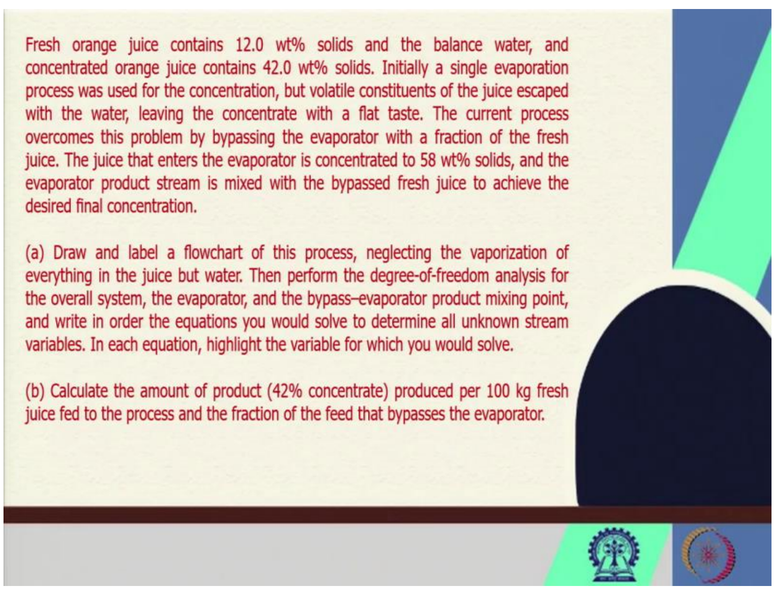
Material and Energy Balance Computations
Prof. ARNAB ATTA
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture –17
Material Balance of Recycle and Bypass Units (Contd.,)

Hello everyone, welcome back once again in the NPTEL online certification course on Material and Energy Balance Computations. We were discussing the recycle and bypass unit of their utility and how to apply material balance around those systems. The system that contains recycle and bypass streams. So in the last couple of classes and in fact 2 classes, we have discussed the utility of recycle stream the balance on the recycle stream and we have seen one example that what it introduces.

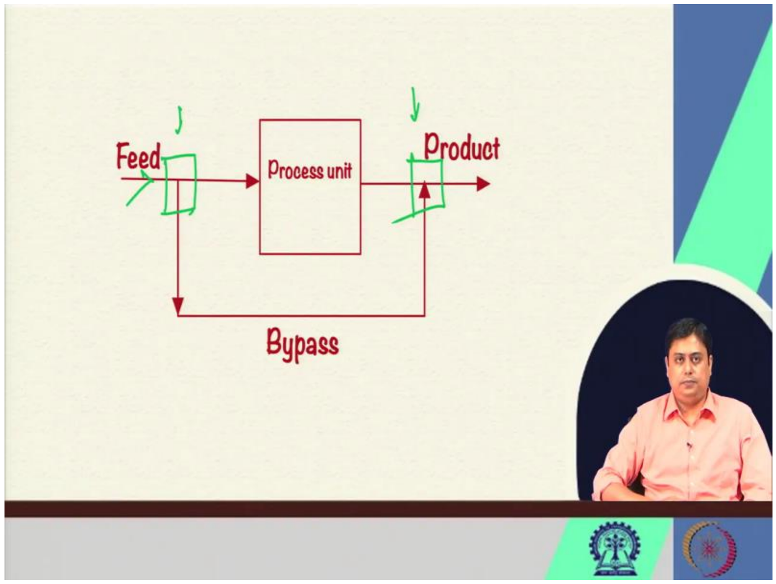
It essential introduces one mixing point additional unit that you can consider as an individual unit while solving the whole system because in multiple units, we have seen that we have to divide the systems, the system into several subsystems. We have to look into the degree of freedom analysis, and then we have to proceed with the approach that is efficient and again efficient means where we have tried to avoid the solution of simultaneous equation.

(Refer Slide Time: 01:42)



So now today we will see what is the bypass system? Bypass system is essentially similar to the recycle stream when it comes to the this application that we are having for material balance. So, when we try to do this material balances on the bypass stream. The process should be similar. But at first let us understand what is the bypass stream?

(Refer Slide Time: 02:10)



So, the bypass stream instead of being recycled like previously we had in the recycle case. Earlier we used to have a recycle stream which we have seen this kind of a streams and there is a mixing point instead the bypass section or the bypass stream is that a fresh feed a part of it is bypassed from a process unit and it is mixed with the product stream. So what happens here? The bypass, we are bypassing a process unit, certain fraction of feed, this feed can be fresh feed or that comes out from another process unit.

That is feed to this particular unit. Some part of it for various reasons we have to bypass and then we mix with the product stream. The utility we will understand immediately when we solve a problem. But before that let us understand the process because in this by pass stream what happens we have 2 different portion one is a splitting point unlike the recycle stream here it was a mixing point in recycle stream.

But we have here a splitting junction where the floor it is split into 2 parts. And here we have a mixing junction in case of recycle this was the splitting point and this was the mixing point, in this case the scenario changes. Now say what is the utility? The utility sometimes appears that we have to dilute the product or we have to reach to certain concentration of the product stream after it is processed. So for example here we have a fresh orange juice production system that contains 12 wt % solids and the balance water.

And the concentrated orange juice contains 42 wt % solids so these are the information. Now initially a single evaporation process was used for the concentration. So you have a dilute solution, you evaporate it like we have seen in the previous example. We evaporate only water so it becomes concentrated. From 12 wt % to 42 wt % we could have done it with a simple evaporator.

The point is that this volatile constituents of the juice also escapes with water and that creates that forms the concentrate with a flat taste not so good which we typically consume. So the solution is that some portion of the fresh feed is by passed from the evaporator and then it is mixed with the product stream which means you have a dilute very dilute concentration. You have a very high concentration.

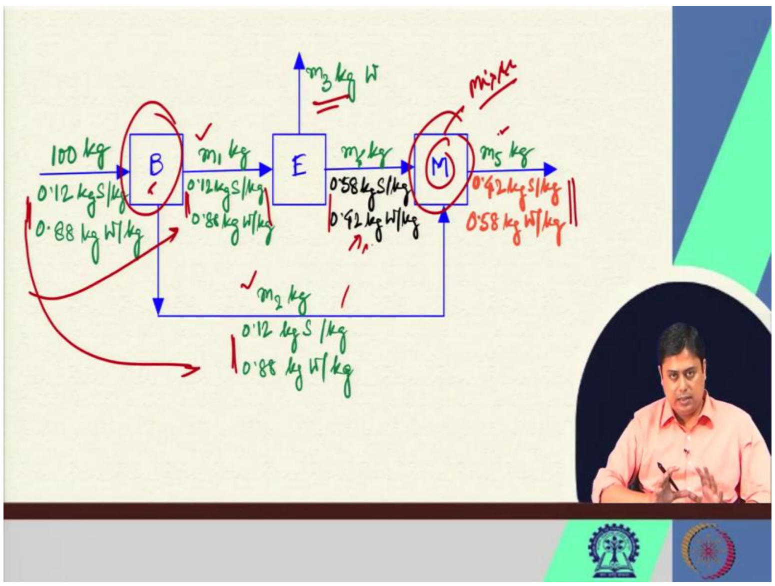
The stream coming and mixing bypassing the process unit which is the evaporator so that and then the mixture is prepared that is we have a concentration which is in between these 2. So the juice that enters the evaporator is concentrated to 58 wt %. And evaporator product stream is mixed with the bypass fresh feed to achieve the final concentration which is 42 wt % which means you had us dilute concentration which goes into the evaporator.

The evaporator then produces something and the final product is of 42%. So, we have to draw and level a flowchart of this process neglecting the vaporization of everything in the juice, but the water for the sake of simplicity that we assume here that only water is being evaporated from the system in the evaporator. Then we have to perform the degree of freedom analysis for the overall system. The bypass evaporator product mixing point and we have to write the order of the equations in which we will solve those unknown string variables.

And in each case we have to highlight the variable like we did in the previous cases. And finally we have to calculate the amount of product that is produced per 100 kg fresh feed to the process and the fraction of feed that bypasses the evaporator. So, like in the previous problem. We have seen that amount of recycle stream is required that that was required per kg of the fresh feed. So here it is the amount of feed that is being bypassed to the evaporator that we have to evaluate or estimate.

So, now I hope you have understood the concept of the utility of bypass stream. We will see another problem where again and other applications or another application of this bypass stream would be realised. So let us focus on this problem.

(Refer Slide Time: 09:19)



So what happens here? We have a bypass point now that is what here since we have introduced the bypass stream here this bypass system is shown separately here which acts as a splitting point and marked as B. We have a bypass junction. So here are some feed was coming and now here again the basis of calculation was not mentioned. So we assume that is say 100 kg of the fresh feed that is coming in. Here the percentage was mentioned weight percentage 12 and 42 in the product stream.

Because in point C the question is the amount of product produced per kg of fresh, so it is quite logical that we assume on the basis of calculation as 100 kg fresh feed, in which we have 0.12 kg of sugar per kg of this fresh feed and the rest is water, so W stands for water and S stands for sugar. This fresh feed comes some portion of it is bypassed. So that is why the bypass junction comes at the first place some portion goes in the bypass stream and some of it goes to the evaporator unit which is here.

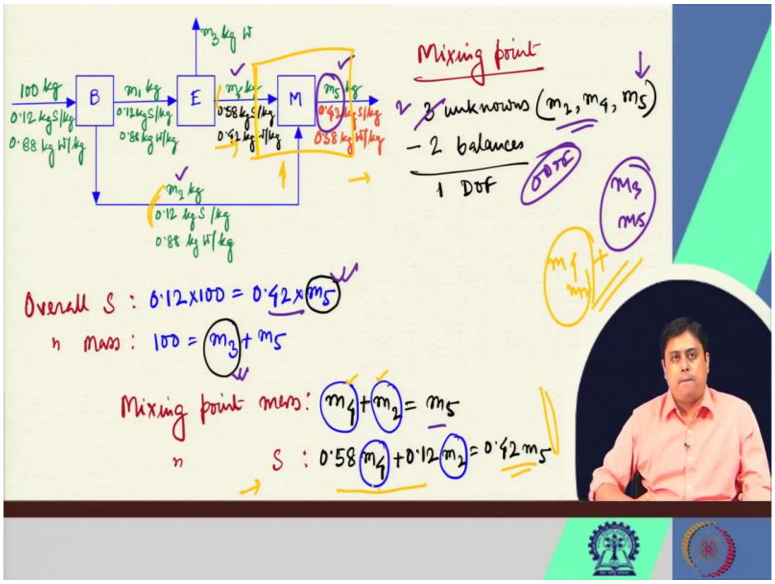
So, m_1 is unknown and m_2 is unknown. The immediate balance one can think is in $m_1 + m_2 = 100$ that is fine will come later that point. But straight forward we can write that these are the unknowns. Now remember this is only the bypass stream nothing is happening there except flow splitting so the concentration would remain identical as that of the fresh feed in both the cases and that is what written here, now the point once it enters the evaporator and leaves the evaporator.

It enters in a dilute concentration exits with 58 wt % of sugar. This much amount of water is being evaporated which is unknown. So here it is m_3 here m_4 this percentage is given on the problem statement. Now this stream is mixed with the bypass stream of the fresh feed. So this m stands for another mixture that I mentioned earlier. So, one we have the splitting point, one we have the mixing point in bypass stream.

In the mixing junction these concentrations are mixed to different concentration and we get the desired products concentration which is of 42 wt % of sugar and the rest is water. The amount of flow rate or amount of flow that is coming out of the amount of product is m_5 kg. So I hope you have understood this schematic or the flowchart and the levelling part here it is pretty simple. The concentrations the only thing you have to be careful that bypass junction acts as a splitting point where no concentration change will happen.

Until and unless it is further processed by some process unit the bypass stream before it makes it is mixed with the outlet stream evaporator. Until unless that is mentioned the bypass stream would basically act as a flow splitter only. So, which means now we apply our understanding that we have seen for the other multiple unit balance cases.

(Refer Slide Time: 14:31)



So we look at overall process. We have gone through these stages again and again. So we have to look at the overall process. The overall process is this process. The streams that are intersecting the system boundary is one inlet and 2 outlets. In this case, we have only 2 unknowns m_5 and m_3. We have 2 species or 2 constituents of this mixture. So we can write 2 independent balance equation, which means we have zero degree of freedom.

The problem is solvable so now we have to determine. The sequence of the solution, so if you go to the bypass point stream. Now in this case for the bypass, we can see that we have 2 unknowns one is m_1 and one is m_2. Here remember the composition is not changing so we can write only one balanced equation. That is the overall mass balance. That is why we can write only one balance. We will have one degree of freedom in the case of a bypass point for this problem because we here we have 2 unknowns.

Then we look at the evaporator the next unit, in the evaporator the number of unknowns m_1, m_3 and m_4. So for evaporator similar to our understanding that we have applied for the overall process and the overall system we can write 2 independent balance equations that means we have one degree of freedom for this case. We look at the mixing unit then, in mixing unit we have m_4, m_2 and m_5 theses are the unknowns.

We have 2 species we can write 2 independent balance which means we have one degree of freedom. So, which means we see that overall process 0, bypass 1, evaporator 1 and mixing point 1. So we must start with overall process balance. So overall either mass or sugar balance you can write but the sequence would be writing the sugar balance at first which is either sugar or you can write for the water as well any component balance.

Because here we have water that is unknown if you some if someone writes 100×0.88 for the water balance that comes in is equals to $m_3 + m_5 \times 0.58$ what will happen you have 2 unknown equations, unknown parameter. And from the overall mass balance there will be another equation which is $100 = m_3 + m_5$. So in that case you have to solve this simultaneous equation in order to find out water in m_3 and m_5, 2 equations 2 unknowns.

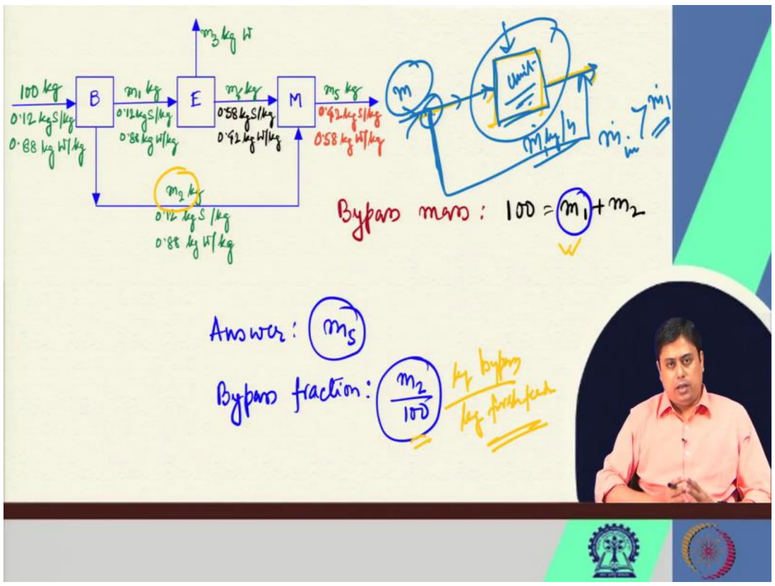
But if someone notices carefully that here the stream is only water there is no sugar because evaporator only evaporates the water. So that means for the overall system you have one stream that is input stream with sugar and one output stream with sugar. So these two had to balance. In this case, you know so it is easier that you apply the sugar balance at first, which is $0.12 \times 100 = 0.42 \times m_5$.

You can easily calculate m_5 without solving simultaneous equation. Once you find that you can easily calculate what is m_3 from the overall mass balance? So which means our m_3 and m_5 are now known. Once that is known we can look in the mixing point balance or the evaporator in any case because if you look at this degree of freedom analysis once your m_3 is known, m_3 and m_5 which is here in case of evaporator it boils down to 2 unknown. So zero degree of freedom which means after over all process one can solve the evaporator as well.

At the same time one can also solve because m_5 is known so mixing point can also be calculated because m_5 known that means now we have 2 unknowns that means we have zero degrees of freedom in this case. Either evaporator or the mixing point one can calculate. So the mixing point mass balance if we look at it. We see $m_4 + m_2 = m_5$, this is the mixing point system boundary. So, on the mixing point along with the mass balance if we write the sugar balance either sugar or water we can write because here both the things are unknown m_4 and m_2.

By writing another component we can find another equation that involves m_4 and m_2. So, for sugar here it is 0.58 m_4 × 0.12 m_2 = 0.42 m_5 because this is output stream and these two are the input stream for this system, 2 equations, 2 unknowns which means now we have m_4 and m_2 are also known. So, these 4 parameters are known to us. So let us revisit the things once again, we have m_3 known, m_3 we know this one, m_2, m_4, m_5 these are known to us. These four parameters are now known to us.

(Refer Slide Time: 24:44)



The bypass mass if we quickly apply because now here the only unknown is here m_1 which we can easily calculate based on the bypass mass 100 kg is treated into m_2 and m_1 we know the value of m_2 so m_1 we can easily calculate. So which means we now have all the unknowns evaluated. We have to go back to the question and look at what specifically has been asked. In this case if we go back to the problem we see calculate the amount of product produced per 100 kg of fresh feed.

The amount of product m_5 kg already the basis of calculation is 100 kg. In fact that is why we have taken the basis of calculation of 100 kg. So, m_5 kg would be our answer for that part and the fraction of feed that bypasses the evaporator. So, the fraction of feed that bypasses the evaporator is m_2 per 100 kg. So this kg of bypass per kg of fresh feed these are the specific answer that has been asked or you can think of as additional quantities that have been asked and we have discussed this in details while having the methodology for solving multiple units.

So, I hope you have understood the process of applying our understanding on knowledge of balancing multiple units and why the special focus or this typical this module has been devoted to the recycle and bypass streams because any practical process unit or process system in commercial cases do not run without the bypass of the recycle stream. So the recycle stream introduces a mixing point with the fresh feed, bypass stream introduces a splitting point immediately after or before any process unit from the fresh feed.

So the utility in order to summarise the recycle streams. We have seen where our reactant the unreacted reactant are precious and we cannot discard it with the product stream we have to recycle if the separation and recycle cost is lower than discarding that unreacted reactant. This is one of the examples.

In case of by passing the streams we see that sometimes say sometimes it may happen that you have product stream from a unit but this fresh feed sometimes comes in a fluctuating manner which means the optimum or say the maximum capacity of this unit say to process a certain amount of fresh feed say m kg of fresh feed, kg per hour of fresh feed. But suddenly your fresh feed input has become much better than this $\dot{m}_1$ kg of capacity that it can handle the unit.

So, what will happen this would be overloaded and the whole scenario can be jeopardized or the whole situation can go beyond control. If suddenly the excessive amount of feed comes into the process unit where it cannot handle that much of feed. Every unit has its own capacity therefore whenever say this amount is excess or excessive amount is coming into the unit. It can be detected with the detector and certain portion can be bypassed from that unit.

So that this equipment functions properly and its optimum or maximum capacity otherwise it is operation would go wrong and the whole downstream product would be of inferior quality. So again the take home message is that in the bypass stream the additional units that are introduced that you have to consider is the splitting unit and the mixing unit in case of recycle you have at first the mixing unit that is mixed with the fresh feed.

And at a later stage you have a splitting unit otherwise the process of solution the methodology of solution remains identical as that of what we have understood for the multiple units. With this understanding, I will sign off today and will see you in the next class.