Plantwide Control of Chemical Processes
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Lecture - 33
Recycle process case study (Contd.)

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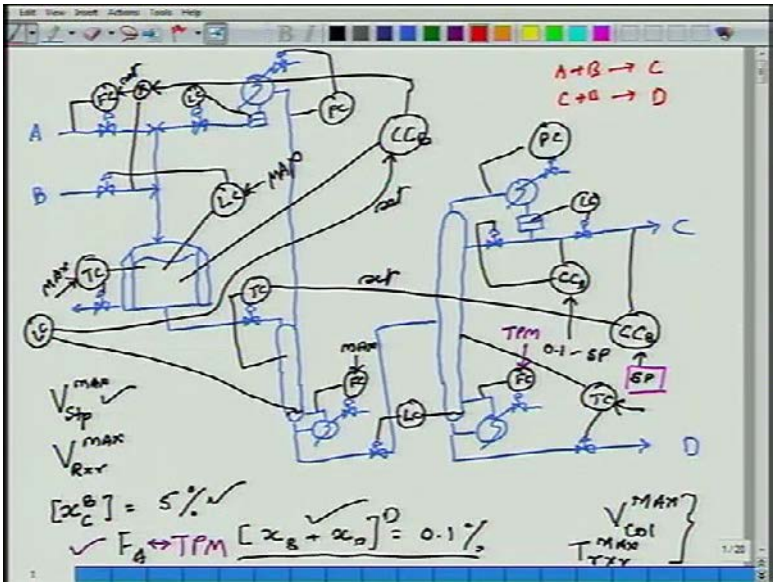

Welcome to this next class. So, we were looking at optimal operation of this process and what I am now saying is active constraint; what were the active constraints? Boil up in the stripper should be maximum. What is that mean? Level inside the reactor should be maximum. What else, what else was active? x C in the bottom stream should be small; let us just say 5 percent because you do not want too much C. C is what earns you the money; if that goes down the bottom, we are losing C. What else? x B plus x D in the distillate of the product column should sum to 0.1 percent; that is what will give you ninety nine point nine percent pure product.

Anything else? Well, I want a certain throughput. This is what and the throughput was whatever is the base case designed value. So, I want to let us say operate such that I am processing hundred kilomoles per hour of fresh A. So, F A is given to me set by market demand and these are the constraints that are active. Then the next thing that we discussed was I may also get an instruction from above which tells me that maximize

throughput and when I try to maximize throughput, what happens is; what happens when I try to maximize throughput? Boil up in the second column goes active.

So, as throughput is being increased, V what is it called, V two or V column boil up in the column reaches max. Also T reactor in order to maximize throughput reaches its max limit and the order is first T reactor becomes active and then boil up reaches maximum. As I am jacking up throughput, reactor temperature becomes maximum and so on, and so forth. Now that I know that my last constraint to become active is V Col max, I say that I am going to use this. See, that means all these constraints need to be tightly controlled; tight control of all these constraints implies V Stp max is a manipulated variable boil up. If I use it for control, I will require back of that will represent an economic penalty.

So, anything that is going to be an active constraint which is a direct manipulated variable while it should be left alone. So, leaving it alone implies that I do this; I do this. Reactor temperature and reactor volume are actually CV'S controlled variables. They are not direct manipulated variables; they have to be controlled. What is the tightest way of controlling reactor temperature which becomes active? Later on let us back off, because these constraints become active later on. Let us talk about product purity control because product purity has to be tightly controlled, this chap.

Therefore x B and x D will have to be tightly controlled. How do I control it tightly? Composition control of D and I am adjusting reflux for that. How do I control the amount of B leaking down the bottoms of the stripper? I cannot use the boil up because boil up is at max, Why is boil up at max; because that maximizes the recycle that minimizes the side reaction. So, how can I control tightly the amount of B leaking down the bottoms of the stripper? There is only one way; that is to do it this way. And of course, every once in a while may be once a shift, when you get the composition reading, if there is too much B that is coming you can always adjust this set point. So, I have taken care of this and by the way because amount of B leaking down the bottoms, this set point must be 0.1 minus whatever is this set point.

Yes or no, that is from this relationship, yes or no. So, I have taken care of this constraint; my throughput manipulator is this guy should be at max. That is because of this chap; I have taken care of this. I also need to control tightly this chap. You know the amount of C leaking down the bottoms. What do I do to hold that constant? I control a

tray temperature here. Alternatively I could do it; critics may say that, well, this is leak stream. The bottom is a leak stream; you should not be controlling the level using the bottoms. So, what I will do is I will control the temperature using the bottoms and the level using this chap; I mean both are acceptable to me. Then the problem was how do I control? The rest is straight forward; you know the inventory control system. I have taken care of this chap, I have taken care of; this is going to become maximum. So, this will be my throughput manipulator; this is what we discussed last time.

This is last constraint to become active. So, I will use this as TPM if I want to increase the throughput manipulator I am going to adjust this. So, I have a certain desired value of fresh A processing rate. I will adjust my throughput manipulator set point such that the amount of fresh A that is getting processed is what I desire. So, this is also taken care of. V reactor max, I have to have level control on the reactor. How do I do that level control? The only option is temperature must be controlled tightly. So, I have a temperature controller; this will give me tight temperature control. I also have to have level control. How did we do it last time? We did it this way L C adjusts this and this is under flow control. The flow controller set point comes by multiplying; this is what we did last time. And if this is A and this is B, we argued that this ratio set point.

This chap here, this set point should be what? Slightly less than one because you require slight extra amount of B than fresh A; why because A plus B goes to C, B plus C goes to D. So, some D is going to get formed small amount, but that D is going to consume extra B 1 extra mole of B; therefore, you need slight excess of B. Slightly higher amount of B compared to whatever A you are putting which inverse of that is A will be slightly less than B. So, the ratio should be slightly less than one on a molar basis, on a per mole basis. So, it may be 0.99, 0.96, 0.97, something like that and how do I adjust this composition set point? Some composition somewhere inside the recycle loop, I am just showing like let us just do a composition controller which adjusts which keeps the limiting; B is the limiting reactant. Limiting reactant composition is maintained. This was the control system that we had and then of course, the rest is straight forward.

Level control is done, level control here is done, you can put in the level controller everywhere else, pressure control, what else? This sets the pressure here. The pressure in the stripper is set by the amount of condensation that you have. This would be level control. The only thing that remains uncontrolled is this chap; you see this chap is

remaining uncontrolled, why? Because in order to ensure because all degrees of freedoms are lost on the stripper. I want boil up at max, I also want tight control of the B that is going to leak out because any B that leaks out is going to contaminate the product; therefore, temperature control is on the feed.

Therefore, there is no control degree; the level control of the bottom stream from the stripper; that is under level control; that is controlling the level in the product column, the bottom level in the product column. Why did that become necessary? Because even in the product column, boil up is not in my hands for temperature control; why is boil up not in my hands? Because I am using it as throughput manipulator; why am I using it at throughput manipulator? Because this is the last constraint to become active; so, this will B my gas pedal. Low throughput, intermediate throughput, high throughput, max throughput, I will be pressing this gas pedal.

So, basically what is that? The problem that this creates for me is that the level in the stripper at the bottom needs to be controlled and the only way to do is that to adjust something inside the reactor because what is happening in the stripper? In the stripper, the C and the D are accumulating at the bottom. Whatever C and D is generated in the reactor is getting accumulated at the bottom in the stripper. So, if the stripper level is going down; that means more C and D need to be generated. How do I generate more C and D; increase the temperature. So, I have this slightly awkward arrangement where this level is getting controlled adjusting this. Instruction comes, jack up the throughput, what do I do? I keep jacking up this TPM set point. The level in the stripper goes down. In order to maintain this level, ultimately temperature inside the reactor will go up and the higher temperature will ensure more C and D are generated which accumulates at the bottom which maintains the level in the stripper.

Sir, it depends on the endothermic reactions or exothermic reactions. Well, why will I cool. Of course yes, it depends. Why does it depend on endothermic or exothermic? In endothermic reaction then compression is high, then product will be more. No, that is basically whether it is in equilibrium reaction or irreversible reaction. If it is an equilibrium reaction, then if it is an endothermic reaction, yes increasing the temperature reduces the equilibrium conversion. What we are studying is irreversible reaction A plus B irreversibly gives C, C plus B irreversibly gives D; that is what we are looking at. So, your argument is not valid. The reaction chemistry is different. We are studying an

irreversible reaction system. Now you can have an irreversible reaction which is endothermic, in which case you will be heating up the reactor using steam or some heating medium. So, just like in an exothermic reactor you have got a cooling stream, cooling duty. Similarly in an endothermic irreversible reactor, you have a heating stream; that is all, yes or no.

What was I saying? So, you are jacking up the throughput and temperature becomes max. When temperature becomes max, this has become max, you still need to control the level, what do you do? You start adjusting the concentration of limiting reactant. I want the concentration of the limiting reactant to be small; let us say 2 percent, 3 percent, 5 percent, but now if I still want throughput to increase, the set point the limiting reactant concentration inside the reactant is increased from 5 percent to may be 10 percent. That will give me further increase in throughput. And I keep jacking up the throughput manipulator; ultimately my flow controller on the boil up in the product column will reach its maximum limit, its capacity constraint and then the throughput is whatever the hell it is. Notice that at maximum throughput, everything is set except one thing. What is that one thing? When I say everything is set of course, this also has to be max.

Operator cannot set; level is set at max, reactor temperature is set at max, boil up is set at max in the stripper, boil up in the product column is set at max. Four things are set at max; composition is set, composition of the D impurity is set. What else is set? I am also maintaining this guy such that the composition, such that too much C does not get lost, six things. Steady state degrees of freedom for this process was what seven; one, two, two for the fresh feeds; two for the reactor; one for the stripper and two for the columns. So, two, three, four, five, six, seven; of seven things 6 set points are set at maximum throughput. What is the one set point that is still in the hands of the operator? The question clears as this chap how should he set this? See you can have 0.1 percent impurity in your product.

It could be mostly benzene; mostly B very little D, such that the sum is 0.1 percent. It could be mostly D, very little B, vice-versa; so, mostly B very little D, mostly D very little B, such that they sum to 0.1. It could also be 50-50; 0.05 percent of B and 0.05 percent of D. How should this set point be chosen if my instruction is maximize throughput, maximize production? I think we discussed this last time, but nevertheless may be I can choose any value between 0 and 0.1 percent; between let us say 0.01 and

0.09 percent for this set point. What value should I choose that is the question and why? Well, what is the last constraint to become active? What is the bottle neck for my process? Which column? Boil up of the column.

I would like this boil up in the column to become active as late as possible. The later the boil up becomes active the higher throughput I will get. How do I do that? If I allow more D to leak out the top, reflux will go down. If reflux goes down, boil up will go down; I can suck in more fresh feed, I can process more feed. So, if the instruction is to maximize production; then if the instruction is to maximize production, then my set point for C C B, the amount of B impurity in my product should be what, tight or lose? Tight, extremely tight, so that D can be loose; impurity D in the product can be loose. Now let us say the instruction is not maximize production, but let us say I am operating at 75 percent of max production. What would be a reasonable choice for B impurity in the product? I think it will be the other way round. Why will it be other way round?

I think it is like taken the reactor from the stripper, the B is leaking down, yeah. This essentially is ending up in the second column product, yeah. So, the lesser the B is coming from chamber; that means the reactor is producing more D stuff. No, that does not mean that. If everything else is fixed, I mean. No, that everything else is fixed depends on what is the structure. Yeah, right; for this structure only I am talking, for this structure. You have the throughput in the second column which is not at max right now V column, boil up of the column, then if everything else is set; that means if you have to choose from 0.1 D or you know the D and B interchange. I think I will answer the question; may be this will answer your question.

What is the reaction stoichiometry that I have? A plus B goes to C, C plus B goes to D. The problems with having large D impurity up the top, what is the problem; for the same D in the bottoms I am consuming what, more B. Even though let us say 0.1 kilomole per hour D is going up the top. In another system that 0.1 is actually 0.01 because you are allowing benzene to leak out. In one mole of D, there is already one mole of A and there are two moles of B; that means my raw material consumption of B goes up by whatever that small extra amount may be; yes or no. I do not want that; unless my instruction is maximize production, I do not care about raw material etc, etc, etc because whatever I am producing is going to earn me significant profit; the product price differential is so

much. I do not know even if it consuming extra moles of B, it does not matter; it still makes money for me. Only then will I receive an instruction maximize production.

Then it makes sense to allow D to leak. In the other case what makes sense is allow maximum B to leave. So, you are losing only one mole of you are losing only B. In the other case, you are losing extra moles. This comes from overall material balance; does this make sense or no. So, basically by a very small amount, your B consumption rate will go up. The amount will be very small, you may say it is negligible, but nevertheless it is true. So, if you are an a engineer and you want to operate the process as efficiently as you want, you would like to make sure that only as much raw material is consumed as its necessary, no more; that requires that you allow the leakage to be of B, D should be as small as possible. Does that make sense or no? It is for this reason. I hope I answered your question.

The problem with this control system is what; a very unconventional level controller where you are adjusting the reactor temperature or limiting B composition, limiting reactant composition in the reactor. Operators may not be comfortable with it. If that is the case, they say this level controller is not acceptable to us; we will have problem in startup shut down whatever or I do not trust you. I am not going to as I have never done it my life before; I would not do it even now, no matter how great a guy you are. So, that fellow says where this level controller is not acceptable. Well, if it is not acceptable to the operator you cannot implement it. What is the next best thing that you can do? In that case, this level controller is not on; operator vetoes it. This is not on; what do you then?

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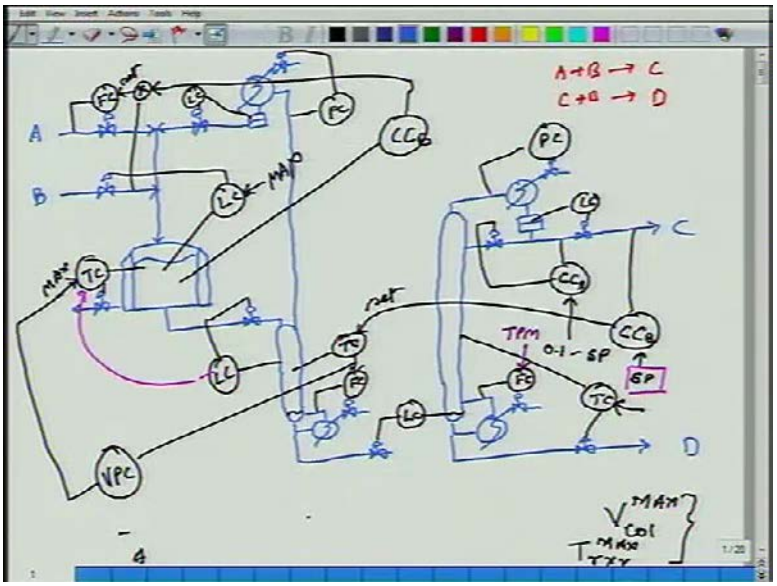

Well than the only way left is to have the level controller this way. This is acceptable to the operator; he has seen the level in the stripper is going down, put more feed. He has seen that and he is convinced that, yes, this will work. The other thing that I was telling he is not convinced it will work; temperature of course, has to be controlled. So, temperature control and this set point which was coming is now going here. What is the problem with this? I am not operating the column at max boil up. The boil up is being set by the temperature controller. How do I bring it to maximum boil up? I know the boil up is not maximum. I know from economics I need to maximize my recycle so that D production rate is minimized, side product production rate is minimized, how will I do that? It is the same thing except that now I know what my boil up is; I wanted it to be near max if it is not max.

So, I put in a valve position controller which adjusts the reactor temperature set point in order to make the boil up higher. Does that make sense or no? I know it is tricky, but let me put it differently. I do not know how to put it differently though. I want to ensure that my boil up is max. Let us say I do not have the V P C there. Does the temperature controller ensure that the boil up is max? No, the boil up is whatever it is. I am going to adjust my throughput manipulator in such a way, such that my A processing rate is whatever I desire 100 kilomoles an hour, 150 kilomoles an hour, whatever the hell. So, I am going to adjust the throughput manipulator to get the desired processing rate. Now if

the boil up is not at max, what does it mean? If the boil up is not at max; that means I am not sending sufficient, there is still scope to send more stuff up.

What does that mean in terms of selectivity? If I reduce the temperature of the reactor, there will be more unreacted stuff that will come up come out the reactor; that more unreacted stuff will have to be sent up, boil up will increase. What does reducing the temperature inside the reactor do to the selectivity? If you reduce the temperature, selectivity goes up; that is because the activation energy of the main reaction is less than the activation energy of the side reaction; we discussed this right, yes or no. So, now what I am doing is whatever scope is there in increasing the boil up, I am using that to reduce the reactor temperature and then the boil up will increase and now I have reduced the reactor temperature as much as I can, so that the selectivity is as high as it can be. Does this make sense or no? I know it gets slightly convoluted, but that is how it is working. Why do I want maximum boil up. So, that recycle rate is as high as possible. So, that A is as much excessive as possible.

Now I am doing that in an indirect way by reducing the reactor temperature. What did I have earlier? Earlier I had level control using temperature; that level controller was doing the same thing, it was reducing the temperature; do you see what I am saying. So, if the operator says your level controller is not acceptable to me, if it turns out that the reactor is so big that changing its temperature takes a long time and in that long time, the stripper level actually overflows or runs dry. It alarms start going off; high level alarm or low level alarm starts going off. Then of course, the operators concern is genuine; then of course, you cannot do what I was recommending. That depends on how big your reactor is; if the reactor is really big, it takes a long time to change its temperature, it takes a long time therefore, to make a change to the C D production rate and in that long time, the level may run dry; the level in the stripper may run dry or overflow.

Then I cannot implement that reactor level scheme. In that scheme what was I doing? To maintain level, I was adjusting temperature of the reactor, boil up at max. Now what am I doing? I am maintaining boil up at max by adjusting temperature in the reactor and level control is I have just basically flipped. Earlier I had temperature control this way and level control this way, this is what I had. Now what do I have? Level control this way, temperature control this way and to keep it at max; so, that is indirectly controlling the temperature by adjusting what the hell is happening in the reactor, but it is an indirect

way of doing it. Now this indirect way of doing it what is the penalty that you suffer? The penalty that you suffer is you need back off in the boil up because if you want to control temperature, you need to move the steam.

You need to control the temperature because if you do not have tight control of the temperature, more B may leak out which will contaminate the product; I do not want that. So, in the earlier control scheme if I was able to operate at 100 percent boil up; here I may only be able to operate at 90 percent boil up. 10 percent margin I have to have in order to ensure that boil up can go up to maintain amount of B leaking down. What will be the effect of that? The net effect of that will be that I am operating at 10 percent lower recycle rate on average than I was using in the previous case.

10 percent lower recycle case causes a slightly less excess an environment in the reactor that causes the yield or the selectivity be to be slightly poorer which represents an economic loss. In fact even if the selectivity is off by 0.1 or 0.2 percent, it is actually a big loss because 0.1 or 0.2 implies extra B consumption and that when you sum it over the whole year, that extra B that you are consuming because the selectivity is 0.2 percent lower, it can actually amount to a lot of extra raw material consumed for the same amount of C produced. And that can run into crores of rupees per year; crores of extra raw material. Crores of money spent on extra raw materials; does that make sense or no.

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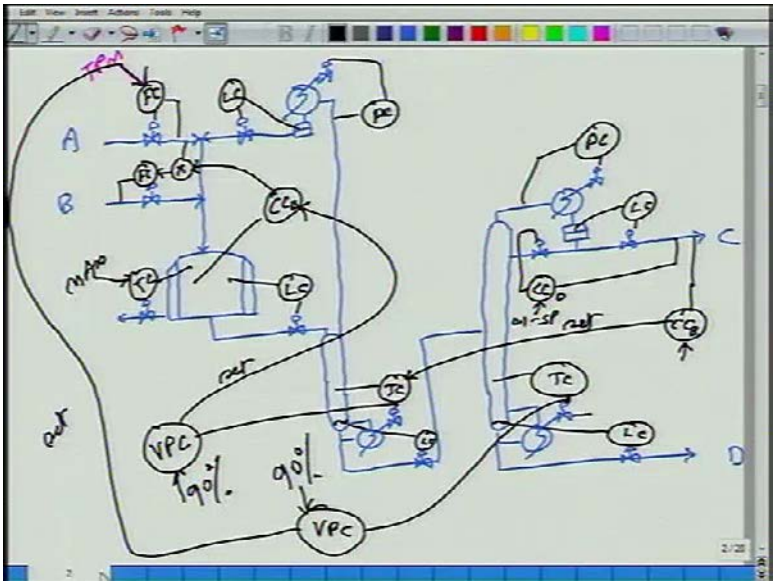

You could also have a situation. Now we will change the set point. How do we change the set point I will tell you? You could also have a situation where the throughput manipulator is not in my hands. Right now I set well; this is the last constraint to become active, I will have the throughput manipulator here. You could have a situation that this is merely a plant in a big refinery complex or a petrochemical complex and how much is to be processed is been set up by some upstream process. It is like what is to be processed by a distillation column is set by the reactor. You can take this logic further and then say that, look, what is my processing rate? The feed to the process is not in my hands; it is set by some upstream process. Do you see what I am saying? Upstream process is saying that look this much fresh A is to be processed. In that case my throughput manipulator is not in my hands; it is what? It is the fresh A feed stream. its set point is coming from some place and whatever is coming needs to be processed.

Nevertheless the operating philosophy, optimal operating process philosophy for this process will remain the same. I would like to maximize the boil up of the second column of the stripper so that excess A is there. So, that side reaction is minimized, yield is maximized. I would like to operate it at the maximum level, etc, etc, etc. So, how do we do the same thing, the same operating philosophy from a steady state point of view given that my throughput manipulator is this guy fresh A. Now let us do this and I am going to do it slightly quicker. So, this is my throughput manipulator, this is being set upstream; amount of B that must come in must be in ratio with A. So, I say well and there is a flow controller here, this is setting the set point here. As before the composition set point for this comes from here, limiting reactant concentration comes from here.

Then the level controller here has to be which way? I can do it two ways; I can control the level by adjusting the recycle stream in which case this reflux drums level will have to be controlled this way; that is one way of doing it or I can control the level in the conventional way where I am doing this. Of course, this is pressure control, this is level control; I am left with no options, but to say that this level has to be controlled. So, I have to go this way. I have temperature control this way, pressure control this way, this is something that you would do conventionally; level control this way, temperature control this way, composition control of D impurity this way, composition control of B impurity this way, and this set point would be what? 0.1 minus whatever this set point is;

everything is done. Is there some level that is floating around? No, of course there is a temperature controller here. So, all valves are taken care of.

Now I ask you, how do I ensure that my boil up is at maximum? If I want to ensure that my boil in the stripper is at maximum, how do I do that? Valve position controller right and this will adjust. Now I keep on increasing the throughput; instruction comes from above. Maximize throughput operated as higher throughput, process as much as you can. So, I keep increasing the throughput manipulator set point and then what happens? The boil up in the second column will ultimately reach; what will happen is this will become maximum and then in order to maintain the boil up, the only thing that I can do is set this. I keep on jacking up the throughput manipulator because I have to process maximum and then what happens? This guy becomes maximum; the boil up in the second column

And then what do I do? I look at the boil up; if it is not at maximum, I will jack up the throughput a little more; that is what an operator would do. Boil up is not at maximum, I can process more A, keep jacking it up. The problem with this approach is because you cannot have too much C leaking down the bottoms; because it is important that the amount of C leaking down the bottoms is maintained, you want tight temperature control. Because you want tight temperature control; that means the boil up must be allowed to move. Therefore, you would for example, this V P C you may only be able to go to 90% percent of maximum boil up. Similarly this V P C you may only be able to go to 90 percent of maximum allowed boil up. So, there is a back off in boil up in the stripper, there is a back off in boil up in the column.

You would have wanted to operate at 100 percent boil up in the stripper, 100 percent boil up in the column; however, because it is important to ensure that too much B does not leak out the stripper, because it is important to ensure that too much C does not leak down the bottoms in the column. In this control scheme, I need to move the boil ups to ensure too much B does not leaks out and to ensure that too much C does not leak out. Because I need to move the boil up, I have to give some margin. I cannot operate at 100 percent boil up because suppose this set point was not 90 percent, if B started leaking out, my boil up is already at 100 percent. I can do nothing; I cannot increase the boil up to send the B up and then my product is going to be contaminated. I will have a sustained

period of operation where I am making contaminated product; unsellable product, that is not acceptable.

What is acceptable is back off from the 100 percent limit to 90 percent; should B leak out I still have that 10 percent margin to send that extra B up instead of contaminating my product. What that means is my excess A in the reactor is lower; if excess A in the reactor is lower, side reaction is more. Per mole A that is being fed, B consumption is that much more; that is the consequence of not having boil up in the stripper at max or 10 percent below max. Similarly, my maximum throughput comes when the boil up in the second column; when the boil up in the column is max, but I do not want precious C that I am generating in the reactor to lead down the bottoms. Therefore, I will have to have that 10 percent margin even in the boil up. That represents what? A loss in production; I was capable of producing so much, but because I am operating at 10 percent lower boil up, my throughput is not that much its lower. Yes or no, does that make sense.

So, this control scheme will also work; however, because of back off A your production will be lower, B your yield will also be lower, your selectivity or B consumption will be higher. The point is what control scheme you put in place governs how close you can go to the active constraint limit. I know my active constraints are boiled up in the second in the two columns, in the stripper and the product column. How close can I operate to that max boil up limit is governed by what control system I put in place. The one that we put earlier; the one that we had put previous class where the level control was using temperature, this purple line that allowed me to operate at 100 percent boil up in the stripper, 100 percent boil up in the column. If level control is not feasible because the level runs dry or whatever, then I need some back off in the boil up which will cause a yield loss; never the less production will be as high as possible.

In this scheme, I need to back off both in the boil up in the stripper as well as in the column. So, I have a yield loss as well as a production loss. Same process, same everything, same pump, same reactor, same column, this that, etc, etc. The control scheme that have implemented dictates what is the best yield that I can get, what is the max production that I can extract out of it. And when you accumulate it over the whole year, it makes a heck of a lot of difference; 2 percent, 3 percent 4, percent extra production will amount to 100s of crores of rupees for a refinery for example. So, if your throughput manipulator is something that is in your hands, you are free to choose it.

It is not being told that fresh A is so much, process it. Then it is not in your hands. Then you are forced to do what I just did; throughput manipulator was not in my hand. But if it is in my hands, I chose it at the last constraint to become active and I put in place a control system that ensured that every active constraint became active actually. I was able to operate very close to it and did not require a large back off; that is all a matter of proper structuring. I think that is the only point; if you take home from this message that you can structure your control system to ensure that whatever needs to be tightly controlled gets tightly controlled, I think the message is pretty much.

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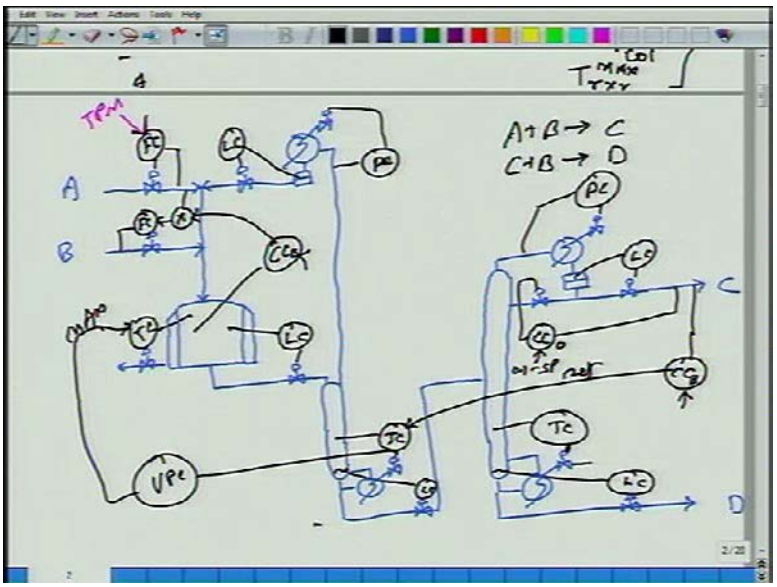

If I look at the overall material balance on the whole plant, per pass conversion of the reactor could be whatever. Overall conversion is 100 percent because every moles of A that is coming in is reacting to form either C or D; no A is leaving the process and no A and no B is leaving the process or negligible of 0.1 percent is leaving so that you can neglect. So, essentially the overall conversion is 100 percent. The reactor per pass conversion may be 10 percent, may be 90 percent. If it is 90 percent, then what happens is my recycle rate is very low. If recycle rate is very low, excess inside the reactor is very low. So, as far as the reactor is concerned, your side product is more; that kills you, right. Now you want, so what tells you that you are getting killed is; well is my boil up near max or not. If it is too low that tells me I have got scope to increase the excess to suppress the side reaction. How do I suppress the side reaction? Well, reducing the

temperature; reducing the temperature will suppress the side reaction; therefore, I have this V P C. Now does it make sense? Therefore, I have this.

Some side reaction also be replaced by less amount of V. Meaning? Sir, side reaction that is produced the C plus B is equal to D goes to D. A plus B goes to C, C plus B goes to D. Side reaction will also be replace by the decreasing the amount of B. Yeah, so B should be the limiting reactant inside the reactor; that implies A should be in large excess inside the reactor, but it does not affect at all the overall material balance. It affects the overall material in the sense if side reaction increases per mole A, B consumption will go up slightly. And by the way the whole assumption in all this is that energy is much much cheaper than raw material or product. It also depends on material cost and overall cost. Well it will always be or most of the time it is energy is much much much cheaper than raw material or product.

Therefore, whatever extra you are paying to boil up more is more than compensated for by the less amount of B that you are requiring and the slight extra amount of C that you are producing. Do you see what I am saying? This is when it makes sense. If energy prices are extremely high, then I would not do this. Let us say raw material is available; let us say raw material is something like trash which is available for free. In fact, people pay me to process this raw material like nuclear hazardous waste disposal, toxic waste disposal. I get paid to process the raw material. There the situation is different. Do you see what I am saying? I am not talking of that situation.

There the economic condition is totally different; there I am spending money my cost is how much energy does it require. Here most of the money is actually going in paying for A and B and the revenue get generated from selling C. How much energy? Energy is a minor component to the cost. Do you see what I am saying? You can have an economic situation where actually raw material is free, then selectivity is not an issue. I am not talking of that kind of a situation. There the reasoning will be I must operate it so that my boil up is least and then I should operate the reactor at max temperature because that is what will give me the maximum conversion, that is what will give me the least amount of boil up; that is best, right.

Here the money is being made from C minus A and B; energy does not contribute much. Let us say less than 1 percent, less than 5 percent; 95 percent of the profit is coming from

product minus raw material and you are paying for the raw material. Raw material is expensive; it is not a dirt cheap kind of toxic waste kind of raw material. Those kinds of industries, the economic scenario will be very different. So, welcome; I think I am going to close this chapter now. At least this process, unless there are some lingering doubts; may be now we can look up another process. We will look it up today and tomorrow and then I think I would have done enough of flow sheeting and devising control systems for processes.