Plantwide Control of Chemical Processes
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Lecture - 36
C4 Isomerization Process Case Study (Contd)

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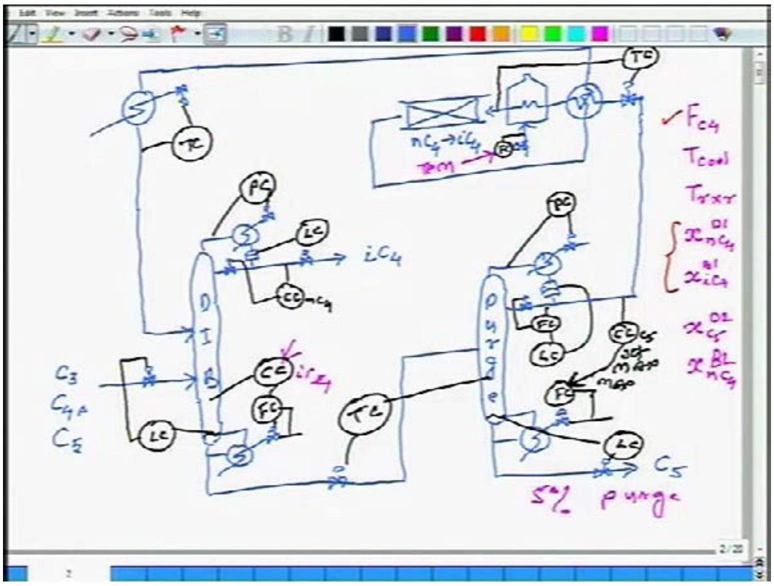

This is what we did last time, any question on this?

Student: Sir, compressor control term from?

Compressor, compressor.

Student: Compressor control in compressor controller of heat exchanger.

This cooler.

Student: No sir heat exchanger.

Heat exchanger yeah cooler. Yes.

Student: Furnace.

That also can be control by direct adjustment of the temperature control and.

Yeah it can be done, yeah it can be done it. So, but we did not do it, why we did not we do it

Student: (( ))

No, it is not due to (( )), because when you are trying to jack up through put furnace become active, furnace duty become active. If you are using it for control then to control that temperature, you need you will need some margin always right. So, you cannot take the furnace due to the 100 percent, you will have to operate on average let say 90 percent furnace duty. So, that the 10 percent margin is there to keep the temperature control. Yes or no?

Student: (( ))

Repeat, I repeat it again. Suppose I am using a variable to control something. Suppose, so let us say I am using Q furnace to control temperature reactor, reactor in. Reactor in temperature is being maintained by adjusting Q furnace. Let say that is what I am doing.

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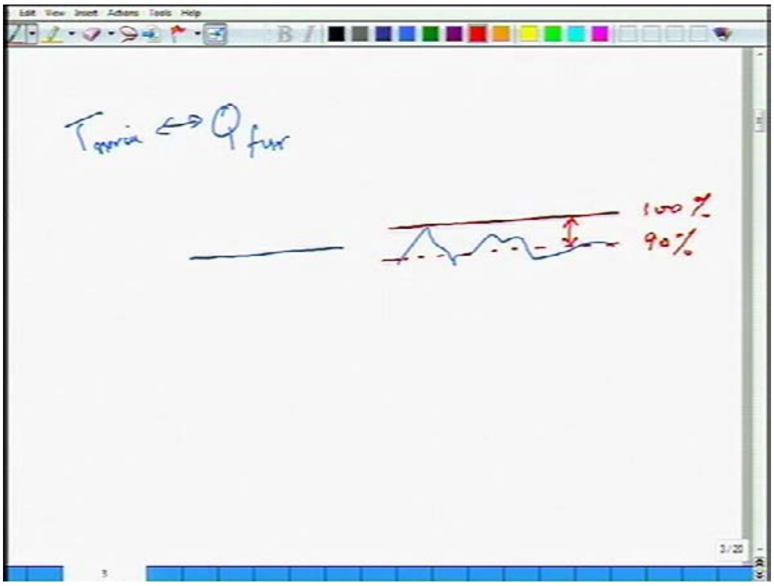

What happens to Q furnace? Temperature will be held constant nearly constant, and Q furnace will go all over the place, yes or no? Yeah, but this Q furnace should not exceed 100 percent - max capacity, because if it exceeds 100 percent then I will lose temperature control of the reactor inlet. That is not acceptable; that means, the case if this is my 100 percent limit my average operation will have to be bellow that 100 percent limit, my average operation is may be 90 percent, may be 95 percent, but definitely not 100 percent. So, let say this average operation is that 90 percent, what is this?

Student: (( ))

Lost production. If I want to maximize production, and furnace is the constrain that limits production furnace duty then if I am using furnace duty to control something, so that whatever I am controlling remains control, I need this back off. Yeah, yes or no? That is why because furnace duty become a becomes a constrain that will be active at maximum production, I am not using it to control anything. So that this throughput manipulator can be taken to 100 percent and left there; that means, furnace duty wall is fully open.

But I need to control the temperature of the reactor, how do I do it, by adjusting the flow to the reactor, that is what it is been done by this temperature controller, yes or no? This is the reason why it was done. If furnace duty was not becoming an active constrain then I would have done it the conventional way, temperature being controlled by adjusting the fuel to the furnace, by adjusting the furnace duty, but because furnace duty is becoming an active constrain that is why I am doing it the other way, yes or no?

Student: (( ))

Any other questions? Why am I controlling temperature in the why is it important to control the temperature in the purge column, this (( )). First of all temperature must be control, why? Now, I am asking questions, since you are not asking question, I will ask question. Why is it important to control a stripping tray temperature inside the purge column.

Forget, what I used to control it, but why is it important to control it.

Student: (( ))

So that I do not lose the pressures in the C 4 down the purge stream, that is why. So, now, the question is ok. So, it is very clear to me that I need to control a stripping tray temperature, to ensure too much n c 4 does not leak down the bottoms, because loss in NC 4 leads to loss in production. Now the question is, what do I control it with. If I control it with the conventional way like this, if I do it this way what is the problem the problem is boiler hits maximum constrains then I lose control of that the movement boiler hits the maximum. It will not be in my hand, how much is leaking down whatever is leaking down is leaking down its not in your hand, I do not want that. Because I know form analysis that boiler does become active, boil up does hit the max constrain yes or no? So, what do I do? I do not do it this way I do it that way by adjusting the feed.

When it is not active, when the boil up is not active in the purge column, it can be used to control something, what is that something that I control the way the control structure is drawn. I am controlling the amount of impurity C 5 going in the distillate by adjusting the boil up. When the boil up heats the maximum that impurity level will float; I lose control of it. Yes or no?

Student: Again, repeat sir.

Again repeat, case is very simple. If I am using something to control something, if I am using a manipulate variable to control s control variable. When that manipulator variable saturates, it reaches its limit then the control of the C v is lost. Yes or no, if M v saturates, C v is not controlled any more, it floats until C v, until M v becomes saturated again, yes or no that very clear. So, when a degree of freedom is lost, when a degree of freedom saturates or a constrain becomes active, control of something must be given off yes or no.

If I was doing it this way, boil up is controlling striping tray temperature, when boil up becomes maximum NC 4 leaking down, become leaking down the bottoms becomes floating, I lose control of it that is not acceptable to me, because it has an economic penalty associated with it. On the other hand, when I am using the same boil up to control the C 5 leaking up the bottom, which is inside the plant. You see how much C 5 is circulating around and around in the plant, when boil up become, when boil up saturated, I lose control of that that is less painful economically. Then allowing more C 4 to lead down the bottom and loosing it forever; do you see what I am saying. These decision, I have to make, what is more important what is gone get saturated, if it is gone get saturated when it is unsaturated what should I use it to control. So, that even if I lose it when it become saturated, it does not hit me much yeah. So, how much is circulating around, even if that floats that does not bother you much versus, if the amount of NC 4 leaking down the bottom is too much yeah. So, therefore, I need to control a striping tray temperature that is clear to me, how to control it. I do not do it this way, because boil up become saturated, I do it the other way.

When it is not saturated the boil up, what does it control? It controls the C 5, recalculating around that is it. These decision have to be thought through, they are coming from what becomes active, what does not become active. Important variables that must always be control, what is the rule what is the basic rule that comes out of it? Important variable that must be always be control. The manipulated variable that are using for them should be such that they do not become active, because should they become active then what? Then you have lost control of that important variable that coat on coat economically important variable.

To the extent possible, I would like to make sure that that does not happen right. Similarly, for example, there is a safety, let say you do not want the oxygen concentration inside the reactor to exceed the certain limit. Because then the fuel you known then the concentration is within goes between the flammability limits. I must always use a variable that is what, that never get saturated, because I cannot afford that oxygen concentration to not be control. It must always be control yeah. Yes or no.

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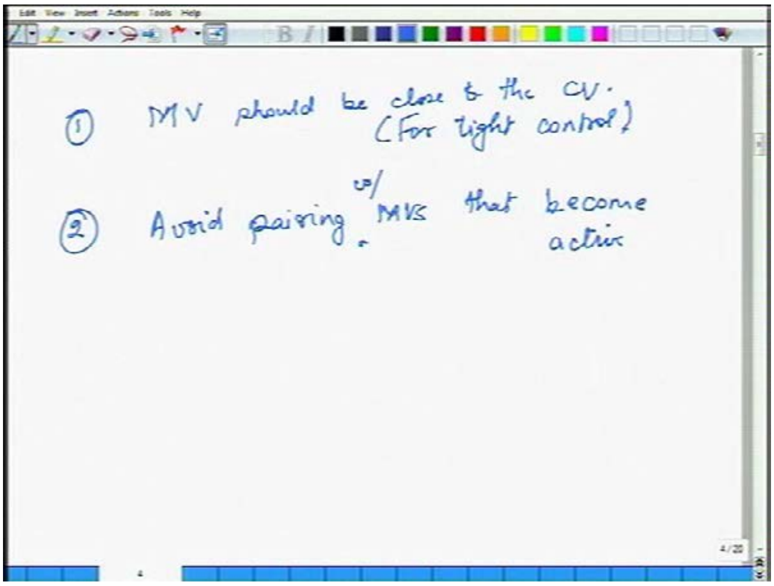

So, now let us go back to I do not know I do not know which well, so what are we saying. We are basically saying one how do you get tight control tight control will happen if the M v is close to the C v yeah yes or no. If the manipulated variable is close to the variable to be controlled then the dynamics would be fast; if the dynamics is fast, I make the change in the manipulated variable quickly. The output variable, the control variable response, I can close the loop and tune it nice and what I will get is really tight control of the C d. So, the first true list M v should be close to the C v that is the first loop, yeah why should that be for tight control. What is the next rule? Next rule is avoid paring M vs that avoid paring with M vs is that become active right if you keep this in mind structuring will happen automatically, yes or no.

Now, we go back to I do not know which date did we write did I write that nine state procedure do you have the date that 16 August here is the 9 6.

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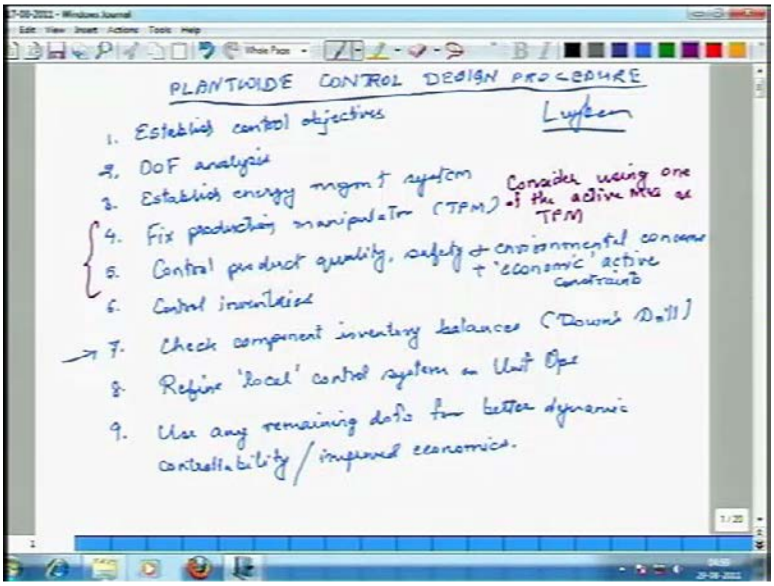

It just that here it is written in one short step 5. Step 5 and step 4, I have bring your attention fixed production manipulator though put manipulator what is the good choice for the though put manipulator I am saying a manipulated variable that becomes saturated should not be used for control (( )) active first or last (( )) last to the extent possible last. I agree and the penalty that you have there is that your thought put manipulator has to be shifted this needs further discussion does not matter all I am trying to say we will discuss it further fixed production rate manipulator you see you have constrain manipulator variable that will become active if you consider the rule hat I just gave you would not be using those M v s for anything or you would be using them to control things that can be given up you know it is to control them, but even if they floats it is right things that are not critical now what I am trying to say one of those active constrains that become active can be can be used for though put manipulation whether it is the first constrains or the last constrains does you know that is that is further level of detail, but one of those constrains that is gone become active can be used as a T p M yes or no yes or no yeah. So, that is a possibility that you should consider.

Step 5 says. So, I would just like to say here that consider using one of the active M vs s T p M yes or no that is saves me a degree of freedom why am I doing it because that is saves me a degree of freedom they should not be touch well I can touch it manipulate though put because any way I am going to be using something to manipulate the though put yeah. So, in M v that will become saturated that is a root candidate the best candidate would be what the constrains that that is the last one to become active. So, first I started jacking of the though put first this column got floated then this got flatted then the furnace duty got maxed out if the order is this then I am better of using furnace duty as my thought put manipulator and then my though put manipulator is the same for the whole operating space from the low though put to intermediate though put to high though put to maximum though put yes or no.

It is also possible that you may use a constrain that becomes active earlier and is not the last one in that case your though put manipulator will switch once this become active you still need to manipulate your though put what do you do you go to the next constrain that is gone be a active start jacking that up and then your though put will increase may be that get seen here how do you go to how do you go to it different file open yeah. So, if you look at this, what we did here? This is the through put manipulator, I keep jacking it up and then what happen, this became saturated, this was the first constrains to become saturated, then what then may through put manipulator shifted to basically this chap what I would say is reduce the composition set point.

So that, there is less C 5 circulating around and so the flow rate of this recycle stream or the distillate from this column will go down, then the temperature here will go down. And I can suck in more yes or no all right we discussed this I do not know may be I think we discuss this in detail yeah basically what I am trying to do is minimize the C 5 that circulating around. So, that I can suck in more what is circulating around in the in the in this loop is essentially NC 4 I C 4 and C 5 I C 4 leaks down the bottom of the d I d I circular botanizer C 5 leaks of the top of the porch column now I am saying minimize this.

So, what I do I start reducing the set point of the composition as I am reducing the set point of the composition the boil up will have to go up right as boil up goes up it will become saturated boil up reach reach its limit once it reaches its limit well that is it jack up the jack of the production further then I will go here minimize the amount of N I C 4 leaking down the bottoms right keep on increasing keep on keep on decreasing keep on decreasing and then what will happen is the boil up will keep on going up up up up until it hits its its max limit and once it hits its max limit that is it.

So, here I have had to shift my though put manipulator from the first active constrain to the next constrain to become active to the next constrain to become active there is this level of complexities that is there.

Why do not we choose the T p M as the last constrain to become active and does it use you want to do that lets do it can be done, but you will have to think well I have never done it before, but let us try doing. So, let us try doing it.

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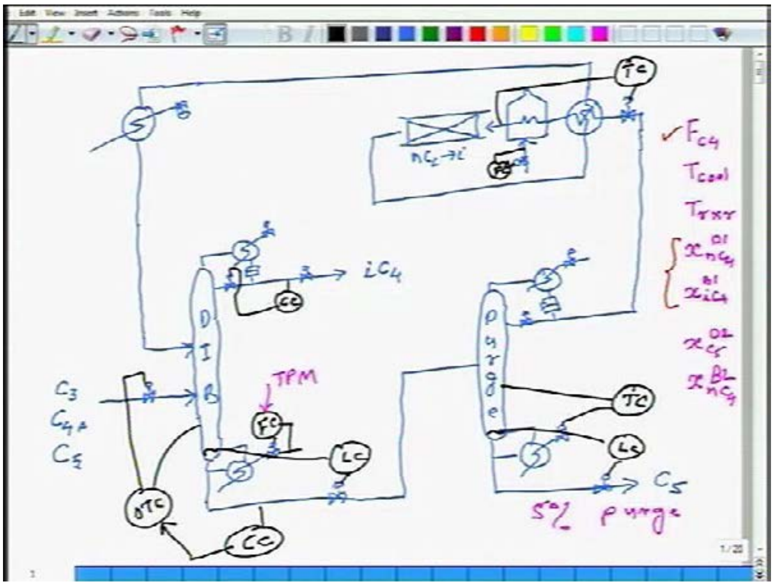

So, you saying, let us use this. This is the last constrain to become active, let this be the T P M. Actually you saying right, everything else goes, let see what those (( )). Furnace duty something that will become active, so flow control it, it is gone become active then what, because I know it going to become active. I say I am going to control the temperature using something, which does not become active. And I need to control the amount of N C 4, N C 4, I C 4 leaking down the bottom of the deisobutanizer, how do I do it. Since you are using this is T P M, boiler up as T P M, the only option is to do this, yes or no?

Then I need to control the amount of impurity NC 4 up the top in the product. The only way to do that is by the way, this may be actually a composition controller, because deisobutanizer, see temperature is not a good measurement, because the components are very close boiling. So, basically what I am saying it is this is composition control which...

Student: What about the lag associated with using the composition controller without usually the time…

Professor: So, there is a lag associated it is not it is not gone be tight yeah, but it really does not matter because what is going down is, this goes into distillation. So, if you cannot use a temperature what you generally use is delta T different between two-tray temperatures. So, may be what you what I can say is what you do is something like this. Why does that happen may be we will discuss it later, but delta T controller and you can always have a composition measurement that had just this delta T set point. Now I will not be too slow. This can be done.

To similarly when I am saying composition control here, this could also be a delta T controller, and the once a shift composition measurement coming from the lab is being used to adjust that delta T set point. And in that (( )), what else I need to control the amount of N C… See that is the problem here. I need to control the amount of NC 5 that is leaking on the bottom or rather NC 4

Student: (( ))

Professor: N C 4, N C 4 leaking down the bottom. If I use the boil up, what happens?

Student: (( ))

Professor: Ah?

Student: (( ))

Professor: It will hit max and so then you see, but I also need to control this level. The only way I can control this level is this. So, I will have to do it this way. Once I am having to do it this way then basically temperature control has to be this way level control has to be this way, yes or no? (( )) Because now when this boil up becomes saturated in the purge column whatever N C 4 is lost I am helpless, just want get lost. Is it what I am saying? Can I devise a control structure that how the hell do we do that then, I can do it and how do I manage this? (( )).

What should I set the furnace duty too, see this furnace duty, yeah this is gone be problematic, I am in the more I think about it the more the previous one seems much more reasonable. What do I do the furnace duty? (( )) Maybe I can do it this way then temperature control, in which case, level control here will go this way then of course, composition control is the conventional conventional thing. Now what is happening is you will have to have some back up in your furnace duty yeah. So, what is happening is, you having a back of in the furnace duty you are also getting a back of in your porch column boil up because it is being used to control temperature yes or no just look it look at this structure when this approaches is maximum you are going to start losing too much NC 4 down the bottom you do not want that.

So, you will you will always operate you will always operate at the throughput where this value is ninety percent open or whatever you're your are only ninety percent your sufficiently bellow the floating limit close to, but not at the floating limit yeah that that back of is need here similarly a back off is needed here yeah in the previous structure by allowing the T P M to move I basically avoided the back off and everything yeah. So, I would go my what is my word goes to the what to what with it which I rubbed off do not have it anymore.

You see if you allow the T P M to move then you are able to get tight control of everything. So, I am not very rigid about now the T P M has to be here sometime operator are very rigid you now they will say what the hell is this when you are driving a car speed is adjusted only by pressing or pressing the gas, but even there when you have to break you step off this peddle and go to the next peddle right. So, that this you have done same something similar here until this one until the furnace is active that is uses the

T P M then until the boil up become active that is uses the T P M then until the boil up in the deisobutanizer is active that is uses the T P M this allows you to have all three constrains active no back off yes or no will that make sense that is it that is I did what I did in that case I think I thought though this and I always got stuck this still have to give up that will have to be given there will be back of here there will be back off there I do not want that back off. So, let me do it the other way I think go through this third process, but this thing remember it.

It may be that a back off here does not really make a big economic impact the back off can be 10 percent and the increase in production or the loss in the production because of that 10 percent back of is only point one percent then you may said this is simpler this is more conventional. Let us do it this way at least in this case you turns out that a back of in this chap in the in the furnaces actually gives you three to 4 or 5 percent though put loss hats a hake of lot some lower year of operation had it been that it only gives me a loss of about 0.1 percent if I have a 10 percent back off then this would have been perfectly ok. The problem is it gives me significant loss in production yeah therefore, I did what I did. In fact, from the process I can clearly see that if this becomes active which really not a big deal because anyway this three meets the small stream even if 5 percent NC 4 goes to 10 percent NC 4 that would not be a hake of a lot because this anyway 2 moles and r or two kilo moles and r 5 percent of that is point how much (( )) 5 percent of 2 is how much 0.1.1 kilo moles in r even if point one goes to 0.2 right it then really make big different when the feed is 100.

So, I make even we willing to leave with this I may be willing to this is not gone a, but I am not willing to live with the back off that is gone gone come up here if maximum allow temperature is 200 degree Celsius I will be operating at may be one ninety 5 degree Celsius, no, I am sorry yeah it is actually the same thing if maximum furnace duty is x I will be operating it 0.595 of x or may be 0.9 of x and that cause my though put to be less by about 4 5 percent that is something that is not acceptable to me this you have done thing which is why did what we did?

So, if the economic penalty something that you have willing to live with let us say the economic penalty here would have been very small then this is just fine it is it will no big deal it turns out at least for this example the economic penalty this is the most I am economic penalty for back off in the boil up two column is not too much that is how it turns out for this example and that is actually makes sense by a by aligning more or less to leak out this three stream is small it would not may really make big difference having back off here what will it do it will essentially limit your ability to if the amount of NC 4 that was recalculating around was you could have put it down to 1 percent now you are putting it down to 1.5 percent. So, economic penalty for back off from the boil up is not that much economic penalty for back up from furnace duty is quite severe therefore, we did, what we did? Yes, do you have question.

Student: Yeah, sir, here in the furnace part, we are considering the temperature of the reactor is constant and you are saying that the Q furnace would be oscillating what that would not be constant.

Yeah

Student: Sir, I mean what have we hold this furnace duty as constant and allow the temperature to be (( )) alone, is that possible?

Earlier catalyst will get scrub, see catalyst is expensive and you would like to hold the temperature of the bed, you do not want the you see what happen is, if you have a thermal swings things melt and condense locally. And then you are active side which was exposed which was active in that melting in that melting and solidification what was previously exposed is essentially become solid and slowly your catalyst starts loosing activity. Even if you hold it constant there will be some swings. So, therefore, what we have is typically a process, you know you will run it for two years and then you will say look we need to change the catalyst, because that is what happens or we need to regenerate the catalyst. Thermal swings on catalyst are not desirable. So, you do want to hold the temperature fixed, you say let it float, you can let it float.

Actually in this process, it can be done. As long as your comfortable with fact that the catalyst is not gone get scrub, in this process you can let the temperature float when we very high and slowly as jacking of through put it will go down that is possible. But that is something that an operator in my opinion it would never agree and the reason has to do with the health of the catalyst. Any process is driven by the catalyst, the health of the catalyst is primary prime important, then you are saying let the temperature be whatever the hell it is, I do not care. So, you may make more money over six month, but I guarantee you what the if you are not controlling the temperature and if you are allowing large thermal swings then the rate of degradation or deactivation of the catalyst will be much higher. Where you needed to shut down the process and change the catalyst every two years with that can of a scheme, you may have to do it every one year and then it is a different all together you know. So, I was able to get 5 percent extra production, because I allow the temperature to float; however, I have to take a shut down and for my process to come back off, I lose actually more than 5 percent production is this you have done thing.

So basically what that means, is that temperature has to be controlled. You cannot let it float, but let us say it is non-catalytic reaction. Let say it is a thermal cracking kind of reaction, even there you have to control the temperature, because things may not crack or may over crack. If the temperature is too high - over cracking, if the temperature is too low - no cracking, so you really cannot let it float.

Student: There it also be I mean there is chance of runaway.

It is a this is adiabatic. So, there is no chance of runaway, it is a adiabatic system means the heat of reaction is not too much, runaway is not the problem catalyst health is the problem here. So, reactor letting the temperature float you may be it is ok, but you better think a number of time before saying that is ok. More likely you are missing something, in a simulation no problem. Because in a simulation you never say the catalyst activity is fixed rate constant is fixed activation energy is fixed everything is fixed, but in real life those things are changing slowly, but slowly that is what is dictating you know you need to take the shut down new catalyst etceteras. So, I would not let the temperature float, done.