Chemical Reaction Engineering 1 (Homogeneous Reactors)
Professor R. Krishnaiah
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Indian Institute of Technology Madras
Lecture No 11
Design of Batch Reactors Part 2

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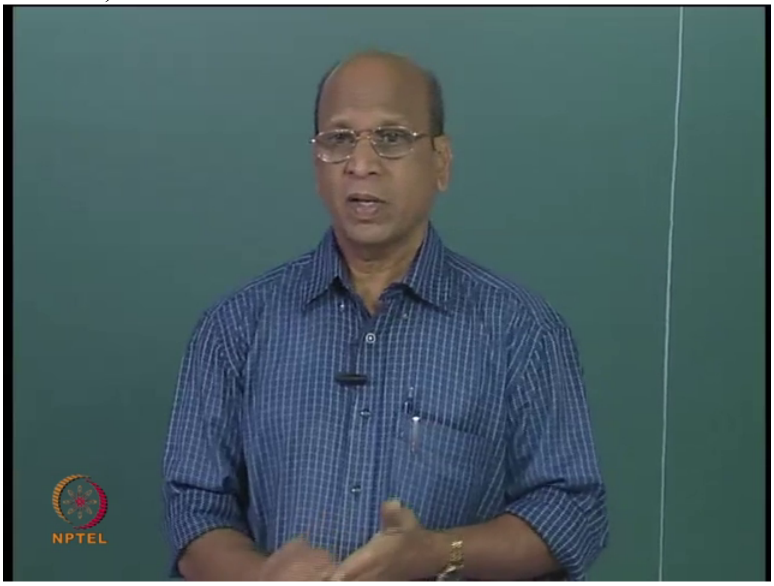

Yeah, how do you calculate volume? Ok. So the general expression what we derived in the earlier class was t equal to C A naught integral zero to X A d X A

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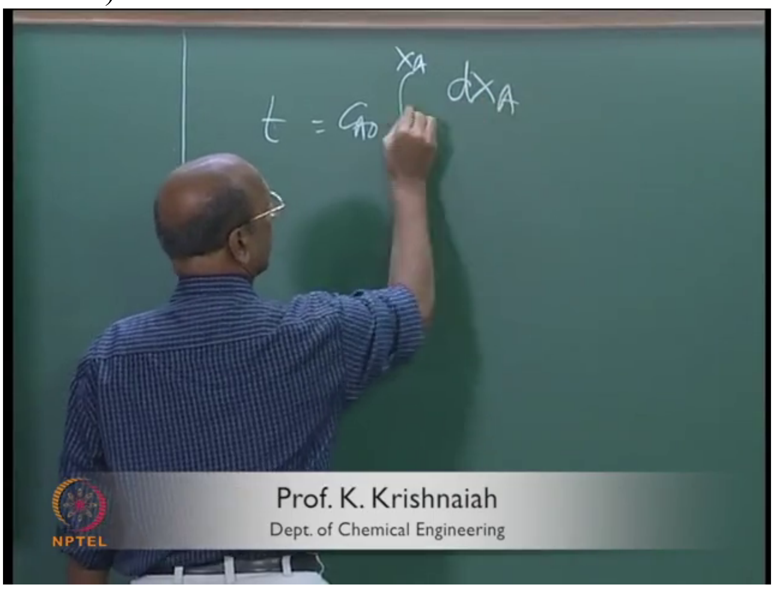

by minus R A, yeah for

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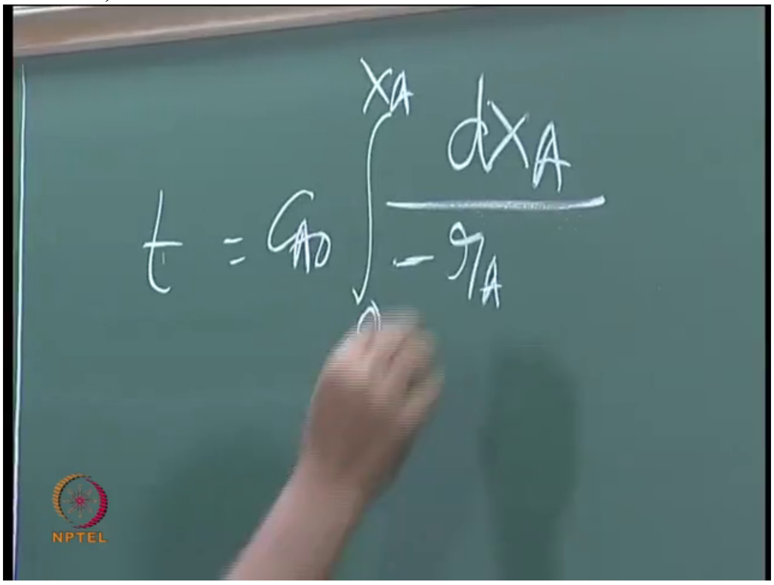

constant system otherwise it is one plus,

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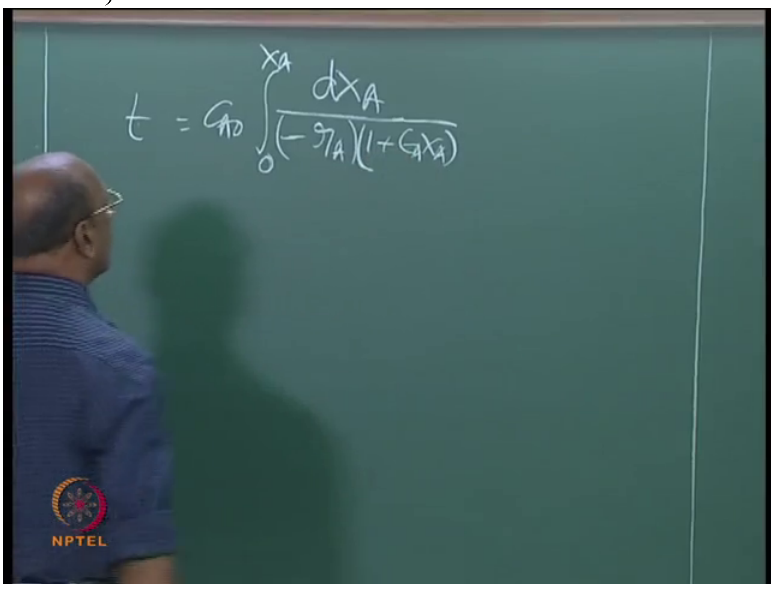

yeah.

So that v equal to v naught, I think that also we will discuss later. So this is the general expression. If it is constant volume, then epsilon equal to

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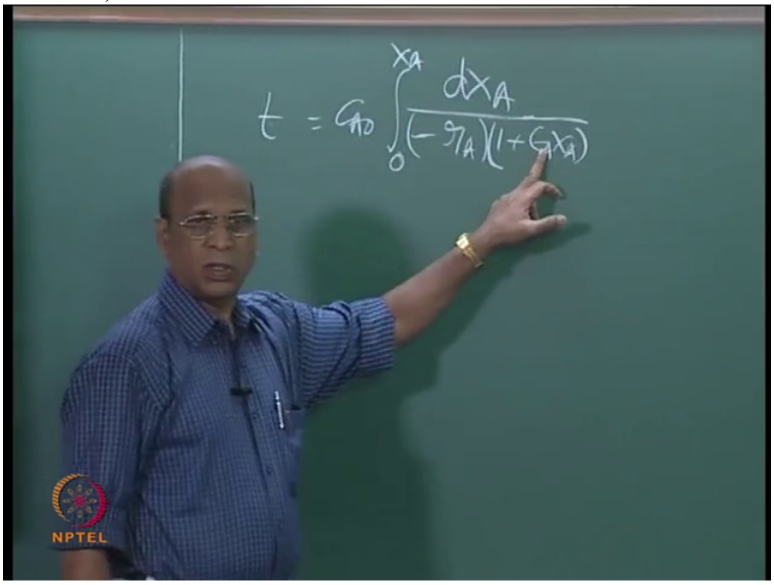

0, Ok so that is why this becomes 1 and this becomes simply minus R A. So then here we do not have specifically volume coming out from the, I mean the design expression.

Whereas if you derive later, because you know already that is why I am telling, so you already seen that for mixed flow reactor and plug flow reactor you get volume as V by F A naught equal to right. So for similarity I will also write this one as t by C N A naught equal to zero to X A d X A by minus R A, general, I think, you know

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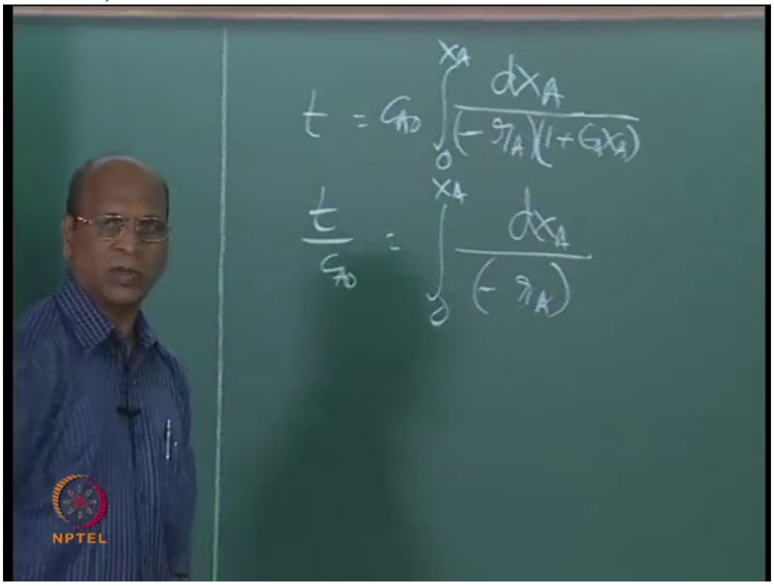

for constant systems let us say, right?

So t by C A naught, this is the general expression for a batch reactor which you are supposed to remember all the time, Ok. But what we have been thinking was this t or this equation does not contain volume. But finally we have to design the volume of the batch reactor. How do you calculate volume? P

What do you know before starting all this reactor design, do you have any information? Just remember that our diagram.

(Professor – student conversation starts)

Student: Yeah

Student: Production

Professor: Production means your F A naught, suppose if it is a flow rate. Ok, here there is no flow. But still

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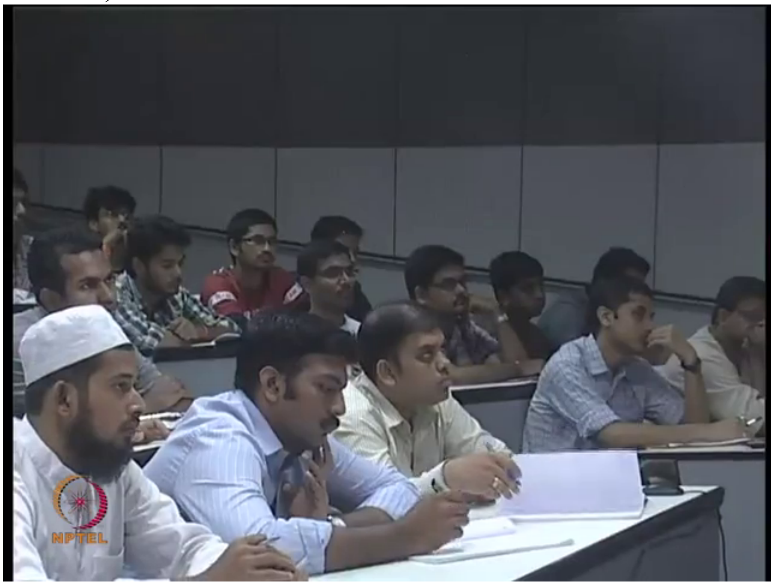

you know what is the production rate, Ok. You know what is the production rate. Let me tell you, just I think for simplicity I have

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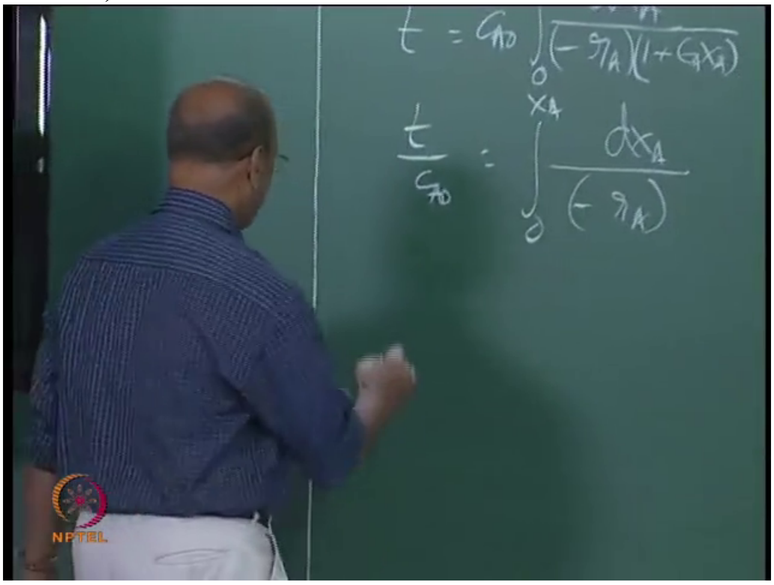

to produce, production rate I have to produce 24 tons per day, right?

(Professor – student conversation ends)

I could have divided, you know I could have calculated per year how much I have to produce then per day, I calculated I got 24 tons

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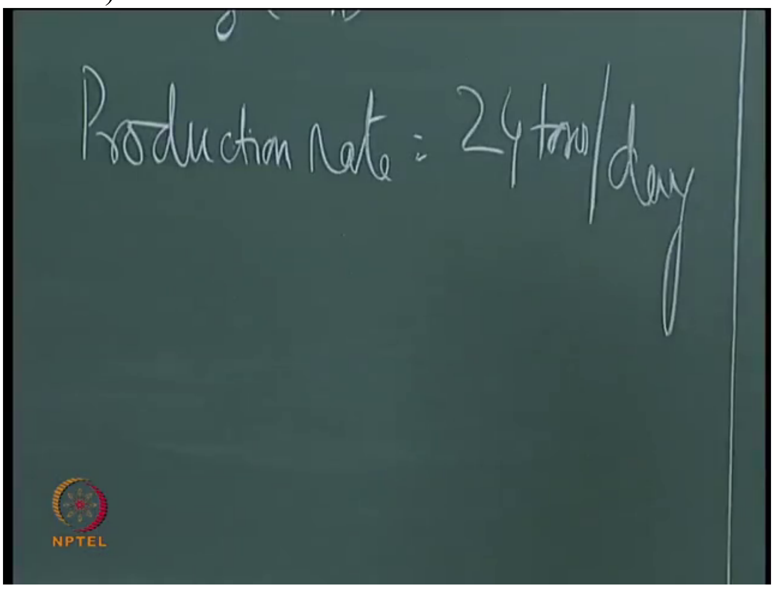

per day, 24 I have taken because it is easy for calculations, right, yeah. But my this design expression will not tell me what is the volume required to produce 24 tons per day. How do I calculate what is the volume of the reactor from this information, 24 tons per day and time.

C A naught I know, that area under the curve, this area under the curve I will evaluate and then find what is t.

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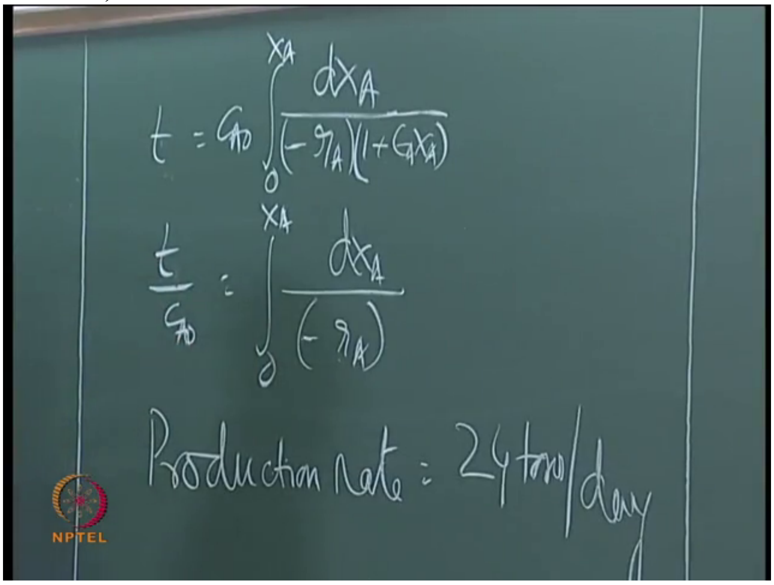

Yeah, that is what I did no, amount of, from conversion,

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let us say for 90 percent conversion if I take, or 99 percent conversion, this equation gives me only time, correct no? That area under the curve when I take, I have to take either 99 percent conversion, 95 percent conversion and so on, whatever.

Because you know that from 95 to 99, OK let me also draw that. This general shape only we are, general shape

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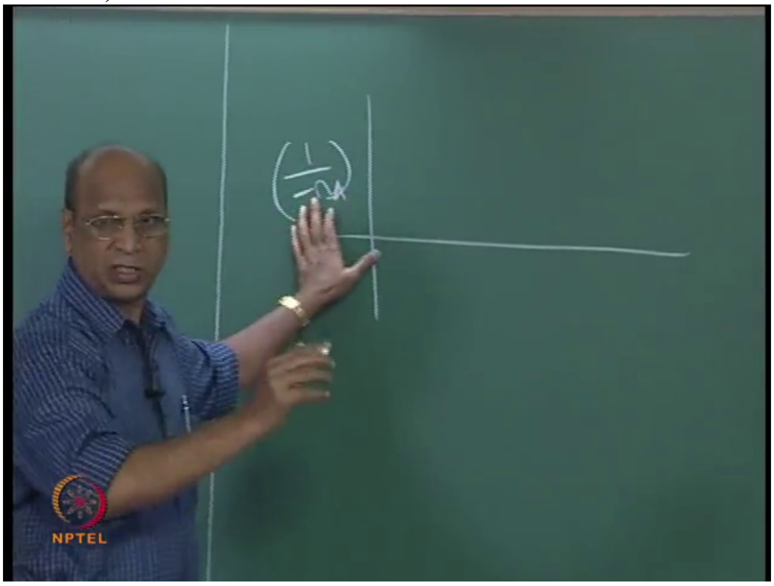

only I am just drawing. So normally you will get most of the time like this. And here you see.

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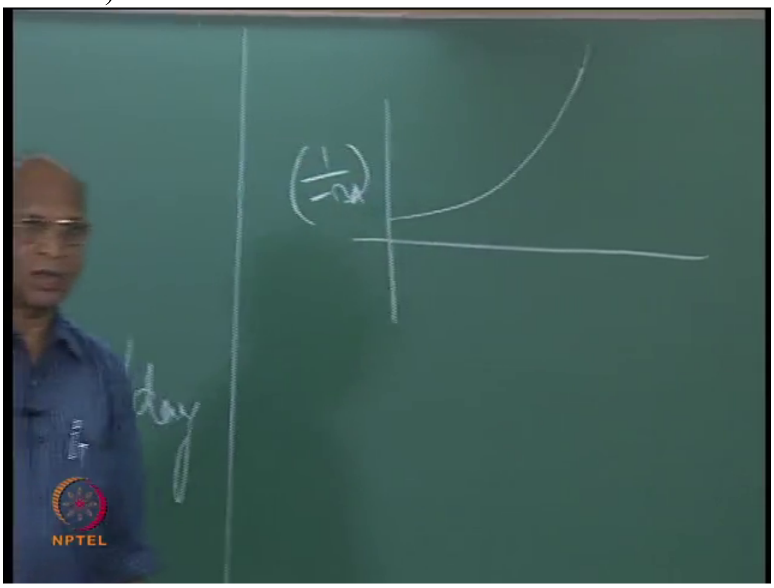

Why it is steeply increasing?

(Professor – student conversation starts)

Student: Sometimes...

Professor: What is R A at x equal to 1? At 100 percent conversion...

Student: There is no reaction.

Professor: What is R mathematically?

Student: Zero

Professor: But what is this coordinate, 1 by

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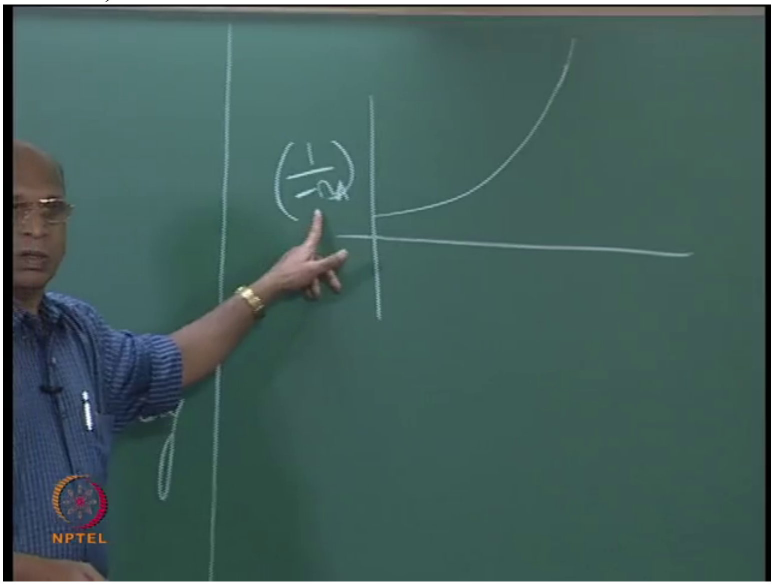

Student: Infinity

Professor: You have to go to infinity. And now just imagine before that it is not just 1; point 9 9 9 9 9. Then you are very close to infinity, right? So that is why if you come back a little bit slowly down this way, then you know that lot of area increase will be there in this region. Whereas here I will not have that much increase.

(Professor – student conversation ends)

That is where the economics in designing the reactor will come because I may go to 99 point 4 nines, 9 9 9 9, Ok I need very, very large volume when compared to point 99 point 9 9, two nines. There will be tremendous difference between these two. That means only to produce point naught 9, Ok, point 9 9, four nines, only I have taken only 2 nines now, then you will have point another zero 1.

So to produce that much small amount, then I have to go for very big volume. No engineer will do like that. Are you able to follow me or...? You are able to follow me, no. Because point 9 9 , point 9 9 9, point 9 9 9 9 every time when you are moving one decimal, your volume also not 10 times increasing, it is sometimes 100 times increasing because it is very steep, very steep going to infinity Ok, here.

And theoretically speaking when point 9 9 9 9 when you put 100 nines you get infinity. Again my same thing. If you have infinite volume you cannot operate the reactor because entire universe is only one reactor, your reactor. So that is the reason why always you have to design whether you have to decide what is the economically viable volume or conversion.

Conversion only gives you that volume. That means you have to decide that volume, right. That means you have to decide Ok, now 99 percent is fine with me, conversion, right. That is why conversion is always coming there. So I am now taking till here, let us say. Ok, that may be point 9 9, or may be point 9 8, right. As engineers you have to find out which is the viable one. Ok.

So this is X A final. So knowing this information

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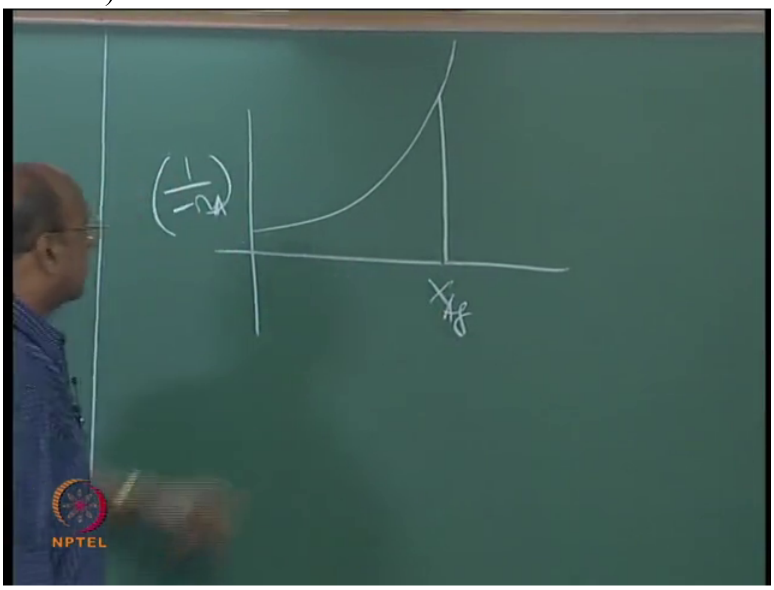

let me say that, Ok I will also give you this area under the curve t by C A naught and even

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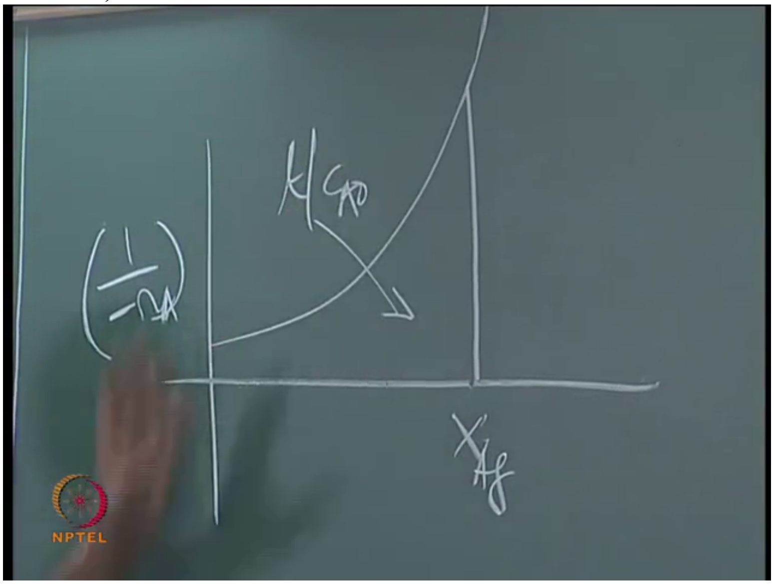

if I take I know C A some value, so the t is let us say 7 hours.

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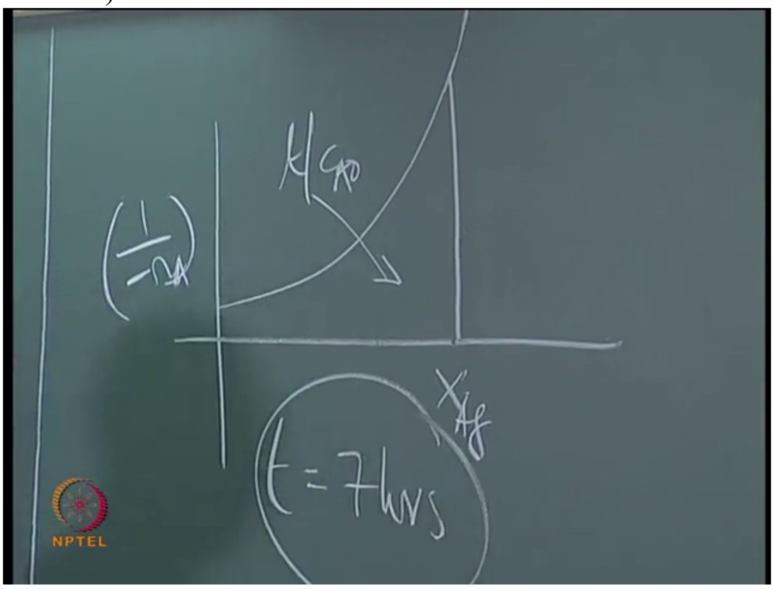

Now you tell me how do I calculate?

That means to produce, I do not know how much amount now, because batch will not tell you what is the amount you have to produce. Whether you take 1 kilo, 1 ton, 100 tons, time is same. That is the beauty with this reactor. But now we have to find out what is the volume depending on production, production rate. Ok. Can you guess?

We have to also try to imagine, Ok. May be a wrong imagination also no problem for us. You should be able to imagine and then tell us, this is what I am thinking. If it is wrong I will tell you. If it is right no, I will appreciate you. Even if you tell wrong, I won't scold you. Ok.

(Professor – student conversation starts)

Student: Multiply production rate into time

Professor: With the time? Ok what do I get when I multiply 7 with 24?

Student: Mass

Student: Divide 0:07:36.3

Professor: I am getting tons only, 24

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tons, 24 into 7 tons.

Student: 7 tons

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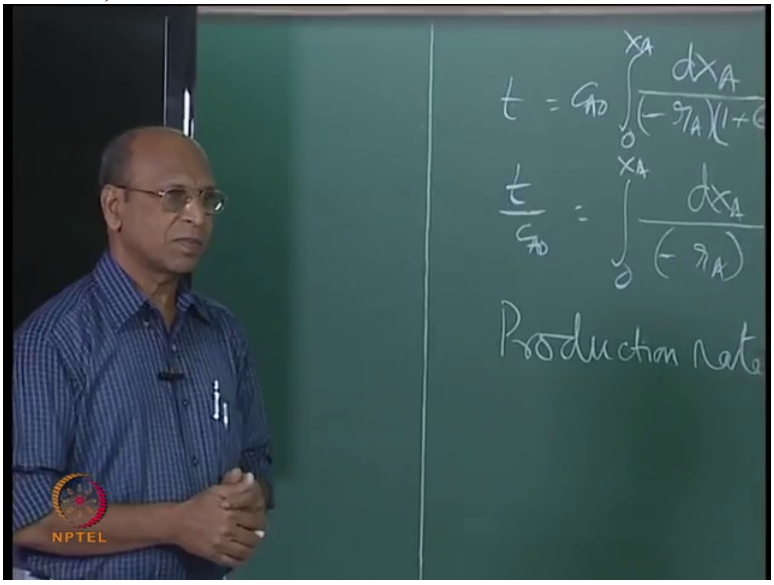

Professor: 24 into 7

Student: 24 by 24

Professor: 24 into

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Student: 7 0:07:50.5

Student: Whatever....

Professor: 7 hours I have.

Student: Mass we are getting.

Student: Rate is converted into hours.

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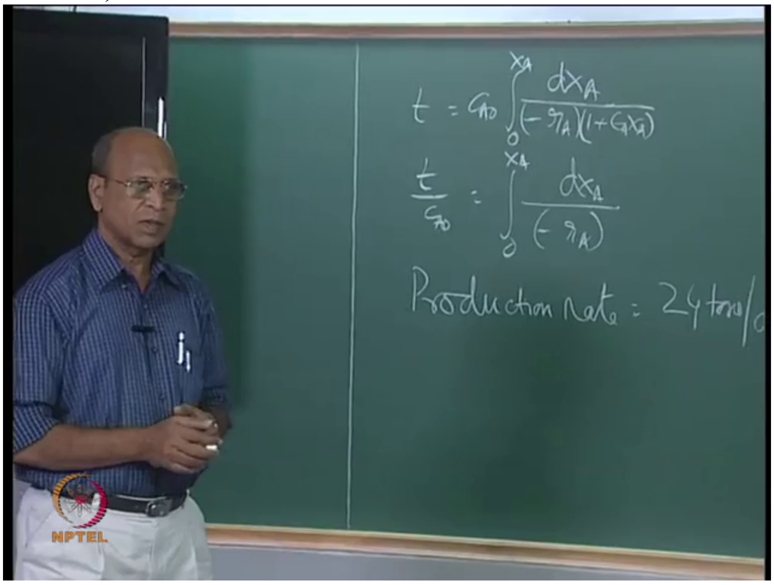

Professor: Ok. First of all you have not asked me one question, you know this time 7 hours, that is the only time you use for calculation?

Student: 0:08:12.8

Professor: Yeah, you have other timings also first of all you have to into account.

(Professor – student conversation ends)

That is why we say that what is called t r x.

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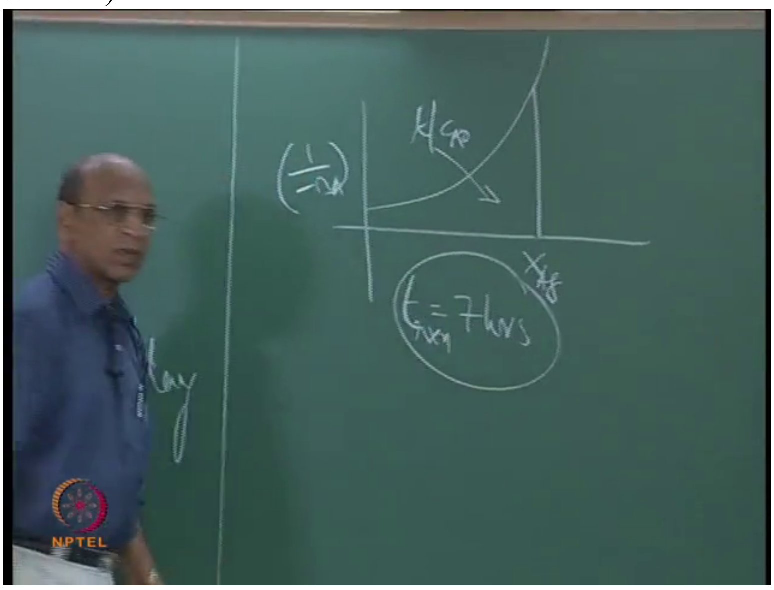

That is only reaction time. See the total batch time, t batch will be t r x n reaction time plus, see you have to first charge, when you are first you know starting the reaction, right, that charging time.

Then after the reaction you have discharging time. And again sometimes you may have to clean, so cleaning time; all those timings will also come into picture. You know particularly biochemical reactions they use sterilization time. Otherwise

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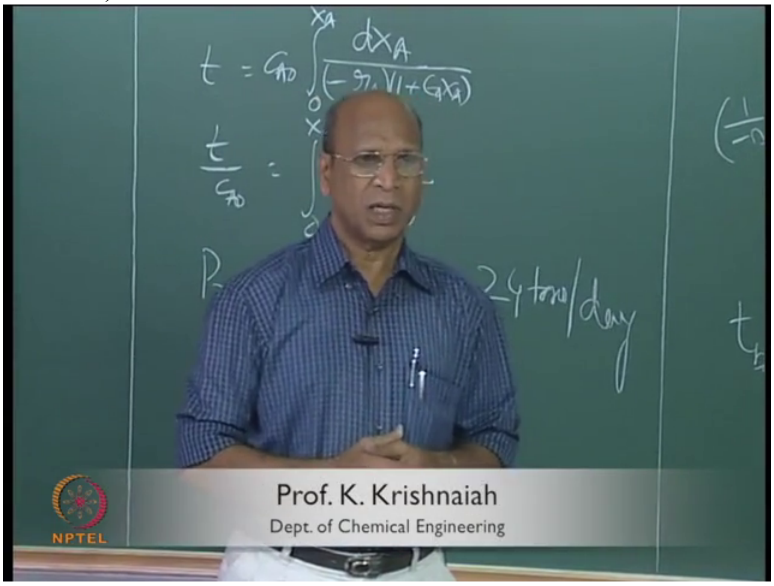

next microorganisms may die, Ok.

And I told you batch reactors we choose because we also have that flexibility in proudest. So the earlier products may contaminate my, the present batch. So that is why, I have to clean it there. So all those timings will come into picture. That is, t what you call, no not cleaning, first one what you said loading. Charging, Ok c h, and also you have t discharge d c h, plus t cleaning anything else, generally these things.

Ok all that timings should be known to us

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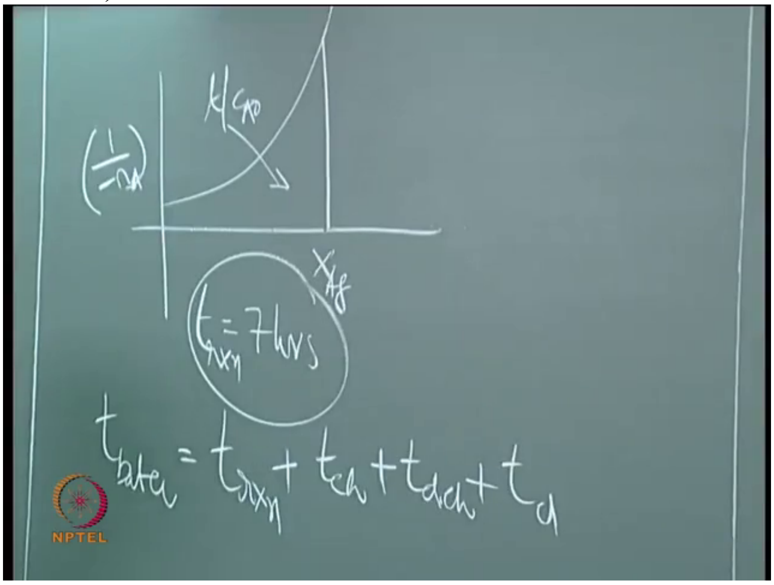

but here we can have some kind of optimization. If your operators are very good, very efficient people then probably all these things will be, in one hour you can finish. Ok. Or if there are very, very lazy people, then it may take two hours. So Ok, so because if you do not have particularly automation and all that.

If you have automation you are replacing humans with machines. Machines are always, you know efficient when compared to humans. Ok, so, in doing general work, Ok, day-to-day work. But when you want to use brains humans are the greatest. Ok, so that is there.

So all this is 1 hour and this is 7 hours. So now I have total batch time,

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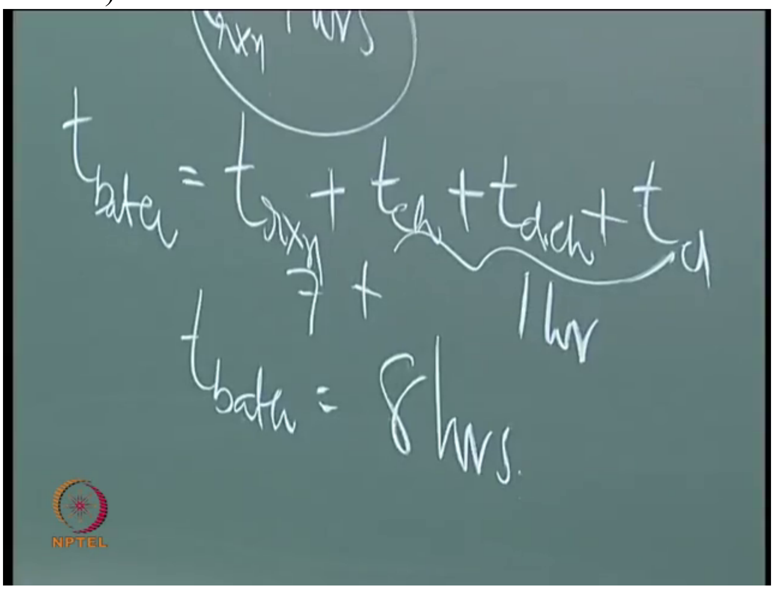

8 hours, Ok. So now what we do is I have to now produce 24 tons per day but I have now 8 hours per batch. Ok. Yeah, how many batches we can now take?

(Professor – student conversation starts)

Student: 3 batches

Professor: Ok, 3 batches. So when now I have 3 batches, Ok so in this case 3 batches, number of batches, number of, 3,

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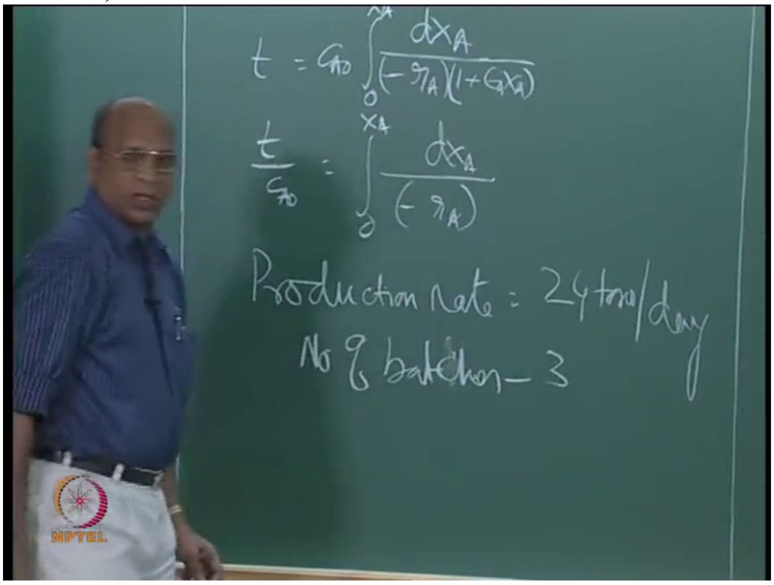

so now, per batch how many tons?

Student: 8 tons

Professor: Yeah, per batch you have now 24 by 3, tons per day, so, sorry, no, no, 3 batches and each batch will have 8 tons. This is tons only, 8 tons.

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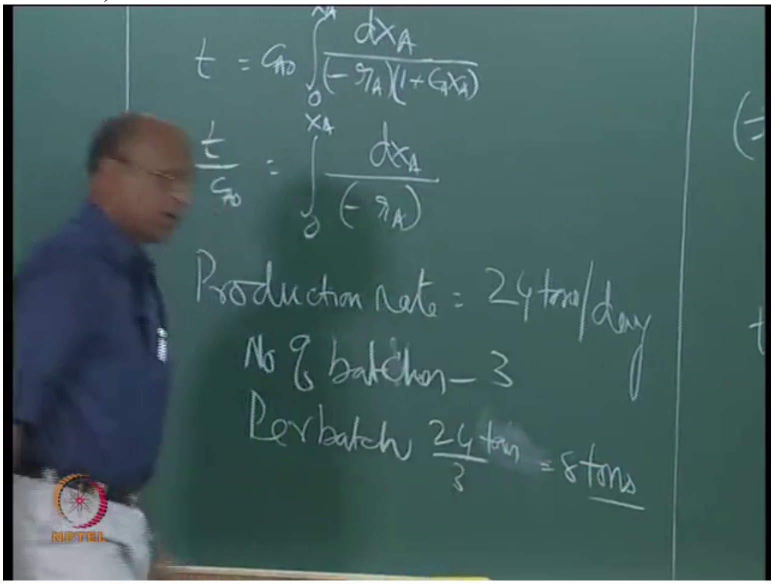

Ok, how do I now calculate the volume?

Student: Density

Professor: Yeah, you know the density of the reaction mixture. Ok, so when we have that density of reaction mixture, 8 tons let us say water, now tell me what is the volume? How exactly like water-like reaction mixture?

Student: 8 meter cube

Professor: 8 meter cube, because 1 ton per...

Student: 1 meter cube

Professor: Yeah 1 meter cube, 1000 kgs no. Thousand kgs per meter cube, right so that means 1 ton per meter cube. So I have to have now 8 meter cubed volume.

And our problem is not yet over. This 8 meter cubed, 8 meter cubed volume I have, how do I now put that one as a physical reactor? That means you should have some diameter and some length.

Student: Thickness also we can have.

Professor: Yeah, that comes later but how do I put this? What is the shape?

(Professor – student conversation ends)

Because if I am a crazy fellow I can take one nanometer and length. Because 8 meter cubed, I can put anywhere no? Now you can calculate what is the length? I think it goes to Mars or may be Jupiter or beyond that.

But it is not engineering. Ok we know that. Then what is there, what else? I can take diameter the earth and then calculate height. What will be the height? Zero. So again where do you put? So what is logical now, engineering logical?

(Professor – student conversation starts)

Student: Apply thumb rule.

Professor: Yes what is thumb rule?

Student: Like some...

Professor: L by d equal to what?

Student: 1

Student: L by d equal to 1.

Professor: Janhavi? Tell something. Tell.

Student: Point 7 5

Professor: Point 7 5, 1

Student: 1

Student: 1

Professor: 2 Ok. L by d, I am asking L by d because

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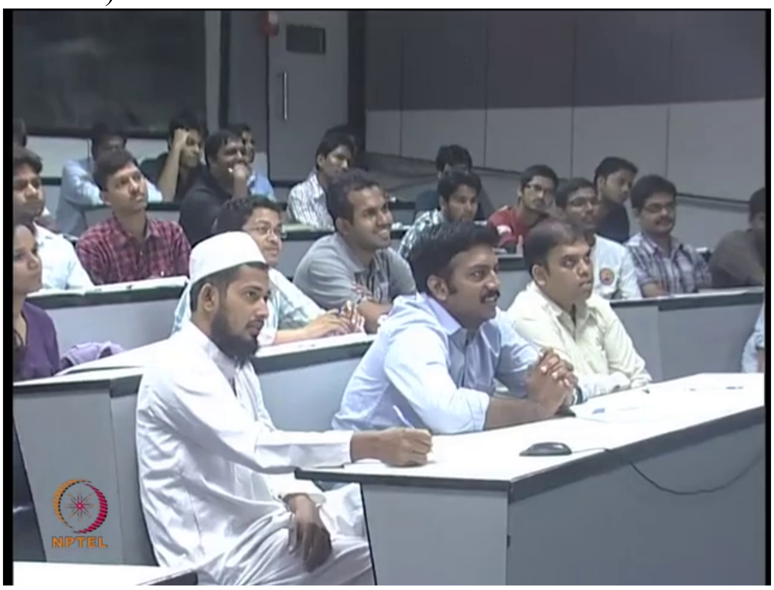

L by d we have to fix.

Two extremes I told. You can take zero,

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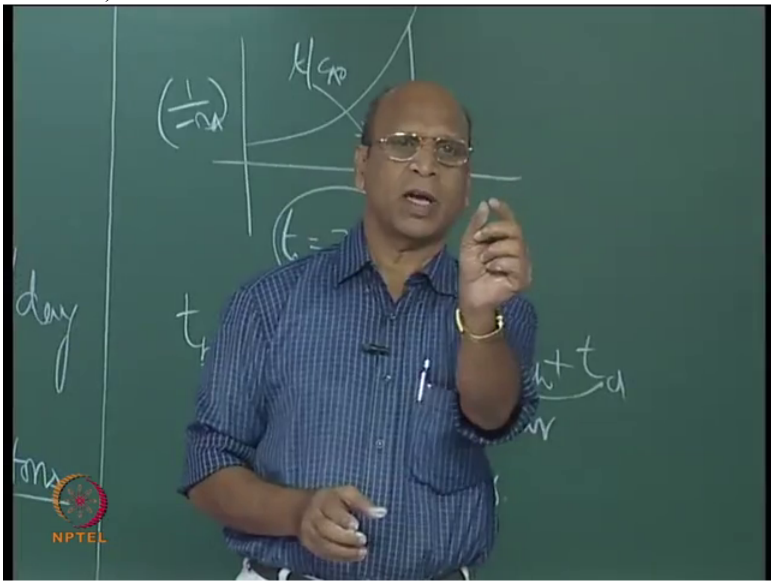

1 nanometer, almost zero and then length you can calculate, not practical. You can take diameter of the earth and then also calculate height. The diameter of the earth is equivalent to your tank diameter, Ok. So then you can calculate height. Ok that is also zero. So these two are not engineering solutions.

So what is engineering solution for fixing L by d? He says point 7 5, he says 2, why do you say 2?

Student: 1

Professor: I will also ask you. Yes, she says, Pooja says 1.

Student: Choose such a L by d where the reactor surface area is less.

Professor: You can never have that kind

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of thing, no because surface area per unit volume, only sphere has minimum. So all our reactors are...

Student: Ideally...

Professor: Should not be, so our reactors are cylindrical.

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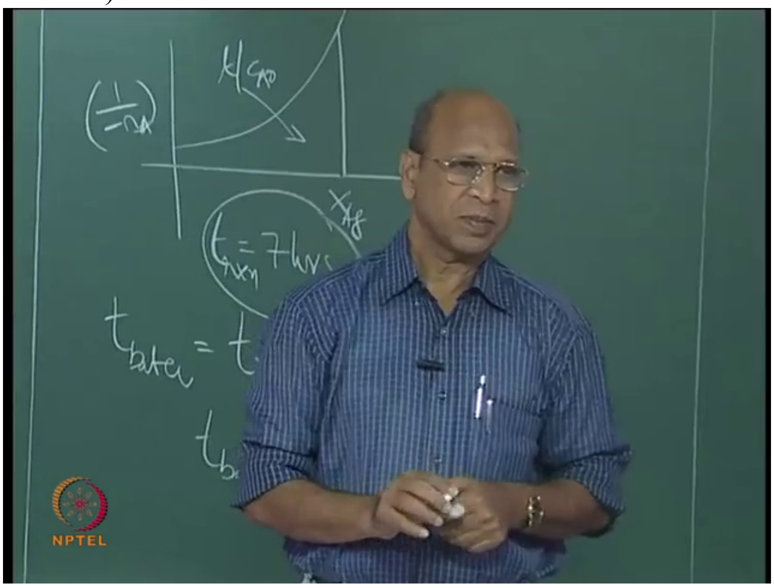

Student: Non-ideality increases.

Professor: What non-ideality?

Student: Dead zones

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Professor: So what, what will happen?

Student: Conversion

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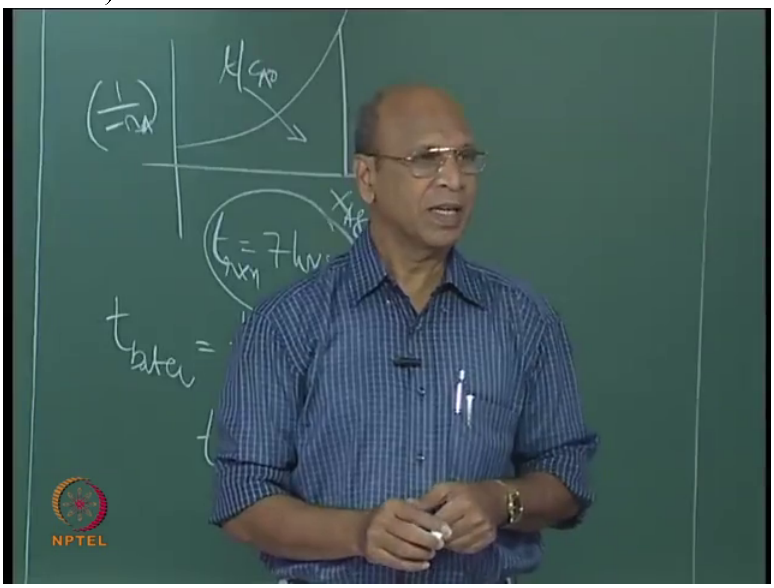

may be affected.

Professor: Why conversion changes if dead zones are there?

Student: Proper mixing will not take place.

Student: Some portion

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of the reactor won't mix...

Professor: How do you avoid that?

Student: Mixing.

Student: Stirring

Professor: Stirring. So my fluid mechanics again will tell you, generally for L by d equal to 1, you have good mixing.

See when you have this tank, so when you put this kind of thing, L by d

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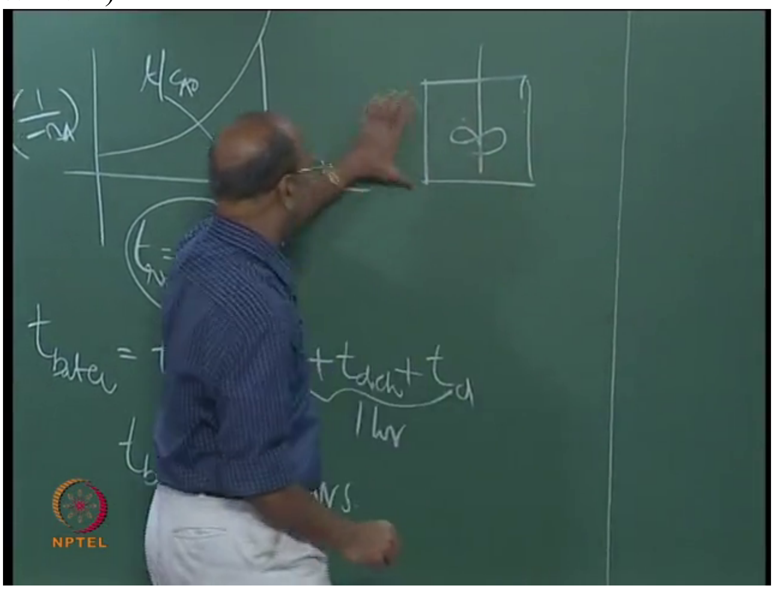

equal to approximately 1, one stirrer is enough. And when you go to L by d equal to 2, then you know sometimes you have seen

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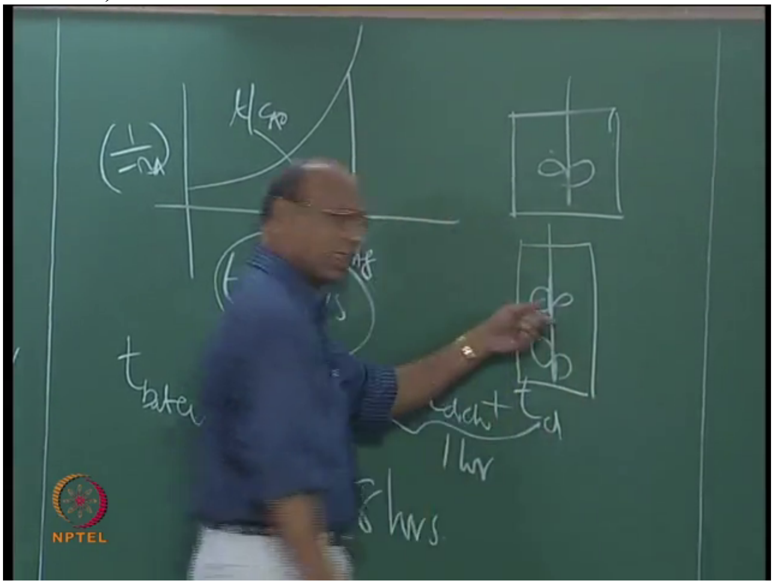

like this, right?

(Professor – student conversation ends)

So general thumb rule is for each L by d you need one type of blade. You know normally we have so many things, we have propeller type stirrers, we have turbine type stirrers, anchor type stirrers, all these things are there. So we know approximately in all these things, L by d equal to 1 will give me good mixing.

That means in this case I should see everywhere uniform concentration and temperature.

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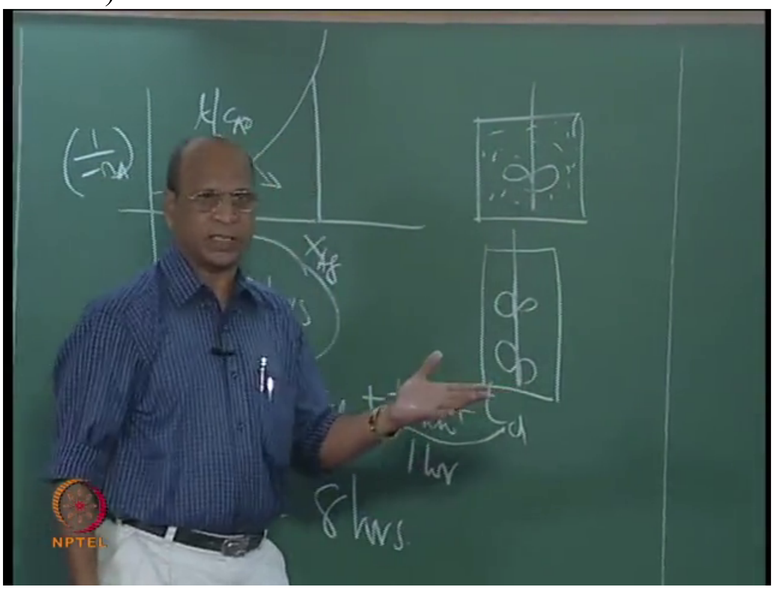

Even if I take L by d equal to 2, many times we take L by d equal to 2, Ok. You know you would have seen batch reactors. But it is not L by d equal to 1 most of the time. It is L by d equal to 2 many times, 3 rarely. That means you know stirring is not that efficient.

But L by d equal to 1 point 5 also is common but criteria is this L by d should be such that your mixing should not be sacrificed, mixing should be perfect. That is the engineering rule, Ok. So now I think I am able to make, you know, some clarity where, you have to remember these simple things. They are not complicated.

We are not really discussing that kind of complicated where we will get Nobel Prize. No one will give us Nobel Prize for this; you know when you take L by d equal to 1.Ok. But we should know why we are taking L by d equal to 1, right? So if someone asks, Ok...why did you say point 7 5?

(Professor – student conversation starts)
Student: Diameter size that is the most you can stand. That is a practically guess.

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Professor: Why, standing I think, standing depends on our structure where you know you put the legs and all that?

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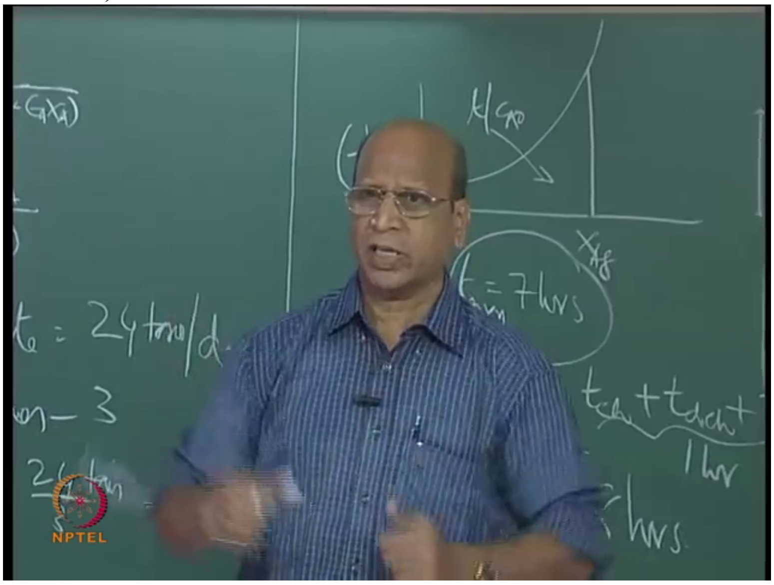

Student: Height needs 0:16:38.9

Professor: No, cylinders only no? Cylinders only, most of the time you go for cylinders. Ok, which size you go other than cylinders you tell me? Why, why again, that is also engineering question, why do you go most of the time for cylinders rather than spheres?

Student: 0:16:52.2

Professor: Very difficult to fabricate, very difficult to construct, Ok. So that much again

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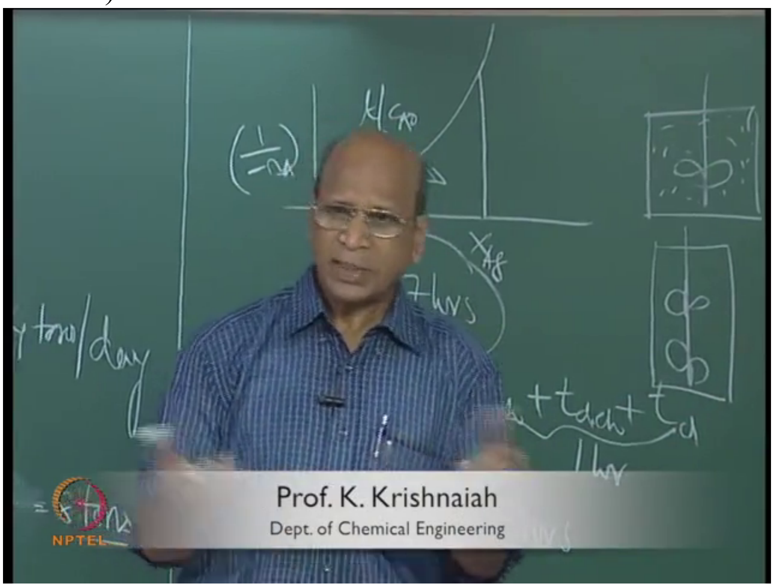

we do not want to spend our time and all that.

(Professor – student conversation ends)

Simple thing is take a big, yeah, like this yeah, like this, a sheet and then fold it.

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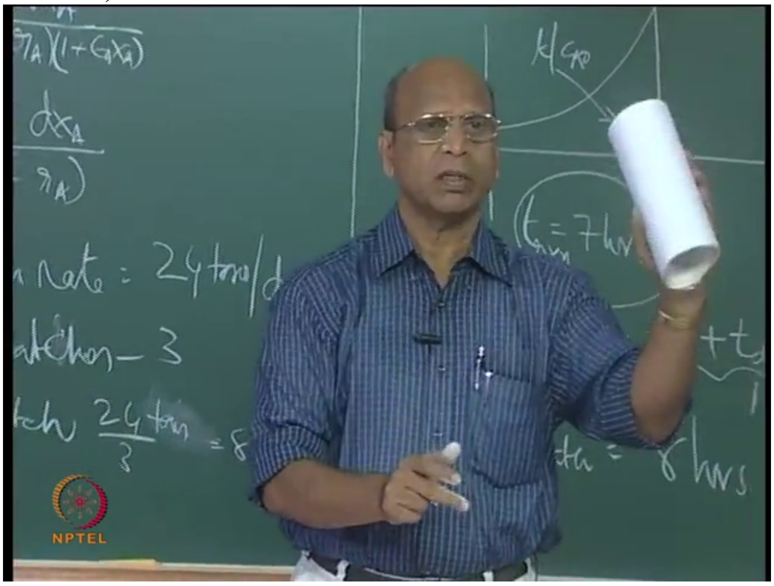

Put one thing here, put another thing there. Not permanently because you have to charge and all that, no. So that is all, that is very simple. Because engineers will think, as I told you in a simplest manner. That is the reason why we have to…

Oh my God! Ok so this is one. So you know how to calculate the volume of the thing. I will give you a problem. May be I will upload or may be tomorrow I will give on a piece of paper and then distribute it to you. You solve that problem.

It is a very good problem but it is a reversible reaction because now you know this r, it can be either reversible reaction or it can be reversible reaction with some orders or without order; all kinds of complicated equations can come.

So that is why, because you are already exposed to this subject, I will give you one problem tomorrow. You solve and tell me the answer. If you are not getting, I will tell you the answer. Because on your own, doing, I think you will really understand everything. Ok?