Advanced Chemical Reaction Engineering
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Lecture - 5
Design Equations II:
Plug Flow Recycle Reactors

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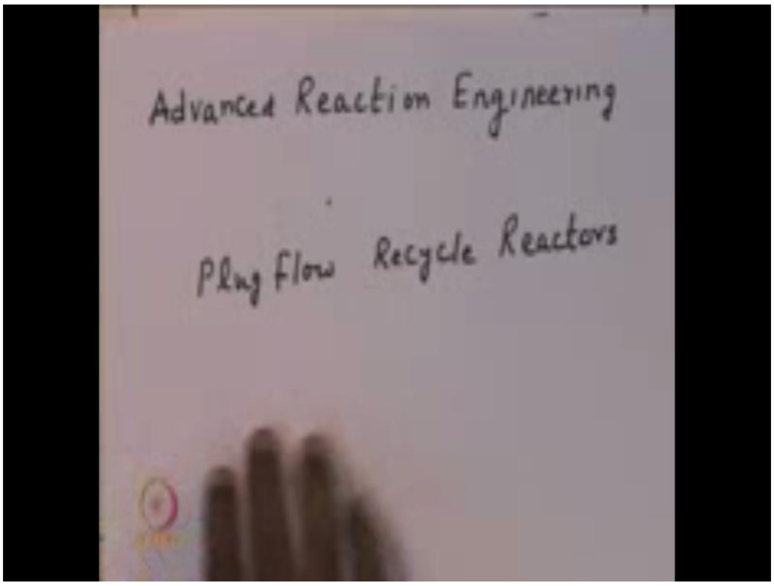

So, we will be looking at plug flow recycle reactors today, something that we have spoken about the earlier.

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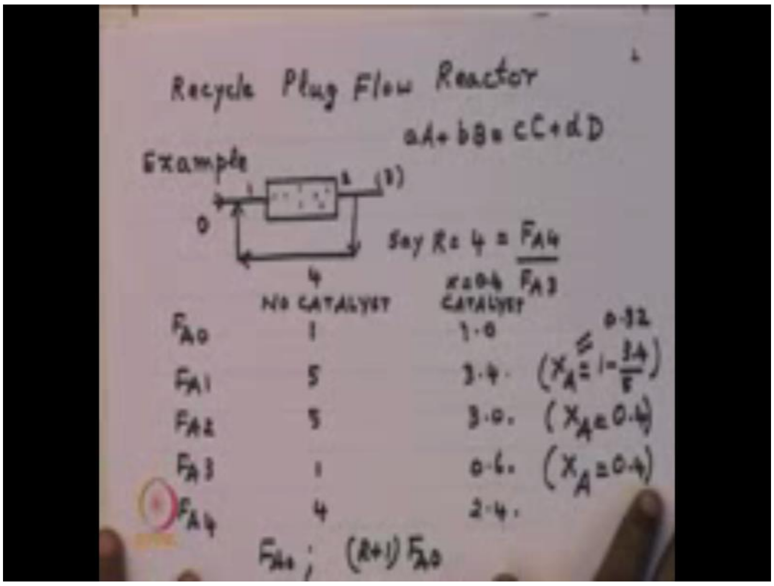

Recycle, so heat is an extends of a plug flow reactor in which this material is taken out and put in back. Now, why do we do recycle? Of course, recycles are pro common in process industry, because the reactions do not go to completions, so you separate and recycle. So, this separation part is not taken into account yet, but the fundamentals of recycle are what we want to understand and setup the basic approach to looking at recycle reactors. Now, just to make it a little easier what I have d1 here is I have take position 0 1 2 3 and 4 to indicate different positions in the equipment.

And I have taken 2 instance is where there is no catalyst in the reactor and second instance where there is a catalyst in the reactor. Now, case 1 when there is no catalyst in the reactor for example, if it take recycle ratio as 4 I will just put down what are the flows going through at different positions which is grow through it. If for instance I have taken F A 0 is 1 and therefore, F A 3 should also be 1, because and whatever comes in and must go out. I have taken R is 4 therefore, F A 4 is 4 times F A 3 therefore, R is F A 4 is 4 and there is no reaction therefore, F A 1 should be F A 0 plus F A 4 which is 5.

So, F A 0 F A 1 F A 2 F A 3 F A 4 this show the number of units that flows through the equipment when there is no catalyst that means no reaction. Now, let us say there is an extend of reactions of something like x equal to 0.4 which means out of 1 unit that is coming in it position 0. 0.4 reacts therefore, the balance is 0.6. So, if balance is 0.6 therefore, at position 4 you should be 4 times 0.6 therefore, it is 2.4. If it is 0.6 4 times

0.6 is 2 0.4. Now, at position 2 it should be F A 4 plus F A 2 is F A 4 plus F A 3 is F A 2 therefore, it is 2.4 plus 0.6 it is 3. And F A 1 it should be F A 0 plus F A 4 which is 3.4. So, this tells us based on material balance what are the flows and different positions. Now, what we would like to see is since there it is no reactor between position 2 and position 3 common sense tells us that the value of conversion that we calculate must be this same at 3 and 2 this common senses.

So, how do we make it? This is the value of conversion to be the same we recognize that conversions are defined on the basis of a reference. Every time we have a reference based on which we defined conversion. Therefore, here if it take our reference as what flows into the equipment. And they absence of reaction which is 5 units then we notice that conversion at position 2 becomes x a equal to 0.4, 3 divided by 5 is 0.6 1 minus 0.6 is 0.4. So, common sense tells us that the reference on which we should defined conversion inside the loop must be number the units they the material that flows into the reactor they absence the reaction. Or putting in terms of re recycle ratio F A 0 is when there is no recycle there is R is 0 when there is recycle then it should be R plus 1 F A 6.

So, that basis for defining conversion inside the loop should be R plus 1 F A 0. If there is different definition the now, formulation will we will change, but the important thing as assuming I will you see as you go along our formulation known change much. If we use this definition you find that when you put R equal to 0 you get what we would have got in when we dent have any recycle. So, that is advantage of this formulation, but it does not matter. As long as you very clear about the definition it does not the matter. Let us just take it us in the absence in the event within the recycle loop we should have r plus 1 F A 0 as the basis. So, that when we go outside the loop R is 0 our basis becomes F A 0. So, it is consistency between inside and outside in the absence which means what enters the reactor in the absence of reaction.

Just to make it clear I said in the s absence of catalyst there is no reaction therefore, what a enters are 5 at 1 is 5 units that is how I explained it. So, I calculated what is the conversion at 1? Conversion at 1 should be 3.4 divided by 5, so what is 3.4 divided by 5? 1 minus is it 0.32. So, it shows that conversion here is 0.32 and here it becomes 0.4. So, important thing to recognize in recycle plug flow recycle is that per pass conversion going from 0.32 0.4, but overall conversion is 0.4 overall conversion 0.4 per pass conversion is 0.32 to 0.4 only point is 0.8. So, per pass conversion is low, but overall conversion is high and there are certain advantages for this we will look at this is equal on is there.

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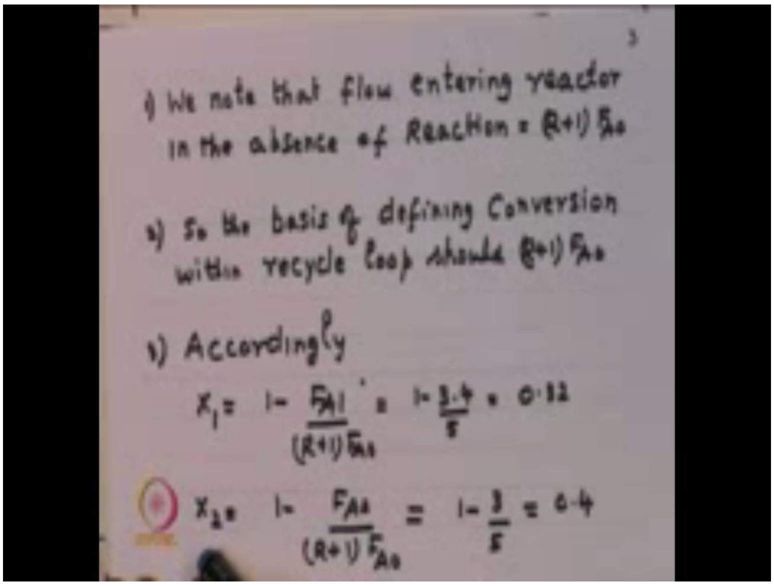

So, adjust summarizing what we have said already that flow entering the reaction they absence of reaction is R plus 1 F A 0. Therefore, the basis for defining conversion within the recycle should be R plus F A 0. Therefore, value of x 1 is 0.32 x 2 is 0.4 and x 3 is 0.4 there is consistency between in inside and outside the loop.

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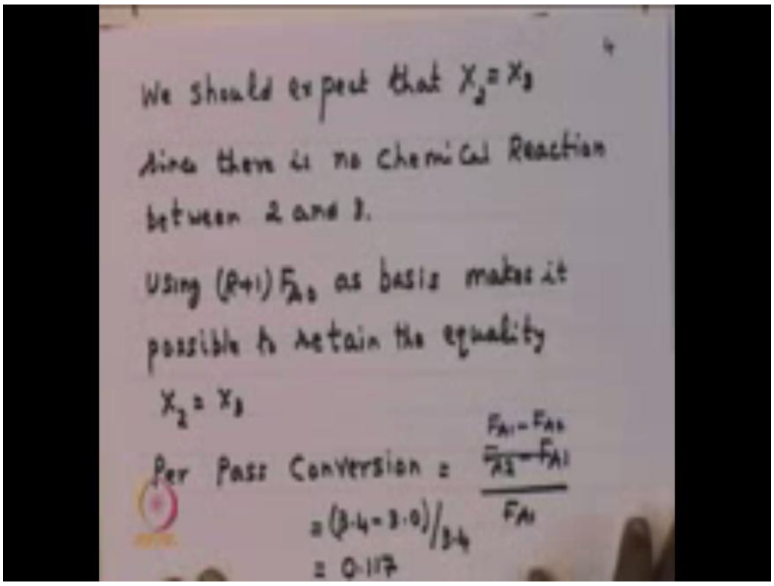

So, we will go for that now when I said we can calculate per pass conversion in this particular case for example, what is per pass conversion? F A 2 its reverse F A 1 minus F A 2 its it is F A 1 minus of F A 2 this per pass conversion. So, 3.4 minus of 3 this is how it will come out 0.117. Now, that we have said that the basis for defining conversion is R plus 1 F A 0 we can write the strike to metric. Just like we have written strike to metric before we can write strike to metric again.

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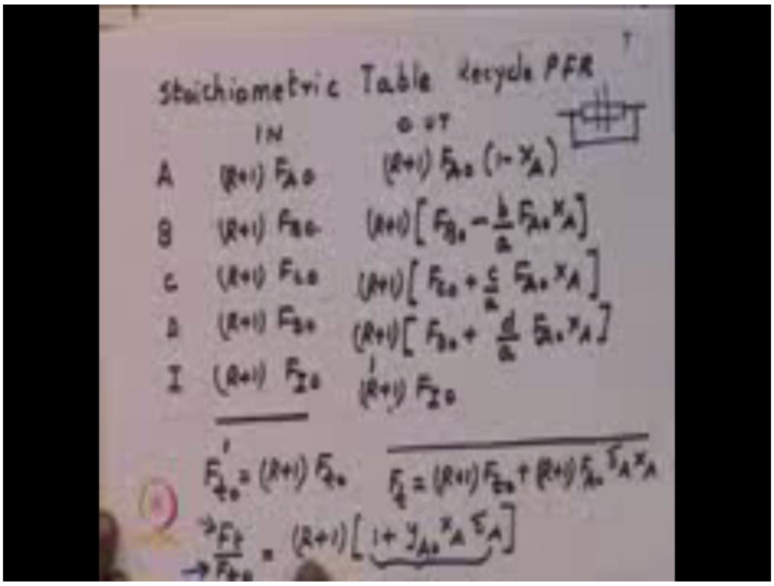

That means what comes in to the process is there R plus 1 F A 0 R plus 1 F B 0 R plus 1 f C R plus 1 F D 0 R plus 1 f I 0. Therefore, the total is R plus 1 F T 0 when R is 0 it is same as what we had if before to what goes out. Since a is the reference R plus 1 F A 0 times 1 minus of x A, is the flow rate of the component a at any position inside the loop it is the daily position. Similarly for component B it is R plus 1 times F B is 0 F B 0 is coming in and this the amount that is reacting. For C components c are R plus 1 times the f is 0 and entering and this the amount that is the reacting similarly, component D similarly, component I. So, that when you add up all this the total moles of components at any position is R plus 1 F D 0 plus R plus 1 F A 0 delta S.

On other words you find that F T by F T is 0 notice here what is the F T 0? F T 0 is, is the actually what is the entering outside the loop? F T 0 is what is the entering outside the loop you can see the way formulated it. F T 0 is what is the entering outside the loop F T is what is inside the loop? And therefore, this term is exactly the term that we had earlier only thing it is multiplied by added plus 1. So, when you put R equal to 0 it is exactly what we had before? This the consistency that what is important that outside the loop and inside the loop the consistency simply put add or equal to 0 you get what you got before? F T is any position inside the react inside the recycle loop have we are taking about inside the recycle.

So, that when you put R equal to 0 you find you get the same result that we got before and this point in the absence of reaction this is what is entering? What we trying to saying is that when we have trying to look at the recycle system our basis should be R plus 1 times what enters the reacting the absence of the reaction. And this is the fundamental difference that we must recognize towards recognizing the basis. Because we need a basis should defined conversion and convert that is why we say this is the basis on which that the action takes place. So, basis is R plus 1 F A 0 therefore, all over conversion are assuming that R plus 1 F A 0 is going through the react. And how did we come to this R plus 1 F A 0 we took the example to understand this when there was no the reaction 5 unit is entering.

And therefore, our basis should be 5 units and you also found out that you know only when we do that there is consistency between position 2 and position 3 same value of conversion. So, that consistency will not be there if we defined is this way. So, the important thing only the choice of the reference is important in recycle. Let us look at the example the example that we have let us gone back to the same example and ask all these question. Let us ask all the question when there was no catalyst we said 5 units are going through and 0.1 when there is the catalyst we find that 0.2 it is 3. So, the conversion at 0.3 is 0.4 conversion at 0.3 is therefore between 2 and 3 you see a consistency. This consistency is fundamentally required for as took in all choose the reference.

The reference is to be chosen to get this consistency between 2 and 3. And that we have got by recognizing that 5 units as flowing at 0.1 when there was no reaction and F A 0 is what? In the absence of reaction the meaning of F A 0 is what enters the process that means when there is no reaction at that point. So, in this same way what enter at position 1 in the absence of reaction is 5 units and in our nomenclature it is the R plus 1 F A 0. Ask answer to a question is we said between 0.2 and 0.3 we should we need consistency that means the value of conversion at 3 and 4 should be 2 and 3 should be this same. Because only then as you move from 2 to 3 the value of conversion does not change that is the consistency we require in our definition or in or choice of reference. And we said that reference choice is R plus 1 F A 0 only then we get this consistency.

So, consistency comes only when we choose our reference properly and reference is what enters equipment in the absence of reaction. And at makes and also what enters equipment in the absence of reaction should be are basis and any way. See if, so much of sulphar dioxide then entering that is the basis, so that we can find out how much of sulphar dioxide is coming. So, in this same way between 0.2 and 0.3 we must have consistency in the same value of x that is why 5 units is chosen the reference that is why R plus 1 F A 0 is chosen as reference. When you put R equal to 0 it becomes our conventional definition that we have being using all the time. So, having said this let us go further now.

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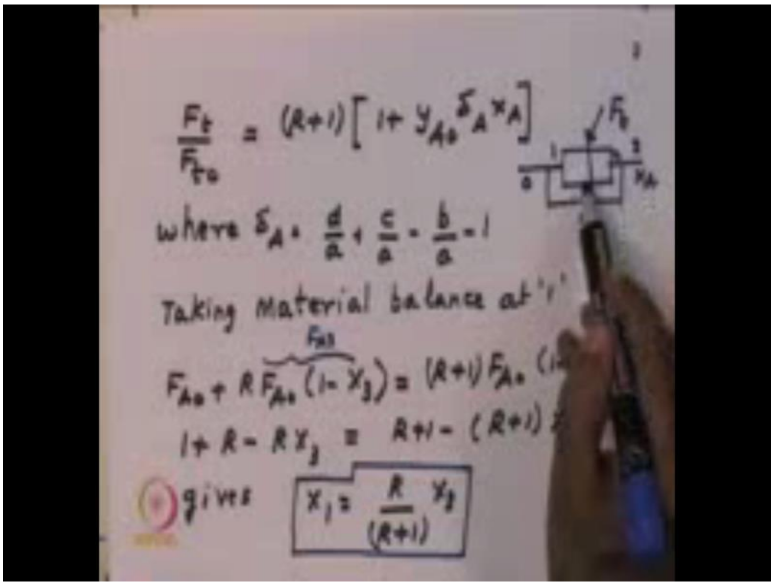

So, what are we saying now? The total mole that is coming out of our let me draws the recycle once second this is our recycle system. So, total moles that any position, so F T is that point F T is R plus 1 multiplied by 1 plus y a this is the position 0. y a is 0 refers to this position this is 1, this is 2, this is 3, this is 4. So, this y a is 0 at refer to position 0 delta a refers to our a strike to metric x c is conversion at this point which is consistent with between 3 and 2. Now what we are now, saying is that if you want what is the conversion at position is 1 is people ask our answer is at position 1 as per hour definition it must be a R plus 1 F A 0 1 minus of x 1 that is are the definition. Our material balance tells us must be F A 0 plus F A 4 what is the F A 4? It is R times F A 0 times 1 by correct, because we have recycling R times 3.

So, F A 0 plus r times F A 0 1 minus this is this is the F A 3 we know that this is the F A 3. So, this, this is the statement of material balance therefore, it gives you this relationship that x 1 is R by R plus 1 x 3, so what is that means? It means the per pass conversion is quite low with overall conversion can be quite high depending on the choice of R. Depending on the choice of R if R is very large what is it means x 1 becomes very close to x 3 which means what? The per pass conversion in the equipment is very low. So, you have very little conversion here between 0.1 and 0.2 per pass is low, but the overall can be quite high. Let us go forward over.

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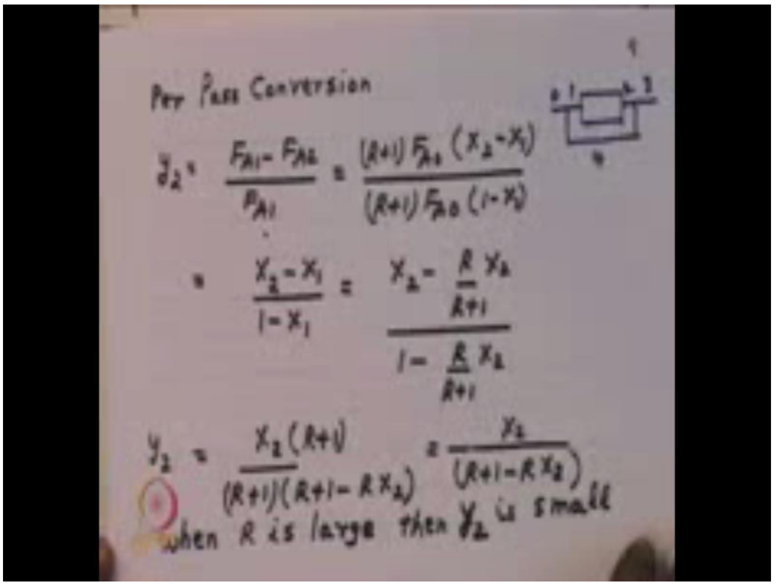

So, what is per pass conversion if I say or position 2 this is the position 2 0 1 2 3 and 4, so what is per pass conversion at 2? Y a F A 1 minus the F A 2 divided to F A 1, so it comes in terms of x 2. So, when R is large you can see that per pass conversion is quite low. So, if, as is sell when would do you interested in as low per pass conversion when you do not want a very high temperature likes, so on. Other words if you own operate an equipment isothermally, because you want to do chemical kinetic measurements. That means you want isothermal data you can get isothermal data in this kind of environment. So, if you have the catalyst which you are prepared you want evaluate the catalyst and determining the chemical kinetics of the catalyst. You can do measurements at isothermal conditions in a recycle kind of device is at relatively easy. Because it is catalyst does not get spoiled in a because in it is in not moving we can through on its lot of Advantages. Alright, so let us look at the designing equations.

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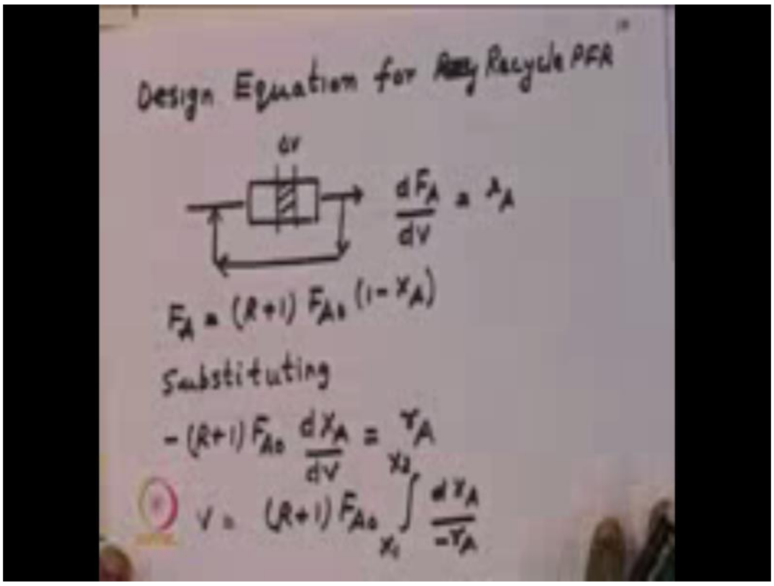

So, what is that designing equation now? You have take a material balance in a volume delta v where the fluoride at that point is R plus 1 is F A 0 1 minus of x a this is our strike to metric table to this how you defined. And our material balance tells do a d F D v equal to r A this something that we have done this is for a PFR. The only thing that as change now, is that our flow at this point is the R plus 1 F A 0 times 1 minus x A. This equation d F D V equal to R there is no change, but value of F A at that point is R plus 1 F A 0 of 1 minus x A, because our basis for defining conversion is R plus 1 F A 0. Therefore, the defined designing equation for a recycle reactor becomes what is mentioned here we could r plus 1 F A 0 integral x 1 to x 2 we are going to 1 to 2.

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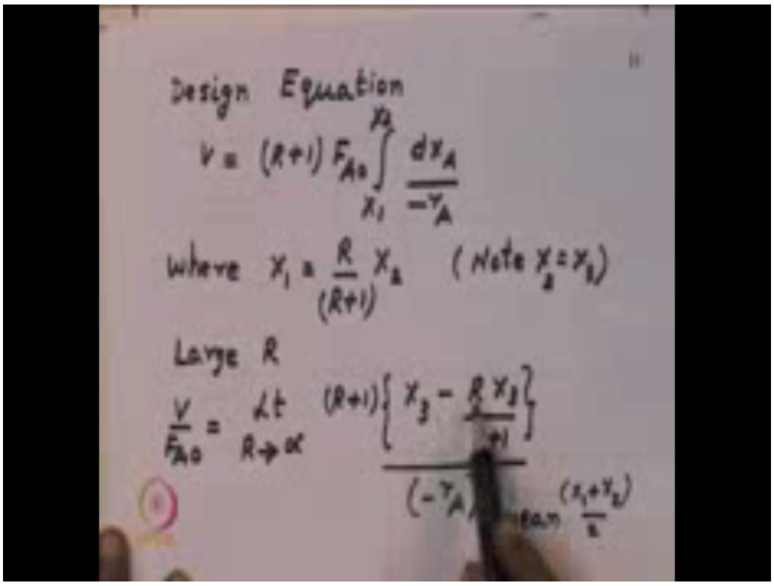

So, let us look at this example detailed. So, design equation is R plus 1 F A 0 going from 1 to 2 while value of x 1 is the R by R plus 1 x 2 and x 2 equal to x 3 as per R definition. Now, let as ask what happens to this when value of R is large what is the value of this integral? What I have one limit as r times to infinity I have just try to find the value of this integral when R is very large adjust set d x a is simply x 3 minus R x 3 by R plus 1. So, this integral and evaluated the denominated minus of r A mean value of x what is the mean we have to take between x 1 x 1 plus x 2 divided by 2. So, this x mean refers to x 1 plus x 1 plus x 2 divided by 2 when R tends to infinity. Let me repeat we are looking we had trying to find out what happens to this when R is large this design equation what happens when R is large? So, I am taking limit r tends to infinity of R plus 1 multiplied by this integral this integral I have written as d x a I have written as x 3 minus R x 3 by R plus 1 denominator the written as r x at x mean which is x mean means x 1 plus x 2 divided by 2 what we say?

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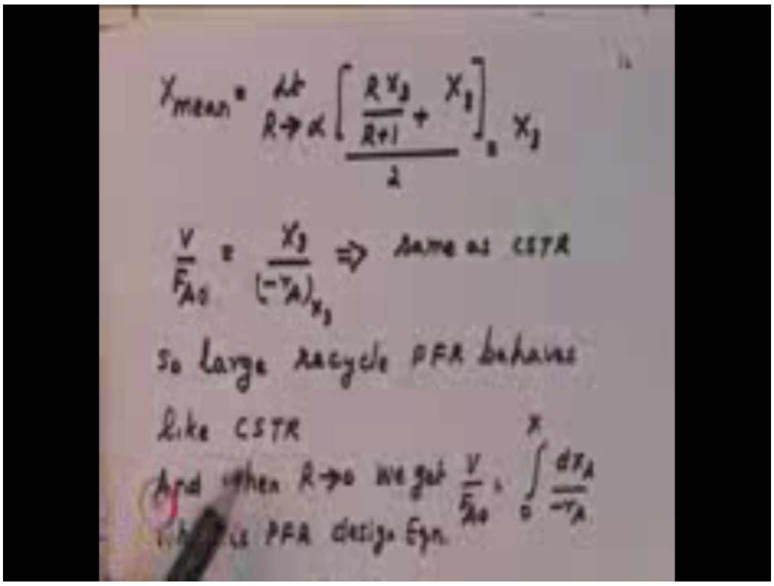

So, let us look at this what, so x mean I have just calculate the value x mean. You can say here the limit as R tends to infinity of this into goes to x 3 you can do it yourself fairly elementary. So, the limit of this as x tends to infinity the x 3. So, that this whole integral now becomes x 3 divided by R value of r A at x 3 what we have saying is this mean is at x 3 and you can see here this whole thing becomes x 3 only. So, numerate becomes x 3 R plus 1 get can cancelled therefore, than this whole thing becomes value of r A at mean value which is x 3 is at clear what we have saying. This limit as the R times to infinity this whole thing becomes the numerated becomes the x 3 and the denominated becomes value of r A at x 3. Because the mean at R times to infinity becomes the x 3, so what are we saying? What we saying is that when R terms to infinity this, whole integral to whole thing actually becomes the equation becomes same as the same C S T R time.

This integral this integral here when R times to infinity by going through this procedure we have shown there it becomes the equation becomes same as the C S T R times when R is large the recycled reactors equations becomes that stead tank. So, what it means that? Stead tank is instance of a plug flow recycle reacted the infinite recycle we infinite recycle that is very it becomes plug flow that is the point that is being made. Now, let us looked at the other instance what happens when R is 0? Then R is 0 x 1 becomes what is x 1? R is 0 x 1 becomes 0 and therefore, this equation becomes that refer p f r which we are talked about. So, we can see the consistency when R is 0 it becomes same as what we have done already when R is infinity becomes another limit of what we already done. So, both cases it tells you that recycle are between plug flow recycle plug flow reactor and stead tank. So, it tells you that recycle are that device which makes you achieve any property between plug flow and mixed flow that is what it is that our definition makes it possible to do this. So, let us plot this and see what it means.

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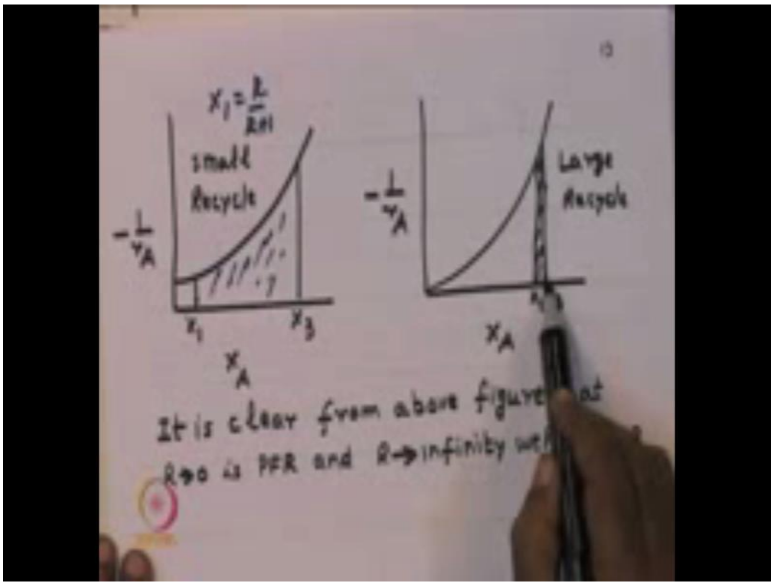

So, when you make a plot of 1 by r A versus x see 1 by added x verses means what it is the property of the reaction. See 1 by r A comes from an experiment, so we this they this data comes from an experiment. So, this curve comes from on the experiment when recycle is small means what? x 1 is what x 1 is R by R plus 1, so x 1 is when r is small then you have this large area when r is large the very small area you can see here. So, r is very large it becomes a point, so you can see when you increase the r when r is 0 it becomes p f r you can see here, when r is infinity it becomes of point which is C S T R you can see understand. So, going from 0 to infinity you are able to get various properties between mixed flow and plug flow. Now, let us just see quickly how does a first order let us see you conduct the first reorder reaction in a recycle plug flow reactor let us say.

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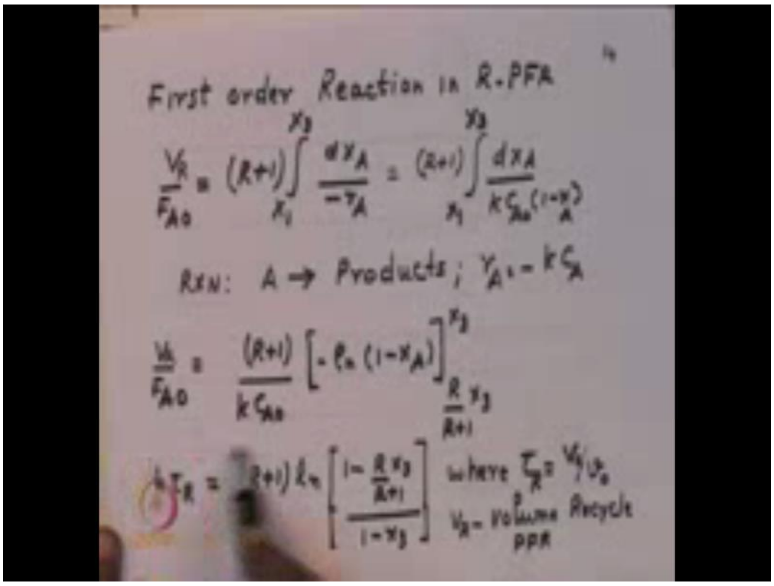

So, what I what is our design equation? So, this minus of r A I will replaced it by a first order representation which is k times C A 0 times 1 minus of x A. So, x 1 is R by R plus 1 x 3, so adjust integrated and put them down. Therefore, our plug flow recycle for a first order reaction which the recycle ratios are this is our integrated form of the design equation when it is an first order reaction beautiful question. But that answered I thought we have already done, but let me do it again. Now, that we ask we I want do this again I will do this here, so your question is what is c A?

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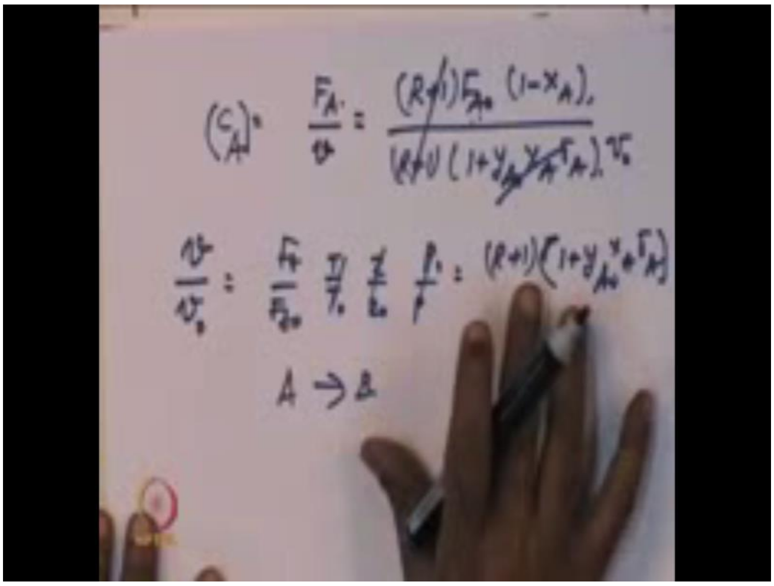

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Basically what is c A? C A is what? F A divided by volumetric flow what is F A? R plus 1 F A 0 into 1 minus of x a what is v? Let us see let us gas base reaction is v by v 0 is Ft is F T by 0 T by T 0 Z by Z 0 P 0 by P and we now, show just now all these if it is 1 this is equal to R plus 1 into what it we show R plus 1 into 1 plus y a is 0 x a time we have shown. Just now if you recall that means the denominate you will this term R plus 1 times 1 plus y a 0 x a times delta A. Now I have taken the instance of a going to products therefore, all these are not there this cancels of therefore, it becomes C A 0 times 1 minus of x a v becomes v 0 times. This at presence cancels all this becomes 1 therefore, is it becomes C A 0 times 1 minus of x A. On other words inside the recycle loop the concentration dependence of x does not change. Because the formulation we have taken is like that that is the importance of the formulation. That formulation in this formulation the form of the C A is to remains the same that is the advantage.

If it take any other formulation then it is little bit maxi is little maxi is at still give is the same correct result only, but this formulation make it elegant. So, what we saying what we saying is that if you have a recycle reactor then the integrate representation for a first order reaction is given by this. So, which means what? If we have a given a recycle ratio see here what are the unknowns? k is the unknown R is the unknown x is the unknown tau R is the unknown. Now, out of 4 if you given 3 you can get calculate the 4th that is the kind of we can have a design problem, the operation problem. What are problem operant appropriately you will put a numbers a to find out what the numbers that you have design it. Now, in all to understand the importance of recycle reactor in a larger context let us look at small example. The example have taken is an n tanks sequence.

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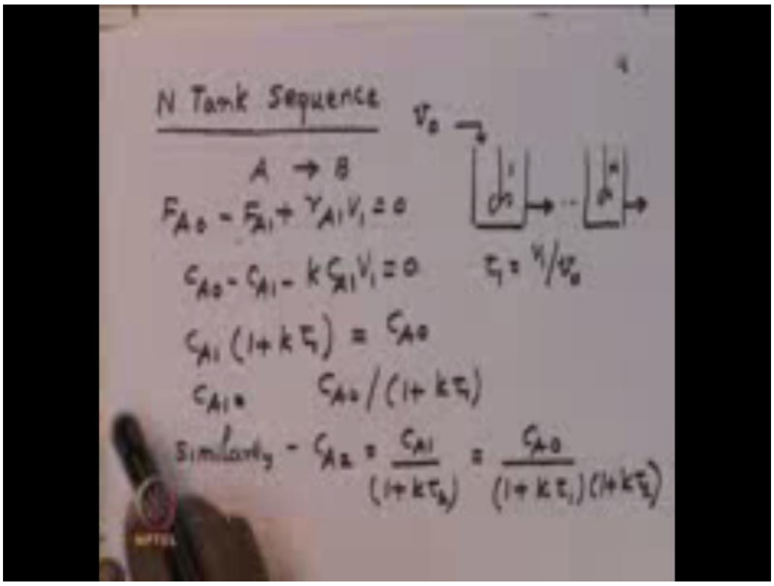

So, what is an n tank sequence? You have stead tanks 1 to 1, 1 to n for in which have taken a reaction which is first order have taken the which is r A is taken as minus k times c A. a goes to products therefore, there is no volume change for which have written the material balance input output generation equal to 0. So, the, I have put the generation term here the C A 1 becomes C A 0 divided by to 1 plus k tau 1. Similarly, C A 2 equal to C A 0 divided by this then just take this analysis forward the little, because it is important.

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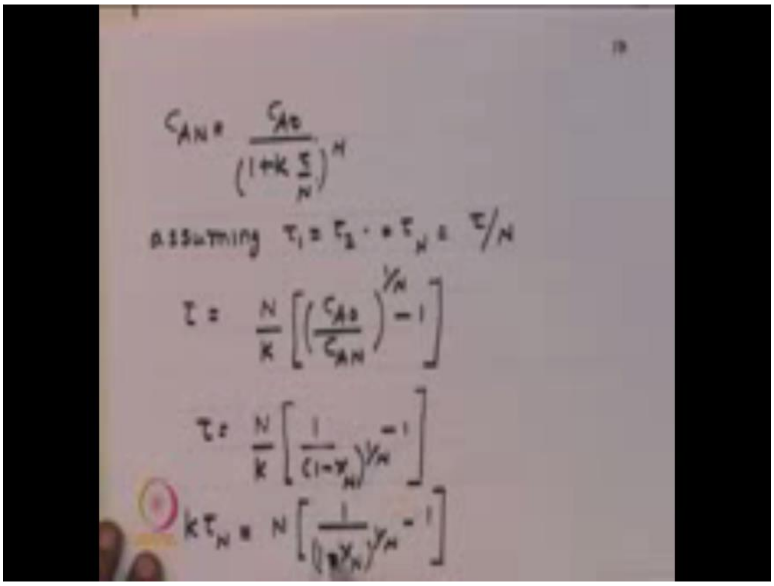

What we saying is that C A N becomes C A 0 divided by k tau by n to the power of n how does it come? It comes from here C A N from here C A N becomes like this number of terms tau 1 tau 2 there all considered equal. Equal to tau divided to n that is in the assumption therefore, you get this kind out to appreciate. That means the value of concentration at the end of the nth tank is C A 0 divided by this term. Now, we can do this manipulation have just elementary manipulation. I have just put this in this form in this form where k times tau and becomes n times 1 minus x to the power of x n to the power of 1 by n minus. It is an very elementary manipulation have done, because C A 0 C A n is 1 minus x to the power n is common sense. Therefore, what it gives you is that a n tank sequence can n tanks sequence the conversion at the end of the n th tank is related to system parameters like this.

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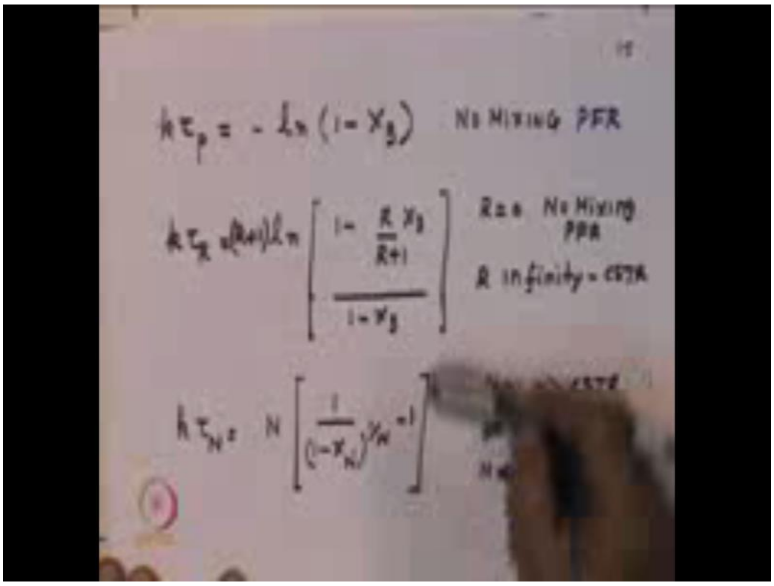

Now, let me just put this in the context of our interest what is our interest? Our interest is to understand the 3 types of equipment we are learn, so far we have learned this is P F R. We just now, setup the equation for an recycle we setup this is the recycle reactor. Now, just now, we talked about in n tank sequence where we got this relationship which has put down here. So, you have a case of P F R there is no mixing you have case of the recycle reactor which R as the recycle ratio. Here case of an n tank sequence where you have k tau n is a parameter k tau r is the parametric here k tau p as the parametric here.

Now, what as change from here to here? From here to hear what does change is that the recycle we have put in the recycle what does change from here to here? Instant of no mixing case this infinite mixing case is than instance of n tank n term infinity the huge amount of mixing or when the number of terms is small it is intermediate mixing. See when you go to n equal to infinity we are shown it is same as a P F R we are show n that when r equal to 0 we say it is same as the P F R. So, R equal to 0 is equivalent n equal to infinity or in both cases R is the measure of mixing n is the measure of mixing.

Because n is able to give you property between plug flow to mixed flow when n is when n is infinity it is plug flow when n is 0. It is a single stead tank infinite mixing. So, what means is that when you go from a P F R to a recycle reacted to an n tank sequence you are able to take in to account various grades of mixing that can occur in your equipment. Which is what happens in the real life in real life your are it deal with mixing it may not be perfect it may be in perfect. So, that recycled reactor or value of R, R as the parameter and similarly, and n as the parameter is the way of Accounting for non idealities due to mixing in your equipment. So, to summarize this let us just look at an example. Let us say you have you have an arbitrary vessel.

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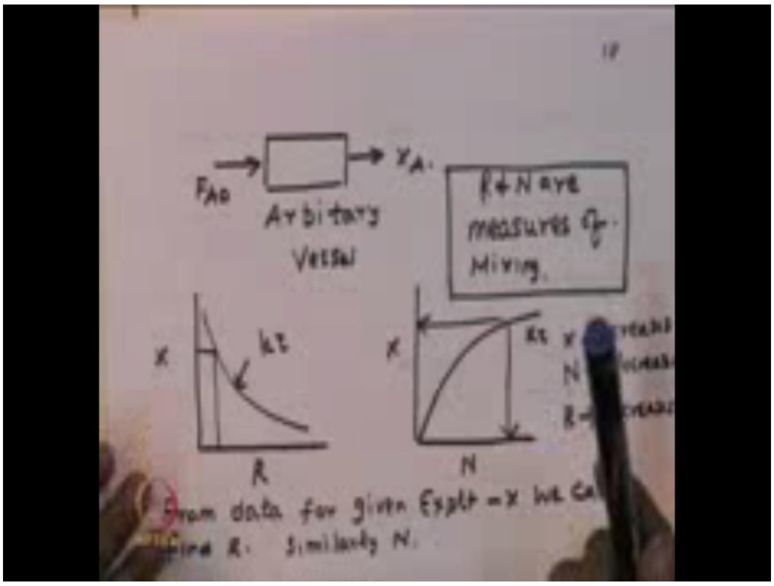

What is the arbitrary vessel? We do not know what it is, so we have doing an experiment then which you putting the F A 0 you get a conversion x A. I ask you know what is visited plug flow reactor what is we do know. What we do now, we simply make a plot now we can make a plotter this function we can make a plotter this function. So, I have done this here I will make up plot this function recycled reactor function here and made plotter to the n tank sequence here. So, this is function relating n tank sequence this is for the recycle reactor as x versus R as R increases which means conversion decreases.

As an R increase that means R is 0 is P F R, R infinity C S T R conversion will keep decreasing. N tank sequence x n infinity is the P F R, so x increase. So, value of R and value of n are measure of mixing suppose you get the conversion x A, it your experiment. So, you will read out the value of R from here you will read out the value n from here. That means this arbitrary vessel can be describe by a value of R, R by value of n and in both in that case if it is value if n it bit describe this function. If it is value of R it bit describe by this function.

So, which means we have a way of describing real life problems. It is no longer idealistic a real life problem whatever be the arbitrary system that you have when able to related to some a fundamental may have understanding react. So, that is the advantage of these 2 equations. An arbitrary system can be understood in terms of recycled ratio can be understood in terms of number of times. Of course, we should know this system parameters which is k tau r and k tau n which comes from independent measurement. Having set this let us see what is the kind of use to which we can put the recycle reactor to do?

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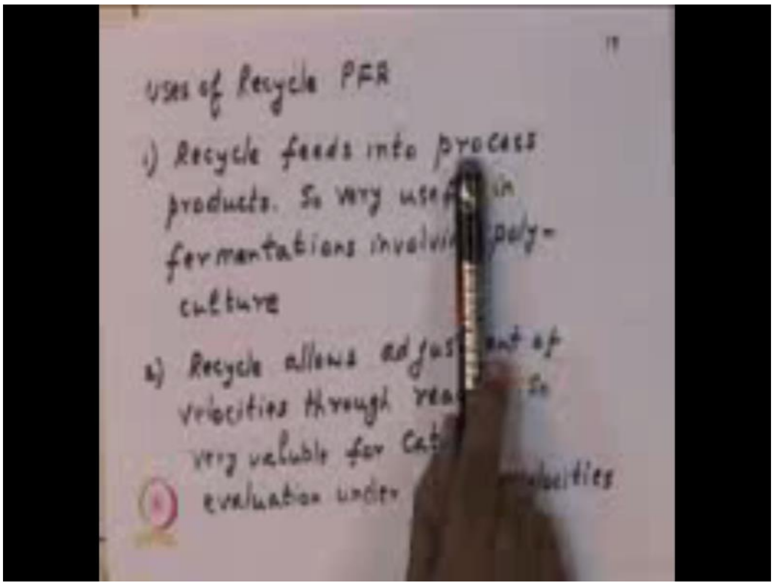

So, now, if you look at recycle reactor what it says is recycle reactor feeds process products into the process see what is it do? It put some products back it the process where is the advantage? The advantage is reaction where you required to food products into the feed otherwise reaction does not go forward that are instance auto catalyst reaction. The good example all biological reactions required product should be put into the feed and therefore, therefore, it is very useful in biological reactions. Now, there is another important base it allows adjustments of velocities through the reactor when you doing an experiment in the or laboratory development you can do your experiment various velocities. Therefore, you can see how good your catalyst is being able to stand the velocities of the industrial use. Therefore, you can appropriately design it for the kind of industrial operation that we are going to have of which I mentioned little earlier is that.

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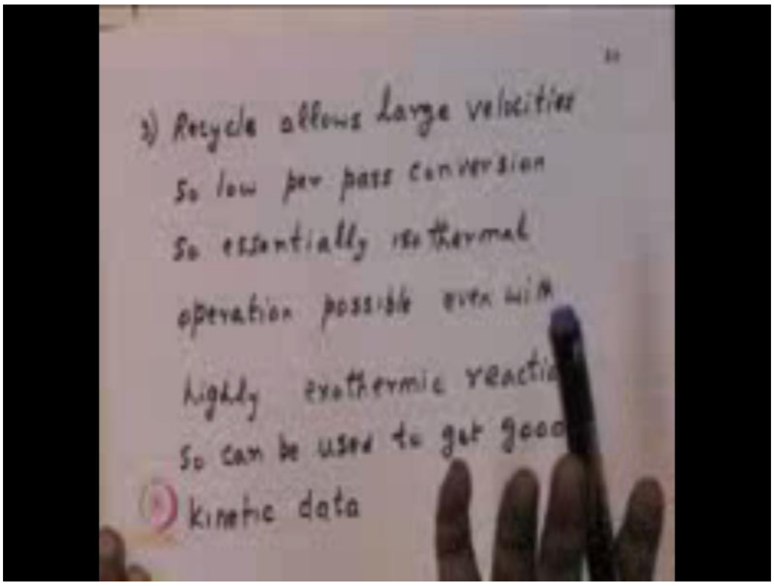

See it allows you to do a very low per pass conversion when you very large recycles per pass conversion are quite low which means essentially isothermal operation becomes possible. And therefore, you can do kinetic measurement in a recycle reactor. And therefore, you will find in catalyst development for example, recycle reactor become particularly useful. Because you are able to get very good can cat measurements and essentially isothermal operation we memo very highly exothermic reaction. But, because of very large recycle per pass conversion are, so low that you able to get isothermal data. So, these are the 3 important advantages that you will have with the recycle reactors.

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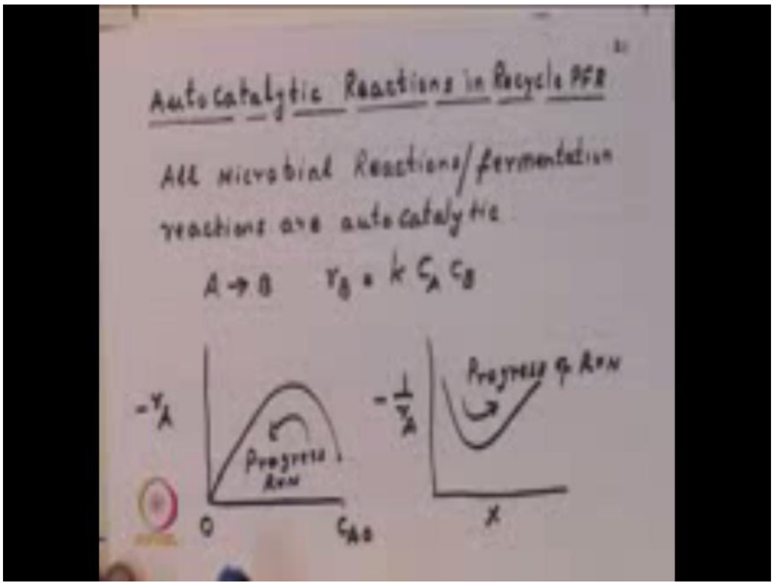

Having set this the real applications that you will see I mean we all I am seen is that in auto catalytic reactions of recycle reacts. So, when you make the plot it was the reaction a goes to B was the rate function looks like this when you plot r A versus, versus x r concentration if its product like this. The progress reaction looks like this. The important point is auto catalytic reactions show a maxima in reaction rate this is the most important thing they should the maxi mine reaction rate what is the show maxima? Because as the products accumulate you will find that they reaction goes up and then comes down. So, this features of maxi mine reaction rate or minimum this kind of plot is useful in design. Because if you going to if you design to system at this point you reaction equipment volumes are very low highest, because the reaction rates are very high. So, that is an advantage, but is an same time they disadvantage that the conversion may not be high enough is it where you should like this which becomes important in sign having set this. Let us let us just look at this in some detail.

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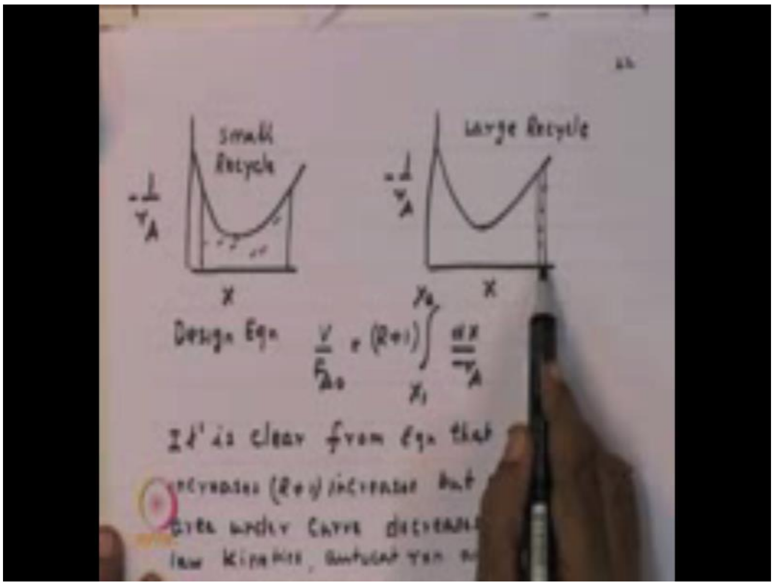

This is 1 by r A versus x 1 by r A versus x now, this is the recycle reactor this is the this is the point of maxi mine reaction rate. Now, when you have a small recycle small recycle large recycle now, if I ask you what is the best value of recycle ratio you would employee? Our answer would be design if look at this function this function R plus 1 increases as R increases. But this function here d x by minus of r A what happens to this function d x by minus of r A. This you can see this function and here you can see it decreases and increases.

So, on other word this is the increasing function, but it has the decreasing in increasing function therefore, there is an optima. There is an optima that means recycled reactor employed in auto catalytic reactions there is an optimal value of recycle ratio which gives in the minimum volume. Now if you ask what is that minimum volume of course, we can set up this equation put the appropriate functions here we will able to in a find out to minimum to occurs. But, there are mathematical techniques by which you can show I am not shown it here it is an exercise in your problem sheet you can show this result.

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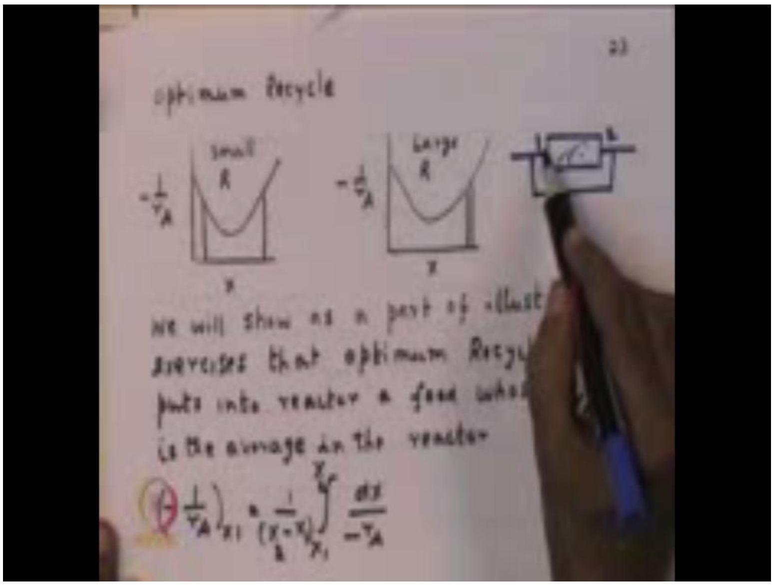

What result is that optimum recycle that optimum exist it come by looking at the shape of this curve you can tell optimum exist what is the optima? You should be able to show, but you have not done it here it is an exercise n. That the optimum recycle puts into the reaction equipment that mean optimum recycle the optimum recycle puts into position 1 this position 1 a feed you puts the feed into the position 1 which is h the satisfied this relationship what is the relationship? The optimum recycle that means the reaction rate at this point it is 1 by r A at x 1, 1 by r A in x 1 is the average of this whole thing what is this term? d x by minus of r A x 1 to x 2 divided by x 2 minus of x 1 this is the average value of this rate over that interval.

The right hand side integral x 1 to x 2 d x by minus r A divided by x 2 minus of x 1 is the average value of this function in that interval x 2 to x 1 is this which means what? The optimum recycle puts into the reactor a feed whose 1 by r A at x 1, 1 by r A x 1 is that mean in the range x 1 to x 2 we will show the mathematically also. But since takes little while a put it an exercise have not shown into here, but we will do it here an exercise as we go along. But it is understood in physically what is important to understand the optimum means what you have choosing a value of r such that the reaction rate measured as 1 by r A at x 1 is the average that we would the quantum in the whole equipment. So, in all that optimum recycle exist and the optimum recycle is that can be form mathematically or graphically as was possible.

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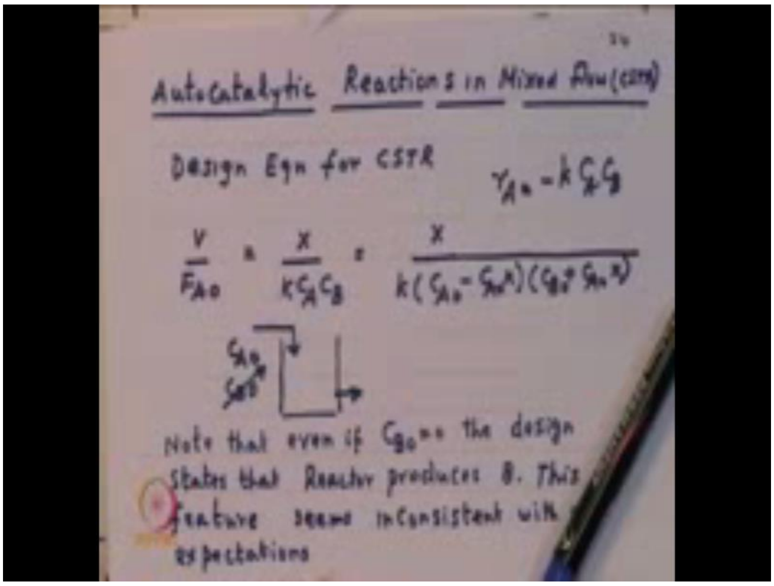

Now, there are some interesting issues that happens in a auto catalytic reactions something that some of as may have appreciated. But I thought its importance to draw attention to this. So, when you write the design equation for C S T R in which in auto catalytic reaction is taking place out design equation look like this v by F A 0 is equal to x by minus of r A r a I have taken our r A value is minus of k times C A c B this what I have substituted with the minus f to come to plus sign. Now, replace C A and c B using are conversional strike to metric.

Now, if we look at this equation carefully what did say is if I specify a conversion x that I want straight away you will able to find the sizes of the equipment. Now, the way if formulated here it does not say that the feed this feed should contain c B 0 it says c B 0 can be 0. Because this result tells us that it does not matter c B 0 need not be present in the feed what we have saying is that if even a auto catalytic reaction being conducted in a C S T R as per the design equation that we have written c B 0 can be 0. That means it is not necessary for you to put the product in the feed even then the reaction it would occur.

And there the finite value of x you will calculate for an for which the volume can be specified. On other words it seems a little difficult to understand why is it auto catalytic degree action which should not take place if there is no product in the feed out design equation seems to a just that have reaction will occur. So, there is appears should be some inconsistency in the way we have formulated are problem. So, we needs to sort out this on at are to understand why this kind of inconsistent it appears to in consistent. So, you want to understand how do we understand this? To understand this what we have done I have written the unstudied equations. So, what happens in the unstudied state once we understand the unstudied state we can understand the studied state after what is steady state? After very long time or the unstudied state this the studied state is the at tight.

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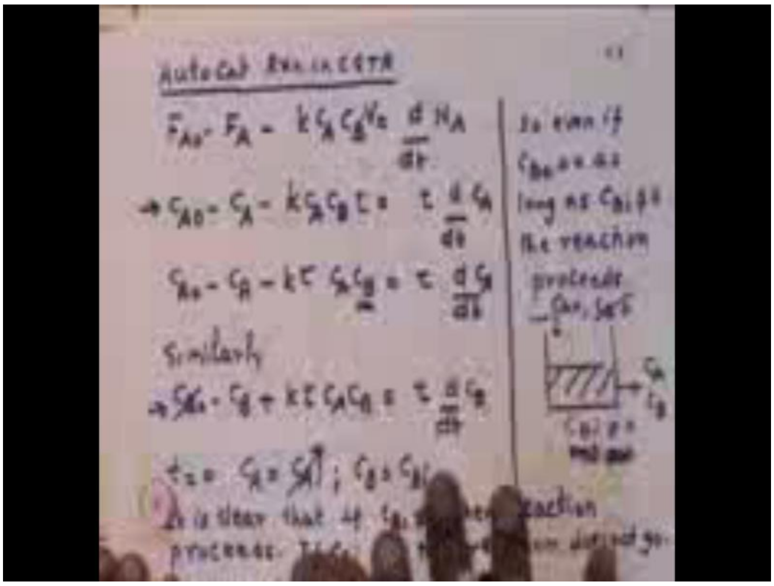

So, what is the equation it says input output generation equal to accumulation. So, for component a component b have be written for component a is for component a this is for component b look carefully at the 2 equations. So, I am saying t equal to 0 C A equal to C A i c B equal to c B i. Let us let us look at this situations when C A c B i 0 what happens when c B i is finite what happens what is c B i and C A i? c B i and C A i is what is in this equipment when we started the reactor from a millionaires ago as an example long time back. But today, we are running it with C A c equal to 0 somewhere, but c B 0 is 0, but when we started this reactor sometimes back in the in the past there was c B i there was C A i we do not know what it was let us see what might happen during the start time. Let us say for case 1 C A i is 0, so c i and c B i is not zero c i is 0, but c B i is not zero. Now, what happens to this function c A? At time t equal to 0 C A is 0 therefore, the reaction rate is 0.

But C A is coming in therefore, after some times C A would become in non zero that means you c B i was finite the reaction would started to take place once C A starts coming into the process. As per equation 1 you can see here if input output generation accumulation when you started the reactor c B i is finite C A is 0, but c B i is not zero therefore, this term it was 0 when we at 0 time, but a little while later C A as started coming in therefore, that is C A in the reactor therefore, this term is finite. Therefore, this reaction would gone this reaction would talk place is at clear what we are saying? This, this reaction would take place, because after at time t 0 plus this term is finite and therefore, the reaction would take place therefore, this reaction can be integrated. This equation also can be integrated. And therefore, it will tell you how long it will take to studied state. Studied c is here what we are saying is that continuous put in c B 0 see what happens? Please is an important question please is the very important question let me answer the question.

See whenever we have an equipment we would start of the equipment sometime in the past we after all we start the process in the someday. At the past at that day when you first start that process, if you had put c B i into n tank what did says is that that c B i would be active how are small it may be? So that this C A times c B becomes finite after time 0 plus therefore, this reaction takes off therefore, this reaction takes off. Therefore, this 2 equation 1 and 2 can be integrated and it tells you how long, it will take to its studied state? At that studied state it may not recognize C A i and c B i it we get studied state values as describe by our studied equation that are we this are the studied study equation. So, the studied state equation to will describe our studied state problem, but this equation here will tell you how long you would taken to which the studied state. And other words what we are saying is that if you have an auto catalytic reaction as long as you have c B i is a non zero when you start that process. Sometime in the history of that it is enough as for as the reactor to reach the studied state value in which your products are positive.

Student: Sir So, the reaction is not there only when a something like in the C A will c b sir c B i is the not 0 what.

C A is there C A is coming C A like this.

Student: C A coming C A what about the react would take.

Reaction would take place that is what it is says. All it says is the time that is required to reach studies state will be determine the value of c B i and C A i C A i yes in, in his during the history.

Student: Sir you another history.

So, that means the day we start up the are the reactor you are put in c B i, but you do not have you to put it every day once a reactor is started it as to be it is not required. But having set this I want to remain you say after all we do not want to wait for a very long time to reach the steady state after all the process as to run it as to steady state quickly. So, for that to happen you may add c B i every day, so that is the decision that you will take. But what our, I mean our formulation tell us use that our studied state will not depend upon for depend upon the quantity on c B i and C A i studied state is independent of the choice of the initial state. So, what, what you trying to point out here is that have to stop here then studied state that you will teach for auto catalytic reaction. You do not require c B i and C A i in the process is not required it is required only during start up. I will stop there.