Chemical Reaction Engineering 1 (Homogeneous Reactors)
Prof. K. Krishnaiah
1 Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 48
Non-isothermal Mixed Flow Reactors Contd. (Multiple steady states) Part I

I think we will start now this is the diagram, I have also given in the last class.

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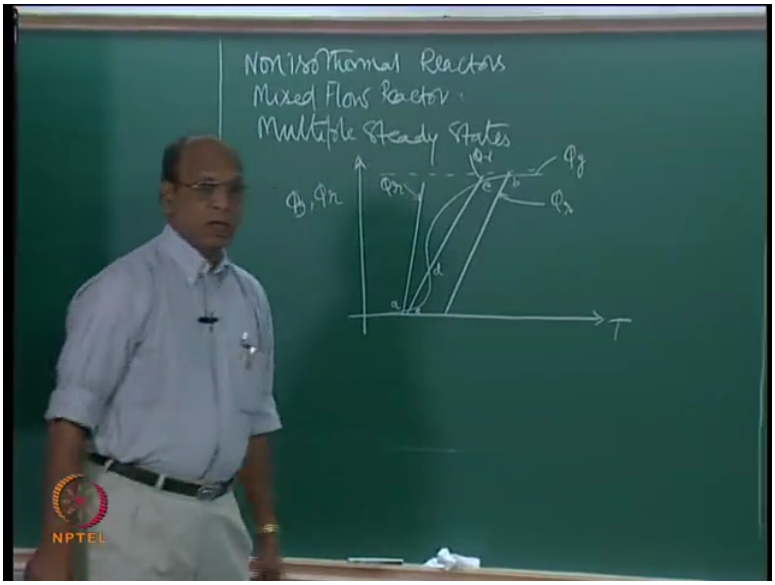

We have seen in a mixed flow reactor how easily one can find out the relationship between temperature and conversion okay there is no trial and error involved. (())(0:29) class no or? Yeah why there is no trial and error involved in mixed flow reactor?

Student: (())(0:36)

Prof: What?

Student: (())(0:42)

Prof: Yeah what happened to third variant.

Student: (())(0:43)

Prof: Yeah.because of the space you know it is lapped parameter system right? Yeah because of its lumping parameter system thats why that changes in the space is they have disappeared so thats why it becomes only 2 parameter problem 2 variable that is temperature and conversion so normally you know conversion you can calculate temperature from that temperature and conversion you can calculate volume of the rector.

But there is some other problem there when you just observed the equations what we have written earlier for. For QG and KR, QR what are the equation I have written for QG tell me minus delta HR.

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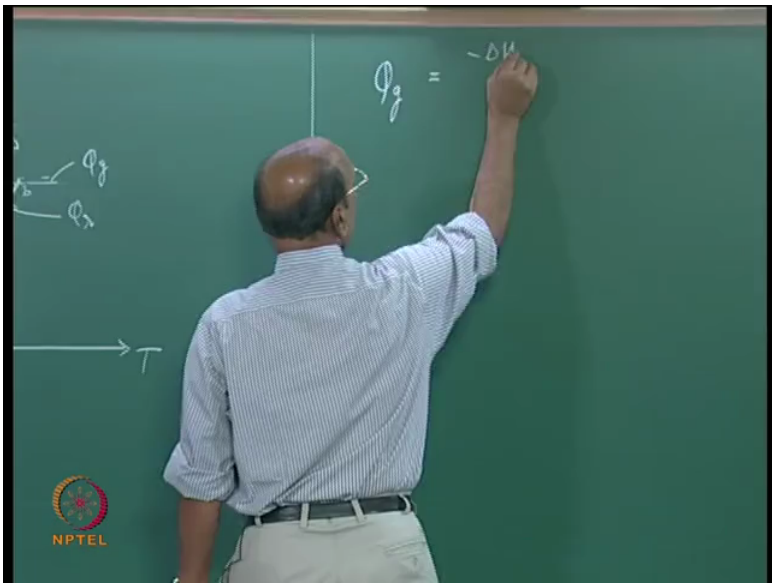

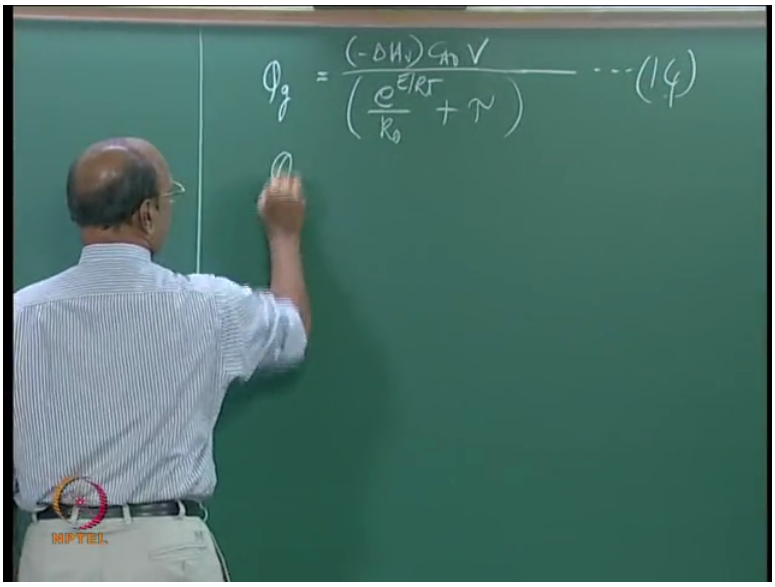

Student: Minus (())(1:31)

Prof: Not that final expression. Minus delta HR CA nought.

Student: CA nought

Prof: V yeah now whole thing divided by 1 plus,

Student: 1 by (())(1:31)

Proff: No no I think in terms of E power and all that you have written.

Student: (())(1:54)

Prof: E power E by RT by K nought plus tou that is the equation. Right?

Student: Volume

Prof: Yeah volume must be there, volume here.

Student: Yes volume (())(2:13) volumetric flow rate

Prof: Right right so volumetric flow rate as come into V so tau so that will not be there. That equation I don't have thats why I am asking you. Because I have slightly complicated equation this is the simple equation okay this is capital V. Right of course here again you have volume by volumetric flow rate so both are there so now this is the one QG, QG what was the equation number.

Stuendt: 14

Prof: One four, one four okay. So heat generation heat removal line was this is same what I have.

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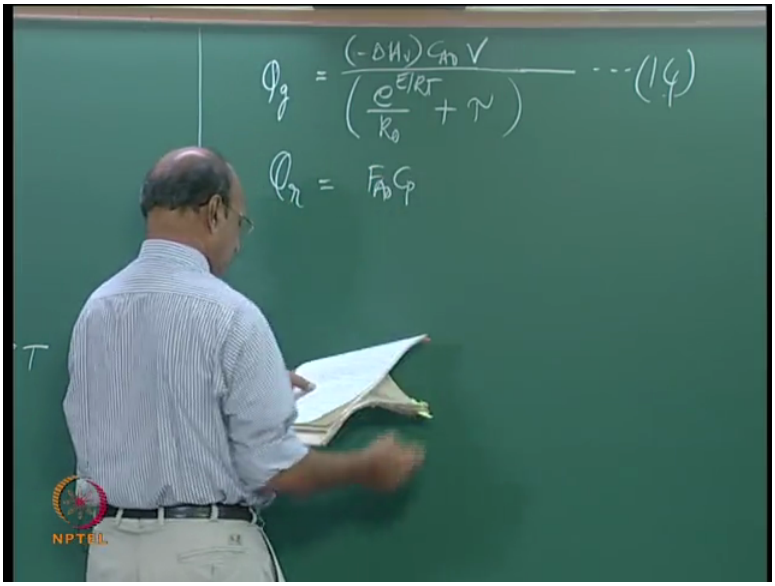

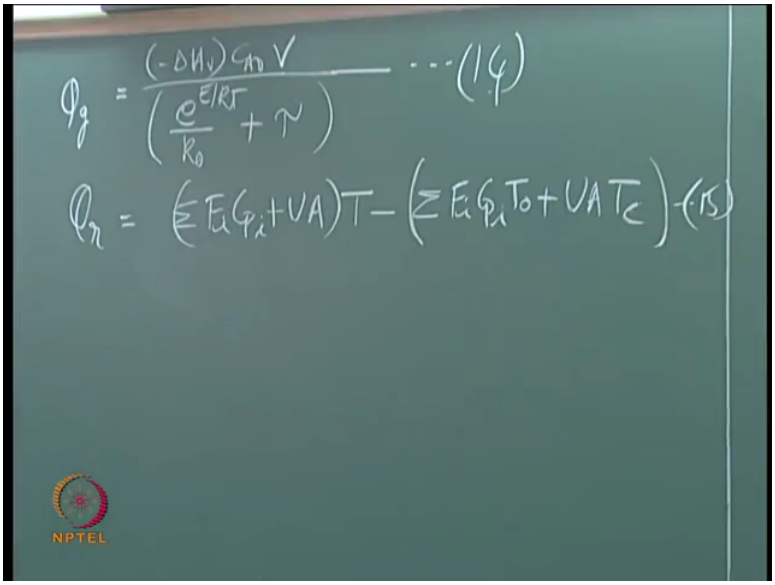

yeah FA nought CP or otherwise yeah you tell me what is the equation I have given there?

Student: (())(3:05)

Prof: That also have slightly different, heat removal line.

Student: Sation (())(3:10)

Prof: Yeah. Sation of Fi CPi plus UA that is bracket there into T temperature.

Student: Minus

Prof: Minus

Student: Sigma Fi CPi, (())(3:26)

Prof: Yeah sigma Fi CPi T nought

Student: T nought plus UTAC

Prof: Plus UA TC so this is the equation

Student: Whole bracket

Prof: Bracket right? Yeah so this is equation 15 so under operation these two QG must be equal to QR because for steady state, right? But we are talking about only steady state mixed flow reactor so this is what we have ploted, we separately ploted equation 14.

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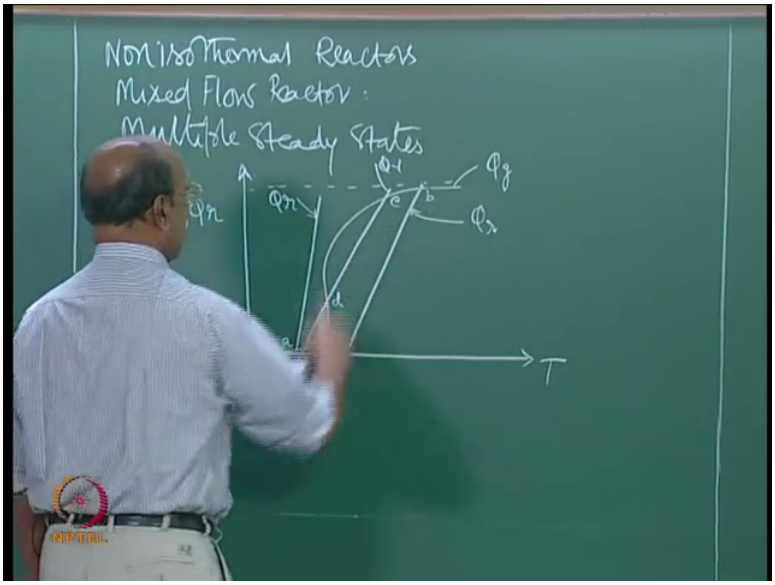

Here this is QG and you have QR lines because this is a straight line this is Y equal to MX plus type this is Y this is M all this is X, okay? So thats why you will have also this negative you know this intercept, okay. Minus and you have UA Fi CPi and your slope depends on this, okay good. Now let us look at this points where you have this 3 for this and one here and one here.

Let us start with this is lowest one where we have yeah. Let this point, at this point if I just look at right and by chance let us say this is operating at 20 degree centigrade it is operating at low temperature because temperature is increasing in this let us say we have one hundred and 20 degree centigrade and let us say because of the flow fluctuation because you know you could have seen either volumetric flow rate when you are measuring, if you are using okay what is the instruments used for measuring flow rates?

Student: Rotometer

Prof: Rotometer,

Student: venturimeter

Prof: Venturimeter,

Student: Orifice

Prof: Orifice meter, yeah what you measure in venturi meter and roto meter?

Student: Pressure

Prof: I don't know whether you looked at those pressure you know the nanometer particularly when we are using always that will be fluctuating a little bit. Okay slightly like this like this like this yeah if that fluctuation causes may be 1 degree in this direction positive that means 20 it is operating but it is going to 21 our question is when you have that 21 that means there is a disturbance from the temperature, okay this is the point what you get.

If I solve those 2 equations okay. Under this conditions right? So under these conditions if I carefully look at that if there is 1 temp 1 degree temperature this way then the temperature is increasing right? So naturally what should happen to the rate of reaction? It should increase when rate of reaction is increasing what what should happen to heat release?

Student: If it is exothermic

Prof: It is exothermic yeah also it is exothermic, okay? So temperature should increase so when so by the by if you don't have exothermic you will never get this shape right? Yeah and yeah once the temperature is increasing then if the temperature goes on increasing or will it subside? Again come back to this,

Student: Come back

Prof: Why it comes back?

Student: (()(6:44)

Prof: Temperature is increasing that means QG line is increasing okay, the point in QG line is increasing so you have it at 20 degrees 21 degrees temperature increase, rate of reaction increases, heat release increases and it will try to go on this line but what is happening? This heat removal the moment it crosses a little bit what is heat removal? Is it is less than QG or QR, greater that QG.

Studnet: greater

Prof: Yeah then what should happen now when it is heat removal is more than heat generated?

Student: Temperature reduced

Prof: Temperature will come down to. Because there is only one state. So at that point so it should come back to that particular point A. Similarly even here it is falling a little bit

temperature by some reason and because if volumetric flow rate is suddenly increased also it may fall that means more heat is now taken by the convection yeah. And you know TC also suddenly increases it may fall.

So but A1 then heat removal line will be yeah yeah here heat generation will be less and heat removal is no at this point when you come back heat removal will be less and heat generation will be more. If I draw a line I mean I am not able to draw that line I will explain that one to you okay there also so then again it starts heating and then goes only to this point so whether I move in this line direction or here it is a small in this direction the stable point is only this one right?

So when it is reducing like for example when the temperature is falling, falling down okay the temperature should the rate of reaction must be less so heat generation must be less okay. So then but when I move this way here you see this point I have less than this QG is less, QG at this point below okay. QG is less so when QG sorry this is QR, QR is less, when QR is less then what should happen again?.

Student: (())(8:57)

Prof: Okay it came to 19 right? But heat removal is less, so then what should happen?

Student: (())(9:04) temperature

Prof: Temperature should increase so that means again it will move to this direction,

Student: (())(9:08) direction

Prof: Yeah so that is why even if there are slight differences around this point absolutely no problem, okay. Now let us do let us talk about this particular case I think here you can easily see that yeah same argument here so when I am moving let us say it is 100 degree centigrade and it move to 105 okay more change so when 105 it is going then the rate of reaction should increase right?

Heat release must increase temperature must increase so it will it will definitely move on this direction but now if I draw a line here then heat removal is more than heat generated so what will happen again it will come back to this state similarly here it move till this point 95 right? Heat generated is more heat removal is less so the temperature should increase so again it will

move to this point so that is why even this point also we will be studying it may be fluctuating around this.

But it will be the only on that point I don't know whether you have discussed this in your process control?

Student: (())(10:22)

Prof: Okay.

Student: Mathematical methods

Prof: Yeah yeah in mathematical methods may be, yeah you would have just for steady state.

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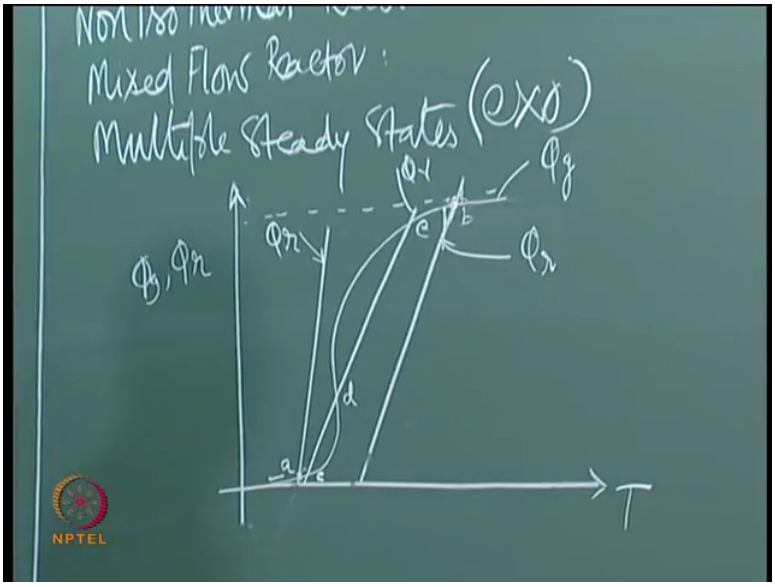

Yeah this is one of the very good example for you know in chemical engineering steady state, okay the reactor steady state and okay, so now this way understood it is steady state and this way we understood it is steady state now, even I have this kind of situation so we have 3 points here, now just try to find out what is happening lets see.

So here also same argument because when the temperature is moving this way okay, yeah slightly when it is a temperature is moving this way, so heat generation will be more but heat removal is more than heat generated much more than heat generated, so again it will come back that means, there is no difference between A and C.

Similarly you can also discuss here when I moving here okay, when I draw this one slightly further yeah, when I moving this side heat removal is more and heat generated is more, even though there is change in temperature and the temperature is trying to increase and heat generation will increase and you know the temperature anywhere try to go on this way QG will increase but at this point again QR is greater than QG.

So that means again it has to come back. Same thing here again when it comes back here then heat removal is less and heat generated is more so it will move on this line and then stabilize there. So A, C, E, B or A, B and C, E there is no problem when the reactor is operating at those temperatures okay. Now without knowing you are at this point now the argument must be very easy, right?

So let us say this is around 75 degree centigrade it went to 76 exactly this way right? This way so now the moment it went this way so that means I am somewhere here, okay. I am somewhere here so then what is the heat generated line this one, what is heat removed this one, so now what should happen to the temperature?

Student: (())(12:35)

Prof: It will again increase more temperature that means more rate of reaction, more heat release, more temperature increase so you will go here till. Because always here QR is less QG is more till it reaches this particular point. Similarly here it is same thing the moment you move this side heat removal is more. Heat generated is less so more and more heat is removed heat generated is not that much because you know this is the point and this is the point, this is the point and this is the point.

So that means you become more and more cooling, temperature will fall again but there is next steady state that is here. Its C, right? So that is why this particular point D is called unstable point or met stable point. So D is met stable or okay. A, B, C, E stable points and D is unstable. In fact the first chapter of you know there is a book process control by Stephanopoulos?

Yeah to justify weight chemical engineering's must read process control he gives this example. Okay? Why should we read process control? right? So in a normal way when even if you don't have control here, no problem for me. Why? Because if there is a disturbance it goes away but again comes back because of the conditions here so where do I need a control? I don't need a control. Right?

So but here, definitely I need a control right. So why I need a control? Let us say my the reaction temperature what I calculated was 75 and 75 is this one but I don't know the because of this 14, 15 non linearity you will get when I solve this I will get this 3 points here that means 3 solution you get for that. Mathematically speaking, so that is what is shown here. Whereas under these conditions that depends on what kind of slope you have, what kind of flow rate you have, what kind of CA nought.

And you know via what else yeah delta HR all these things will come into picture so that is why theoretically speaking I can draw QG by varying all those variables like for example tou changing QG alone, forget about the other one will come back because just as a mathematical exercise, how many parameters I have there? Temperature is anyway I am plotting here QG is here the other parameter K nought is constant E is constant and for a given system delta HR is also a constant then it will change with, volumetric flow rate right?

Of course normally the stability and all that we will come once you have the reactor right? But even when you are designing a new reactor the procedure is this you have calculated using the method what you have discussed in the last class what was the method? Write the energy bal, material balance write the energy balance and energy balance is very simple because there is no trial and error involved for mixed flow reactor.

So then calculate temperature for given conversion, take this temperature and conversion to design equation. Okay design equation is V by FNRT equal to XA by minus RA, minus RA has this T and X, right? So then calculate V. So now you know you also know the for that particular temperature what is T? That is the first type what you have done. Right? From energy balance T you have calculated for a given X now the question comes.

Whether that temperature is stable or not? Thats why this analysis is required, right? So how you have to do is people who really like mathematic they simply go for these equation and try to find out by trial and error, okay. Or using some methods, to find out whether there is you know only one solution or more number of solutions, okay and this is okay I also how to write.

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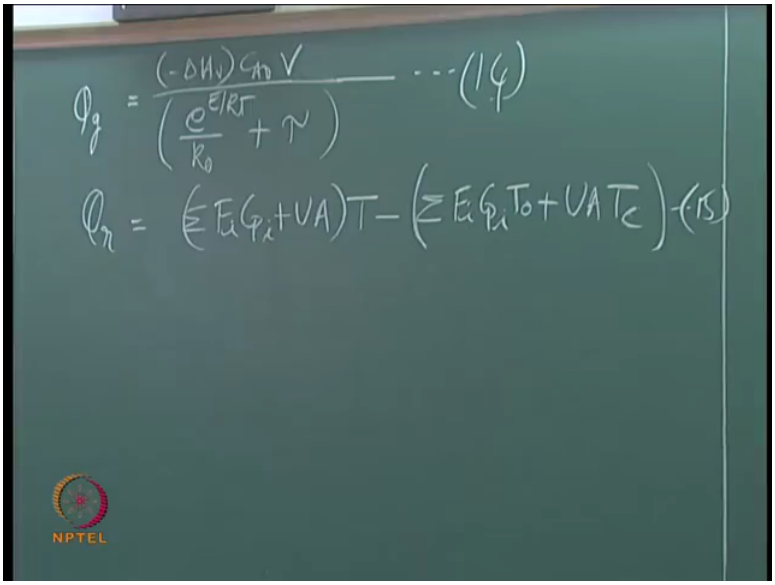

It is simple reversible sorry irreversible exothermic reaction. Okay for this case, again the moment I go to irreversible, sorry this is irreversible, reversible and also if I go to A going to R, R going to S right. So endothermic all the cases will be different, good. So now the criteria given for necessary condition okay by the by. I think you know this point A will happen, point A and point A no one would like to operate. Why?

Student: (())(17:29) conversion

Prof: Conversion is very very small okay. Corresponding to this because temperature is very very small, right. So conversion will also be very very small so that is the reason why you normally we don't want to operate but here we would like to operate. So for that reason sometimes you have to move the T nought, Correct? T nought we will use. So that is why by taking this equation T nought is here for different T noughts and for fixing you know normally we don't change TC once you fix TC.

And once you fix the heat exchanger this is constant right? And for a given flow rate and all that this is constant only T you can vary and then draw a various lines. All will be parallel, why parallel? Because slope is not changing but T nought depending on that, that is also important for us because all this is happening because of T nought also, right? So I may have a if I fixed T nought like this one line another line like this another line like this, okay this also possible another line like that.

All that I have to do so now when I am doing all this, this slope is falling correct? Yeah and also yeah the operating temperature will be increasing because when I put here and then draw

this line I am talking about if I fix this right? And also it is definitely better to avoid this point because if I fix this point I have to draw a line like this otherwise it will touch here correct?

It should not touch here. Right? This line QC line the moment it touch as then you have a solution there so to avoid that you draw the number of lines with T0 as parameter and then you will have an idea where you have to fix that temperature T nought okay? Good fine.

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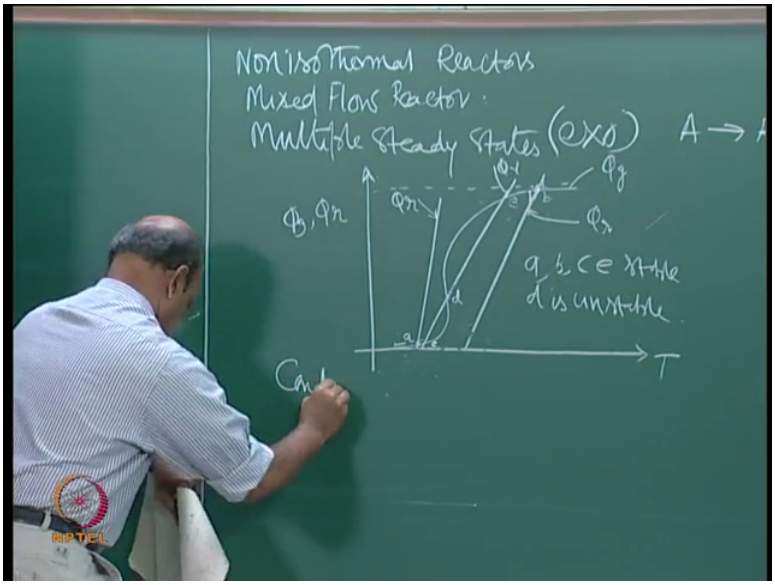

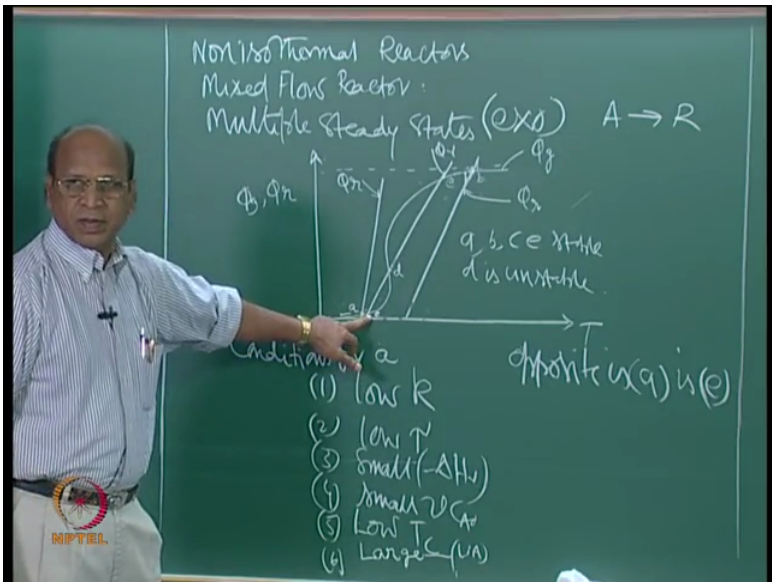

So now the conditions for A or 1 low K value, K means the reaction rate constant or 2 it can be low tou, low tou and it also can be small delta HR and also it can be small V into CA nought. V into CA nought is nothing but?

Student: FA nought

Prof: FA nought okay? So it also can happen with low TC okay or it can also happen large, large U , large UA or separately U RA also, correct? All these are common sense now once you understand that. Why? Because low K will give me low conversion, low tou also will give me okay. Why? Why low tou you will see low conversion?

Student: (())(20:56)

Prof: Because time is not provided sufficient time then small delta HR because heat release itself is not much so the temperature is very very low, because heat release is not that much temperature so again low conversions. And small V into CA nought,

Student: FA nought

Prof: FA nought okay, FA nought is small again again that is low then you have low TC that means I am removing too much heat, TC low means so naturally you will have low temperature so low conversion and large UA, large UA will again will remove lot of heat. Okay, and exactly opposite points are.

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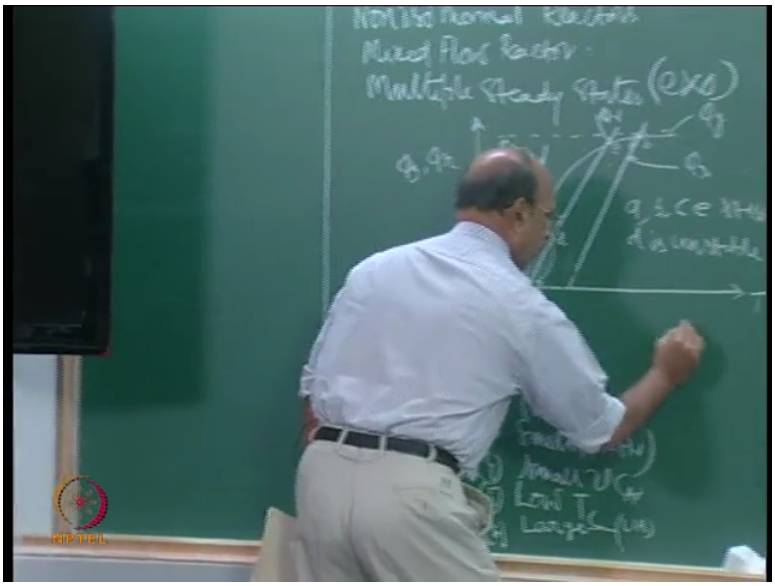

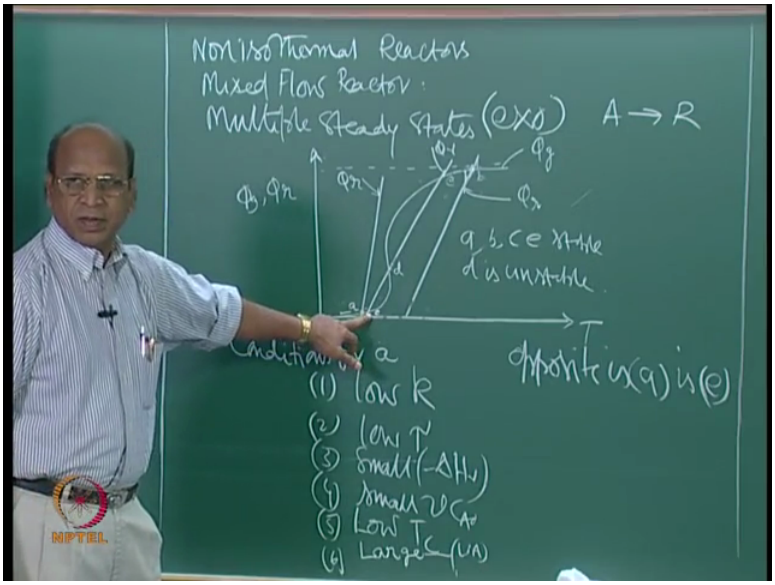

Opposite of A is what?

Student: Point E

Prof: Point E, exactly opposite then only you will get that kind of things that means if you know that your values delta HR values are large, your K value is large and you are not using that much UA so then you may expect this condition. Okay good. So in between yeah unfortunately sometimes you have to fix only this condition because even though this gives me more conversion if I draw a line here temperature may be let us say 175 and that 175 will spoil my product.

Okay so that means there may be side reactions or that may be it may be chart because it depends on again you know what kind of products you are dealing with so the physical properties of the reactants and product so that will also once R is our ignition point you know there is a flash point where it may catch fire, the uncertain points so all this will happen here, and I don't know whether you have observed this how many of you used bulls and burner? Bulls and burner?

Student: (())(22:49)

Prof: Only used burner? Not for cooking, for doing experiments I am telling. Yeah bulls and burner only 3?

Student: ())(22:56)

Prof: What Rashmi you never used bulls and burner? Used it? But the question is so stupid so thats why you don't want to answer anything? Yeah because you have used but did you observe something? (())(23:09) there.

Student: (())(23:13)

Prof: Can you stabilize the flame? When did you stabilize this?

Student: At low flow rate

Prof: Low flow rate is this, you cannot. Because there must be a balance between the amount of you know the gas coming and also the temperature that is able to sustain there must be a balance. If you also used too much gas that also not sustainable. If you use too less gas then that is also not sustainable. Okay that means you are somewhere here right?

But you if you correctly used the amount of gas and also you know there must be a oxygen supply also that is why you have the bottom there are two holes you know? 2 or 3 holes I think okay. Yeah did you observed you know that present at the bottom? That is only for oxygen to enter. So that second thing if it is not that much then it cannot stabilize so that means there is there must be a balance between amount of oxygen, amount of fuel and then it will sustain for long time.

Otherwise you sent too much oxygen, too low fuel it wont. Vice versa too much oxygen but very sorry.

Student: Too much fuel

Prof: Yeah too much fuel and less oxygen again it wont sustain. Right? And how many of you its a bad question smoke?

Student:

Prof: None of you all good boys and girls? Okay good. Yeah nobody has gone for some happy smoking, seen TV and all that and I think in Hyderabad there are many pubs its seems where you go and ask why are you smoking means what is wrong if I smoke? Nothing is wrong, nothing will happen only your lung will disappear after sometime, thats all I think okay.

Yeah anyway any smoke of any kind for lung is very bad. Lung doesn't like smoke it only likes oxygen. Okay good anyway so when you are using match stick, match stick right when you hit like this particularly rainy season and all that will it catch fire? Okay when its not catching fire you are under what condition here? On this line.

Student: Lower side

Prof: The lowest conditions that means here practically you don't have any reactions. Okay and then you may again strike and then wait for sometime without even shaking and all that then it catches fire and also that phosphorous which is at the tip of this match stick which will also makes some particular sound (phonetically) "shhhhh" like that okay.

So when you have (phonetically) "shhh" that (phonetically) "shhh" sound can take you either to this point or this point. Right? I think you know you don't know this is a experiment what you can do? In bulls and burnol you may not get in your house okay. So you can buy a match stick and then go on experimenting on this whether its really you know this point right? In sometimes when you strike you will get spark but it will not catch fire.

That means temporarily you are at this point and now a days, I think not now a days in this season all of you are going to destroy environment because of Dipavali. Correct? Diwali? you burn lot of crackers, I feel I think you are practically you are burning money. Thats all nothing else it is waste as chemical engineers no one should do that. Why?

Pollution, "Bhayankaram Pollution" I think in fact I think you should not, yeah and you also find out the moment you if you are stan standing there you know some many people make at (())(26:53) and all that right? So there also you know normally we have that yeah that crackers red once and laxmi (())(26:53) is very very laxmi cracker? Is very very you know sound lot of sound it gives and there are other thing also they tie with something and also what you call that?

Student: (())(27:15)

Prof; Thats call atom bomb? Atom bomb without atoms there okay. Okay so that one also w1ill give you so then what we do we put that here and then go to like this. You take away that very big stick you know with that fire at there and then slowly put but I think yeah yeah I mean you you are afraid that suddenly it may blop so that is why you just touch and come, touch.

And then come so that is why it may stop (phonetically) “shhh” stop (phonetically) “shhh” like that it may go because that fuse is there outside, right. Till that means there must be a sustainable fire in the fuse itself then the fuse goes and then opens up okay, and why it should gives lot of sound.

Student: Because (())28:04)

Prof: Yeah what is the simple formula they use there in making crackers?

Student: (())(28:11)

Prof: There is an equation beautiful equation that is involved in this.

Student: (())(28:11)

Prof: Yeah but I am just asking only equation, no explanation.

Student: (())(28:20)

Prof: What equation?

Student: E equal to Mc square, (())(28:27)

Prof: He said only E equal to FZ square and you are telling E equal to FZ square plus XA plus XB. (())(28:42) pplus XE.

Student: (())(28:40)

Prof: See how sad it is you know that we use we are studying in the this is high school question. Okay simply it is PV equal to RT. Thats all PV equal to RT nothing else and we I think till now 25 years we have a burnt so many crackers without knowing what is the formula behind that okay. Any way at the age of 2, 3, 4, 5 you may not know but once you go to school you should know equation PV equal to RT. Why it is PV equal to RT?

Student: Volume will get constant.

Prof: Volume is get constant okay. Thats not the only (())(29:23) yeah and if temperature is increased right so PV equal to RT volume constant R is constant temperature is increasing because of explosion then what will happen to pressure?

Student: Pressure increase

Prof: Pressure should increase. But you are having that you know that papers some kind of thread and all that around that but you know if you have too much threading and where it is not at all able to crack that then you wont get any sound. Really you don't get any sound so that means that pressure it is able to contain. Like you know ammonia reactor, ammonia reactor thickness of the reactor is I think you know it is 4 inches 5 inches thick right?

So it wont explode if it explode that is I think thousand times laxmi cracker. Okay because 500 atmosphere. Correct? 350 atmospheres? Or 250 atmosphere? Okay if very high so that is the reason why PV equal to RT that is why in laxmi cracker you will have slightly tougher more number of papers. Thats smallest one is the red one okay. So that wont give you that much sound so some people I think people like merit and all they will have hold it in hand and then crack.

Not afraid at all, he is a bold guy so that is the reason why you know no problem at all there are some more things you know that red small things caps or something they call. That red very small one I think may be 5 mm, 6 mm diameter and inside you have small thing and you take one stone and then hit it. Okay

Student: (())(31:05)

Prof: I am trainee I am giving you training for you for Diwali. Okay what are the fundas so you put that and take a stone and hit it as you know it is a great thing and no one will hear except you. Sound is so small because explosion is so small but still it gives sound because of the pressure you know which you are creating. (())(30:06)

Student: (())(31:33)

Prof: Cracking something there?

Student: (())(31:36)

Prof: Cracking jokes only na?

Student: In diwali it make lot of sound, Gun, gun

Prof: Gun yeah yeah yeah that gun is also mechanical is not purely chemical. Gun is mechanical right. Yeah when bullet is leaving what is that?

Student: (())(31:55)

Prof: yeah thats okay that also require pressure you apply in there I thought he is talking about heat gun. Okay good so all the things are happening so that is why you are getting more and more sound so now if someone ask why laxmi gives more sound than that some other that small one. Small one is called what?

Student: (())(32:20)

Prof: Not the round one the same cylinder type and then small one cracker only. No pencils and all that no sound only light. See all our diwali things is sound or light yeah you will have pencils, and you will have sudarshan chakras, so all kind of poor fellows they don't make noise. They will only make light okay. So that is what I think you know even this particular curve is also responsible for that MIC disaster.

You know MIC disaster in Bhopal. Yeah chemicals can be really dangerous they can kill many people. Civil engineer if he kills I think only building falls (())(33:06) okay so all of us how many 60 people may not be there in the world. Okay if it falls or may be some more people down okay. So thanks to dean room and all, below this only deans room is there. Okay all these things may happen.

But if a gas leaks and then imagine you cannot stop breeze you know, so where ever it goes it kills. You know what has happened there at that time. There was MIC stored right and its a catalytic reaction its seems in the presence of water the reaction is much faster water by mistake or so water entered so reaction started and it is highly exothermic reaction so the moment water small amount water has gone and reaction started then temperature is increased.

So that temperature again heat released because of exothermic reaction temperature increase that temperature increase is again rate of reaction so that rate of reaction again created more temperature it goes on building because there was lot of MIC stored but unfortunately if that kind of things happen they should have a safety valve. That safety valve did not open so but it is concrete tank right.

But the pressure inside is so much like this cracker so then it burst. Okay if that tank is very very strong it could have not happened. I know if that a concrete tank if it is very very strong it could have not happened. That is why if you go to this nuclear power plants that thickness of the walls where they are 3 meters, 4 meters, 5 meters depending on the amount of fuel you put there, thick okay and that much is required.

Because I think those radio activity should not diffuse again through concrete. I think thats why civil engineering is also study diffusion of concrete through porous media like you know this concrete. And those people who are doing this construction over that structure engineering concrete and all that they also study that diffusion because that should not come out. Right?

So all these things are just because of this you know exothermic reaction and temperature going on increasing so that is why endothermic people are very happy. Thats why most of us I think you know if there is active fellow only problem if in active fellow there is no problem. Cause he is any way in active, he may not even laugh also cause he may not have patience to laugh for this I think that kind of endothermic reaction.

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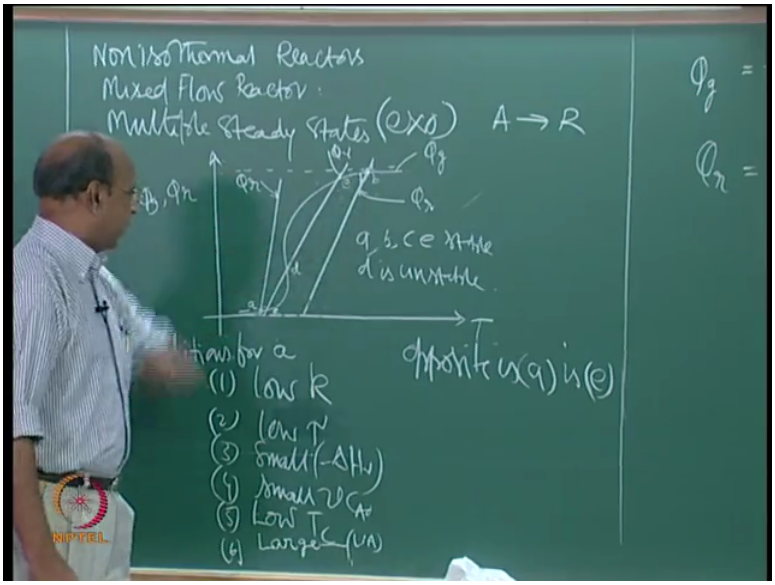

So that is why I think anyway this also very good so all these things may happen that is why we are getting this particular state either go here and then go here and when I told you that when this unstable state is trying to go here then this is explosion point if this point is explosion point then the entire reactor will explode. Okay, so good, so this is fine, so then mathematically speaking the condition here why it is stable? Or here or here okay or here why it is stable that is given is as QD.

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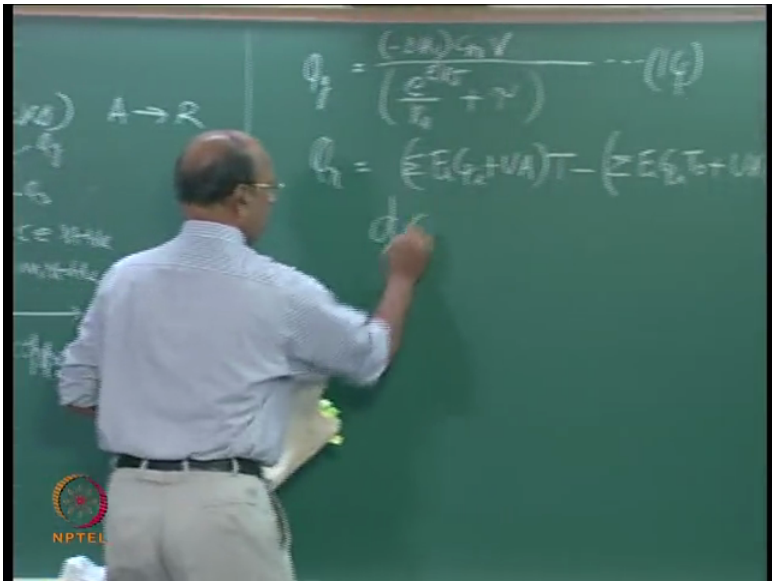

Slope of (())(36:17) dT must be greater than, this is the slope criteria this is the sufficient condition no sorry necessary condition. Necessary condition for stability, necessary condition for stability okay. So that means if you take these two equations and then you can differentiate Rashmi. Okay? You can differentiate this and once you differentiate if you know all this values you will be knowing definitely E value.

And also yeah differentiate with respect to T and delta HR all these values you can substitute and then calculate which slope is more? Right so depending on that value you can find out whether the pro system is stable or not but that gives you only one condition that is necessary condition but the sufficient condition will be.

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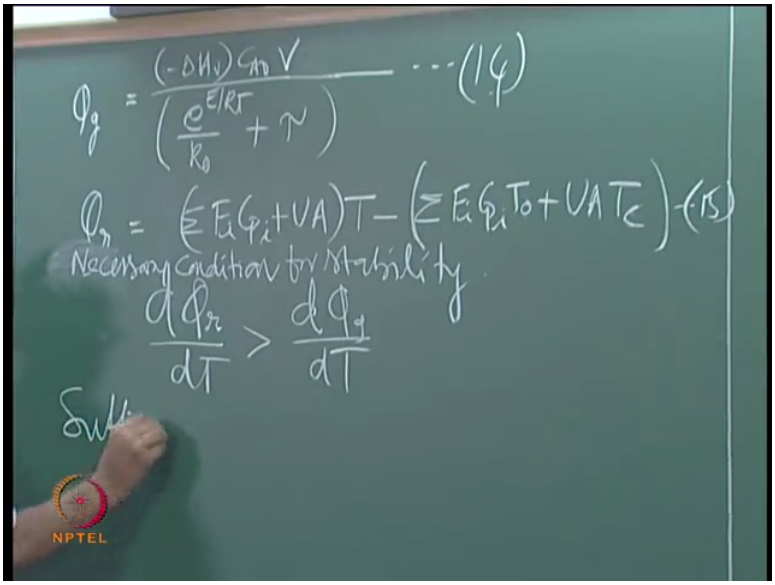

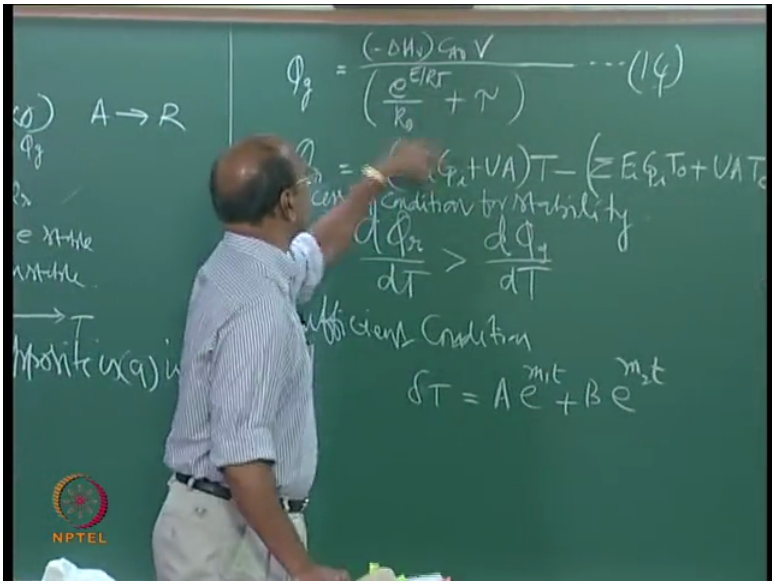

The sufficient condition is doing in terms of process control. What do they do? For process control?

Student: (())(37:42)

Prof: They write unsteady state equations first because as I told you know all process control people are unsteady state. They don't have any business in steady state, okay. Only unsteady state so once you have that unsteady state equations and then you have to expand those terms you know that tailors series and take like the way you do and take the first few terms and then write the equation you get one condition.

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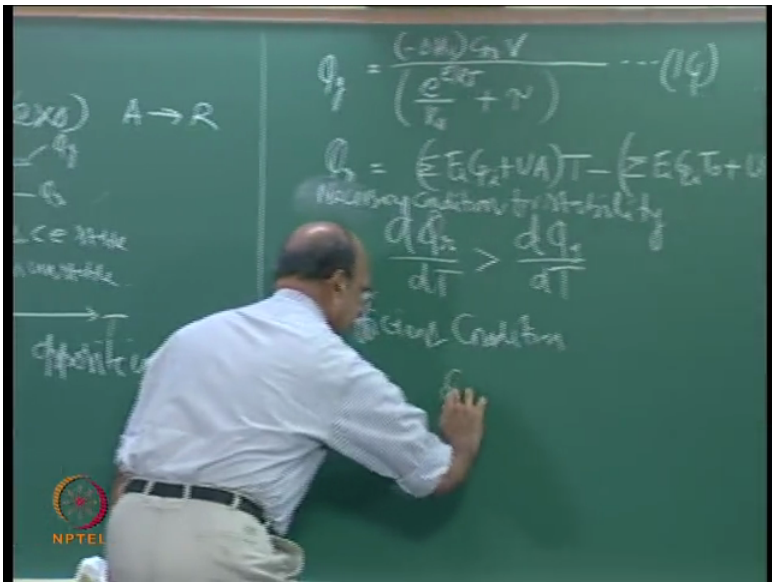

Where the change in temperature delta T will be some constant into M1, T plus V into this you should have got many times I am not doing all that M2 T. When do you say that the condition will be you know stable the point will be stable?

Student: When M1(())(38:30)

Prof: When M1 and M2 must be real values of negative. Right? so that is the condition so now you have to do this and you have to also write the material and energy balances and then write the equation you know in terms of tailors expansion and all that and then bring it to this level and then try to examine what is M1 value what is M2 value ?

If you do that this M1 and M2 contains all these parameters, this M1 and M2 contains all these parameters like you know delta HR all these things will be there tou, V okay. All these parameters will be there so then if M1 and M2 are negative real parts.

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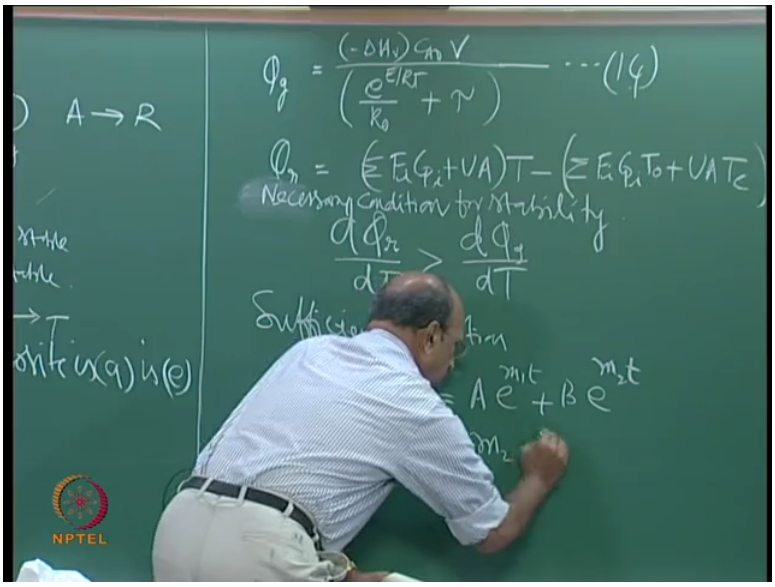

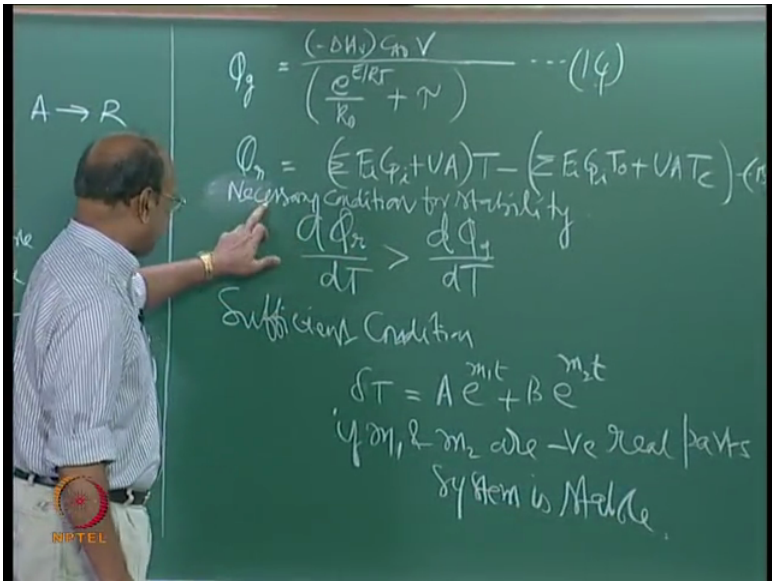

Or negative real parts if then system is stable this is very good condition because you have to do this, this is one condition necessary condition this is sufficient condition both one has to check whether it is really stable or not. Okay good, excellent I think this is nice. Yeah this is very nice interesting thing but I tell you if I give this same thing in the examination you will have hell.

Because you don't even know how to plot and if you are going by trial and error okay thinking that okay I like mathematic and I will do it but in examination call you cannot do. Because it is exponential you have to find out 3 values and you don't know first of all there are three values there may be 2 sometimes depending on the shape of the curve. Right?

So that is why by trial and error if you do, don't blame me because you may take 3 hours for 1 problem. Okay yeah for 1 problem you may take 3 hours by trial and error, but if you draw the graph correctly you may get it quickly, you may get provided you also know how to calculate correctly QG. QG is the main problem, QR is not that problem because straight line fellow, all curves are dangerous only straight line very happy no problem at all, right?

So that is what as far as examination concern. So this is what is the condition in fact there is lot of information available on this I know you should avoid of limit cycles, okay and also unsteady state you know when process control people analyse this system they start, it is unsteady state at time T equal to 0 they start until what time it comes to this stable point if that is the point that is there.

So if this is a point where ever you start so there are lines like this goes, goes, goes and finally goes to this point and you may start this side you may start this side, this side means

on low temperature high temperatures, the front flow rates all that okay so, that phase diagrams are beautifully given wherever you start how this comes to finally to your stable point and there are also you know things called limit cycle.

I have not gone through all that because I think my interest is just to expose you to this and move to residence time distribution. Because we are losing time now right? Yeah so thats why I just want to point out all these things for to you those who are more interested because that goes into process control. I told you if you would have started with definition all ready known very well that means first, second, third, fourth, fifth chapters of (())(42:00) is completed I should have started with sixth or seventh chapter, then we should have done all this.

I also should have enjoyed that, but I think now it is more fundas and also exposure to as much as possible okay that real things that are necessary so that is the reason why I am not able to go that kind of analysis in terms of unsteady state, otherwise it is not only the business of process control people even though I am telling many times but it is also reactor design engineer beauty to find out whether the system is stable or not, and if you uses only one condition that may not be sufficient okay.

So that may be necessary but I think that condition again may not guarantee stability. Okay yeah so that is the reason why?

Student: (())(42:49)

Prof: What is that?

Student: If we get sufficient condition proved then why do we need necessary condition?

Prof: Yeah I mean see when you are starting this in the beginning itself no problem but as a chemical engineer I am sorry as a reactor engineer what do we do first? I design the steady state here and then I go for.

Student: Unsteady state

Prof: Unsteady state. Okay to check whether only for in this case. Right? So that is the reason why I am telling this one first because my idea is first to calculate what is steady state temperature. Now go to the analysis so at that time if I say that yes I have one more point yes. This is necessary I mean necessary condition this is stable right?

And this is problem for me because I can do as a second step this one to find out whether guaranteed stability or not okay good. And for endothermic reaction this kind of things will not happen why endothermic reaction this kind of thing will not come into picture at all. Mathematically also you can tell, what will be the value of DQG by dT for endothermic section system.

Student: Zero

Prof: You can not say 0.

Student: (())(44:00) negative

Prof: Negatives? Okay and what will be the slope? dQR by dT is nothing but a slope.

Student: (())(44:09)

Prof: Will it many time negative?

Student: (())(44:13)

Prof: Extend extend brain a little bit I say, expand the brain. It is always, why? UA cannot be negative and Fi CPi cannot be negative I think it will that kind of expansion must be there in the brain I say, or only simple not in hands and many heads and all that I think you know that expansion when does that come catching fire okay, immediately before the teacher tells that you should have told the answer.

At this point of time you know our bit is very easy I told you, you know can it be negative and you have the equation, it is straight there and that is why the physics unfortunate is missing whenever in all the subject and you are interested in only in of course in examination.

Thats all you may or may be thinking that whether this fellow gives this problem in the examination or not, if it is not in the examination I will switch off the brain, if it is as it is lot of things in the brain, so switching off because of too much of loading and all that is your problem, right? I think this can take you know this is I only you have now one terabyte GB right? As the hard disk only one terabyte or increased?

Student: (())(45:25)

Prof: More than one terabyte also available? But this one has infinite terabyte, but if you have willingness to accept, willingness to learn, then only it has terabyte in unlimited terabyte but if you are restricting to only examination and all the time that will be only 256 Mb thats why it will never grow more than that, 256 (())(45:47) half of that came into beginning, I think only 256 I saw the minimum one.

Student: 64

Prof: 64 (())(45:56) also was there? Yeah so thats all. Okay so that is why I think may be at PHD and MS, Mtech may be that goes to 256 or little bit more so that is why don't imagine all this in examination and all that, okay good.

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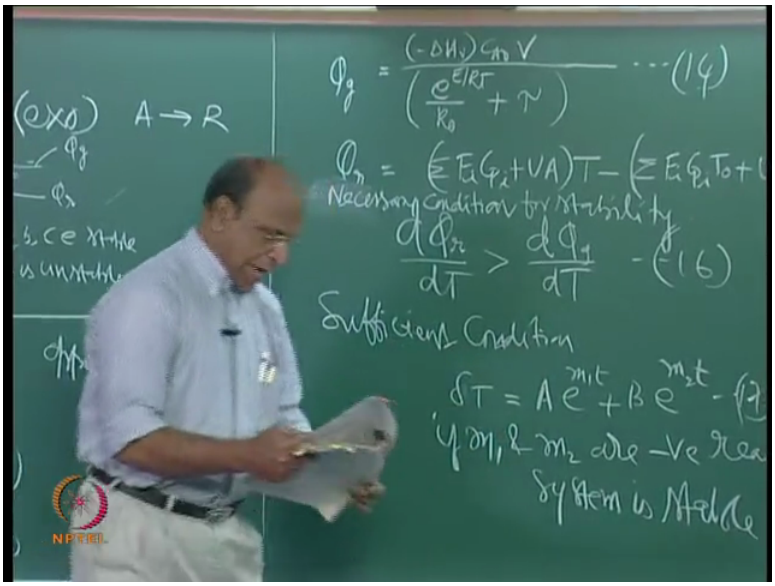

So this is the one what we have about this one and so that is why endothermic reaction is not a problem. Another question I asked is why I have not talked anything about plug flow but why I am talking about only mixed flow? Is it possible to have multiple steady state even in plug flow, no expansion only 256 may be 64 or 32 mb or 16 mb.

Student: (())(46:37)(inaudible)

Prof: So what will happen?

Student: (())(46:47) (inaudible)

Prof: So what happens okay it is very in continuously, so

Student: (())(46:53) (inaudible)

Prof: Heat removal is there you put outside that.

Student: (())(46:57)

Prof: Anybody is interested in control here or all may be interested in control?

Student: No

Prof: Yeah those who are taking I think PHD

Student: Rahul

Prof: Rahul.

Student: (())(47:13) (inaudible)

Prof: Why?? Practical we have not discussed that you know if there must have been any problem, I am asking why? Pooja what area is yours?

Student: Sir my is rheology

Prof: rheological so you are not a (())(47:34) (inaudible)only Rheology she always closed.

Student: Rashmi control sir, Rashmi control

Prof: Rashmi control yeah, Rashmi control I saw only PHD control or something now this has become Rashmi control. Yeah shall I give one word it depends on the feedback?

Student: (())(48:03)

Prof: Now you can tell Rashmi.

Student: You cannot measure temperature.

Prof: Measure temperature, why I cannot measure temperature?

Student: depends on the (())(48:16)(inaudible)

Prof: Any number of (())(45:19) beautifully I can measure it. Because here whatever temperature fluctuations are there that is going as feedback to the reactor and then slowly it is increasing but what will happen in a continuous flow where across along the length of the

reactor if there is a temperature fluctuation. What will happen to that temperature fluctuation? Abhijeet? You told like this so I thought you understood.

Student: (())(48:47)

Prof: Yeah it is just washed out, so any that means there is no feedback, so there is no point for the yeah accumulation of the heat there, yeah but here the heat that is which is about to go out will be brought back and then mixed with the feed that is why its called back mixing reactor. Okay?

So that is why this happens inside. And temperature multiple steady state is not a problem with yeah normal plug flow but we have another problem there what is called parameter sensitivity in terms of plug flow and also batch reactor. Batch reactor also same problem, in time forward it moves okay. But I think thats what ram Krishna has done I think none of you solved that problem.

Did you solve? the batch reactor problem which I gave you, no no not simple adiabatic batch, non iso thermal adiabatic batch. (())(49:44) reactor, (())(49:46) reactor none of you have solved.

Student: (())(49:47)

Prof: Yeah the first I am not asking about quiz I am talking about batch reactor which I gave you in the class for adiabatic system. Yeah but did you by do this by trial and error?

Student: No I didn't (())(50:02) (inaudible)

Prof: Yeah no no UA

Student: (())(50:06)

Prof: Thats what I am telling adiabatic only you solved some of you. But you don't even know that there is a problem for non adiabatic which I gave you thats why I think its 0 MB I say so not even 64 yeah absolutely no storage space is there. Yeah so then he has done it and he found that at one point the temperature will shoot up all the time.

You know normally what you except when you have non isothermal it has to go to maximum and then fall. But that will not happen in CSTR sorry in mixed flow reactor in batch reactor and plug flow because you will get the point only under one UA condition. UA heat removal

because that is the parameter we have I have given you to change. Right? But I also gave you that how much is 2,4 or something like that.

Student: Point 54 (())(51:00) (inaudible)

Prof: Yeah

Student: Increasing till 111 sir.

Prof: Yeah 111 UA so then only you will get increasing and decreasing that will be the stable point I mean not stable, so that will be maximum it will reach and then fall but here a small change in UA will be shooting up, you know thats called parametric sensitivity that means by chance there is a small temperature change okay.

Along the line of parametric sensitivity it goes up and shoots up. Okay so I am not able to do that because again you know my timing and other portions I have to do that I just want to mention first of all in plug flow reactor you will not get multiple steady states under normal conditions as I going to R and all that okay. Yeah so then I think again I don't know about what happens in autocatalytic in plug flow okay.

Yeah so but this one in nor for normal reaction plug flow will not have multiple steady state but due to have another problem called parametric sensitivity. That is the problem what you will have there so that means there will be uncontrollable parametric after some conditions. Okay at some condition that also one has to find out.

Okay thats the only problem there and within beautiful information is available by Amundson you know Amundson is another grandfather of ours mathematical methods in chemical engineering there are books you know 3 books by Iris and Amundson okay.

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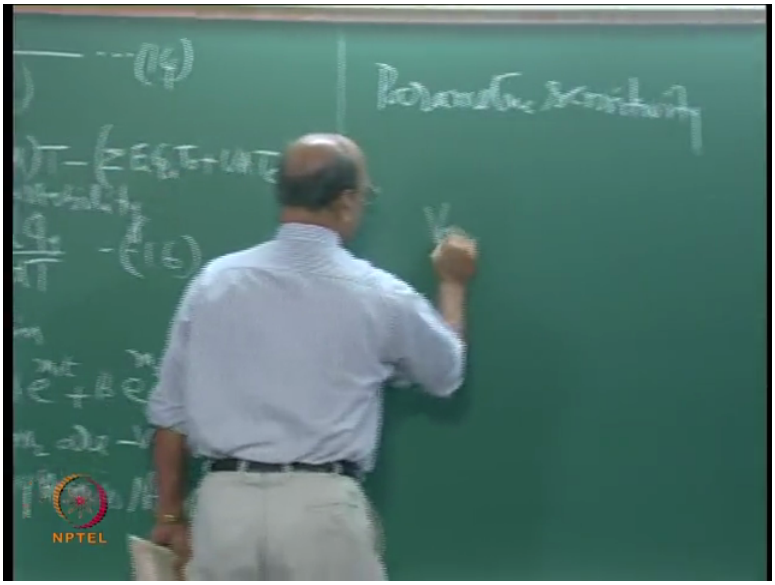

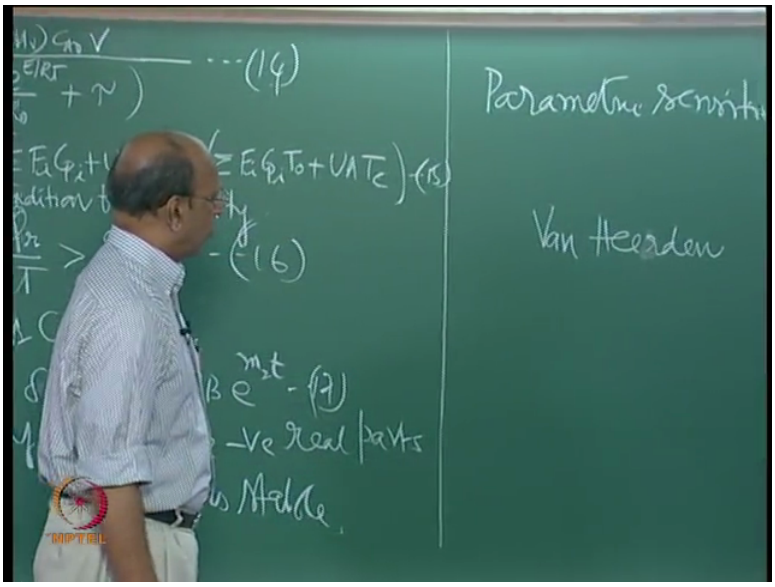

So I think Amundson was the actually this multiple steady states first found out by Van Heerden I think 2 Hardeena may be another E also is there I don't know I just put this yeah. Van Heerdein he is from Netherlands, Netherlands is also a beautiful place for, for in fact chemical reaction engineering name came from Netherlands I told you.

You would have forgotten again 0 mb okay and the first few classes I told that and who was the person I also give name. Name of the person who told chemical reaction engineering how beautifully he call that name. Okay yeah I think I have to stop here but I think still I am not able to complete this also so I have to tell one more one or two things about this like for example adiabatic case what will happen?

UA is zero this UA will be zero then you will have only this 2 then this must be equal to that equation equal to QR adiabatic as this is 0, this is 0 must be equal to this, you will get a multiple steady state?

Student: (())(53:52) (inaudible)

Prof: Why yes?

Student: Because the line is still in there.

Prof: Excellent not only line will be there but (())(54:04) will be there as usual

Student: QG (())(54:05) (inaudible)

Prof: QG S shaped come (())(54:05) okay so that is what only this slope will be different now because UA is UA term is not there that intercept also you know that TC and all that is not there. Intercept will be there but he is only this term, only this term T nought okay, yeah Fi CPi T nought so thats why A1 for adiabatic case also you will get multiple steady states. Okay good I think we will stop here because you have to go to class.