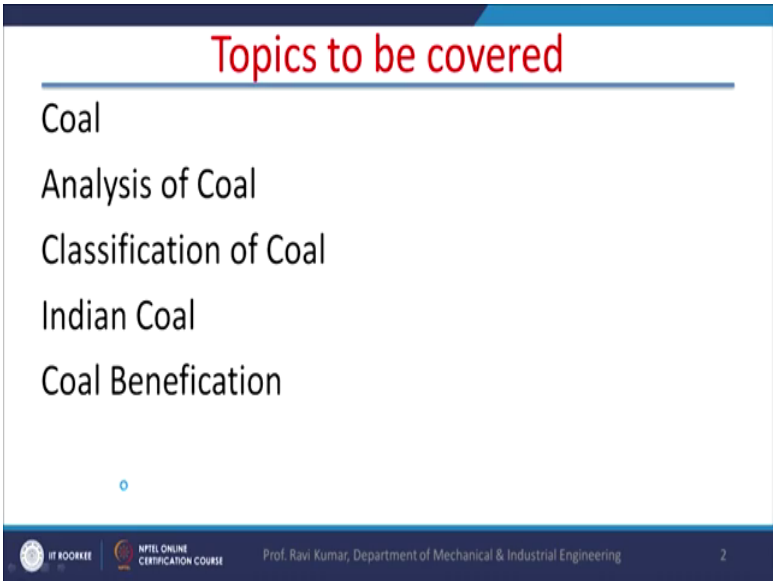
Power Plant Engineering
Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 08
Coal Properties

Hello, I welcome you all in this course on Power Plant Engineering. Now we have discussed boilers and the performance of the boilers in the previous lectures. Now the coal is used in the thermal power plant. Coal is the main fuel which is used in the thermal power plants. And today we will discuss about the properties of coal.

(Refer Slide Time: 00:47)



And we will discuss topics to be covered today are first of all discuss about the coal, analysis of coal, classification of coal, we will talk about the Indian coal and coal beneficiation. Now, regarding the coal is the oldest fuel which is used in the power plant. Actually oldest fuel is the

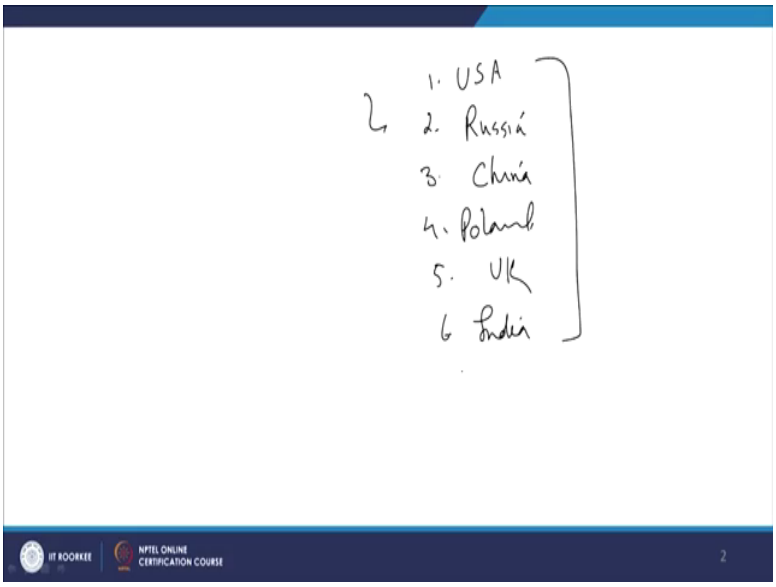
wood; I mean which is used for heat generation or in power plant also earlier the wood was used, but coal is the main I mean for the commercial power generation the coal is the oldest fuel. And the earth has sufficient reserve for the coal for the another let us say 20 30 years. So, still we can go for the coal based power plants.

Shifting earlier many of the power plants were running with using oil as the fuel with there certain power plants thermal power plants which run with oil. There are certain power plants which run with the gas also they are known as gas based power plants or oil based power plants. But what happened in 1973, when this there was a sudden hike in the price of the oil the shifting of power plants from oil to coal started. And again let us say for example, in our country 60 percent of the power is generated is through thermal power plants and upto 2050; I mean we have sufficient reserves and we can afford to have thermal based thermal power plants up to net coming 20 30 years.

Coal is very reliable source of energy. It has the certain disadvantage of course, it has certain disadvantages also and hydrogen content is more in the coal. If you look at the development of the civilization forget about the power generation, if you look for the source of energy thermal energy where initially was used. So, wood was used I mean it has it has low hydrogen content then came the coal. Coal had higher hydrogen content then LPGs.

Nowadays we are using LPGs for the cooking purpose. It has more hydrogen content. Perhaps in the future we will use pure hydrogen. Hydrogen is the fuel of the future, but it will take time, it will take a lot of time. Yeah I mean meanwhile at present coal is the best alternative for power generation because we cannot go as a country we cannot go for the oil based power plants because our import bill of oil we are I mean we are importing 150 percent of our oil; I mean import coal import bill is approximately 45 percent of the total import bill of oil.

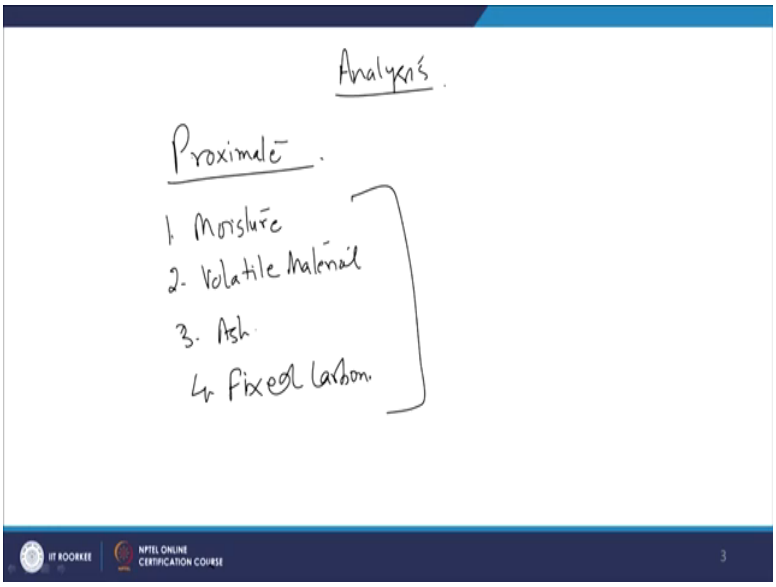
(Refer Slide Time: 03:51)



So, oil import because everybody is moving with a motorized vehicle. So, that is why the oil consumption is very high and we are importing a lot of oil. And regarding the coal production we rank 7 ah. The first is USA. USA is the highest. First is USA, second is Russia or USSR right and Russia, second is Russia, third is China, fourth is Poland. Poland has a lot of coal reserve then UK and then sixth is India.

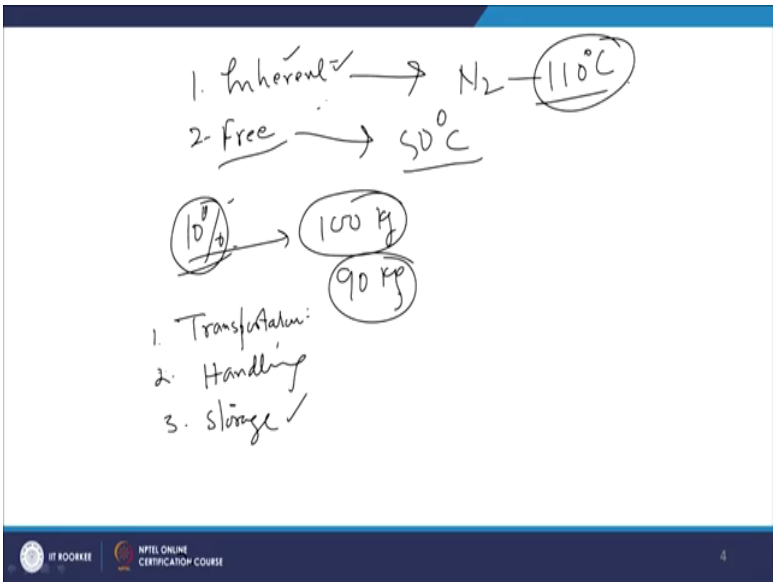
We have coal reserves in I mean Bihar, West Bengal. Most of the coal reserves are in Bihar and West Bengal and still it is advisable to go for coal based power plant; because oil based power plant we cannot afford I mean already we are importing 150 percent of the requirement by importing oil and oil based plants are costly also.

(Refer Slide Time: 04:56)



So, for the when we are using coal. So, we should start with the analysis of the coal analysis. So, there is a method which is known as a proximate analysis proximate analysis. In proximate analysis, we estimate the moisture, moisture in the coal, volatile material, ash content. Ash content in the coal can be as a 30 percent right. Indian coal has very high ash content that is coal which is generated in India has very high ash content then fixed carbon. So, this is they these values are estimated in approximate analysis.

(Refer Slide Time: 05:49)



Now, regarding moisture we will start with the moisture. So, in the moisture there are two types of moistures in the coal. One is inherent moisture and second is free moisture. Now inherent moisture is because when the formation of coal was taking place inside the earth moisture was trapped in the coal so, it is in the pockets right.

And another moisture is which absorbed by the coal. It is just taken from the atmosphere or some other sources. So, which is inherent in moisture that the moisture which is I mean which is trapped in the or the water body water which is trapped in the coal during the formation right.

So, this moisture can also be removed, but for the removal of this moisture the coal has to be exposed to nitrogen right; because we cannot use any other oxidize or any other we cannot

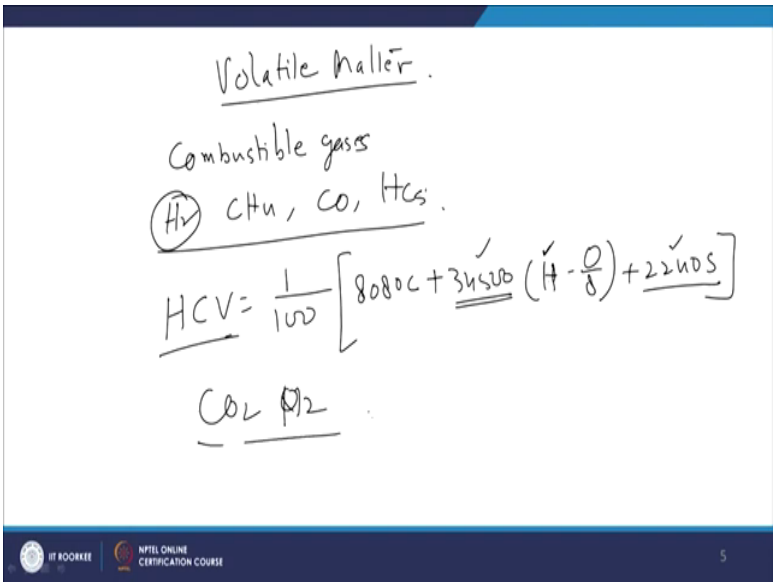
use air because air has oxygen it will oxidize coal. So, normally nitrogen is used because it is easily available at 110 degree centigrade.

So, it is passed through the coal so, inherent moisture can be removed by this process. Free moisture can be removed by any I mean by air at 50 centigrade air or it is simply drying the coal. So, if you pass this 50 60 degree centigrade air through the coal, it will remove the moisture from the coal. So, for, but for the purpose of removing the inherent moisture we have to pass, we have to flow make we have to use nitrogen at 110 degree centigrade.

Now, moisture not only it affects the performance of the boiler it has other additional cost also. Suppose a coal has 10 percent moisture 10 percent moisture is not very high. 10 percent moisture means, if you are carrying 100 kg of coal you are carrying 10 kg of water also. So, effectively you are carrying 90 kg of coal; because 10 kg of moisture is of no use right. So, it increases the transportation cost. Number 1 moisture increases the transportation cost.

Or in addition to that, it increases the handling cost handling cost is also increased because more bulk of the coal has to be handled by the handling units and it increases the storage cost also. You are paying for 100 kg, but 90 kg of coal is stored. So, storage cost is yours and it does not play any useful role in the entire process in the entire process of power generation right. Because part of this is carried away by the heat and it quench a fire also. So, in this moisture is undesired in a coal, but some percentage of moisture is also present in the coal so, it cannot be avoided.

(Refer Slide Time: 08:48)



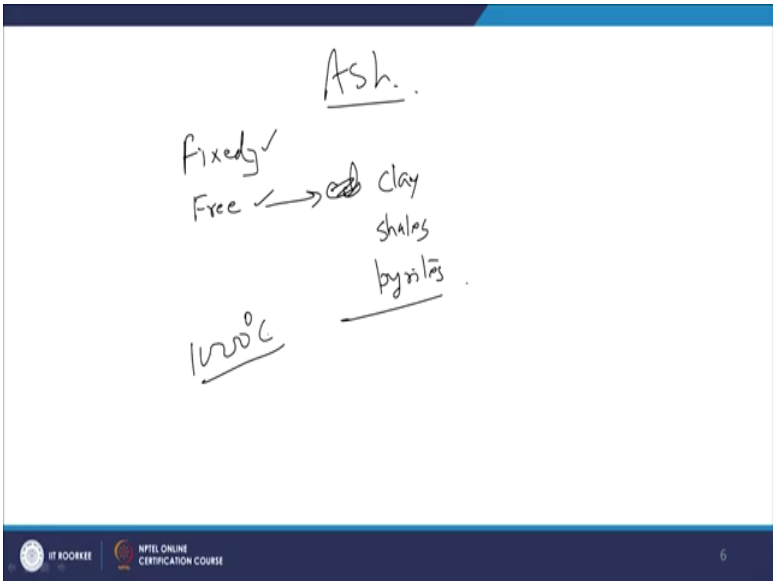
So, the second component of the coal is volatile matter. Now, volatile matter means combustible gases combustible gases right hydrogen right methane, carbon monoxide or hydrocarbons also right they are volatile metals which can be oxidized. And through these volatile metals matters the power is generated.

Now, here interesting thing is hydrogen. Hydrogen forms a water hydrogen oxide and presence of water is not required. So, in fact we should not have hydrogen in the in the coal right, but hydrogen is very much required if you look at the calorific value of the coal if you look at the calorific if you want to calculate calorific value of the fuel you will have to go by this formula 8080 C. This C is the percentage of carbon plus 34500 H minus O by 8 plus 2240 S. This is the formula for calculating calorific value right.

So, here you can see, that the burning of hydrogen a lot of heat is generated. So, presence of hydrogen is also required because a lot of heat is generated by burning the hydrogen. And at the same time you should get a sulphur, sulphur is not required, sulphur is not desired because some part of heat is added by burner of sulphur also, but sulphur has many harmful effect in the boiler.

It creates the acidic medium and it causes the corrosion and erosion of the boiler so, but in any case hydrogen presence of hydrogen now from here you can see the presence of hydrogen is very much required in the combustion. Some in combustible gases are also there like CO 2 and nitrogen also is also present right.

(Refer Slide Time: 11:10)

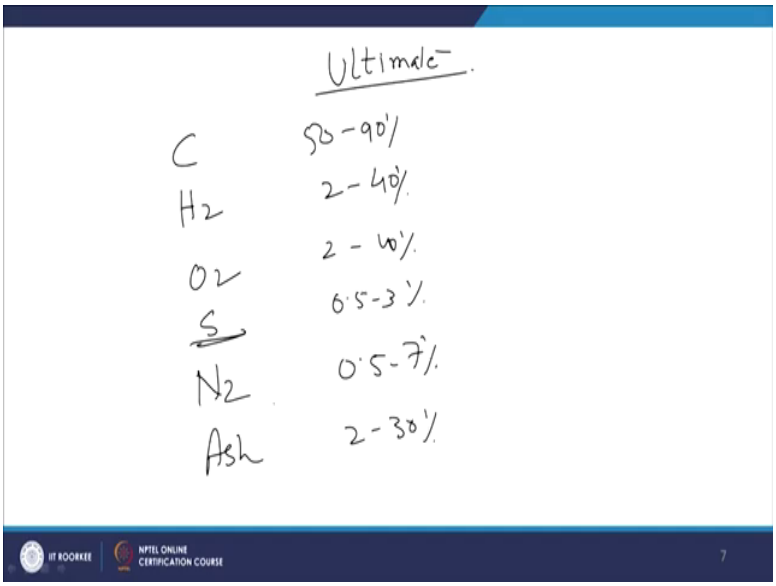


Now, after this the most I mean undesired part in the coal is that is ash right. There are two types of ashes that is the fixed ash and the free ash. The fixed ash has come from the original

vegetable matter. I mean when the coal was found below the earth due to the formation of the coal the this fixed ash has come into the coal right.

And the free ash it constitutes clay it constitutes shales, it constitutes pyrites and the ashes undesired because it forms the clinkers. When at around 1,000 degree centigrade the ash it melts and it forms clinker on the coal surface and these clinkers they act as a thermal barrier. They do not allow heat to be transmitted and sometimes in the in the crate or in the combustion chamber they block the air passage also. So, declinkling is all periodically required in the boilers, declinkling is in periodically required in the boiler.

(Refer Slide Time: 12:36)

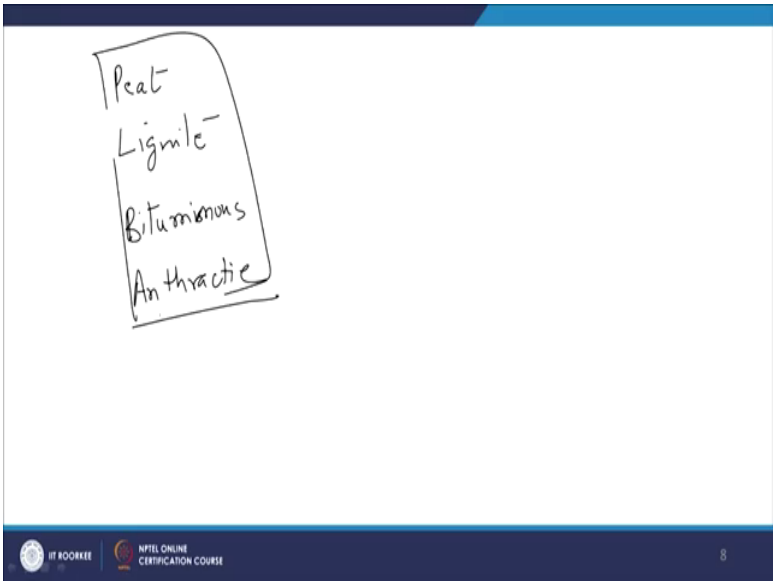


And another type of analysis of the coal this is proximate analysis. Another analysis of the coal is ultimate analysis. Normally Orsat apparatus is used for the ultimate analysis right and ultimate analysis we measure the carbon. Carbon in the coal can be in a range of 50 to 90

percent or more than that it hydrogen ultimate analysis hydrogen it present 2 to 40 percent, oxygen 2 to 40 percent, sulphur 0.5 to 3 percent.

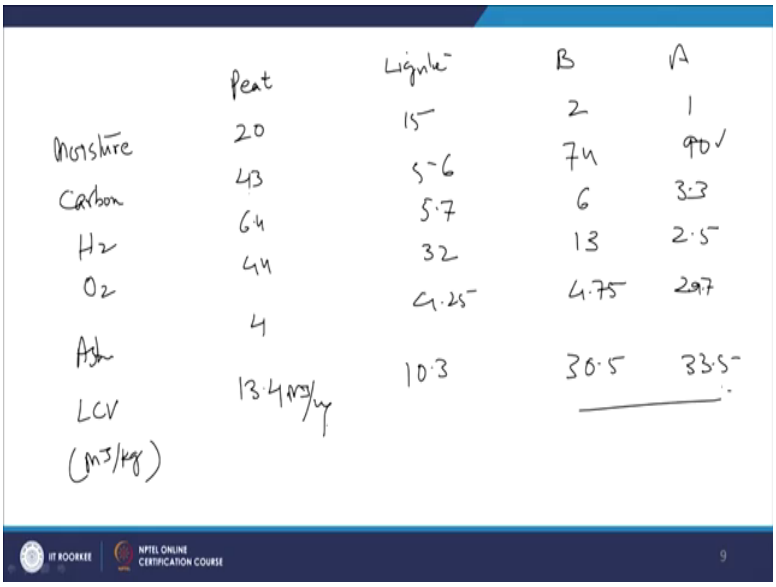
But sulphur is not desired as I said earlier because it causes corrosion and what we will call the formation of the clinkers oh sorry it also promotes the formation of clinkers in the boiler then nitrogen 0.5 to 7 percent and ash which is 2 to 30 percent right. Now, if you classify the coal because there are different varieties of coal huh which are available.

(Refer Slide Time: 13:55)



So, if you take in order of increase in the heat value. So, first comes the peat coal. It is the lowest quality of coal. It is then comes the lignite coal. Lignite coal there are lot of lignite mines in India so, lignite coal. Third one is bituminous; bituminous coal and last one is anthracite coal anthracite coal. There are four types of coals right if you look at the composition of these coals.

(Refer Slide Time: 14:33)



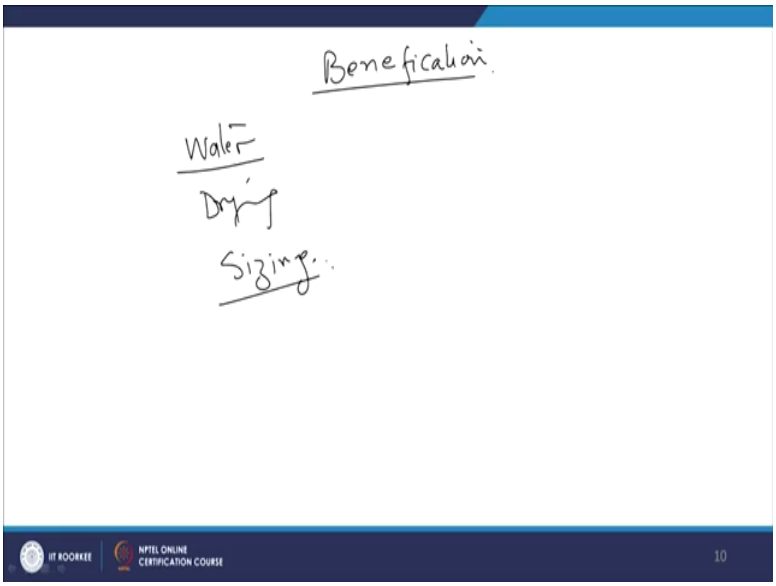
Now we will start with the we will we will make a table peat coal, lignite coal, bituminous coal and anthracite coal starting with the moisture. In peat coal the moisture is 20 percent. It can go up to 20 percent. Lignite it is up to 15 percent, bituminous 2 percent, anthracite 1 percent. So, you just see the difference in the moisture, here it is 1 percent and here is in 20 percent. So, if you are carrying 100 kg of peat coal effectively you are carrying 80 kg of peat coal only ok.

Now, the carbon contents now the carbon is peat coal it is only 43 percent, lignite 56 percent, it is 74 percent and it goes upto 90 percent. So, carbon content of because carbon content decides carbon contents mainly decide how much heat will be generated by the coal. So, anthracite coal it is it goes up to 90 percent here it is 43 percent almost half of this. So, if you are burning 2 kg of peat coal it will be equivalent to approximately 1 kg of anthracite coal.

Now, hydrogen content it is 6.4 percent, 5.7 percent, 6 percent and 3.3 percent. So, anthracite coal has a little less hydrogen, oxygen 44 percent, 32 percent, 13 percent and 2.5 percent. Ash content which is of major concern it has 4 percent, 4.25 percent, 4.75 percent, 2.97 percent.

Lower calorific value 13.4 percent. Sorry no 13.4 mega Joules per kg, 10.3 mega Joules per kg mega Joules per kg (Refer time: 16:35) mega Joules per kg. It is 30.5 and it is 33.5. So, for bituminous and anthracite coal the calorific value is quite high.

(Refer Slide Time: 16:58)



Now, after this coal processing is also done which is known as coal beneficiation, coal beneficiation; for example, cleaning of coal. Cleaning of coal is required it can be done during the mining or post mining also the beneficiation it can be done for cleaning the coal the best media is water. So, water jets the coal the coal is clean. So, the best is water. It have (Refer

time: 17:27) the sulphur also. The sulphur which is sticking on the surface of the coal the if you wash the coal with the water the sulphur will be removed.

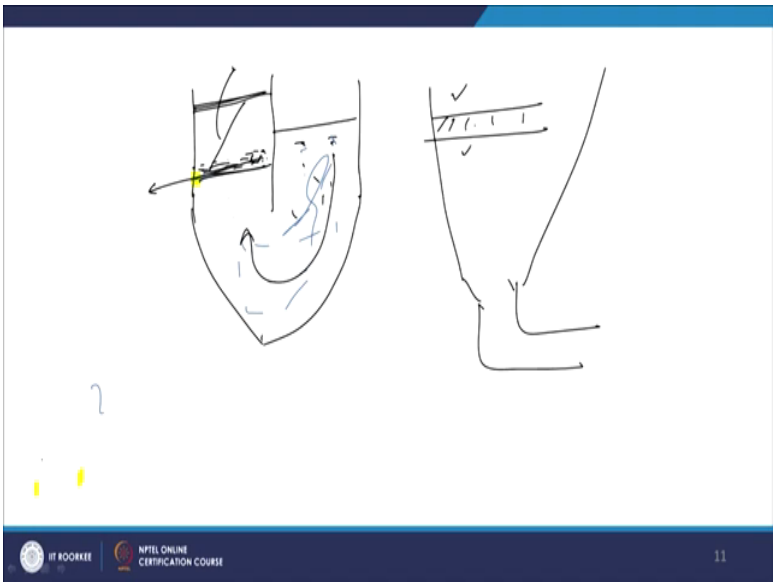
And there are certain coal cleaning equipment also, I mean it is not simply spraying the water. The coal is put into the cleaning equipment and where the cleaning of coal takes place. Then coal drying is done because most of the moisture has to be removed from the coal after washing because unnecessarily the we will be carrying the weight of the coal so, drying has to be done. Then the coal sizing is also important.

Sizing means proper the coal has to be in a particular range for proper burning in the combustion chamber of the boiler. If the size is too big, incomplete combustion will be there. So, proper sizing has to of the coal has to be done.

So, for sulphur removal sulphur removal can be done by not only by washing it can be done by hand picking also. And organic sulphur which is present in the coal which is in built in the coal it cannot be even it cannot be done any physical process. I mean some chemical process has to be adopted normally it is not done.

Sulphur is removed either by hand picking, cleaning the coal or by cleaning coal with the water which is sulphur which is sticking on the surface of the coal will be washed away.Now, the for washing the coal it is not simply I as I said earlier it is putting part or washing with the water, water jigs are used right.

(Refer Slide Time: 19:06)

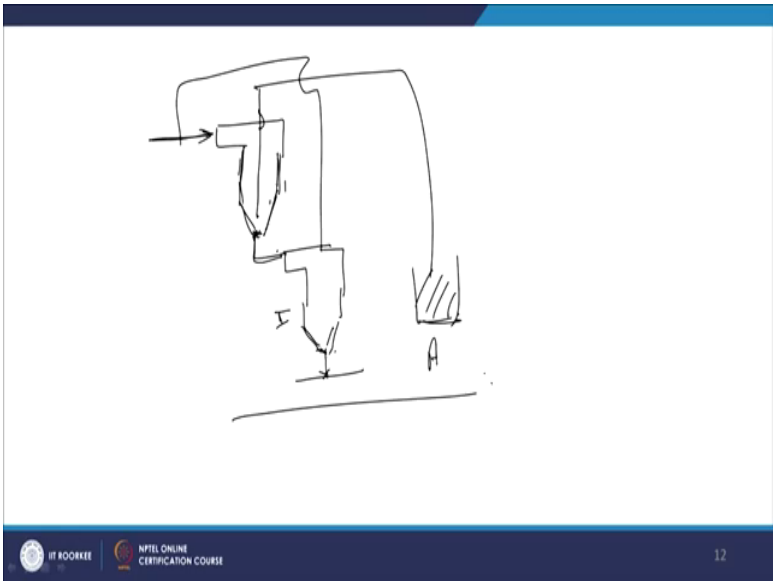


And water jigs are I will I will show draw a sketch. Water jigs are like this. It is tapering below and this side it is filled with water, it is filled with water right and here this is put under vibrations and the movement of the fluid is like this right and small particles they have high density because big size of the coal if the coal size is big it will have some trapped air also. So, density will be lower right and high density particles are accumulated at the bottom, low density particles will go up.

So, after stratification here of the low density particles periodically they will be removed, but what happens slowly density gradient will be formed. You will not know from where to remove the settlement. Initially you will find a distinct distinction between the high density and the lower density, but in due course of time with continuous use you will get a get a get a very smooth variation in the density and then it becomes difficult where from to coal is removed.

And for this purpose, if feldspar bed is provided in the in the cone itself in the cone itself cone itself. A feldspar bed is provided which separates the low density and high density particles. So, in fact the coal which is used for the burning will fall in the category of low density fine particles are the high density particles. So, they have to be removed from the coal. So, that is the one method. Another method is two stage cyclone. two stage cyclone is also used for separation of I mean fine particles from the coal. So, that is the stage one.

(Refer Slide Time: 21:15)



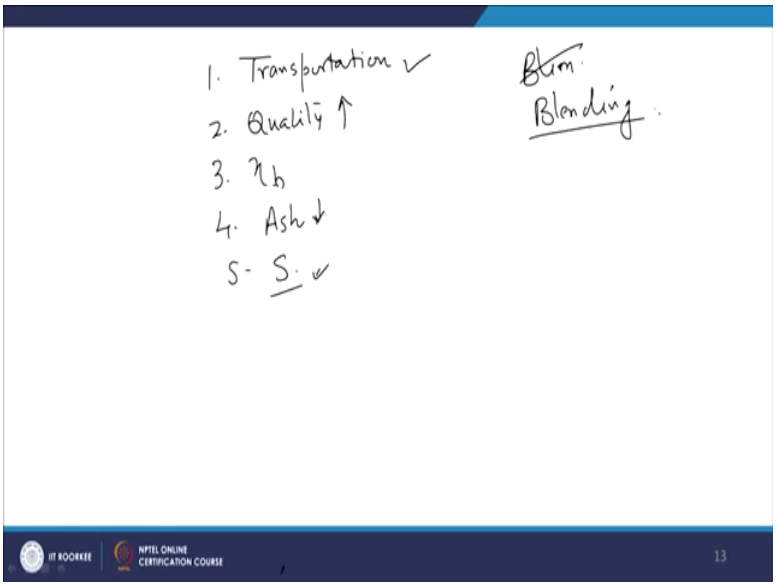
So, that is stage one. This is a cyclone. So, stage one raw coal is they will enter from here raw coal will enter from this side. High density due to centrifugal force high density for particles will stick to the surroundings and it they will drain down right and the low density particles they will go up with the swirl and leave the cyclone. No they will leave the cyclone and they will be collected somewhere else.

So, the hard density the high density particles they will again go to another cyclone right. And secondary process is done and here also those particles which are refused they will come here and they will drain down here; because as they are draining from here they will drain down here and this will go this part will go again here and again it will be processed. So, it is a two way two stage separation of high density low density particles. We did low density low density coal or particles which is low.

So, first the raw coal will enter it will go the first cyclone to do centrifugal process because small particles are high density. They will stick to the surface of the cyclone and they will be drained from the bottom. Coal which is low density big size particles which are which we require they will leave from the center with the swirl will go up and they will be accumulated at one place. This is excepted lot.

Now, again the exit of this is low density high density particles leaving the first cyclone they will enter second cyclone ok. Again they will be filtered and the low density particles they will not be accepted initially they will go back again for the same process right. So, that is a two stage process of clearing the coal.

(Refer Slide Time: 23:34)



Now, what are the advantages of preparation of the coal? The advantages of number one transportation cost is reduced, if we refine the coal then coal if we do the preparation of the coal the transportation cost is reduced. Quality of the coal is improved quality of the coal is improved. Boiler performance of the boiler performance is also improved. Fourth is less ash less ash has to be handled; because ash handling is also a big issue in the thermal power plant nowadays because it causes the pollution. So, less ash will have to be handled in the boiler power plant.

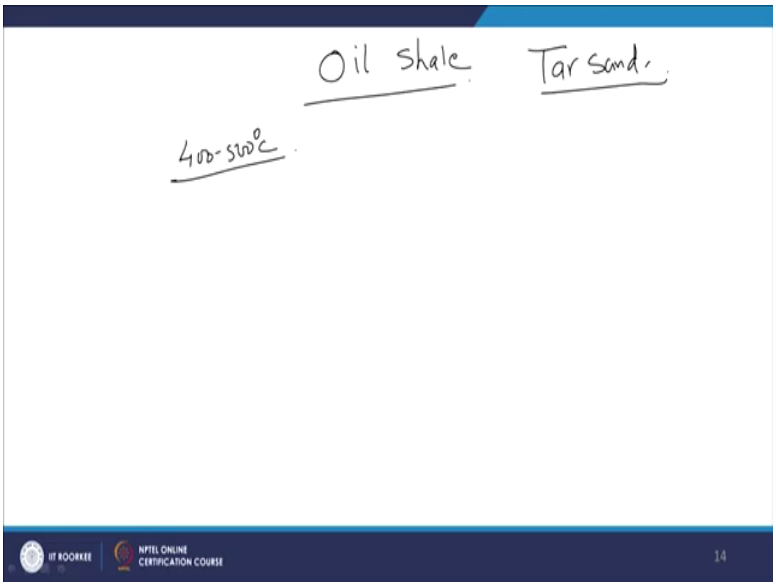
Now, sulphur removal have its one advantages because sulphur is also not desirable because it has corrosive nature. So, that is also that is the benefit of having the coal preparation. Now, blending of coal is also because we do not get coal from the same source. We are getting coal from different sources in the thermal power plant right. So, if we inject one coal for one

source the efficiency of the boiler is different from the from the fact that when we inject coal from another source right.

So, in order to have uniform performance of the boiler blending of the coal is done blending of the coal is done. So, the for coal blending let us say we have coal from 10 sources right. So, we will take part of say 5 percent or 10 percent from all source and mix them and feed to the boiler. So, say one source we have very superior coal another source we have a little I mean inferior coal. So, by mixing we will get some average performance and this performance because for the boiler maintaining constant performance is important right.

So, the boiler perform so the system also remains in balance. So, for that purpose the blending of coal is done. There are several methods bed blending on a bed the blending is done, on a conveyor belt also the blending is done and there are automatic blending is also done. I mean their machines where we can say 5 percent of a coal, 10 percent b, 20 percent c automatically it will blend the coal, but coal blending is important and unavoidable.

(Refer Slide Time: 26:15)

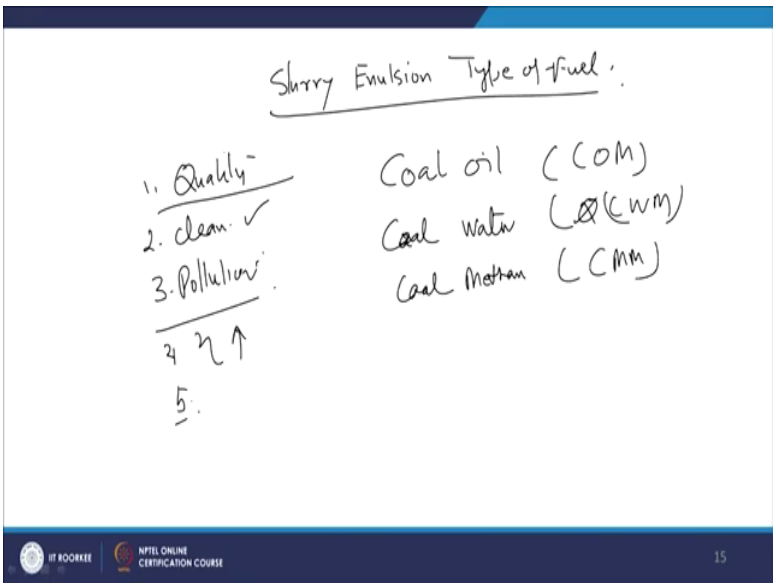


Nowadays, there is a another type of oil is available which is known as shale oil. You must have heard oil shale. They are carbonis rocks. Shale oil because shale oil nowadays it has been discovered abundance in USA. Shale gas they call it shale gas and shale oil and that is why it is affecting the other methods of power generation like nuclear power or the coal based power plants. So, it is a carbonis rock and the from carbonis rocks cracking is done cracking is done around 400 to 500 degrees centigrade.

So, after cracking the oil is extracted from the rocks. It is known as shale oil it is very popular point of discussion because shale gas, shale oils has been discovered in abundance in USA, it is a discovered in Canada and Brazil also. And this is hampering the progress of other fuel based industries; because the government is switching to the oil shale because it is I mean the extraction is cheaper right.

And another is tar sand. This is again bituminous sand oil. This is also getting the fuel the sand oil sand oil is especially in the Canada a lot of sand oil has been discovered and the oil companies are focusing there for the extraction of the sand oil. It is known as tar sand.

(Refer Slide Time: 28:02)



So, switching from now let us go back to the switching of oil based power plants to the coal based power plants. So, there is a hybrid type of technique which is known as where slurry emulsion type of fuel is used. Emulsion is made between oil and the fine particles of coal right and this emulsion is fed into the oil based power plants right and used for power generation. The benefit of is because if you change from oil base to the coal based power plant a capital investment is required first of all it is storage cold storage coal handling for this capital investment has to be made. So, instead of that a slurry is made emulsion slurry is made with oil with the coal oil and coal.

So, these this capital cost investment can be reduced. It is a it is a sort of a hybrid type of arrangement. And advantage is immediate shift improves the quality of the burn first of all it improves the quality of the burn. It keeps the boiler clean because even if you burn the oil boiler is cleaner, but if you mix the coal with the coal if you use some slurry also the boiler remains clean, pollution is reduced right and increases the efficiency increases. And fourth is and the fifth is which is very important existing pumps and pipelines. Pumps may have to be replaced because we are dealing with the slurry, but the pipelines existing pipelines can be used for the movement of slurry right.

Now, slurry emulsion mixture they are different type of mixture like coal oil, mixtures which is known as COM coal water mixture is also there C sorry CWM coal oil, coal water coal methane right CMM. So, slurry emulsion type of fuel is also used in power plants ah. That is all for today.

Thank you very much.