Chemical Reaction Engineering 1 (Homogeneous Reactors)
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Lecture 57
Multi-parameter model (MFR with dead space and bypass)

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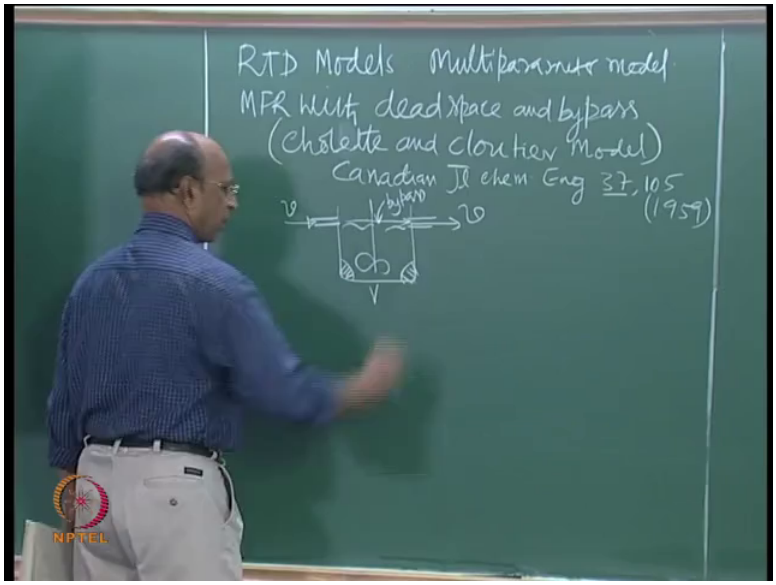

Yes, we will start now, the next model after single parameter model that is tanks in series and actual dispersion. We are going to talk about multi-parameter model, yes. So the name of this one is Cholette and cloutier model these are the first people who suggested this model, yes right. Actually if someone is interested I can also give the reference this is Canadian general of chemical engineering volume 37 what normally we write, Page 105 1959.

I am sure most of you would have never born at that time, okay. Yes, so normally what we visualize here is that we have a Cstr something like this, so continuously we have the fluid entering and continuously coming out volumetric flow rate, volumetric flow rate, this is v, right hand we have a stirrer. So this is the actual real mutual flow reactor what we will show and here what we are going to expect the non-idealities will be the bypass straight like this without spending much time it may go as by pass, okay that is bypass and you also may have dead space, this is dead space.

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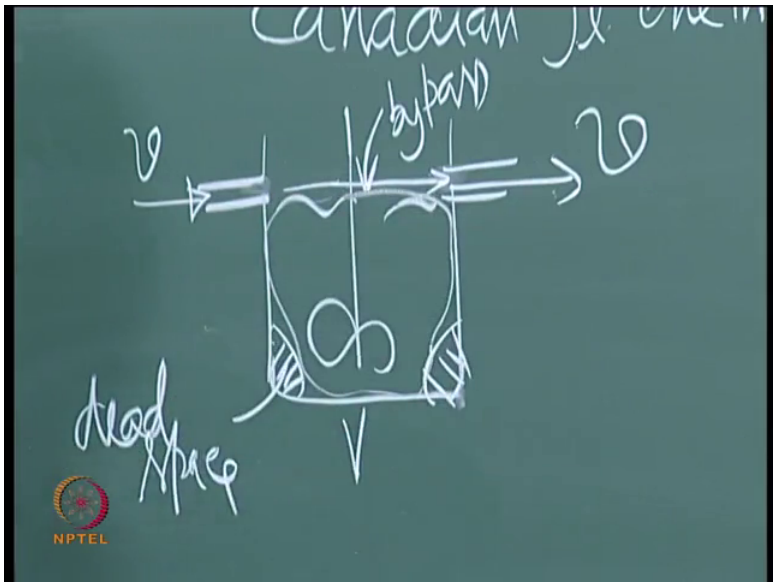

So when I have this situation how do I model? So that means actually I have an active zone something like this, that is active zone then I have some volume in dead space and some bypass, right? So to write the equation first I should have a model in my mind and that will be shown something like this.

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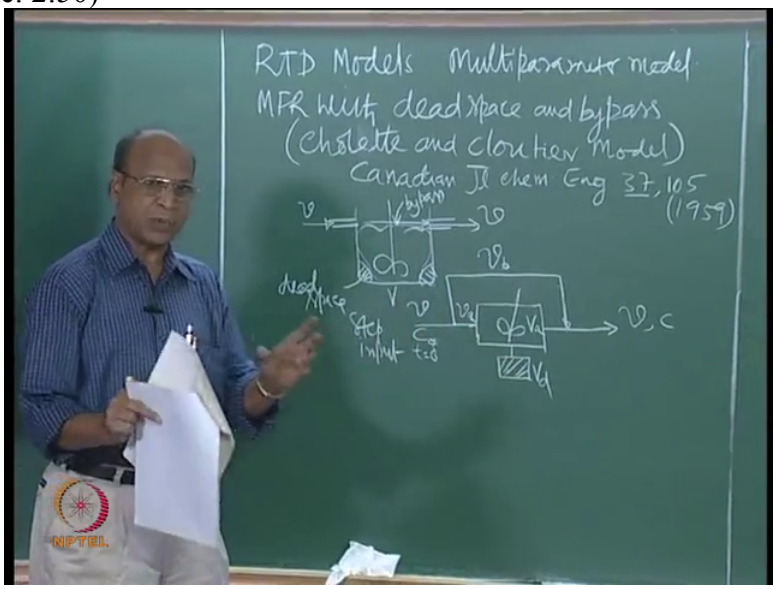

I have an active zone, so this is the active zone then we have this stream entering into active zone this may be v and volumetric flow rate and yes, there is a dead space, that is dead space and that means the active zone I am showing this one as active zone and the volume of this will be Va and the volume of this will be Vd, right? Vd is the volume of dead space and now we also have the bypass we have shown like that.

That means practically it is not spending anytime inside the reactor. Yes, to show active zone we are showing this stirrer, this is bypass, so this volumetric flow rate v is split into now this is va, small va, volumetric flow rate going through active zone and this is Vb, okay and both of them are coming and then again, you know mixing here what we see is some concentration c, okay and I can solve this one either for pulse input or for step input. Let us take step input where continuously I am sending the concentration the step input, okay. Concentration of time t equal to 0, C0 time t equal to 0, so then we are writing the balance after some time t to this model.

You see now this is what you have to do also, you know, most of the time when you are modelling and the physical system you have to imagine that what are the problems? How do you break up the problem into this kind of diagram where now it is very easy for me to write the equations for each zone, right?

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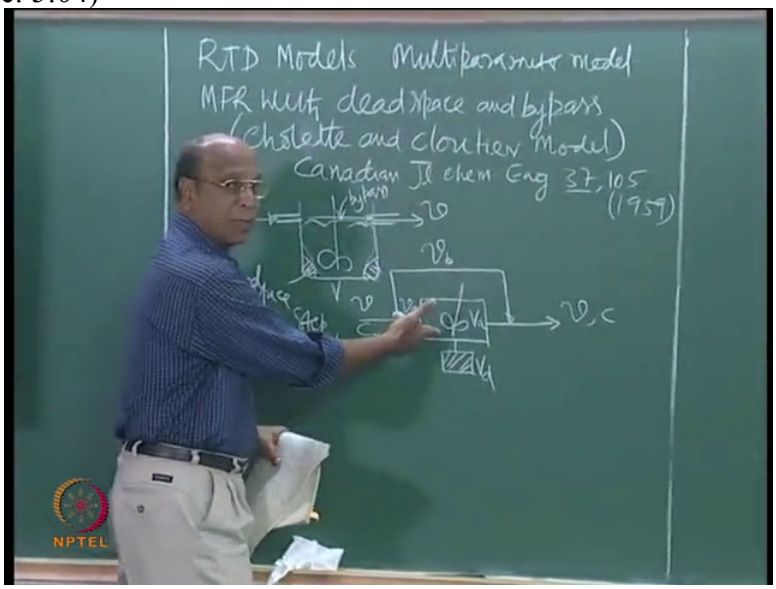

Like for example this is active zone you have only perfect mixing here.

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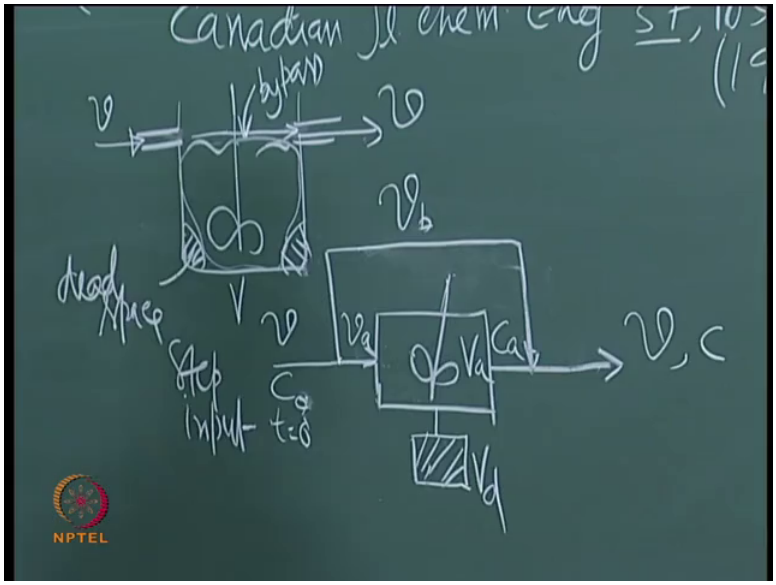

What is the flow rate entering va, no I have va into Cnot because it is a tracer input, right? And then here it is coming Va and Ca, that is coming out, right?

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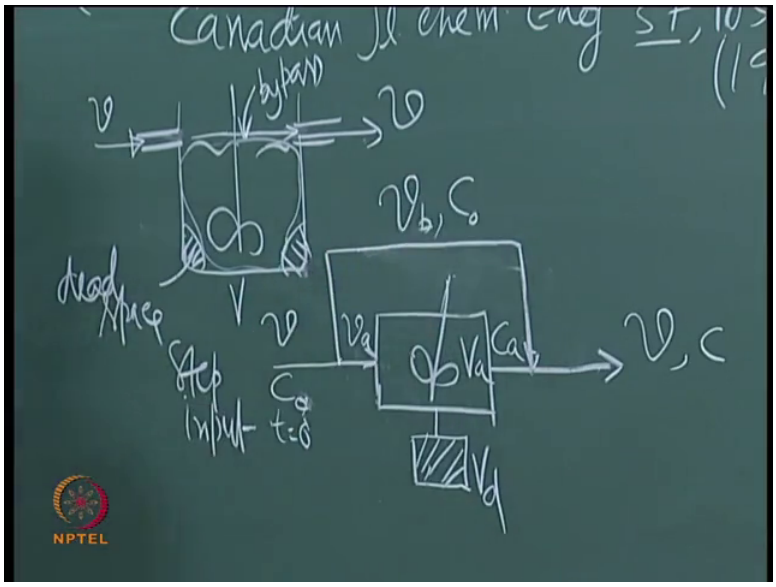

And I have the bypass now Vb and what is the concentration here, C not, very good, right? Because I think you know it is practically not spending anytime inside the reactor, so that we will have. Now these 2 mixing with this Ca and volumetric flow rate Va.

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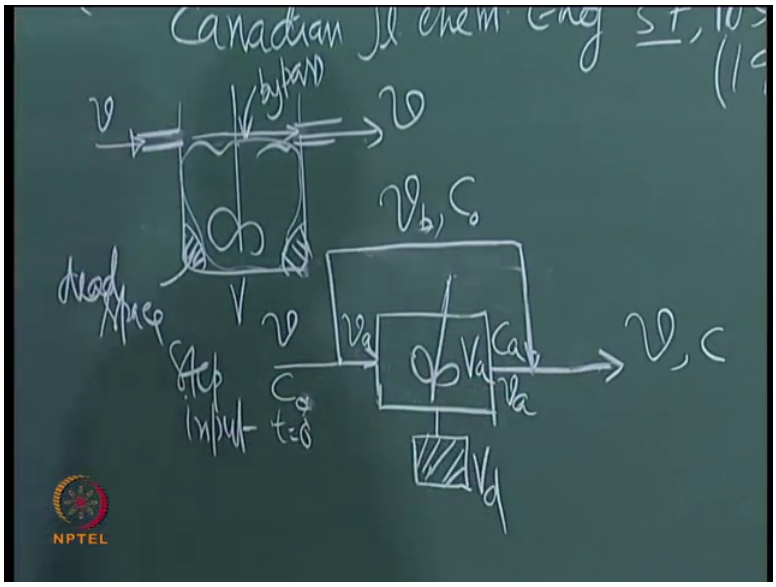

Here also volumetric flow rate same thing Va because we are talking about constant hd systems, right? Va entering, Va coming out there is no volume expansion or anything. So ther Vb and with Cnot, so now this Va, Ca, Vb, Cnot together will give me V into Ca that is what I see, right?

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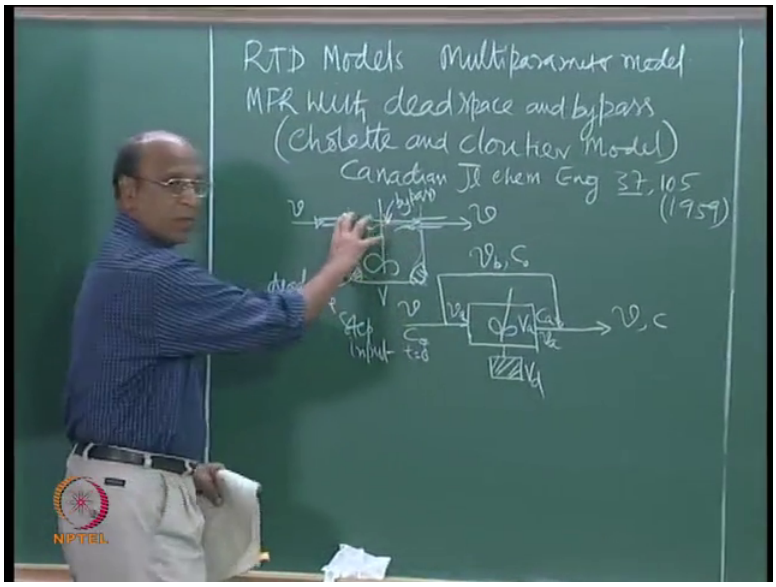

But these are all black box, in fact this entire thing is this. What I put here is C not and what I get here is C that is what I know. Because it is not very ideal that means you know the response is not C is exponentially decreasing with time then I have to imagine now what could be the reason? The reasons may be dead space whenever you have perfect mixing we also listed out what are the possible non-idealities, okay.

Whenever we have plug flow, we have also seen what are the possible non-ideal parameters, okay. So for plug flow what are the non-ideal parameters? Channelling, actual mixing should not be there. Actual mixing must be 0 ideally, yes. Radial non uniformity because actually we expect for ideal system, the radial mixing equal to infinity that is not there then you also may have dead space.

Dead space particularly in the corners when (())(6:47), right? Normally simple tubular reactor you may not have dead space, it is also not good to unnecessarily put the parameter which is no physically existing. Like you know, if you take normal tubular reactor without any packing then you have normal diameters what you choose, I told you know 4 inches, okay. Occasionally we take 6 inches is really large, right?

So then in 6 inches and also what is the length? Length will be sometimes you know 100 meters, 200meters, 500 meters also, okay. So that is why you put like this, like this, like this, right? So this flow disturbance we are not talking. When you assume ideal plug flow when

you have the same diameter normally we never expect dead space in this category but whereas you have to have a packet bath.

Packet bath diameter will be 1 meter, okay, 2feet or 3feet or 4 feet or 5 feet, right? Sometimes very big means even it may be 2 meters 6 feet. So now for that 6 feet you do not normally put either you put a conical feet that will again eliminate dead space or otherwise you put flat like this.

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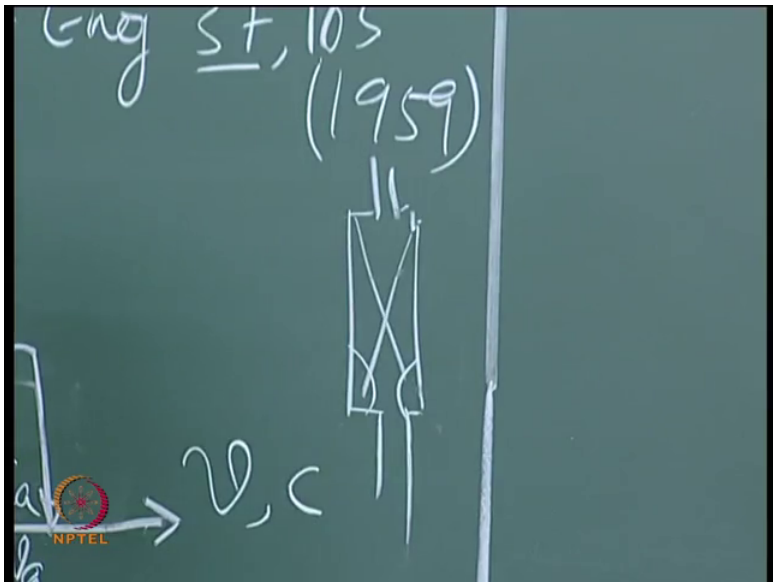

Okay, like this flat and then that is the feet, so all this is packet bath. So again it is coming like this. So this area, this volume, this volume maybe acting as, okay. And on top of it, if you loosely pack the packing then you may also have channelling like this, bypassing is the word which we use practically when it is not spending any time inside the reactor whereas channelling it will spend some time.

And particularly when you have packet bath our tubular reactor, very lengthy tubular reactor or maybe short tubular reactor definitely that stream will spend some time, that is why we say it is channelling and short circuiting also sometimes used I think loosely for both, right? The correct word for short circuiting again is bypassing only because it is short circuit it is not going the way it is supposed to go at all.

So that is why some books may use short circuiting, some books may use by pass, some

books may use channelling. What you have to understand conceptually is that channeling means you will have that stream spending sometime in the reactor whereas by passing on short circuiting means practically 0, I mean that too when compared to your mean residence times, okay.

If mean residence time is, let us say 10 minutes and where it is spending only 1 second inside the reactor then that we call it as bypassing, so like that, okay. Whereas in the packet bath, when you have 10 minutes at least 3-4 minutes it may spend in the channelling, yes in the reactor, okay that we call it as channelling. So that is why we have to remember that, yes. So all this phenomena we have to put now in this diagram and then we have to now write the equations for this.

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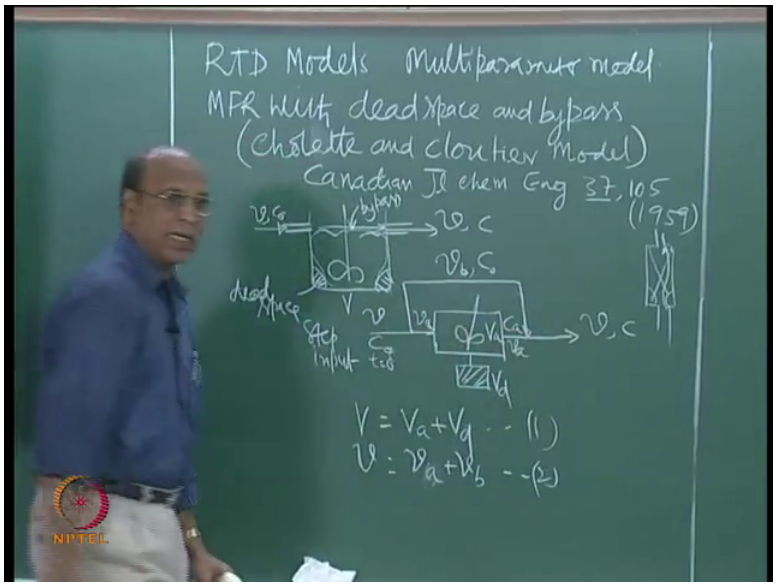

And we know we have already 1 or 2 equations here, capital V is split into Va plus Vb, so this is equation 1 I will say Vd, okay and small v is aplit into Va plus Vb, Vb is bypass and Va is active that is number 2, okay. So now, yes, now I have to write the material balance for this particular active zone, right? So here again we have tracer input after some time t and tracer output and accumulation and reaction, right?

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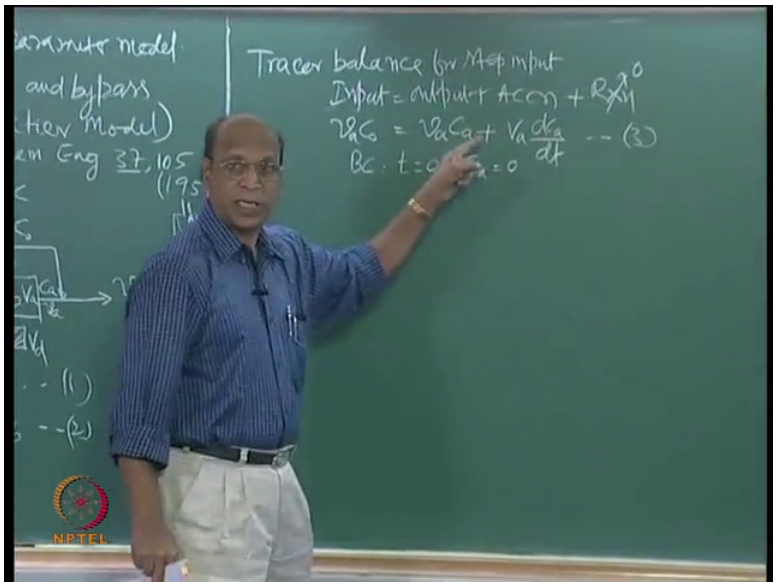

So in reaction we are writing only for tracer balance, yes reaction is 0. Okay, let me write again once more input, output plus accumulation plus the reaction, okay. So reaction equal to 0 and these things you already know, what is input Va into C not? Because we are giving step input, okay. Tracer balance for step input, step input is C not, okay good. So now next one is Va into Ca plus accumulation is?

(Conversation between Professor-student starts)

Student: Vd Ca by Va.

Professor: We are writing only for this active zone. So Va dca by dt, so this is the equation, this is equation 3 and what is the boundary condition for this?

(Conversation between Professor-student ends)

You will have t equal to 0 and Ca equal to 0 that is Bc, not same. See initial condition, we are writing but the equation is a tracer balance, right? A time t equal to 0 and also this equation gives me the response in the outlet. So what is the outlet concentration at time t equal to 0? Okay, so that is what. Do not get confused with the inlet thing, okay, good, so that is what.

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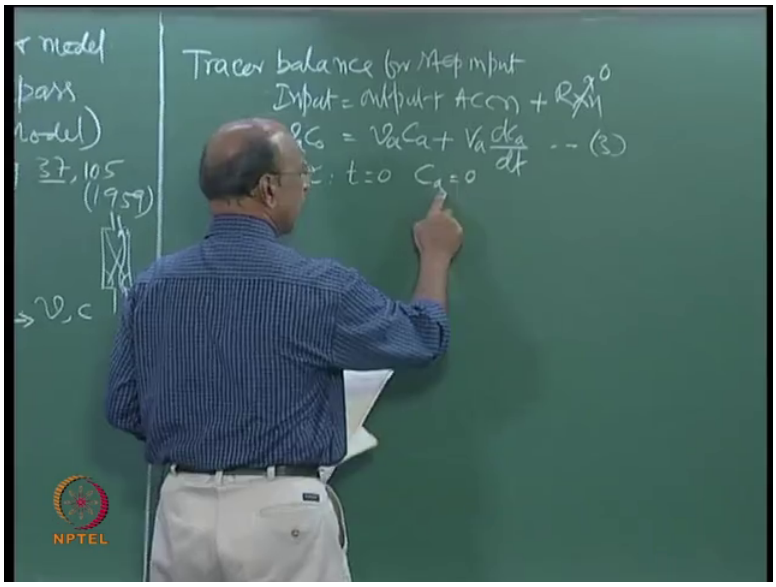

So here I have Ca equal to 0, right? Yes, so now when I solve this, already we have this solution this is Ca by C not equal to 1 minus e power minus t by t bar, no? So here t and that t bar will be Va by va, capital Va by small va that is t bar a if you want, right? Correct, no? Yes, so I have written that Va by va as it is t bar a, right? Okay, yes good.

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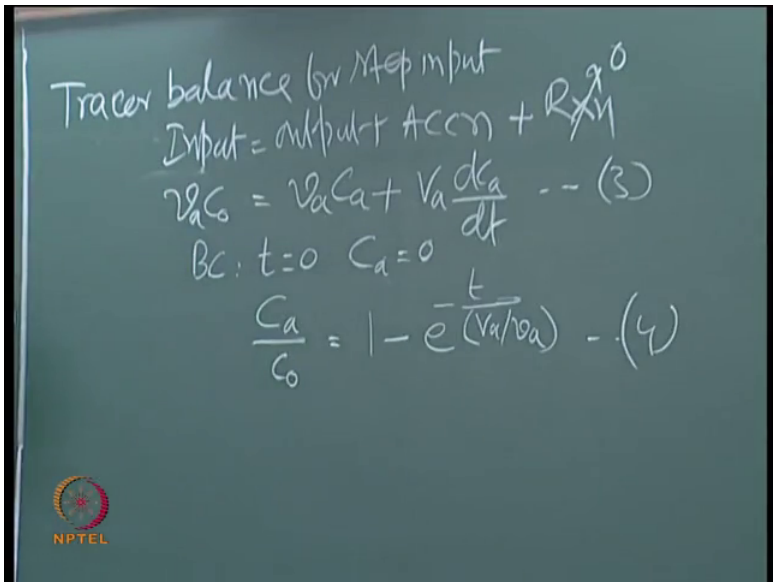

So this equation is equation 4. So now this equation is no use for me, this equation is no use, why? Because this is in terms of variables which I cannot measure this is my imagination.

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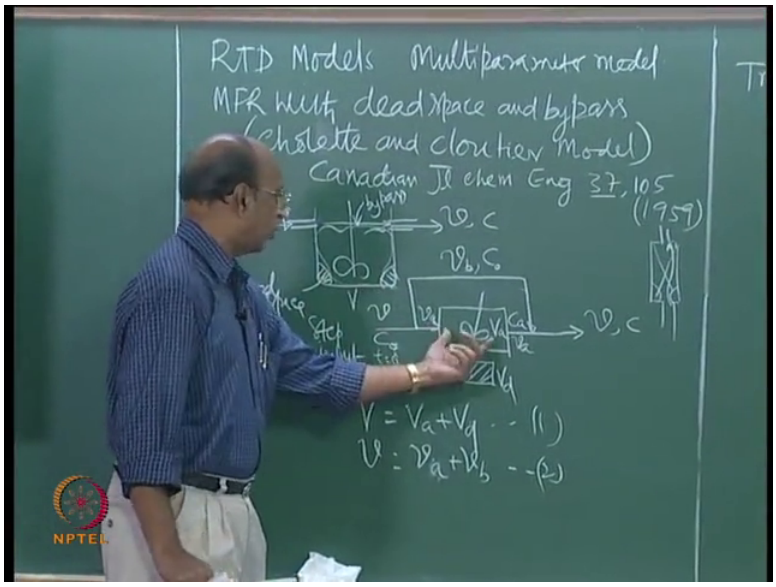

My imagination is that you in this one I have an active zone where through the active zone va is going and also va is coming out and that will have Ca after perfectly mix. All that is my imagination but what I measure is only v into C not, V into c. So now that equation has to be converted into C by C not which is ft because we are writing for step input. So what I do, that means I have to eliminate Ca and we have to also eliminate this capital Va and small va, right?

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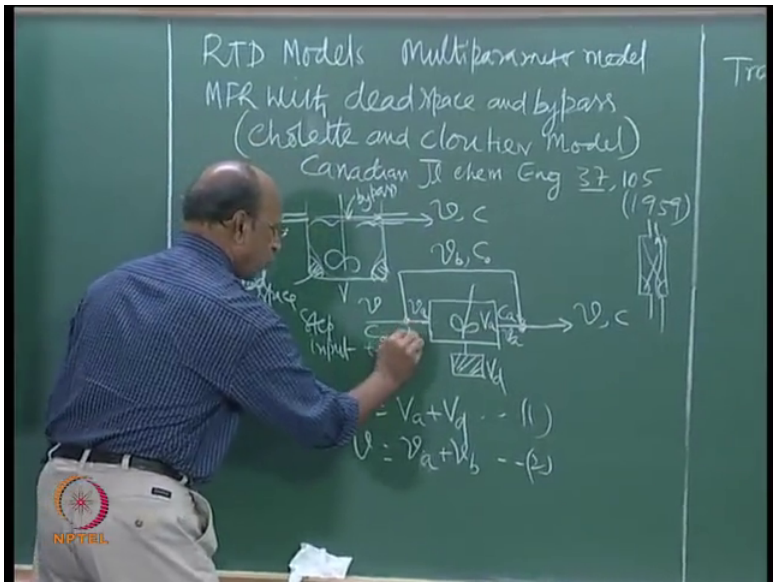

So for that we have another balance here, okay. So if I take this one as L and this one as k point.

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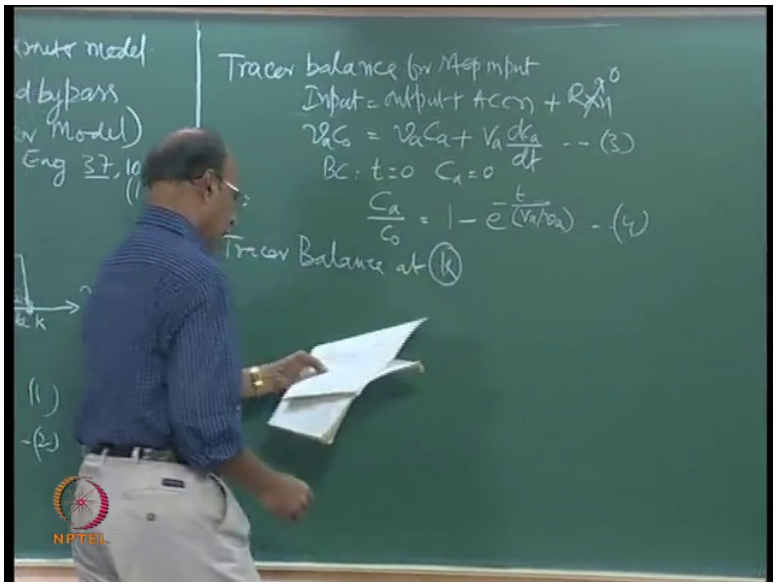

So balance at k, tracer balance, okay. Tracer balance at k, yes anyone can tell that.

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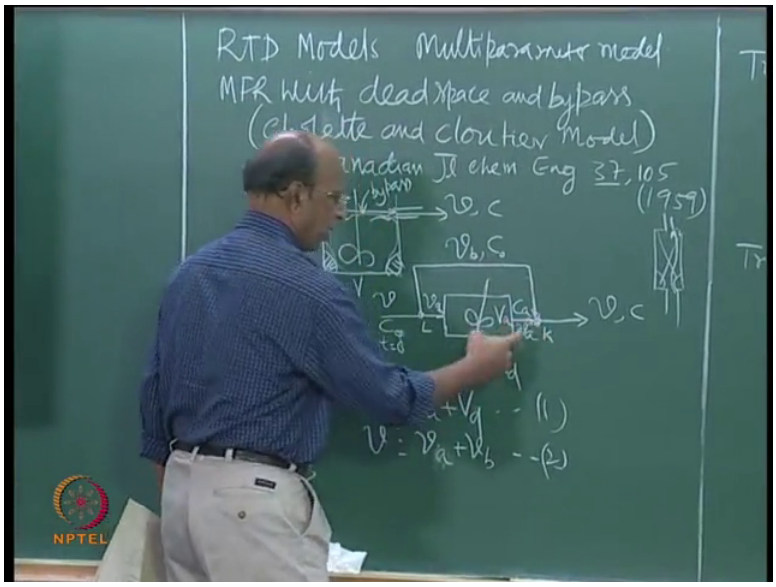

Yes this is, no 2 (())(14:03) are coming, yes Va Ca and vb, C not.

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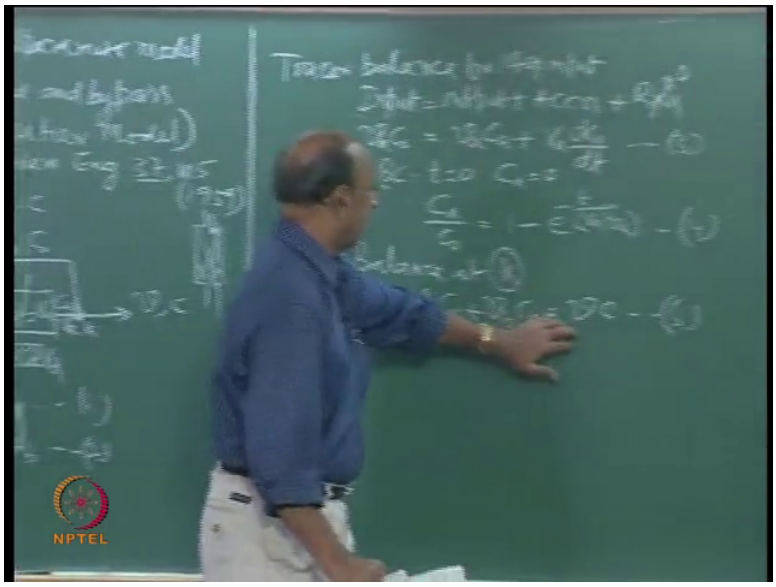

Va Ca plus vb Cnot equal to vc, so this is equation 5. Correct, no? V into c only, right? Yes, okay so using this equation we should be able to eliminate that particular one, sorry?

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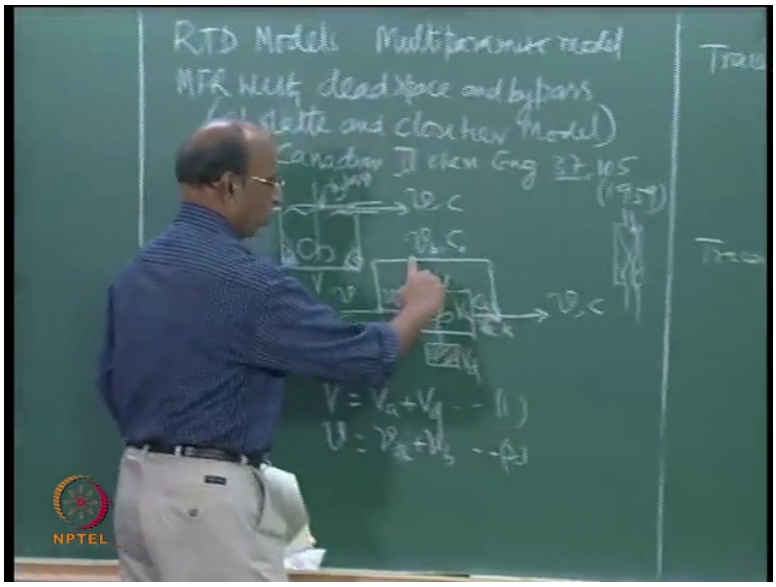

This stream V not, see it is again grams per second only, mass (())(14:41) we are talking, vb, C not is coming here and Va Ca is coming here together which gives me V into C, Pooja, correct no? Yes.

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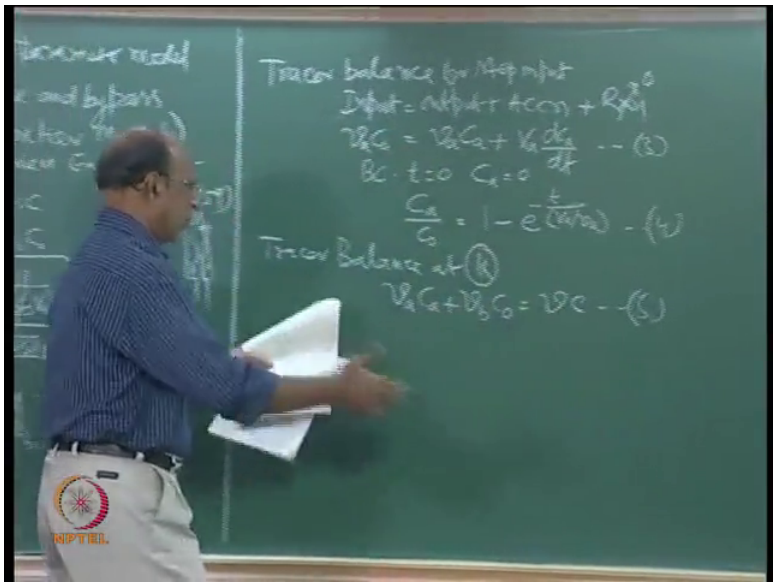

Okay so now this one and now we have to write this equation in such a way that all those things are eliminated.

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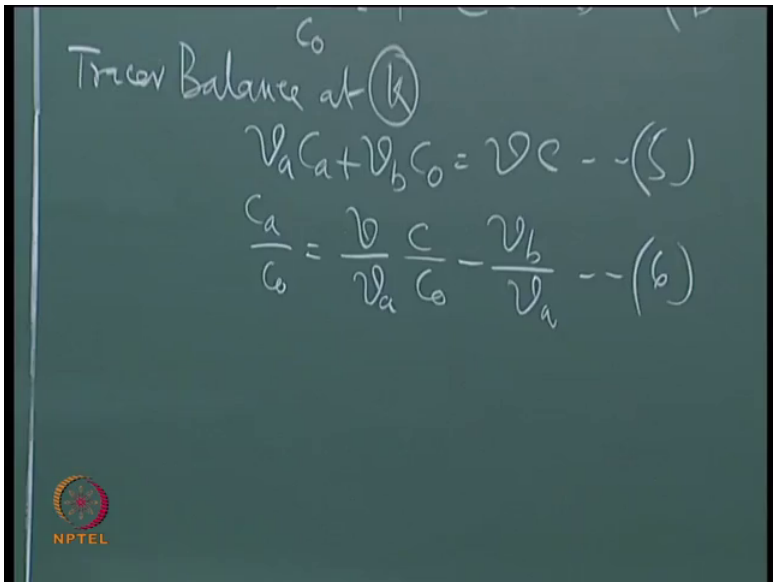

The first one what you can write there is, Ca by Ca not, I am not giving the mathematical details you have to just find out that. This is v by va, c by c not minus vb by va all small vs. So this is equation 6. Okay, can you get on this? Simply divided by C not and then you will get that, okay and also arrange, right? So, why I have done this one?

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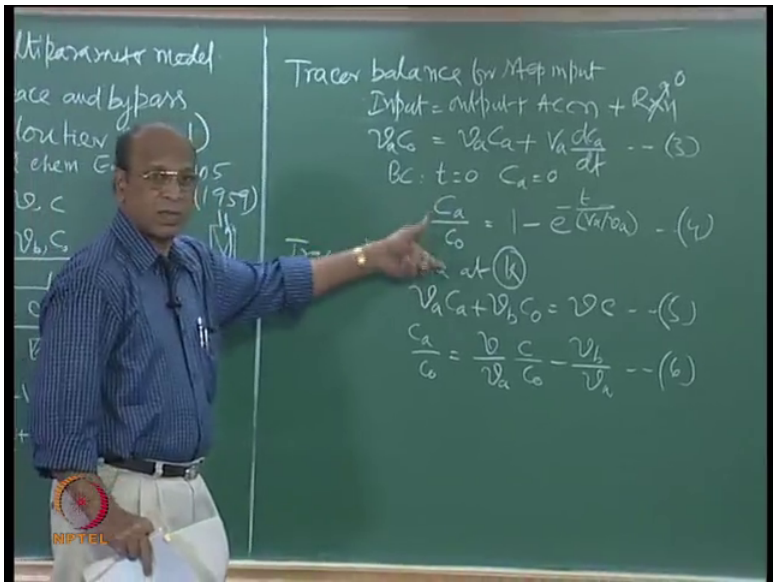

Because I have here Ca by Ca not, this first I have to eliminate, right? This Ca by Ca not is, yes one if I eliminate, if I write this equation in terms of this then I have C by C not, okay, yes. So now substituting equation 6 in 4 and rearranging you write that there are few steps in between I think you know you have to do that. …

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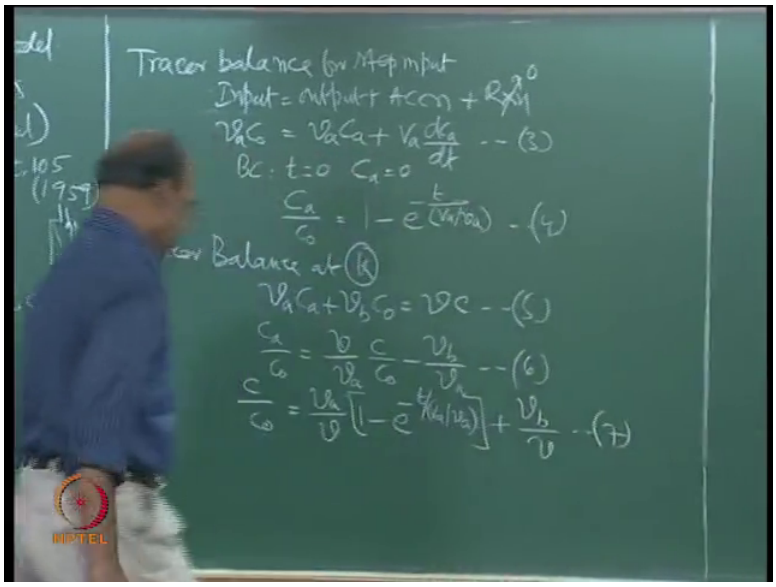

Substituting equation 6 in 4 and rearranging what you get is C by Cnot equal to va by capital V, 1 minus e power minus t by this is t bar a, so that is Va by Va that I put the bracket, right? So this whole thing is plus Vb by capital V. So this is equation 7.

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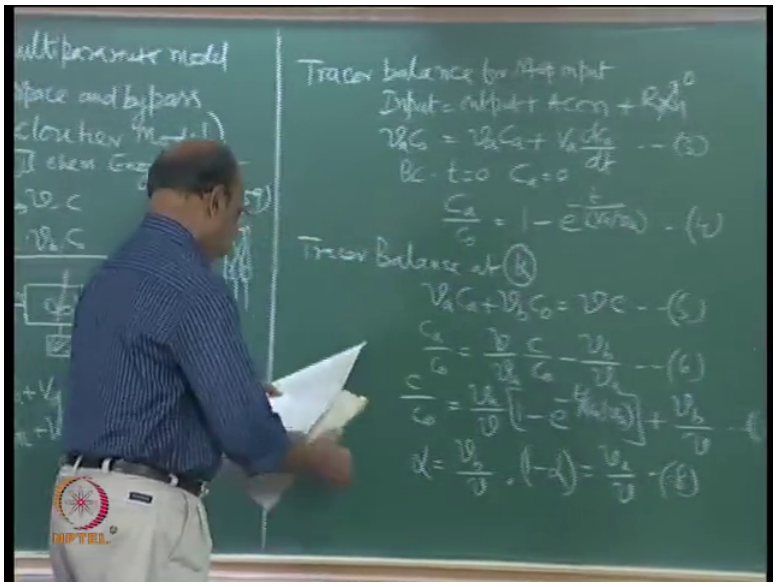

Actually this is sufficient for me but to have slightly more meaningful parameters, let me define alpha as Vb by v, what is the meaning of this? So 1 minus alpha will be naturally Va by V, yes.

(Conversation between Professor-student starts)

Professor: Abhishek you are telling something.

Student: Percentage is by pass.

Professor: Yes fraction of bypass, okay

.

(Conversation between Professor-student ends)

So if Vb by v equal to 0.1 then I can say that I have 10 percent bypass. So alpha equlat to 0.1 is 10 percent bypass. The reaming one is which is going through active zone. So this one is equation 8.

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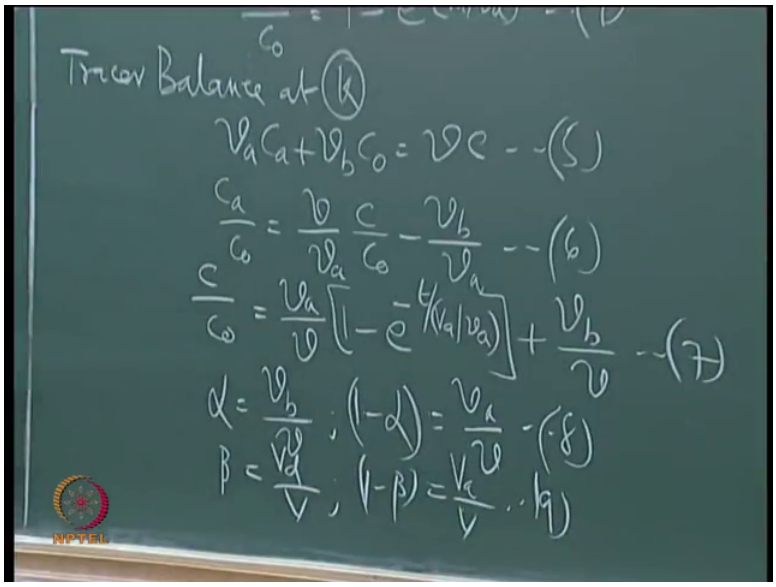

So similarly I can also define another one beta dead space which is Vd, capital V by capital V. This again gives me, if beta equal to 0.1, I will say that I have 10 percent dead space. So out of 10 litres 1 litre is the dead space that is what is the meaning of that. Okay, so 1 minus beta will be active zone. So this is capital Va by capital V. So this is equation 9.

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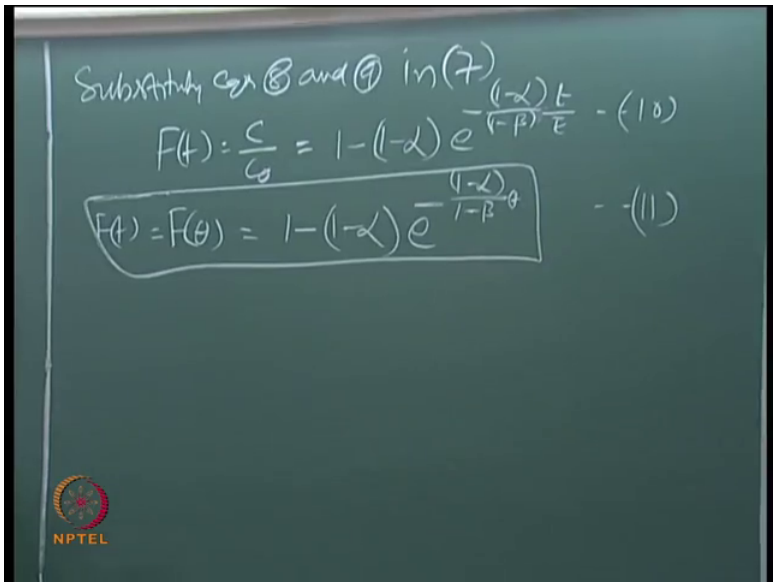

Good, so if you substitute these things and also we know that it is ft, so substituting equations 8 and 9 in 7, okay. Then what we get is Ft equal to C by C not, yes, so we have 1 minus 1 minus alpha e power minus 1 minus alpha by 1 minus beta into you will get t by t bar, okay. That is all, yes. Or I can also write Ft equal to F theta, let me also write Ft equal to F theta only thing I have to write here is, this is 1 minus 1 minus alpha e power minus 1 minus alpha 1 minus beta theta, so that is the equation. This is the equation for F theta in terms of theta.

Good, so this is equation number 9, this is 10, this is 11, good, okay.

(Conversation between Professor-student starts)

Professor: So, yes now what is the idea? Idea means you know, why did we derive this first of all?

Student: Laughs.

Professor: I have to ask that question I say; always I have to bring you to the basic question. Why are we doing all this? Because sometimes you may forget, correct no? What Simi?

Simi: Because...

Professor: Why we have to do all this?

Student: That is the conversion...

Professor: You may be thinking that okay, sir it is coming in the examination that is why we have to come here because you asked us to come.

Student: Conversion.

Student: Options in non-idealities.

Professor: Abdul?

Student: To quantify the non-idealities.

Professor: Yes. To actually quantify the non-idealities in a real Cstr where we expect some kind of dead space and...

Student: Bypass.

Student: Bypass.

Student: Bypass.

Professor: By pass, okay that is the idea.

(Conversation between Professor-student ends)

Now how do I use this equation to do that? Because now this is the model for me, right? RTD models we have written no, like we understood everything clearly. Okay that is RTD models that is a model now for Cstr with dead space and bypass, okay. Now what do I do with this model?

(Conversation between Professor-student starts)

Student: That alpha and beta...

Professor: Who has the loudest voice I am hearing? Okay, Rahul tell me.

Rahul: Do the tracer test and get the alpha beta value and make that alpha beta value...

Professor: Simply doing the tracer test it gives alpha beta values.

Rahul: No, fit the data...

Professor: Yes, How do I fit that?

Rahul: I do not know.

Student: Laughs

Professor: No. That can be a universal answer for anything whatever I ask go to Matlab. Are you going to eat lunch? Yes sir Matlab, so now for everything Matlab. Okay anyway, correct, yes.

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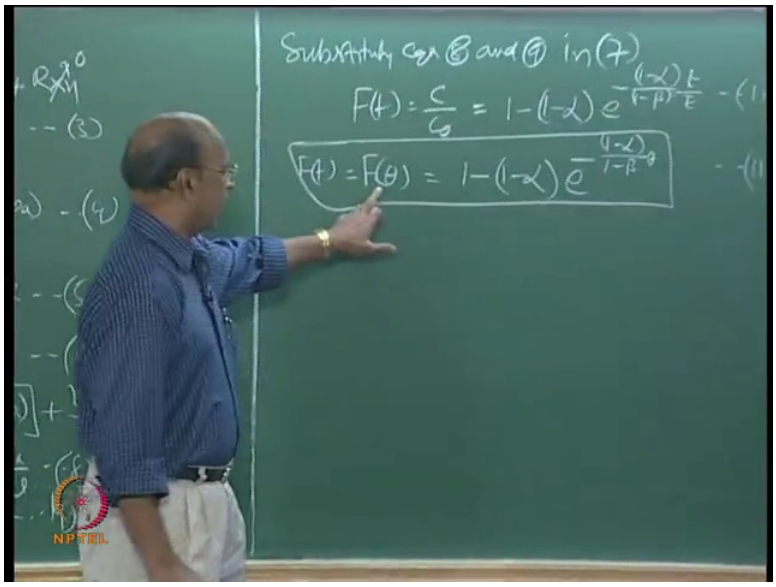

See again as you said I can feed F theta and also I can give a guess value of alpha and guess value of beta and then try to match, right? But there are other simple methods also which you can do, mad lab is not the ultimate, right? So before going to mad lab if you want to have that I am telling you know, all the time feel, feel that feel should come first for the subject. Unless you have that feel you will never enjoy otherwise it is just ritual.

Ritual no one will enjoy, right? You know that, no one will enjoy the ritual that is why it is called ritual in fact, okay. So that means it is the repeated mechanical, so that is why if you go to Matlab every time you will not have any feel because you do not what is happening inside the Matlab, right?

You cannot go and see that and only thing is you may be imagining this may be happening, this may be, by the time you think answer is there. Okay that is why afterwards you do not think also. That is why before going to mad labs if you are doing some exercise it will be very very good. In this case particularly when you have one parameter and 2 parameters you can always graphically do that and then get the actual parameters.

Yes, the values you do not have to go again fit and guess and all that. I think unnecessarily it is wasting of power and all that, correct no? Computer, power and India does not have any power at all, throughout the country I think we have only power cuts, power cuts, power cuts luckily in IIT we are not facing that, outside it is hell, correct no?

(Conversation between Professor-student starts)

Professor: How many hours you have power cuts? 2 hours is very small, okay. Yes in Andhra they give only power for 2 hours, here cut is 2 hours, okay. Not only in Andhra many states may be Kerala may be self sufficient, no?

Student: 1 hour.

Professor: You also have. May be Gujarat I think that is all.

Student: Yes Gujarat.

Professor: People say Gujarat may be self sufficient. Even in Delhi you have power cuts and all that. So why unnecessarily wasting by going to...

When you can do it very simply, right? How do I plot this to get the...

You see always whenever you have the equation that is what I do not know whether you got the real meaning of 3rd chapter in(())(23:40).

Student: (())(23:43)

Professor: See, someone has to tell or you yourself should be able to imagine that, okay. 3rd chapter of a (())(23:48) sphere, if you now go back and then see, right? Every equation you will try to arrange that as a...

Student: Straight line.

Professor: Why? Because straight lines are very easy to understand and also you know to see whether it is really falling in a straight line or not, right? And then from slope and intercept you should be able to get whatever you are supposed to get, right? So anyway for that you need only 2 parameters.

If you have 3 parameters I think we cannot unless you put another parameter constant and then you can do, okay for various things, good.

(Conversation between Professor-student ends)

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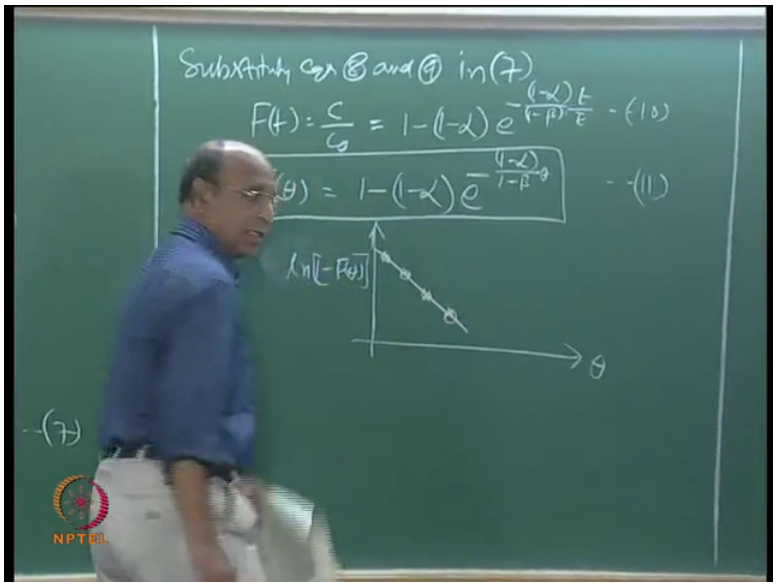

So that way we can actually plot this as 1 minus F theta lawn, okay.

(Conversation between Professor-student starts)

Professor: Plotting first, yes, (())(24:35) 1 minus F theta versus theta. What will happen to this, Rahul? If I plot like that.

Student: Negative slope.

Professor: Will I get a straight line?

Student: Yes.

Student: Sir you will get a straight line.

Student: Yes sir.

Professor: Yes because I will simply bring this 1 minus here or 1 minus F theta I will take this side this one I will bring. So then this will be, you will get as slope on intercept, okay. I think if you do like this you will get very good straight line because first drawing the line putting the points later, okay.

Normally in the lab we have to do the reverse, please do not do this, okay. First you have to take the data put the points if it is straight only joint a straight line, okay. If it is (())(25:22) do not try to join a straight line because there may be something wrong what you have done but I came to know that in our department also I think few people are there who are putting first line and even earlier (())(25:32) draw the line and put the points and then take those points and put in the notebook.

Show it to the (())(25:39), wonderful experiment. Yes it will be wonderful, whenever you first draw the line because something noble prize information you will be missing, if you are not really...

Really true I say. So there may be noble prize information you may be missing, yes. Unless you really collect the data and then see and number of times if you do and then if you are not able to explain some phenomena experimentally what you observe then that is equal to noble prize only because if you are able to explain that this is what is happening. Now I can tell you when he was taught heating water.

You put the heater and then switch it on the electricity, now imagine that it is slowly temperature is decreasing that is what the noble prize. Yes why it is decreasing? It is supposed to increase, correct no? Then you have to give the proper explanation because of this reason it is decreasing, you try to prove that. Really I think you know then you will have the...

Or you can do simplest thing 1 plus 1 equal to 5 (())(26:43) you will get a noble prize. If you are really able to prove, so that is why I think those people who are doing experiments they never try to cheat, we should never try to cheat because there may be real, I am not really joking now but there may be wonderful information which you may be missing you just have to force it.

Even though it is not a straight line, you imagine it must be a straight line and then just draw the line. There may be a clear trend that it may be going like this and you say that, okay draw the line from here horizontally and for that excel is best there is a linear option, one point in Adyar, another point in Pallikaranai, another point in Saidapet still it joints as a straight line, okay.

Because I think, you know excel, so I think that is the best option if you want to do but do not force that. I think, you know Adyar, Pallikaranai, Saidapet it is a curve like this it goes, okay. That you are trying to force as a straight line noble prize goes there, okay.

(Conversation between Professor-student ends)

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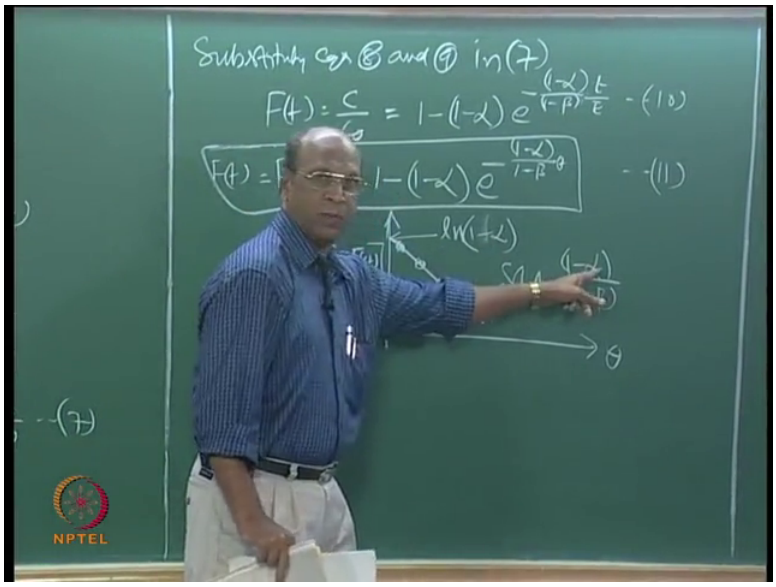

So this one what is the intercept? (())(27:50) of 1 minus alpha and what is the slope? Yes, this negative only 1 minus alpha by 1 minus beta. So first you go to, first read this line and get alpha and get the slope alpha already I know and then you can calculate beta, right? So that is the one and we can also show this, okay.

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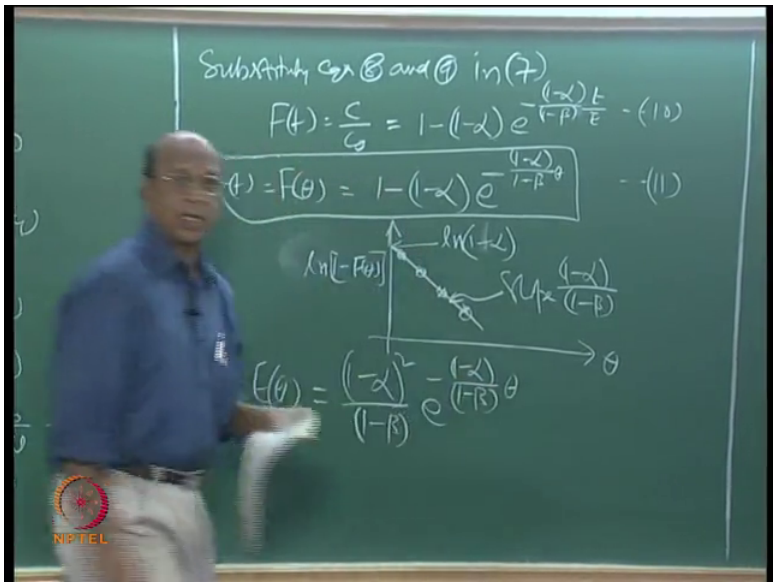

We can also derive and E theta, yes that also you can do but I think there is another important information d by d theta cannot give you exactly but you have to have that physical feel and then do it. 1 minus Alpha Square by 1 minus beta e power minus 1 minus alpha by 1 minus beta theta, okay. There is another nice information there, something else that something else is plus alpha delta theta equal to 0. What is the meaning of this?

(Conversation between Professor-student starts)

Professor: Abhishek, what is the meaning of that?

Student: That is because when bypass...

Professor: Rahul is not Abhishek, Abhishek is not Rahul, okay yes, unless we say that sir I am now substituting for Abhishek, you are substituting can you think of that? Yes, Rahul tell me.

Rahul: That is because of the bypass, by pass will come after only like that C not will cone immediately.

Professor: Come before.

Rahul: Will come immediately.

Professor: After what? You said bypass comes after something.

Rahul: Yes sir.

Professor: Where?

Rahul: Some certain time.

Professor: Where is time there? What is delta theta equal to 0?

Student: Immediately.

Professor: Yes, direct delta function is there, when that direct delta function is valid, so that is why again you know always I will bring to you that earlier thing, so that you remember number of times it is only grinding, grinding, grinding, okay. It is a mixture only that is why I know that none of you would have not (())(30:08) .

So delta theta minus theta equal to 0, so that means that bypass because it is not, what is our definition of bypass? It is not spending anytime practically 0 type, so the moment it goes to the bypass it appears in the outlet, correct no? It appears in the outlet, right?

(Conversation between Professor-student ends)

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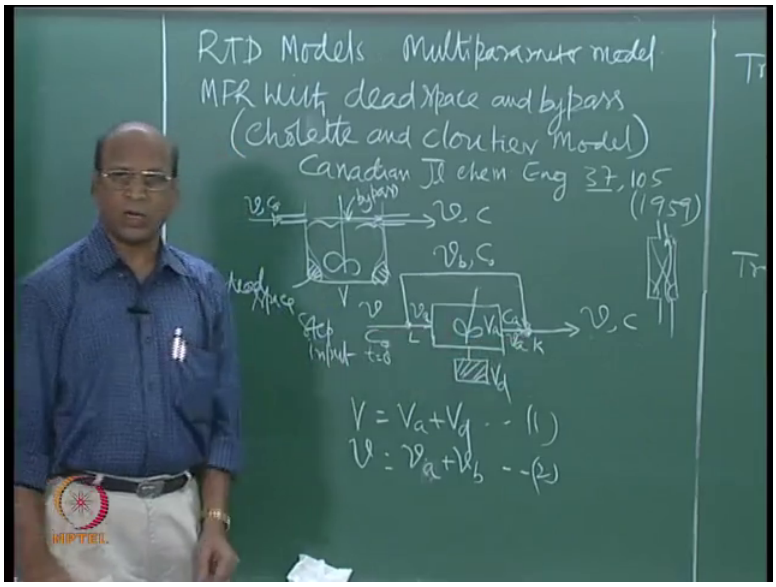

So that is why what is the time taken by this stream to come to the outlet 0 that is what our assumption bypass, right? But in reality it may not be but our definition of bypass is that, right? I mean definitely it will take some time, right? So that is why this fraction and how much is that? That is alpha.

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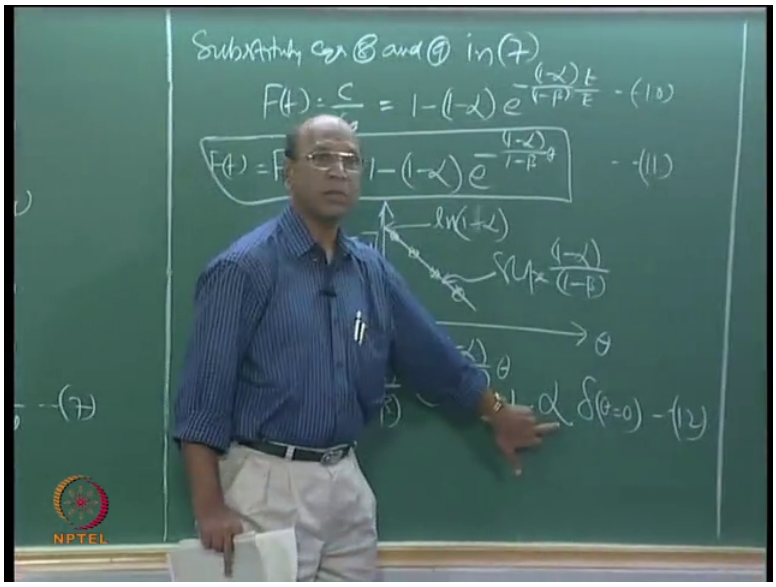

(Conversation between Professor-student starts)

Professor: What is Alpha?

Student: Fraction of the bypass.

Professor: So that much amount of tracer will come if you take the area under the curve as one, okay. Area under the curve as one, so this will be let us say Alpha equals to 0.1, so that 0.1 area as direct delta function will come at time theta equal to 0 that means instantaneously it is coming, right?

And that is getting mixed in the outlet and then coming out that actually you cannot see, right? But if you are able to plot that E theta, what kind of curve you get?

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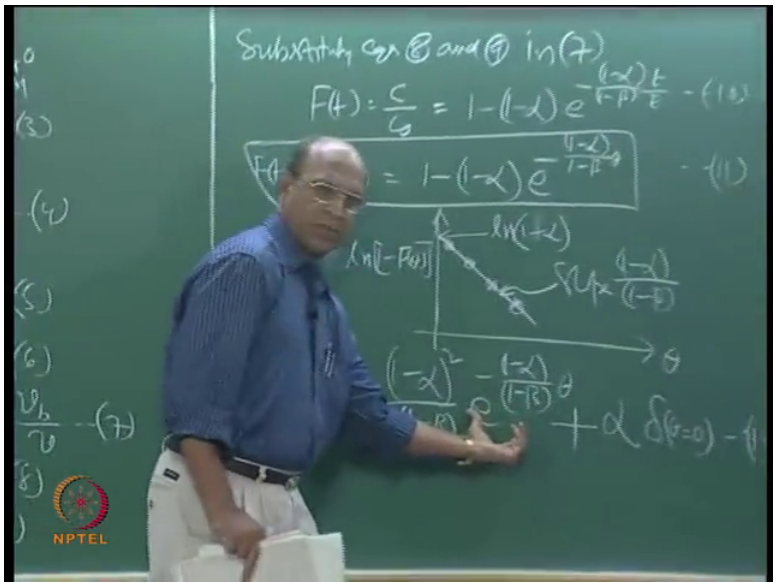

This is exponential decay, there is some constant here that is okay, yes.

Student: 1 minus...

Professor: So that means it may not stop at theta equal to 0 means this is 1 and this will be the 1 that is starting point, correct no? At theta equal to 0 then this will become 1 and that, okay.

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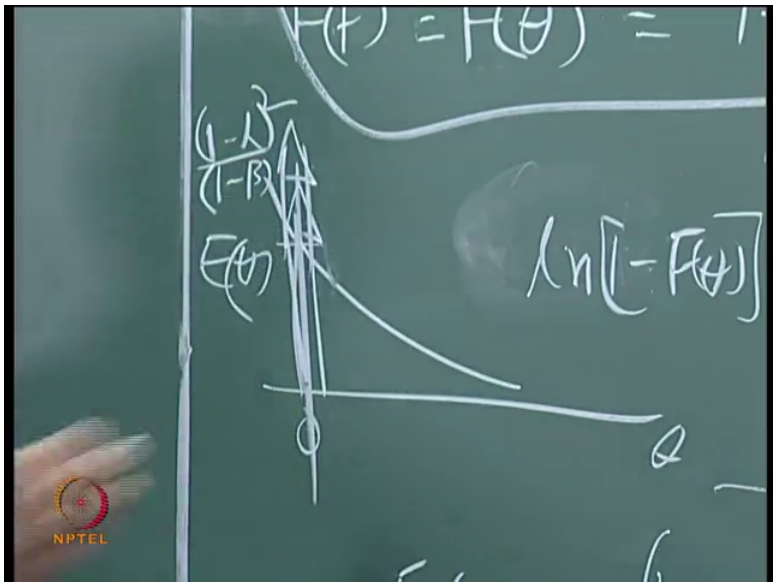

Let me plot that E theta, theta, right? So this will be somewhere here what is that value? 1 minus alpha square by, correct no? If theta equal to 0, this is 0, okay. So then it is exponential decay and anyway there is a constant, yes again here 1 minus alpha beta or 1 minus alpha by 1 minus beta. So it is going like this, right?

Okay, now what is the other portion, where do I see that? That is all, so you will get a...

Student: sudden down.

Professor: Not sudden down, a peak.

Student: And then it comes...

Professor: And then it comes, suddenly it starts here, okay and that depends on the area, you know, yes. And then from then onwards it drops out, okay. So that is how you have to plot that.

Actually I do not know whether you still remember or not you just see what is the curve we have plotted with bypass or mixture flow? Only yesterday we discussed it. Yesterday or day before yesterday?

Student: Monday.

Professor: Yes. Peak sudden and then it is coming exponential decay, correct no? You have drawn that. Sudden peak and then slowly comes out, so that is what is that. There we have not shown exact direct delta function there we have shown sudden peak like that and then slowly coming out, okay. Good, excellent, okay.

Okay, this is nice, so I will ask Pooja a very simple question. Pooja when alpha 0 beta 0, what is the equation for E theta?
Pooja: E theta minus...

Professor: E4 minus theta, very good and for F theta? I mean what is this E4 minus theta?

Student: Ideal mixture...

Professor: Ideal mixture, okay. For F theta alpha 0 beta 0?

Student: Sir 1 minus beta and...

Professor: That is what is the equation for ideal. yes for ideal mixture.

(Conversation between Professor-student ends)

Okay, so now the next one is how to develop a reactor model with bypass and dead space. Okay reactor model with bypass and dead space, so that is what is the next one, okay. Understood, no? The sequence you understood that is why you now approach to the subject.

I think in the last RTD models what we have done is, first RTD estimate non-idealities, okay, amount of actual mixing or amount of dead space, amount of channelling. Now you cannot do anything with that because you are not able to correct that then use that information and calculate what is the real conversion? And as said if there is a possibility of converting and improving real conversion will be less, right?

Ideal conversion 90 percent with this alpha beta values you may get only 65 either you live

with that or you go to the system again and then try to convert increase the stirrer, okay. Increase the speed of stirrer or change the stirrer you will get dead space almost 0, okay and see the position of inlet and outlet, if they are in correct position without much bypassing correct it, okay.

Such that there is no bypassing then you will get an ideal reactor, right? So once you get an ideal reactor again you have to calculate conversion. So that is what is the, with RTD models used for, you know always first estimation of the parameters next using those parameters find out conversion, that's all. I mean at least those things you note down in big letters in your notes I say. Those are the things which you have to remember lifelong even if you are not becoming a chemical engineer later, okay good.

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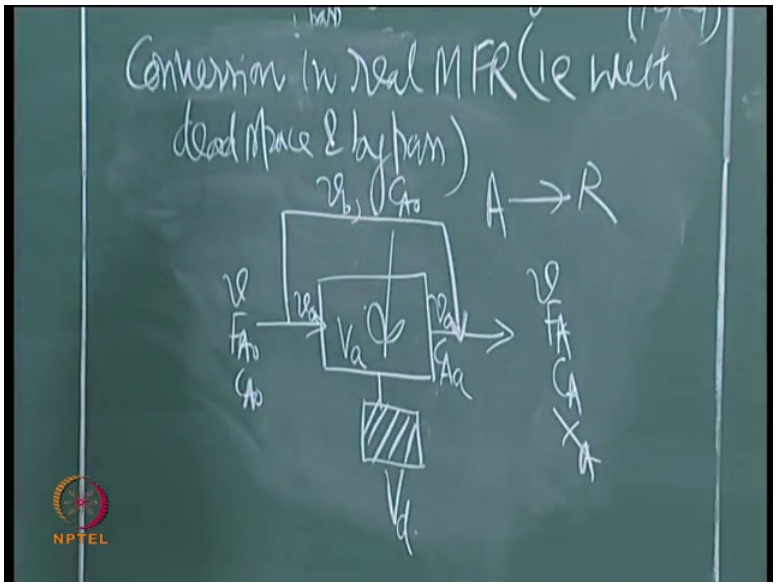

So now conversion in real MFR that is with dead space and by pass, okay good. Again I should have a model here because now I know that I have a reactor with bypass and dead space because I conducted RTD experiments and then estimated those values they are there, they are real now. So that is why we write another same model for reactions now. So here I have stream entering, stream leaving, this is ideal, right? And we have the bypass.

Now when I show this one for reactor, no? Yes, okay let us say that we have the simplest reaction A going to R first order, okay. Constant density because A is going to only R, so this is volumetric flow rate, this is FA not, this is CA not, XA equal to 0. Here I will get this is V FA CA and XA those are the things normally we see but actually here I have dead space this is again Vd, this is Va, this is V is there anyway. So this is small va, this is small vb and here of course those things are right and then what else?

Yes, at this point I have now, yes va and CAa, say capital A is for reactant, small a is for active, okay good, So that is the way. So here I have Vb and what is concentration in this? CA not, okay good.

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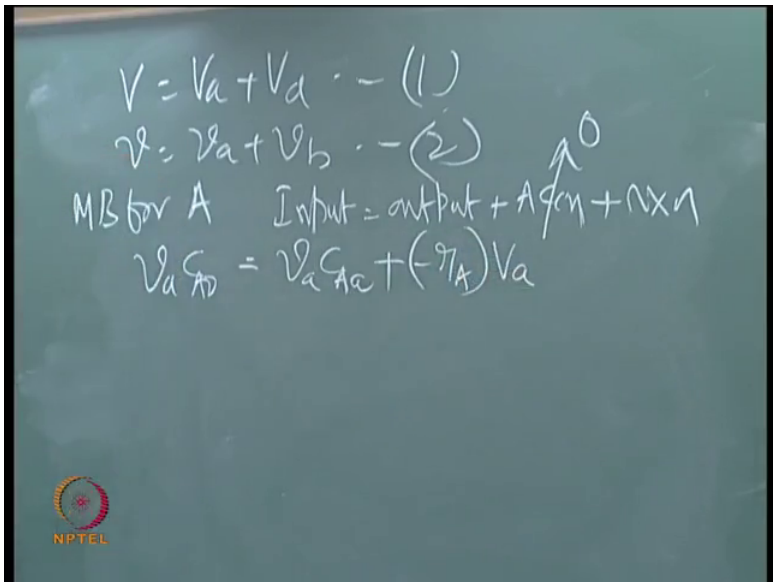

So now what is the procedure first anyway we are going to list out the same, the first thing is capital V equal to Va plus Vd, so that is equation 1. Small v equal to va plus vb that is 2 same thing. So now balance here, balance for the active zone, okay yes. Here also I have CA not, right, no?

(Conversation between Professor-student starts)

Professor: Okay, Pooja what is entering?

Pooja: 30.

Professor: Okay MB for A, capital A reacted, va into CA not equal to that is input, oh! I have to write this, no, okay. Let me write once more I am writing so many times so that you know those who do not want to remember can remember.

Student: Laughs.

Professor: Correct no? So many times if you write neural system automatically accepts that. Accumulation plus reaction, so now accumulation will be 0 reaction because study states, right? Okay, yes, now tell me Pooja va into C not and output?

Pooja: CAA.

Professor: va into CAa, excellent Pooja, once more.

Student: Laughs.

Professor: va into CAa plus...

Pooja: Reaction minus rA.

Professor: Minus rA.

Pooja: Into Va plus Vd, no Va...

Student: V.

Student: V.

Pooja: Va.

Professor: Yes.

Student: Into V.

Pooja: Capital V.

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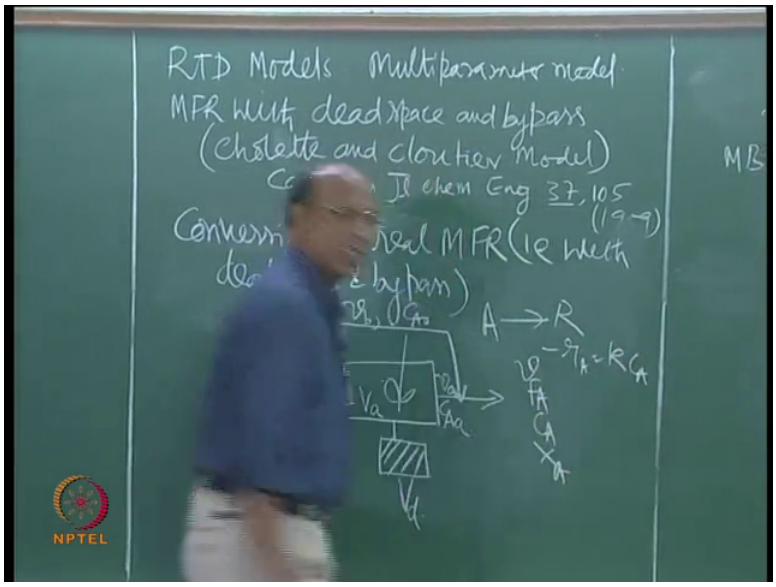

Professor: Right, so when I have this one as minus A going to R as minus rA equal to k into CA for first order reaction. Second order reaction I will ask in the examination. Okay, first order reaction I will take, okay.

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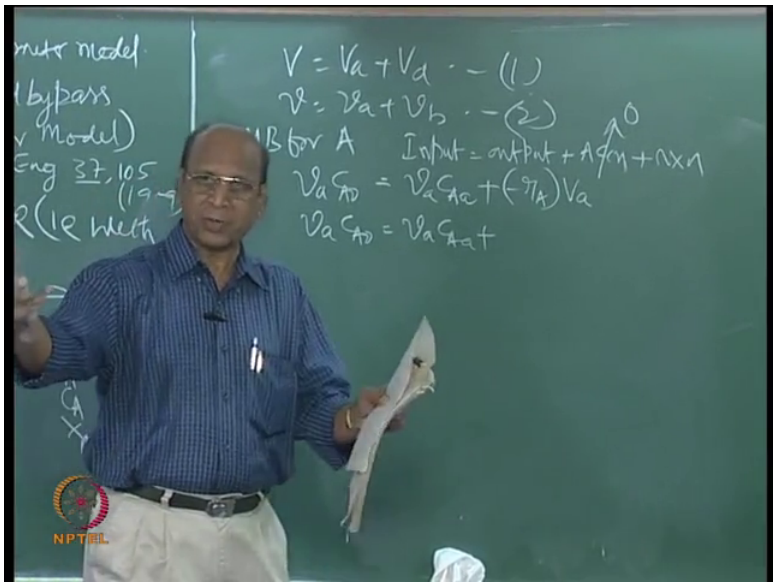

So when I write the next one also, so that will be Va CA not, va CAa, okay, now tell me Pooja minus rA equal to? kCA, no it is not kCA.

Pooja: kCA not.

Student: Laughs.

Professor: You know, kCAa, reaction is here and what is that a?

Student: kCA.

Professor: You said only one A, you have to say twice a, right? kCAa, okay.

Student: She said that.

Professor: She said that?

Student: Yes sir.

Professor: I did not hear.

Student: Yes sir.

Professor: See how many supporters are there for you. No supporter for me, okay. This is kCAA va, so this is equation 3.

Student: Sir?

Professor: Yes.

Student: The, you are not considering the dead zone. The dead zone?

Professor: I think this is happening in dead zone.

Student: There is no reaction.

Student: When it comes slowly from the dead zone...

Professor: That is another one, that you will have 3rd parameter, right? So that is what I want to tell after this is over because dead zone is really dead here, right? But in reality it is not really dead, it is only just alive, okay. A little bit again, so then what happens is, because now you asked me there is an exchange of material between dead zone and...

Student: Active.

Professor: Active zone that is how much is the exchange is another parameter then it becomes 3 parameters, right?

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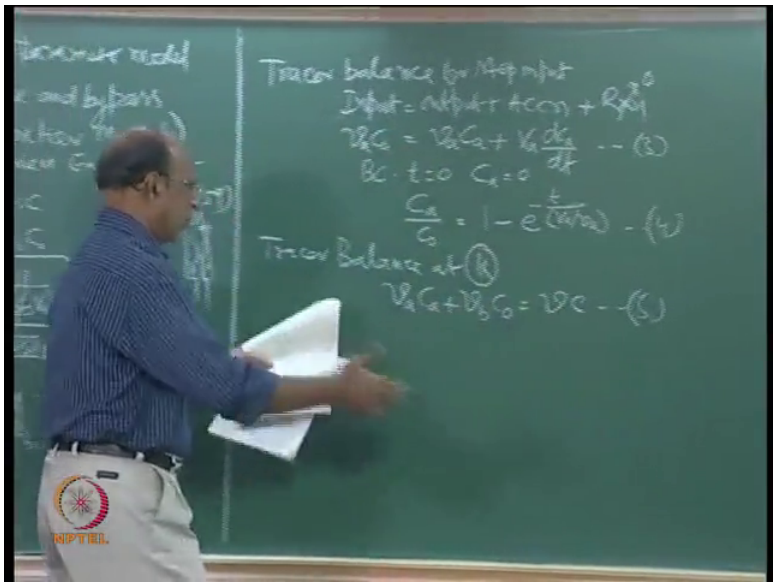

Because now it is dead, so that is why I am interested only in this one, you know active volume and this is dead totally, okay ignore it. So like I have been doing no, there may be some people who do not participate in the class at all from the beginning, from the semester onwards I ignored them dead space, okay. That is equivalent to dead space, if there is a little bit exchange that is another parameter.

How to bring them again to the class, again explain to them all that I am not saying I know anyone like that but still I am just saying, okay good. So that will become another parameter that we will discuss at the end, okay.

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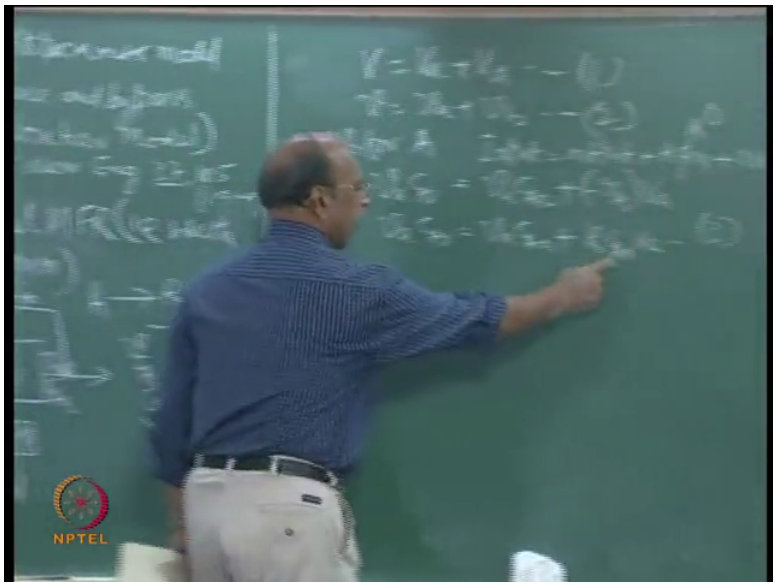

So now this one, now as usual I have to now eliminate this unknown volumetric flow rates like va CAa that is all, okay. Yes and I have another equation for, okay. I think this is simplest one let me from equation 3, let me write this one as CAa by CA not, correct no equal to anyone?

Student: (())(42:30)

Professor: va by...

Student: va by va plus...

Professor: va plus...

Student: kv.

Professor: k capital V, correct. Yes, so this is, right?

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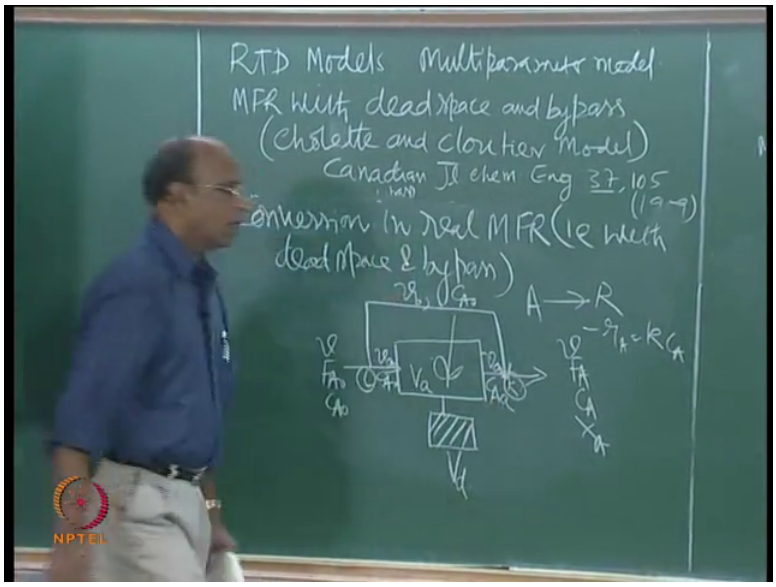

So now I have another equation which I can write that is here balance again k, so this is L this is k, yes who will tell now balance at k? Debayana, yes k balance.

Debayana: va into Ca.

Professor: Balance at k, okay.

Student: Va into ca...

Professor: Which va? Small va or capital Va.

Student: Sir small va.

Professor: Small va into?

Student: Small va into CAa.

Professor: CAa?

Student: Plus small vb...

Professor: Excellent.

Student: Into CA not.

Professor: CA not.

Student: Equal small v into CA.

Professor: That is all. Very good, very good Debayan. That is fine, right. So as usual we will now try to eliminate using this equation. Again I have to write here CAa by CA not, so I divide by CA not, yes and also arrange in this fashion and then try to that equation because we have done already I think I will just give you the final expression for conversion first order, okay.

(Conversation between Professor-student ends)

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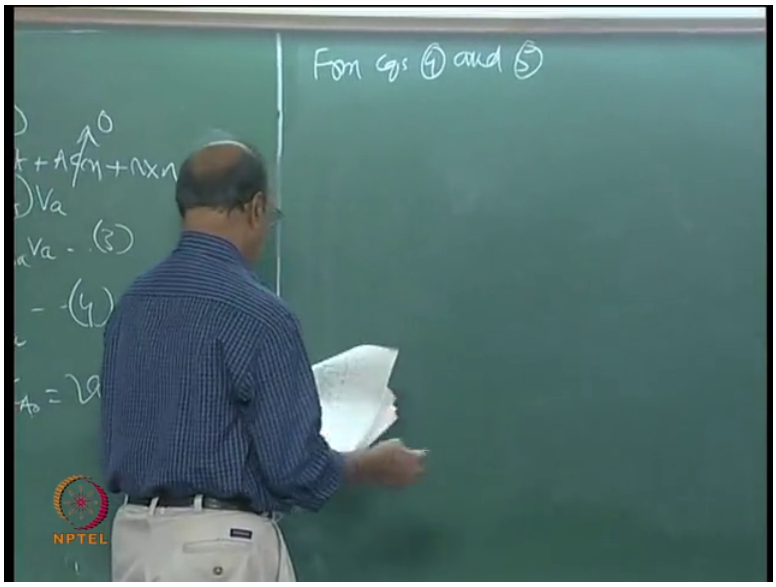

Yes from equation 4 and 5, okay I will write here from equations 4 and 5 that means you have to show the Algebra and if I ask that as a derivation.

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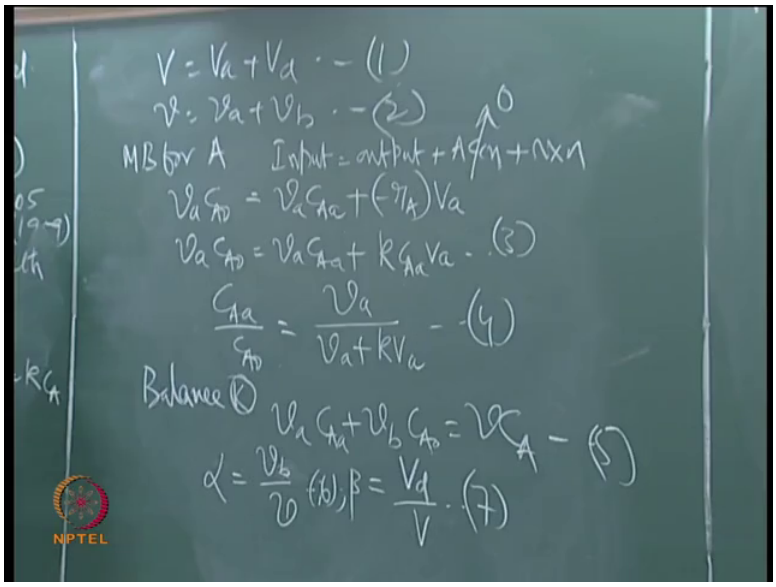

And again here also we are defining alpha equal to small va by small v and beta equal to Vd by capital v, capital Vd by capital V that is again fraction, correct no? Bhagyashree. Same thing 1 minus I have written just for the other C. So again using, yes this may be this is 6, this is 7, correct no? Please point out if I write something wrong, you know when I write something wrong.

Oh! That is what she was telling, right very good. You know we can also define alpha that way but this is straight forward, right? Alpha 0.1 means then I know it is 10 percent bypass, okay good. So that is why, yes right thank you Bhagyashree, okay good.

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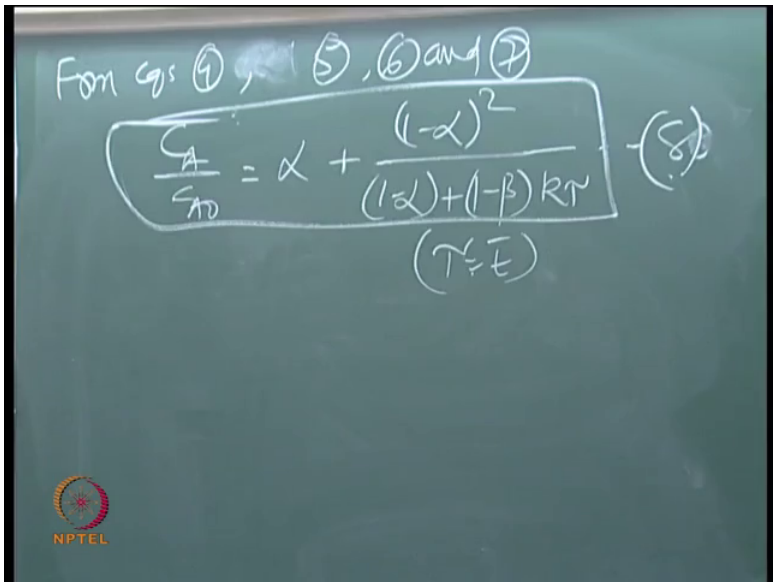

So now using 6,7 and 5 and 4 from equations 4, 5, 6 and 7 we get the final expression as CA by CA not equal to alpha plus 1 minus alpha square, 1 minus alpha plus 1 minus beta k tau or kt bar, okay. Yes k tau and somewhere out right tau equal to t bar also. So this is equation 8, so that is the equation, okay. So now of course if I say that I have only alpha there is no bypass my input and inlet and outlet properly maintained.

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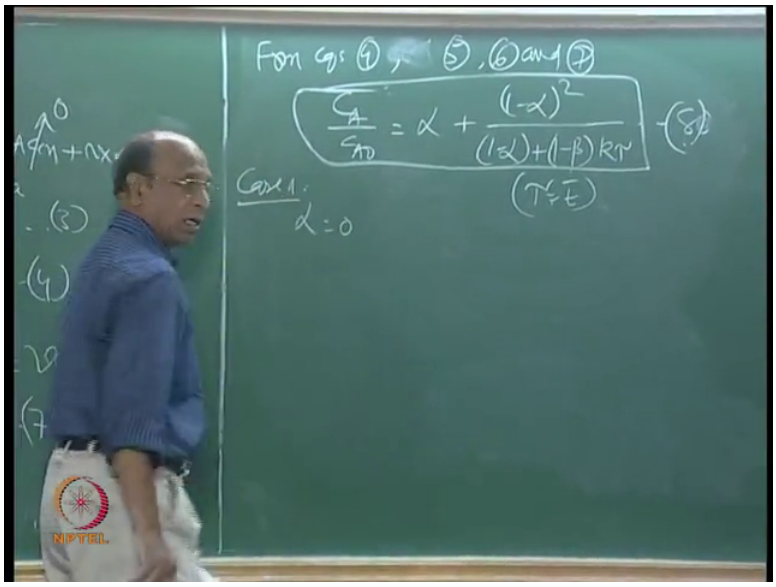

So then what will be for alpha 0 case 1 alpha 0 I have CA that means only dead space, CA by CA not equal to 1 by 1 plus 1 minus beta k tau, correct no? Okay, for beta 0 case 2 CA by CA not equal to alpha plus, yes 1 minus alpha whole square by plus k tau, so that is...

Okay case 3 both 0, alpha equal to beta equal to 0, yes. CA by CA not equal 1 by 1 plus k tau, okay. All this I think we are expert, so this is 9, 10 and 11. Good. So I mean what parameter seems to be more effective here that means, is it dead space more dangerous and? You know, again the question is that to easily answer for you, is it heart attack which is dangerous or is it diabetes which is dangerous?

(Conversation between Professor-student starts)

Professor: Yes, so which is heart attack here? Which one out of those 2, which is heart attack and which is?

Student: Bet is heart attack sir.

Student: Bypass is dangerous.

Student: Bypass is dangerous.

Professor: Why do you say bypass is dangerous?

Student: Because there is no...

Student: No...

Professor: Or this you answer after really plotting for different alphas and betas. I have that here plots, okay but I want you to think, there is something I have to leave you know for thinking, right? But logically what you think.

Student: Alpha is dangerous.

Professor: Alpha... Because the flow is not practically spending any time at all in the reactor and that comes and mixes with already reacted part. If it goes away without mixing it is fine no problem, no it will come and spoil, it has to come and spoil this also. So that is the reason why in fact bypass is dangerous.

So try to eliminate bypass rather than dead space but unless you are a greatest fluid mechanics engineer where you do not know how to design stirrer at all, okay. If you do that everything will be dead space, okay. So that is the worst case, normally you do not expect that, okay. So that is why you just plot that, you know these are the things very simple, Pooja, Happiness will come when you are able to plot, see and interpret on your own.

Real happiness comes in interpreting on your own, understanding on your own, okay listening the tutor is okay because there may be some difficult concepts where if someone explains, Oh! You may be thinking that, okay I understood but the real happiness in the subject will come only when you understand and when you are able to interpret and when does that come?

Without cursing if you do all assignments then only that happiness comes, otherwise if you are cursing also doing assignments will not make you happy because I am there all the time in the mind rather than the problem, okay. Correct, no? I am the problem not the problem is the problem because always think that oh! This KK fellow, so many assignments, so many problems I think why he is troubling us.

He is a really painful guy; he is a true virus, so all that you will say, okay. Really you may be thinking at least not all, few people may be thinking that. So that is why those people have not come also, you know this was earlier full but now this now has become a (())(50:08) here, okay. I do not know dead spaces are empty spaces I think now.

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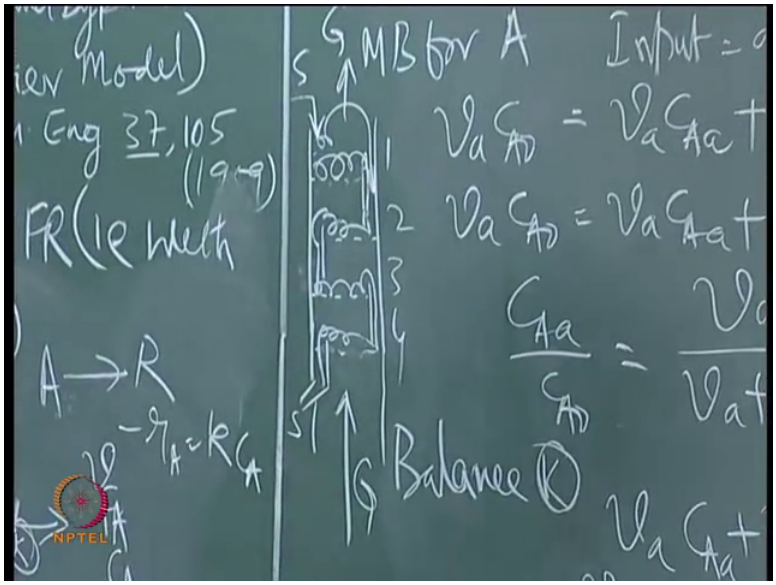

Okay good, so this is the one and now the question is if I want to make this one as now next parameter, 3 parameter, model then I have to put an exchange quotient here, right? Yes, so this will tell me how much of the volume is exchanged between active volume and dead space, right? So that equation will be much more complicated, in fact my guide who retired long time back I did only my PHD here, Professor YBG Verma, one of his PHD students they have done this model for fluid (())(50:54).

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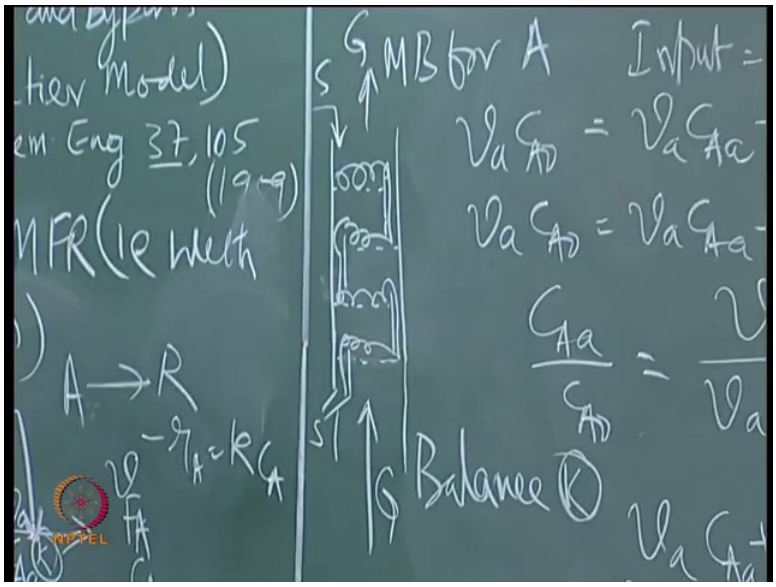

Actually there was another parameter also called number of tanks and series. See what they have done was, they have done a multi-staged fluidized bed where the fluidized bed will be something like this, this is the down comer. This is the down comer that 3 stages, okay like this maybe 5 stages they have taken, okay. So like this, yes and you feed here solids will go come here, solids will go come here, come and then you may take out here. Send the gas here, gas comes out. Solids, solids, okay. This is called multi stage fluidized bed; one bed is above the other bed.

So you send the same gas, so then (())(51:40) similar experiments, okay for drying, he has used this one for drying and then the particles will start coming here, this is counter current, so they come here and then through the down comer they come and this is 1 stage. On this stage there maybe by pass of the solids because in a fluidized beds the solids contacting pattern is mixture...

The solids will be always in perfect mixing, right? So you are sending gas and gas will try to also have the bubbles and bubbles will create very good mixing between the particles, okay. So that is why any time when you look into fluidized bed, gas-solid particularly, so the solids will be jumping here and there and if you put some coloured sand in that or coloured material, then that coloured material will be immediately dispersed throughout, what is the meaning? Perfect mixing that is the meaning, okay.

But if I have designed my distributor loosely then I may have one side fluidizing and there is not fluidizing, what do I create then? Dead space and some solids may be slightly jumping here, see when you are putting the solids are jumping up and down because of the bubbles like this. So some particles directly may enter here because of the bubbles bursting there taking some of the particles and then directly coming through this down coming that goes to the next stage.

So what are the parameters here, bypass is one parameter, dead space is one parameter and they also did that experiments they put the tracer, actually blue sand and white sand they mix it, mixer means fluidizing they added blue sand. Under some gas flow rates there was some cluster of blue sand sitting there and then slowly that is dissolving into the main stream that is what is here.

So this one will become dead some part and then slowly this blue will go to the white, white will come to the blue and then slowly it dissolves. So that means it is dead space is not really dead then it is actually exchanging the material between active zone and dead zone and that ratio also you have to define properly and then that means, how much of material in the dead space is exchanging with the amount of material in the active zone? There is some ratio definition so that will become another parameter.

That will become 3rd bypass, dead space, exchange ratio between the dead and thing and also number of stages, this is 1, 2, 3, 4, so how many parameters now? 4 parameters that is why they had 4 papers in chemical engineering, okay. It is not each parameter but there is a solid work, right? So that is why it is actually, that is why when you are modelling you have to understand the system.

Now we know in this model everything physics beautifully explains the model, model beautifully explains the physics. The model has come based on the physical observation what is happening, you know you put the sand, right? Some solids coloured solids immediately short circuited or bypassed, so then that means I have bypassed, right? Then dead space I think no reactor and no distributor can be perfectly designed anywhere for any system where there is a distributor.

Because it is found that distributor has a special disease, when you have the distributor

particularly if the area is more than whatever velocities you send, equal velocities through each and every perforation is impossible to go, right? So through some perforation you will have low velocity, through some perforation you will have high velocity because of the material moving up and down even if it is liquid.

If you have observed I do not know any one of you saw a distributor plate with liquid where gas is sent from the bottom like bubbling then you can see it will have waves bigger the diameter bigger the waves. So whenever you have the higher wave then you know delta P across this is too much then it will not go through that, it will go through the other height, so gas there will be active because it has less resistance because liquid height is less then where you have more liquid, more delta P, gas will not go through that, so whenever you have distributor this is a automatic disease for the distributor.

Okay, so dead space is justified and it is jumping of the particles to the down comer straight away bypass and then the exchange also, you know between dead zone and active zone and physical (())(56:24) for 5 stages are there, right? It is called 4 parameters, good. Next semester I can tell you fluidize bed has been modelled using 6 parameters and they got wonderful results, okay.

Bypass can it be negative? Is a physical quantity, you should get you know at least 0.1 or above 0, right? You have 1 percent by pass, 10 percent by pass or maybe 100 percent by pass if you very nicely design then nothing is going into the reactor everything is bypassing only, okay. That is possible but what you mean by negative 10 percent? No, do not imagine, how can you have negative?

(Conversation between Professor-student starts)

Student: Third person thing.

Professor: Not coming at all, not coming means alpha equal to 0, so that kind of stupid values people have obtained by simply going to mad lab.

Student: Laughs

Professor: What they have done was, they have that model and the 6 parameters, all 6 guesses they have given but unless you guess and give Matlab it cannot start, correct no? It is a fuse, fuses you, your gas, okay. I am telling fuse because I think next week you are again going to burn your money, you know just like that Diwali time crackers, okay. There also there is a fuse unless you start fuse, yes lightning fire then otherwise you know it would not burst, no?

Same thing here Matlab cannot work unless you give the gas value. They have given the gas values they have got this kind of wonderful, I think volumes also, dead space minus 10, How to interpret? So that kind of stupid values they got for one of the fluidized beds that I can tell you next semester, okay good. So this is what we mean by, okay thank you Avinash to ask that question because multi-parameter models I could give, right?

So I have also, Rahul you got that paper?

(Conversation between Professor-student ends)