**Clean Coal Technology**

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**Week-12**

**Lecture-60**

Hi, Professor Barun Kumar Nandi, welcome to the NPTEL online certification course on clean coal technology. We are in module 12, discussing UCG, CBM, CMM, and case studies. So, in the previous lectures, I have discussed underground coal gasification, coal bed methane, recovery of coal bed methane, CMM, abandoned coal mines, etc. I also discussed one case study on clean coal technology.

So, in this lecture, I will continue with the case studies on clean coal technology and finally conclude. So, let us start lecture 5 on clean coal technology case studies. So, in these case studies, I will discuss power production using IGCC-based techniques and similar aspects. Conventionally, as we have discussed earlier, we can produce electricity or power through Rankine cycle-based steam turbine cycles as well as integrated gasification combined cycle-based plants. In the case of Rankine cycle-based steam turbine cycles, coal is directly burned in the boiler, steam is produced, and electricity is generated. In the case of IGCC, coal is initially gasified, then cleaned of all types of impurities, and the syngas is further sent to the combined cycle, where initially it is the gas turbine cycle (GT), followed by the steam turbine cycle (ST). So, in the case of IGCC-based plants, the method is a little bit tedious. There are four or five units operated continuously but with a higher quantity of electricity output, whereas in the case of direct coal combustion units, the number of units is relatively less. However, the efficiency or total output of the plant is on the lower side. However, at present, due to their simplicity, direct Rankine cycle-based steam turbines are the most popular and account for more than 90 to 95 percent of coal-based power plants. Whereas, IGCC-based power plants, due to their larger infrastructure requirements and investment costs, the number of plants is a little bit on the lower side. So here, we will analyze some of the results available in online literature and on some websites where we have collected data about some IGCC-based plants. So overall, if we see the IGCC-based plants, their environmental impact is much less as the syngas is cleaned and removed of sulfur, nitrogen, as well as other particulate matters, and then only the gaseous fuel is burned in the combined cycle. So, the environmental impact is much less here. So here, Edwardsport Power Plant, USA, has a 618-megawatt integrated gasification

combined cycle-based power plant. In 2007, Duke Energy Indiana begins construction of such plants, and this plant was the first of its kind where IGCC was used to produce electricity. Here, the gasification process makes coal react with pure oxygen and steam to produce syngas. This syngas is cleaned of all types of impurities, removing mercury and other pollutants. From the syngas itself, all types of pollutants, impurities, mercury, and heavy metals are removed. The gas is then sent to the combustor or to the combined cycle to generate electricity. Since we are burning syngas here, it burns cleaner than directly burning coal and stripping pollutants from the exhaust gas. These results show the emission characteristics from normal plants. The permissible limit for sulfur dioxide gas is 0.16, whereas the plant releases sulfur dioxide far below 0.014 percent. Similarly, the permissible limit for NOx gases is 0.12, whereas the IGCC-based plant releases NOx at 0.02. Similarly, the particulate matter or fine ash particles released into the environment are significantly lower in this case. This clearly shows how IGCC plants are very helpful in reducing the environmental impact of coal-based power generation. If we opt for direct coal-based power generation, typically in most plants, these values are significantly higher. They face difficulty in meeting the required values of 0.16, 0.12, and 0.015. These plants struggle to maintain these values and consume a large amount of auxiliary power to meet the permissible limits of sulfur dioxide, nitrogen oxides, and particulate matter. But IGCC-based units can easily maintain compliance with environmental guidelines, and their emission characteristics are much lower than the permissible limits. Similarly, in 2015, Mitsubishi installed a power plant in Japan, in Nasako, which was particularly focused after the earthquake and other events related to the Fukushima power plant during the 2011 earthquake and tsunami.

In 2011, a severe earthquake followed by a tsunami occurred. As a result, in Japan, specifically in Fukushima, its nuclear power plant was severely damaged, releasing large quantities of harmful chemicals and radioactive materials. After that, Japan decided to focus on cleaner energy and reduce reliance on nuclear-based power. They opted for IGCC-based power plants, successfully commissioning one in April 2021, which has been operational since then. Other examples also exist. Overall, Japan is moving in this direction, focusing on IGCC-based plants to replace even nuclear-based thermal power plants. Similarly, another company's example in the Czech Republic shows they reconfigured IGCC-based technology, planning to gasify approximately 2,000 tons per day of locally available lignite coal. They gasify it through a fixed-bed gasifier, and the syngas is then fired in a 2,000-megawatt combined-cycle power station installed with GE turbines, achieving an electricity output of 400 megawatts. The syngas

is cleaned through various removal methods, including acid gases and other methods, particularly recovering sulfur gases to produce sulfuric acid as a byproduct. Beyond electricity, the plant also produces other byproducts like coal tar, phenol concentrate, and liquid ammonia. During the cleaning process, impurities in the syngas, such as ammonia, sulfur compounds, and coal tar (a volatile material), are removed. They recover coal tar, phenol, and other materials, obtaining them as byproducts from the plant. Apart from conventional electricity output, this plant produces other valuable chemicals from coal gasification units.

Similarly, they have another gasifier to increase output, particularly for byproducts like coal tar. Economically, this makes sense as electricity prices remain higher than the value of the liquids. Additionally, gasifying the liquids allows more gas to be produced in a counter-current process. They are reducing dependency on local stocks. So even if they are going for the gasification, which allow them to produce much more quantity of syn gas, and from this syn gas they are getting different type of valuable chemicals. So, in other example, In Indian case in 2015 Ministry of Coal approved and comprehensive policy framework for the usage in coal and lignite bearing areas. So Indian government has also focused on underground coal classification units where the lignites and similar coal are available and where the conventional coal mining is little bit difficult. And in this case, Coal India has selected Kasta Coal Blocks for implement of UCG based technology to required for the Indian conditions. And it is managed by the Eastern Coal Field India Limited that ECL in collaboration with the CMPDI Ranchi and other private companies. They have started plant installation here and that commenced in the June 22 in 2024, So involving preparing and technical feasibility reports through borehole drilling and core testing and second phase will focus on the coal classification at pilot scale. So in they have started this project to identify the potential of UCG based gas generation, syn gas generation from different coal mines particularly where the conventional coal mining is difficult and these projects are already started their analysis or feasibility report is already started and once this is successful then in the next phase it will go for other type of more a bigger type of plant where UCG will be used to produce syn gas and others and particularly it will transform opportunities to the India's energy sector showcasing the sustainable and efficient use of countries local resources. So overall if we see this case study shows that in all over the world different aspects of clean coal technology is being used worldwide where the conventional coal-based units are they are modified using the different types of clean coal technology either using the coal washing in terms of thermal power generation as well as using the IGCC and other units. So, if we summarize our entire coal clean

coal technology syllabus based on this case studies we have to we can summarize that coal is an extremely heterogeneous and hydrocarbon rich material. So, whenever we consider coal it is an extremely heterogeneous hydrocarbon-based material and we have to consider all the aspects of different types of hydrocarbons present their properties, their impact on coal combustion, coal gasification and other aspects. So, in such case, coal is considered to be like a hydrocarbon-based fuel. The properties of coal entirely depend on the hydrocarbon structure. Its composition: what are the bonds present there? What is the mineral matters present? What is the composition of mineral matter? How will this mineral matter impact coal utilization? And how will this mineral matter change the particle density, settling behavior, combustion kinetics behavior, or gasification kinetics behavior? How will this hydrocarbon change the combustion behavior, gasification behavior, and everything? So, we have to consider all these aspects whenever we try to utilize this coal or whenever we utilize this coal. So, it is not simply that we can call it coal. So, conventionally, we call it lignite coal; it should burn. But in real time, all these coal compositions, coal combustion characteristics, its hydrocarbon structure, its surface area, porosity, particle density—all these aspects play a tremendous role whenever we utilize coal.

So, whenever we utilize coal, we should consider all these aspects very carefully. We should characterize the coal accordingly. And after considering their suitability only, we should utilize the coal in suitable applications. If any requirement is there, such properties can be modified using different types of coal preparation methods or coal cleaning methods that can be used to remove any such impurities. Or we can use any such technologies where the combustion properties, gasification properties, or other properties can be modified as per requirement. So, we should consider— that it is a hydrocarbon-based fuel; it is not simply like coal. And coal utilization needs to be done considering that coal is a hydrocarbon source. Typically, in most cases, we don't consider that it is a hydrocarbon source and it is simply a rock and other. It is obviously a rock and rock-based fossil fuel, but primarily, it is a hydrocarbon-based source. So, all the properties depend on the properties of the hydrocarbons, their chemical bonding, and others. So, the composition of this coal varies each day, each mine, each seam, etc. So, whatever coal we are extracting, as it is an extremely heterogeneous material and it is a natural deposit.

So, coal composition varies in terms of hydrocarbon composition, mineral matter composition and other properties. They vary across the coal seam. So whatever coal we are extracting from any particular coal mine or coal seam. It will vary on each day or each mine, each location. So, whenever we utilize this coal, we should consider all these aspects. We cannot blindly believe

that this coal is obtained from the particular mine. So, it should have these properties. Even for any particular mines, this coal property will vary on day-to-day basis. on hour-to-hour basis depending on which location we are mining the coal and that particular coal has been generated or developed or originated from which particular type of plant material. So, it will vary. During the utilization, actually the hydrocarbon presents in coal, they react with gases and the reaction kinetics are different for each type of hydrocarbon. Even although we characterize the coal based on the proximate analysis and hydrocarbon analysis, but they do not, informs us about the entire thing about the coal properties. They give about some broad characteristics of the coal that how much amount of carbon is there, how much amount of sulfur, hydrogen, nitrogen are there and how much amount of mineral matter are there. But during the actual utilization the individual hydrocarbons whatever is present there in along with the mineral matter they react with the reactant gases either combustion, gasification or pyrolysis or whatever. So, they react. So, their property decides the coal properties and coal utilization. So it is based on that so although this proximate and ultimate analysis parameters give some information preliminary information but they does not give the all the information they does not give the exact 100 percent information so and there is also impact of mineral matter, maturity, porosity and all these things must be considered whenever we utilize the coal in different applications and particularly IGCC, UCG, modern pulverized coal combustion units they are capable of operating with minimum pollution if we see the different coal combustion technologies with improvement in the technology and improvement in the combustion related equipments coal grinding equipments and other parameters. So, all these units IGCC based unit, UCG, Modern coal combustion units, pulverized coal combustion units, modern fluidized bed combustion units, fluidized bed classification units, they all are capable of operating with the minimum pollutions. And particularly we have to follow the suitable coal beneficiation technology must be used if any coal is not suitable for any particular operation and if some variations or deviations are there we should consider such deviations and we should apply or utilize suitable coal beneficiation technology or coal blending technology, coal combustion technology or coal gasification technology as per requirement. If we are not doing this as per the properties of the coal whatever we are utilizing. So, there will always be some pollution issues.

But if we consider all these aspects on day to day or for each mine to mine or source to source basis and if we apply suitable clean coal technology either in the coal beneficiation or in the coal combustion or gasification as well as the environmental pollution control units, we will be able to utilize coal in much cleaner way. and if we go for the reference book for these subjects

what I recommend is that you should have to always go for the regular textbooks available with the coal and others but the advanced materials are not there this most of the textbooks are written 10 15 20 years ago and they Clearly mentioned about the basic properties of the coal and others. So fundamental properties of coal, they are coal cleaning, coal combustion, coal gasification, all these informations can be available from any of the textbook. But for the recent updates, whatever is happening on day-to-day basis, what new technology are coming. I always recommend going for different types of online resources like papers published through online platforms such as Elsevier, Springer, Taylor & Francis, and other reputable journals. We should follow all these journals to see the new developments, how new methods are being applied to coal, and how it is efficiently utilized in different industries and countries worldwide. So, we should always read various scientific reports, including those published by the Government of India and other agencies, both online and in hard copies. We should follow these to stay regularly updated on coal combustion, coal gasification, and the coal industry sectors, as well as news about how different countries or different entities are progressing. R&D labs are developing new technologies, and government policies are changing based on coal utilization. We should also review different types of plant data available for day-to-day applications, such as how plants utilize coal, their efficiency, and other factors. Overall, using clean coal technology, we can always utilize coal in a much cleaner and more environmentally friendly way if we consider the detailed properties of coal, recent developments, and recent changes in government policies.

Thank you.