Energy Resources and Technology
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Lecture - 5
Other Fossil Fuels

Through the assignment that you did, I was hoping to obtain the decision, the conclusion about what is the effect of each of these parameters and from the submissions, I could see that at least this much can be inferred that if you vary …..

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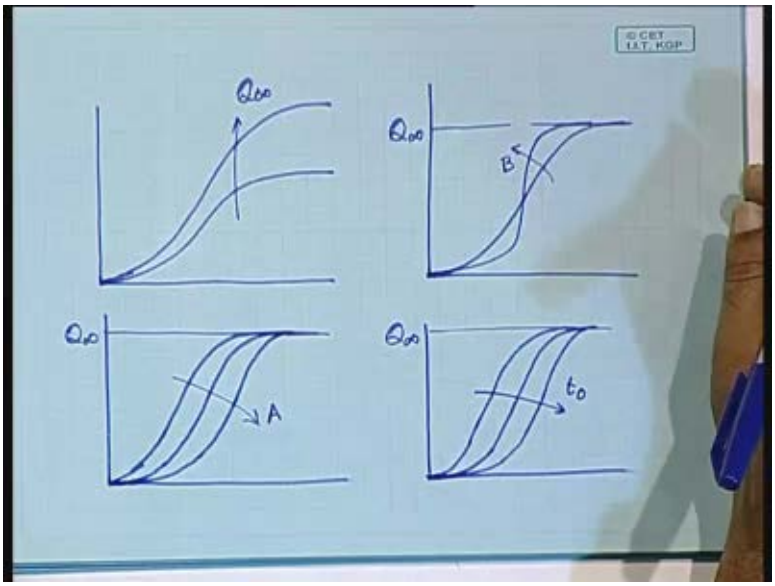

What is the problem? I said the only way you can talk is to me; hard rule. So, if you have a variation of Q infinity, then it would go from here to here and so on and so forth. If instead, so this is for varying of Q infinity. If you have the variation of say B, then if this is the Q infinity level, then for one value of B it would go like this and for a higher value of B it would go like this, right; that you have seen. So, this is for a larger value of B, but from your graphs, the way you have presented the effect of the variation of A and t naught seems to be smudged. So, from the graphs, I can see that if this is the value of Q

infinity, then if this is the graph for one value of A, this is the graph for a lower value of A and this is the graph for a higher value of A, right.

Opposite, okay, yeah; so, this would be for a higher value of A and this is for a lower value of A. So, this is how A that is and for the variation of t naught, again you have a similar characteristics. Which way is the variation of t naught? For the larger values of t naught, it is like this. So, there has to be some way of distinguishing the effects of A and t naught. So, that is again what I should leave for you to decide, by tomorrow. You have to, you have to take a very good look at it and try to figure out in what way the effects of A and t naught are different. Then only, given the data, you will be able to properly fit the numbers; otherwise, you will have difficulty. So, that is about it and I asked you to download the data that you have. Have you been able to do that? So, you did not find

Yes; so, if some information is there in a website, you have not yet learnt how to locate it. The easiest way of doing it is in most sites there should be a site map. That means all the information that is there in a site there should be some kind of a link to it. So, if you go to the site map and try to find out the articles that are available that is the right place where you can expect it to be there. But of course, I can do it for you. Since the graphs I have already downloaded, I can make it available. So, that is what I will do. I will put it in my web page and you see that. So, my web page is …..

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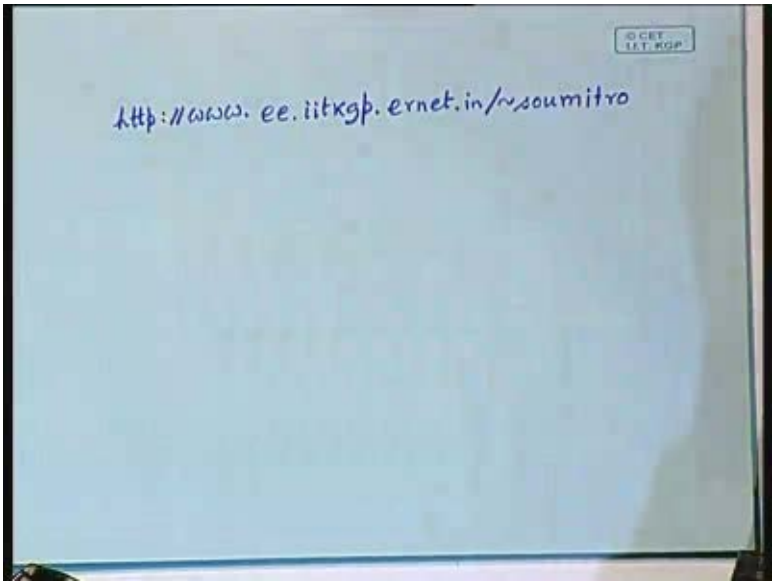

Can you read? So, this is our departments web page and in that the faculty web pages are with the faculty …….. name extension. So, inside you will find there is a link to the courses that I teach and if you click on back, I will put there. I have not yet put there; I will have to put there. So, all that you have to do then is to download it and from there, look at the points which are the points of dQ P dT, integrate or keep on adding them, so that you have the cumulative graph and then plot it and then try to fit the information using the data about Q infinity that I have already given separately.

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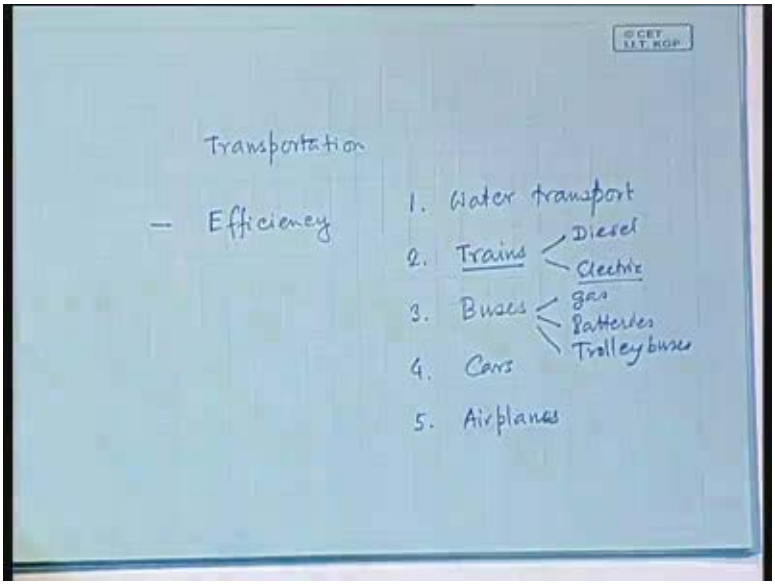

So, now, in yesterday's class, we had decided that the only way we can survive, the nation can survive, is to find some way of reducing our dependence on fossil fuels and in that we had discussed that the main place where fossils fuels are used is transportation. So, that is where the attack should be mounted and in terms of efficiency, this is the order in which the efficiency of transportation is ordered. So, we had decided that water transport has to be increased as much as possible and in that you know that India is very well …. out, because we have mighty rivers which most of the countries do not have; so, they have to build canals in order to have water transport, but in in our country most of the big cities are linked by rivers and so, you can have water transport.

We also decided that the right course for the country should be to increase the dependence on trains, mainly electric locomotives and take away the dependence on the diesel locomotives and in that there are certain things that you should understand at this stage, things that often evade attention. Can you imagine how much is the wastage if Rajdhani express is delayed by 1 hour? It is running on diesel. Suppose it is running on diesel; the whole train is air conditioned and is delayed by 1 hour. It is a huge wastage, not a meager amount. A whole train air conditioned, there is a huge amount of energy expenditure on the air conditioning system and that is wasted completely. So, there is an

enormous amount of advantage to be gained in making the trains faster, so that point to point time is reduced and of course the tendency of going towards, air conditioning tendency is something that within another 10 years we will not be able to afford, but now that we are going towards it, so that is another problematic issue. We were used to the climate; we no longer remain used to the climate, so that is another problem.

So, trains, we should really go for a larger amount of transport through trains and as I told you, the planning is now going in a different direction which is counterproductive from the energy perspective. For example, the connection between Bangalore and Mysore, two big cities in Karnataka, huge amount of traffic, both goods as well as human traffic, so what should carry it? So far, it used to be trains, but now a very big multilane highway has been built, so that most people ply by cars. The whole thing obviously is enormously energy expensive, right. So, this is what I am saying that you, as an engineer student, understand that this is not the right direction of development. Buses, as I pointed out, that buses and cars they all run at a specific speed most efficiently, right; so, a particular speed normally in the range of 30 – 35, 30 - 40 kilometers per hour. But then, since cars have to accelerate and since most of the cars are built to be able to prove that a higher speed say, most cars can at least cruise at a speed of like 140 kilometers per hour, therefore even if the car really does not have to, no car in city can ever exceed the speed of 40 kilometers per hour, yet the cars are built in order to cruise at 140. As a result you have an enormously larger engine. So, if you can rationally design the engines, then we can, it is possible to cut down the fuel consumption.

Nowadays, probably you have heard the word SUV. Have you heard?

Student: Sports utility vehicles.

Sports utility vehicles - very popular in western countries, things that guzzle about 5 times more, they call it gas, we call it petrol, same thing, gasoline, than the normal cars; made for very high acceleration, very high cruising speed, but there is no road in United States where you can really run at that speed, because the speed limits are there, the cops

are behind you. But still the cars are made. Why because, it sort of satisfies ego. You like to have a car that can in theory run at that speed; you never run it. So, these are the typical things that we do, that actually ruin the amount of energy resources we have. So, for our country at least, it would be counterproductive to think about such big powerful cars. It is more productive to think about rationally what is the possible speed that I can reach within a city transport and accordingly build cars.

This brings us to the issue of CNG. As I told you, when we did all this, this was essentially the graph for petroleum and in addition to petroleum we have other resources, fossil fuel resources and the major one is natural gas. So, you need to have a clear idea about where do we stand, India in terms of the national natural gas resource and as you know that some of the cities have gone in a big way towards natural gas based transport, CNG, compressed natural gas based transport. This is a very, very good move, but in order to really spread that all over the country we need to understand how much we have.

Now, on that point let me tell you that as yet the place from where natural gas is produced in India is the offshore oil rigs that are placed beyond the shore of Bombay. So, these are called Bombay high rigs and initially all those gas were simply burnt. So, if you saw the pictures, images of Bombay high rigs in the initial years, you would find a big flare on top of it. That means the natural gas that came along with the petrol, petroleum, would be burnt. But nowadays, you have gas pipelines that bring the gas on shore and we use them, so we have some way. Apart from that, we really do not have any, as yet, we do not have any source of gas, though only a few months back there were reports that people have found gas deposits in Andhra Pradesh basin. So, that is not yet been utilized.

So, where else can we get the gas from? Wherever petroleum is produced, there is some gas produced as a byproduct. Some has a large petroleum deposit, so it also has some gas deposit, we do get that, but that is not large amount. But, our neighboring country Bangladesh has a lot, large amount. Bangladesh's main stock is really gas, not petroleum. It has a very large amount of gas reserve and that is why in Bangladesh the cooking gas is free; you know that cooking gas is free. So, you simply have the pipeline coming into

your home and they run it. That is why in most of Bangladesh's households the oven runs all the time. When you want to prepare tea, simply put something. You never extinguish it, so that is the standard way of doing things there. But, they feel that this gas should be really stopped and should not be exported to other countries. So, it is their countries decision that is why we do not really get the gas from Bangladesh.

Myanmar, the country further east of Bangladesh has a lot of gas resource and nowadays there is a talk of building a pipeline to bring the gas from Myanmar to India, eastern coast. There is also gas finding these days in Tripura, which is within the Indian borders. But unfortunately, if you want to build a pipeline, it has to come through Bangladesh or it has to come all the way through Assam and …. like that. It is a very long route, so nothing has been done to that yet. So, that is the status of gas. That means as it stands, we have sufficient amount of gas to run two cities Bombay and Delhi, but as yet two other big cities or even in Bangalore do not have the gas pipelines. That is why they still have to run on petrol and diesel and that is why in these two cities the pollution level is quite high in these cities. Why?

In the cities that have moved towards natural gas, the pollution level is quite low, because much of the pollution comes from unburnt hydrocarbons. But, if you have gas, gas is what? Natural gas is methane CH 4, so that burns far easier. That is why it is far easier to have complete burning. Even if it is not complete burning, it is not a polluting thing. So, the natural course for the country in future years, we are talking about the situation when you are engineers, so that will be another 40 years or so, so then at that time, obviously, we need to project, we need to look forward to that kind of a time frame and obviously the direction in which the country should proceed is to utilize more and more of its gas resource. Wherever it is possible, should find and tap it.

Airplanes use a different type of fuel. Different type of fuel means it is also petroleum product, but not really the petrol and diesel. So, as petroleum is fractionally distilled, the lightest part is the natural gas. Then what? That is CH four. What is the next component? C 2 H 6. What is the next component? C 3 H 8; C n H 2n+2. So, the next part would be

the LPG, the liquefied petroleum gas. The next part would be petrol, then diesel, then kerosene, then all that and finally, you have the heavy products that normally cannot be used in these kinds of fabrications.

Heavy products mean naphtha, very heavy ones and also tar. Nowadays, in most of the petroleum refineries there are systems of cracking the naphtha. Cracking means adding hydrogen to it, so that that breaks up into smaller hydrocarbon component, so that you can extract more number of more usable substances out of it. So, that is another way we do use this. The other way where we talk about the thermal power plants, we will realize that all thermal power plants, even the ones that run on coal also need oil for certain purposes. So, there, those relatively heavier components are used and the heavier components are also used as kerosene for normal burning and these are the relatively cheaper components. So, you have all these possibilities finally leading to the stock that you have, clear.

Now, when we move to electricity based transportation, as I told you in city, the natural direction, normal direction should be to make more and more public transport system rather than private transport system, because in most of the cities, the roads, the road area in comparison to the total city area, if you take a satellite image, you can count the road area, measure the road area and that is far smaller than the city area, because they developed quite long back with narrow roads. The amount of road area that is necessary for a proper transportation is not there in almost all the cities, except possibly Delhi, because Delhi was developed much later.

Now, in those cities, obviously then, the right way of doing things is by, to build public transport system. The more private transport system will be there, the more individuals car will be there, the more traffic condition will be there. If a large number of people can be transported by one vehicle, it is for more convenient, so one has to build in future years a stronger public transport system and public transport system, more based on electricity. Now, when we talk about electricity, we talk about the normal trains, electric trains, the tube rail, metro rails, trams, trolley buses, all possibilities and all possibilities

should ……. But, you might ask that is in the end using the fossil fuels, because the coal is not the primary, the electricity is not the primary energy; it is secondary energy.

Primary energy is either coal or gas or whatever. Obviously true, but then that depends on how much we have in stock, all these individual resources and we need to understand how much we have gas as well as coal. Are we really utilizing electricity? We are utilizing either our hydrolytic potential or we are using our coal potential, mainly coal though. So, we need to understand how much we have. Do you know how much we have? First what are the different types of coal you have learned in school? The most concentrated carbon is anthracite coal, which is no longer found in India. So, anthracite coal we do need for our steel plants and that is important. So, we do not have that.

The next grade is bituminous. We have a reasonably large stock large deposit. Where? Mainly in today's Jarkhand; mainly in today's Jarkhand and some part of West Bengal, some part of Bihar. Mainly that is the place where coal deposits are found in large amount and that is bituminous. There is also some coal deposit in Assam more or less of the same type and the third grade is what? Lignite; do you have any deposit of that? Yes, in Tamil Nadu a very, very large deposit of lignite. So, we have a, we are reasonably well off in terms of coal availability; reasonably well off. Nevertheless, we will understand later that coal burning has its own problems when we talk about the fossils fuels and how power plants are build. You will realize that there are inherent problems; nevertheless, we have a reasonable amount of stock.

That is why when we build our power plants, these electricity sources, then these are essentially built on our stock; our stock of coal and in the whole of the eastern region the coal supply comes from this region – Bihar, Jarkhand, west of West Bengal and in south mainly there are a large number of pithead power plants that means where the coal supply is there, right there you have power plants, so that it, coal, does not have to be transported and for lignite, since it is not a very high quality coal, so if you have to transport and if the coal has 60% ash, then essentially you are transporting system has ash. So, that is counterproductive. That is why normally if you have lignite source you have pithead

power plants, while if you have bituminous coal, the transportation justifies itself, because it can then go to more logical locations and that is why you have power plants. For example, as you go from Kharagpur to Calcutta you see a power plant, don't you? That is in Kolaghat. There is no coal mine nearby. That is, that is normally brought in from west of West Bengal, but nevertheless that is feasible for bituminous coal.

Now, we need to understand the other issues related to transportation. Transportation also causes a large amount of pollution. So, when we discuss transportation and the use of energy, we also need to relate that to the pollution it causes. Probably in the winter months if you go to Calcutta, you have encountered the problem of burning of eyes, right; a burning sensation sensed in the eyes. You feel a bit of breathing problem. Do you know what causes it? Smoke, alright; but, smokes are of various types. Smog, alright, but smog, no; smog is different issue. Smog does not happen in Calcutta or place like that. So, what, what is it? Essentially the pollution comes from three sources. Number 1 - suspended particulate matter in the air. So, let us categories these pollutions.

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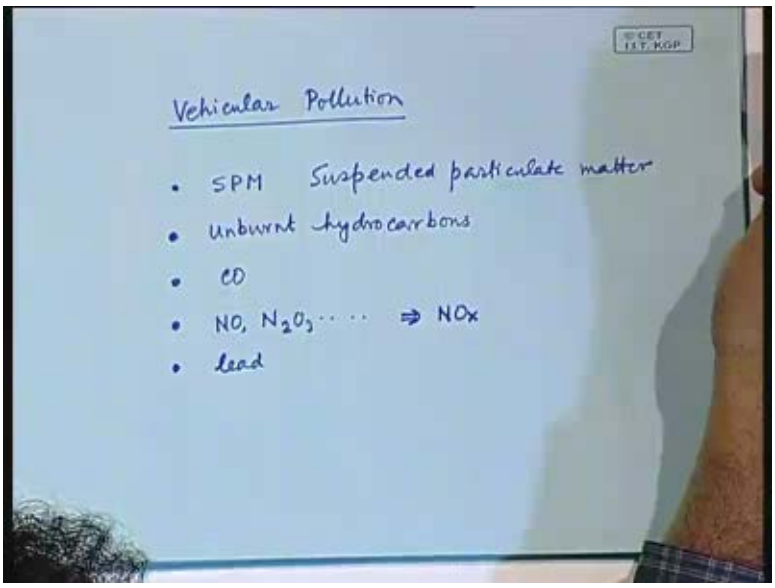

When you come to vehicular pollution, SPM is suspended particulate matter. What is that? As diesel is burnt, a part of it may remain unburnt and since diesel is hydrocarbon,

at that heat the carbon and the hydrogen may separate out and the carbon part may remain unburnt. So, that is what produces this suspended particulate matter in the main. So, suspended particulate matter or the, or the thick smoke that you could see coming out of the pipe of the vehicles that is essentially unburnt carbon, right. Second - unburnt hydrocarbons; that means a part of diesel or petrol may remain unburnt as it is as hydrocarbon, so that goes into the air which you can smell. Carbon you cannot smell, but when it comes to vehicular pollution, it can smell, right and that is unburnt hydrocarbon remaining.

Third – CO; CO 2 is of course produced that is the main product of the burning, but that is not a pollutant per say; pollutant per say is the incomplete burning causing production of CO. So, these three plus there is another thing that is produced which is NO, N 2 O 3 and so on and so forth. There are various combinations of nitrogen and oxygen, in general these are called NO x or in short NOX. These are also pollutants produced by vehicles and we need to understand what produces them. Well petrol also contains lead and the lead going into the air is also a pollutant, so that is also another. So, what produces the suspended particulate matter? Incomplete burning. What produces the unburnt hydrocarbons? Incomplete burning. What produces CO? Incomplete burning.

So, if you can produce the proper temperature and proper fuel air ratio, then obviously you can achieve complete burning and therefore, these will not be there and these days you have catalytic processes that also ensure complete burning. That is why you hear of the term the Euro II standards. So, that is essentially some process that ensures complete burning and most of the modern cars have them fitted. So, most of the modern cars you do not see much thick sooty smoke coming out of the exhaust pipe, but that requires regular tuning. Tuning means setting the ratio of wear and tear and that is often not done by the commercial vehicles, buses, taxies and that is why buses and taxies, you will often find, even police cars; police cars are one of the worst offenders in that sense thick smoke coming out of them. Nobody can catch them, because they are police.

So, you have, you really have to have regular tuning. Unfortunately there is a rule in India where you have to get it tuned every some, some months and there is a pollution testing facility, where you have to get a certificate which these days can be had for 10 rupees. So, nobody really gets them tuned. They buy the certificate for 10 rupees so that is a there is a problem that we have in India.

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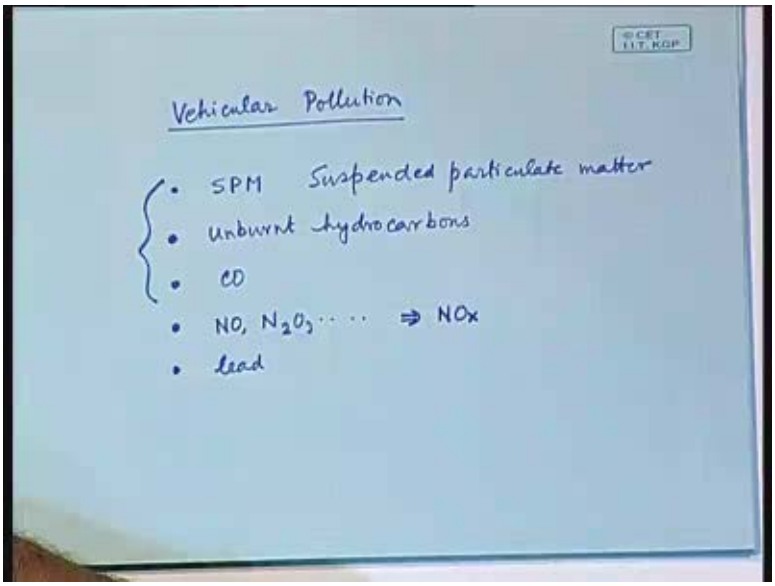

So, we have these problems that are easily overcomable; we have the technologies to overcome them. What about NOX? Why are they produced? Well, NOX is obviously not there in the petrol or diesel. It is produced in some other process. What is the process? Because, inside the cylinder you produce a high temperature, in that high temperature the nitrogen that is there in the air, oxygen that is there in the air, they combine and produce the NOX. So, NOX is actually a pollutant that produces problems in the breathing ducts, asthma and number of breathing problems. But, that is something that is produced because of the high temperature.

Can you help it? Can you do something about it? Is it possible? Well, these days a lot of research is going on to find out ways of reducing the NOX production. Essentially, how to ensure complete burning, yet slightly reduce the temperature inside the cylinder, so

that complete burning is ensured as well as the temperature necessary for the production of NOX is avoided. So, it is still something doable. So, you can see, lead is also, lead free fuels are now available; so, that is also another thing that we can talk. So, the point is that all these are avoidable problems. They are not essential to the transport system using fossil fuels, but we have them as a very big problem, because, because of what? Can you ascribe reasons to it? Because, firstly, we are not aware of the problems; mostly people are not aware of the problem and secondly, the economics do not work out; economics do not work out.

It is far easier to buy a second hand very old car, which does not have the facilities for catalytic conversion and tuning is also expensive; it is far easier to simply buy a certificate. That is why because of these aberrations, the pollution standards have not been properly imposed in most cities in India. We have a very high pollution problem in most of the Indian cities, though because of the, even though these problems are there, because of the introduction of CNG, the problem has more or less been abated in Delhi. So, you have these problems related to …. So, what would be your recommendation then? When you become engineers, if you are in a position to make policies, what will be your recommendation then, in order to make the Indian cities pollution free as well as you know, people should ply. What will be the, what will be the recommendation, what will be the national policy, in terms of transport? Common, say that.

Common, within the city, how can I have a water transport. I am talking about city transport.

Student: Increase public transport.

Number 1 - increase public transport, then …

Student: Electric based public transport

Electric based public transport, then …

Student: more use of CNG

More use of CNG, then …

Student: Make petrol …

Petrol, making petrol a little more unavailable for general use

Student: So that people generally avoid using it for normal purposes, for any purpose. They will only use if it is necessary.

That is exactly why you have a difference between the prices of petrol and diesel, right. That is, that is essentially the reason. In other countries it is not there; they have the same price.

Student: …

Yes; so, in India you have the difference in price, because of exactly the reason that he is talking about. That means private transport is mainly petrol based, while the public transport is diesel based. So, that is why diesel is made relatively less expensive than petrol, but both are going up now. But then, you have pubic private transport cars also now based on diesel, ……. some other problem. So, people are moving towards diesel based private transport. The last option you said?

Student: Encourage hybrid car research and then make them …….

So, encourage hybrid car research and make them more available. Yes, of course, but that requires futuristic vision from the, from the policy planners and the people who make the cars. Normally for people who make the cars, what matters is how much profit you make and if you can convince the people that right now, you buy car, just any car ……. the production is naturally for the normal petrol based cars and that is what is happening

today. The technology is there; the technology development is there. Hybrid cars are there in the market, yet no Indian manufacturer is going for hybrid cars as yet. They are only manufacturing the petrol or diesel based cars that is because of this reason. The liquefied petroleum gas, LPG that is normally used for, for what?

Student: Cooking.

Cooking; that is the lightest part C 2 H 8 that part. That is normally used for cooking, alright, but that can also be used for vehicular transport and these days that is …. The problem is a bit political that this is for the purpose of cooking. It is a bit subsidized and so, people who could run their cars by petrol, they are now running that by LPG. So, there is only a small conversion that is necessary; essentially, the fuel air ratio would be different and that is what is implemented. But, if the country decides they will produce more of LPG and then will run cars by LPG, there is also another option. There is also another clean option. The point is that a fuel, what really matters is the energy density of the fuel. Why are liquid fuels more popular? Because, liquid fuels, in unit amount of liquid fuel, just 1 liter, a huge amount of energy is concentrated. It is concentrated form of energy; in gas it is more distributed.

So, though CNG, compressed natural gas is a way of utilizing the gas, but you have to realize that that is a more dilute form of energy. If you can liquefy it, the whole thing becomes very compact, very small volume. So, making more of LPG is another option, because that is liquefied a small amount of space you can cramp a large amount of energy. So, another deduction that the country met is to produce more of LPG by cracking of naphtha, by combination of natural gas. Natural gas is CH 4, from there it is possible to produce LPG. So, either you break up larger molecules or you join smaller molecules, both are possible. So, it is possible to produce more of LPG, if then the country decides to go in that channel that is another option. So, you have various options available for the use of this.

In coal burning also, in CNG burning also, which of these problems do you foresee? These five things that are possible in vehicular transport, five types of pollution, in CNG based transport, which one do you, do you foresee that might be there?

Student: NOX.

NOX; suspended particular matter would be almost entirely eliminated, because there is hardly any possibility of that lone C to remain in the exhaust. Unburnt hydrocarbons, the CH 4 is not really pollutant. I will come to the issue of global warming; it is not really true that it is not a pollutant, it causes global warming, but there is a huge amount of methane that is all the time being produced, because of the degradation of bio mass. So, in comparison to that, the amount that may escape is very small. So, it is not really a big problem. CO is also, can be easily taken care of in gas burning, but NOX is due to the temperature and obviously that remains. So, still there has to be some research going on into the specific way of taking care of the NOX problem in CNG based vehicles and as yet, there has been no move in that direction really. Since you will be engineers, I am putting this problem to you. Lead is of course not there in CNG.

So, my point is that as you go from relatively lighter fuel based transport either gas based or LPG based transport, much of these problems are really taken care of. These problems are more acute in heavier fuel based transport and mostly diesel based transport. You might have noticed that in the villages, there are tube wells from which people withdraw water, by pumping. How do they run? How do they run those things? Normally by diesel; normally by diesel, in places that is by electricity, but normally by diesel and these days even people mix kerosene with the diesel.

So, what will be the result of that? Even more acute problem of these, all these, because kerosene is a larger molecule; obviously then, some part of it, it will remain unburnt, some part of it will remain as carbon particles, some part of it will remain as CO. So, all these problems are acute. The most worrisome fact is that it has been detected in some cases that even petrol pumps do that in their diesel, in the diesel that they sell. So, that is,

you should understand, that is even more acute problem. This guy is making profit alright, because kerosene is cheaper; but, for the rest of the society it is very, very harmful, because of these reasons. Even the car can run; even if the car can run, it is still very, very harmful.

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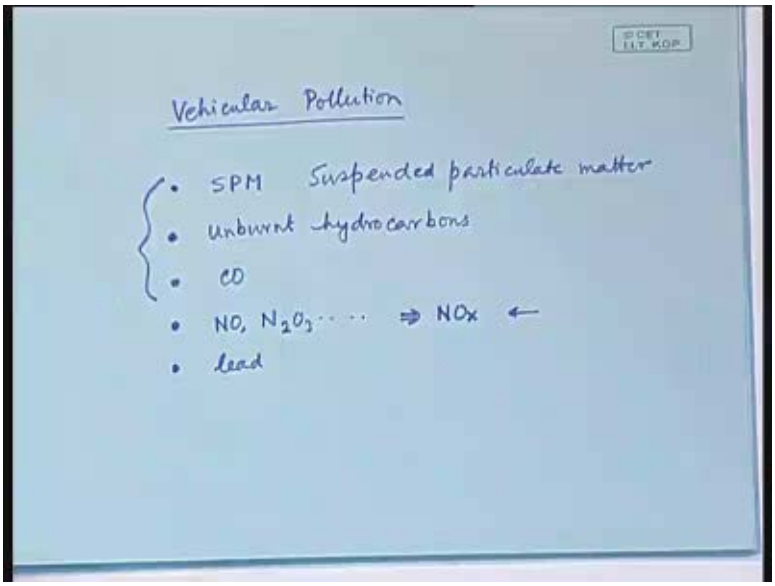

So, we have, we have essentially …… into this as the remaining problem and let me tell you that this is also a problem whenever you burn anything, whenever you burn anything. In power plants, coal is burnt and if the temperature is beyond the threshold that produces NOX, there also NOX will be produced. So, wherever, in nuclear power plants the places where there is nothing burnt, still if the temperature is high, this will be produced. So, you have the problem of NOX, which we need to address and in the future classes, I will tell how to address this problem. The technologies are there. It is possible to counter that problem. So, regarding the vehicular transport, we try to cover the things necessary to know in terms of future direction. I really did not talk about how to make a car and how to make its engine and things like that. Those of you, who are interested, may learn it in mechanical engineering. Essentially, we talked about the fuel, the pollution and these, the ratios in transport. Is there any question on that? Then, we will go to a different issue.

Regarding the fuel, there is another thing I need to tell you that power plants are also notorious polluting places. Power plants mean thermal power plants that run what? Coal. What are the pollutions coming out of that? Can we list them?

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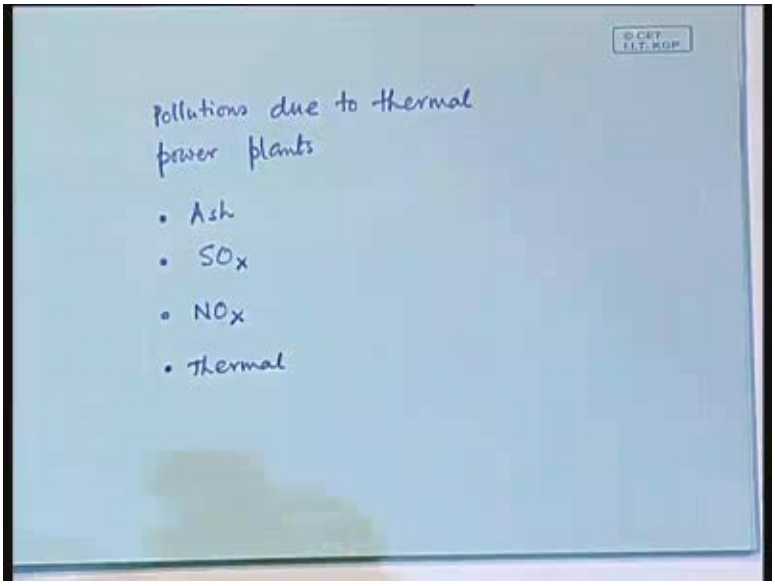

Number 1 – ash; unless that is properly used or disposed, ash is a problem. Two – anything, heard of any other problem, pollution problem due to power plants? Have you heard of acid rains? Yes; acid rains happen because acidic materials go into the atmosphere. What is the source of the acid rain material? Sulphur dioxide; so, sulphur dioxide, sulphur trioxide, so all that mixed together, we call it SOX and of course, we talked about NOX. So, in the main these are the pollutions, also there is a thermal pollution, which we will talk about.

Now, since in today's class we are discussing about the fuels, I need to tell you one advantage that we have. Indian coal has very little sulphur. In contrast to European coal, coal that is available in Europe - in Germany, in England - in contrast to those coals, Indian coal has very little sulphur. That is why Indian power plants produce very little SOX, because SOX is produced due to the presence of sulphur, it is unlike NOX. NOX does not require the presence of something in the coal; it is because of temperature, while

SOX is because the sulphur in the coal is burnt and that produces SOX and since Indian coal has very little SOX, very little sulphur, SOX production is very little and that is why we have a major advantage there in comparison to the Western countries, but we do produce NOX. We do produce the other things.

So, when we discuss about the pollutions and how power plants are made and what are the future directions in making power plants, you should keep that in mind that is a typical characteristic of Indian coal, one advantage that we have, clear.

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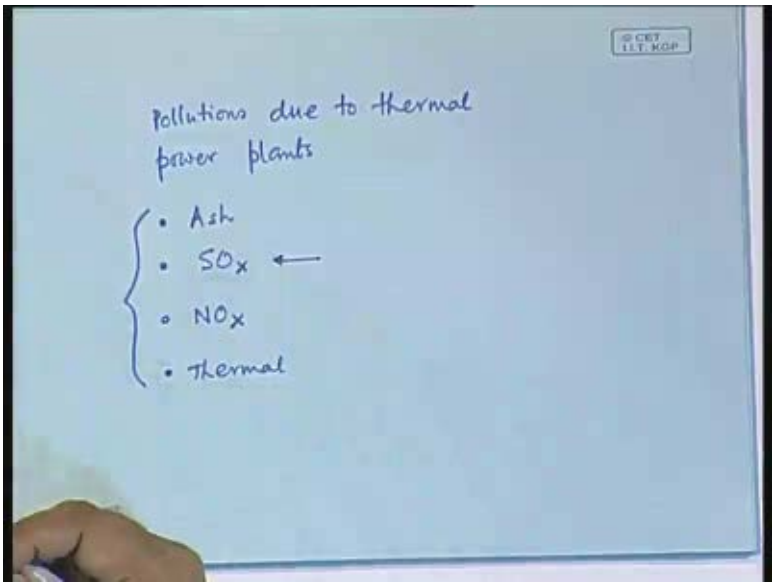

So, we have, when we talk about power plants remind me or remember that we need to discuss each of these and how to overcome these problems. But, due to this specific situation that we have in this country, I will put less emphasis on SOX, while if you are European, then I would have put most emphasis on SOX, because European forests have been denuded because of the acid rain problem that is mainly because of SOX.

So, it is time, let us call it day today. We will reassemble tomorrow, but before that I want you to take a very close look at the graphs that you obtained and decide what is the difference between the effects of A and t naught.

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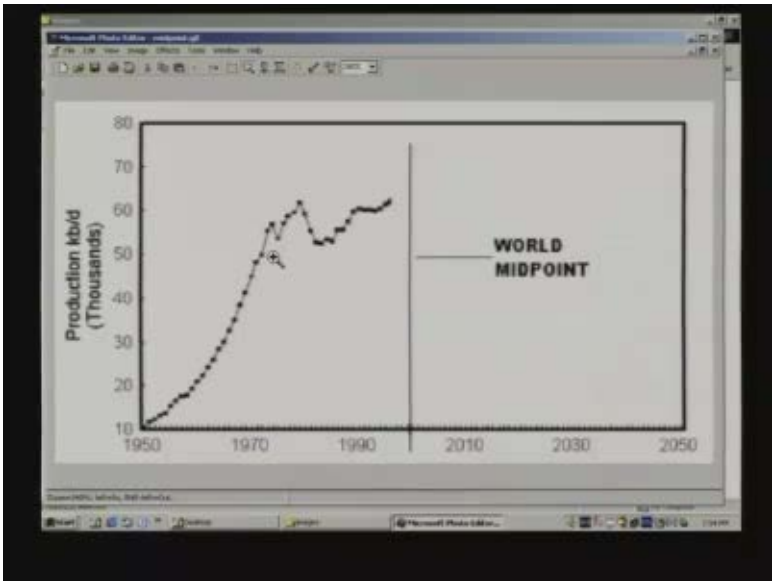

We can give you the graph over the Internet, by email or whatever, but for those who will see this video in posterity later, for them the video is the only medium I have to communicate to you. So, what I will do is I will display this graph for quite some time, so that you have you can note down these points, even if it is approximate, so that the assignment that I have given to my students that can be done by all those who have a, who will be seeing this video later. So, I will display it for some time and I request the viewer to note down the points or at least sketch the graph even if it is approximate.

The nature of the assignment that I have given is essentially where you have to first convert this graph which is actually dQ P dT graph given in a specific unit kilo barrel per day, that will have to be first converted to kilo barrel per year and then that has to be summed up to obtain the Q P graph, not dQ P dT graph, but Q P graph, cumulative production graph. So, from here the data will first have to be converted into the cumulative production graph and then, you plot that graph, then you estimate the values of A, B, t naught, with Q infinity assumed to be 1750 Giga barrels. So, after that is done, you have to plot the original Q P graph as well as the estimated Q P graph on top of each other, so that it is possible for you to see how good a fit it is.

Now, the reason I gave the earlier assignment which was essentially to understand the effects of the individual parameters A, B and t naught. If you have done that assignment properly, then you understand that if your graph, the one that you have estimated, differs from the, from the graph that is given, but not exactly this graph, but its transform into Q P graph, the way your graph differs from that graph, from there you should be able to understand which particular parameter or combinations of parameters need to be changed and in what way, so that you can play with the parameters and get a reasonably good fit.

After you have obtained the best fit according to you, the best fit graph, then finally the job is to obtain those critical points. In which year did the dQ P dT maximize, which here is given as a particular year 1999, but after you have done the estimation, it might be slightly this way or that way; estimation of that is a part of the assignment. In which year will 75% of the resource be exhausted? That is another critical year that you have to estimate. You have already seen that the graph for reserve has a particular characteristic, where it goes up and down to the negative side and goes up; the year when it goes to the negative side and stops to grow up, that particular year that is another critical year; you have to estimate that.

So, all these estimations have to be done depending on the graph, depending on your estimate of the A, B and t naught. That is the assignment.
Thank you very much.