Chemical Reaction Engineering 1 (Homogeneous Reactors)
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 05
What is Chemical Reaction Engineering Part 1

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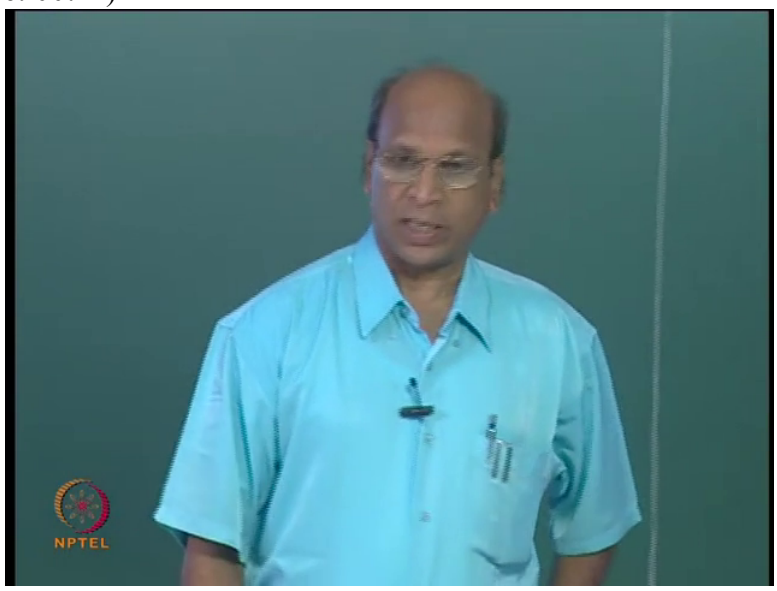

Ok, so now the next question is what is chemical reaction engineering? Chemical reaction, Ok we will abbreviate, yeah this is a wonderful question. Do you have any definition for this? What is chemical reaction engineering?

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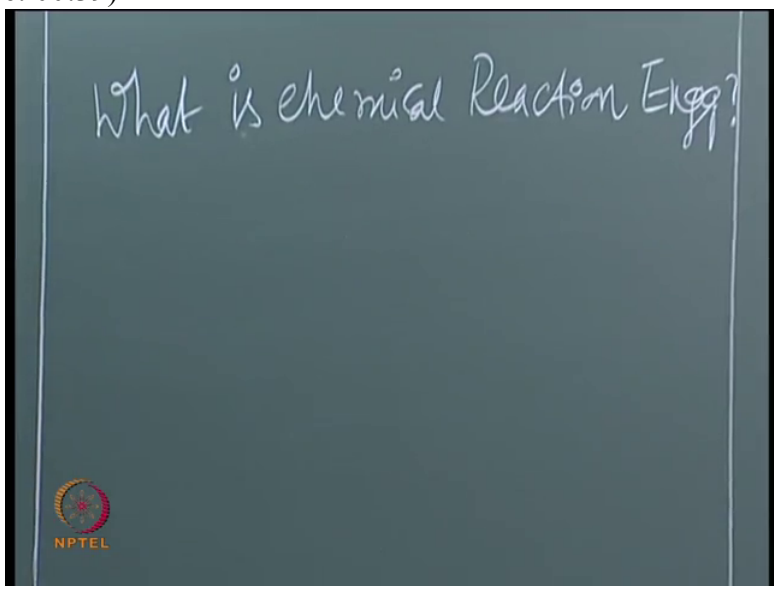

That is what is chemical reaction engineering?

Ok. I mean, because some of these things we know, Ok but we do not know how to explain, right. It is exactly like love, right.

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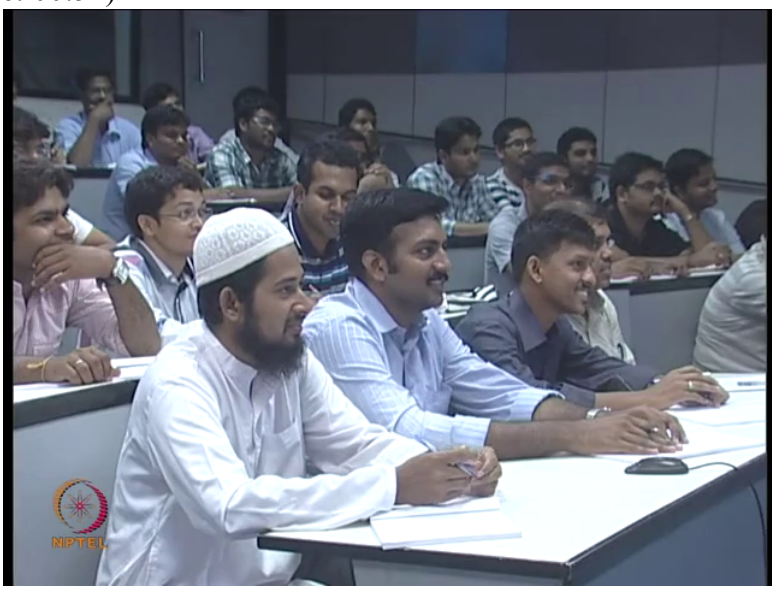

Similarly chemical reaction engineering,

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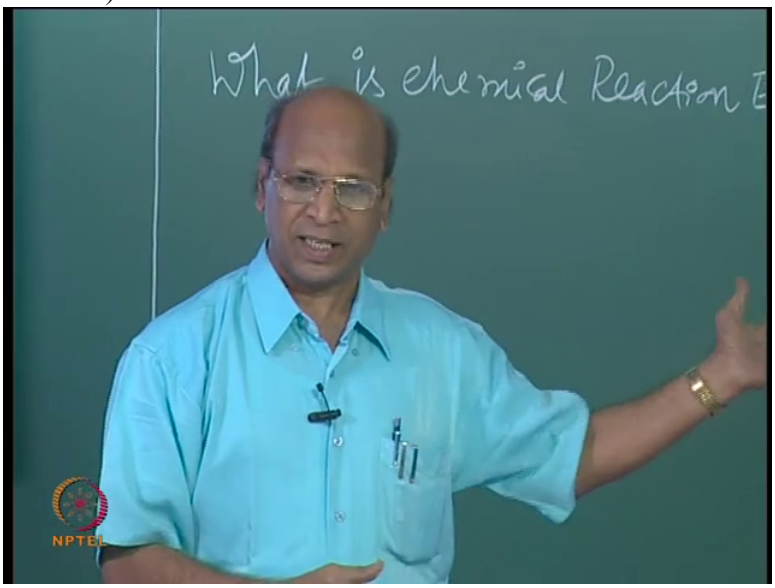

it is not so bad, but the definition itself is in the title, chemical reaction engineering. Ok, you are engineering the chemical reactions. That is what is the good definition.

But again unless you do not know what you mean by engineering you cannot explain further. Ok. And I do not know, some of you would have seen, there are many books, new books coming in chemical reaction engineering, one of the books I think by Schmidt, S c h m i d t, what is the title of that book, you have seen that book?

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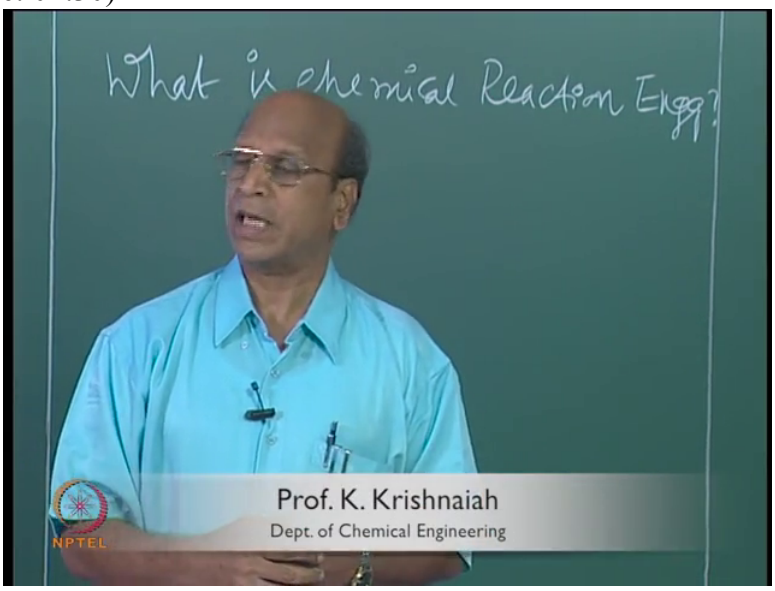

What is the title of that book?

(Professor – student conversation starts)

Student: Engineering of Chemical Reactions

Professor: Excellent. That is Engineering of Chemical Reactions. And really that is what is the true meaning. And I really appreciate the name itself, who suggested. Do you know who suggested that name? In fact that is one of the latest names in Chemical Engineering. By the way, unit operations who suggested the name?

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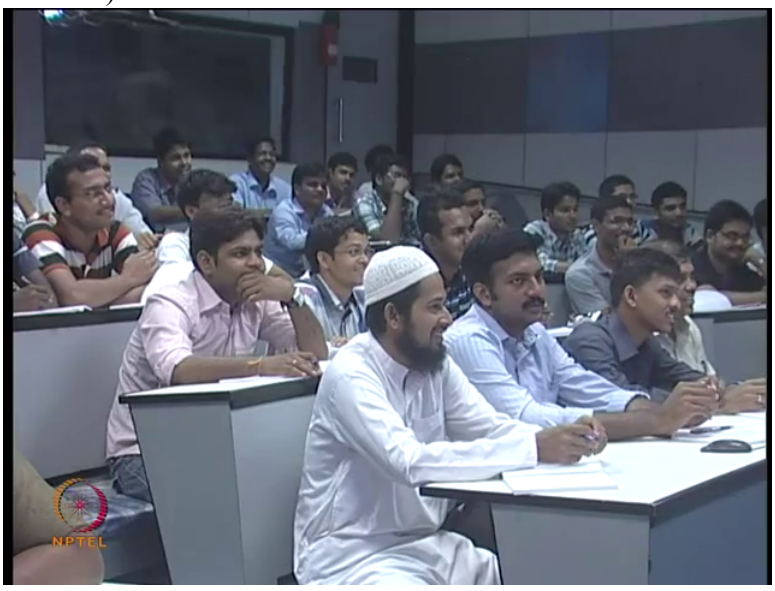

Student: Little 0:01:57.5

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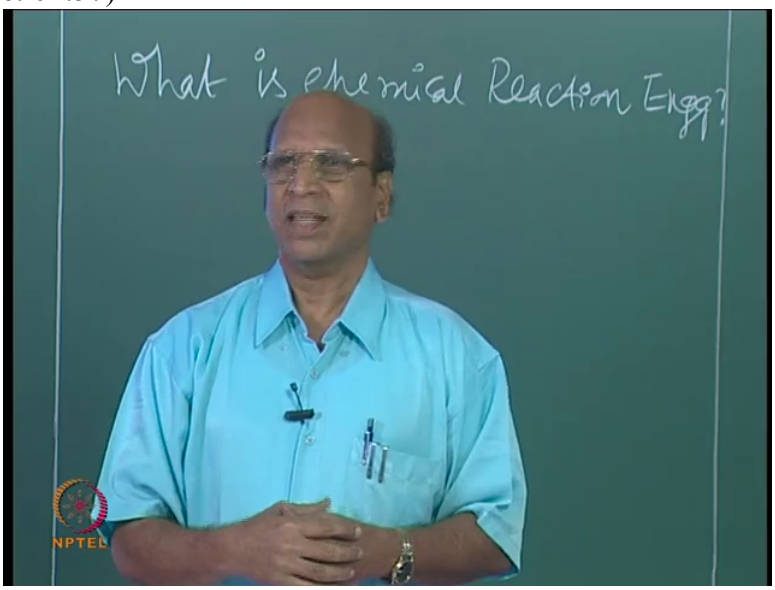

Professor: Yeah, it is Arthur D. Little that you should know. I think you have to make a note of that. This is Arthur D. Little. After giving the definition,

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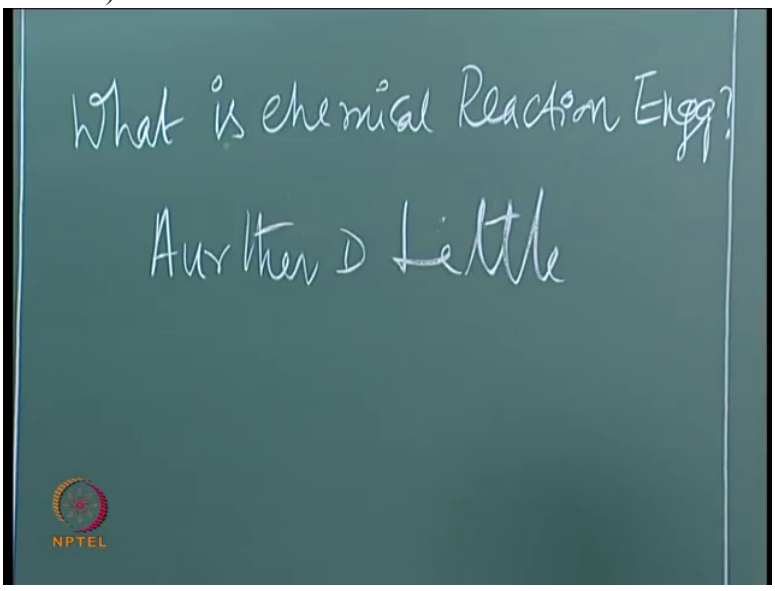

Little has become really big. Arthur D. Little. But before him, there was another person called G. E. Davis. Ok, this Arthur D. Little, can you guess which country?

Student: 0:02:31.7

Professor: Don't know? But how do you know the name? In memory, you searched and got it? He is from U S.

(Professor – student conversation ends)

Actually the idea came from Davis where this Davis

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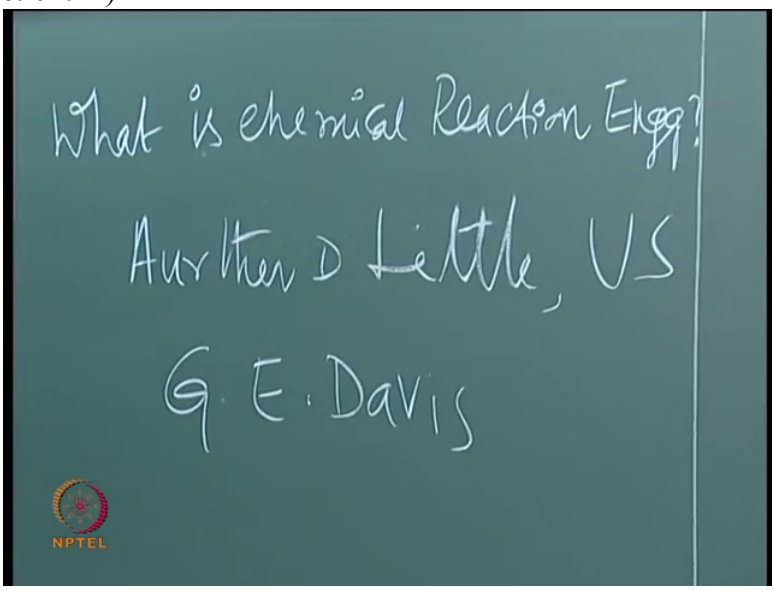

was in U K, when was that, in 1860s,

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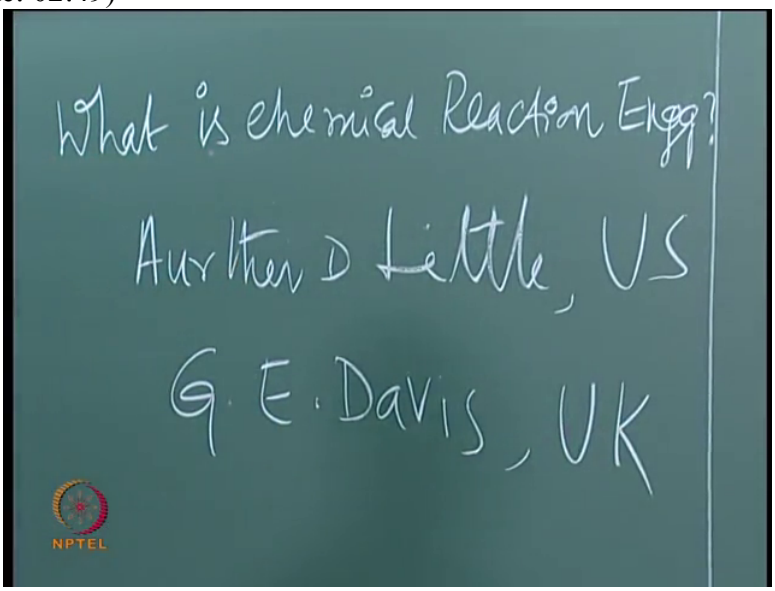

70s, he was the factory inspector. Actually he was the first person who gave a course in Chemical Engineering. Ok, that was I think 1897, 1895 at that time, 18 Ok.

So at that time when he was a factory inspector, you know, even at that time there was a lot of pollution. Particularly from sulphuric acid industries, chlor alkali industries lot of chlorine just used to come, lot of sulphur dioxide just used to come. So that is why U K government appointed him as a factory inspector where he has to visit all these factories and then try to find out how to reduce the pollution.

So when he went and visited various industries, he found something common among all these industries. Whatever industries he goes there was fluid flow, right. Whatever industry he goes, he saw heat exchange. That means different forms of, you know, even condensation is a kind of heat exchange, and normal heat exchangers so all kinds of heat exchange equipment, right? And he also saw distillation columns.

But without knowing all that names they were doing them. Distillation they know but I think you know that unit operations name was not there at that time. So he recorded all that. Now instead of teaching you know, before that how they were teaching chemical engineering was by industry-wise. Take chloro, that means chemical technology, pure chemical technology was at that time.

You take one industry, like chlor-alkali industry and then discuss the various chemicals, what is the production method, what are the temperatures, what are the pressures, like our chemical technology they used to discuss. Ok, in applied chemistry department, chemical engineering departments also were not there at that time. I am talking about 1800s, 70s, 80s, 90s at that time.

So then he said that there are many common operations and that common operations are, he listed them and he gave a course, I think 12 lectures. I want to get the original lectures but I am not able to get the original lectures. And he taught them saying that Ok, so instead of telling about particular industry, particular chemical, now let me talk about general operations.

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Like about fluid flow.

And you know materials of construction was very seriously taken. When we were

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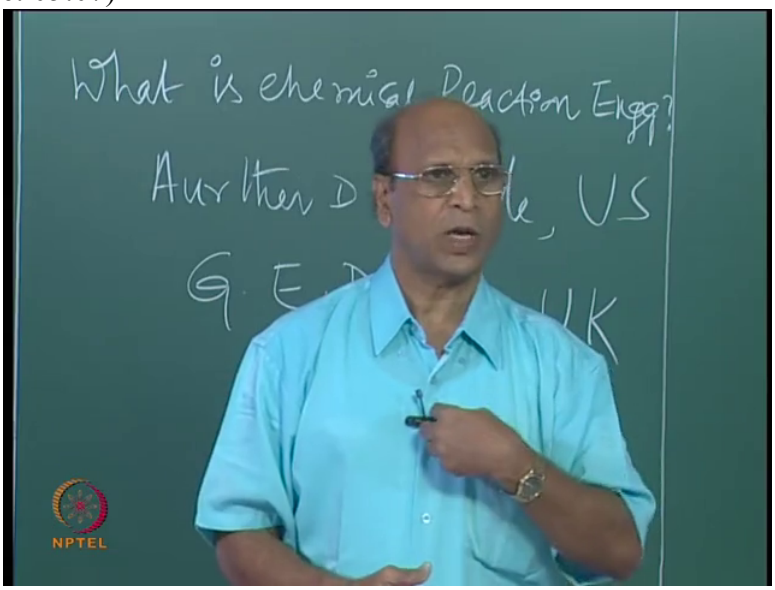

doing our B Tech, materials of construction one or two courses we had. Ranganathan, you also had? Yeah. But now it has gone. I do not know whether you have taken materials of construction. And plant utilities there was a course. Some universities still follow. Very old universities still follow that. Plant utilities and there was one or two courses on plant utilities.

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Ok.

So he gave that course and then U S people

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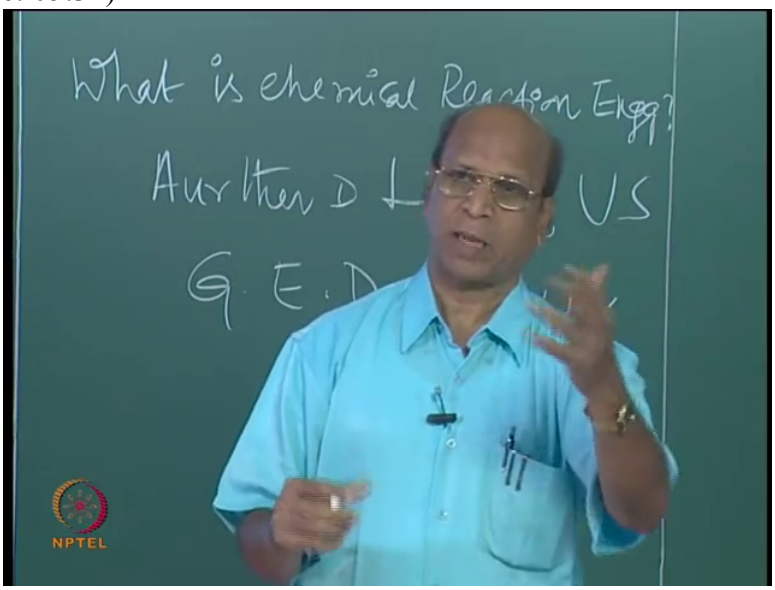

came to know that Ok, in U K this kind of teaching is going on. Then Arthur D. Little found out that let us give a name for these common operations. And he said unit operations. What a wonderful name! Ok. So now under unit operations you have distillation, extraction, crystallization, I mean of course heat transfer all these operations will come.

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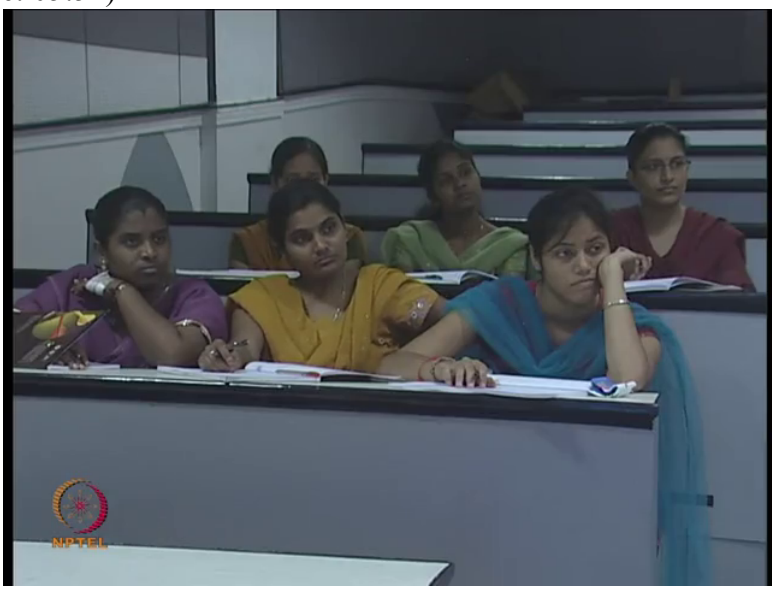

Then beautifully McCabe Healey, sorry McCabe Smith used

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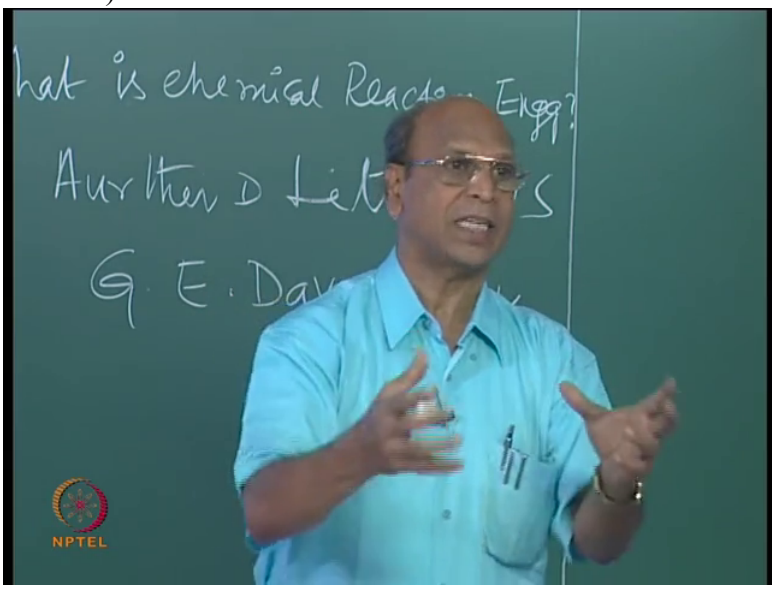

the title as it is, Unit Operations in Chemical Engineering that is the title of the book, no? Yeah. Similarly in 1957, that was very late in fact. Chemical engineering was very much established a little bit but still chemical reaction engineering was not established. 57, there was a conference in Netherlands where the title of that conference was chemical reaction and they wanted to concentrate only on reaction.

And you know in unit operations, all the focus is on separation or you know, mass transfer, heat transfer that kind of thing. There is no chemical change, only physical change. So that is

why all unit operations deal with physical changes. Then they wanted to know, but can we also have a separate course on reactions? Till then reactions were not very seriously taken.

They do not know how to find out, for example kinetics. But approximately they know that this is the temperature, this is the pressure, that is why applied chemists; you know that exploratory research I told you, exploratory research is by trial and error. So through that they know these reactions will have this kind of temperature, this kind of pressures, this kind of equipment we can use, all that they have fixed it but it was not a science. Or it was not even engineering. I will also tell you what is the difference of the science and the engineering, right.

So at that time the name of that person was J C Vlugter, in Europe that V is called as Fau, F, Ok. Flaugter yeah, J C Flaugter, V l u g t e r, yeah

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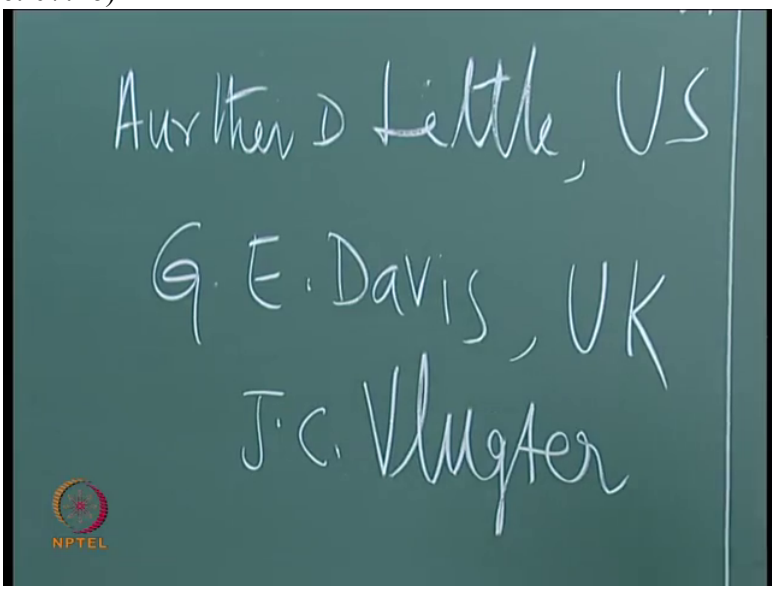

he was the person who gave this name for chemical reaction engineering for that conference. And they wanted to discuss in that conference as Gani said, and Abdul was telling that, all the things, I mean how do you design the reactor. What is the information required for reactors?

So all those proceeding, the first conference proceedings is, Ok, had been published in chemical engineering Science 1958 edition. In 1958 you know there are many issues. May be some 8 or 6 issues. Or so. I think I am not talking, I am talking only in English no, there is a

Journal called Chemical Engineering Science. That started, I think in1953. That is the first volume, no? Or 51? 53 is second volume, third volume.

Yeah, Ok, so 1951 it started, this chemical engineering science. So in 1958 volume, because per year we put all the two, all the issues in one place and then we call that is volume, 1958 volume, complete all the papers that have been published in that conference, or discussed in that conference, they are there in the volume and 1958 volume is available in our library also.

Now online is available. Simply go to ScienceDirect. And then open Chemical Engineering Science, go to 1958, I think if I am right, may be June edition or July edition, I am not very sure but you can check it, Ok. Yeah. There he has given that name, what a wonderful name!

You are engineering the chemical reactions. What do you mean by engineering chemical reaction? For this you should know the difference between what is science, what is engineering and what is the next one? Technology.

These are the words very frequently we use without knowing. I will tell you another nice thing. You know when you want to join for engineering, what is the examination you write, some entrance exam? May be J E E or may be every state has their own CET, KCET means Kerala CET, and you know, I think, M-CET and I think in here, C-CET?

(Professor – student conversation starts)
Student: TANCET
Professor: TANCET, all CETs only but different examinations are there. So what are the subjects you choose for that examination, if you want to become engineer?
Student: Maths, Physics, Chemistry
Professor: Maths, Physics, Chemistry, right? So once you pass or once you got good rank in that then where do you go for engineering, you go to

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some engineering, right? And at the end what is the degree you get? Did you read your degree?

Student: Bachelor of Technology

Professor: Bachelor of Technology. Did you ever thought what is the connection, what is this, yaar? We have

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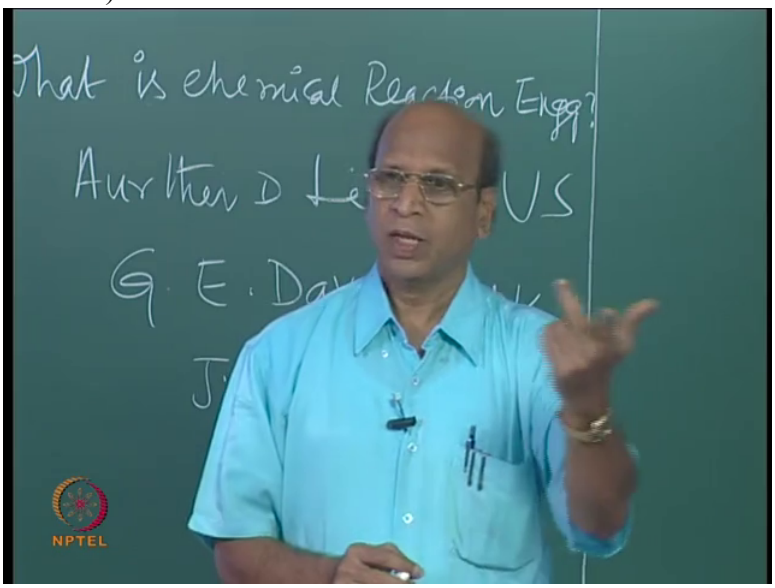

only written entrance examination as Maths, Physics, Chemistry, then someone told that Ok,you join chemical engineering, or mechanical engineering, or Civil Engineering. Then at the end we are getting only Bachelor of Technology

(Professor – student conversation ends)

Where is the connection? Do you know the connection? Even after M Tech do you know the connection? Forget about B Tech. You never thought about that, no? Fundamental questions I think. You should question yourself that why I am here, so why I was born only to these parents, why not to Ambanis or somewhere else. Ok, so then very happy, no, always flying and beautiful houses, you do not have to do anything, Ok. Or take our, your father's business. And already you are rich, you do not have to keep your money, you can sleep on the currency, eat currency, sleep currency...

(Professor – student conversation starts)

Student: (laugh)

Professor: So all beautiful things, no.

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But anyway it is unfortunate, you know. Ok good, we do not have choice but we are happy

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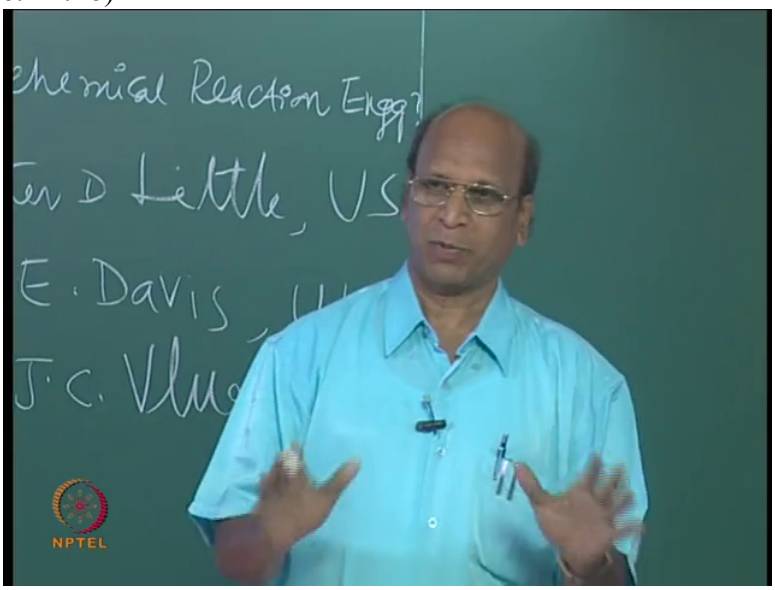

what we are. So that is the kind of basic questions, you know. I do not know any one of you thought about that? Or if you thought, just raise your hand. It is very good. You thought about that?

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What time, now or earlier?

Student: Earlier

Professor: Before, Ok (laugh). That is very good. That kind of thinking is required, right?

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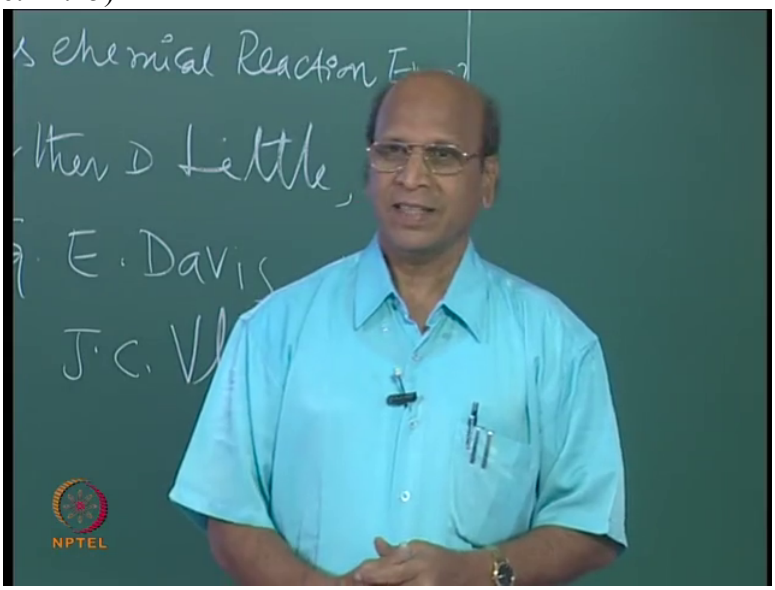

(Professor – student conversation ends)

Then what is the difference, any one has been exposed to what is the connection or what is the definition of science, engineering and technology? Some teachers would have told you. People like me, I think there are people, who talk about many things, Ok and which is important.

I know it is not that I have a beautiful quotation where they write that an excellent teacher not only teaches the subject but he teaches an approach to it. If you want to get approach to a particular subject you need many, many general things. Otherwise you never see the approach. I could have finished 50 percent of the syllabus by the last 2 weeks if I started straightaway, Ok, first order reaction, second order reaction, third order reaction.

But no, I think you need this kind of background. You need these kind of seeds in your mind. That is mind clearing, in fact. You know, before putting some other data, if there is useless data, you delete all the data, no, cleaning. So all the virus, I know, they should be cleaned. Our hard disk. That is what the thing which I am trying to do now. I am trying to clean your hard disk.

Except chemical engineering knowledge there should not be any another thing in mind, Ok. So that is why. You know one of the definitions given is application of science is engineering

and application of engineering is technology. But if I ask you explain, again you cannot explain. Correct no? Yeah.

Shall I write that? Application of science is, again small,

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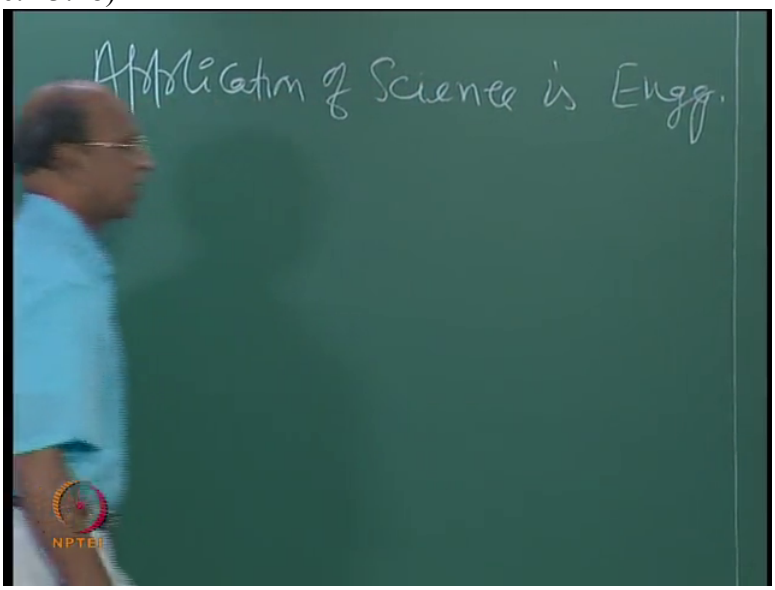

abbreviation, engg/engineering and application of engineering is technology. Ok

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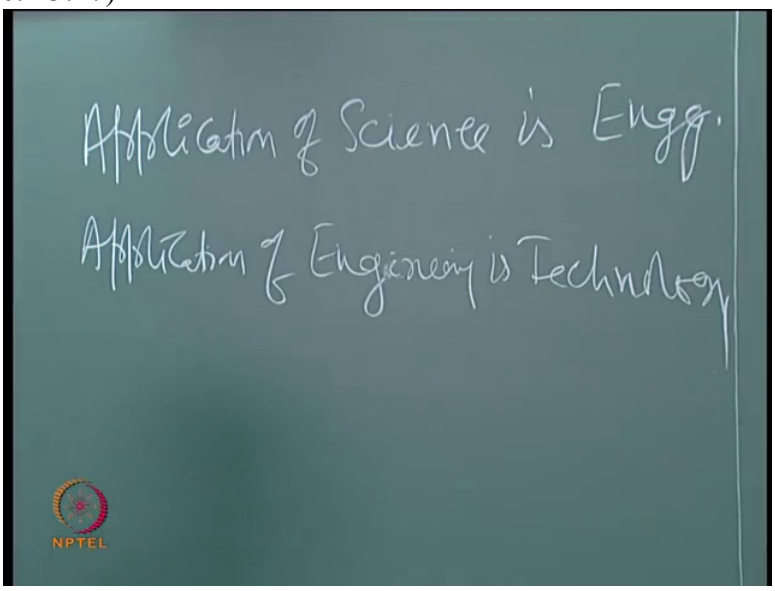

In fact technology is the highest form. But unfortunately without knowing any engineering, without knowing any science you can become a technologist. However, yeah we have been doing. Human race started doing for long time, Ok.

They constructed beautiful forts, beautiful houses, beautiful temples, beautiful churches, all, beautiful churches or mosques I think wonderfully they have done without having a engineering degree, civil engineering degree, right. So they are the people who are technologists. How do they know? See.

And we also know medicine. In villages and also of course, 0:14:29.8 everything was village only long time back, so in villages there will be a doctor. And he will know. Somehow he developed that kind of knowledge. But there was no M B B S at that time, there was no M S, Ok. But still they could. And I tell you, how do you produce bricks? Ok before going to bricks, how do you produce curd? In your house. Ok your mother knows very well, right? What does she do?

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(Professor – student conversation starts)

Student: 0:14:58.6

Professor: Yeah, but no, suddenly she will not take no. First step is not taking curd and putting where? In the mouth or somewhere else? (laugh) Yeah the first thing is to find out where is the milk. Take the milk and boil it. Why should we boil?

Student: Pasteurize

Professor: Everything is a question, yeah. Why should we boil?

Student: Pasteurization

Professor: Dhanya, what?

Student: Pasteurization

Professor: What is Pasteurization?

Student: (laugh)

Student: To kill the microorganisms

Professor: To kill some other microorganisms which should not destroy the curd making microorganisms. So that is the reason we boil and then after boiling she knows, I think now always whistles no, now always in kitchen only whistles have come.

First whistle, second whistle, third whistle. Ok (laugh) because of the pressure cookers and all that, right. All whistling only. Cooking means now whistling. Ok anyway she knows when she has to stop that boiling. Then what she will do? Immediately we add...

Student: Cool it

Professor: Yeah, why we cannot add immediately?

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Student: The microorganisms will die.

Professor: Because microorganisms will die. They cannot, you know, like asking, you know, putting,

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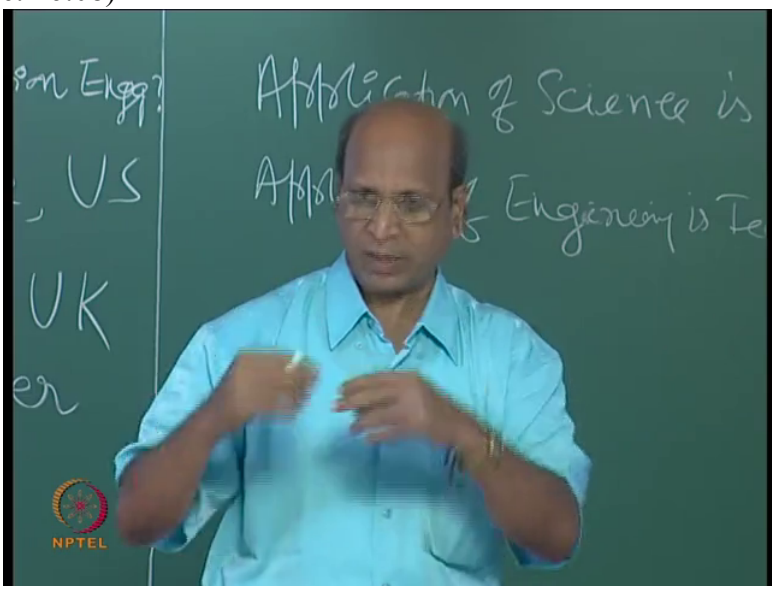

someone coming and putting us in a furnace at 100 degrees Centigrade. That is all. We are out. Ok (laugh). Yeah, similarly when you boil and then immediately put the microorganism they will die. That is why she cools.

(Professor – student conversation ends)

It is not sudden cooling. She will not use 0:16:26.4 with minus 5 degrees and then suddenly cools. She will wait patiently. And then every time she goes and touches the surface of the container and when she touches, she knows what is the temperature, right temperature. At that time she puts yesterday's curd or yesterday's buttermilk where there are microorganisms. Ok and then her duty is over.

Now it is microorganisms' duty. Right then after, after may be 6 hours, 7 hours, 8 hours you will get beautiful curd. We know how to eat curd. But I think how much technology is there inside because without having any degree, she does not know what is biochemistry, you know mother

(Professor – student conversation starts)

Student: (laugh)

Professor: (laugh), Ok, yeah she does not know what is heat transfer, still she boils, right? She boils to what temperature? She never measures the temperature, correct no? She never measures the temperature. So she knows that when it is coming that, the milk will come up with lot of foam and all that. So once or twice she will see and then switch off.

(Professor – student conversation ends)

Then she waits, so like that. You know, generally she may try to stir a little in between but that is also not required for liquid. Right, even sambar making, you know, they will stir and all that. So actually mother is a excellent technologist. Really, without knowing anything she can cook food. And I told you know last time also, mother's food is the food, lifelong you can eat. But if you go to Tiffany's, 2 days maximum.

(Professor – student conversation starts)
Student: (laugh)
Professor: Ok (laugh). Third day, you will say that go to hell, yaar we will go to some other house, some other place. That is all. You see the appreciation for the mother?
(Professor – student conversation ends)

So that is the kind of technology what she developed. Ok now technologist, technologist is one who knows how to make things by finding out some right temp/temperature, some right conditions, may be temperature, may be pressure, I am talking about our, you know, chemical technologies.

You know we have chemical technology, for example fertilizer technology, rubber technology, polymer technology, cement technology. All these things have been done even when there is no chemical engineering. How they are doing? By trial and error. May be 50 years, 60 years, 70 years they could have used, they could have spent time to come to those points.

And then after you stabilize for those conditions, then transfer of knowledge is very easy. You train him; you know to maintain these conditions. And next person will come. He will train some other people. So like that it goes. That is what is the technology which we think is the lowest but that is not correct, right? Yeah. So that is one thing.

Even brick also, how do they make brick, bricks? Because most of you are born in cities, you may not know, I think. You would have never seen also brick kiln I think, how they make. But if you go to village sides or suburbans of any cities you will see lot of brick kilns.

They take mud and they do not take whatever mud is available. They will take mud with some sand, clay with some percentage of solid that is also very important. But they never measure. But they feel. The moment they take mud into hand, they will tell whether is a good brick or a bad brick; it will become a good brick or bad brick, Ok.

And then they will put sufficient amount of water. And then they will make it as a paste. How will they make it as a paste? With legs, most of the time. That is the technology. These are the mixers, correct no, like this, like this, like this, like this you do all the time.

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Ok. So then they mix it and, they know the right consistency.

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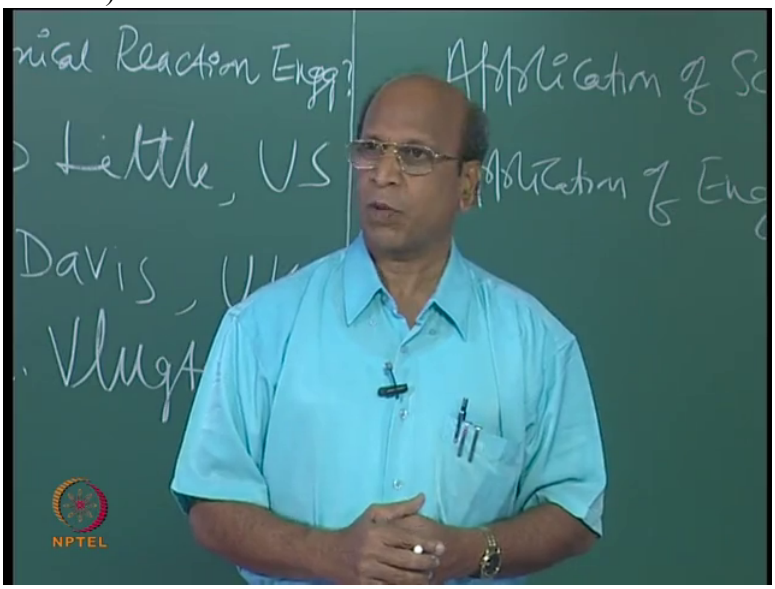

They won't put more water, they also will not put less water; less water also is difficult; more water is also, right amount.

Then they take the moulds, brick moulds. Then they just paste it, just pour it, and then make level and then remove it. But again that leveling is not that, all of us cannot do, they know how much pressure they have to correctly apply for that mould, on the surface of that mould. Otherwise you will not get again right, brick; the strength will not be there.

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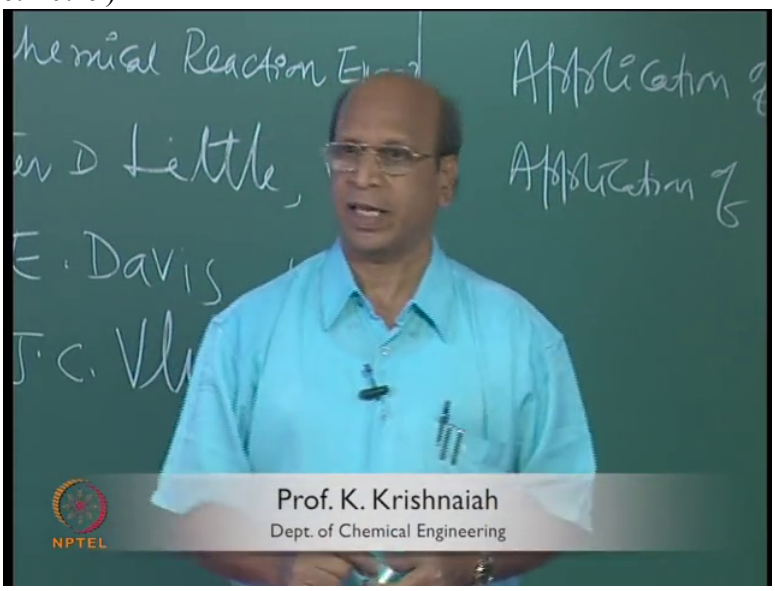

So then what you do, the drying, the drying, natural drying you know the solar drying, right? After solar drying, then if you use the brick then again if rain comes it will dissolve. So that is why they have to sinter it. That sintering is done in kiln. Then you will have the strength, the bond between all those particles, mud that becomes very, very strong.

Ok, but where is engineering and where is technology here, I mean where is science here? And when mother does this, I mean, curd, what science she is using? What engineering she is using? Now I will ask you a question. Mother does, what is the scale, production of this curd?

(Professor – student conversation starts)

Student: 1 liter

Professor: Maximum 1 liter or if some guests, may be maximum 3 liters, 4 liters she can go. Now ask her to try 100 liter. Impossible, she will run away.

(Professor – student conversation ends)

That is where chemistry stops, I told you no. And engineering starts. Ok, yeah I mean not exactly chemistry there I am telling. That is where, because you know, scale up because now we are talking about large scale.

Now we have 8000 students in the hostel, not even 8000 you know, I think you know 7400 students. Now we want to make curd for 7400 students. How do you make it? As chemical engineer what do you do? And you know that every student will eat, may be 300 m l of curd, 300 m l is too much. Ok, 100 m l, 100 m l of curd and I do not know many North Indians may not use the curd but South Indians end point is only curd. After curd only they stop eating. Till then they keep on eating.

(Professor – student conversation starts)
Student: (laugh)
Professor: (laugh). Either curd or butter milk. And recently I went to some tour, you know to Leh and Ladakh and that area, so I think North India, I think from Delhi onwards early morning they start with the curd, Ok, many people, you know they have aloo paratha.
(Professor – student conversation ends)

Aloo paratha, then we asked how do you eat, I mean what is the other side dish for this? They say aachar; I did not know what was aachar. Aachar was pickles, yeah I mean it is mouth-watering, it is good, very tasty (laugh), yeah. So this aachar with curd, what a wonderful taste! It is a wonderful taste, I tell you. Very good taste, I liked it. But unfortunately this side we cannot make that beautiful aloo paratha, right?

But problem is I can guarantee that health will be spoiled in 2 to 3 years, Ok. So if you eat everyday that, yeah, because aachar is very bad. Because there is tons and tons of sugar, salt, salt is always bad for the health, and of course they also put lot of oil to make aloo paratha. And curd also is bad, I think. Actually curd is not required for human beings I tell you. Ok. It is not required at all. I have separate theory. When I have separate time we will discuss about that particular thing.

So, anyway. So the curd is the last point. You know 100 m l for each one and you know 8000, 7000 students and approximately you have to calculate and that much milk you have to boil.

How do you boil? Now engineering comes. First of all, you have to take a big, big vessels, Ok. You can also make a choice whether is a continuous boiling or it is batch boiling, Ok.

Food normally, continuous food cooking I think 15-20 years back I thought, why cannot we have a continuous rice cooker. That means you feed at one point rice and other point you should have, you know that is, yeah this is grains and that is cooked food, Ok. But there was lot of; it is not easy to do that. Why?

Because I have to maintain very clear plug flow. That I will discuss later, what is plug flow and all. So that is why, the continuous system or batch system that is why most of the time, in all cookings you go for batch. What a wonderful concept! Without knowing what is plug flow, they used batch cooking.

In batch cooking, every particle will stay exactly same time. Because you are not allowing no. You are allowing 10 minutes cooking, 10 minutes means all the particles are there. So uniformly cooked. If you allow them to go, flow, there may be small particles which may come faster, there may be large particles, you know uniform grains you never get. Even the best Basmati you take, I think nowadays I think Basmati is coming almost 1 inch long.

(Professor – student conversation starts)
Student: (laugh)
Professor: I think I do not know how do you put that inside.
Student: (laugh)
Professor: So that one when it is flowing, shear factor is very bad. The flow, fluid mechanics I think you will not have that kind of nice flow for this kind of particles, Ok. Anyway.
(Professor – student conversation ends)

So then either batch or continuous we have to choose. And you cannot simply boil it. Because there is large amount of milk in that vessel and when you boil, which portion, which part of the vessel will get first heat? Bottom and sides also you know, if it is metal, Ok, so then when you are boiling this, then the top liquid will not get sufficient heat, right?
So then when if you are, when you are continuously boiling then milk will get spoiled which is very near to the surface. So it will become charred. So that is why you need stirring. Then

only you will get uniform heat for the entire, for the all, you know all milk. So now that is an engineering principle. How do you supply heat for this vessel is the engineering principle.

All this were not when mother was doing it. She knows how beautifully it can go and she knows what kind of vessel she has to use, Ok. Normally we never use for boiling of water, boiling of milk, any mud vessels, no. Mud vessels are there, pots, we never use, do you use? We use only metal. Why? Heat transfer is good. See all these things they do not know but they still do it. That is what is technologists, you know, do.

So like this now, curd making itself, you know, the engineering automatically comes into when you are thinking on large scale. So now what is engineering then? You have to learn what is heat transfer, how do you supply this heat, what are the equations required, if you want to raise the temperature from room temperature to 100 degrees Centigrade, or may be 80 degrees Centigrade for milk, how much heat is required, all that calculations will come. Those are all engineering principles.

And now you stir it. What kind of stir is required? And how do you stir this? You put people and make them like this, or you put your motor and motor is connected to the electricity, all that you have to discuss. And when you want to decide actual mechanical stirrer you need again that information. That is why you have to go for again mechanical operations or fluid mechanics wherever you are taught no, this agitation and mixing and agitation, there is a chapter no?

Yeah, so all that, that is what is engineering. So now you know what is technology and what is engineering. That means engineering means I am not describing in terms of words but the moment you come to engineering you have to now use really equations to calculate something, to find something, Ok and if you are really, Ok, then science will come, same example I can tell, now how much time it takes for curd to finally come? 6 to 7 hours

(Professor – student conversation starts)

Student: 6

Professor: Now you want to make instantaneous curd.

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It is not 6 to 7, you do not have patience. In 10 minutes you should have curd. What do you do? What is responsible for curd-making?

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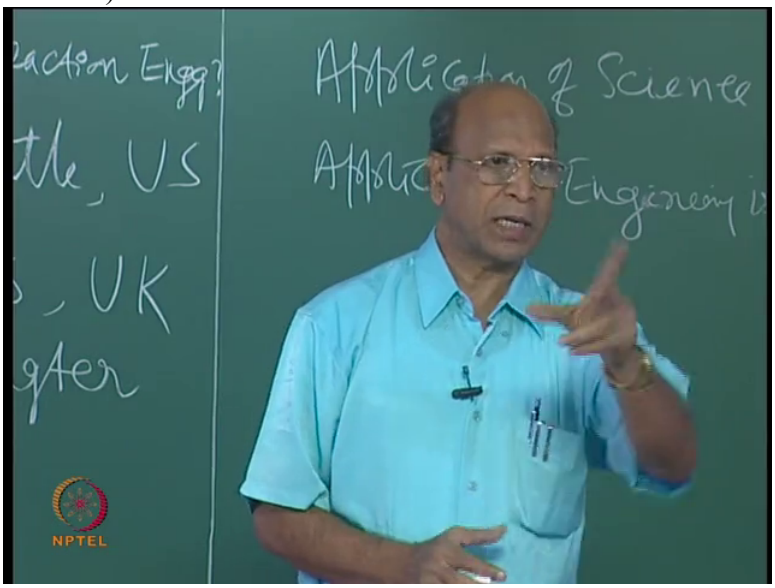

Converting milk into; by the way is it chemical operation or physical operation?

Student: Chemical operation.

Professor: Very good, it is chemical. Why?

Student: Reaction

Professor: Because the starting material and the final material both have different properties, Ok. It is this, Ok. So that is why, we can, and then this one has a type of chemical reaction, Ok. So what was the question I was asking? How quickly you can increase the rate of reaction? Earlier it was 8 hours. Now you want only 10 minutes. What do you do?

Student: 0:28:54.8

Professor: yeah, one is to find out catalyst. But catalyst for what?

Student: 0:29:00.3

Professor: Catalyst, where do you put these catalysts? Because we know microorganisms are responsible for conversion. So do you put catalyst into the microorganism? Yes, you have to put. (laugh).

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(Professor – student conversation ends)

Really, it is yes you have to put. How do you put that? Change the genes of that microorganism.

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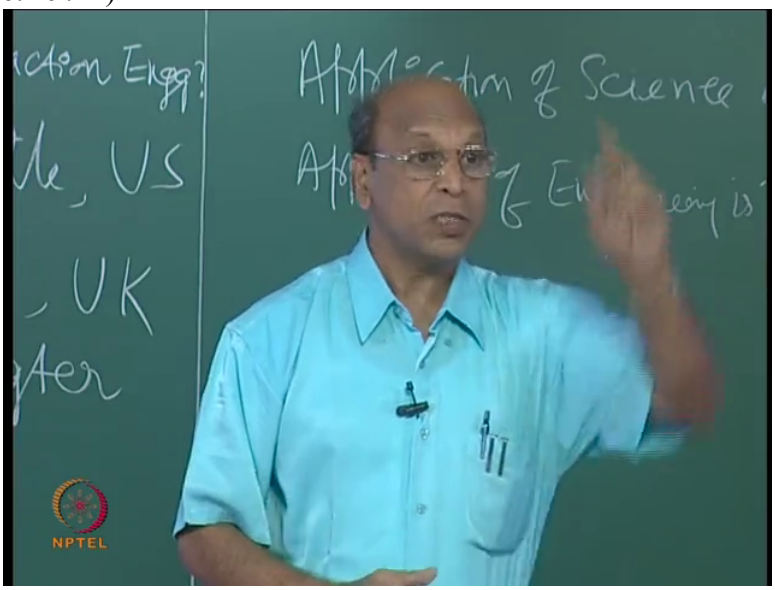

That is what is science. That now you are really talking about science. You know now, no technology, engineering and if you want to go for science, now you can go to that microorganisms, look at the microorganisms and then say that Ok, now you are taking 8 hours, now I will change you to some super bug Ok where you will convert the milk into curd in 10 seconds.

That is what Hitler tried to do during Second World War. He wanted to change people, Ok. So he was telling, you know Aryans are the best breed and all that, you know at that time. So he actually separated the best German boys and best German girls. They have to get married and they have to produce children. Ok, the best breed when he has chosen, now the children automatically will become very, very intelligent.

That is what he tried but unfortunately that experiment was not successful, that is what. That means he did not know at that time D N A sequencing and all that, Ok, that is why one of the simplest ways is you know, when you get married and then when you have children, what is that you are doing? This nature has chosen all living beings only to propagate their own species. We are here not to do chemical engineering. We are exactly, really (laugh). Ok and not to do any job. Our job is only to produce children

(Professor – student conversation starts)

Student: (laugh)

Professor: No that is what is the real I say, the nature of planet is that. We do not have to be ashamed of that. Otherwise that species will get extincted. That is what; you take anything which has got life, even trees.
(Professor – student conversation ends)

One tree, why should it produce thousands of fruits? And within 1 fruit, again thousands of seeds? What is the reason? Nature wants to maximize every species in its own way to propagate. And if you see really nature, I mean I really like it, there are, you know, different shapes of fruits, right and different construction of fruits.

Tell me why should we have for coconut, that pith and all that, you know, that thick shell, why should we have? Simply not to remove and then break to God. Ok that only we know for coconut. Ok, it is not actually true. Because unless, you know it is changing its density by putting that extra thickness as pith. That thick, you know, the other one comes as pith, that one, how does it change the buoyancy?

Because if we take inside shell, that density is different. What will happen if you take coconut after removing all this pith and put in water? Yeah, if it goes down it cannot propagate its species. So that is why, what it does is it, nature has already constructed that extra pith there so that it floats and goes from place to place.

And most of the times, coconuts they come wherever there is large amount of water, large amount of water I think that is beautiful place for them is large amount of water. Ok, so then it goes and then wherever there is a place and then there is a good fertile land it just stays there and then automatically it will get germinated and then another coconut will come.

So everything, every fruit you know like another thing, cotton. What a wonderful mechanism for that! Now cotton seed is there and cotton has beautiful fur coming there. And you know again to buoyancy, to make, you know, lighter, so that it floats in air, and then goes and falls somewhere, and again it germinates there.

And if you see mangroves, there are some trees there. And you know shape of those fruits there? It is like a stick, like a stick, very long stick, like you know drumsticks what we eat.

And you see the drumsticks at the end? It is very sharp. And why you know, that sharpness? The same sharpness is also there, this in; you know mangroves, where near the seas and all that.

So near seas what will happen is, they know, what is that, flow, tide and, yeah low tide and high tide, right, Ok, there is, you have slushiness in the, at that place. So now this, once it is ripe, this fruit will simply fall. And the sharpness will just go and then that will just stick to the slushy mud. And that will germinate there.

So every tree has a wonderful story. So that is what is the nature's propagation. That is why, you know, our, our job is only to propagate. In fact we are not listening to nature. That is why we have all the problems. If you listen to the nature, I think the planet will be excellent, no sustainability because you, you are designed by nature only for sustainability. Because we got intelligence and our intelligence is spoiling the planet.

(Professor – student conversation starts)
Student: (laugh)
Professor: Really. Really I tell you. We think that we are very intelligent and then we create all kinds of materials that create pollution that changes the constitution of atmosphere, Ok.
(Professor – student conversation ends)

So that is why, given a chance I want to go to that 10 million years before how people were there, Ok without technology and all that. That is what is sustainable. Ok, anyway, good. So that is what is the science I was trying to do, trying to tell you.

If you want to change the genes of these microorganisms, and you make them a super bug where its duty is only to convert milk into curd. So like that you take any process. Catalyst, by trial and error you found out that you have some catalyst and that is working. But now science will tell you now what kind of surface you need for very good reaction, what kind of orientation of these molecules and how they have to go inside and sit there and get converted.

In fact what is happening is that the molecules will break into, you know we have the theory. The molecules will go and get adsorbed and after adsorption it breaks into different

compounds, intermediates and those intermediates and again come together and for breaking you need some energy, that is what what you say activation energy, right? So if you reduce the activation energy it will quickly break.

So now when you are talking about science, I told you no, that Ertl, E r t l, Ok I do not know how many of you have seen that. He has done that, what kind of surface and on surface what is happening, what is surface phenomena required for catalyst and all that so that your catalytical reaction must be; earlier it was minutes, now it should be in seconds. So that is what is science.

Now I think at least you have an idea what is science, what is technology and what is technology, what is engineering and what is science? Science is the highest form where it does not care about the applications. Because when you are trying to change the genes you know, genetic engineering started because of this.

You have the bugs already available, nature created them. You take one of those, the microorganisms and try to put some other genes there so that you will become very, very active. That is what, what, theoretically we can also be changed. There are many science fiction movies no, where they do the experiments and then they want to try to make super human beings, Superman and all that, then finally they become Frankensteins.

Really I think Frankenstein experiment failed, they wanted to produce actually the most beautiful person on the, intelligent, everything, intelligent person but finally the experiment failed and then Frankenstein was created. Frankenstein is a devil. Very awkward and all that. So that is what the science is, science is the highest form without talking any application.

They want to know, just Ok. How do I change this, this bug genetically? He never bothers whether it will change the curd or it will change, waste water also is a, biological waste water treatment is also by microorganisms. And now biological treatment takes place almost 2 weeks, 3 weeks, 4 weeks. You know that big ponds what you have? Yeah.

How do you make them to immediately convert the waste into some product or some, you know, neutralize all the waste so that you can easily discharge, right. So that is where the

genetic engineer, that is why science is one where you just have some ideas, Ok how do I make this process very fast. And at molecular level, at microorganism level, then if you apply that to engineering then you have engineering discipline.

Like now we are applying this catalyst and then trying to produce on large scale through catalytical reactions, ammonia for example or some other reaction where catalysts are there. Or by changing the kinetics for example, S O 2 to S O 3, S O 2 to S O 3 is also a catalytic reaction, right. I can use some other molecules or I can use some other catalysts. But when I am doing that in the science level I do not worry about which operation is really this. We never bother.

So that is why highest form is science, application of that to engineering, and now next highest form is in fact this technology. But unfortunately technology can be done without this knowledge and if you do with this knowledge,

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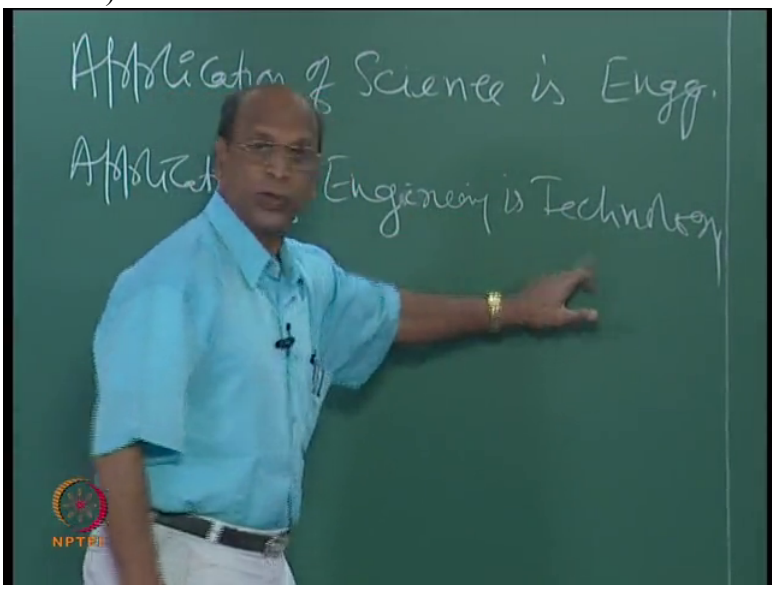

you get the wonderful technology, excellent technology.

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One example is, yeah,

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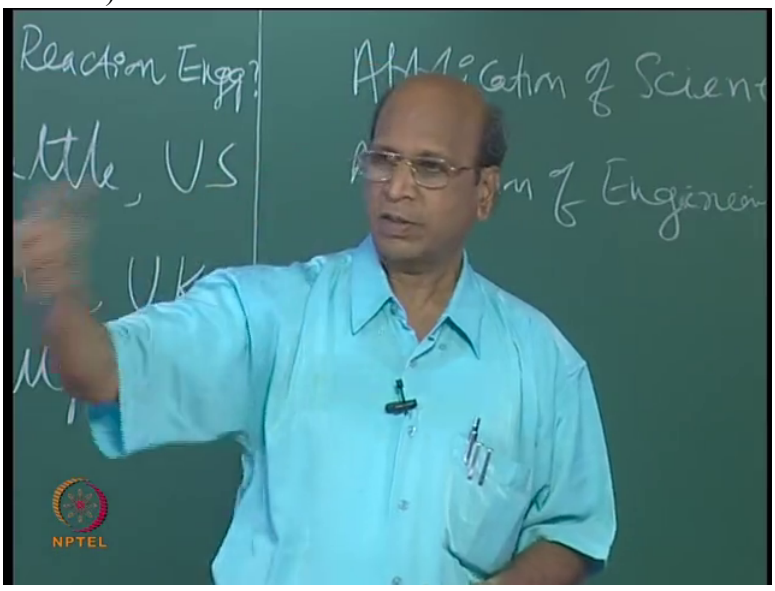

planes, aeroplanes. Aeroplane, you cannot do by trial and error. You need theory. You need science there. That is what is the wonderful technology because they are applying science and also they are applying engineering, right, from science they come to engineering, from engineering to technology, and they produce aeroplanes. Ok. I tell you maximum technology is only in aeroplanes.

And the next one is electronics. The theory between, the, the, the theory between application and theory, the real theory, the application is very, very quick. The moment they develop a theory, immediately they can make a product without, without any time lapse in between

where as in mechanical engineering, chemical engineering, civil engineering, it takes minimum 25 to 50 years.

If I develop a new theory in chemical engineering, for example we are talking of micro-reactions, micro-reaction engineering, even now it started almost 75, almost it is 35, yeah around 35 years. But still we do not have readymade plants for that. So theory is different for us, particularly mechanical, chemical and electrical and even for combustion for example.

When I developed a new theory for combustion, immediately I cannot apply that. It takes time, only trial and error, whether it works or not, so much time. But unless in communications electronics, the moment you have theory, immediately it is applied, satellite is sent. That is in this

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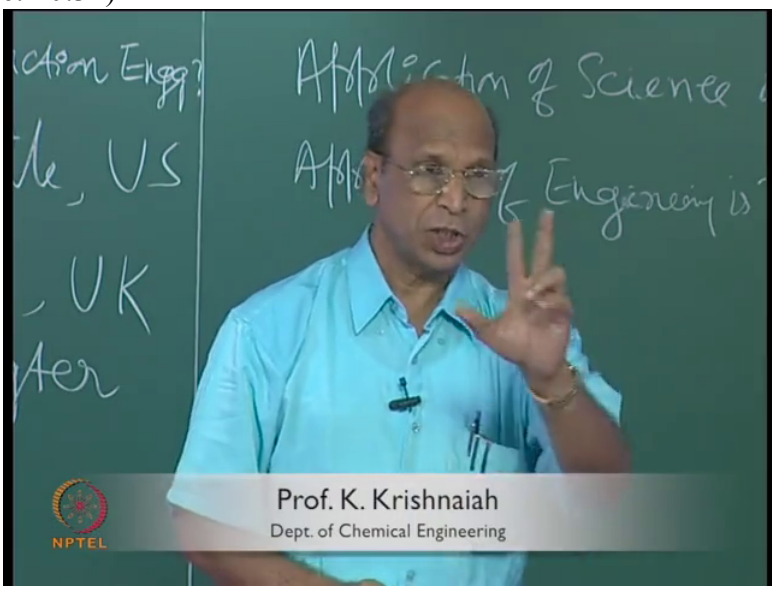

these two areas, the gap between actual practice and theory is very, very, very less.

In fact medicine also less. The moment someone finds out some new equipment, immediately that is used on the patients. But chemical engineering, civil engineering, mechanical engineering, metallurgy, you need at least 20 to 50 years time. Ok, so this is what I just wanted to tell as I know, you have the class, yeah. I just close it. I think we will close it. Tomorrow morning we will continue.