Fuels, Refractory & Furnaces

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Lecture No. # 06

Heat Balance and Clean Development Mechanism

Today, we will talk on energy balance in coke oven and Clean Development Mechanism. In the previous lecture, you have heard about material balance, and material balance is a prime requisite for energy balance. The objective of energy balance is to find the flow of energy, what are the sources through which energy is entering into the for example, coke oven and what are the energy outputs.

Now, this energy balance in fact you can also call it to be energy auditing, you want to audit the energy in terms of its input and output, and the objective is very clear, you want to know what is happening to the input of energy, where it is being utilized, how is it being used utilized, where are it where are the energy going to waste, and what can be done. In the present context, the energy auditing has assumed a very, very important role in all the industries.

Now, in relation to energy auditing let me introduce another term which is the clean development mechanism. The whole idea is if you want if you save the energy, you are saving the environment also. That is where the concept of clean development mechanism, has been introduced in the last few years, and the clean development mechanism, that is the in short, it is called CDM.

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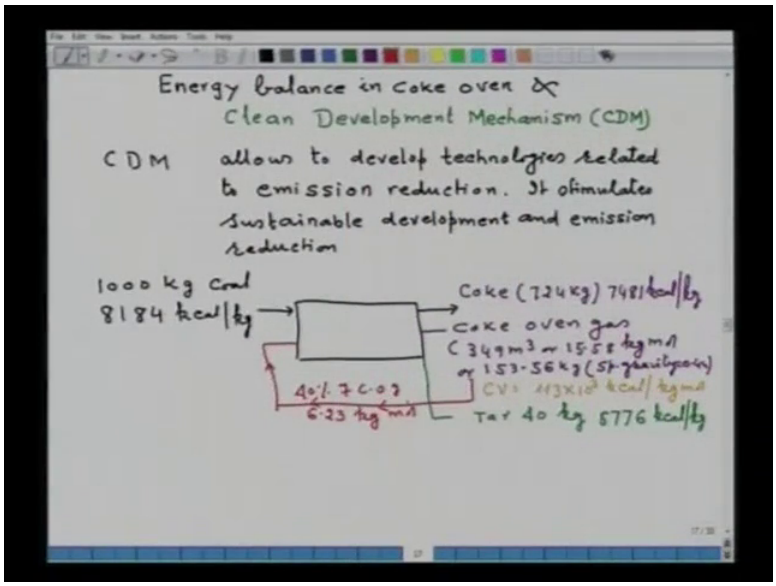

And this clean development mechanism, it allows to develop it allows to develop technologies (No audio from 02:20 to 02:30) related to emission reduction to emission reduction. It is stimulates it is stimulates sustainable development sustainable development and emission reduction. Now, this concept was introduced in order to reduce the emissions, which are discharged into the environment by the use of energy of the fossil fuel under the Kyoto protocol.

So, all those technologies which help in reduction of emissions, they come under clean development mechanism. And it has certain its economic benefits, I will not going to the detail. So, now, it is in this perceptive, let us see how the energy balances in coke oven, it relates to clean development mechanism. So, I will again make the heat balance of the problem, which we have taken in the last lecture. We have determined the various inputs and outputs and I am rewriting those inputs and outputs, because energy balance it cannot be done without any material balance.

So, for that purpose I am making energy balance for 1000 Kg of coal, so if this is a symbolic representation of coke oven, then here say 1000 Kg coal is entering 1000 Kg coal is entering and it has calorific value 8184 kilo calorie per Kg, that is what we have seen (Refer Slide Time 04:18). Now, here coke is produced of 724 Kg and its calorific value was 7481 kilo calorie per Kg, then coke oven gas is produced and coke oven gas was 349 meter cube or it was 15.58 Kg mole or 153.6 153.56 Kg considering specific gravity of coke oven gas, that is

equal to 0.44 in relation to air. We have also determined calorific value of this was equal to (( )) 113 into 10 to the power 3 kilo calorie per Kg mole that is what we have determined. Now, either result of this coke oven operation, we have also found that tar is also produced and the tar was amounting to 40 Kg contains 8776 kilo calorie per Kg as its calorific value.

Now, what we are doing is that say 40 percent of this coke oven gas say 40 percent of this coke oven gas, that is 40 percent of coke oven gas is recycled into the coke oven chamber for combustion, and this 40 percent correspond to 6.23 Kg mole is use for burning and supplying the heat to the coke oven chamber. So, now we are in a position to make the heat balance, and analyze the heat balance.

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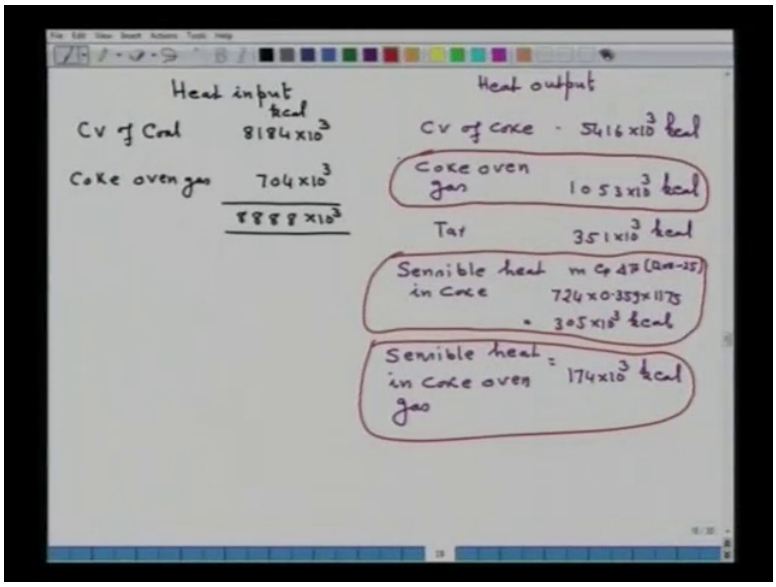

So, if we do that we will consider say energy input or we can call heat input whichever, way you want to understand. So, heat input was calorific value of coal and that is equal to 8184 into 10 to the power 3, these values are in kilo calories. Now, also coke oven gas because 40 percent of coke oven gas is burned, so accordingly the heat which is entering is 704 into 10 to the power 3 kilo calorie, and that makes a total 8888 into 10 to the power 3 kilo calorie as the heat input.

Now, let us see in the heat output side, so heat output, now first of all calorific value of coke, we are able to get the heat or in the form of calorific value of the coke, that was 5416 into 10 to the power 3 kilo calorie that was the heat output, then coke oven gas the remaining coke oven gas, I am talking because 40 percent has been recycled and 60 percent is left over, and I

am calculating the calorific value of this 60 percent of the coke oven gas which is now discharged into the environment of the coke oven chamber. So, this has a calorific value of 1053 into 10 to the power 3 kilo calorie, then tar tar is also produced and tar has a 351 into 10 to the power 3 kilo calorie, we are able to recover into the tar.

Now, the coke is discharged for example, at 1200 degree celsius, then coke also carries sensible heat, so I am calculating sensible heat in coke sensible heat in coke that is very simple m C p into delta T. And C p values that is C p value one can take 0.359, and one can calculate very easily sensible heat in the coke, say through m C p delta T where m is say 724 Kg, C p is 0.359 kilo calorie per Kg degree celsius into multiplied by 1175, that is delta T that is equal to 1200 minus 25 by taking 25 degree celsius as the reference temperature.

So, sensible heat in coke that is equal to 305 into 10 to the power 3 kilo calorie, then also coke oven gas also discharge as at the similar temperature, so one can also calculate sensible heat in coke oven gas sensible heat in coke oven gas. Again m C p delta T and if one calculate sensible heat in the coke oven gas by taking for example, C p as 0.965 and if you calculate the sensible heat in coke oven gas of entire amount of coke oven gas which is 349 meter cube, then the sensible heat in coke oven gas correspond to 174 into 10 to the power 3 kilo calorie.

Now, of the special attention that I want to draw is on the sensible heat in coke oven, that is the sensible heat in coke and sensible heat in coke oven gas, these are the important things, because rest says calorific value of the coke, that you can use it, while charging into the blast furnace. Now, here the coke oven gas also possesses calorific value, that can be use and I also would like to draw your attention about the calorific value of coke oven gas; very large amount of calorific value of the coke oven gas is available, that is what the energy balance suggest you. So, if I want to summarize, say if I want to say the say, what is the energy balance shows.

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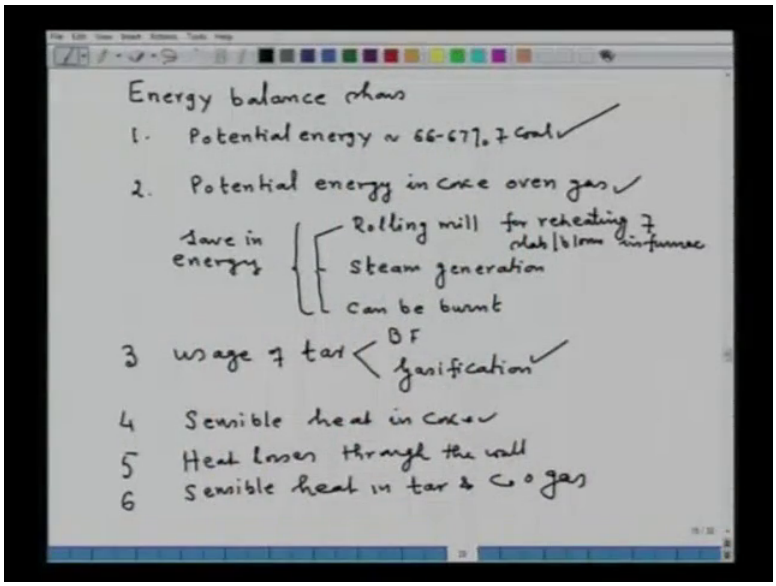

So, energy balance shows energy balance shows the following important thing, that means first potential energy of coke or potential energy that is calorific value in coke is approximately 66 to 67 percent of coal, that means this energy you are able to recover of the original calorific value of coal of course, this can be reused for charging into the blast furnace, no problem at all. Second you have potential energy in coke oven gas potential energy in coke oven gas and this energy also correspond to 21 percent; it may vary little bit, because the composition might vary depending upon the type of coal carbonization temperature and so on.

But, even then a substantial amount of calorific value in coke oven gas is available, and it is of the order of let us say 21 percent in this calculation of the original calorific value of the coal, that is a very substantial amount of coke oven gas calorific value is available point number. Now, here once should also think what you are going to do with that calorific value of the coke oven gas that is available to you; so here itself one should think, that this calorific value can be used for say in rolling mill a for furnace reheating.

For reheating of slab bloom in furnaces, because in thermo mechanical processing the slab blade or bloom they are heated to high temperature, and then they are being rolled, so in that coke oven gas can be considered its potential application. Another application that one can think of is the steam generation is the steam generation, and the steam can use for electricity production and whatever the use, that you can anticipate for its. Third a part of the coke oven

can be burned also part of the coke oven gas can be burned in order to create some amount of energy for heating coke oven chamber. So, what this all three uses of the coke oven gas will lead to, they will lead to say save in energy, save in energy by partial replacement of the original fuel that was that were used in all these units. So, that will help for example in two ways the reduction in the fossil fuel, as well as reduction in the emissions that were earlier through the uses of fossil fuel.

Now, third thing is that you are also observing that a considerable amount of tar is also being produced, so usage of tar usage of tar, tar also it has a very high calorific value and hence its usage must be considered. When you want to think where the tar can be use of its calorific value, one way is that injection into the blast furnace, another way you can think of its usage by gasification, as I will show you towards the end of my lecture, tar can be use reused for gasification purposes.

Fourth important thing that you observed, that is the sensible heat in coke (No audio from 18:13 to 18:21), a very large amount of sensible heat in the coke is available and hence, it must be reused that means, suitable methods are to be devised, where sensible heat of coke can be used. Fifth you are seeing is that, well heat losses through the wall though they have not be shown, but if you do the subtraction heat losses through the walls of the coke oven chamber, not much can be done what you can do at the most is to have the refractive all of the coke oven chamber, which is of little bit low thermal conductivity.

But, then it will create the problem, because coke oven chamber is indirectly heated, so not much can be done, what six say sensible heat in tar sensible heat in tar, and coke oven gas. So, this is what the energy balance tells you the output of the energy as the result of input of energy through the coal. Now, here as regards reporting incident of the coke, we are using it no problem, then as regards the potential energy in coke oven gas, we can plant it use in the plant itself, because the coke oven they are part of the integrated steel plant. So, one has to think its use within the integrated steel plant, and yes this use can be found out and it can be used; tar can also be done similar way, either it can be rerouted for the blast furnace purposes or it can be used to gasify it and to produce gas fuels.

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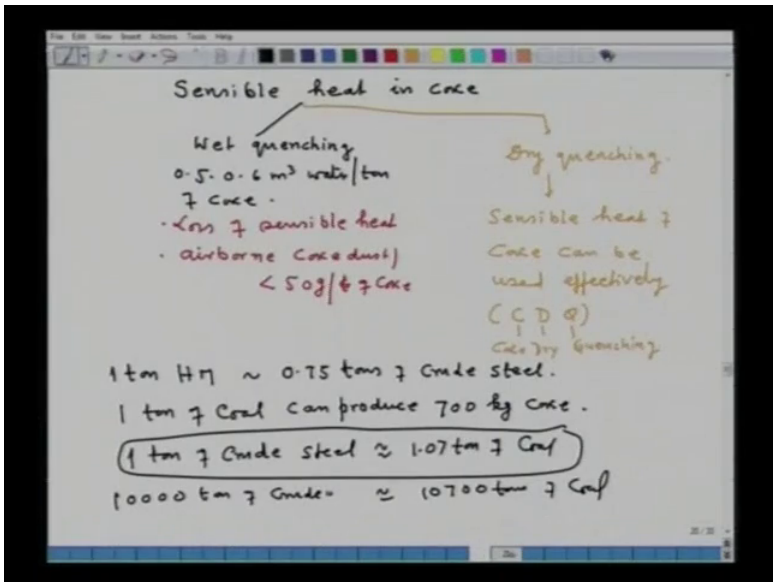

Now, about the sensible heat of the coke I have to say something, now the sensible heat of coke is to be used, sensible heat in coke, because it has a very large amount of sensible heat, and in the earlier method we have one used to have wet quenching, for considerable period of time wet quenching was done, and water is above, above water was vaporized and it is released into the atmosphere. So, you required on 0.5 to 0.6 meter cube water per ton of coke is required.

Now, in using wet quenching, because water vapor is formed they have lost in the surrounding, so as a result loss of sensible heat loss of sensible heat point number one. And second due to the cooling through water, airborne airborne coke dust that is as the form of emission they are also formed and they are less than 50 gram per ton of coke.

So, what I mean to say is that, this wet quenching you lose all the sensible heat, and therefore, an another method has been developed and that is the dry quenching. In the dry quenching gas is used to cool the hot coke, and as a result of action the heat between the hot coke and the gas, the gas gets heated up. So, energy is transferred from the hot coke to the gas, to the coke is discharged at lower temperature, and gas is heated up and this heated gas can be used for for performing several operations.

So, now dry quenching in fact, here the sensible heat sensible heat of coke can be used very effectively, all that you have to develop a system where heat can be stored, and then heat can be reused. So, before I go a little bit about this dry quenching, which is in short is also called

CDQ, C is stands for coke, D is stands for dry, and Q is stands for quenching. So, before this I just want to give you a fee, what amount of coke you are we are producing in order to sustain, the requirement of steel, because for your information the production of coke is required for the production of steel in all integrated steel plant. Now, in terms of that just to get a fee, how much amount of coke is being produced and how much amount of sensible heat would be, so that one is tempted to utilize the sensible heat, and at the same time to have a clean environment.

Now, let us see for example, coke is the principle fuel which is used in the integrated steel plant, now most of the plant they have their captive coke oven. Now, just a figure say 1 ton hot metal 1 ton hot metal after losses oxidation and so on, approximately it gives 0.75 tons of crude steel. Now, 1 ton of coal 1 ton of coal it can produce 700 Kg coke, so in terms of coal requirement, now what I am doing is that I am calculating, if you are producing 1 ton of crude steel, how much amount of coal will be required through coke.

So, in terms of coal requirement 1 ton of crude steel 1 ton of crude steel would required approximately 1.07 ton of coal and that is the important. So, if you produce 10000 tons of crude steel, then you will be requiring of the order of 10700 tons of coal.

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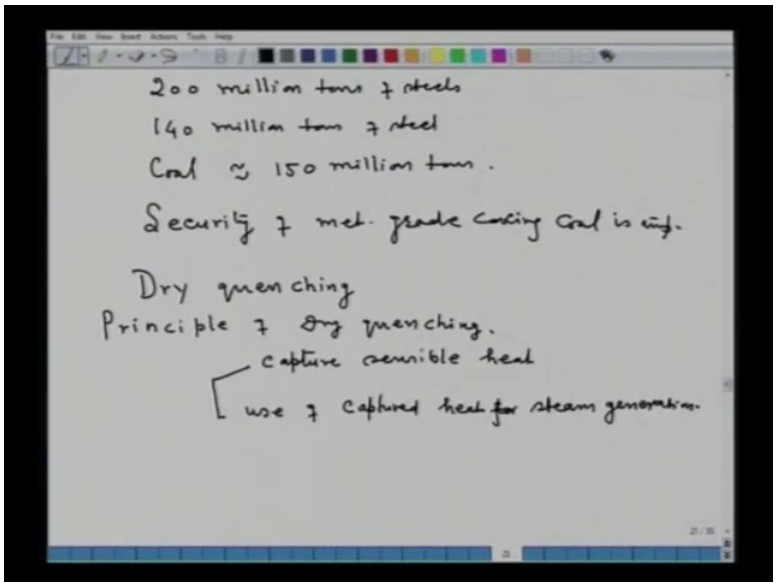

Now, in an estimation India would be producing around 200 million tons of steel 200 million tons of steel by the end of 2020 to sustain 8 to 9 percent economic growth, about 70 percent of this 200 million tons will be produced through blast furnace, and BOF integrated steel

plant root. So, that means by 2020, you will be producing around 140 million tons of steel, through BOF, through blast furnace and basic oxygen furnace root.

So, in order to produce this much amount of steel you will be requiring coal of the order of 150 million tons, also the cocaine coal it accounts for 65 to 85 percent of the primary sources of energy. Now, what this calculation means knowing the input that India has a shortage of metallurgical great cooking coal, the deficit is made through the imports.

So, security of metallurgical grade cocaine coal is important security of metallurgical grade cocaine coal is very, very important that means, one has to found out the means and weight, so that coke can be conserved or cocaine coal less cocaine coal is used. And several alternative methods are been developed for example, smelting reduction, DRI root, development of post of pulverize coal in blast furnace and so on, so this heat balance it gives you all these information.

Now, coming back to the sensible heat, because you see that you a non amount of coke would be required in a non amount of sensible heat will be available, so the dry quenching dry quenching is being introduced as a technology and which is being considered as a clean development mechanism, because first it eliminates emissions which are caused due to wet quenching, and second the coke dry quenching allows adopting concept of capturing heat, and then reused that is by co generation, I will tell you just little bit in detail.

So, what are the principle or dry quenching principle of dry quenching (No audio from 29:45 to 29:55) is that the heated coke is taken in a chamber, where gas is passed gas is heated up, then it is taken into the boiler, water gas heated up and the cool gas is further recycled into the reaction chamber. So, in order to apply these concept and develop a technology, what technology means, needs the first thing is that, we need to design a reactor, we need to design the boiler, and also we need we have to see, the clinic of the coke oven gas, because it may contain dust particle and so on so forth.

So, the technology for development of dry quenching it consist of for example, first it should have provision to capture sensible heat, that is you have to design reactor, where coke and gas can be filled up, and heat action can occur. A counter current mechanism would be very useful, because counter current mechanism ensures a faster rate of heat transfer. And second you also required to see the use of captured heat, because you are capturing heat in the gas, to use of captured heat for for say steam generation for examples, if we are planning to do that.

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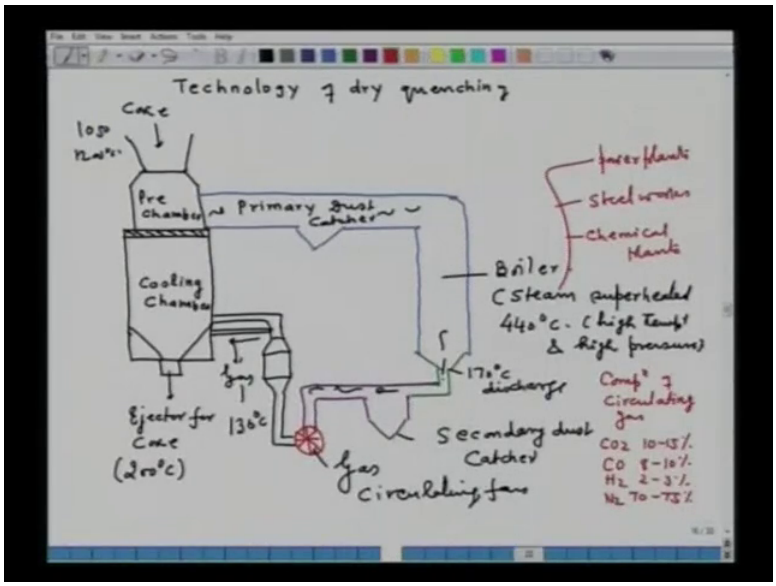

So, if we see that these are the technological requirement, so this is what the the sketch which have drown is shows the principle of dry quenching or the technology of dry quenching technology of dry quenching. Now, here coke is being placed over here say for example, temperature could be 1050 or up to 1200 degree celsius, then this is the pre chamber and this is the cooling chamber, and this is the ejector for coke ejector for coke say if it enter around 1050 or 1200 it exists at around 200 degree celsius.

You can think of the sensible heat which will be recover per ton of coke cooling from 1050 to 200 that is the heat which is given, and the heat which is taken by the gas. So, this is the primary dust catcher that is here the gas flows the dust is being eliminated, and this is the boiler, and reserve the boilers to convert water into steam, and as a result we get steam rather superheated steam, we get superheated steam it around 440 degree Celsius this is in fact high temperature and high pressure steam.

Now, this steam which is produced here, it can be used either in the power plant or in the steel works or in the chemical plant depend upon the location and so on, so many factors. Now, then the cool gas is at around 170 degree celsius gas, it discharge from the boiler and it is taken over here, this is the secondary dust catcher this is the secondary dust catcher this is the circulating fan, this is the gas circulating fan and then the gas enters again gas enters again, gas at around 130 degree celsius. So, that is in principle how the gas how the dry quenching is done in the practice (Refer Slide Time: 35:20).

Now, here say say the consumption of gas, the composition of circulating gas is also important, because the gas should have high thermal conductivity. So, the composition of circulating gas the composition of circulating gas say is for example, CO2 10 to 15 percent, CO 8 to 10 percent, then hydrogen it is 2 to 3 percent, and nitrogen is 70 to 75 percent; so that is the the composition of the circulating gas, that is being used.

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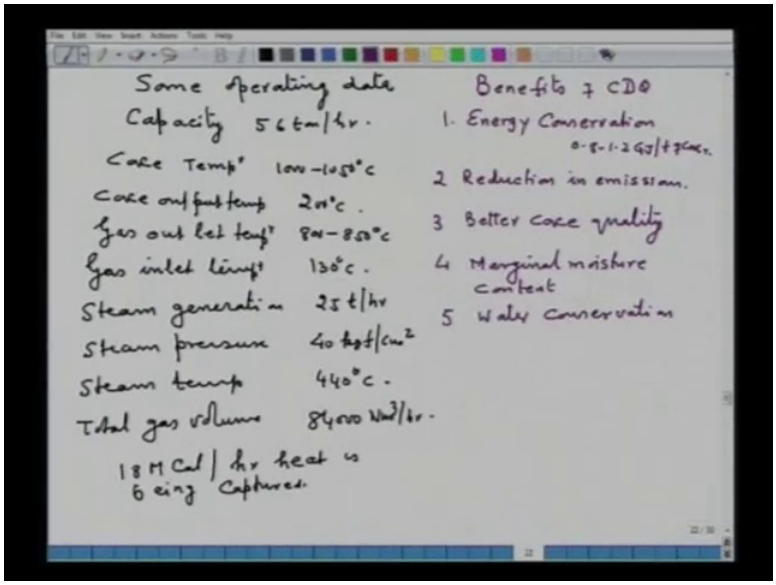

Now, some say operating data just to give you a feel (No audio from 36:58 to 37:06), some operating data of coke dry quenching for example, in some location the capacity is 56 ton per hour, coke temperature say 1000 to 1050 degree celsius, coke output temperature 200 degree celsius, gas outlet temperature that is, (( )) heated temperature is 800 to 850 degree celsius.

Where as gas inlet temperature is 130 degree celsius, steam generation is 25 ton per hour, you can imagine the size of the boiler and what you can do with the recovered sensible heat from the coke, and that is an important thing. So, steam pressure is a very high pressure is around 40 Kg force per centimeter square, the steam temperature is say 440 degree celsius and the total gas volume total gas volume is of the order of 84000 normal meter cube per hour.

And through this method that is when you charged coke at 1050 and discharged it at 200 degree celsius, the heat which is coming in question considering 56 tons per hour, the heat which is coming is question is around 80 mega calorie per hour, heat is being captured in this particular example. Can you imagine a very large amount of heat is being captured, and is being used some of the benefits of CDQ, benefits of CDQ that is a coke dry quenching, one is

the energy conservation energy conservation it is claimed of the order of 0.8 to 1.2 giga joule per ton of coke.

Second, a reduction in environment emission, a reduction in emissions, third advantage better coke quality, and fourth advantage marginal moisture content, because you are doing now dry quenching, so there is very little moisture is present and less moisture it says coke, while charging in the blast furnace, fifth is the water conservation. So, in fact the technology of coke dry quenching as introduced into the coke oven plant it contributes to reduction mechanism, as and you said in the concept of clean development mechanism.

Therefore, the coke dry quenching is considered to be a technology which helps to reduction in emission, and hence it is termed under the class of clean development mechanism as prompted by the protocol. Now, say a sustain considerable amount of developments has also been done for coke oven for example, tall coke (( )) tall coke oven batteries, they are used and so on, these are all the development in case of say coke oven.

Now, another thing that you should also see about the coke oven gas, because in the coke oven gas it contains hydrogen, it contains methane, it contains benzene, it contains ammonia and so on, as you see all its composition, there are several uses can also one can think of the coke oven gas which is being discharge from the coke oven plant. Now, one use of course, we take coke oven gas for heating purpose, but there there are several alternative utilization possibilities exist.

For example, say I will just put say utilization of coke oven gas as a fuel is already a possibility over there, but there could be several other possibilities that are, that one can explore in order to use the coke oven gas.

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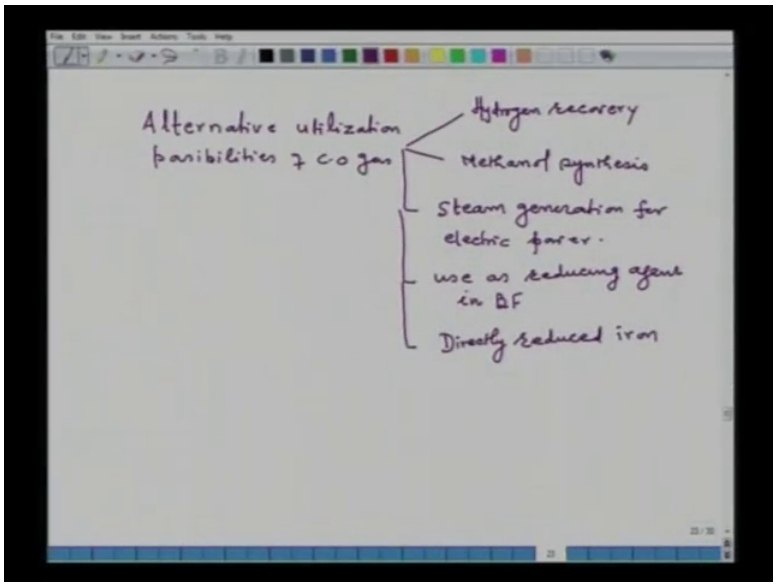

So, let me list down say alternative alternative utilization possibility of coke oven gas, say one hydrogen recovery (No audio from 43:25 to 43:33) 56 percent hydrogen is present, you can think of hydrogen recovery. Another methanol synthesis methanol synthesis, third steam generation (No audio from 43:53 to 44:01) for electric power, fourth coke oven gas is hydrogen methane, one can think of use as reducing agent in BF, one can also think of the use of coke oven gas for the production of directly reduced iron (No audio from 44:33 to 44:40). So, these are the other possibilities of using this coke oven gas.

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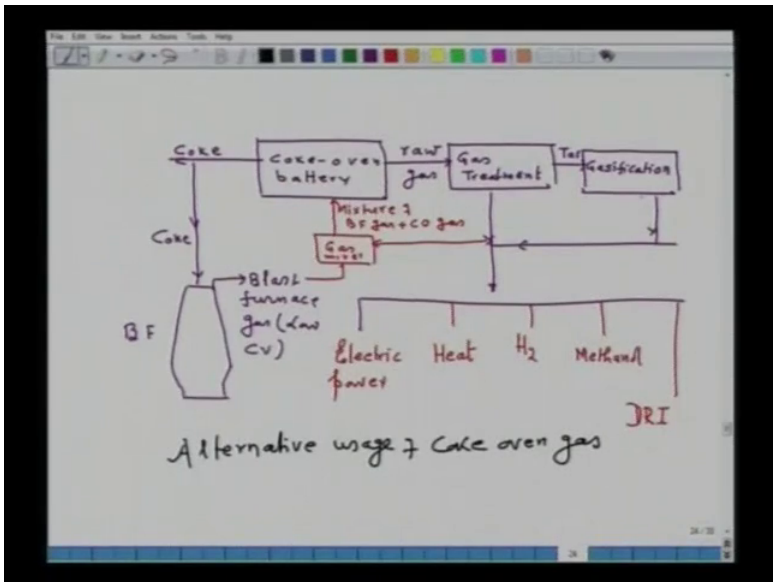

Now, in order to show this possibilities, let me draw a sketch for you, so that you can understand now for example, we have the coke oven battery, say this is the coke oven battery (No audio from 45:07 to 45:16), the coke is being produced, now coke and of course, it is used in the blast furnace (No audio from 45:30 to 45:43), so here this is the blast furnace and here the use of coke, now we have air blast furnace gas low calorific value. Blast furnace gas has a very, very low calorific value.

Now, coke oven battery you have the raw gas, raw gas means it is unclean, it contained dust particle, and it contained many, many other impurities, so it is subjected to gas treatment gas treatment. Then we have we can extract a tar and tar can be subjected to the so called gasification, and the gasification you can produce another fuel, gaseous fuel, because tar contains carbon hydrogen, so one can gasify it carbon convert to CO, one can gasify in presence of steam, so further CO and hydrogen can be produced.

Now, then this gasification from here a for the clean gas, one can be take you can take directly here, and from the gasification gas and this and from here this, so now it can be used for several purposes for example, electric power electric power, one can use you can generate electric power. Now, remember, if from this you are generating electric power then earlier when you are using fossil fuel for generation of electric power, now you are saving the fossil fuel.

Now, if you are saving the fossil fuel you are contributing to the environment also, because less emissions which were occurring through the use of fossil fuel will not be there now because of this particular mechanism of partial production of electricity by the use of coke oven gas, so that is what is important. Second one can also use to produce heat, because coke oven gas it is very high calorific value gas, it can be used for heating purposes, manier times as a rolling mill in the integrated steel plant.

So, coke oven gas can be directed over there or heating, at least partially heat can replace for example, fuel oil, but the only issue over here that the coke oven gas is produced, wherever coke oven plant is there, and most of the coke oven gas plants they are the, they are in the integrated steels plants, so those use one can think of within the integrated steel plant.

Another use you can think you can extract hydrogen, now it contains 56 percent hydrogen hydrogen is a potential reducing agent, and hydrogen can also save carbon because whatever reduction that carbon can do hydrogen can also do. So, if you partially replace, hydrogen by

carbon by hydrogen off course, you are again contributing to reduction in the emission, because H2O on reduction, it will produce H2O no emission will be there, fourth you can also hexane methane, methanol off course, methanol can be sold in the market; and then one can also think of connecting or producing directly reduced iron.

So, these are say alternative uses of coke oven gas, now here say part of the coke oven gas it can also be mixed with the, this is the gas mixture, here the blast furnace gas is mixed, and coke oven gas both gases are mixed and a mixture can be used for combustion purposes. So, here a mixture of BF gas plus coke oven gas; so what I mean, if I these are this say alternative uses of coke oven gas, so in short what I wanted to say here is that, there is the strong correlation between the energy balance, and finding out the ways for energy security and environment sustainability.

Energy balance is a very, very powerful tool which can tell you the flow of energy, and can identify the potential sources of energy output, where one can plan, what can be done about the energy, which is being obtained in the form of product in byproduct. And typical example, which I have given the use of energy balance as a tool to contribute to energy and environment.

And you can see from here, that by knowing the various quantities of energy in the outputs, one can plan the use of energy, and one can significantly contribute to the saving of primary energy resources, which is being required, because as you know that the fuel, fossil fuel results are limited use of fossil fuel it creates lot of environment pollution and any such things, where you can reduce the pollution that will help the environment, and it is in this connection energy balance is a very, very powerful tool, thank you.