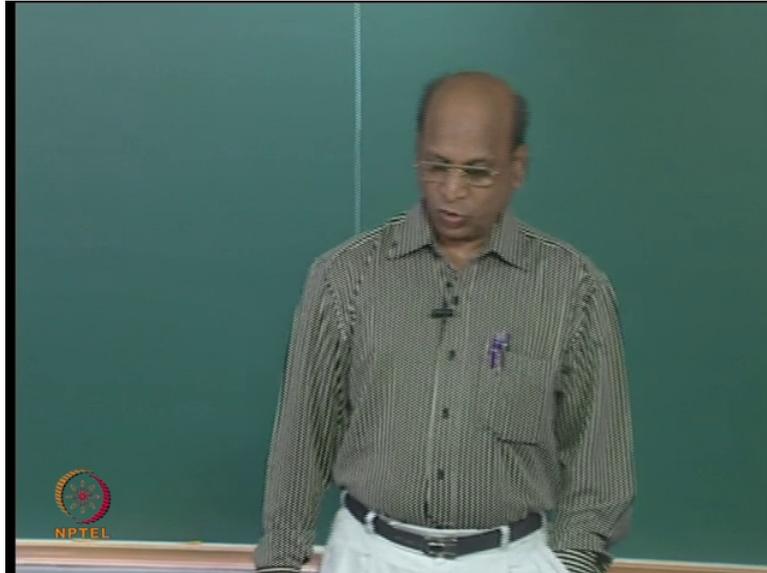


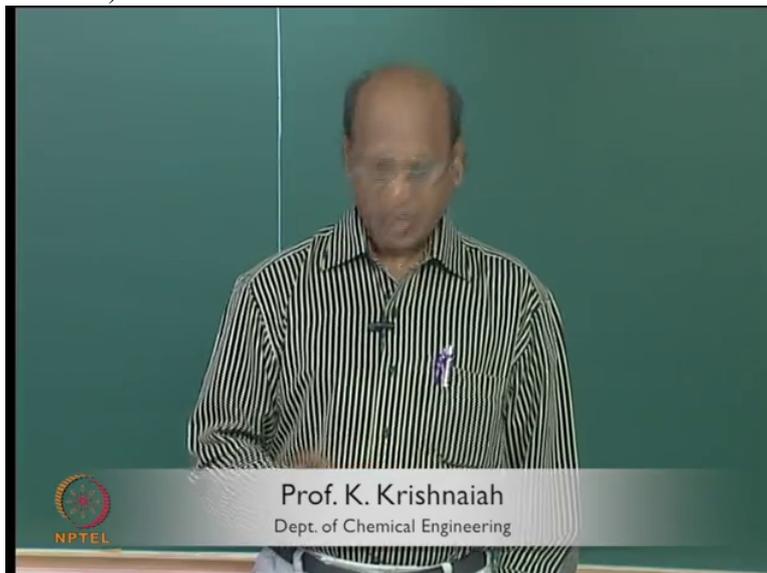
Chemical Reaction Engineering 1 (Homogeneous Reactors)
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 03
What is Chemical Engineering Part 1

(Refer Slide Time: 00:10)



So in the last class we have discussed about that first question, what is chemical engineering?
But I do not know how many of you have the real definitions of chemical engineering.

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I have one definition; this is given by A I C H E. I do not know whether you have heard of this or not. What is that A I C H E?

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(Professor – student conversation starts)

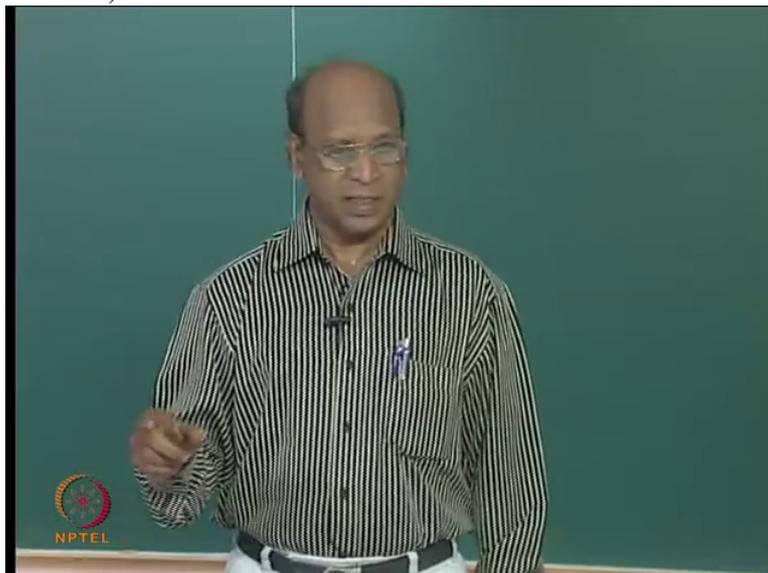
Student: American Institute of Chemical Engineers

Professor: American Institute of Chemical Engineers. You know everything about America.

(Professor – student conversation ends)

Ok so American Institute of Chemical Engineers

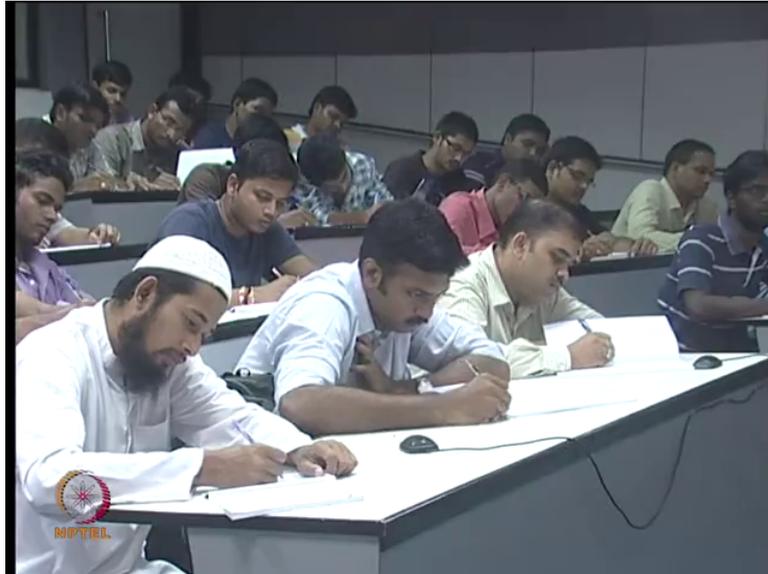
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definition, I will just read, please write. Because it is, let it be there in the books. I do not know whether you really spend time to understand this but let it be there, I think, when time is required, I think when this required, so you can try to use this definition.

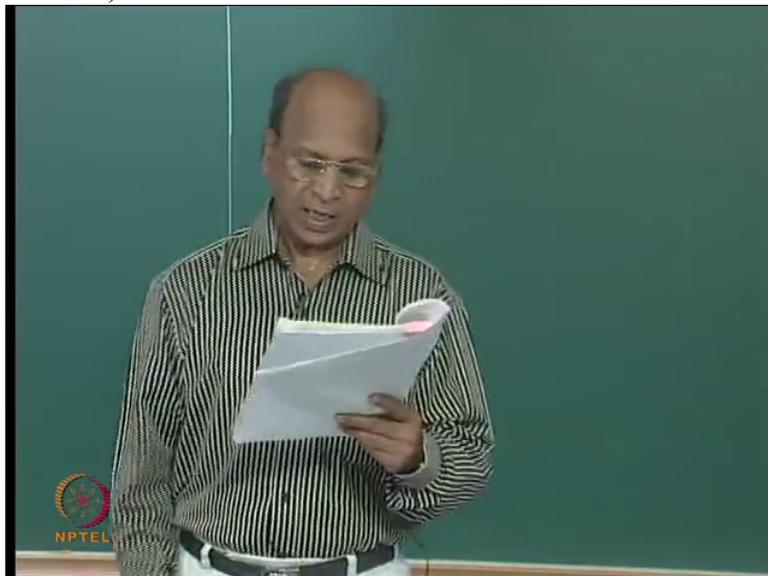
Yeah the official definition of A I C H E is sufficiently broad to include all aspects of the profession. Now you can write within inverted commas, "Chemical engineering is the application of the principles of physical sciences together with the principles of economics and human relations to

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fields that pertain directly, pertain p e r t a i n, that pertain

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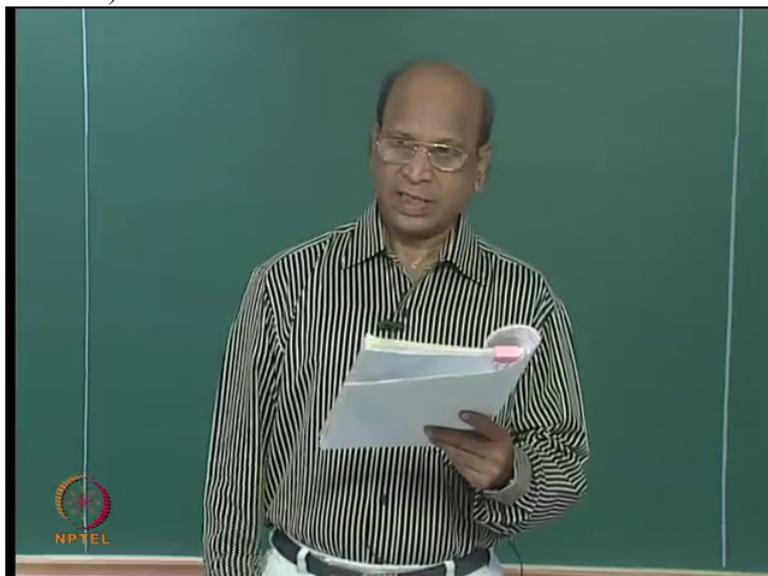
directly to processes and process equipment in which matter is treated to effect e f f e c t,

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to effect a change in state comma energy content or composition.

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Ok that is the one. I think inverted commas closed” Yeah so Gani can you read this louder so that everyone I think, you would also give the meaning, Ok.

(Professor – student conversation starts)

Student: Physical sciences together with the principles

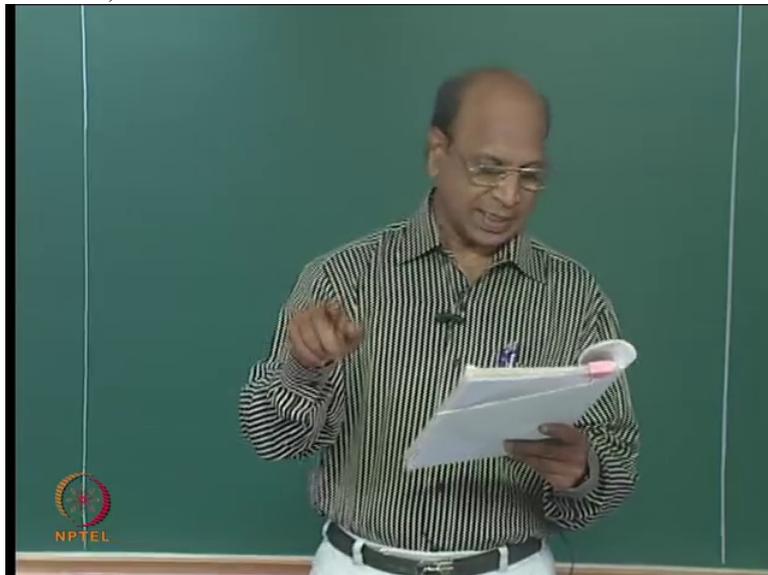
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of economics and human relations to fields that pertain directly to processes and process equipments in which matter is treated to effect a change in state, energy content or composition.

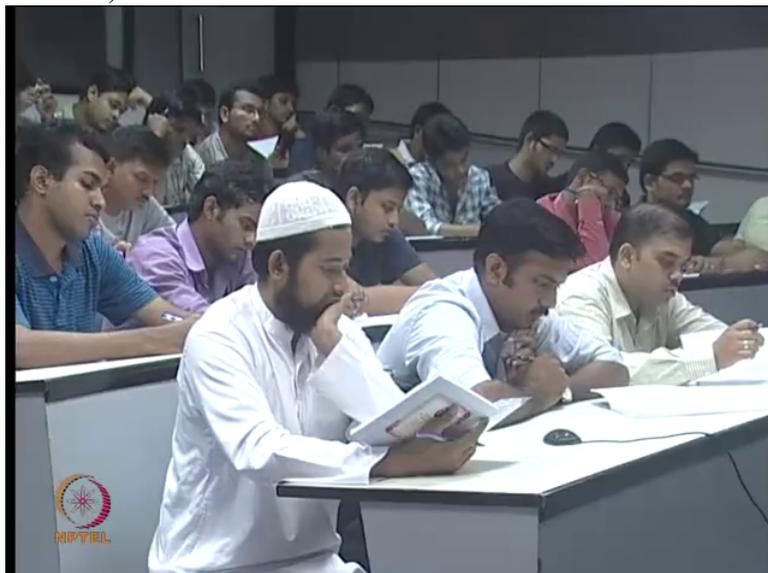
Professor: Yeah, what is that you said the first one, chemical engineering

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is the application of the principles of physical sciences, principles missing? Yeah I think some people would have missed it. Yeah, chemical engineering is the, what is the meaning of that, can you just read it and just try to understand?

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(Professor – student conversation ends)

What is the meaning of that? What is the meaning of that? Louder. I think you know you can interact with me. There is no problem, you should not be afraid that you know you are not able to tell and all that. We are all learning. So that is why absolutely there is no fear for making mistake. You should not be afraid of making mistakes. You should happily make the mistake, mistakes as many as possible but the only thing is you should not repeat them. Ok. Tomorrow also you cannot do the same mistake, yeah.

(Professor – student conversation starts)

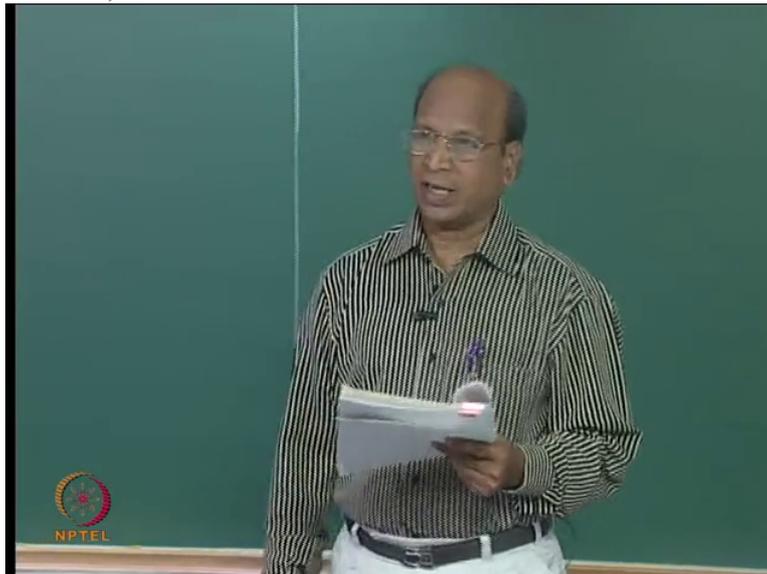
Student: 0:02:56.7 Physical sciences 0:02:57.0 all is this. Chemistry and all...

Professor: Yeah, all sciences yeah.

Student: It is the knowledge about the sciences and the economic viability of, economics of profit which...

Professor: Yeah, economic principles, yeah, that means whether process is economic

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or not. Yeah then?

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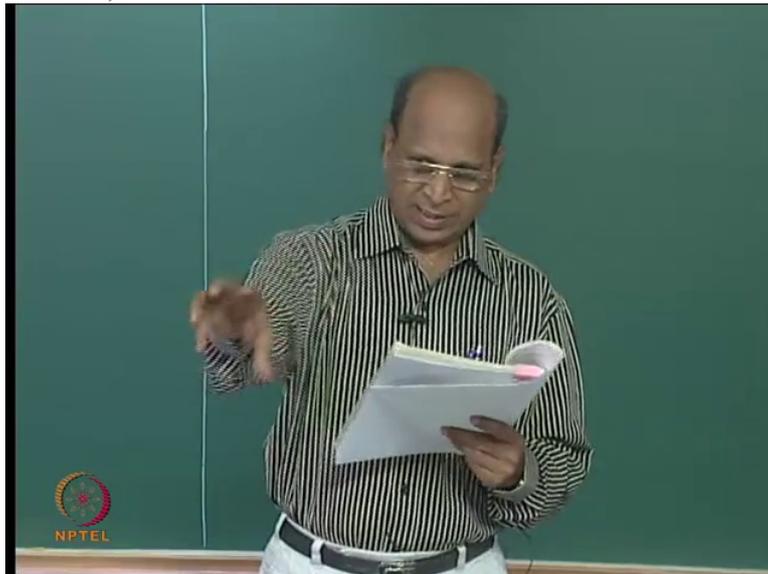
Student: How it can affect the interaction from 0:03:21.2, environment, the people

Professor: Environment has not come here in this one.

Student: That is 0:03:25.3

Professor: Ok, yeah but do not create your own definition. Just

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understand this definition. Then we will create our own

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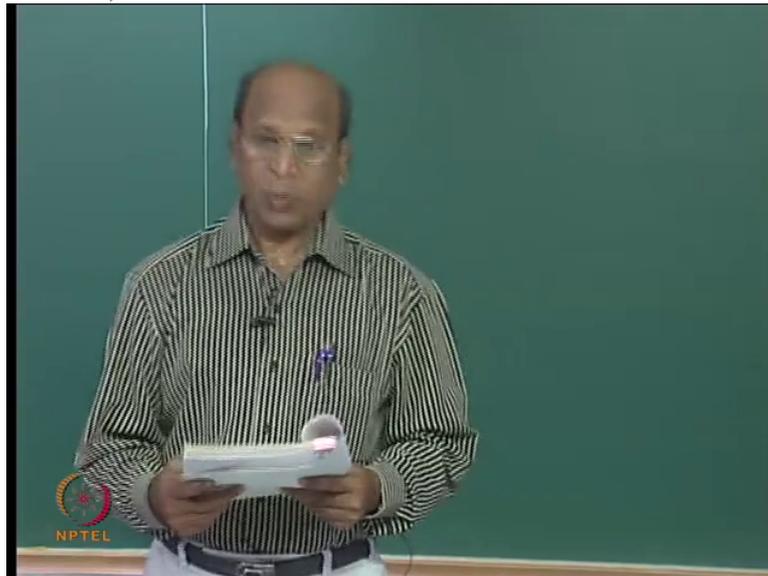


definitions later. Yeah?

Student: Human relations that use, given there...

Professor: Yeah, you know

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human relations are also very, very important.

(Professor – student conversation ends)

That is what, you know, this is physical sciences that means maths, physics, chemistry, of course chemical engineering is based on that mainly. Now we have biochemistry. This is very one of the oldest definitions. So pertaining to the, that pertain directly to processes and process equipment in which matter is treated to effect a change in state, energy content or composition.

This last statement also, state, energy content or composition. So that means, you know, during the reaction if everything is in gas phase so then you have to condense that and then you can make it as a liquid or if it is a liquid, to solid, that is the state thing, and also the energy content.

Energy content that means at may be very high temperatures you have to cool it to room temperature because you cannot store everything only at high temperatures so the changes in composition or energy content or state. That covers everything. That means in which equipment you are changing the state?

(Professor – student conversation starts)

Student: Condensers

Professor: That is only physical problem. But the reactor also you are changing the state. Because sometimes during the reaction itself precipitation occurs. Sometimes you know that itself is the product. Ok.

(Professor – student conversation ends)

So this covers few equipment. And also energy content. Energy content mostly of course, even in the reactors again you know, you add heat, remove heat and all. That means you are trying to change the energy content of that. And also composition in which equipment? Distillation columns, absorption columns and all that.

So that means this also talks everything, almost all the equipment, Ok, so all these equipment you know, final equipment design. Even though most of the young faculty members nowadays, they get very bored about, you also, the moment you become faculty member also, you hate equipment design.

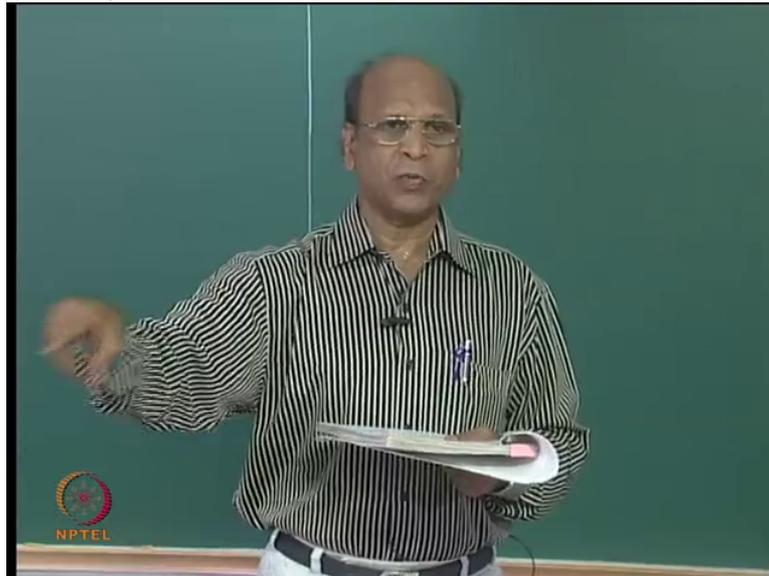
Ok why, because there are not much mathematics involved. There are only some rules that you know, to design for example condensers. Or heat exchangers or distillation columns. You have some principles. So just follow them and then design. So what is the thrill there, people say?

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But ultimately all the theory what you have developed finally will go to this part. And if you neglect the end part

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and if you are very happy only with the theory part, then who will use your theory? Ok, so that is the reason why, all, this entire thing is very important. We need theory to understand, right like for example distillation columns; always we see it is vertical. And also number of plates and all that.

But now people started thinking about very small size of the equipment for distillation and they use centrifugal force. When it is moving the liquid will be just simply spread on the thin sheets at very high speed, you know. So then thin she/sheets, when you have very, very thin sheets of liquids then evaporation is much easier, right? So the low volatiles will easily come out and high volatiles will stay there. So then you are separating very, very fast.

And you have 20 meters, 30 meters distillation columns. Now they have become only 6 feet, 7 feet. That means 2 meters, 3 meters. So that is because of the new theory. You are now able to think that at molecular level what is happening. And how to use that information to create very, very thin film and we know that when we have very, very thin film of molecules; it is very easy for the molecules to come out. Because resistance is simply less.

Right, so that is the theory. And using that theory you are able to develop this equipment. So finally the ultimate aim is only the equipment design. Otherwise where do you conduct these reactions, you know, where do you conduct these separation processes? Or crystallization? All these processes where do you conduct unless you have this kind of equipment?

And also nanotechnology, very fashionable word to use, you know, many times. But at the end what do you do with that nanotechnology? You should still design a reactor or some other equipment for our processes. So that is why do not simply get carried away with these beautiful words unless you understand those words and unless you use those words properly for the final design. See ultimate aim of our profession is to produce chemicals. That is all.

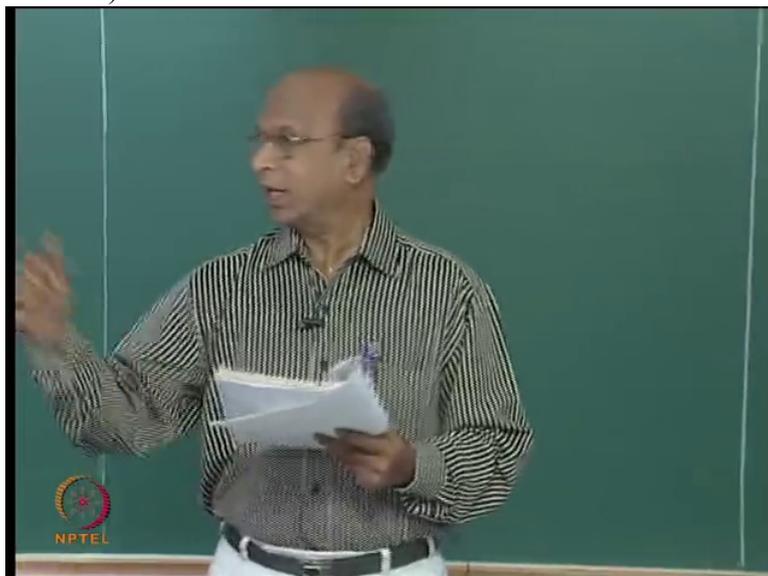
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So that is the second definition I just want to tell. This is the official definition.

The second definition is that, you know, a simple definition is a chemical engineer carries out large scale reactions developed in the laboratory by the chemist.

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So the chemist will definitely try to find out whether the reaction is feasible or not but in minute scale, micrograms.

But with micrograms, I think nowadays if you go, you get headache after this class and go to hospital and they will give you aspirin tablet. Or some other, you know analgin or many, many tablets are there. Ok. So if you look at them, then there will be amount also given 500 mg. So they may not produce even 500 mg for this one person sufficient.

Ok, so that is what is actually happened in penicillin production. They could not produce on large scale, one patient actually in U K, he has got some infection. That made him I think one week or so or 4 days, 5 days alright, and because they could not continue, they did not have sufficient amount of antibiotics they produced in the laboratory and afterwards he died. That is bad thing to say like that but operation successful, patient died.

Because as far as antibiotics are concerned that was successful. They know how to produce now, on a small scale. But unfortunately this patient could not get sufficient amount of antibiotics so he died, right? So that is why our business is, as chemical engineers to produce chemicals on very, very large scale. Generally the starting point is

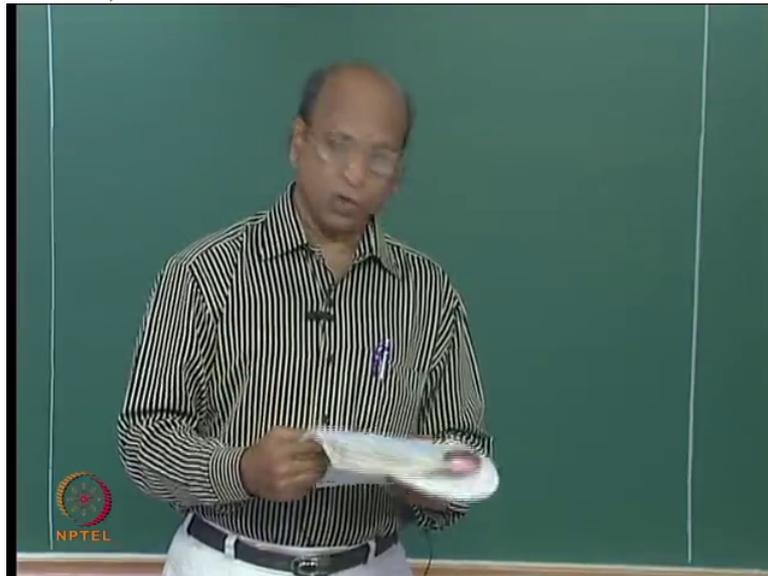
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a chemist. He would have produced and told that this product is there. So it may be useful for this, this, this. Good? Yeah.

Then again I think this, some of you may be knowing

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a jocular definition of chemical engineering. You know? Anyone knows about the jocular definition of chemical engineering? No. Yeah I will tell you. A chemical engineer is one, another definition, this is a jocular definition, you can write jocular definition, a chemical engineer is one who talks engineering in the presence of chemists comma a chemical engineer is one who talks engineering in the presence of chemists, chemistry in the presence of engineers, chemistry in the presence of engineers comma and politics in the presence of both. That is the definition. Ok.

What do you understand this? That means we do not know sufficient amount of chemistry, we do not know sufficient amount of engineering and when both are there, our ignorance should not come out, we divert the topic to politics. Because politics anyone can talk. Because everyone has an opinion in politics, right? Yeah. But there is a, there is a beautiful meaning behind this definition.

Though it is jocular definition, it is not really jocular. It is very serious definition. Because many jokes there is serious information, Ok. That means this is the only engineering which is based on science, Ok, from the beginning, right that means what? Unless you understand basic chemistry you cannot carry out further your processes. That is what is the meaning, right.

So a chemist who is a scientist, who has sufficient knowledge in that science, right, so he should have sufficient information how to produce this chemical. It is not by trial and error.

Theoretically also you should be able to find out; Ok this is feasible because of this reason, this reason, this reason.

So afterwards you cannot produce large amounts because of you know engineering is coming there, for example I told you, mixing is a kind of engineering principle. Heat exchange is a kind of engineering principle, right, on large scale. How do you do that? So that is why engineering will come into picture. So engineering knowledge is necessary.

In fact in the beginning, it is applied chemists, not even pure chemists, applied chemists and mechanical engineers are the people who are producing chemicals. I am talking about 1800s, 1700s. Ok. So the definition of chemical engineer at that time was applied chemist plus mechanical engineer equal to chemical engineer, right?

And then they thought that Ok, we need a separate profession where we need some information from the science side, of course physics automatically comes whenever you have heat transfer, fluid flow and all that, right? And without maths you cannot quantify. The greatness of maths is anything you want to say a number math automatically come. And unfortunately or fortunately you have to tell a number.

So if someone asks Ok, tell me the design of this particular reactor, you say, Ok, use 1 meter cubed volume, 1 meter cubed is a number. And how do you calculate 1 meter cubed and all that, again you have to use some equation. So mathematics you can never neglect at all. It is a part of all

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the processes, every day also, every day also I think mathematics is used.

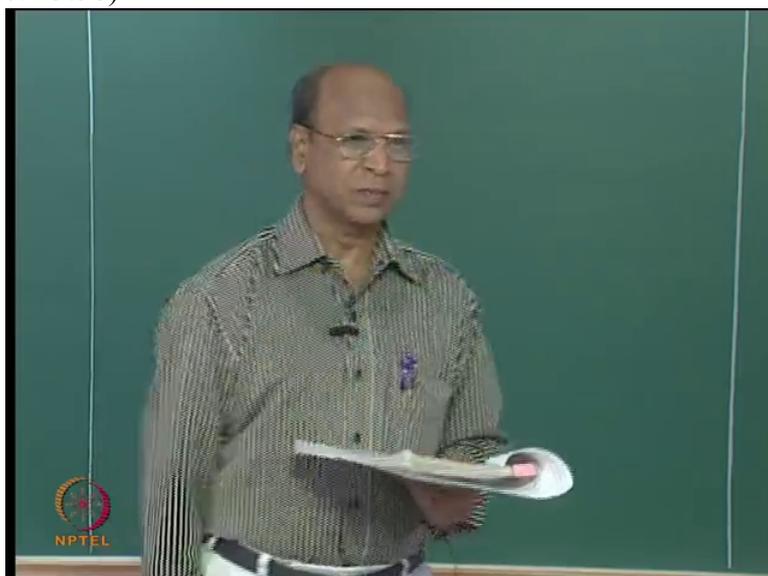
I think you know when you have 20 Rupees and go for Tiffany's and coffee will be 25 Rupees so then you may come back, Oh 5 Rupees less! Subtraction. Ok. Nowadays everything is costly, no. I do not know how much is there? What is the cost, Rahul? 6 Rupees

(Professor – student conversation starts)

Student: 7

Professor: 7, they are creaming you a lot because this is subsidy given to the students.

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So that is why they are creaming you a lot.

(Professor – student conversation ends)

But anyway, anything, everything there may be a time now coming, the inflation that is going on, even 100 Rupees you do not get one coffee also. Ok, anyway coffee is bad for health, do not drink. Ok (laugh) that way you can escape. For that 100 Rupees you can buy a fruit, a small fruit and then you eat; whatever fruit that comes. That is much better. Ok so this is another definition.

And the latest definition that is given by Denn, I do not know whether you heard of him, Martin/Morton Denn D e n n, he has written a book recently, may be a year back, 2 years back, Chemical Engineering: An Introduction. Chemical Engineering: An Introduction, Ok, that is the name of the book. D e n n, double n, with one n he is not happy. So D e n n, Martin/Morton Denn, Ok. Martin Denn, Ok, good.

He wrote that book, Chemical Engineering: An Introduction. In our library, 1 or 2 books may be there. And he of course, he started at a high funda level and all that, but anyway one of the definitions he has given, this is the, may be, current definition. Please write that.

Chemical engineering is the field of applied science that employs physical comma chemical comma and bio-chemical rate processes for the betterment of humanity. That is the latest definition. And if you go to U K chemical engineering site, you will have a different definition. If you go to India; it will be a different definition. If you go to Japan, Chemical Engineering Society and all that, so they may have slight difference.

But the ultimate aim is to produce chemicals and bio-chemicals. That is why chemical engineering and bio-chemical engineering no way different. Here you need chemistry background, chemistry information for the reaction whether it is taking place or you know, on a catalyst or all that theory, and in biochemistry, bio-chemical engineering you need information on biological processes, right.

So if you have sufficient knowledge there and you know that there is a reaction that can be continue/continued, that can be conducted, then that information will automatically come into the reactor design. So that is why chemical engineering and bio-chemical engineering or bio-

technology, if you are talking about production of chemicals in the industrial level, at the industrial level, Ok. So bio-chemical engineering or biotechnology or chemical engineering all are same.

In fact, chemical engineering is so wide, for example environment engineering, many civil engineers start environment engineering but the real environment engineering is only with chemical engineering. The reason is most of the pollution is from the chemical industries. Ok And civil engineers have come into picture because traditionally they are the people who are treating sewage. And that sewage is mainly from human waste and kitchen waste and all that. That is all.

So they logically extended their field saying that we will also talk about this pollution. But it is chemical engineers who create pollution and also it is our business to control pollution. Now zero pollution. You should have the processes, you should have heard no, green chemistry, green engineering and all that. So idea there is that we do not have to produce any waste product at all. So it must be, at the end everything should be useful. Ok those are new processes we have not yet started teaching in the chemical engineering. Few universities abroad I think, they have started.

But we do not have green chemical engineering or green processes. We do not have 0:17:29.0, yeah and also sustainability engineering. Yeah sustainability energy enrolment always is 0:17:34.3.

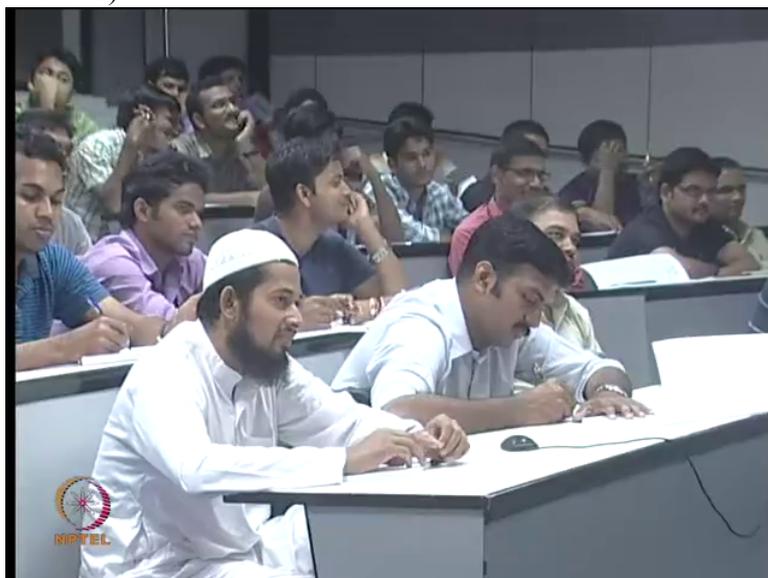
Ok so that is why new definitions will be coming according to the definition, current situation on this planet and this definition you see, again it is very simple and straight-forward; applied science, chemical engineering is the field of applied science that employs physical, chemical and bio-chemical rate processes, rate of reaction, right?

So that rate of reaction you should use in the reactor design expression so that you, you will produce. And if you are able to produce, I told you using dream reactor. What is dream reactor? Yeah, directly reactants to products at room temperature, 100 percent conversion and you know that means there are no separation process, no byproducts.

Separation processes are not required because at room temperature in the beginning we do not have to heat the reactant, everything at room temperature, so, so beautiful! I think why do not you try to design that kind of dream! That is what is really sustainable. You do not need any energy.

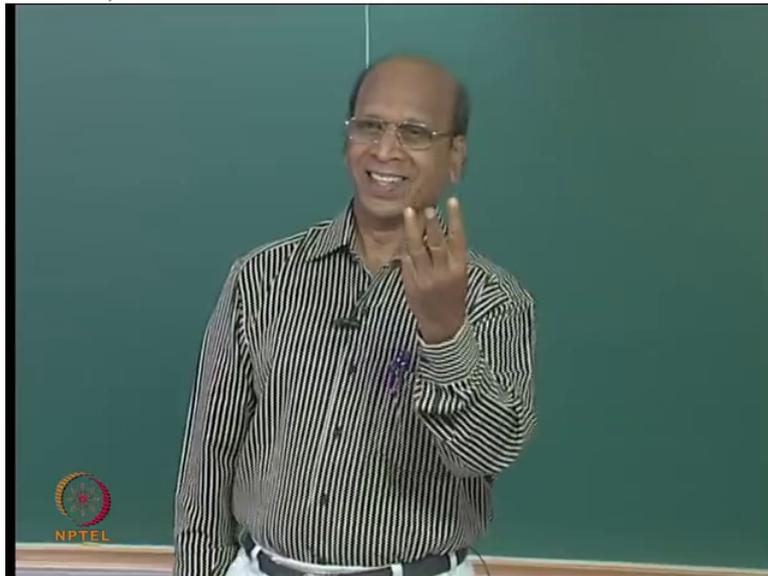
Try to produce ammonia at room temperature and room pressure. You will be given Nobel Prize, not 1, 10. I think Haber got only one.

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Because still it is high T, temperatures are very high. Ok. And pressures are very high. At least reduce the pressure. And you know, conduct the ammonia reaction, ammonia synthesis reaction at ambient pressure you will get Nobel Prize, temperature also if you reduce, 2 Ok, and catalyst if you remove 3.

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Because now you need catalyst. Right. What catalyst they used?

(Professor – student conversation starts)

Student: Iron

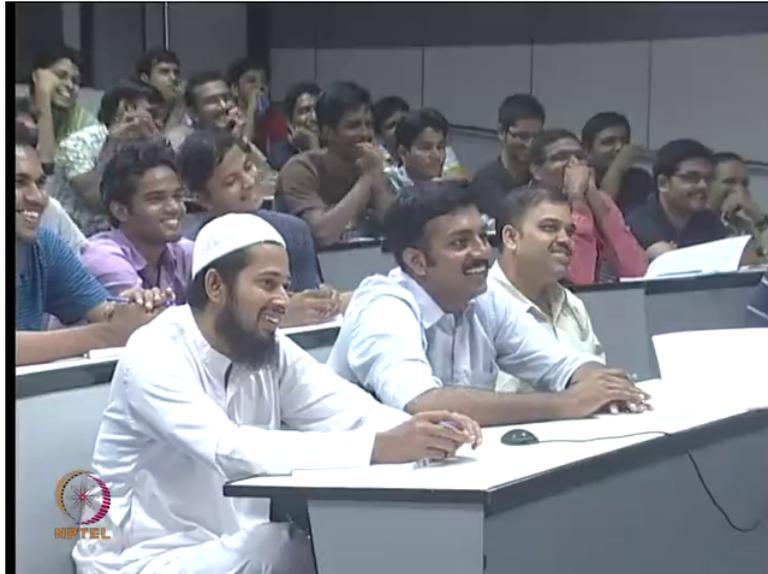
Professor: Iron of course mixed with slight, yeah all other small chemi/chemicals, small metals are there but mainly it is iron. Ok and he found it.

(Professor – student conversation ends)

In fact I was lucky to see his room where he has worked in this process, you know, in University of Karlsruhe in Germany. I also worked there for some time. So at that time I saw his room. And his reactor has now been brought, after I think may be, I do not know how many years, may be 15-20 years of operation, actual reactor which he and other person Bosch, Haber and Bosch, that is why Haber-Bosch process we say.

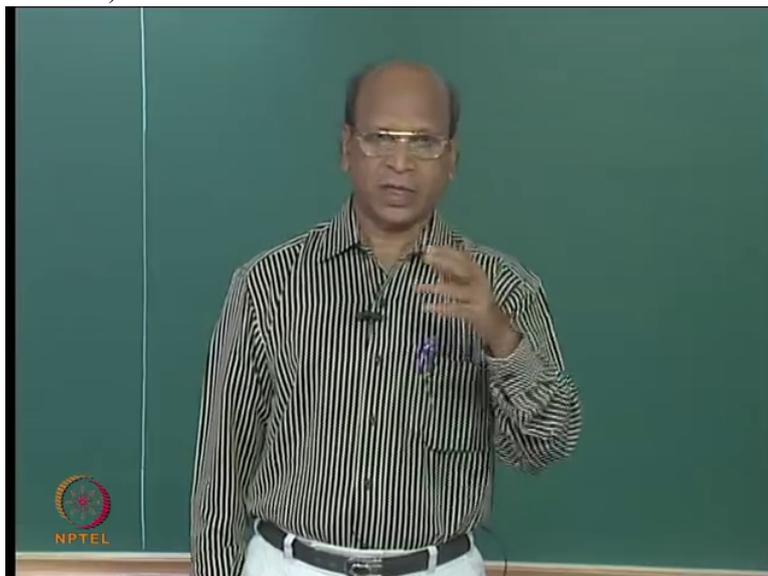
Bosch was a, is not a directly chemical engineer but he declared himself as a chemical engineer because he was dealing

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with all chemical engineering processes in B A S F. B A S F is a company, you may have heard no? Yeah B A S F has a nice expansion in Germany, German language. So he,

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after he produced that in lab scale, lab scale reactor also is there.

If you promise me that you will read the papers which I send, I can send wonderful information. But otherwise I do not want to create e-pollution. E-pollution, that means I send the paper to you, you just click and save. And then you never open that again. Ok, that is pollution no, on your computer. You are not using that. It is waste. That is waste product only, right?

That is why if you promise, all of you if you promise me I will read and then only I will send. I think I have the picture of his original reactor, lab scale as well as industrial scale. Now you appreciate. Most of these things we also teach in process calculation, whatever I am telling you now, right. But at that time you really never able to enjoy what you are trying to say but at this point of time, you enjoy.

That is the reason why I repeat. Many people may be thinking he does not know anything except this so that is why he is repeating, people may be thinking. Ok. But you know, because I enjoy, because at this point of time you enjoy more all these things. Otherwise you know whatever you learnt in school, you need not enjoy in school. You learnt only, you enjoy only when you come to U G or P G, how beautiful you know, we learnt in the school.

So that is why there is always a time lag. That is why I repeat all these things in my course. So at least some of you may catch this and then try to enjoy. Ok and there are some minds which are already been switched off. They come here, sit, laugh and then go. But I think nothing will enter, like black holes at least people say radiation will come out, Ok. Radiation can be measured from black holes. Black hole means you cannot see anything.

So I think the human mind is, if you switch off the brain, human mind is much worse than black hole. You do not know anything what is happening there. Ok and perfect insulators are human brains. Yeah, if you are able to take and put it, nothing will enter, nothing will come. That is why, at least you know some matter in black hole will radiate. Ok. That is also not possible.

So if you already have, you know normally you will have around 20, 15 percent already switched off brains; they come, sit down and then go. And those are the people who really spoil, you know, the juniors who are coming. Unfortunately if those people are exposed to these 10 to 15 percent, they give all fully wrong information, complete total virus. You cannot clean it with anything. Ok, No antibiotic dot is possible for that.

So unfortunately many people will go and ask them only. They won't ask a good student. Good student means he will definitely tell, this is good, this is bad and clearly you can

believe him. But unfortunately for them, it is everything bad except staying in the hostel, Ok and seeing movies and all that, right? So that is why this is very unfortunate if you ask them.

So that is why I am not talking about that 10 percent. I do not know right now who is that 10 percent but statistics show that that 10 to 15 percent already exist, Ok but not able to pinpoint them right now. But you know yourself. You definitely know whether you are enjoying it, or whether you want to learn or you simply come because your guide told or someone else told that you have to take this.

So it is a punishment, 40 hours, 50 hours punishment. So that is what probably you are doing it; that is all. But anyway if you do not have a choice, try to relax and enjoy, Ok. Because all M Tech people do not have a choice. It is compulsory for you, Ok and I think P h d also compulsory? P h d also I think compulsory because

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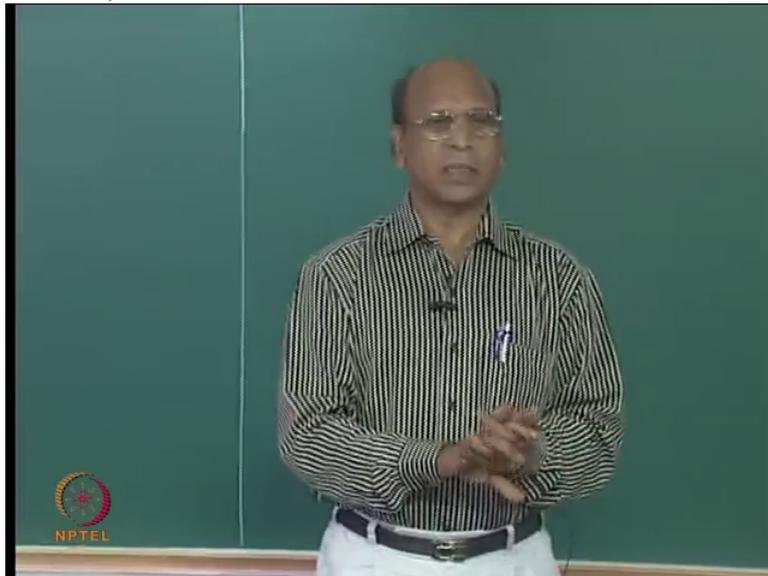


for their comprehensive viva or something, Ok.

So that is why those who do not have choice, try to learn something. If you have choice, put a hole through the ceiling and then go out. Ok like Superman or something like that, put a hole and then go. Ok, good.

So this is what is the complete answer for the first question,

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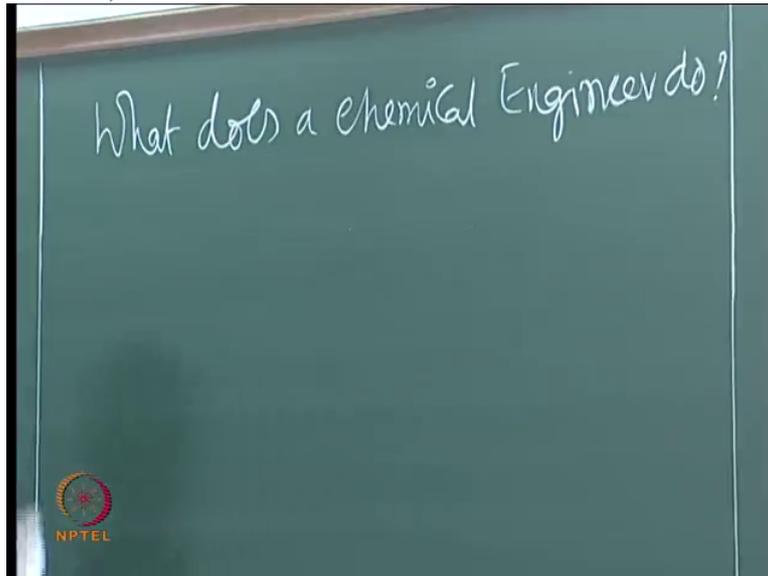
what is chemical engineering, OK. Now the second question is what do you do as chemical engineers? Ok, the reason is most of the chemical engineers are going for I T jobs. Now they think that only going to I T job is chemical engineering. That is what is the job of the chemical engineer.

So if you ask them to write what the chemical engineers do, go to Infosys, open the computer and then do whatever they give exercise. That is what the people may think. Ok. But what are the things what a chemical engineer can do; I will just list out here and then discuss one by one very quickly, Ok.

The second question is, what does a chemical engineer, ah, you have to squeeze there, yeah.

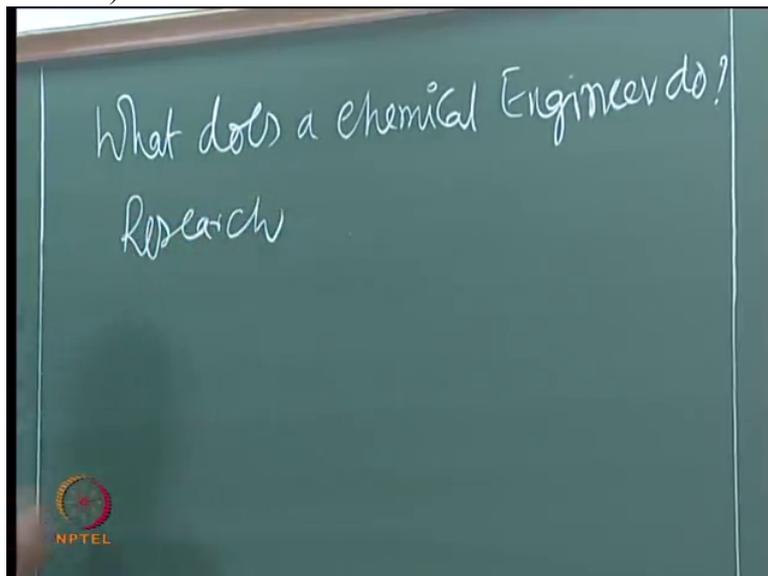
The first one

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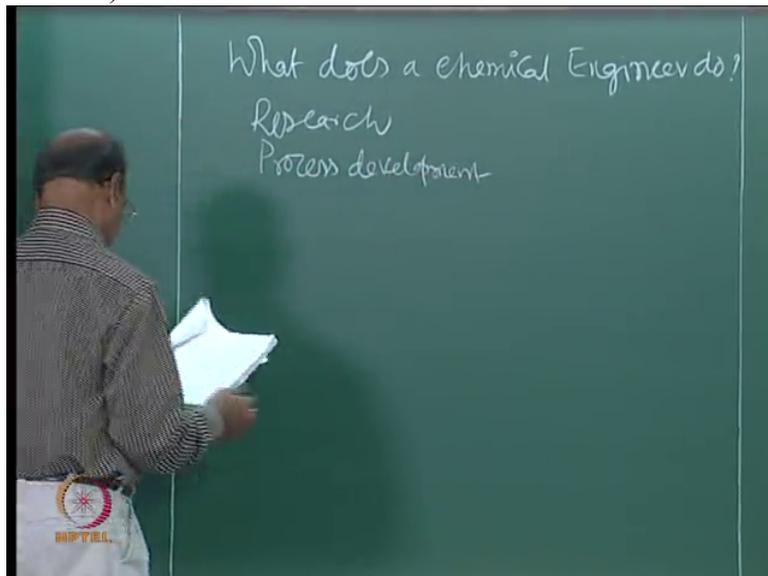


is research.

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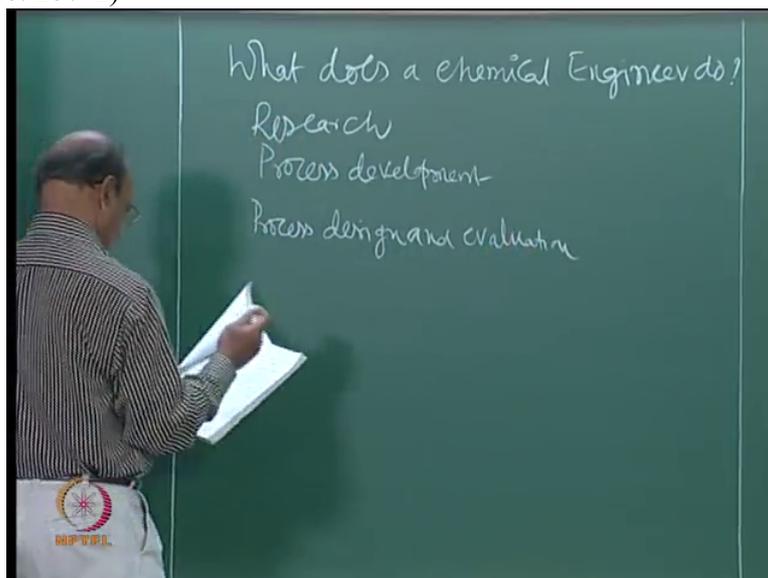


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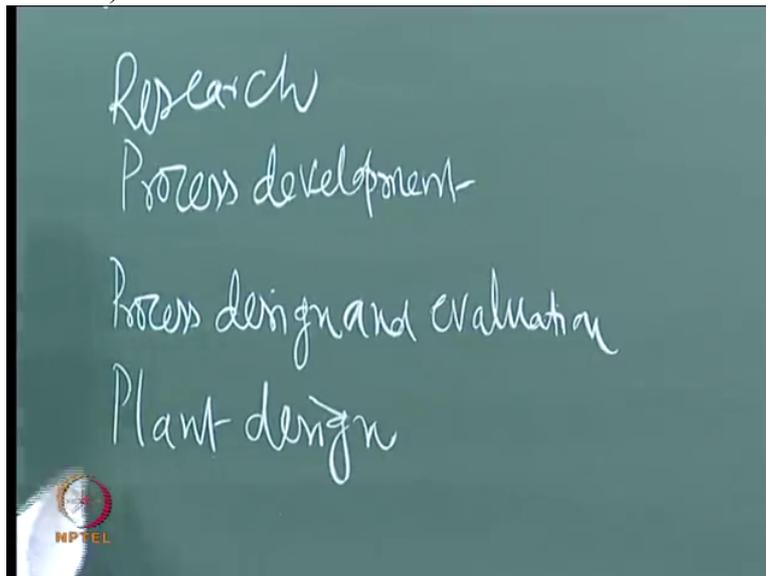
Process development, process design and evaluation,

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process design, Ok, plant design, Ok I think

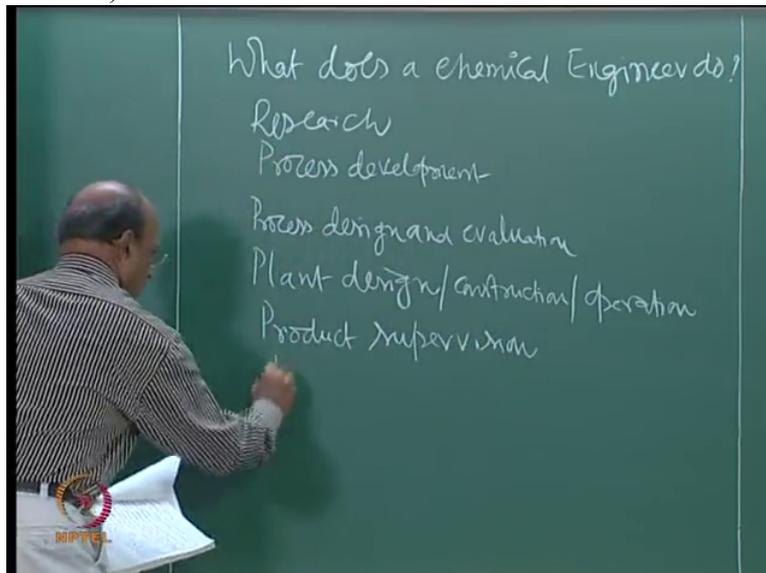
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will write all these things in one; plant design, construction and operation.

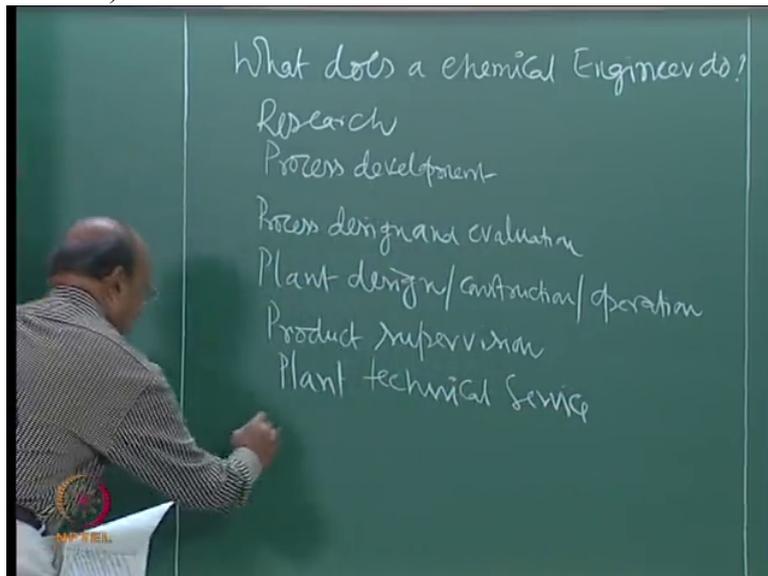
Then we have product supervision.

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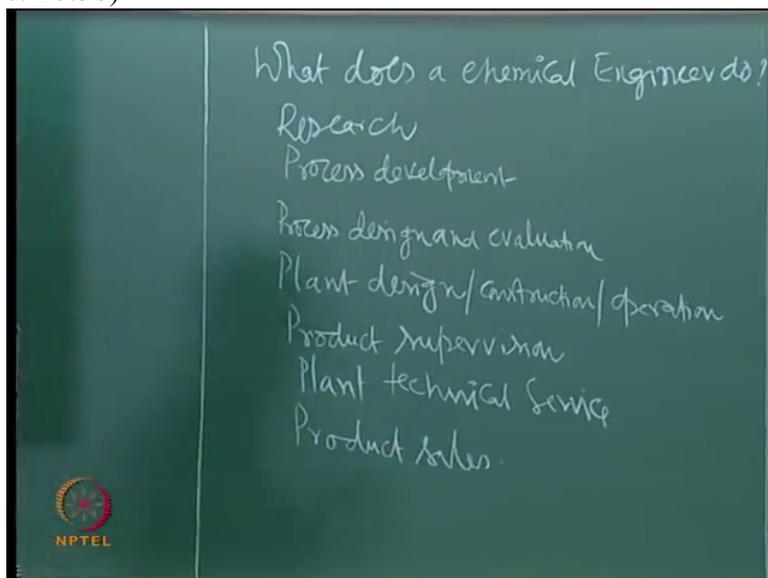
Plant technical service, technical service and then

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product sales,

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so those are the things. Able to see, last benches? Able to see, no, size? OK, good. These are the ones. The first one is the research, Ok. Chemical engineering automatically associated with research.

Whereas this research component, if I take mechanical engineering example, it is not there. So if you are designing a boiler or if they are designing a automobile, Ok, generally the principles are known. But if I want to design a new chemical I do not know anything. And how many chemicals can you list out?

(Professor – student conversation starts)

Student: Many 0:27:15.7

Professor: In inorganic chemistry how many, in organic chemistry, how many? How many chemicals? Thousands of chemicals.

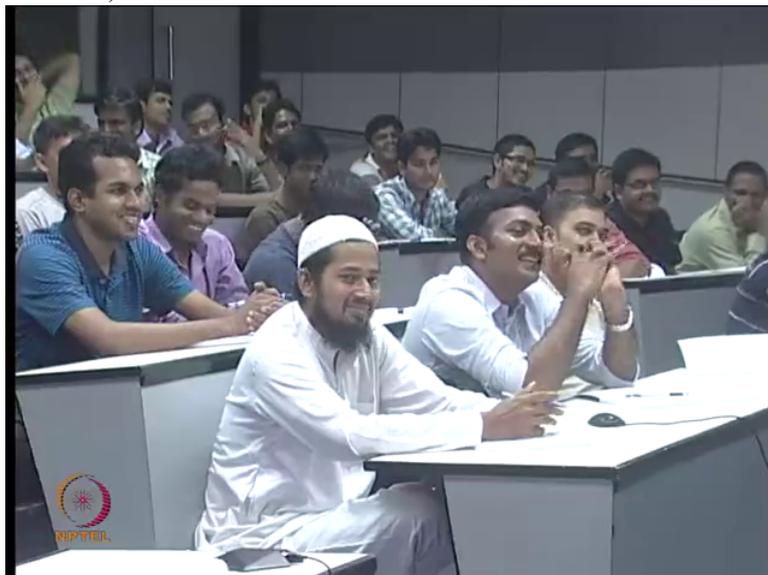
(Professor – student conversation ends)

And the beauty with chemical engineering is every process has a flowchart. How do you develop that flowchart? Without a flowchart did you anytime see a particular production of a chemical? Never. So how that particular flowchart was developed. And now of course, if I know how to produce sulphuric acid, I do not have to do research, even though it is possible, Ok and nothing is saturated in chemical engineering.

Those people who say that Oh, chemical engineering saturated means it is not chemical engineering saturated, it is his brain saturated. Ok, because he is not able to see anything different. So this is saturated. He is happy. And then like going to I T. I T, what is there?

They give some instructions. Sometime you follow on the computer and lifelong you do there. And if you, they will not allow you. They will give you more money but they will also give you more work and always sitting. So that is why after 3-4 years you will have back pain, Ok, stomach will be coming this much

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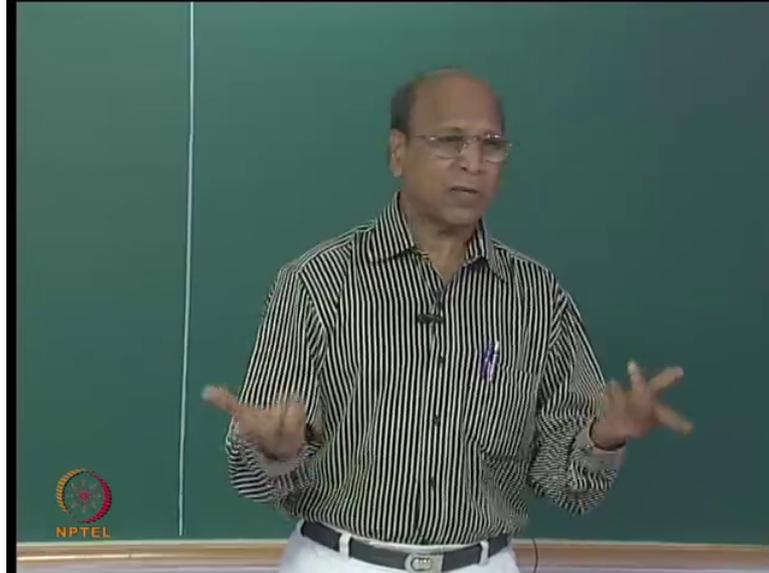


(Professor – student conversation starts)

Student: (laugh)

Professor: Because I think...where is the

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physical activity? There is no physical activity; there is no mental activity also. Because already everything is known. You just only enter, enter, enter. That is all. I mean, if you are developing a new software, excellent.

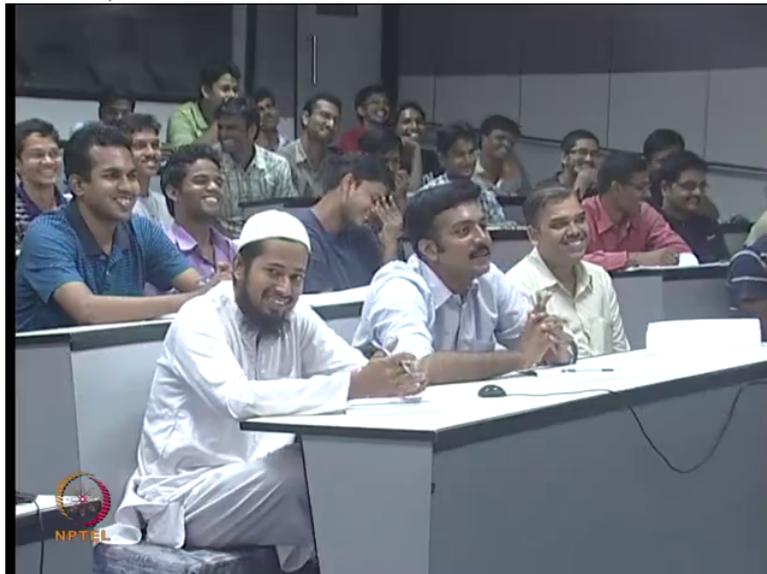
(Professor – student conversation ends)

If you are developing the computer like you know, that Jurassic Park movie you have seen? That entire thing is computer controlled. Those big structures you know, the, may be, height may be 50 feet, 60 feet high, you know those 1 or 2 models what they have shown. So if you are doing that, excellent.

Or even if you are making that beautiful cartoons, very good, no problem. Because cartoon movies and all that, lot of computer work is there. So at least you are using brain. Because if you are producing the same cartoon in 2 movies, no one will see the second movie. That is why I feel that in movies only there is tremendous of innovation, tremendous amount of innovation. Really I have to appreciate that.

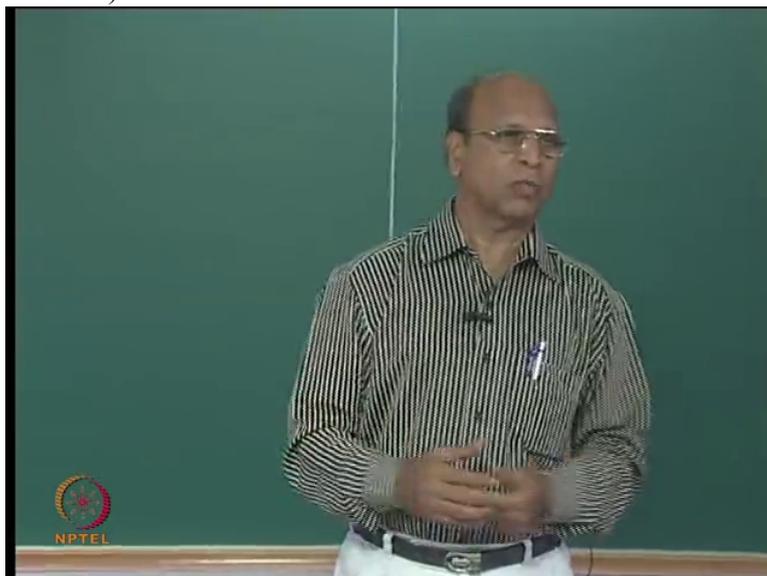
How many dresses they change in one song, I say?

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And you have to think so much, right. No one will go

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to that movie. First information will go; it is same thing as other movie, closed. Ok, so that is all. And they are spending thousands of, and fights? Oh my God! Sometimes I think if man is not sufficient, two cars will come and fight.

(Professor – student conversation starts)

Student: (laugh)

Professor: And two aeroplanes will come and fight. Oh my God! Anything, tremendous innovation is only in movies. So if you have that kind of innovation, no problem. But in chemical engineering that innovation is there. Ok why? Because every chemical is new to me.

(Professor – student conversation ends)

If it is already existing like sulphuric acid, I told you know. What is the first step? Sulphur is burnt to sulphur dioxide. Then sulphur dioxide is converted to sulphur trioxide and we know the catalyst. And beauty is first one is non-catalytical reaction. It is sulphur plus oxygen giving you S O_2 . The second reaction S O_2 to S O_3 is S O_2 plus half, yeah half O_2 giving you S O_3 in the presence of vanadium pentoxide. How do I know?

The first one does not have any catalyst. The second one has a catalyst. How do I know that? Ok and this is not only the final process, final process. But can you also produce also sulphuric acid this S O_2 to S O_3 without catalyst. That is why it is beautiful engineering, chemical engineering. Fortunately many people mistake that with chemistry, right?

So like that any process you take. Ammonia I told you. Bring down the temperature. Now I think people are working on that. Now I think the temperature has come down to 130 or so. Earlier it was 250, how much was the temperature? I do not remember the exact value for ammonia, 550, and pressure 350. Ok, yeah 200 bar and then this is 550, you bring down that one to 100 or 200 degrees Centigrade.

How much energy is saved? And bring down the pressure, from 200, 250 atmosphere to even 10 atmospheres. Your design would be so simple now. Otherwise you are operating an atom bomb at 250 centimeter I mean atmospheres. That is why the original reactor which I see, which I saw there in Germany, I think; you know the nut and bolt itself is this thick and then this hard, solid iron. And the flanges thickness I think is 6 inches or 8 inches.

Yeah, I think I have that photo also, I have taken. I will show you. Sometime I will bring and then show you that. Ok. So that is the kind of thing. All that materials of construction, all that will become very, very less the moment you come to, you know room temperature is too ambitious, but at least 100 degree Centigrade. So that is why everywhere research, research and research in chemical engineering provided you do not know the process.

That means someone would have already done that. Sulphuric acid also it took long time for the development. In fact because of sulphuric acid only, chemical engineering started. I do

not know how many of you really know this. Because of purely chemical, sulphuric acid, chemical engineering started because of that. What is the connection? Connection is Industrial Revolution.

In Industrial Revolution the first thing many people started doing that time was the steam engine. And the next thing is all the people are trying to produce textiles as many as possible. That is why Manchester, this Coimbatore is also called Manchester of India. Ok. Why? Because the conditions are correct there to make the textiles and all, Ok.

And for textiles you have to put dyes. Dye. So to produce dye, you need sulphuric acid. And sulphuric acid at that time was only produced in glass reactors. How much big glass reactor can you make? You cannot make bigger. You cannot make more than 50 liters or 100 liters glass, right. That is why they want to produce more and more.

That is why they have gone to that first process, lead chamber process, because of the corrosion. Then of course, afterwards contact process, this process, that process, many processes have come. And during that time, people realized that My God! There is heat transfer coming. There is mass transfer coming. There is fluid flow coming.

And all this is not there in one engineering. With reactions. Fluid flow, mechanical engineers do. Even fuel engineers do. Hydraulics they call. And mass transfer, to some extent mechanical engineers do in combustion. Because when they are burning coal, without oxygen you know, they cannot burn coal. Oxygen has to be supplied to, to the coal surface. So then only the reaction takes place.

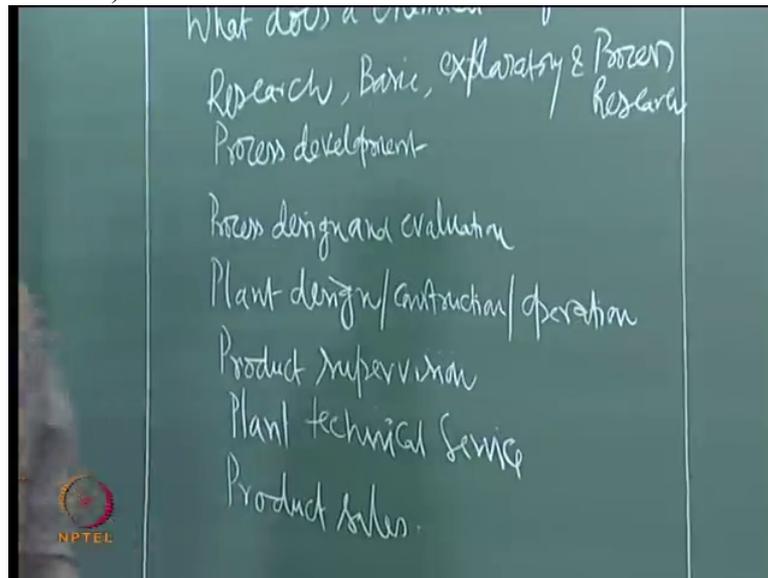
So that is the reason why there is some amount of, some knowledge is required how much oxygen is being transferred continuously to the surface of coal. So all these things also, heat transfer they are experts anyway. They are better than us, heat transfer. Because most of the time we do not worry about radiation. But they will worry about radiation and all that, right. So they have more knowledge than us.

But still, reactions means they will run away. Ok. Even now coal combustion they do but mainly coal combustion is controlled by mass transfer, oxygen supply. The kinetics you

know, but of course there also they have increased the combustion science and technology. They are doing also lot of work. But all that can be done easily by chemical engineering. So that is why now chemical engineering started.

And that is why research is the one where every process you need. What kind of research we do? We do research as basic research, I will just write here, basic you can also write exploratory, and we have process research, process research, yeah.

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So I do not know whether you know the meanings of all these.

This is for research. Basic research we call, we also say that Oh we are doing fundamental research. If I take one example, probably it would be easy for you to remember this, right? Let us talk about some catalytic reaction, Ok. For example ammonia production itself, right?

So recently, 2008 I think, recent only one person got Nobel Prize in Germany for telling the mechanism of this hydrogen, sorry ammonia synthesis, hydrogen and nitrogen, how they combine on the surface. What is happening on the surface? He is not worried about what kind of reactor he has to use.

He took the catalyst and then he wanted to study on the surface how the molecules are going and sitting. What is the orientation for proper reaction and what is happening during the

reaction, all that. He has designed the equipment and then shown that actually what is happening during reaction.

And he also extended that study for C O, carbon monoxide to carbon dioxide, a few more reactions. For that he got the Nobel Prize. Greatness of him is that his name is Ertl, E r t l, we also wanted to bring him here but I think he is not able to, since travel, may be health is not good, right. So that is why, he, he has shown what is happening, particularly for C O, C O 2 he exerted a lot.

It seems on the surface also, there are some kind of waves generated during the reaction. If you go to his website Ertl, E r t l, Ok, Nobel laureate Ertl, he has got a website where all this information is very nicely given. The mechanism is given. So that is what we are talking here, in the basic research. That much information is required for us.

Otherwise it is blind, microscopic research. Ok, that is process research. You just take a solid surface as catalyst, some solid trial and error, change the solid, whether the reaction is taking place, no, this is no reaction. Bring another solid, different metals. You go to periodic table and then take metals. If one is not producing any chemical, any product, then mix two, two metals.

May be I think you are telling, iron and cobalt. Again percentage, what is the composition, you can vary from zero to 100. Zero did not work, you know that. Ok. So 100 also would not worked, the other side. Now in-between combinations. So that is what is trial and error research where not much theory, it is not basic. That is exploratory. That means you are only trying to find out what is feasible, what is not feasible. Ok.

And in the basic research, you just try to find out some new theories based on your observations. That is why I told you no, unless we have this experimental verification, no one will get Nobel Prize for only just producing theory. That is why theory producers be, you know, some of you also may be very much interested in theory. Because you do not have to do the experiments.

Experiments means doing with hand, that means your hands may get dirtied and most of you may not like it, Ok. And I tell you there is only the pleasure in doing the experiments because what you are doing, you are seeing. You have the control. Where as in theory, change the boundary conditions, you will get another equation, another solution, right, a differential equation.

Most of the time in theory, you start with only differential equation. So in theory what you do, you imagine a process, take a small volume if there is a continuous change in that volume, and then you write the elemental balance on that, 0:39:31.8 approach. That book is famous only for that, Elemental Volumes. 0:39:37.6.

And then exchange that from entry to exit. That is boundary conditions. And then solve it. And when you are solving the equation, you can find out what is the concentration change, or the velocity change with the, with the, distance Ok or with the geometry inside the, or inside a particular equipment or temperature, concentration, and velocity, only these 3, mass, momentum and heat, right? That is all.

And from that you will now try to find that moment temperature is given, concentration is given, velocity is given, you can find out what is called flux. That means you know how much has been transferred from one place to another place and all that. You can find out that no, the moment we give an equation for concentration, can you find out flux? You cannot. I have concentration versus length as an equation. Flux you cannot find? What is Fick's law definition?

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(Professor – student conversation starts)

Student: 0:40:38.7

Professor: You know only definition but you do not know how to use it. $N A$, flux equal to what?

Student: 0:40:46.8

Professor: 0:40:48.4 by

Student: $d z$

Professor: What is $d C$ by $d z$?

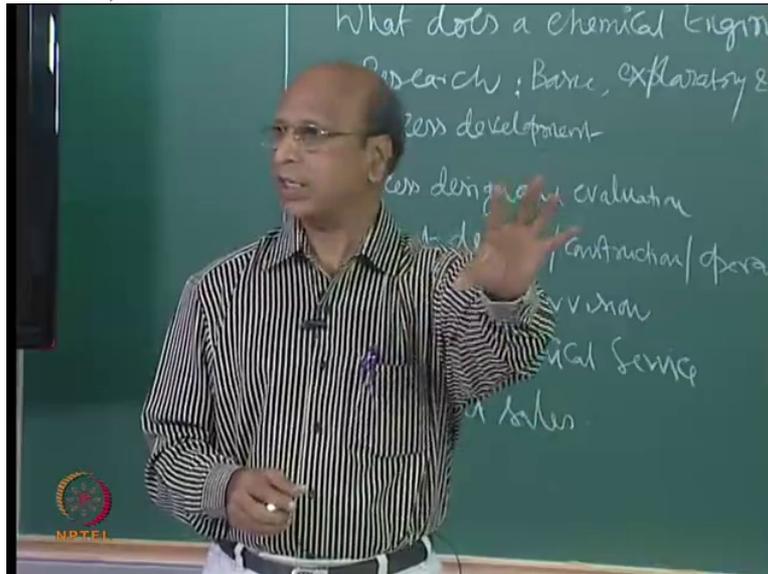
Student: Concentration gradient.

Professor: Yeah. If I give you concentration versus length, you have to find that differentiation and evaluate wherever you want, right? Yeah.

(Professor – student conversation ends)

So then why do you say that we do not know how to find out? Because application we do not know. We have theory

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but we do not know how to apply that. In fact that is one of the favorite problems in GATE and I was GATE chairman 0:41:12.5. That was in 2000. Ok.

Yeah, so that is a very nice problem, very simple problem because as all of you know, that you mug up beautifully Fick's first law and second law and you do not know when a problem is given, how to use this information to find out flux, right? So that is all.

And in the basic research what you find out is, that kind of new theories, for example you know in mass transfer you have, you know various theories, film theory, right? And Higbie's penetration theory and what the third one, surface renewal theory, all these theories are coming from basic research.

In fact these theories are not that basic as I told you for this Nobel Prize you know, on the surface. Because still in this theory, penetration theory, we never talk about molecules. We talk about only a group of molecules, a bulk of molecules moving from one place to the other place. We know only in film theory, across the film all the resistance is there and molecules are moving from this side to that side.

But still you are not worried about how individual molecules are moving. So that is why, in basic research what you try to do is development of new theories, right? So with the understanding of that catalyst what kind of catalyst you use, you know, you know every

catalyst has that holes, defects and all that, so what kind of defects are required, all that you can produce if you understand that theory. That is what is basic research.

And we have the exploratory research where trial and error, most of the time. Catalyst is very good example. One catalyst you try, you do not know. Normally we have one thumb rule that Ok the periodic table may give you, you know, some of the periodic table elements will behave as catalysts.

So you take only those and then you try to find out whether this is, you know, what combination or a single metal is useful for catalyst, all that trial and error that is exploratory. At the end what you record is what is the, for that particular reaction what are possible catalysts and what are not possible catalysts, so that others, they need not again repeat.

And in process research, this is, many people won't do except the laboratories, Regional Research laboratories, or N C L Poona, so they take the reaction, it is not only one reaction they do it, and you know, you would have heard of laboratory scale then pilot plant scale and then finally commercial scale.

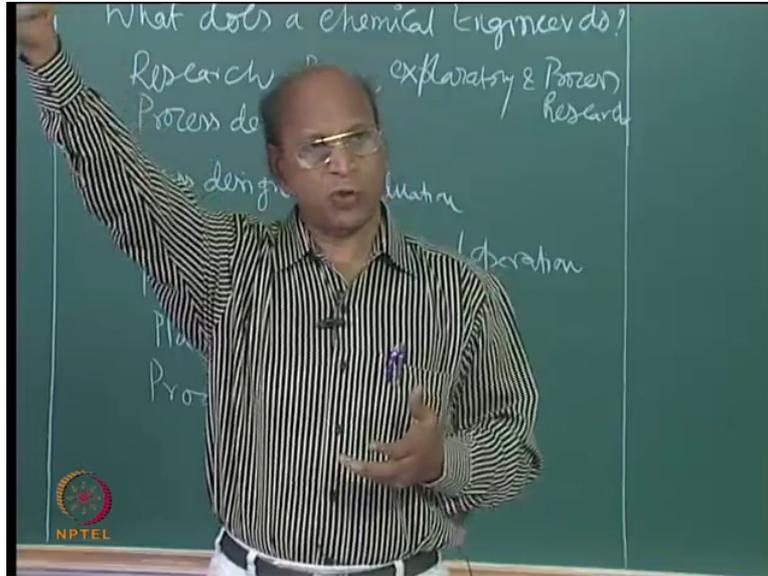
Laboratory scale also there are 2-3 varieties, simple lab or bin scale. Bin scale where

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chemical engineers come. Lab scale is only still chemists, right. So you conduct some experiments in laboratory scale. You are not confident that straightaway this can be scaled up to

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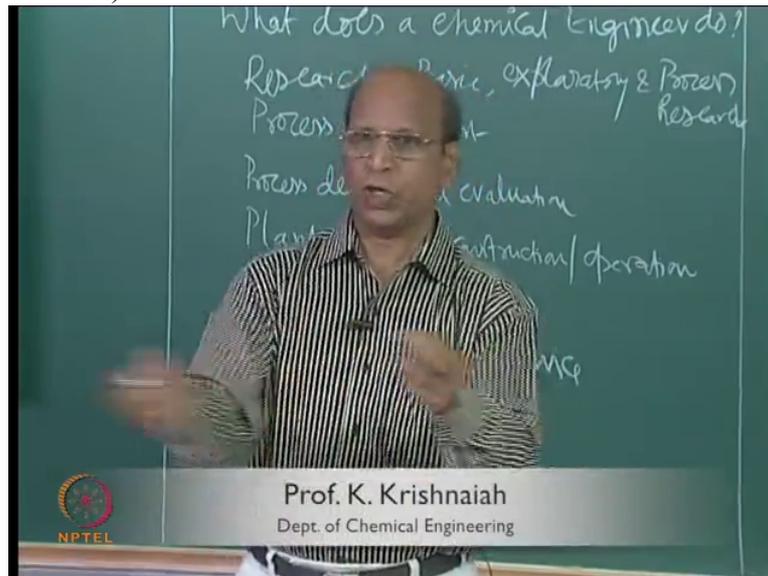


industrial scale. So then what you have to do?

You have to do some experiments in between and for that some experiment, you now decide whether you have to go for bin scale, or pilot point scale or ultimate scale. Ultimate scale direct scale up is not possible for many reactions. That is what we do in the process research. At the end of the process research what you will have roughly, Ok , on this one k g scale, I have all the information, starting from raw material to product.

That means if you want a condenser 0:44:43.2, if you have a reactor, use a small glass beaker. If it is a continuous one, only input and output

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required. So all that information, all that information you would like to get that in the process design, sorry process research, right? Laboratory scale you limit only till laboratory scale.

The moment you come to process development that is where you come to now, either pilot scale or large scale or pilot point scale. Large scale I am talking compared to laboratory scale. So in the process development what we do is, using pilot plant and trying to get as much as data possible so that you will not have much problem in the actual scale.

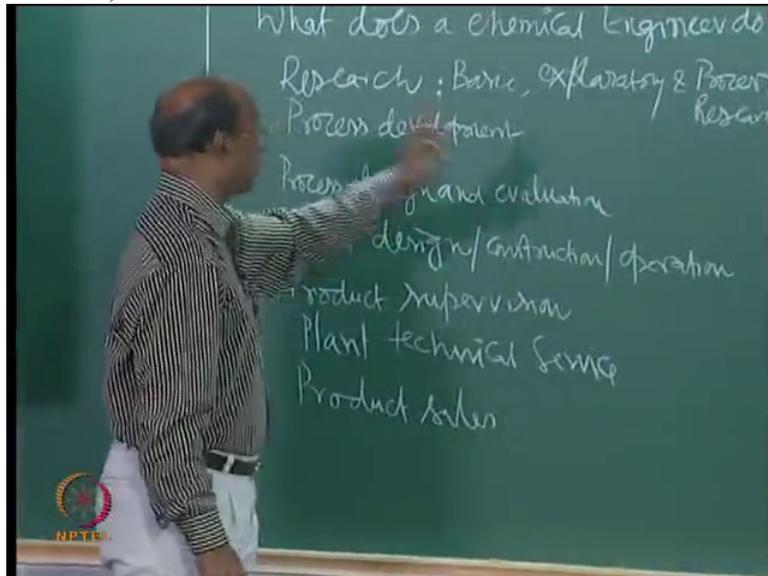
What data you get in process development, for example you have a bubble column, single phase is not that difficult but 2-phase heterogeneous system may be difficult in scalar. Why, because I may take a laboratory and then beautifully bubble, all bubbles are very nice, same size and all that. The very moment I go to very large, you know reactors are as big as these rooms also. So here how do I produce those kind of bubbles with uniform size? That is what is a big scalar problem.

And you know in the laboratory, small bubbles more surface area per unit volume. But in the large scale, you have large bubbles, surface area will decrease. So in the laboratory you may get 90 percent conversion. In the actual scale, you may get only 30 percent conversion, simply interfacial area is not reproducible at that scale. How do you do that to reproduce?

Whether you go for multi-stage? Whether you put many, many dispersers? Whether you put stirrers where you break the bubbles or whether you put in-between perforated plates where

big bubble will go and touch the perforated place and it cannot pass through. So that is why it has to break itself and then again go to, yeah to the next two plates and all that. All that information is required here in the process development

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so that you can go for big scale.