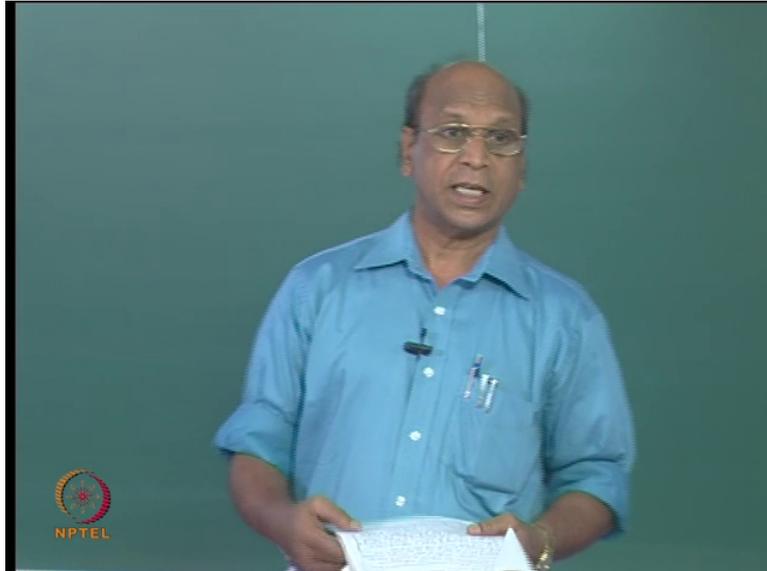


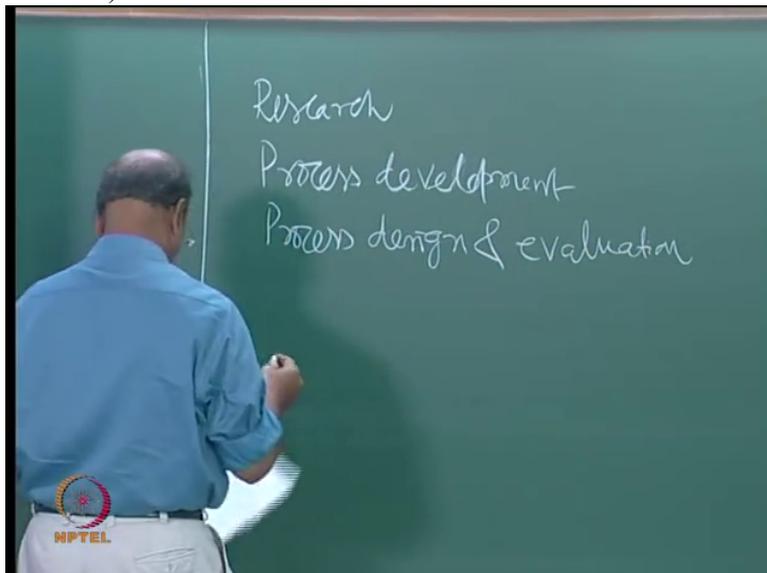
Chemical Reaction Engineering 1 (Homogeneous Reactors)
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 04
What is Chemical Engineering Part 2

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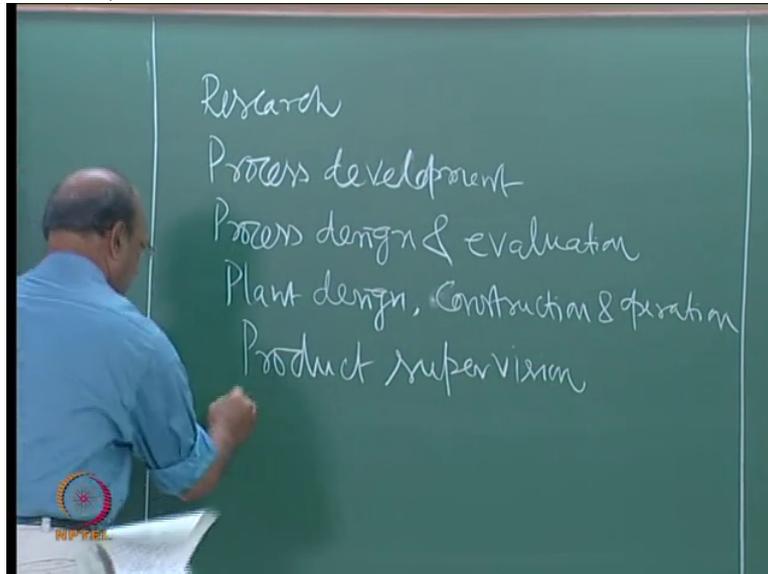
So yesterday's questions I have written there. I think what does a chemical engineer do, and below that we have written research, and yeah, research we have discussed. And next one was process development, I think I better write for continuity sake, research, process, development, process design and evaluation,

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yeah and then we have plant design, I have written plant design, construction and operation, yeah, operation then product supervision

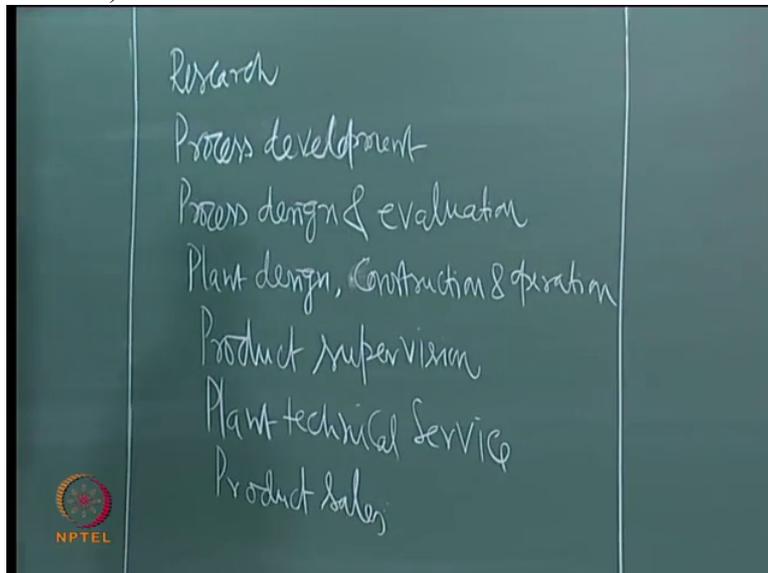
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and technical service, product sales.

Ok,

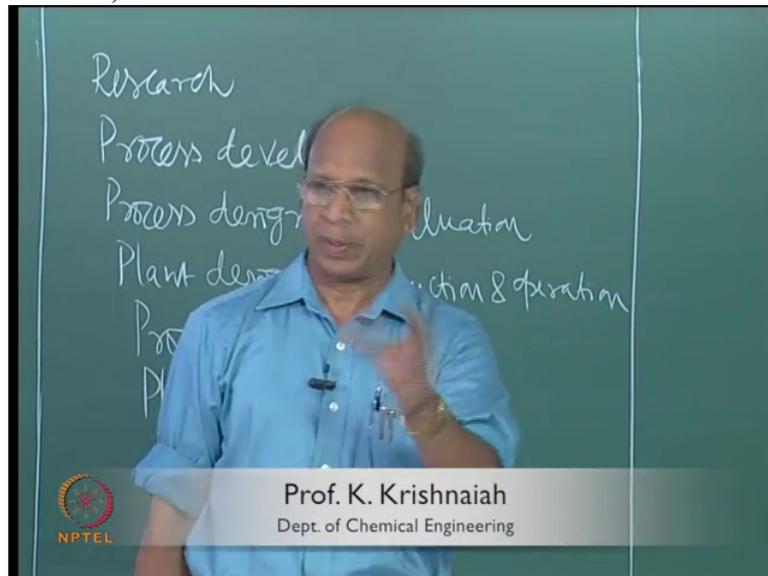
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these are the things we have been discussing. I think quickly I have to go through, and research we have told, three types you know, this is basic research, exploratory research, I think you have to remember these words, I think you have to make a note of that. And third one is process research. In process research what do we do?

In exploratory research

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we will try to find out which catalyst is better and all that. In basic research, how the catalyst is working, how the molecules are moving, where they are getting adsorbed, why should they get adsorbed there only, why cannot go somewhere else? All that basic questions are answered in the basic research.

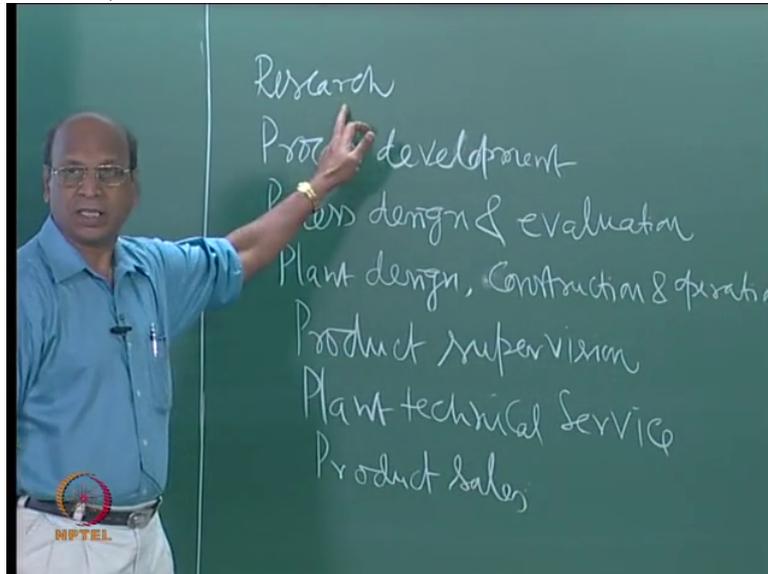
And exploratory research, particularly in industry when you do not have much time, you try, even ammonia 20000 catalysts it seems they have tried. I will send you one beautiful, you have to collect ids of all the, you are doing that, yeah, so I will send you some information regarding to one paper today, I think the title is Which saved the World or something

So it is about ammonia process where there was a chemist who has patiently tried 20000 catalysts of different combination. Finally they could come up with this, you know, iron with some mixed metals. Otherwise originally it is osmium and something else where Haber actually did it. But that is not practical.

So that is why Haber also got Nobel Prize for what he did. He proved that it could be possible to produce at, you know large quantities and the other person Bosch, Karl Bosch, he also got Nobel Prize. And how much work he has done is beautifully written in that paper. I will show it to you. You will be proud of, proud to be chemical engineer if you read that.

How many things one has to do? Even this, all these things I have written there, you can be lifelong a research chemical engineer.

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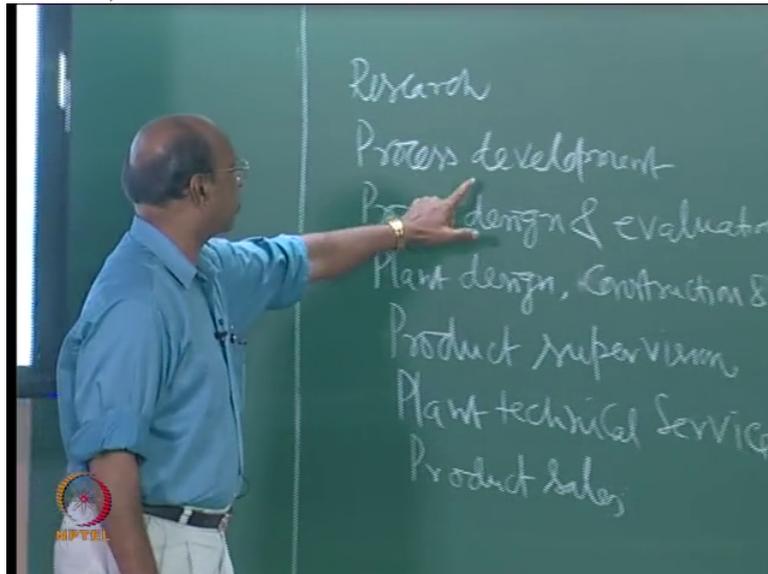


Ok. That is your profession. So, this is what chemical engineers do means you are not going to all these things. If you are doing all these things you cannot do anything. Ok. Because I think you know you are not expert in anything.

So that is why you can choose that if you are interested in research, if your brain is very sharp and if you want to put your brain always under sharp conditions, then this is the best one. Because always it thinks that something new, something new, something new, right.

And then this

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process development. Process development, I told you, once you have this process design, on every small scale, may be 1 k g in the laboratory, and then you can try that various equipment will also be there under process design where as in exploratory design, the exploratory research we are only concentrating on the one aspect, catalyst alone.

So like that, for example it is not catalyst. In some other process, may be how the bubbles are moving in a bubble column reactor, Ok. So all your research is only on the bubbles. What kind of bubbles you have? How do you want? Normally we would like to, all of us enjoy very, very spherical bubbles. But unfortunately if you look at, you know, the aquarium, all of them are not spherical bubbles.

Some will be like this, hat shaped. Some will be slugs, if the diameter is very small. Some will be very beautiful spherical bubbles. So, I mean all chemical engineers should fall in love with only spherical bubbles. Why? Easy for what? 0:05:20.5

(Professor – student conversation starts)

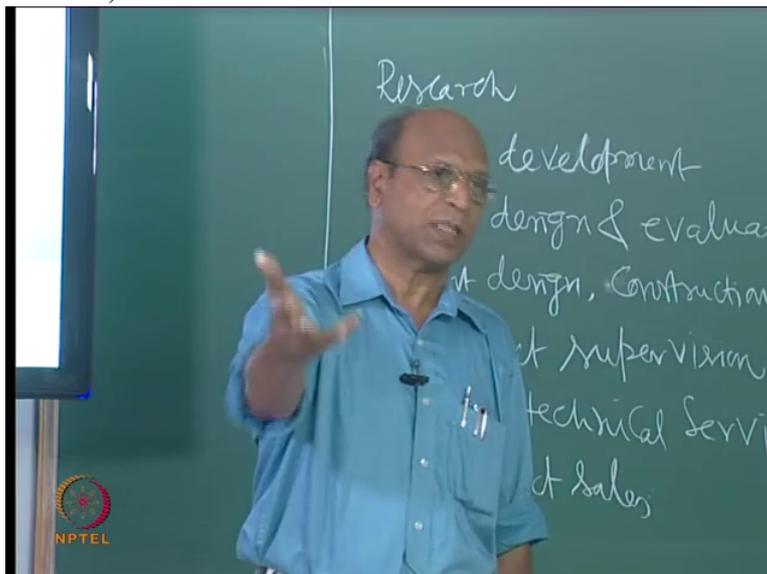
Student: Easy for measurement.

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Professor: Yeah, easy for measurement. If you are able to measure the diameter, then you can find what is the

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surface area. And we know that in all these processes, surface area is very important. Because all these, whenever you have heterogeneous system it is the interfacial area or surface area which is more important. So that is why.

(Professor – student conversation ends)

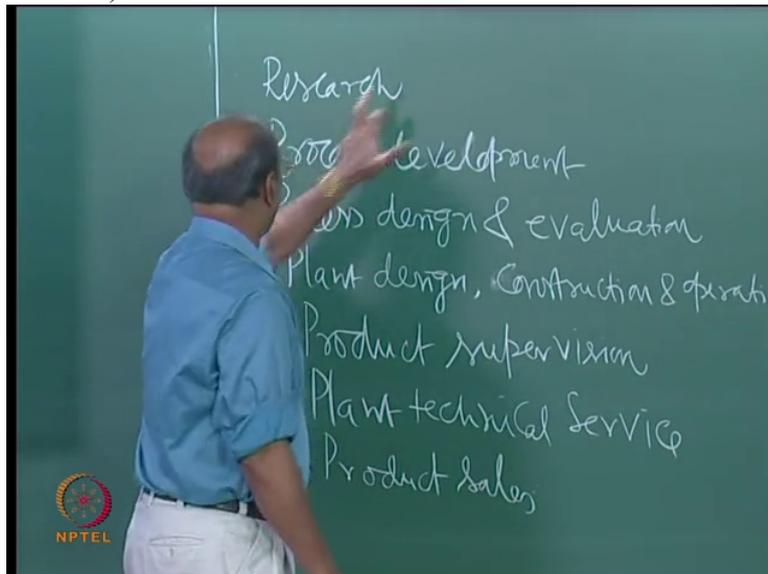
That is why spherical bubbles are very easy to, but unfortunately life is not that easy. So that is why you have to live with slug shaped bubbles, and also hat shaped bubbles and also you know some spherical bubbles and also not only that, some large bubbles, some small bubbles

all combinations. That is why we say bubble size distribution. And lifelong you can work only on these bubbles. Drops. Ok.

Particles are not that difficult and you will never get a spherical particle. And always in the class we draw only spherical particles and then write what is entering, what is leaving through this particle and all that. But you will never get a very beautiful spherical particle except when you are playing these, you know, marbles. Those particles are beautiful particles. No chemical industry can produce that kind of particles for catalysts.

Ok that is why most of the time they go for, the cylindrical particles, easy to produce, right. So that is why in this,

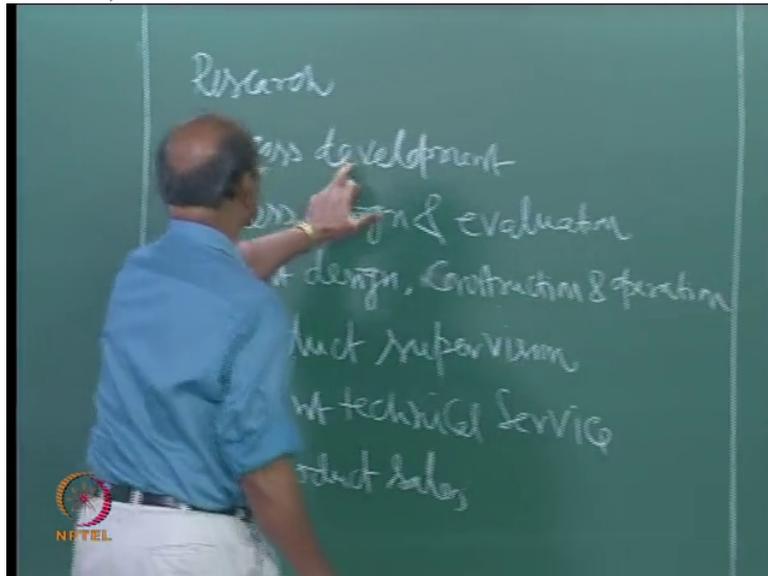
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process design, process research when you are talking we are talking about small scale getting as much information as possible starting from heat exchangers if there are, and small condensers if you want to have distillation and condensation. So all kinds of things you will have.

Then come to this level,

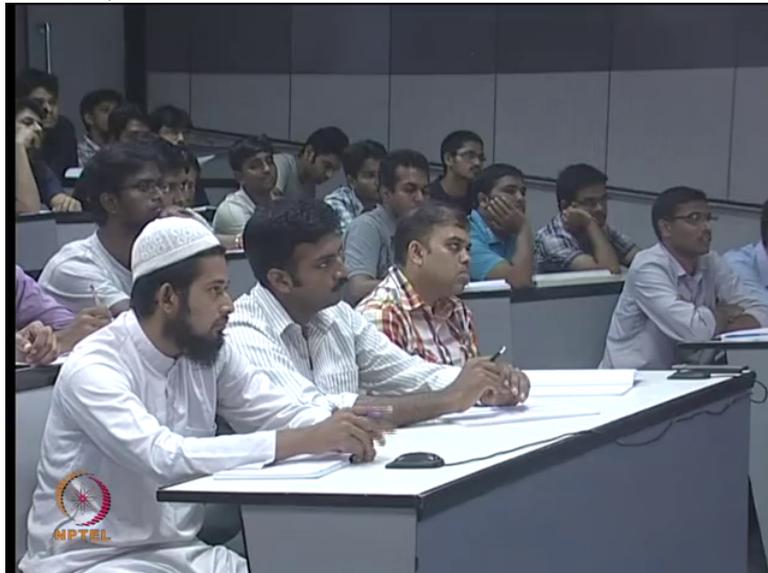
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process development. In process development you focus on pilot plants. Why should we do that? I told you already. That because I do not know that whether, straightaway from process research to industrial scale when I go, I am not confident whether things will work or not, right? Most of the times it won't work, right?

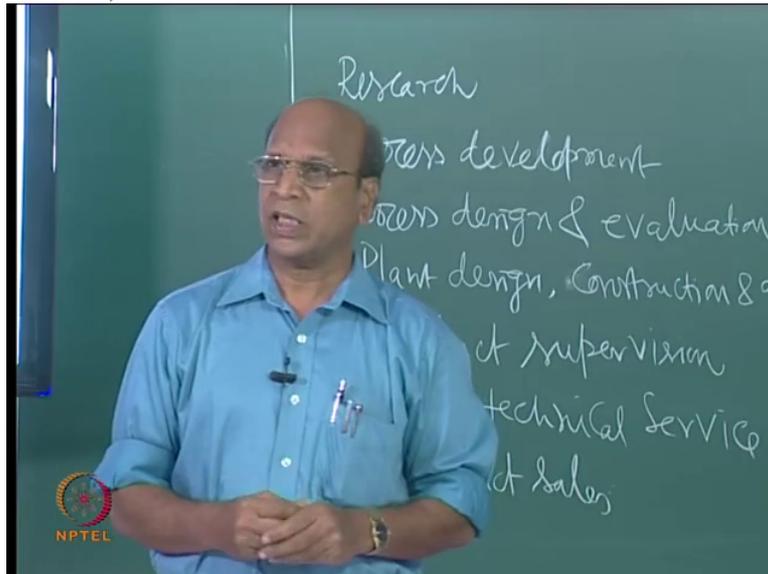
The reason is all the chemical engineering processes

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are, I mean most of them are only heterogeneous systems.

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In heterogeneous systems either you have bubbles, drops or particles. In fact, if you understand bubbles, drops and particles you understand whole chemical engineering, right.

Any system you see, you will have either bubbles or particles or drops. And all of them behave differently. The way bubble behaves when it is moving is slightly different from the way the drop moves. And when compared to these two, with particles, the particles behave in a different way. So that is why that behavior is very important.

Inside the reactor how they are moving, right? So that is why you have to get that pilot plant level, you should have studied already in your process design course, I think you should have some process design course, right, where, process design and economics, process

(Professor – student conversation starts)

Student: Equipment design

Professor: Equipment design is different, where you calculate you know the total time required for complete money recovery once you design the plant and try to operate

Student: Plant design and...

Professor: Process and....plant design and process economics, yeah. So I think you should have. You know different universities have a with a different name.

(Professor – student conversation ends)

So in all that also, always we talk about pilot plants. Pilot plants are very, very costly. If you are able to really predict, or nowadays with computers if you are able to simulate the entire pilot plant and able to see that what are problems you may face at pilot plant scale, that is why C F D will help you, Ok.

So with the latest softwares, you can do that also, you know, to avoid the, the actual construction of pilot plant and collecting data, instead of that if you are able to create the pilot plant on computer and then try to simulate. Simulation means trying various parameters. And then every time recording what is happening at the end of the simulation.

Because your target is to produce maximum amount of material with minimum amount of cost. That is what is whole chemical engineering process, right. So that is why this pilot plant scale we cannot avoid. We have to go through that, unless you, I think, you know every one of you, that is what I told you no, some of you would have told that chemical engineering is already saturated. It is not saturated. Only his brain is saturated. He is not able to see the problem.

So if you make your brain sharp you can always try to find out some improvement. In fact in our department, now recently the trend changed last 5, 6 years but always what we have been doing in our department for the last 30-40 years is that how to improve the performance of equipment. It may be heat exchanger; it may be a distillation column. It may be a reactor

Ok and in reactors how many kind of reactors you can see. Basically we can divide them only into three parts, Ok, ideal reactor. But if you look at the reactors, you have fluidized bed, you have packed bed, we have moving beds and we have bubble columns, right and we have again, you know liquid-liquid reactor what is that mixed/mixer settlers, mixed/mixer settlers are also reactors, Ok and you have rotary kilns, right but rotary kiln can also be imagined in one of these perfect, I mean, ideal reactors, Ok but all these reactors are there.

That is why lifelong people will work only on the improvement of rotary kiln. It is not that easy. That in very slowly, sluggishly move, very, very slowly. You know the speed is only 5 r p m or less than 5 r p m. You cannot put 100 r p m, Ok. That is only for fans and all that. But

you cannot. So the moment you put 100 r p m, you know that won't act as a reactor. Ok and lifelong people can work only on that.

Or only on fluidized bed or only on packed bed or only on slurry reactor. Slurry reactor has 3 phases, gas, liquid and solid like your production of hydrogen, hydrogenation of vegetable oils; you know Dalda and all that. So you have catalyst as a Raney nickel catalyst and liquid as oil, unsaturated oil and hydrogen as the gas. You have 3 phases.

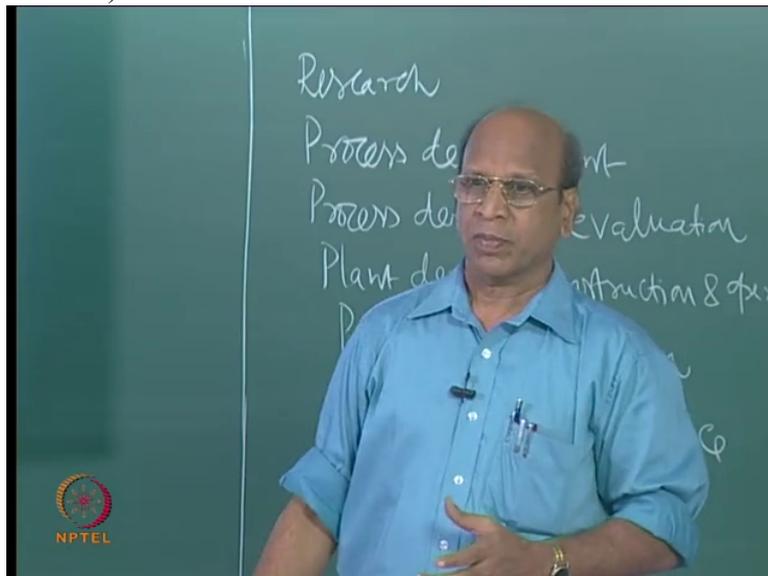
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Lifelong people will work only there.

Ok so that is why you have to choose one of the steps and then try to find out where your interest is. That is why, what does the chemical engineer do means it is not he is doing all these.

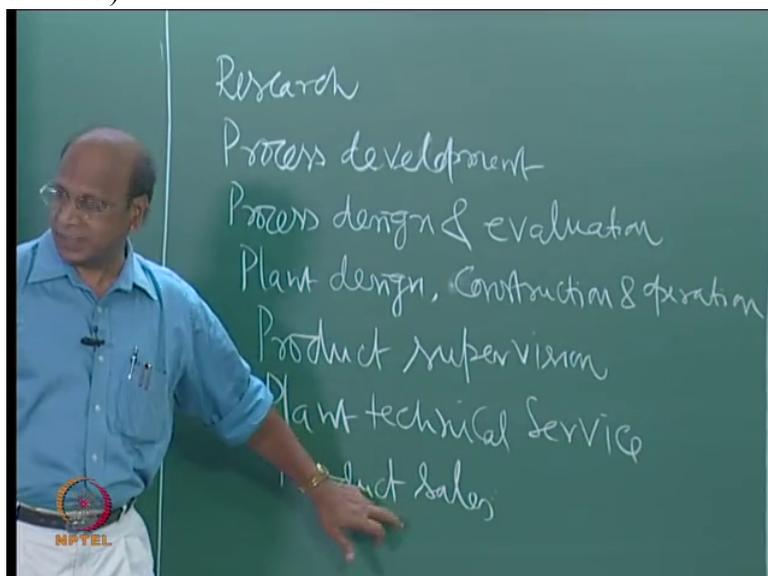
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You have to choose either that or this or this or the last.

I think this is the easiest one, Ok. Because

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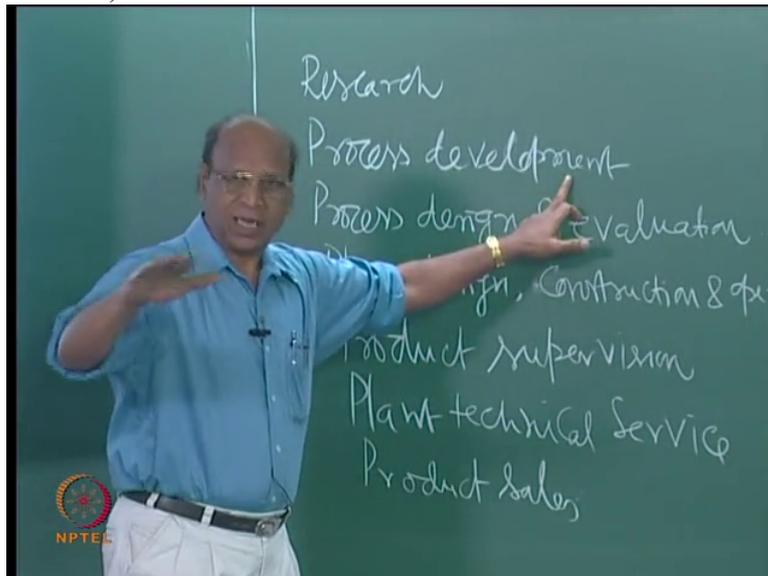
this is what they do in M B A, management, Ok, product sales. Ok you can go and talk to them happily in English but you should have good English, Ok to convince them. Even I think you can say right, wrong as right, so by convincing them then they will buy something.

That is what, you know, people come and then sell soaps and powder and all that. I pity them most of the time. When they come, immediately you will say go away, in the houses when

they come, Saturdays, Sundays I mean it is very unfortunate, still we do that. It is very bad. So this is what the easiest one, without brain you can do this, but only with mouth, talking.

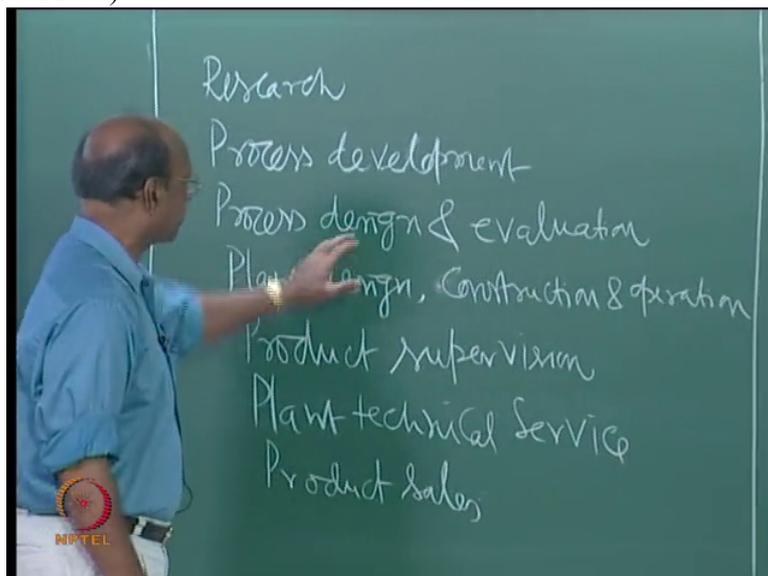
All other things definitely they need lot of thinking, and lot of knowledge from chemical engineering. So Ok, process development is pilot plant scale,

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that you can remember that. Process development means pilot plant scale and at the end of that what you normally have is,

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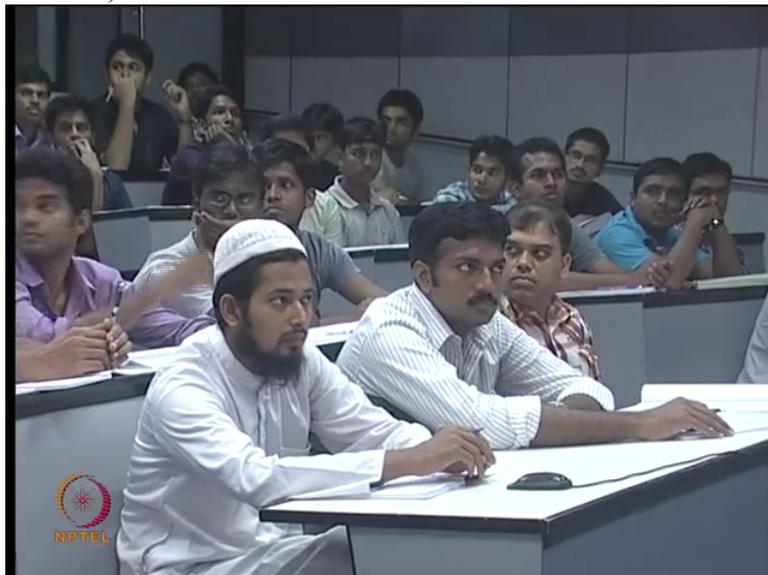


that lots of data. Lots of data on whatever doubts you have.

For example fluidized beds are terrible reactors. Even now we do not have good, I mean procedures to design a fluidized bed reactor. You know what is the problem? You have the solid particles, gas will go and the particles will behave in a different way, gas also behaves in a different way and gas creates large bubbles inside the solids and you know diameter can be 3 meter, 4 meter like a big well. 3 meter, 4 meter diameter is not small. Ok.

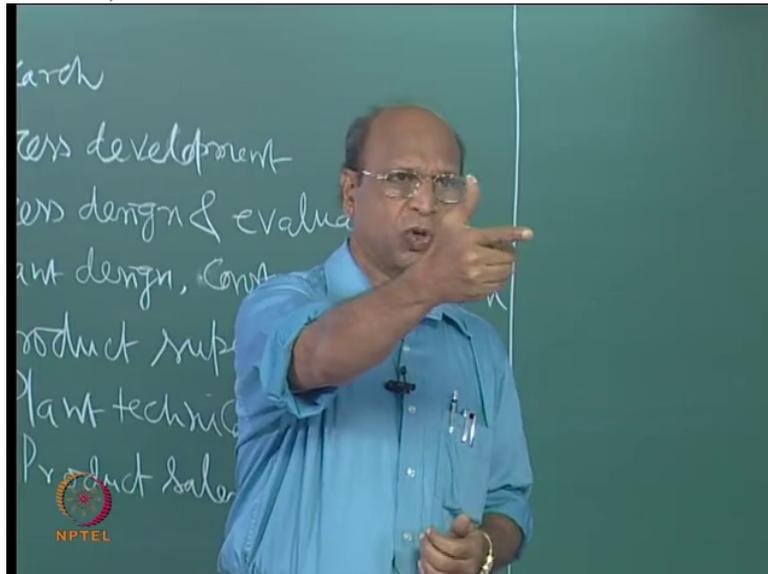
So under those conditions you have tons and tons of solids there. And you have to send gas to fluidize. I hope all of you know what is fluidization, right? All of you have studied this in fluid mechanics, I am sorry for chemistry people but I think chemistry people have to slightly work more, that is you know catalyst. Particularly I think in catalyst, how many people are there chemistry background, how many people are chemical engineering background? Four are there, right?

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Chaya, you are Chaya, right?

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You are chemistry,

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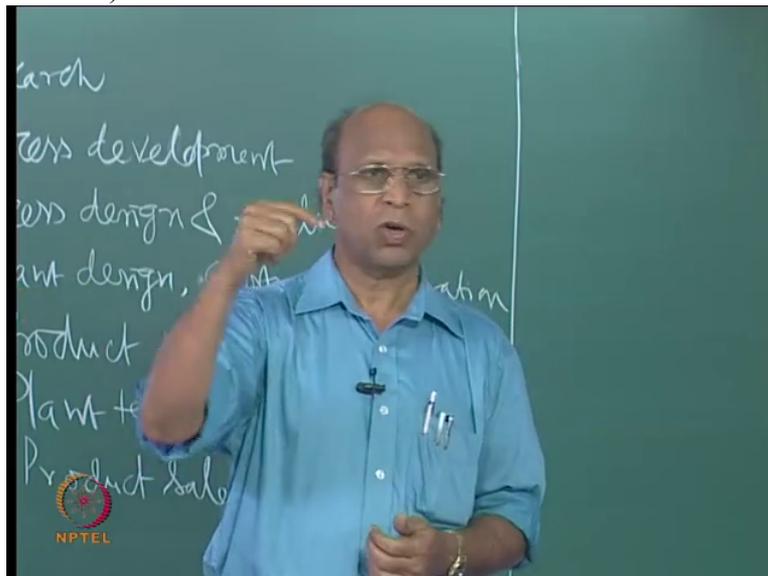
chemistry

(Professor – student conversation starts)

Student: Chemical engineering

Professor: Chemical engineering, one more?

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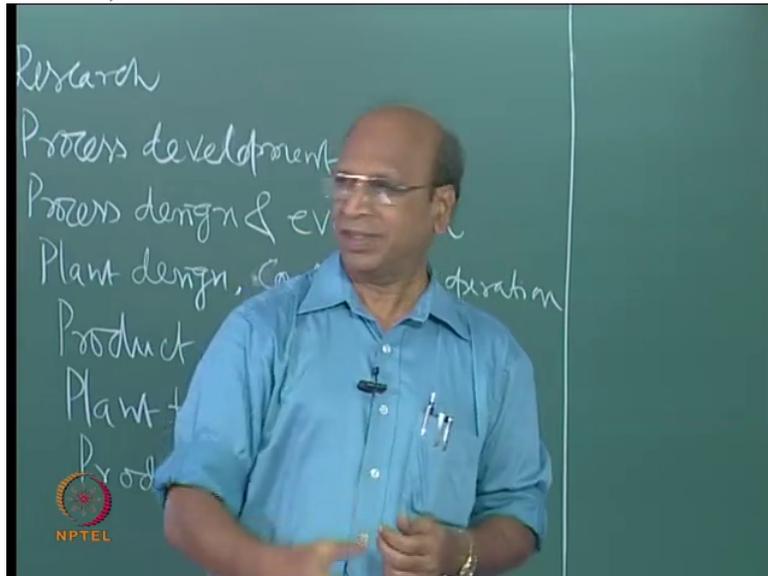


Oh 2, 2. Ok

(Professor – student conversation ends)

I think two of you should teach them after the class is over, what I have

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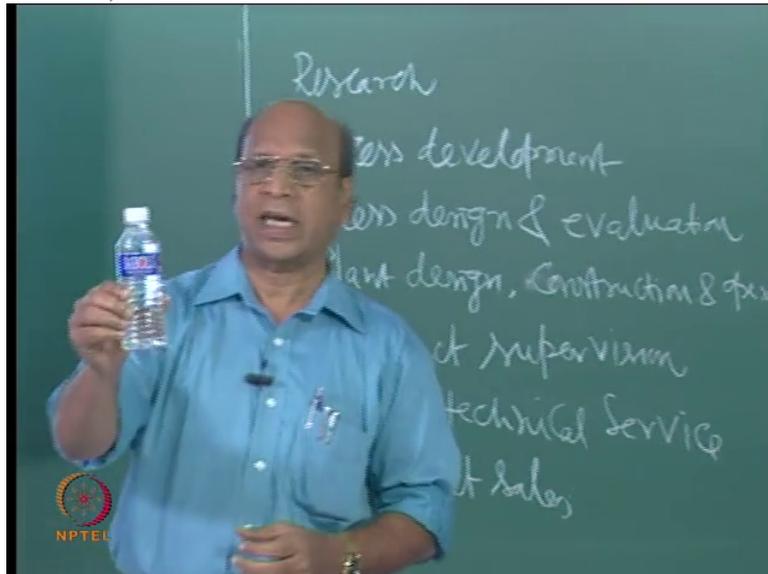


talked (laugh). So that way you remember as well as they will also be comfortable. Please help them, Ok. I think, because they might not understand what is fluidized bed and of course only 2 people will be out of class even though physically they are present here. So that is why I do not know how to take the simple examples. I think they may not know the simple reactors also but slowly we will make them understand. But I think you can help them, right?

Yeah it is very, very difficult to have direct scale-up for the fluidized beds. So that is the reason why you have various scales of fluidized beds finally to design the final one, large scale one, Ok. That is why you have lots of data how the bubbles are moving if it is fluidized bed, even bubble columns are not that easy.

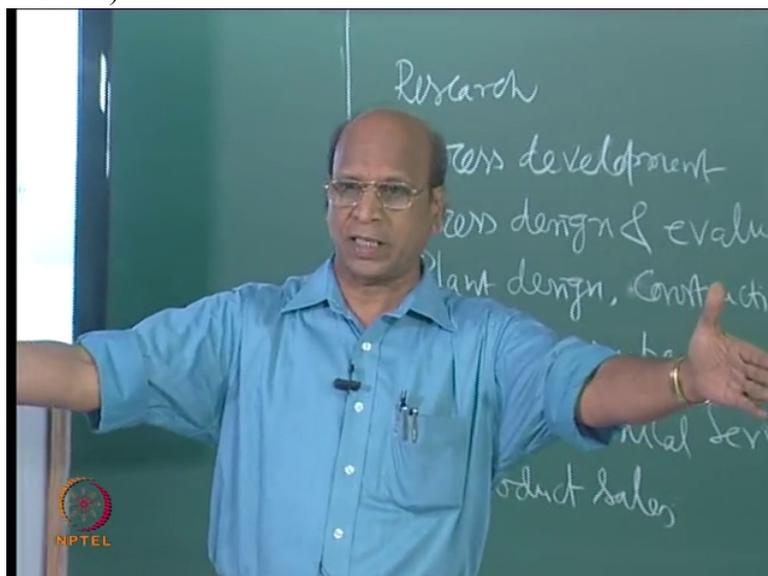
Because when you take a small, nice, yeah this size reactor

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and then bubble, you will get very nice bubbles. Now in the industry, this kind of size reactors no one will use. Ok, they will be again 2 meters, 3 meters diameters

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bubble columns. And height may be again 4-5 meters, right. So you do not even know how much gas you have to push through to keep that, you know, the bubbles move.

That is why pressure drop and all that we calculate, compressors and all that we use, right. Even blowers will not be sufficient. Only compressors will be sufficient, will be required, so then the bubbles will move, will be moving but here maximum size it can go, may be let us say, 5 m m, 6 m m or 10 m m bubbles.

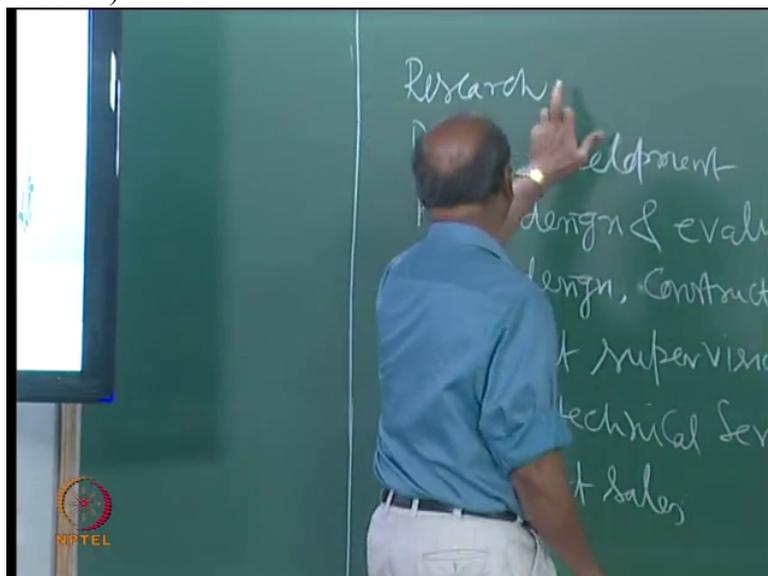
But there to start with itself you may have 1 foot diameter bubbles, 1 foot diameter bubbles. So then how do you tackle that? That is why the scale-up problems come in chemical engineering. And in other engineering, it is not, it is not there.

For example in cars, automobile design of mechanical engineers, so whatever car size outside, you know body and you know backside dickey, front side engine, all those things only will change. But the engine size will not change much. Depending on the capacity they may have, you know, slight variation. So that is why they have control over combustion there, right?

That droplet combustion when they spray and then spark plug will start, and then it will burn and that volume increases so it moves the pistons, all that. So it is very easy to imagine and there is nothing more to that except what kind of fuel you use, if you change the fuel what will happen, nowadays we want to use alcohol as fuel or you know, oils, some oils as fuel all that. That is what the research all they do but the basic shape of the engine is not changing.

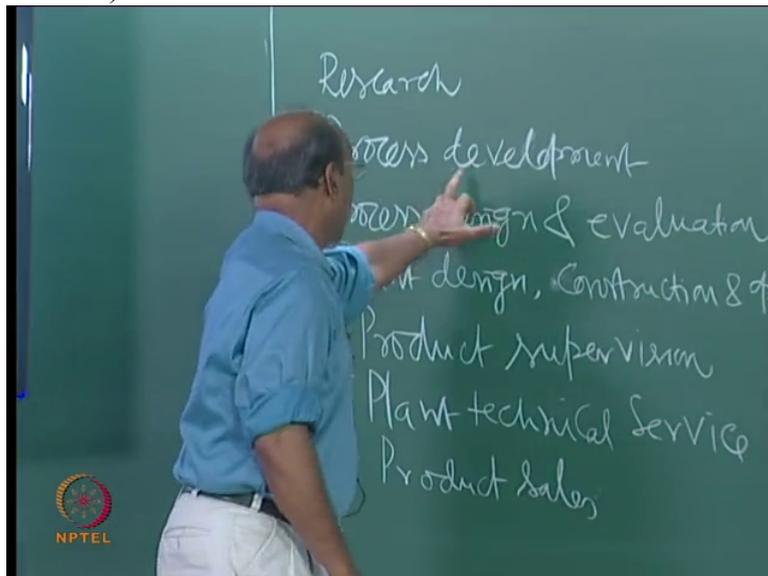
But in chemical engineering every equipment changes, every equipment in that flowchart. So that is why in the process research here,

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you will have approximate idea of what are the equipments that are coming there, Ok in the process research. That means very, very small scale. Then you go to this scale

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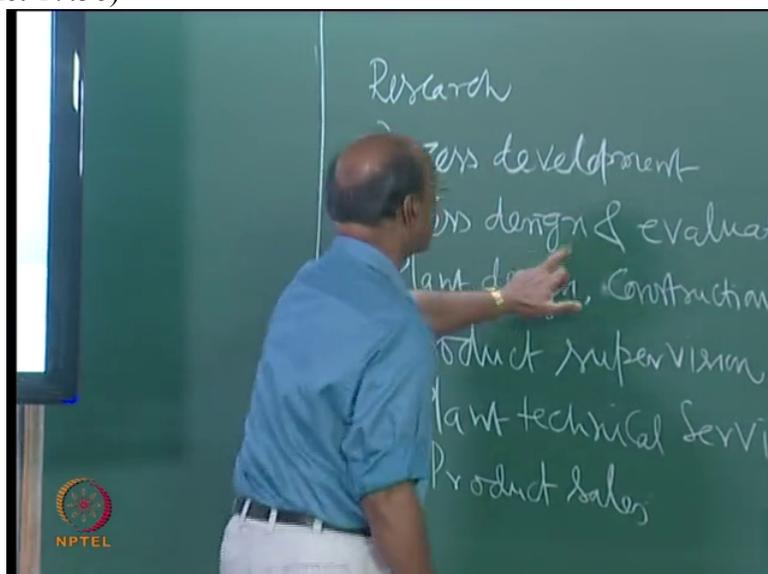


and then you just, a little bit magnify all those equipment, then you have to collect the data how the bubbles are moving if it is bubble column or even heat exchangers.

In large scale diameters generally heat exchangers behave properly, right but in spite of that how do you distribute uniformly, you know, through the tube side and also what is that, shell side, all that information you have to collect and if it is reactor you have to collect lots of information, temperature wise and also kinetics all that you have to see that what you get in the laboratory also happening in the pilot plant scale.

So that means you have lots of data there and with that data, go to

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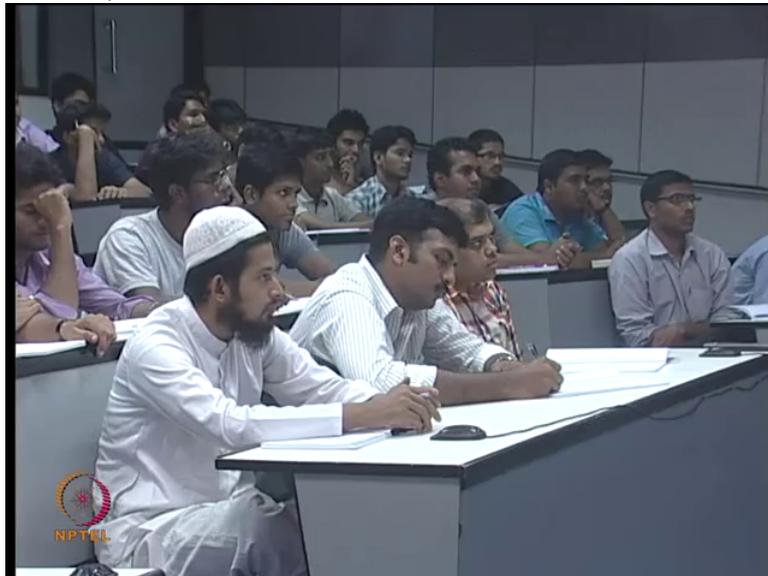


process design and evaluation. What you do there is, everything on paper you should now draw the flowchart. In the process design and development. You know, process design is different and equipment design is different.

In equipment design actually you produce, you know, the equipment size, right, volume. And whereas in the process design, you cannot say that, you know the volume of process is so much. But there what you have to do in process design is the steps like flowchart; it is exactly like flowchart development. The real flowchart, the final flowchart which you see in Shreve and Dryden, most of you would have used that, those flowcharts are developed here.

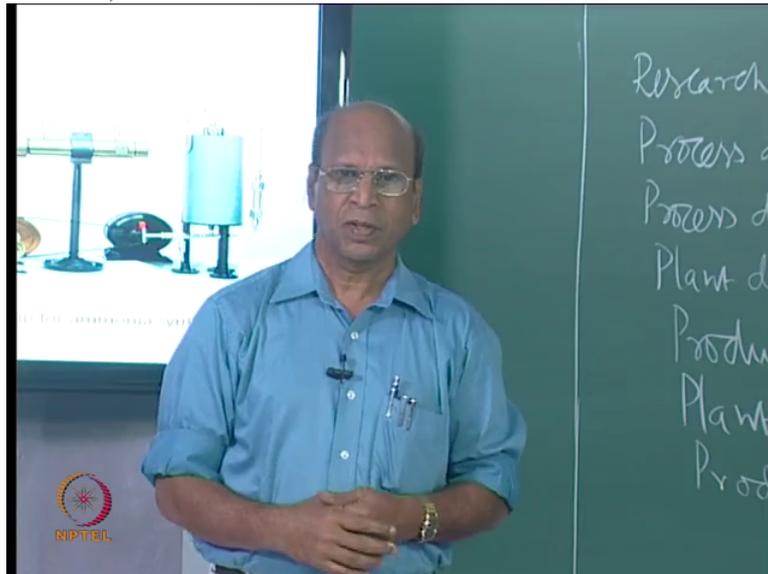
Probably you would be thinking that why the hell I have joined chemical engineering? Ok it is so much difficult. It is not that easy job. That is why we must be proud for that. How much information is required for one process to develop? That is why, after collecting all your email ids, I will send you that paper. It is only 2 pages but how beautifully it is explained and how much work is involved in that.

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And Karl Bosch, how much work, I think he is a chemical engineer but I thought he was a mechanical engineer converted but they straightaway said he is a chemical engineer. But I said because there was no chemical engineering in Germany,

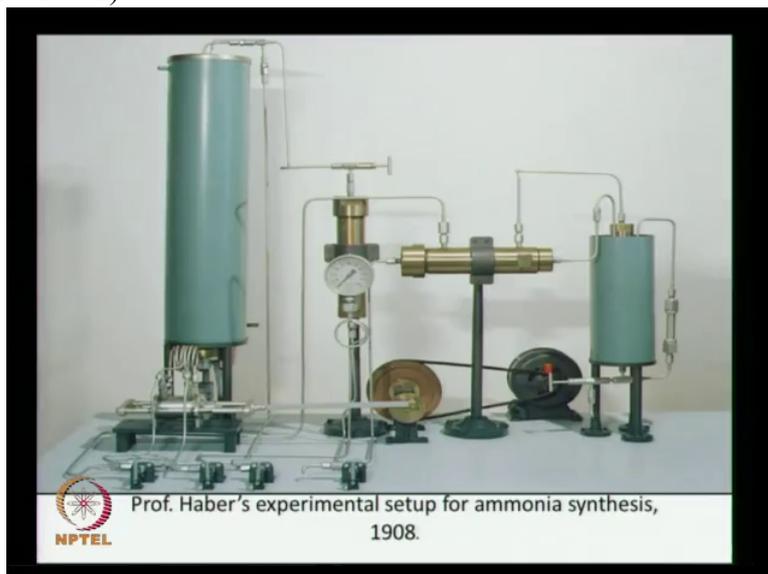
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Ok as far as I remember, may be technical chemist or something may be there, but I think how much work he has done and his team, how many things, I think, for everything is a big problem for him.

Ok, that is at pilot plant scale. Because the pressure is around 300 atmosphere and the temperature is around 500 to 550 Centigrade, temperature is Ok to maintain but the pressure to go to that level is not possible. That is why that is the simplest reactor what they have, and I think

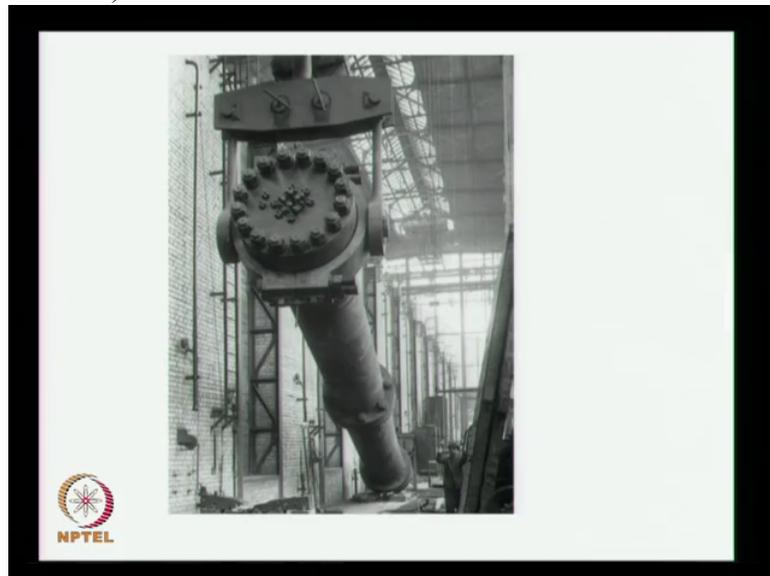
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this is the reactor and all other things are to know, pressurize the system, that is in the laboratory what they have used.

And that one must be the compressor where it keeps the pressure high and with that too, the next one,

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to this level he has gone. That is the reactor. Dimensions are not given but I think I will show you next one,

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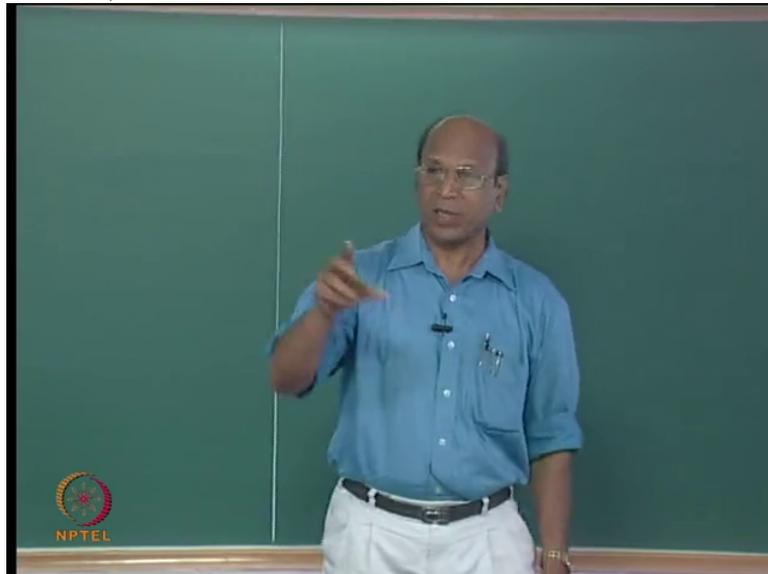
this is what I told you I have seen in the, in the University of Karlsruhe, right. There is a guy also standing here, that is me.

(Professor – student conversation starts)

Student: (laugh)

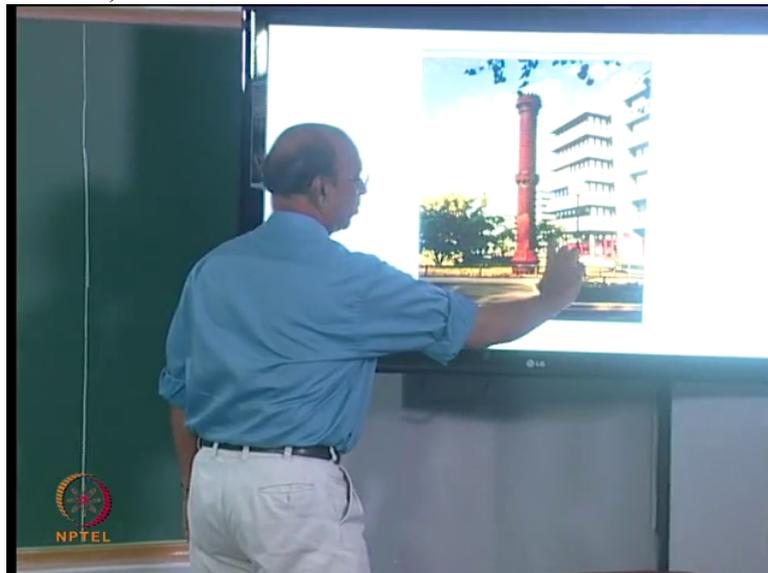
Professor: Ok (laugh) Yeah. You can now

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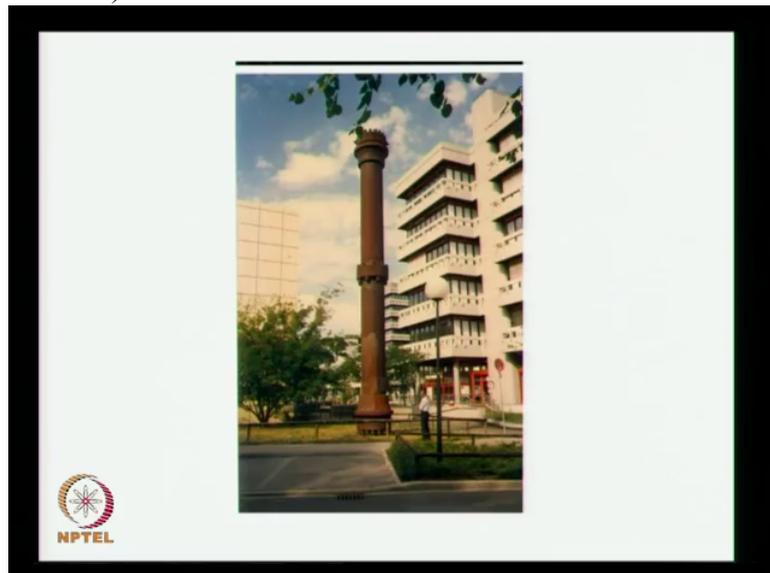
imagine. My height is only 5 and half.

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Now you can measure how many 5 and halves. How many? 6? Yeah.

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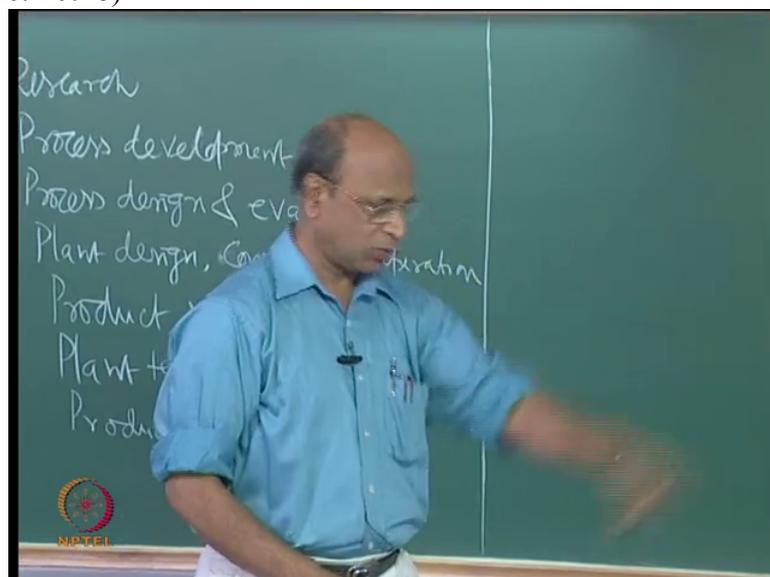


So maybe, 30-40 feet at that time.

(Professor – student conversation ends)

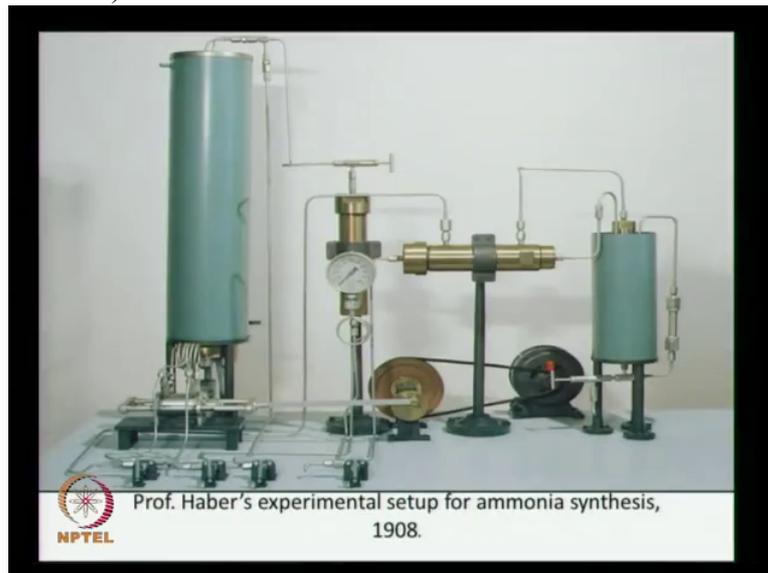
And they have produced this,

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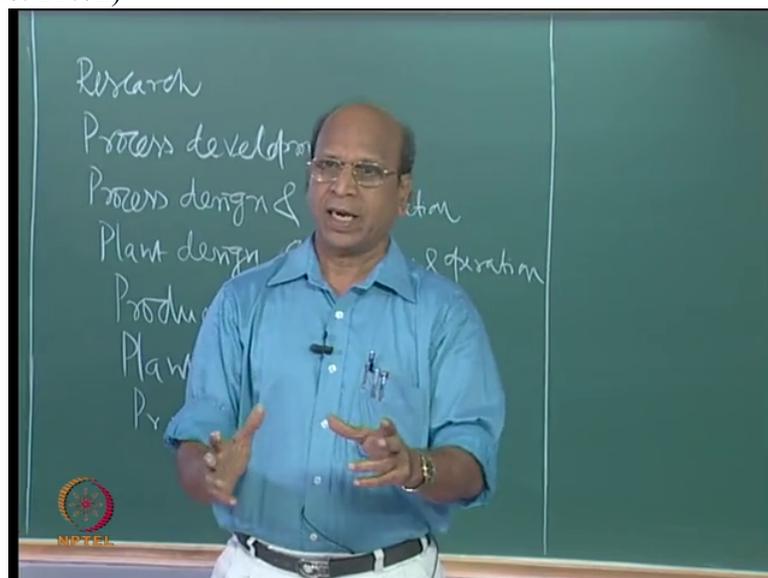
that is what is information that was there, I think this is in 1913. And 1908, what is the first one, Ok,

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1908 yeah, 1908 he just proved the concept, it can be done and then they

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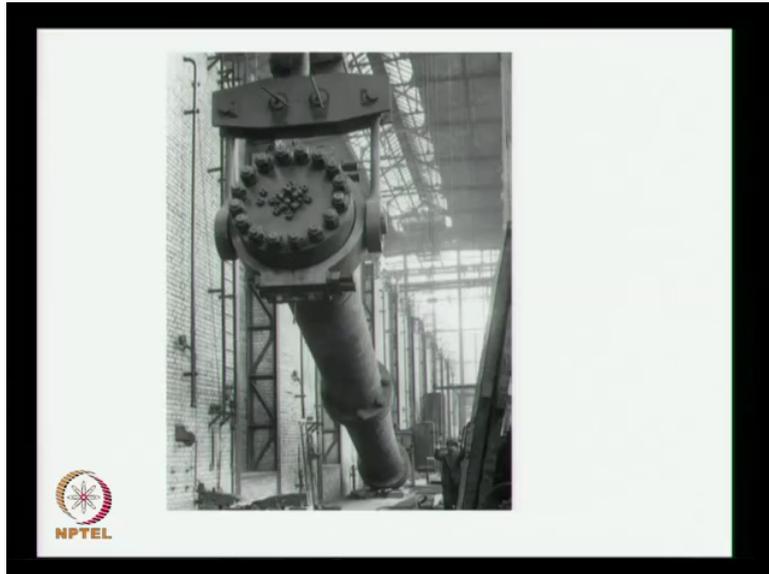


handed over to Karl Bosch in that B A S F company.

From then onwards, day and night they have worked in 1913, they have designed the whole thing and then finally they have produced, I think 7200 tons per, metric tons I think, must be per annum. Then afterwards also I had some other information. I think by 1921, it has gone up to 72000 I think and then afterwards it went to 450,000 that is almost half a million tons. That is in 1991.

Using the same technology. Even now people use only iron catalyst, right? Ok so that is what.

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And this

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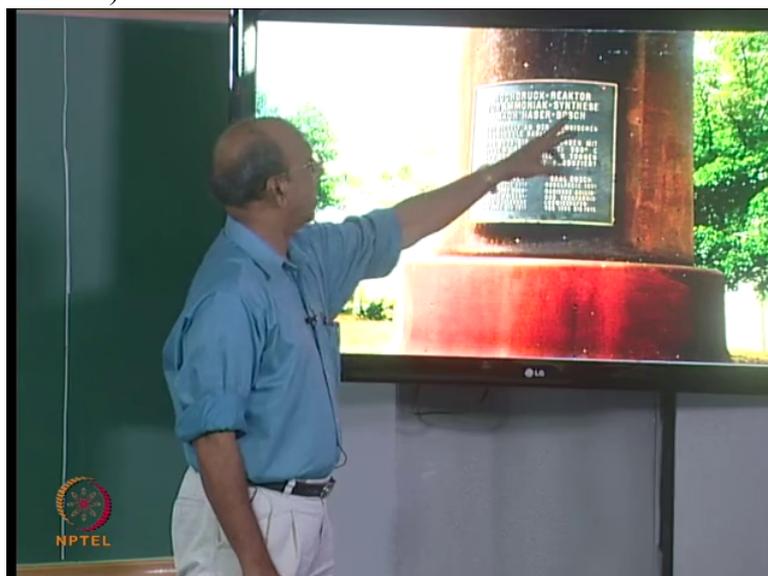


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one, that is in German language, this is hoher Druck means I know little, high pressure reactor for ammonia

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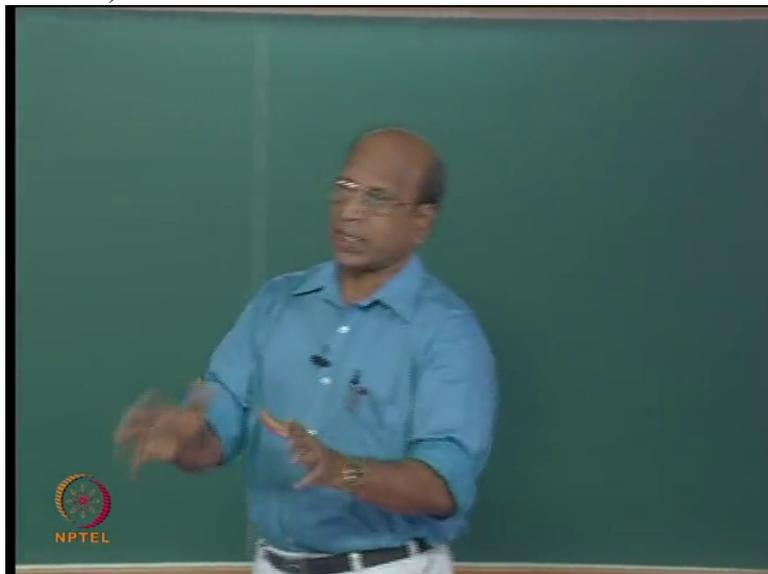


synthesis nach means after, Haber and Bosch. Haber is the scientist and Bosch is the chemical engineer.

Then this is entwickelt means developed, developed at the University technisch Hochschule Karlsruhe. Karlsruhe, they call Hochschule means high school, technical high school, Karlsruhe. That is what. That is developed there. And this is from 1923 to 1982; this reactor at 500 degree Celsius and 300 bar produced 1 million tons of ammonia. How many years there, from 1923 to 1982, right.

After that

(Refer Slide Time: 22:41)



they have removed that reactor and then put another reactor. Everything was a problem for him. Because you know, hydrogen being the lightest molecule, then it used to diffuse through the reactor. That means through the interstices of, you know the metal parts in the wall, it used to come and, it used to diffuse and come out.

So what happens, it seems after some time, the strength of the wall will go. It will burst. So, so many problems. All these problems beautifully he has solved. And that is what is happening in each and every process I tell you.

In each and every chemical, if you take, we are talking about ammonia, you talk sulphuric acid, you have the same stories, Ok. You take for example, sodium chloride. Sodium chloride is salt from sea, we can easily get. No, not sodium, sodium bicarbonate, what is washing soda?

(Professor – student conversation starts)

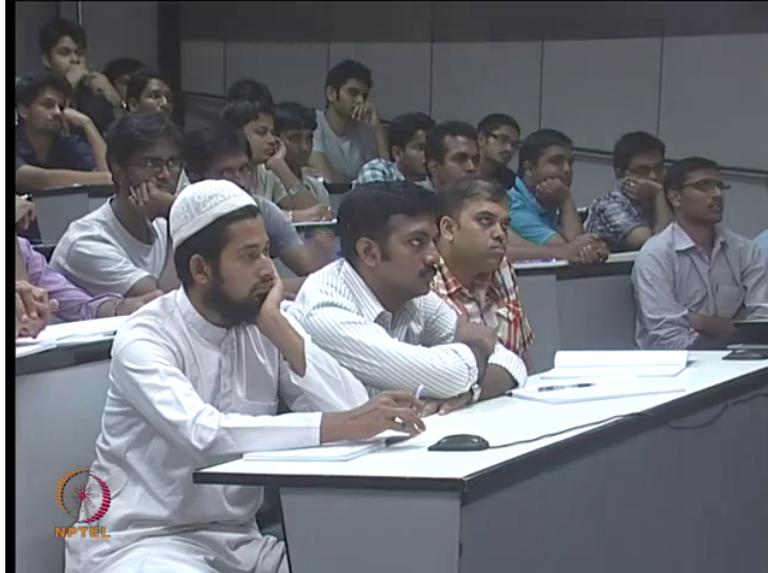
Student: Sodium carbonate

Professor: Yeah, production of that. And chloro-alkalies, many compo/compounds, compounds. All these, everything will have a story.

(Professor – student conversation ends)

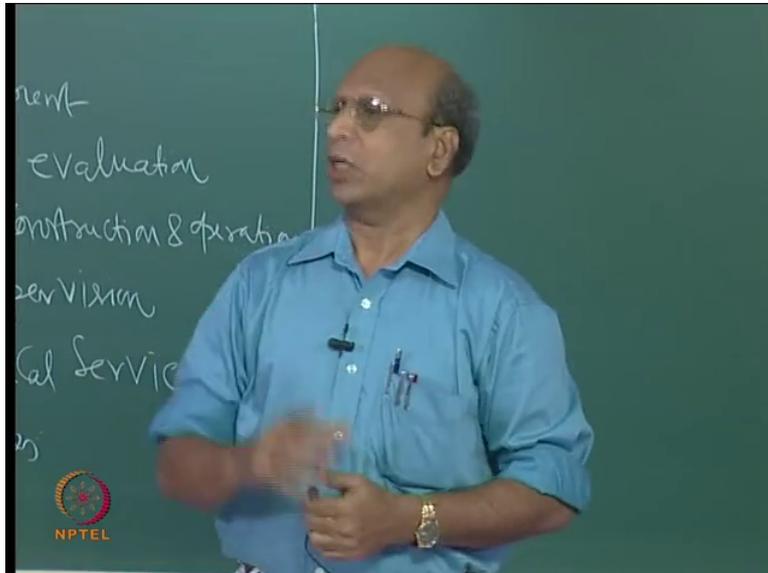
How to produce benzene will have a story. How to produce toluene you will have a story, right? So if you take

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chemical technology, everything is stories only because we do not tell the stories there, we just give the final flowchart

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with all the conditions and all that.

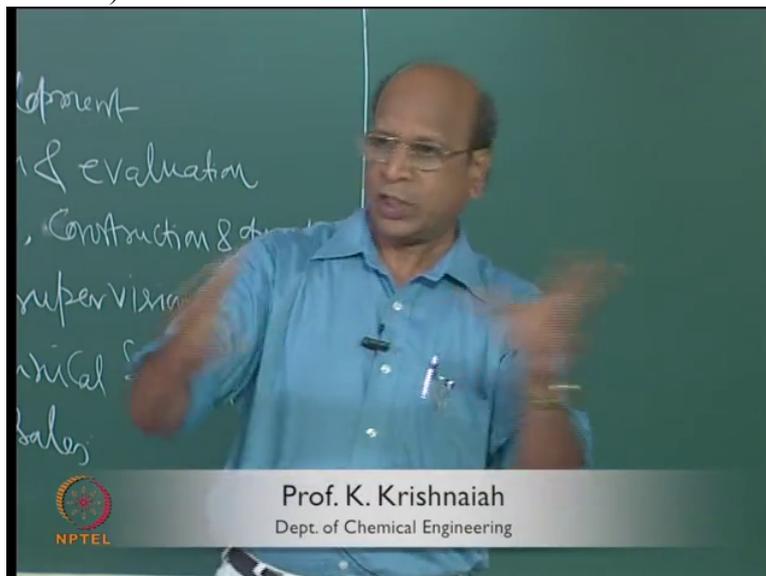
So for every condition to be fixed either in distillation column or heat exchanger or in reactor, people would have struggled there. So, so much sweat and flesh has gone to produce each and every process. That is why I am proud of chemical engineering.

I really enjoy, I think when someone talks about chemical engineering, my volume will become double mentally, so because I think you know, so happy because we are the people who are dealing with very, very, very complicated processes.

And we do not have one rule for example, one rule in the sense, Ok, we have now developed a process for sulphuric acid. Can I use the same process, same information for producing nitric acid? This is also acid, that is also acid. No, you cannot. That is the problem.

Not only that, in organic synthesis only one molecule will change, you know in that ring, benzene ring for example. Only one molecule will change. So one molecule change, so Ok it is almost like benzene only. So let me do

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the same process here, means you cannot do that. Totally you will have to think differently. Kinetics will change and your temperatures will change, pressure will change in the reactor. Everything may change. And everything starts with reaction. Everything starts with reaction. So that is why I think, really start loving chemical engineering and try to learn at least now more interesting subjects.

Every subject is interesting in chemical engineering. Including chemical technology is very interesting if the, normally we do not know how to teach, so that is why you are getting bored. But if the way, I mean, Russians have developed, I think, the Russians' chemical

engineering, chemical technology books I do not know whether you have seen or not. You would not have been born I think, at that time.

So there was one publication called Mir Publication, M i r, Mir Publication, there was lot of translations from Russian to English. But there, every process they start with reaction, thermodynamics, and you know other steps, and everything together, one by one they do that.

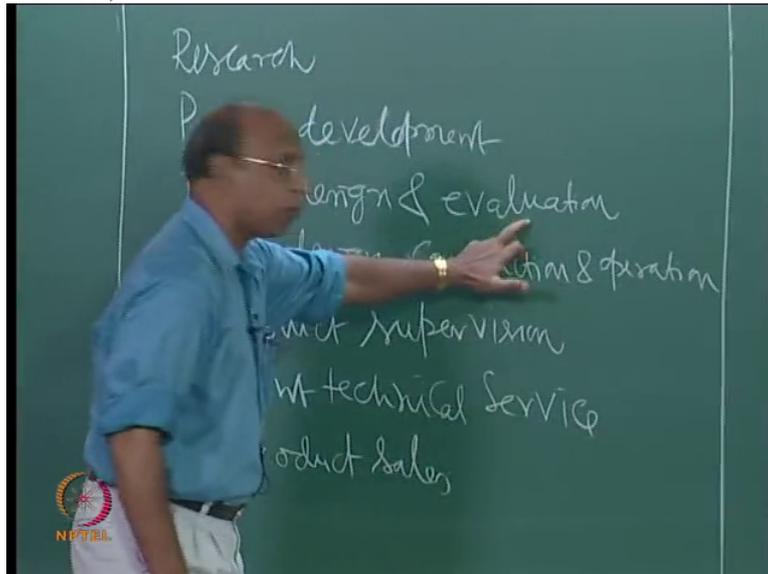
Dryden tried that, I think in some of the flowcharts but Shreve and all that, directly statistics they give. Then process they give. And process also so much details you get fed of it. Because we are only reading that as only for our examination. But industry people love that. Why?

Because in industry every step is important. Every information given there is important, you know, if they open the Shreve book. I hope I am talking only English, no? Shreve, Ok Shreve book, yeah. So Shreve book also has lot of information for industry, right?

So that is why every process has this kind of problems which have come through all these steps, step 1, step 2 this is pilot plant level, step 3 is the actual flowchart development level. And economics also will come. After drawing the flowchart now calculate in each step what is the cost, what should be, even sizing of the reactors, everything you have done there in the flowchart. All the information is there.

That means just before constructing the house, they will have the blueprint, right that plan and all that, that everything is there with you for the process, right? So at that point of time you know what is the size of the reactor, how much material is used for the reactor, what is the material cost and what will be the temperature you know, if 200 degrees Centigrade, how much energy has to be put, you know energy cost, everything you have to calculate and then evaluate

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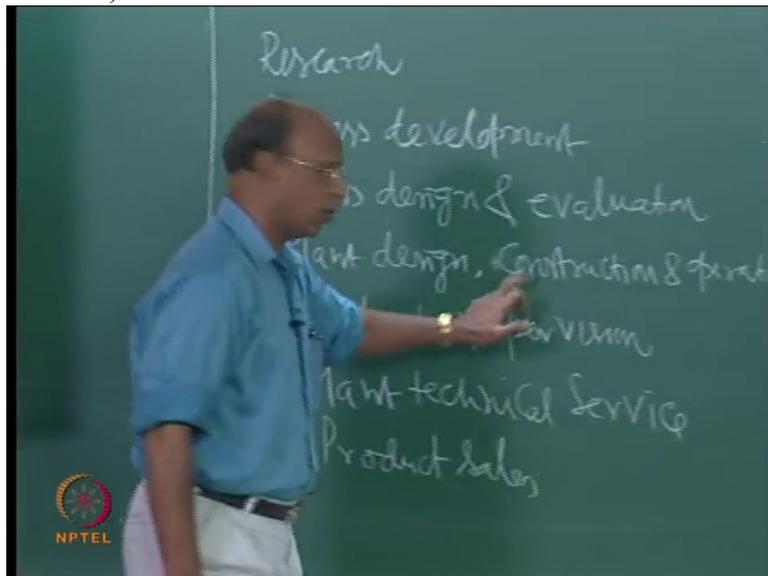


whether the process is economically viable or not. That what is process design and evolution? And unfortunately if it is not economically viable, what do you do? Start again from here. Again exploratory research or basic research or process research and then onwards again pilot plant, all that. So that is why even though you are doing that, it is not guaranteed that you will be successful every time. That only gives us kick, no?

If we are not successful, again with more vigor; you have to come and try to solve the problem, not run away. Or not take bottles. Ok, no use of taking bottle, you are not deceiving anyone, you are only deceiving yourself. Because whenever we are depressed you go for bottle. Ok and these bottles also I will tell you later, what kind of process is that. It is a herbal process. Yeah. If you know the actual process you do not even drink that.

Ok, anyway, so process design and evolution. Ok we know that only micro-organism is doing. I think it is different, Ok (laugh). Yeah. Process design and evolution that is the one. Then we have the plant design. Once you, once it is economically viable, then go to plant design. So give, may be here mechanical engineers are more,

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they can help us, right, construction wise?

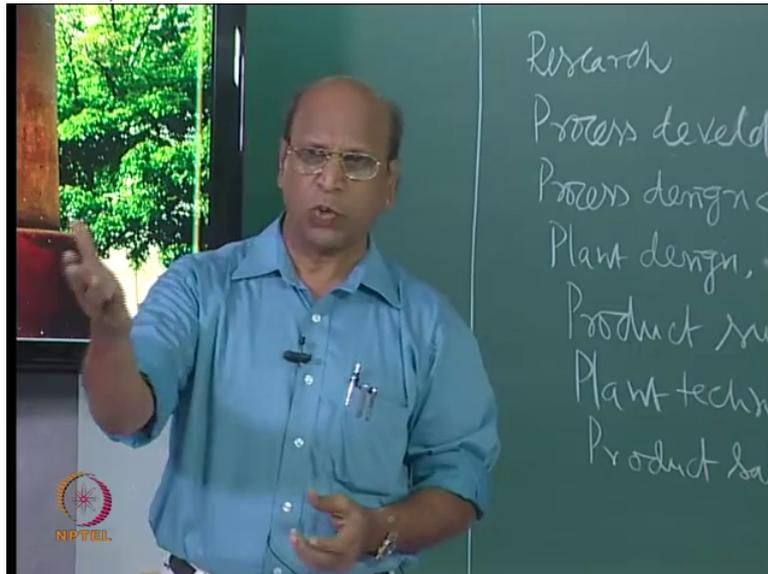
So we know very clearly that is what you have to fabricate. This is the size of the reactor. That is the diameter. That is the height. This is the thickness of the wall you should

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have, Ok. And the nuts and bolts everything. That part. I think some of you

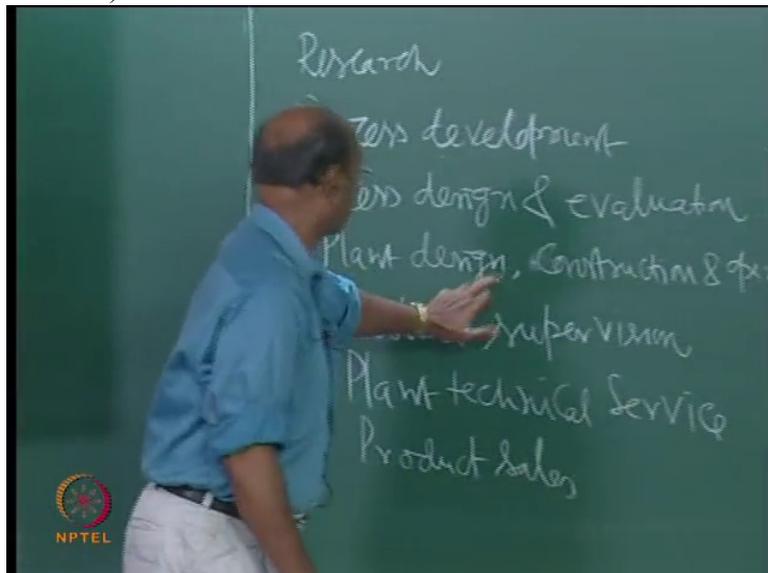
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who worked in industry; you should have known all this.

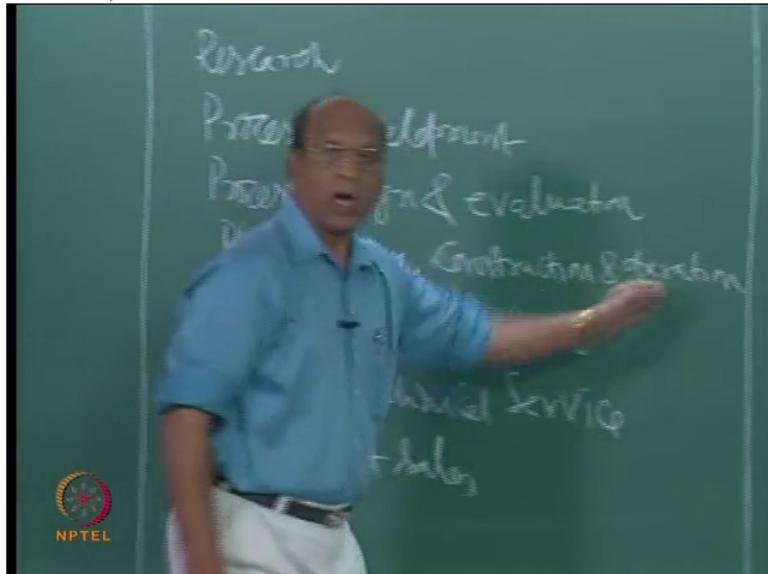
There are now companies specializing only in this step.

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Right, once you know this step, process design on the, on the paper you have all the information what is step 1, step 2, step 3 what are the equipment all that. Then afterwards they will convert everything into plant design where they will go, and then nut and bolt they start constructing. After construction and they have to

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operate, that is what is the, what is that first time you call? Commissioning and also the first time what you call is...

(Professor – student conversation starts)

Student: Erection

Student: E P C

Professor: Erection and

Student: Procurement

Professor: Online

Student: Procurement

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Student: Pre-commission

Professor: Pre-commission

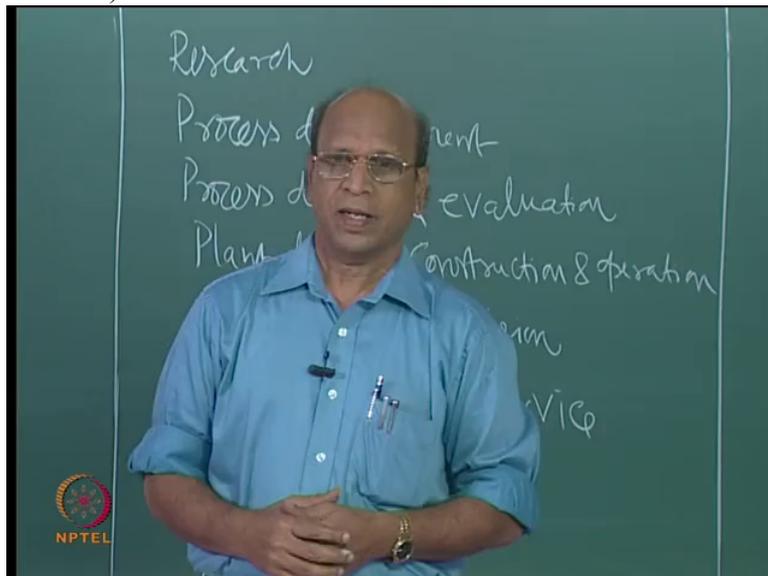
Student: Procurement

Student: Startup

Professor: Startup

Student: installing

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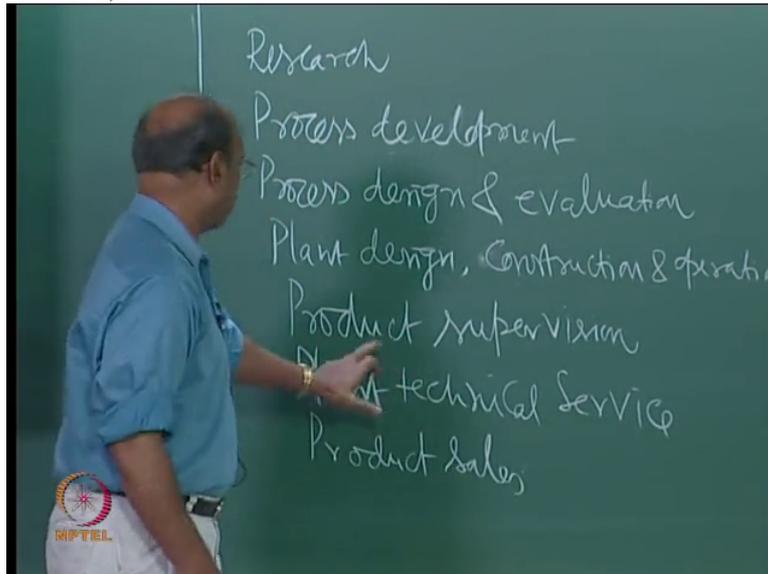
Professor: Yeah, no, startup. Actual starting up is really problem in chemical industry. Right. Because that is the first time you are starting the entire process.

(Professor – student conversation ends)

So that means it starts with the reactants and then the reactants have to flow from, they have to get heated up and then go to the reactor and then react, come to next one and then if it is a distillation process what you are using the separation then you will have, it has to go to distillation column and all that.

Because first time we do not know where it is blocked or it may be blocking somewhere and you do not know whether we have opened or closed. Even though you have taken sufficient care, so that is why people are really worried at the time of this startup, Ok. So that is what it operate, operation, then once of course smoothly everything happening then we have the product supervision.

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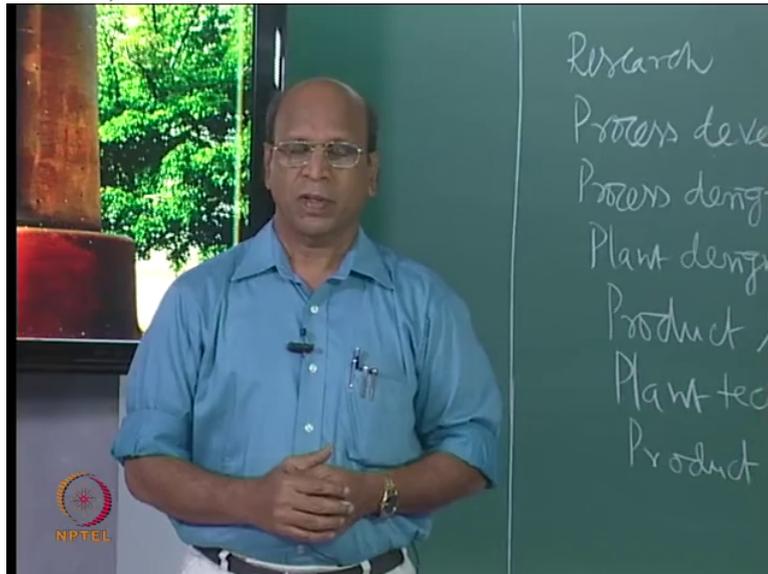
This is what most of us prefer to be, you know as chemical engineers because here

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the work is not that much except just looking at the reactor whether there is something going on, suddenly something may go wrong.

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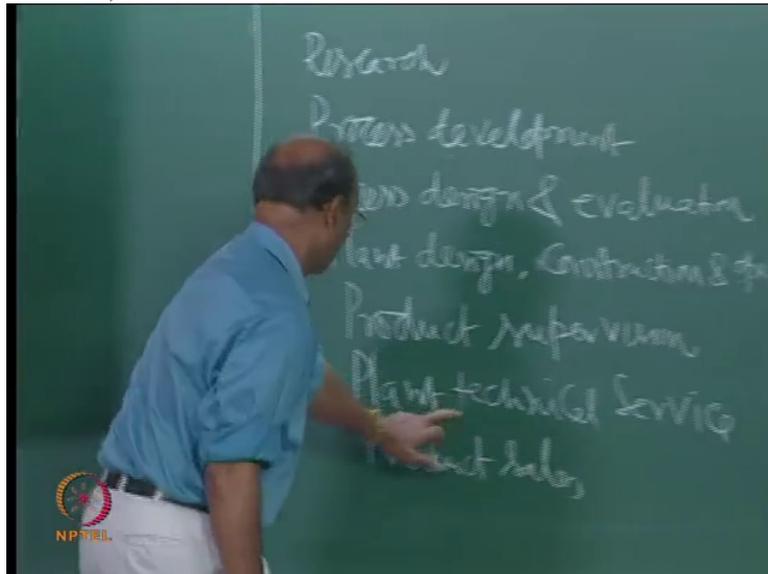


And in this, at this level you should be more, you should have very good personal relationship with the workers, with the operators. Otherwise I am an engineer, you are a operator, you do means he will say go to hell. Or go inside the reactor. Ok (laugh) That is what they may tell.

That is why human relations are very, very important in chemical engineering. Because after all the steps are over, next is only human relation. And then the next one is plant technical service. So that means this man will be operating and then looking at the reactor, or heat exchanger or distillation column, if there is suddenly something wrong then he will call you. I have a problem, come here. He won't solve. Ok, he is only problem recorder.

Problem solvers are here,

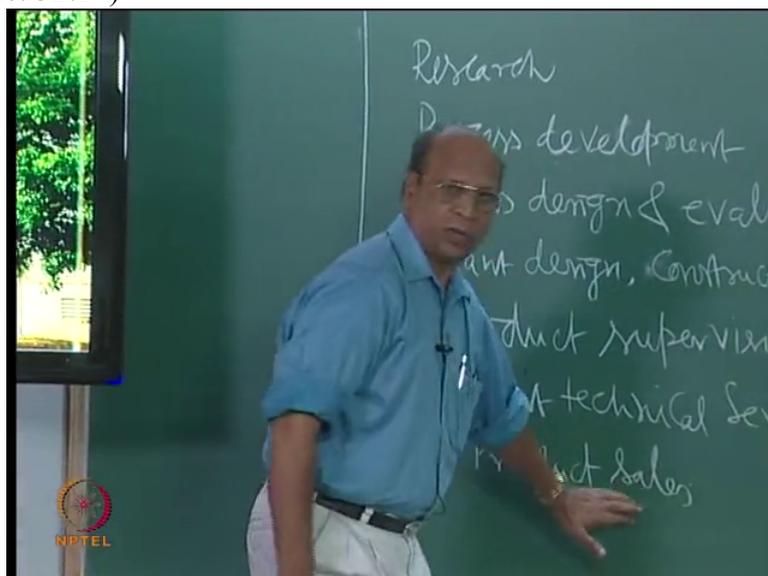
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plant technical service. Or steam is not coming at the required pressure. Or water is not flowing or the reactants are not flowing at the required pressure. That means they cannot enter the reactor. So all those problems will be solved by this technical service. Then without any problems if you are able to produce, then the product comes, the product how beautifully you can pack, all that you know, imagination.

I think there is also, here also there is of course,

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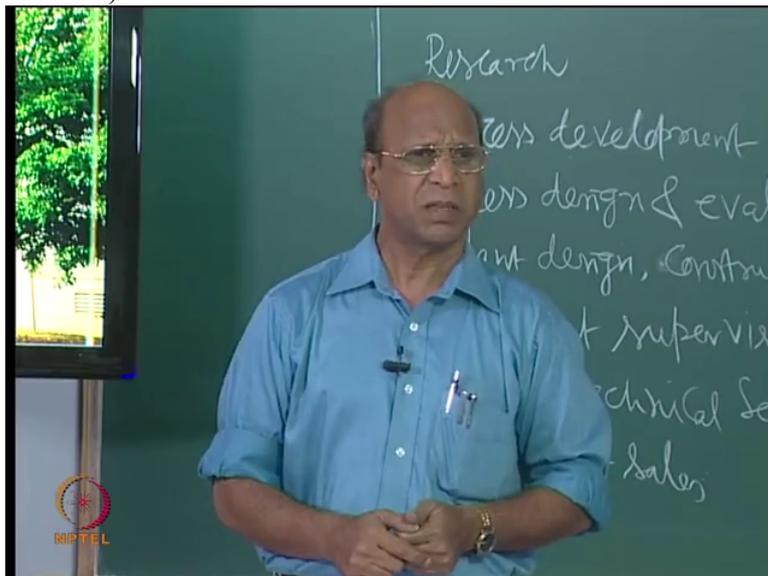
sales people I am not talking but other than that, how do you pack these products? Nowadays I think most of the products we are alarmed with the packing no, in fact there may not be anything but still I think you see the packing and then take it. Including I think

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chocolate, I think how, what a kind of beautiful paper they make,

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it is a waste, because they throw it out and we eat. Correct no?

I think what do you do with that paper? You do not do anything with that paper. So beautiful paper, very costly. That also we have to be proud that we are only producing that paper, very nice paper. It can be paper sometimes, it can be plastic sometimes. And what kind of packing is coming nowadays? Tremendous amount of varieties of packing. Right, so all that.

So this is what is the one, the answer for overall, the answers for the second step, for the second question. What is the second question? What does the chemical engineer do? Ok.

Please remember these things at least. You know, that is why I tell you, now when you get to your room, catch one computer science guy, innocent guy, so then take him for coffee and then explain all this. Then only you will remember. Otherwise you do not remember.

How do you think I remember? Because I am telling you all the time (laugh). Ok like that if you tell someone you remember. Otherwise you just postpone that, Ok, the first quiz is on next month, June, July sometime, August or September, Ok. So we will postpone till that means all the files are deleted, you do not know what is happening at that time. So that is why. Ok Good.

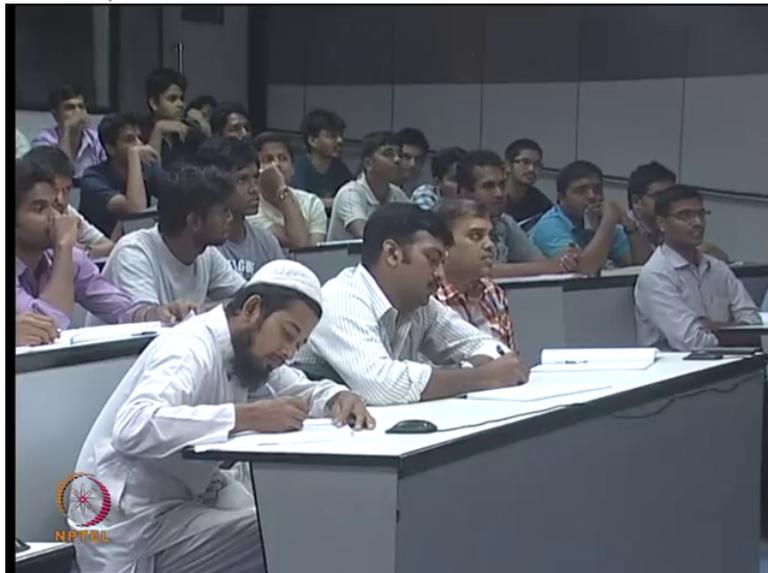
So this is what is about the second question, what does the chemical engineer do? You can choose this, the simplest one, Ok or you can choose this one which is a very, very complicated step. So it is both extremes, right. But you know this is really thrilling, I say. Tell you, really thrilling. Nowadays you have G E or this is closed already? G M, G M is closed?

(Professor – student conversation starts)

Student: Yes Sir

Professor: General Motors are closed

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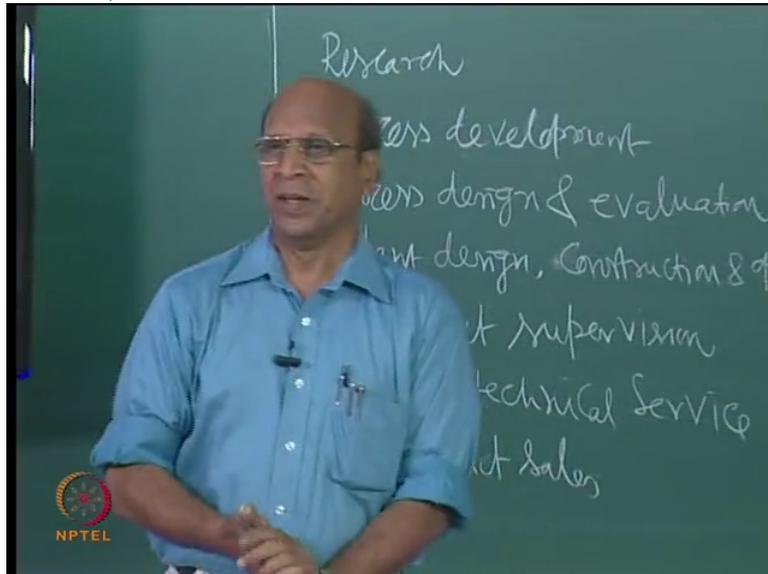
Student: General Motors closed.

Professor: Which section, chemical engineering section? Which section is closed?

Student: Research section

Professor: Research section, Oh my God, if you remove that, I think there is

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no thrill there, yeah. Development is there.

(Professor – student conversation ends)

Ok, development also, these steps are very important steps. Lot of thinking is required. In fact in these two steps only, in that paper only you will read, that Karl Bosch steps, how much work he has really done. So that is why, this is, I think at this point of time at least you know, some people would have definitely explained to you all this when you were in B Tech.

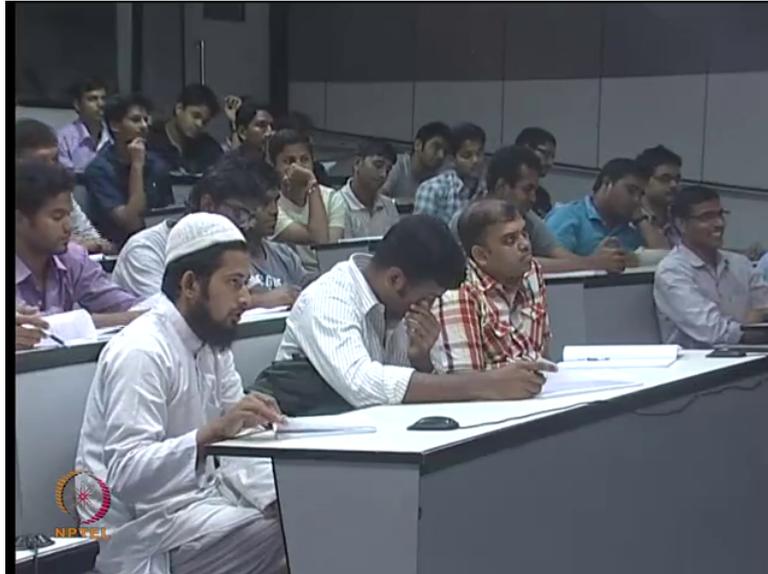
Ok, I do not know, may be some teachers would have exposed you to this information. But at that point of time, probably you would not have enjoyed like this. But now you will enjoy more. If you come to P h d again after M Tech, again if I tell you the same thing you will enjoy much more. It is not simply repetition. Do not feel that it is simply repetition.

But I think it is only the memory where you are going to have more and more, if it is exposed, if we explain this many times. And this is what is required. If someone asks you now, what do you do as a chemical engineer; you can give him a big lecture now. Till he really runs away from you. Because you are getting so much information.

But earlier I do not know how much, you know what is the definition of chemical engineering, definitions we do not have to tell. We do not have to mug up and reproduce. But

if you are able to tell what is the meaning of this chemical engineering, what do you do as a chemical engineer and how are you helping the society as a chemical engineer that is enough. I hope now you have more confidence on that. What is the next question? How does a chemical process...

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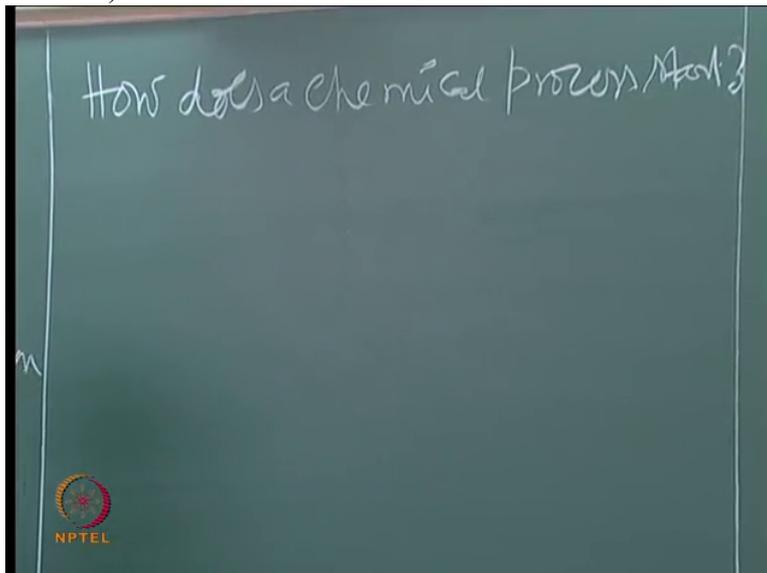


(Professor – student conversation starts)

Student: start 0:35:44.9

Professor: This is again a very, very interesting question. How does a chemical process start? Ok, I mean what is the starting point. Or I think you know you can also say how does a chemical flowchart

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start? What is the starting point for any chemical process?

Student: Raw materials

Professor: Raw materials. I think this is the answer which all of us give, which is wrong. It is not raw materials. What do you do with raw materials? I say I give you two raw materials, what you produce? Please tell. Do not be afraid.

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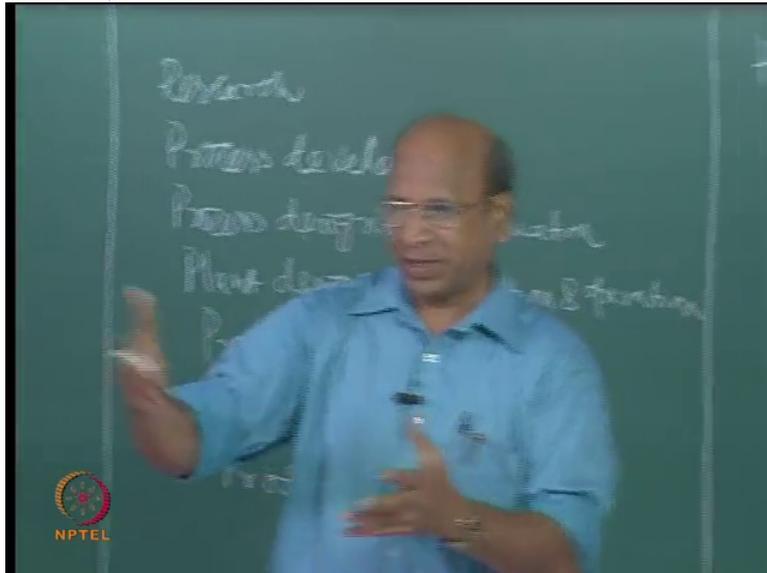
What did he say?

Student: Knowledge.

Student: Processing knowledge.

Professor: Knowledge is required, but (laugh), for a particular process you want to produce, you know,

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you design a particular process what is the starting point? This is also you know, last 15-20 years also no one is answering immediately. I think 3-4 years back; one person told that, Sir, I know the correct answer I will tell you. It is very simple. So then how do you know? You only told me, Sir. You came to Tirupati and gave this lecture.

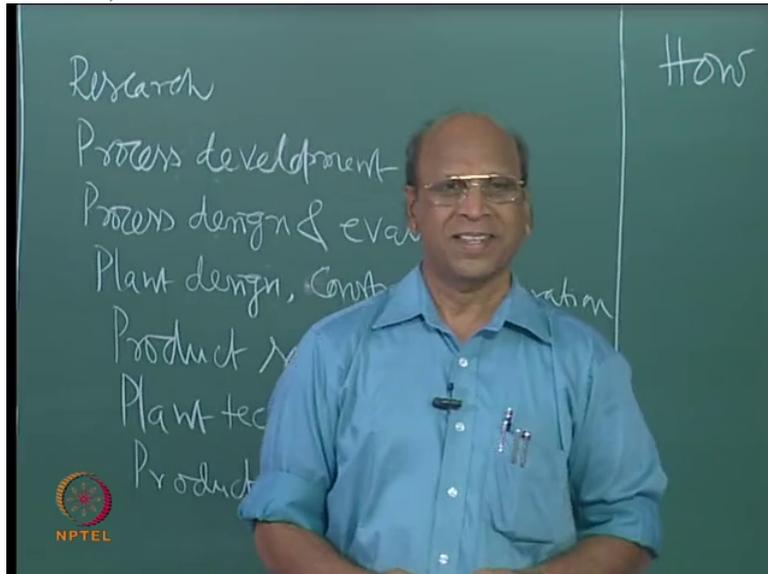
Student: (laugh)

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Professor: He joined here after he was in third year or second year.

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I think he was remembering and then he told that. No, it is the product which is the starting point.

(Professor – student conversation ends)

Really it is the product. I think that we do not know. Maybe it is obvious. You may think it is quite obvious. I think I tell you with my whole experience, now I am 65 years old, not 65, 64 only, 65 means I cannot be here, they will throw me out. Yeah. So my experience is that obvious is not obvious, common sense is not common. These two I really learnt.

So that is why even $1 + 1 = 2$, I repeat many times. It is not obvious. And you know many teachers think that it is obvious and then they ignore that step. That step may be the crucial step for a particular student. Beyond that he cannot imagine. But you give that connection, automatically come.

That is why all my teaching is based on really very, very basic person, starting person. In any course, I start only like that. Because that is important. Otherwise, Ok at high level I start and most of them are not able to connect there, then what is the use? Whom I am talking to? I am talking to benches and then walls. Because students are there, a dead space. Because they are there, live and dead.

That is the reason I tell very, very simple things also. So that is why it is the product which is the starting point. So what do you do? I think you know I give you example. Now let us

imagine that, now we have on this planet one of the biggest diseases is AIDS, for example, AIDS, cancer. We do not have still good medicine for that, right.

Suddenly you think you have to produce some medicine. Ok. You can recruit number of chemists, and then start doing research, try to find out which medicine may be the best for cancer. Ok now what is the starting point now? Cancer drug is the starting point. That is what I told you, that is the starting point for any process.

So now, suppose you are now successful in finding, in identifying out, in identifying a particular drug. You are successful. I think your chemists did, or chemical engineers you join with them and try to do together and then finally identify this is the drug which will be useful for cancer. How do you produce this drug?

How do you produce that drug? That means how the chemist would have come to that understanding of, Ok this is the product? They would have conducted some reactions. That reaction would have a stoichiometric reaction. Because you are only putting, you know, reactant A reactant B giving you the product. But definitely all the steps are required for us.

So that means once you identify a drug and if you are able to produce that drug in a very, very small scale, that means we have a stoichiometric equation ready with you. Ok, so then what is next point after producing the drug? Now you take the statistics. How many people have cancer? And what is the amount of drug you have to give per patient? Let us say I think over 1 year, 1 k g he has to take, the total amount, may be one year he has to be treated with this drug.

So now you know that how many patients and per patient how much quantity required, very simple no? Process calculation, that is why we teach that subject as the first subject. So now you will calculate all this, Ok so much you have to produce. That automatically determines your plant, you know Levenspiel's F_a naught in the design expression of reactor, that F_a naught is this, right? This drug how much, you know, I think it is simple, no to understand?

Yeah, we know per patient how much we have to give. How many patients are there? So that will say that Ok, now you will have to produce 100 tons per day. To produce 100 tons per day, now I have the stoichiometric equation, because we already identified the drug.

So that means there must be one stoichiometric equation or more than one stoichiometric equation, more than one step required so that from that you will back-calculate and then find out that Ok, if it is 90 percent conversion already in the lab when you are identifying drug, when you are conducting that small reaction with small quantities you know that is what is the conversion possible.

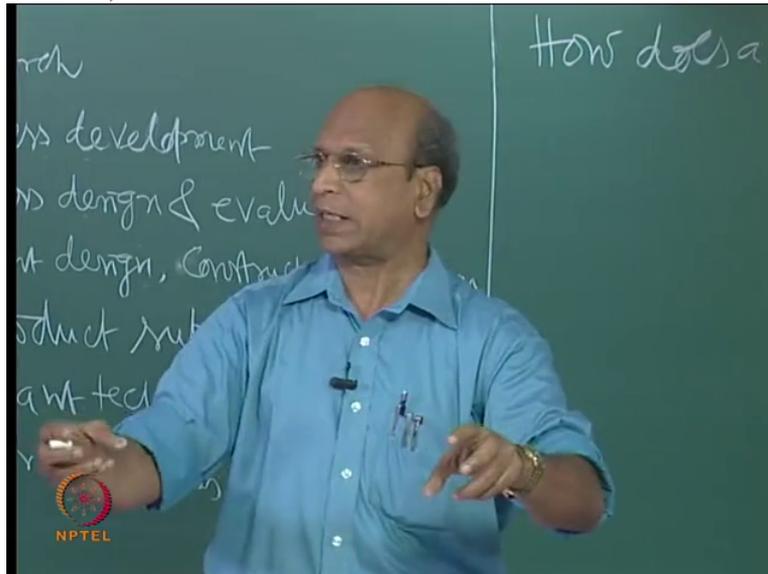
If 100 percent conversion, it is excellent, right. So based on the conversion, now you calculate what will be the reactants you have to produce. Reactants will come there, not in the beginning. Right, you told no, reactants? Yeah, so the reactants will come only

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after that. And that much reactants you have to produce and you have to send to the

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reactor where you have that F_a naught.

I think when you write that equation I will again remind you there. That 0:41:51.8. Ok, good now you have only one, I think in that reactor design expression, because you have already done two reaction engineering courses, most of you, there are 4 parameters. One is F_a naught, other one is minus R_a , yeah, other one is X_a

(Professor – student conversation starts)

Student: C_r

Student: X_a

Professor: X_a only and yeah other one is volume. I hate tau because tau is not required at all. In the design expression you will never get tau. You will get only v by F_a naught. Ok if you want to convert that v into tau by dividing something else you do it. But not required directly. So volume, first one is volume, conversion, reaction rate and

Student: F_a naught

Professor: These are the four. Out of these four, you know F_a naught. How do you get F_a naught? The reactant how much you have to send to the reactor, you get only from market survey.

(Professor – student conversation ends)

There you can employ M B As. You can ask them to go the market and find out how many people are patients and how much they require and all that information. So one parameter you have already decided.

But now, you in the laboratory, you just proved on a very small scale whether it is, whether the reaction is feasible or not. But you do not know exactly what are the temperatures because I told you some temperature you use and then shake it and then try to shake it and then try to produce and one small, wait for some time and then take that product out, analyze, if you get the product you jump up and down, that you got the product.

You never really bothered about what is the exact temperature I have to use 0:43:22.8 or what is the range of temperature that we have to use. Because in any reactor you cannot exactly maintain only 100 degree Centigrade. Either it goes to 105 or it may go to 95, some range you require. How do you get this information?

You have the stoichiometric equation and from stoichiometric equation you can get lots of information. I think most of you may not think about this, no? What is the information you will get from stoichiometry, Gani?

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(Professor – student conversation starts)

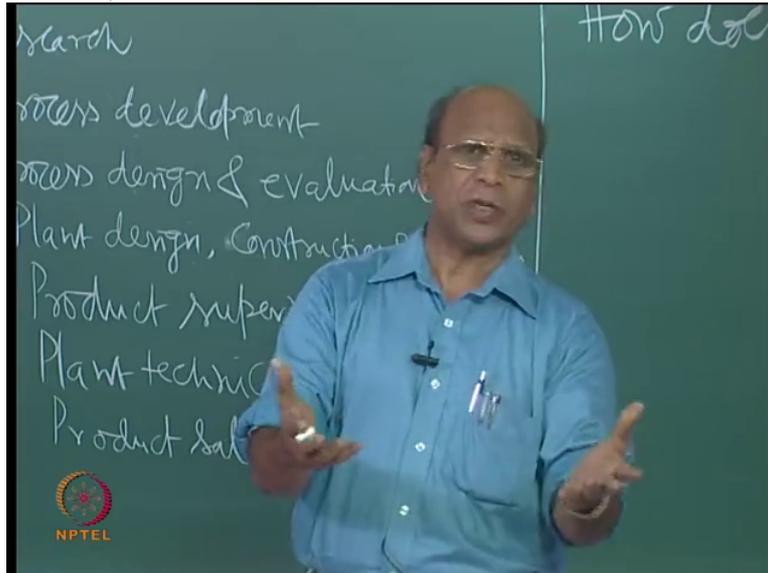
Student: The raw materials required.

Professor: That is all, we have already used that if we have not calculated, apart from that what do you get?

(Professor – student conversation ends)

See these are again,

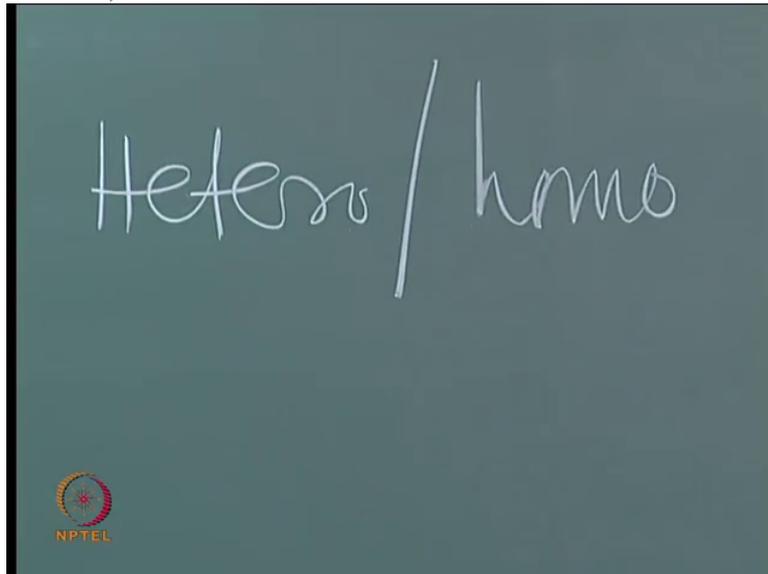
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all these things if I tell you but I think you do not think that. The first thing that can tell you is that whether the reaction is heterogeneous or homogenous. How do you know? Because reactant A, reactant B what is the physical status? Ok, so that will give you whether the reaction is heterogeneous or homogenous.

So stoichiometry can give you hetero or homogenous reaction. So what else it can give?

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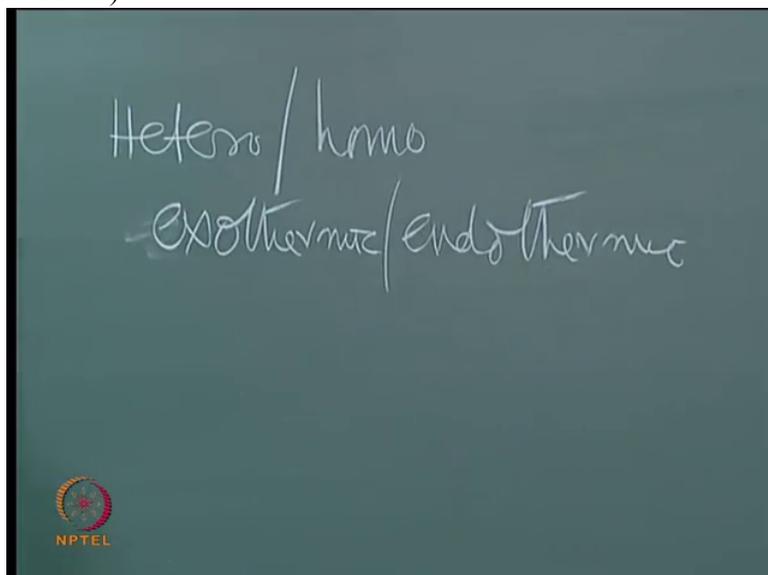


Excellent. Exothermic or endothermic, exothermic or endothermic. Still what information it can give?

(Professor – student conversation starts)

Student: Condition, temperature

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Professor: How does that give you temperature condition, temperature? Yeah 0:44:51.3, you are telling something?

Student: Reversible or irreversible

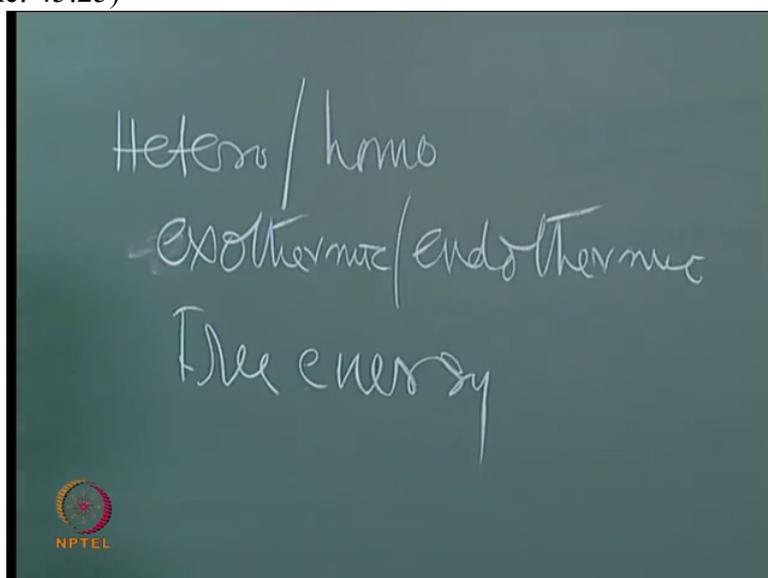
Professor: Excellent, reversible or irreversible. It will give an idea that means by looking at it you cannot say. But by conducting again some reactions only you can find out whether it is reversible or irreversible.

(Professor – student conversation ends)

But you can also do that using thermodynamics. Because here stoichiometry when you are using, stoichiometric equation, how do you calculate ΔF ? You need stoichiometric equation, right. So Free energy also you can calculate from stoichiometric equation.

How do you calculate enthalpy?

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That will give you, here in fact heterogen/heterogeneous, I mean homogen/homogenous, exothermic or endothermic. ΔH , when you calculate, that will tell you whether it is positive, endothermic, negative exothermic. So that is the information what you get. And what information what you do get from Free energy? Reaction first of all is possible or not, Ok. So then that Δ , Free energy ΔG you will equate with $-\Delta G = RT \ln k$, what is that k ?

(Professor – student conversation starts)

Student: Equilibrium constant

Professor: Equilibrium constant. If k is very, very large what is your prediction?

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Student: Irreversible

Student: stoichiometry

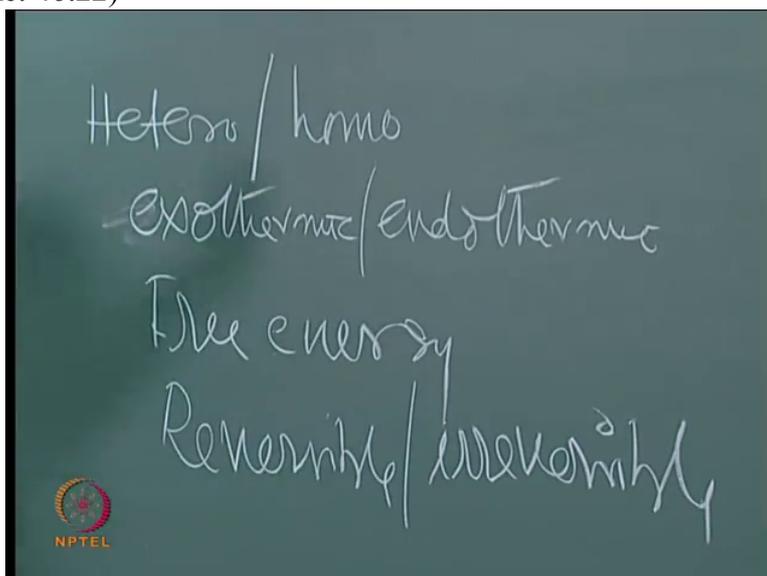
Student: Irreversible reaction

Professor: That gives you whether you have, yeah someone was telling no, reversible or irreversible, yeah reversible or irreversible, Ok.

(Professor - student conversation ends)

So

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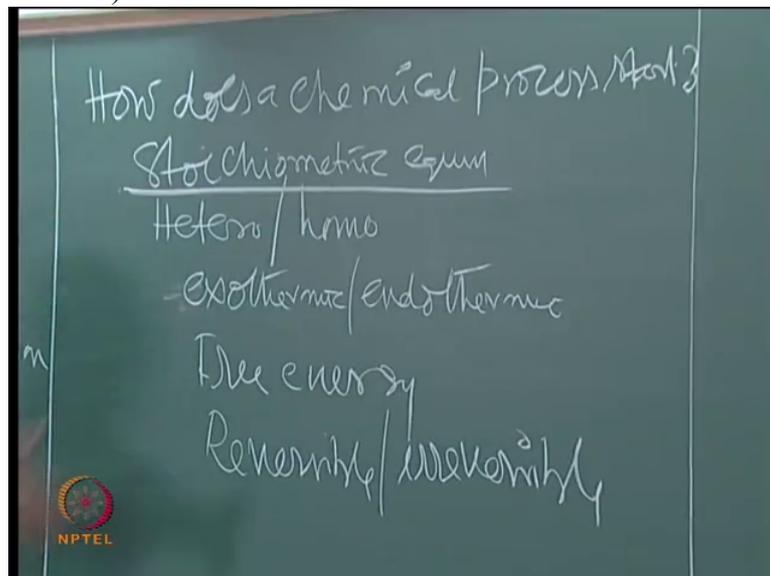
you see, how much information you can get from that simple stoichiometric equation. All from thermodynamics, right and Free energy, thermodynamic data you need to calculate. And ΔH_r again thermodynamic data you need to calculate.

And that will give you whether the system is exothermic, endothermic and all that, Ok and even this equation, Free energy will give you reversible and irreversible and not only that, it will also fix temperature and pressure. That is what I think someone was telling there.

At this point of time when you have ΔG is equal to $-\ln K$ so this K and $R T$ is there. So for every T , there is a K . And for pressure also if you change, then you will know what will be the equilibrium conversions $X_{a,e}$, right? So the maximum conversion that is possible is dictated by this equation and that is connected with temperatures.

That is what I asked one of the questions in your, the first test, you know, conversion versus temperature for exothermic reaction, endothermic reaction, Ok. That we will do, later we will do that, ok. So all this information you will get from stoichiometric equation. This is stoichiometric equation. Ok, from that you see how much information

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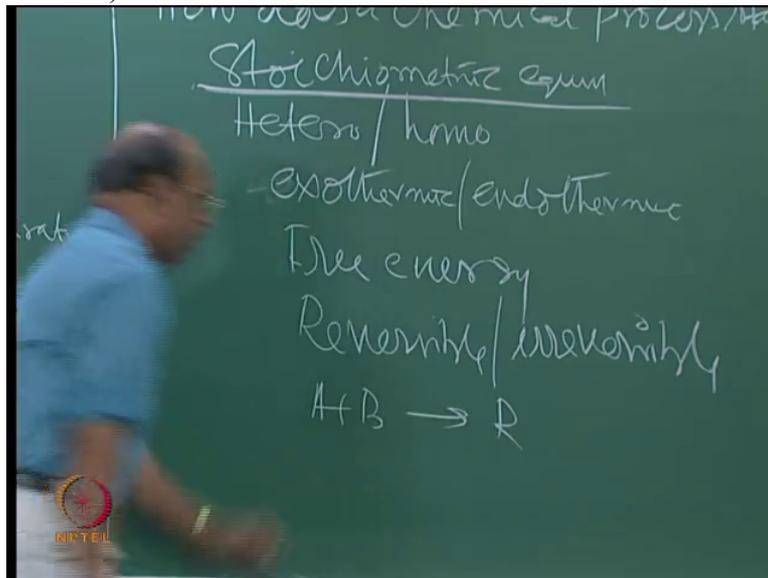


but now you see, we have used thermodynamics data or thermodynamics subject we have to understand and process calculations we have to also understand and these two subjects automatically come there.

Then what is the next step? You have started with your product and it was feasible on a very small scale but you do not know what will be the temperature conditions, whether there is variation, in that variation what will be the changes in equilibrium conversion all that you do not know, all that data now you got.

What is the next step? What information you get still from this stoichiometric equation? Can you tell me, if I have A plus B going to R, what is the

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order of reaction? This is stoichiometry. You cannot. Right, because, so how do you know whether the equation is first order, second order?

(Professor – student conversation starts)

Student: 0:48:47.6

Professor: Yeah, if it is elementary, I know. How do you know it is elementary by looking at that? How do you know I am good guy or bad guy when you look at me?

(Professor – student conversation ends)

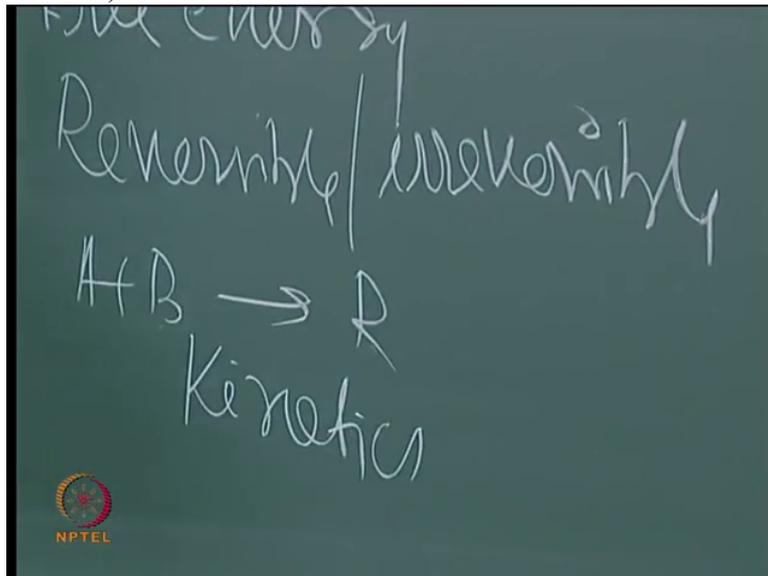
Impossible no, I can be a dangerous fellow, Ok? Or I can be a very good fellow, you do not know, Ok. So that is why by looking at the reactions, like people, we cannot find out whether this is, you know, what is the order of reaction. So that is why experiment is a must. You do not have any other choice. You have to do an experiment.

Even kinetic theory of gases will beautifully tell me if it is gaseous reaction this is A g, A gas B gas giving you R gas then our imagination goes, one molecule of A and one molecule of B, they come together, they collide. All energetic collisions will provide, will produce R. All that beautiful theory is there, right?

It is only beautiful theory because at molecular level we cannot imagine. Molecules are so small; I think you know you cannot imagine that. But still you do the calculations from theory and then find out from the experiment whether your theory is right or wrong. If the theory is not correct, change the theory and again measure and then try to find out. Ok.

So next step is after finding out all these, next step is kinetics. Kinetics only will give you

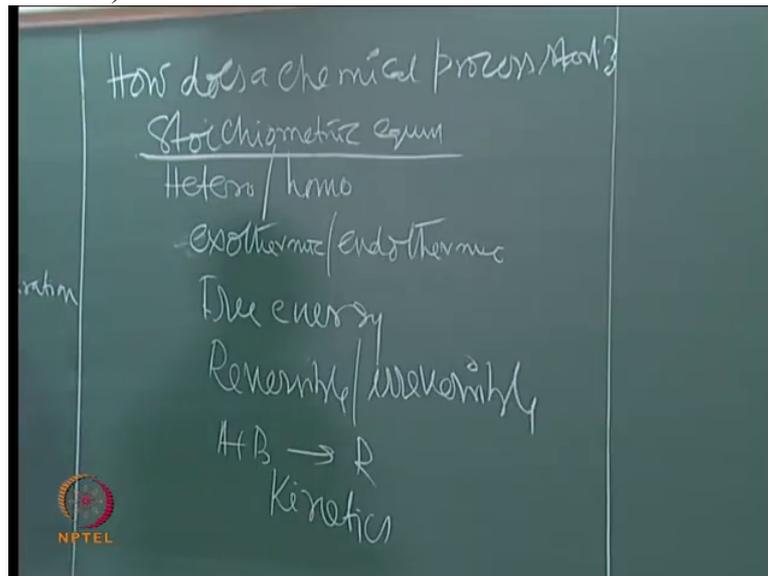
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whether you have order of reaction or whether you know there is no order of reaction. That is also possible. It is not that always I should have order of reaction for this. I may have a very, very complicated equation where you cannot talk about order, yeah. Now you see we have come to the kinetics part.

So I mean, just trying to tell you the sequence of subjects also. The first one is process calculations, the second subject normally you taught is thermodynamics no, thermodynamics and fluid mechanics simultaneously they come. And then of course heat transfer and all that will come, all you know, exothermic reaction means now you have to imagine

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it is highly exothermic, the reactor will get heated up. Now I have to remove heat from the reactor, then heat transfer automatically come.

And now after the reaction is over, it is liquid phase, let us imagine for easy imagination, and this liquid phase has now reactants and also products, right yeah so then we have to separate them. The easiest process we can imagine is distillation. So that fixes even downstream operation.

So once you fix that distillation is possible, and now you use distillation column design, Ok, mass transfer, you have come to mass transfer. Under what conditions is distillation not possible? I have the liquid phase. 0:51:31.2 also now we have become experts no?

(Professor – student conversation starts)

Student: 0:51:33.9

Professor: Yeah, I think in the simplest language if the boiling points are very close then your distillation column will reach moon, height yeah. It has to touch moon. So moon will feel, you know traffic jam and all that. So I think, so for that kind of (laugh) long tall reactors we do not have to really design. So that is the reason why you go to the next operation. What is the next operation?

Student: Extraction

Professor: But extraction again you cannot avoid distillation. Yeah, yeah, you know you again separate into some other component and again you have to separate those two, right? So that

is how all downstream processing is designed. So now mass transfer automatically came, right?

(Professor – student conversation ends)

So like that in now, if you want to start from the heat exchanger because the temperature 100 degree Centigrade you have to heat them , and the reactants have to flow through heat exchanger and then go to reactor, from reactor to distillation column, from distillation column to may be storage tank, all, everywhere you have the flow involved. That is why we teach fluid mechanics.

Now you see fluid mechanics have come, thermodynamics, process calculations, heat transfer, mass transfer and reaction engineering will come. Without talking any reactor we have talked all this. We said only it goes to reactor. So in actually what reactor you take Ok and what process you take, whether it is continuous process or batch process? All that will come in Chemical Reaction Engineering.

And for all this we need control. 100 degrees means you need 100 degrees Centigrade. How do you control? Or even concentration of the, in a distillation column Ok, those concentrations can be again controlled by temperature control inside the distillation column, right? So that is why control automatically comes. And the chemical technology will give you the real information about what is chemical engineering?

All subjects covered? Yeah and afterwards of course you have plant design and equipment design, all that only to supplement this. That is why the entire chemical engineering is only based on 5 or 6 subjects. Any plant you bring, that is the greatness of chemical engineering. Any product you think, only these 5 subjects are enough.

Ok if you put everything in transport phenomena, mass, mass, heat and momentum then C R E, thermodynamics, process calculation, that is all, these are the subjects. And of course control. Control is there. Ok so how does a chemical process starts means with a product and now with all this information you have a flowchart with you. I do not know whether you have noticed that, almost I told you how to develop a flowchart.

How do you develop a flowchart? We have first told that you identify the product. And then you try to find out, you know, through the stoichiometric equation what is the total amount of material, right? Yeah. Now from thermodynamics you will find out the temperature and pressure. So that means, yeah now we have the reactants, reactants are available for you, that is A plus B is available.

Now temperature is 200 degrees Centigrade. So that means and these A and B available only at room temperature. Now you have to heat them to 200 degree Centigrade and send it to reactor. Or you can also heat that inside the reactor itself. That becomes a batch system. But when you have the continuous system so you have to send the reactants continuously through the heat exchanger. That is one of the equipments in the flowchart.

The first is storage tank, pumps then heat exchanger 200 degrees Centigrade right so that means it is entering at 30 degrees or 40 degrees Centigrade and leaving at 200 degrees Centigrade. Now you have heat exchanger in between. Then that goes to reactor.

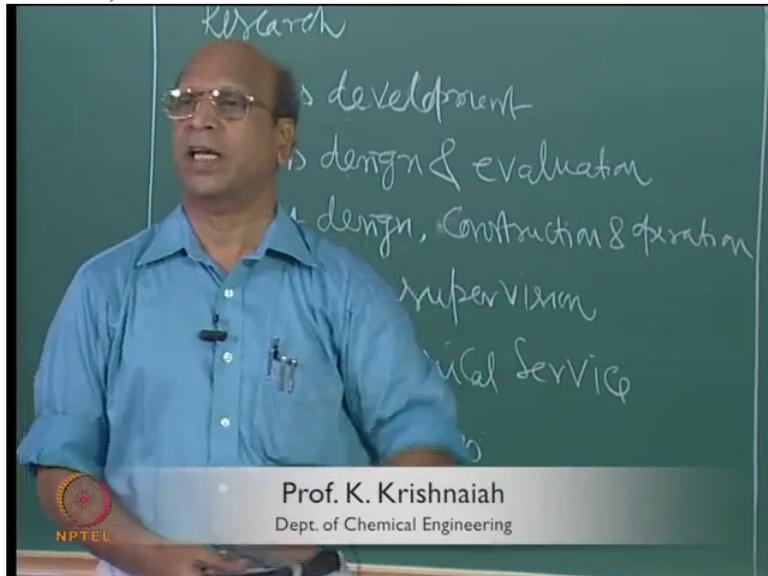
And reactor you have liquid product as an example. Then you will have, if it is a gas product again you can imagine what is the downstream operating, operation. Then in the reactor you have the liquid. Boiling points are very far. Then you know distillation is the operation what you have to use then distillation column.

Now you draw the flowchart, very simplified. That is how I feel we have to teach chemical technology. You explain the process clearly and then automatically the equipment will fall there. We do not teach that. We first draw that and this is a heat exchanger and this is reactor, this is distillation column, this is finally storage tank, that is what we explain without telling the real process.

And most of the teachers, we do not know how to teach chemical technology nicely. That is what I told you no, the Russians have only taught/taught like that. Their books are all focused on that, every step. So if you understand every step there and the conditions are given from thermodynamics.

In fact, they, in chemical technology book they also calculate from thermodynamics what is Free energy, what are the temperatures possible, what are the pressures, what are the conversions, everything

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they calculate. That gives the overall picture.

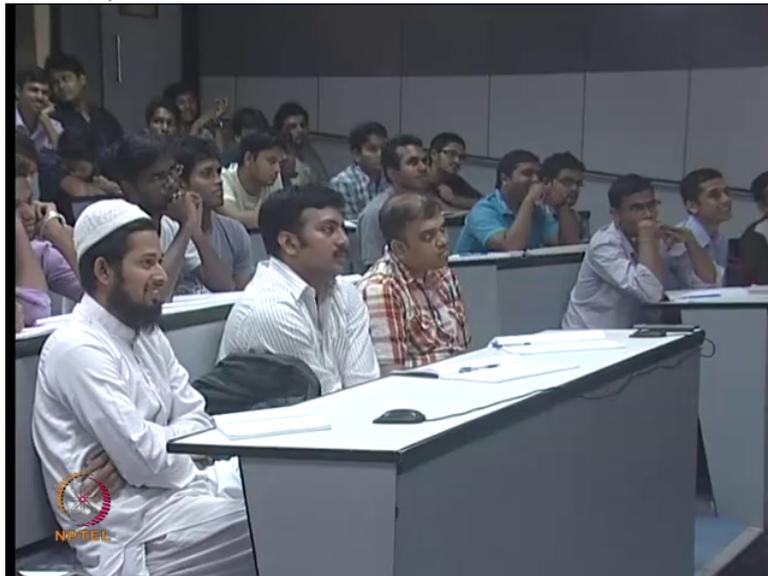
But problem is why we do not teach in that way is entire semester you can teach only one flowchart. And there are how many flowcharts, you have rubber, you have cement I am just telling inorganic things, how many things are there? Paper, plastics, soaps

(Professor – student conversation starts)

Student: Alkali

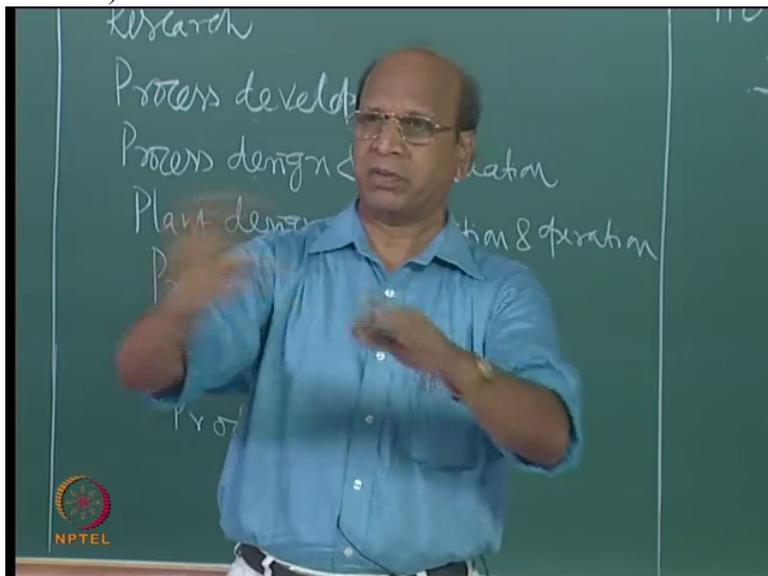
Professor: Alkalies yeah, so many you see. So many things are coming.

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So that is the reason why, everything mug up quickly and say that

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these are the things.

(Professor – student conversation ends)

But that gives you the real feeling for chemical engineering. Chemical technology gives you the real feeling for chemical engineering. So this is what I wanted to tell you in the third question, how does a chemical process start means it is almost development of a flowchart. Equipment automatically falls into that. This is the overall picture what you get now from that question, Ok. Yeah I think we will stop here.