Plant Wide Control of Chemical Processes
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Lecture - 27
Throughput manipulator selection
Illustration of the radiation rule

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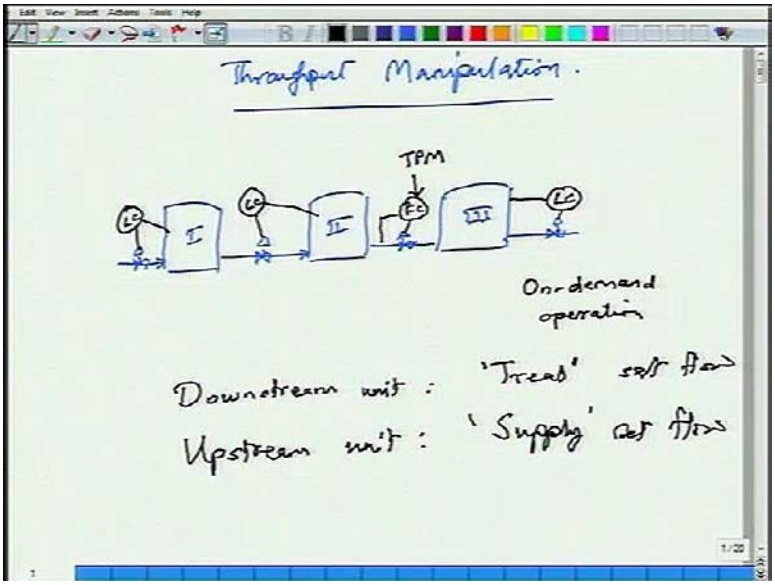

So, welcome to the next class. Today we are going to talk about throughput manipulation, what do you mean by throughput? Throughput, what do you mean by throughput? Production? Essentially production. So, last time we sought of quickly went through an example, which was you know a very simple tanks in series, but it need not necessarily the tank in series. Each of this tanks for example, represent process section; plant number 1, plant number 2, plant number 3, and they are connected in series.

So, I can set the throughput act the feed to the unit or to this train, so the feed to the train is flow controlled, then level control has to be in the direction of flow. The flow to the train is downstream and the level controllers are also oriented downstream, if you want to increase or decrease your throughput, this is the set point which your operator would adjust TPM throughput manipulator.

So, the set point use to increase or decrease production is called the throughput manipulator... the throughput manipulator is like a gas pedal in the car, that is what you

use to increase or decrease its speed. Usually you will have one throughput manipulator, but there are situations there in throughput manipulator has to be shifted, because some constrained conductive will talk about that later, but the point is there is a set point that is justice to increase or decrease production. So, for this control system throughput manipulator is discharged, the feet to the unit, right.

Alternatively, I could have a situation where the customer demands is what next to be satisfied immediately, customer says remove your product, have to do that immediately or customer says give me less product, I have to do that immediately. If that is a situation then what is happening is I am sorry, since we are doing black, then what is happening is my throughput is set for as the product, my throughput is set as the product line, and it is insided the product line for its for on demand operation, on demand, demand from whom, from the customers.

So, my throughput manipulator is as a product stream, and then level must be controlled in what? Reverse direction of process flow..., if I want to jack up or reduce the production, the set point that the operator adjust is this that the TPM. Therefore, this is the throughput manipulator; the set point use to manipulate the throughput is the throughput manipulator. Is this the only option, no, you could also have throughput manipulator as an intermediate stream, and let us say I could also have something which is of type, then level control downstream is in the direction of flow, level control up stream is in the reverse direction of flow, yes or no? And this is my throughput manipulator.

If I want to now, which such a location of the throughput manipulator is not, is a throughput manipulator is as an intermediate location inside a process stream, or process it is not as a speed, it is not as a product, it’s somewhere inside; then upstream units must supply the set flow, downstream units must treat the set flow. Thus the throughput manipulator is setting the flow to the downstream unit, to the downstream unit must treat that flow, upstream unit must supply that set flow, does that make sense or no, I mean its very straight forward, but I think it is important to understand it.

So, downstream units must treat set flow or set throughout, upstream unit must do what? It must supply the set flow, that is as long you can read by itself, its k right. The point is there are in-numerable numbers of options, even for this simple process.

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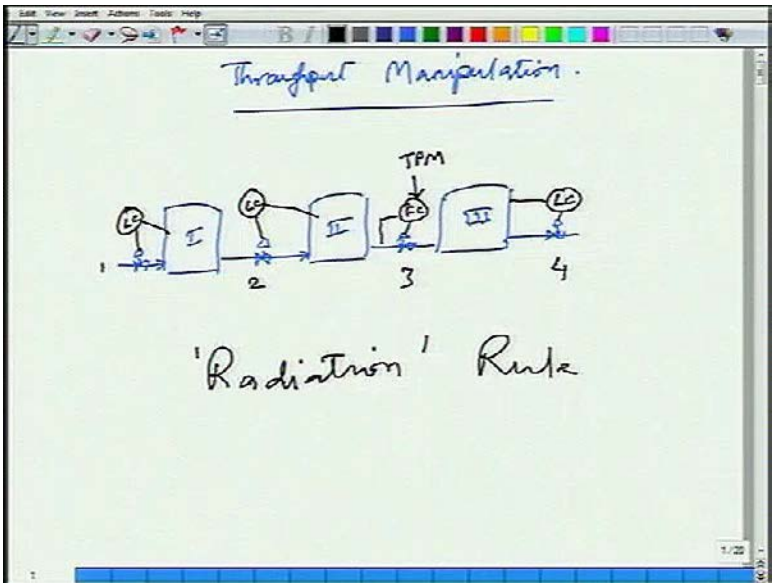

You can have a throughput manipulator at any one of these process streams, speed merely you can have it in stream 1, stream 2, stream 3 or stream 4, so throughput manipulator can be located in four locations, and each one of these control systems would work, it will provide you effectively inventory regulations.

So, where should we put the throughput manipulator that is the question? Yet, that question I do not think will address it right now; I just wanted to show the variety that you can choose the throughput manipulator, where ever you want and a control system can be designed around it. By the way this is called a radiation rule, if you look at plant wide control in literature this is called a radiation rule, the inventory control radiates outwards from the throughput manipulator location, that is not make sense or no? It outwardly radiating, means moving away downstream you know, if you are going downstream, does this radiation rule make sense to you or not?

The inventory control radiates outwards from the TPM, right yes or no, yes or no,

Student: we do not understand exactly

Do not understand exactly, so please stay close all right. So, how do I explain it to you? Level controller was oriented downstream in the direction of process flow; level controller was oriented in the reverse direction of flow, upstream of the TPM. So, was this is the radiation rule, if this is my TPM, level inventory control radiates outwards,

flow here is fixed, inventory is must be moved out this way, and it must inventory it must be stuck in this way. That is the radiation rule, it refers to as a radiation rule because the orientation radiates outwards from the TPM of the level controller. This is for the radiation rule.

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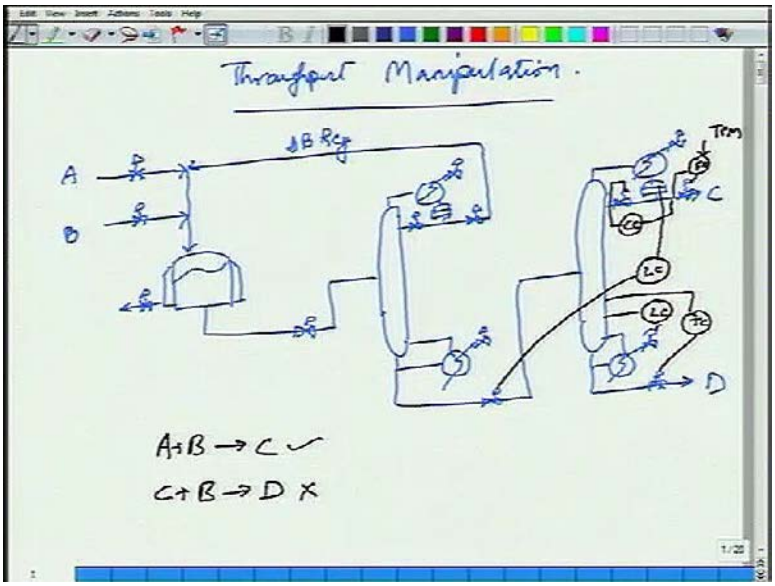

Now, let us take another example, this was a very simple trivial example, let us take may be a process example, and the keep we keep things simple, things simple will just stick to it, what we have been looking at for some time now.

I will just bring a little bit of additional complexity to more realism. A plus B goes to C and C plus B goes D, D is undesired product, C is the desired product. So, we putting in fresh A, we putting in fresh B. Heat is removed from the reactor the excessthermic reaction, reactor affluent is sent to earth, recycle column, what does the recycle column do? It recycles un-reacted A and B at the top, the product and the heavy product and the byproduct C and D are taken down the bottoms. And since, I want to sell my product, it must be nearly pure C, I send it to a product column and what will happen in the product column is light C goes up the top, heavy D goes on the bottoms, this is TB recycle.

So, valves well, what is the degree of the steady state operating degree of a freedom subject process, just for looking in to the process tell me

Student: 8, 8,

2, 2, 4, 3, 2, 8 exactly, see how simple it is? No counting of equations, steady state operating degree of a freedom for this process is A, how many independent valves, do I have on this process? Count down, what is the control degree of this freedom process, process that is the question, 5 plus 5 10, 11, 12, 13, 14, 14.

So, I have that 14 valves, have got 8 steady state operating degrees of freedom, 8 minus 14 is what 6, 6 valve were essentially there for 6 extra valves are there which are basically there for what? Inventory regulation. Just like a just like your column has got 5 valves, 3 get use for inventory control, steady state degree the freedom is 2, always you will have extra valves for inventory regulation. And your steady state degrees freedom will always be you know, much much less than your number of valves that are availability, that will always be the case.

Now, let us start we already looked at you know, is pressure is the throughput manipulator, we already looked at the control system like that, that. Let us see the let us see I want in on demand controls, on demand means product C rate is on demand, how I draw that control system? So, then in that case my throughput manipulator is what? Discharge, this is my throughput manipulator, this is my TPM. How will I manage reflux from level control? See reflux must be used to ensure product quality, because the product has to have should not get contaminated by D, because if it is contaminated I cannot set it off.

So, I am going to use the reflux to ensure the D does not go at the top, reflex you know, because I am I want tight product duality control, that always one of my objectives. So, you are you can say level control can be done using a reflux, but I would say don not do in that way, also to do it, well the level control can be done this way, let us see..., how will you adjust the stream inside this column? Stream to the revival why that?

Sutdent: why

Because, conventionally, what I do is that, I control the level of the request revival using the display, but my display is the throughput manipulator, I do not have, its already been used as my throughput manipulator, it is not in my hands, now that it is not in my hands, I can either use the reflux or the repeat.

I am using repeat, because I would like to use reflux for tight product purity control, because controlling product purity is definitely required, tight control of product purity is almost always required, is that does make sense or no? So, what I am saying is I will be doing this from position control, using reflects, I could have flip this also level control this way, and composition control using the feet, that could have also been done. I am not going to frust whether this is right or that is right, both are acceptable, I am not going to frust whether it should be this way or that way, my preference is for this, that is my bias you can call it.

Now, how will I manage the stream on the revolver? What happened, if I do not manipulate my stream, and I keep it fixed, what will happen? Should I adjust my stream, what is the stripping section of the product problem doing functionally, what function is the competition, if it is not a competition you have any function, then why will I put it there? You see, it must be accomplishing some function, what are they doing?

Student: In reach D, in reach D,

In reach D, why is no other way around, it prevents C from dropping down the bottoms. If is C dropping down the bottom; you are going to use stream to you are going to use revolve to body top, right. Is it important? What if more C drops down? What if more C drops down? So, what. So, C is dropping down, let it drop down, how does it matter? No economically it will not make sense, because your C production rate will be down.

You could have, you are not earning money at D, in fact you are paying the processing penalty on D, let say disposal or waste disposal penalty or whatever garbage disposal penalty. So, you will be paying more, because C is dropping down, but any way you have to pay the penalty on the project or the amount of the discharge, your discharge is more we going to pay more penalty, also we are going to pay less because what could have been sent up, and we would have earn money for it now sending down, right. Therefore, therefore, what you must ensure that C into D in the bottoms, there is no way you know, it does not become too large, yes or no. Therefore, there has to be temperature control, I can control the temperature using the C, all right.

The problem with that is, you see my reaction stream is A plus B goes to C, C plus let say what, C plus B goes to D, let that say, this is my reactor. So, it is sort of series reaction C; obviously, in order to suppress C is desirable, D is undesirable in order to a

suppress de coordination, I need to run my reactor in excess, what would be excess? Excess A right. So, that D is limiting and therefore, a side reaction will be suppress, D concentration is as small as possible, so that the small, so that side reaction rate is small. If I am doing it that way, then my selectivity would be more; that means, we cannot putting 100 moles of A, 100 moles of B approximately. 95, 95 percent of reaction would be towards C, D would be only 5 percent, yes or no, yes sir.

So, if I then come to this column, C fluoride is about 95 kilo moles per hour, D fluoride is about what? 5. D fluoride about 5, what is that mean? That means, it's a leak stream, there is a big stream coming to the column, 95 percent of the material is going at the top. Only 5 percent is dropping down the bottoms, it is a very slued column, most of the flow is going at the top very little is drop, you know there is leak down the bottoms, yes or no,

Student: yes sir.

Do you think you can control a level using a leak, you can if temperature is control, but what is the operator through put temperature controller are on on manual, operators often switch on, switch off a loop, what will happen? Then we will use level control in the bottoms, you do not want that to happen.

So, what, So, what you do is level control is using C, temperature control is using the bottom slow rate, does this make sense or not? Why did I do this? May be it have some explanation.

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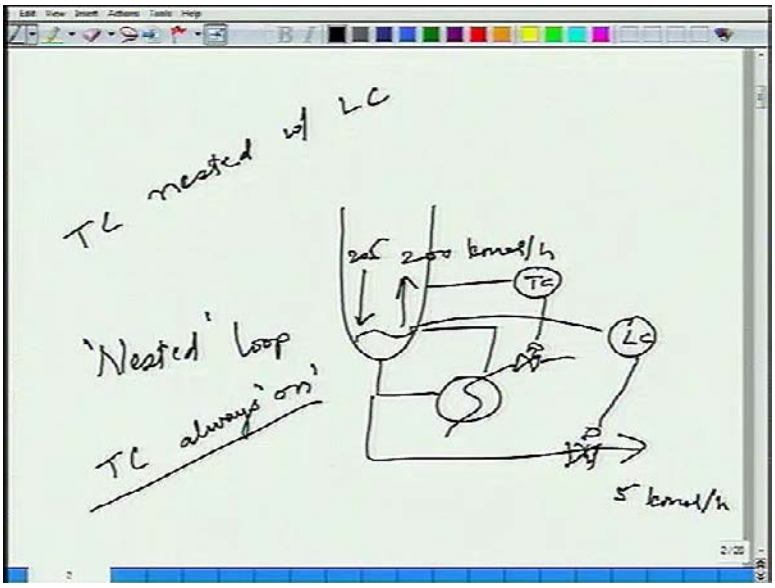

If I look at the bottom of the column, this flow rate is 5 or 5 kilo mole per hour, for example, what is dropping down and what is going up? the boilup, boilup is large may be it is of the order of may be 200 kilo mole per hour. By material balance, how much is dropping down? what is the liquid flow rate? 205 right. Now, 205 kilo mole per hour liquid is flowing to the bottom, you are removing 5 kilo moles per hour of liquid, do you think you can control level using this small leak, it does not make sense right.

So, in the absence of any other information you are better of to do what? To control level using the bigger string which is the bigger string, the bigger string that is available between the two is is the revolver is the column is the revolver duty, yes or no. So, I will control the level using the revolver; that means, bottom stream for temperature control, how does this temperature controller work,work? If the temperature is for example, increasing what does it mean?

It means heavy material is accumulating at the bottoms string, so what do I do acts because heavy material is accumulating at the bottoms, I need to open my valve, so that it goes out, I open my valve more material starts to flow out, level slowly starts to decrease. And then what does the level controller do? Level is decreasing. So, level controller will decrease the stream, now that the level controller is decreasing the stream, what will happen to the temperature? Temperature will come down; you see what is going on. So, the action of the temperature controller is nested with the level controller.

If the level controller is off, you will not get good temperature control, yes or no. Therefore, this is called a nested loop ok.

TC nested with LC, if the level controller is off temperature control will not be very good, then the temperature control would not work well. In fact, it may actually just do nothing; I can also do it the other way round, which is to have temperature control this way, and level control this way. As long as the temperature controller is on, I will get level control my level will get maintain, but I must be aware that should be operator switch off the temperature controller for any reason, then then level control will not be effective, does that make sense or no, yes or no.

Why would it not be effective? That because my temperature controller is off, let us say more ready material is importing, it is all getting accumulated down the bottoms, I am not changing the stream, I am not changing at the top, and I expect this 5 kilo mole per hour stream to take the load of taking it out, it cannot handle that load, you see what I am saying. So, this scheme will also worth provide if TC is on, this scheme will also worth provided a temperature controller is always on, it is never switched off. If it is switched off, be aware that you might actually end up with… You know, your bottom stream will not be able to control level, does that make sense, ok.

Usually what happens is operator is switch on or switch off a temperature controller or a composition controller, then they usually do not switch on or switch off a level controller, because level controller must always beyond, because the level is non-separable entity. So, what may I recommends is do this, do not do this, my personal opinion is both are locate, as long as you are aware that in this case temperature controller should not be switched off, because then you likely to use loose level control, that is about it.

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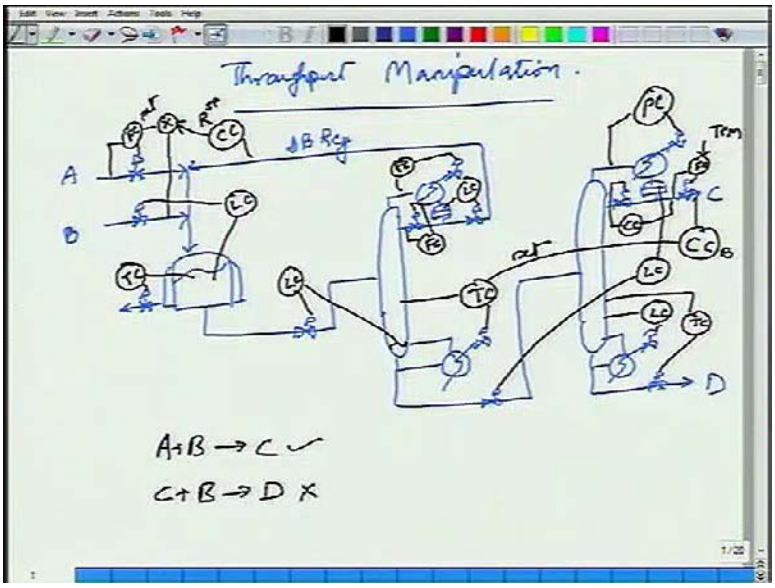

So, why we are putting this temperature controller? So, that too much C does not leaked on the bottom, because that would affect my production of, that will reduce the production rate of C, which is what which is what is finding me the money, yes or no.

So, I have setup the control system on of course, this on the pressure control, understand it. Now, let us come to the column, what do we do on the recycle column, what is the purpose of the striking sec of, the striking section in the recycle column, what function is the striking section on the recycle column accomplishes? A is the lightest, B is the heavier, C is still heavier, D is the heaviest A, B, C, D. So, preventing reaction on what?

Student: the output C and D,

no is not a force, un-reacted B whichever is the light key component, if could B is going on the top, A B lighter than B, it guaranty goes the top right, yes or no. So, what there at what the striking section in a recycle column is doing is, preventing D from leaking down the bottoms, why is it necessary to prevent D from leaking down the bottoms? because A,

Student: B does not go, coming, B it does not go C in to section.

Because anything leaks down, before it is lighten it is guaranteed to go at the top, so if too much B leaks down, it is guaranteed to go at the top, yes product is guaranteed to be contaminated substandard. It will not be 99.9 percent pure, it may be just 99.9, 99.5

percent pure, because some 5 percent D leaks down. So, I must have this for tight control of D leakage down the bottoms, this has to be there.

Then usually C composition is measured you have the impurities, that has there in C in both are impurities B and D that composition would be available for example, one session or may be 5 session or maybe there is an online analyzer, no matter what you will have, some clue of what is the impurity level, that is in my C, using that data, you can always compo, composition control which component, composition of component B, you do this, if you find that too much B is coming in my product, what do I need to do to the temperature set point,

Student: increase, increase,

increase it, so that B does not go down, that is the basic idea, if two little B is not going at the bottoms, if two little B is coming in my, in my product let us say, I am over purifying, so my product it may only suppose to be 99 percent pure, but I am making 99.9 percent pure product, I am over purifying.

That is not a good idea, why it is not a good idea? It is not a good idea, because I am unnecessarily using too much stream in my recycle column. If I tighten the amount of D leaking down the bottoms, I have to boil more, yes or no. So, if I am if my C is overflow, what does that means is, my D leakage down the bottoms is too small, if it is too small; that means, I am over purifying in my recycle column, what that means, is I am using more boiler in my recycle column that is not good. Customer is asking 99.5 percent, I am giving in 99.9 percent, that 0.4 percent extra purity, that I am giving him; I am paying for it indirectly in terms of extra stream consumption, yes or no. So, that is not a good idea. So, therefore, this composition controller should be there.

If there is two little D, that is going in the product, what we need to reduce? We need to increase the temperature set, increase or decrease? Decrease the temperature set point, so, that some more D is leak down, and the stream consumption in the column will go down, yes or no. So, therefore, this composition controller make sense, it should be there. How do I control the level in the column, the bottom level in the column? Well again it has to be done this way; you see what is happening my throughput has been set at the product stream, now level control is in the reverse direction of flow. If you remember; where I have to talk, I should it not talk at all, if you remember my points in

series process, if I am setting my throughput here, level control is this way, same thing is happening here.

So, level control is this way, while pressure control as usual will be this way, level control would be this way, this would be under flow control. I want just about sufficient reflux, so that, so that what, what is the function of the rectifying section of the recycling column? What function is it serving? If it is serving no function why then we put it in the first page?

Student: We are going prevent c.

Preventing C from going at the top, why that important to prevent C from going at the top?

Student: it is that much of

No, it is getting recycling, it does not really matter, there is reason for that, now is going round and round, I can move energy because boiling C up will cause extra cost, that is reason number one, any other reason?

Student: actually D and C,

If I am recycling C, reactor composition of C goes up, what do I have for the side reaction, C plus B goes to D. I will be editing the side reaction, which one of the two reasons is more critical, this reason is more critical, I do not want the side reaction, I want to separate the side reaction as much as possible. Because, it is a product that fetches me the money not the side product, in fact side product ends up signalizing, because I have to pay disposal cost. So, it is important to ensure C does not leak at the bottoms, to do that we must have sufficient reflux, if C is C does not leak at the top, if C is leaking at the top, you can always increase the reflux, yes or no alright.

So, we have done this. Now, we come to the reactor, always the temperature control has to be this way, what about level control? I can control the level let us say, I do level control this way, I know that if B flow rate goes up by 10 percent, A flow rate must also fresh flow rate, must also go up by 10 percent that is a psychometric of the reaction. Side

reaction is negligible or very small, basically 1 mole of A, react with 1 mole of B to give 1 mole of C. So, therefore, what I do is, I maintain A, so have a flow controller on A, and the flow control flow set point is come comes after multiplying by whatever is the fresh B flow rate, this ratio this is a multi I did not do properly, maybe I should again.

This is a multiplier; you are multiplying the flow rate of B, fresh B by some number, what is that number? That number will be about 1 in terms of moles, moles of this and moles of that, moles per hour of this, and moles per hour of that. This ratio set point, then suggested to do what? This is that is, that something still missing 2 mole of A may be 1.05, 5 percent more A or may be 95 percent, you know 5 percent less here, that will happen here, yes or no. Because, I am setting the flow rate and that flow rate can be set slightly in excess of slightly above or slightly below, what is necessary.

So, either A is being, being slight in slight excess, or B is being slight in slight excess, what is that mean, that excess is bound to build up in the recycle loop, how do we how did we address this last time? What we did was, we did some kind of a composition control right, somewhere in the recycle loop. So, am just drawing it, for the sake of convenience this way. So, here is we do a control system on a similar process, where the throughput was been set at the fresh AB, remember that? now we are drawn the control system for the same process at the product stream. I can also draw a control system for this process at any intermediate process stream, let me just do that for the sake of illustration.

The point that I want to make is, you free to set the throughput anywhere, you can set it at the feet, you can set it at the product, you can set it somewhere inside alright, and a control system can be devised around it. Here, if I increase this set point which is called the throughput manipulator, basically what I will have is the level in the reflux down will go down. If the level in the reflux down goes down, I start sucking in more from the recycle column bottoms, the level in the recycle column bottoms goes down, I start sucking in from more from the reactor, and in the level in the reactor goes down, start sucking in more A and B production goes down.

In the previous stream what was, when I was setting at the fresh C, what happen I increase the pressure the flow rate, level increases more be expect to the next column,

level in those column in that column increases, and then more be expect to the downstream column, see the variability is propagated downstream, here you are sucking.

Whatever is been demanded is being supply through reaction of the inventory controllers, through reaction of the level controllers, does that make sense or not?

Student: sir, the control B fresh input B of

A fresh input B of A

Student: if that multiplier x can be through the total input of B or facing through?

It could be, I have just done something. There are other options; I have just done something the point is to illustrate the loop here and sucking more, because demand is set. If I draw a control system where my throughput manipulator as is at fresh A, then I essentially supplying downstream, process this, this is what needs to be process, then it process. The level controllers are essentially ensuring that, does that make sense or no.

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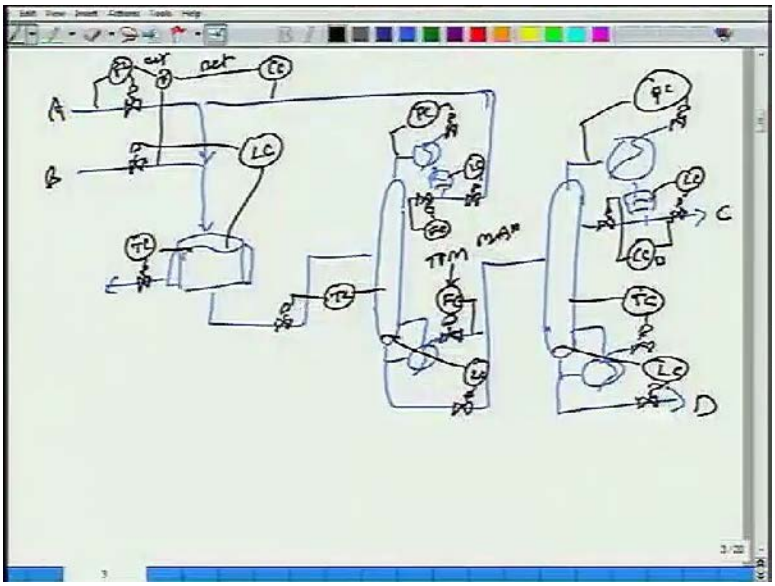

So, we will try and put it down, so simply A B..... and let us say... I want to for some reason, I want my throughput manipulator to be the stream to the second column well, let me draw the valves first mainly..... Let say I want to set my throughput here, why do I want set throughput here? There can be a reason for it for example, let us say I want run my process at maximum boiler, why do I want to run my process at maximum boiler?

Because that maximizes the recycle flow rate, if the recycle flow rate is large, recycle is mostly A. Therefore, my excess A in the reactor is more, therefore side reaction get suppressed. So, I want to run my process at max boiler, why because it helps me, suppress side reaction more.

What are the main reason? I just gave to some reason. So, this is my throughput manipulator, now I want to draw a control system around it, I want to quickly do it without sucking too much. Level controller is this way, column temperature control is this way, you see the temperature cannot be control using stream now, so I am controlling using the feed, if the temperature in the striking section is decreasing, that means, what is that mean? Increase increase the feed or decrease the feed, if the temperature in the striking section is decreasing, what could I do to the feed?

Student: decreasing the feed

because the field is cold, so, you need to actually decrease the feed, if putting in too much feed, temperature and the boil up is fixed, if you putting in too much feed lights up is start going down right, and it will start decreasing the temperature. So, if the temperature decreasing you need to decrease the feed. So, that is what the temperature controller is doing. And of course I have the usual stuff, so this is temperature control, I will do the rest quickly because time is short, and may be you can draw it, and understand it, that is what the hell I was doing.

Multiplier, low controller is sets this, flow composition controller sets this ratio, set point the usual pressure control, of course, I have level control this way that is possible, and of course I have sufficient reflex, so that C does not go at the top. Pressure control, level control, impurity in the product control, which impurity? Impurity D, D should go up right, this is C, this is D, this is A, this is B. And of course, I have a temperature controller that ensures too much C does not go down the bottoms, because that that fix my production of the desired product of what we should sold, and of course.. and this is my throughput manipulator. What is happening? If I jack up to throughput manipulator set point, what am I doing? I am increasing the boiler, more material gets boiled up.

If more material gets boiled up, level goes; more material gets boiled up, if more material gets boiled up, the temperature inside on the tray increases, to decrease that temperature I sucking more from the reactor, level inside the reactor drops, and then the level

controller sucks in more A and B, does that make sense or no. So, upstream I am sucking more, downstream I am feeding, this is what is the sets flow downstream I am feeding. The point is for any process, you can set the throughput where ever you want, I just giving you example, it could be that the throughput must be set at the feed, because an upstream unit is detecting process so much, this is the feed to you, it is not in your hands, and upstream process is same process it, easy only.

Another thing could, another scenario could be customer is saying give me this right, now then, we get the on demand structure that I drew, another scenario could be you have sufficient time capacity at the feed, sufficient in the sense, there is time farm you can sucking as much as you want, and you can produce as much you want, it will going to the time farm, in that case you are free to set the throughput anywhere you want.

I just give an example, if you set it here so, the example that the boil up, what you are doing is you are maximizing the recycle, if you are maximizing the recycle, so if I set, if I set my boil up at max. My recycle is max recycle is mostly A, A composition inside the reactor is max, side product formation is minimized, my selectivity or yied to desire product is maximize. So, there is the good reason to set the, set the throughput here, why it is a good reason will talk about it may be next time.

I hope, what the message that you get is you can set, once you decide what is your throughput manipulator? What is your gas pedal, rest of the control system comes from there, we can set it at the feed, we can set it at the product, you can set it somewhere inside, for a good reason, and then divide the control system around it, does that make sense? So, we could do two or three, it could have been set at the reactor also it could have been set at the one of the intermediate flows, let us say between column 1 and column 2, and we could have still device a perfectly workable control system, that is the basic point.

Student: Sir, how does this refectory production of C, I mean how will that propagate to C to the next column, I mean sir suppose, if I am increasing the stream what effect would have on the production of C?

See, C is getting produced inside the reactor.

Once C is getting produced is getting is getting produced inside the reactor,

Student: but how is it going to affect, like for example, if I am increasing stream, I will be, I am sucking

I am sucking in more, what could I say more I am, I am putting in more A and B. So, If I am putting in more A and B, what happens is low feed reactor is the composition of A and B goes up, if composition of A and B goes up, production of C goes, generation rate of C goes up? So, because more C is being produced, where is that C and D is accumulate inside the process, it accumulates in the second column bottom, what is the second column bottoms do, it is C and D are going down, A and B are going up, so if more C and D are getting produced, level of the bottom in the second column, will after sometime not immediately, but after sometime we can definitely increase, as it is increasing you are the level controller, this level controller will increase the flow to the next column; flow to the next column is increased, ultimately C will also increase, D is also increase, now does it make sense? This is very important to think, to think this true, if you do not think this true, it is very lightly some inventory, somewhere is not properly accountable, ok alright.

Thank you.