Material and Energy Balances
Prof.Vingesh Muthuvijayan
Department of Biotechnology
Indian Institute of Technology – Madras

Module No # 02
Lecture No # 08
Material Balance Calculations for Multiple Units Without Reactions - Part 1

Hello everybody welcome to today's lecture on material balance calculations for multiple unit processes without reaction in those cases industrial processes are not single unit processes. There are multiple units which are connected together to perform and overall process this type of a system is represented using a process flow sheet or flow chart which is basically a classical representation of the process.

This provides sufficient detail to formulate material and energy balances and it can be also be used for trouble shooting and for controlling and operating conditions and optimizing the condition. Instead of drawing the process flow sheet which is quiet tedious we can also draw something called block diagram which is basically representation of the process using blocks are squares.

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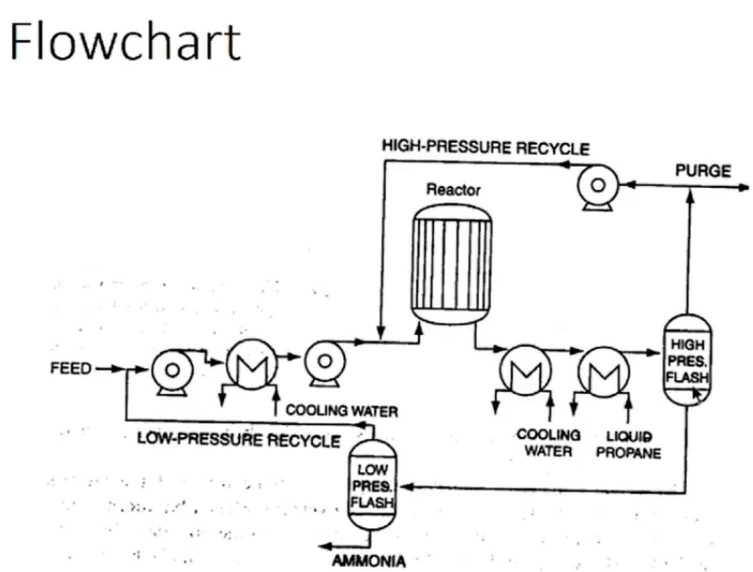

So this is the flow chart what you see here is feed entering getting mixed with a low pressure recycle then getting pumped to enter into a heat exchanger then again getting pumped to be with mixed with high pressure recycle and the mixture entering into the reactor and the product of the reactor counts is cooled by two different heat exchanger.

The exit of the heat exchanger enters into the higher pressure flash and the product of this high pressure flash either gets recycled or purged and the recycle stream is pumped to form the higher high pressure recycle the other product stream of the high pressure flash is then sent to a low pressure flash where ammonia is recovered and the low pressure recycle is sent back to the next with the feed.

So this process flow sheets gives you all the details of the process which is happening as you can see individual processor are represented using proper diagram which represent what type of the system it is. For example a pump is represented the way it is shown here and you have heat exchanges which is shown here and you have the reactor which is shown here and again heat exchangers and high pressure flash low pressure flash and so on.

In case this is too tidies you can also draw something called a block diagram which is shown here.

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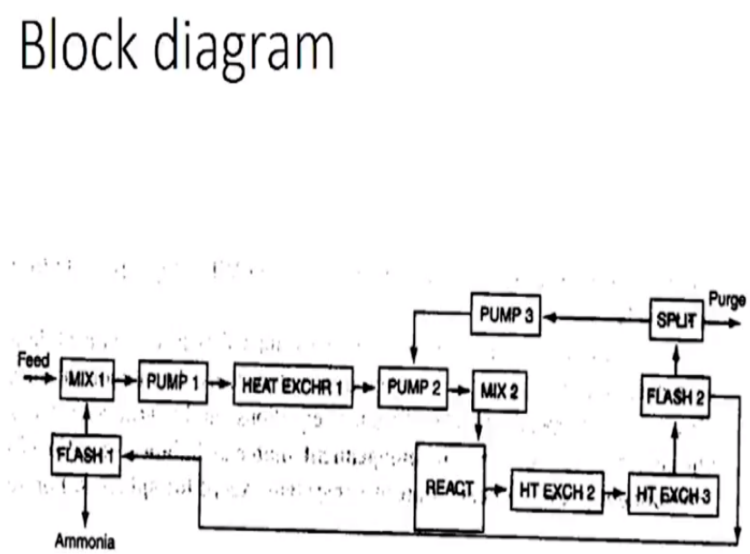

So the process which we described earlier is exactly depicted in the block diagram of also. However instead of using specific representation individual process here we just draw blocks with proper labels. So these are two ways to represent a multi-unit process.

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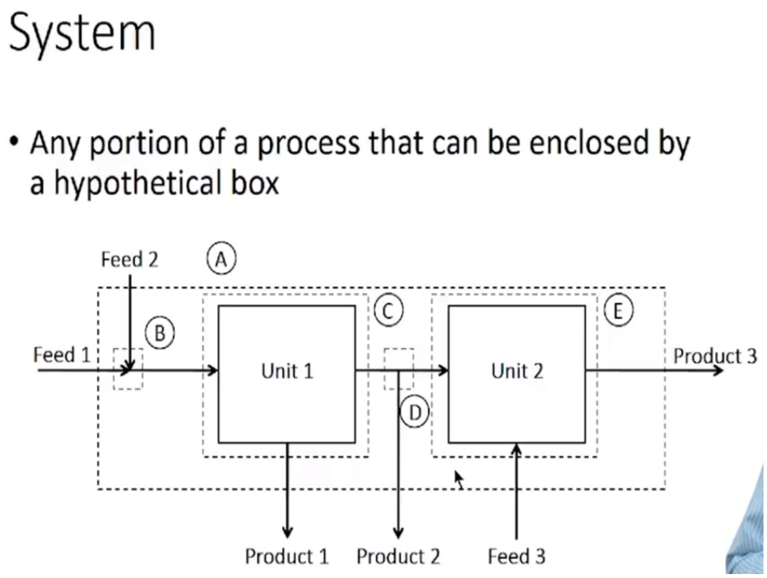

So let us look at a multi-unit process as an example so here is an example problem where you have two feeds which are getting mixed to the enter into unit 1 a product stream is recovered from this unit 1 and another product stream which leaves unit 1 is split into product 2 and this unit 2 has another input which is feed 3 finally forming product 3.

So this particular process can actually have multiple system the way we define a system earlier was any portion of a process that can be enclosed by hypothetical box. This means we can actually draw a different boxes to represent what each of these system would be this is an overall system.

You see that every process which process within the system every single unit which is present within the unit is actually been encompassed by this overall system this make sure that there is only feeds which are crossing the feeds boundary and products which are leaving the system boundary. It does not account for the mixing points or the splitters or the units separately so this is called the overall system.

Instead of drawing something like this you can also draw boxes which covers the individual system for example you could have only the mixing point as the system or only unit to 1 as the system or the splitter as the system or unit 2 as the system. In addition to this you can also draw combination of these system you could have B + C as a system or C + D as a system or you can have B + C + D as a system as so on.

So drawing the system make sure that you actually have portion of the process which you are going to observe in. So you will perform the material balances using this as a system and considering the stream which cross the boundaries of the system as your inputs and output.

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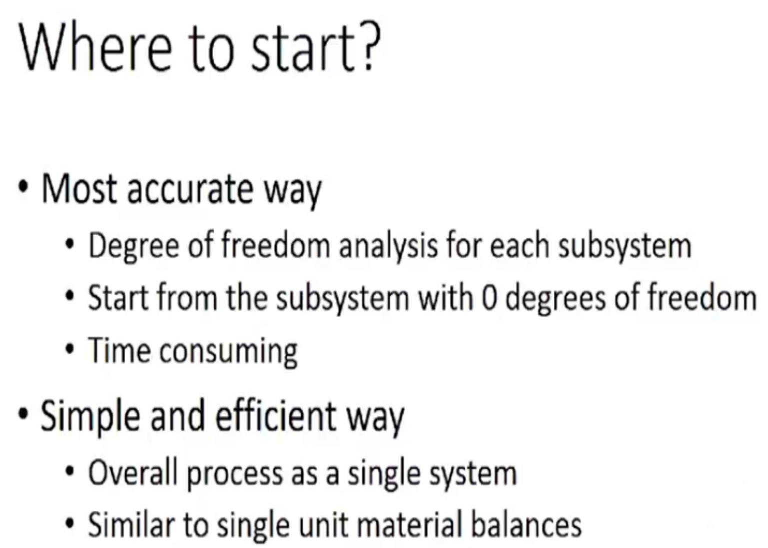

This means there are multiple system which we can study in a single unit process we had only one and it was simple to study. So here because there are multiple system where do we start the accurate way is to perform degree of freedom analysis for each of the sub system which we drew and start from the sub system which has 0 degrees of freedom this process is very time consuming.

So instead a simple and more efficient way to start with overall process as a single system and then continue with individual processes to perform the overall balances. So when you consider this overall process as the single system then what happens is the entire process is like a single unit system and the performance and the material balance is performed is similar to what we have done earlier. Another approach would be to start with either the finals system or the initial system.

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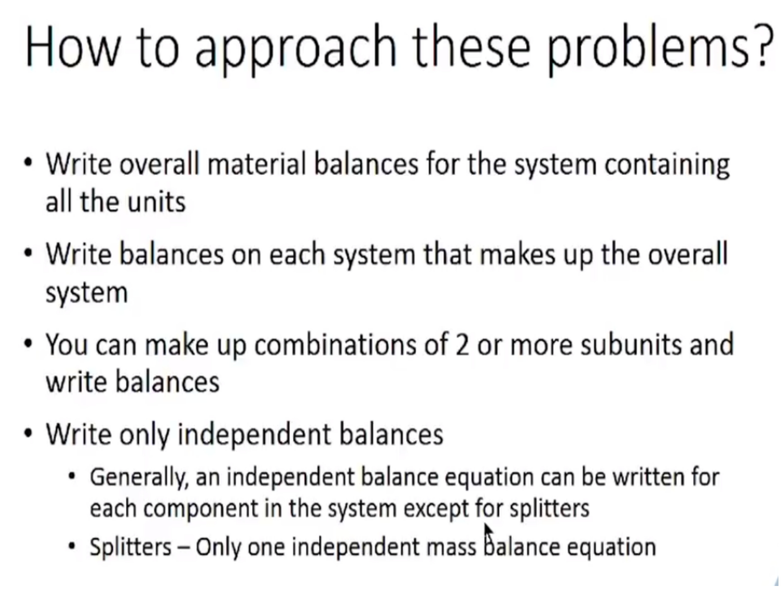

So how do we approach these problems first we write the overall balances for the system which are containing all the units which is the overall system and then we can write the balances on each of the system which makes up the overall system and we can also make combination of two or more sub units to form a system and there by write balances for these we need to be careful and write only independent balances.

Generally one independent balance can we written per component for most of the system except for splitters as we already saw splitter only have one independent mass equation which is the total balance equation.

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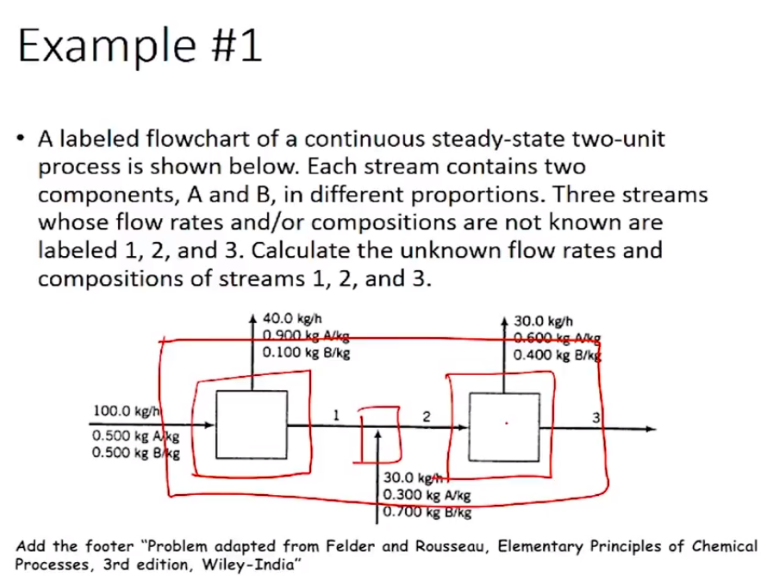

Now having looked at this we will see three different example problem each of them using different approaches which helps us in identifying how to solve these multi unit processes the first example is given here a label flow chart of continuous steady state two unit process is shown below each stream contains two components A and B I different proportions three streams whose flow rates and are composition are not know as labeled as 1, 2 and 3.

Calculate the unknown flow rate and the composition of streams 1, 2 and 3 now this process as 1 input which enters into particular process giving two output and one of the output leaves as a product and the other one gets mixed with another input so this mixed inputs enters into the unit formation to different product so this is what the system represents this si what the process represents.

Now what are the system which we can draw for this process just like how we saw in the previous illustration we can actually draw a overall system which contains all the units which are present so which is unit one your mixing point and unit 2 all of these together form an overall system or you could consider only the unit one only the mixing point unit two. You could also have combinations of unit 1 and mixing point or mixing point and unit 2 and so on.

So now that we have the possible systems we will start with the overall system that would be the easiest and efficient way to solve such a problem okay.

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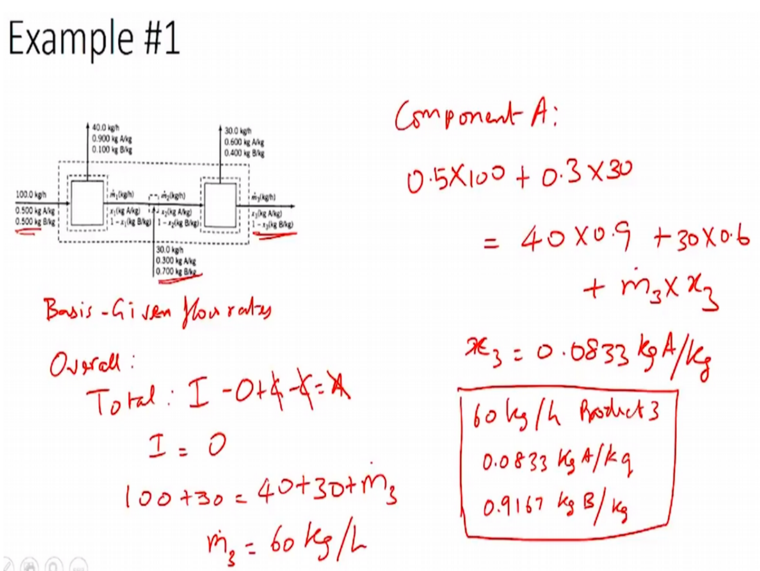

Let us now solving this problem we have multiple systems which we have chosen and we need to identify which system to start our calculation with before we do that before we identify basis for this system would be. So for this process we will have to use the basis as given flow rate as we have multiple flow rates that have been provided once we choose the basis.

We now have to identify which system we want to start with so we have multiple option you will first start with the overall system. Why do we want to start with the overall system if you look at the different systems the overall system actually gives you one information which is the unknown is only one stream which is M3.

You do not know information about the product stream which si the mass and the composition of the product 3 stream all the other stream which are causing the system boundary are unknown. SO we could start with the overall system let us start with this to perform this calculations for the overall system we can write the total system as input – output + generation – consumption = accumulation.

Assuming steady state accumulation geos to 0 and as the system does not have any reactive processes generation and consumption goes to 0 giving you input = output. The input streams are 1 stream which is entering at 100 kilogram per hour and the other stream which is entering at 30 kilograms per hour. So input is 100 + 30 = output stream which are 40 + 30 + M3 so now using this equation we can N3 dot as 60 kilograms per hour.

So now that we have calculated as mass flow rate of product stream 3 we need to calculate the product stream of 3 that we can do by performing component balances for the stream. We will first write the component A balance.

So what we have is 2 input streams where the composition are known so it is 0.5 times 100 which is A entering through the stream and it is 0.3 times 30 based on A entering through the other stream and you again have the output stream which are 40 times 0.9 + 30 times 0.6 + M3 dot times X3 where X3 is the composition of A in the product stream 3.

So why we have written this is again we assume input = output because generation and consumption are 0 and the processes as steady state. So from this we can calculate X3 as 0.0833 kilograms of A per kilogram so from this we have the information about the product stream 3. So the product stream 3 basically contains 60 kilograms per hour product 3 which contains 0.833 kilograms of A per kilograms.

So and the rest which is 0.9167 kilogram would be the composition of B per kilogram of the product. So this gives you the information about product 3 so the next step is to calculate the information for the streams 1 and 2.

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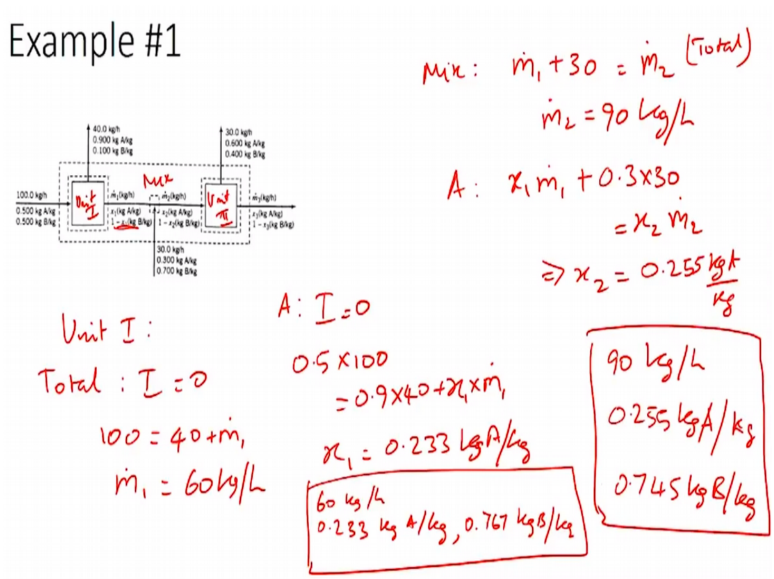

So let us start with unit 1 let us just call this as unit 1 so when we write a balance equation for unit 1 you will be able to get information about the stream 1 we can write a balance equation for unit 2 to get the information for stream 2. So let us first start with unit 1 with unit 1 we have a total balance equation which will come down to input = output which is 100 = 40+M1 dot.

So this gives you M1 dot as 60 kilograms per hour again by writing a components balance for A across unit 1 we can write it as input = output which is 0.5 times 100 = 0.9 times 40 + X1 times M1 dot. As already know M1 dot we can calculate X1 as 0.233 kilograms of A per kilogram so product stream which is leaving the unit 1 which is the stream 1 basically contains 60 kilograms per hour with 0.233 kilograms of A per kilogram and 0.767 kilograms of B per kilogram.

The composition of B is basically 1 – the mass fraction of A now we need to calculate the information for product stream 2. For that we could either write a balance equation for unit 2 or we could write a balance equation for the mixing product either of these would give us the information about product stream 2.

Now here I have chosen the write the balance equation or the mixing point using the mixing point we have M1 dot + 30 kilograms = 30 dot as the total balance. So this is the total balance from here we already know M1 dot so we can calculate M2 dot as 90 kilograms per hour we can again write a component balance for A across the mixing point as X1 M1 dot + .3 times equals X2 M2 dot.

Solving this equation we can get X2 as .255 kilograms of A per kilograms of the mixture so this means the stream 2 basically is 90 kilograms per hour containing 0.255 kilograms of A per kilograms the rest which is 0.745 kilograms of B per kilogram. So these three things which we have calculated gives us the information about the mass flow rates of stream 1, 2 and 3 and their composition.

So with that we have solved a multiunit process what you understand here is we used an overall which basically made the multiple units into single unit process and then broke down individual units and starting solving material balances for each of them separately with this we were able to get all the information that was required in the next lecture we will look at more example problems so we will look at an example problem where we approach a multiple unit system with a different approach rather than starting off with the overall system thank you.