

Clean Coal Technology
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Week-12
Lecture-56

Hi, I am Professor Barun Kumar Nandi, welcoming you to the NPTEL online certification course on Clean Coal Technology. From today, we will be starting our final module, which is Module 12, discussing underground coal gasification (UCG), coal bed methane, coal mine methane, and case studies. These are the contents that will be covered in this module, including UCG, CBM, CMM, abandoned coal mines, case studies on different aspects, and some model examples of utilizing clean coal technology in different plant applications. So, let's start Lecture 1 on underground coal gasification. Underground coal gasification (UCG) is another technology where we can use coal for gasification without mining the coal.

In the case of UCG, coal is gasified at the mine itself. That is, at the mine location in the coal seam itself, without actually mining the coal or disturbing the coal surface, we can carry out the gasification process. That's why it is called coal gasification, and as these reactions or this gasification is carried out below the coal surface or mostly underground, it is not the case for surface coal mines. That's why it is called underground. This gasification happens below the earth's surface inside the coal mines or underground coal seams. Here, the entire coal mine or coal seam acts as the reactor for coal gasification. In the case of coal gasification, we have seen that different types of reactors exist.

Lurgi gasification reactors, fluidized bed gasification reactors, or other types of gasification reactors are available. Here, the coal mine or coal seam itself acts as the reactor. The coal present in the seam or mine reacts with the gasifying reagent, which can be water steam (high-temperature steam), air, or oxygen—whatever is required for coal gasification. In coal gasification, we can use either hot air, oxygen, or steam. These are injected into the coal seam without actual coal mining. In the coal seam, identified below the earth's surface—perhaps at 200, 400, or even 1 kilometer depth—we inject reactant gases like oxygen, air, or steam, and they react with the coal seam. The injected gases react with the coal to form combustible gases like the syn gas. So, after this reaction, as per the happening the reaction stoichiometry, depending on the percentage of steam, percentage of air, percentage of oxygen or other reagents

available, other chemicals available in the coal seam, it will produce a combustible gas, mostly the syn gas. It can be water gas or other gas. So, this gas will be that is product syn gas is collected at the surface. Whatever the gas is produced that we will be collecting at the surface through a pipeline and later it can be purified or cleaned for any type of impurities and we can use that syn gas for different applications. It is major advantage is that it is the major cost saving in terms of without doing any actual mining. So, whatever the cost associated with the installation of mines, mining activities and other aspects, we can also save all these costs and we can directly gasify the coal. So, it is the major cost saving and simplifying advantage and not required that coal to be mined at all in order to be gasified in conventional cases coal are mined using the different mining technologies they are brought to surface and brought to some particular reactor and they are gasified so there is lot of such activities is there which are sometimes cost saving sometimes complex in nature and sometimes difficulties also. So, in this case of underground coal gasification all these aspects are not required so if we go for simple system like this is the location where coal seam is there below the earth surface and this is the other layer of surface like there is the ground level water table overburden etc. is there so coal is available at this surface. So, we can put the oxygen or gas system air here. Here it will react with the coal seam and through the other pipeline it will go to the syn gas out at the other location. So, in such case we do not need to actually do any type of coal mining at all only the from the surface or above the earth surface we have to put the installation for generation of steam and others and we have to put installation required for the collection of gases and cleaning of gases.

So typically, how we do this coal gasification is that typically at first cases we install the injection valve that injection wells are drilled because we have to go to the below the earth surface we have to drink some oil and typically this is done through the injection well through some pipeline. So, this pipeline can be longer as per the requirement of the or depth of the whole seam. So, they are drill into an unmined coal. Typically, any unmined coal seam is used where coal mining has not been done at present. So, where any unmined coal seam is there that means the coal is available below the earth surface and still it has to be started with any type of mining activities it is completely fresh coal seam is there. So, in such case the coal seam and that particular location we inject we drill to create the to send the reactant. So, injection where such drill in an unmined coal seam either air or oxygen or steam whatever is required they are said along with the hot water. Coal is at the high temperature; this coal phase will start ignition because we are sending oxygen at high temperature.

The coal seam will ignite and they are produced at high temperature about 800 degrees centigrade from the combustion and as there is limited amount of oxygen is available, we are sending oxygen from the top surface. so not adequate amount of oxygen is available limited quantity of oxygen is available so as a result it will go for partial oxidation process and produce hydrogen gas carbon monoxide gas carbon dioxide gas and other gases like methane, H₂S and other gases as applicable at what we have seen in case of coal gasification reaction. So, depending on the reaction, coal composition and other parameter, coal will create different type of gaseous products like hydrogen, carbon monoxide, carbon dioxide, H₂S, HCN and other gases. So all these gases, these product gases flow to the surface through one or more production well so all these gases will come to another well where from that production well we will collect the gases in the surface so they are typically located at some other distance so this more production will located ahead of the combustion zone so in where the coal combustion will happen that partial gasification partial combustion or gasification will happen from that zone we will collect the these product gases at the face is burned and area is depleted operation is moved to follow the seam as the coal reaction that gasification will complete it will continue so after some time or after some year this coal seam will be finished so we have to move to the other location for doing again the gasification so overall if we see the details how it is done so it is the inlet well coal where we input all the steam air and oxygen they are sent here. So they will go to this part and this is the actually the coal seam where coal is available particularly this is the location where coal is available and this depth can be few kilometers or 100 meters 200 meters or higher depth and we using this hole this reactor will set and it will react in this zone and after this reaction they will go to this path which is located at some other distance not exactly at the same distance if we put it at the same distance the same steam and oxygen will go out without any major reaction so to allow their reactions to happen for some time this outlet hole is placed at some other location it is not at the same location as it is here so this outlet hole will be there and again in the gasification there can have different type of zone like here oxygen concentration is on the higher side. So, at this zone it will be the oxidation zone and oxygen concentration will be on the higher side. Later it will move to the reduction zone where oxygen concentration will be less. Here carbon dioxide and other gas will react with coal to produce some more quantity of carbon monoxide. So, this will be the reduction zone followed by this hot air will pass through this fresh coal here. So, it will have the dry zone or distillation zone.

So, this same reaction scheme whatever we have seen in case of counter current gasifier or the updraft gasifier whatever we have seen in our classification chapter the same reaction will happen so from this side oxygen or gas is moving and coal is available in this oxygen bed so coal is here not moving coal is acting like an effect fixed bed and oxygen or this Stream whatever we have entered here they are passing through it. Initially it will react with here to produce carbon dioxide and others because concentration of oxygen will be at higher side. So initially it will pass through the oxidation zone followed by it will pass through the reduction zone and followed by the distillation zone. So, in this way gasification reaction will occur and gas will move and if we see the other gases in the other picture like this. So, this depth can be about thousand meters or above typically the site selection for this underground coal gasification is considered in such way that where the conventional mining is little bit difficult as we have We know during the mining when the depth of the coal is not too much high, it is available around 10-, 50-, 20- or 100-meters depth. Typically, open cast mining is done so that mining activity can be very much simple. But if the depth of this coal seam is far depth, maybe 200 meters to 300 meters, 400 meters, there typically underground coal mines are installed. and if the depth of this coal seam is significantly higher like one kilometer or much more. So, in such case installation of conventional underground coal mines is very much costly and very much risky also because at that depth the plant installation cost and other installation of conveyor belt coal cutting equipment's or everything will be too much expensive as well as the if the in the coal surface contains some amount of methane gas and other gases. So proper ventilation system for all this is very much costly and difficult. So underground coal gasification size is mostly preferred where the coal depth is coal is available at much depth maybe one kilometer and more so here if we see oxygen is entered here and oxygen will go through this well and here it will start reacting producing syn gas and others and they will come out. And wherever the gases are coming out they can be hydrogen gas, carbon dioxide, carbon monoxide, methane, H₂S. All these gases can come out which is at the surface. So, all this will come out and further they will be treated, purified as per the requirement of coal to chemicals or production of syngas to other chemicals etc.

So, they are sent here and we can get all other gases also. And if we want we can send pure oxygen there to increase the reactivity during the gasification reaction. And here most important for the underground coal gasification is that site selection is the paramount to a successful underground coal gasification project. that is at which location we can install the gasification plant the major characteristics of the coal seam is important, we have to know the

exact data or exact map of that coal seam is required. So that we can successfully do the gasification reactor if the data about the coal seam is not clear It is up to what depth coal is available, what is the coal type of available, how coal will react, is there any cracks or other impurities are there.

So, all these informations are required for successful installation and operation of the coal seam. If there is some sudden change in the coal quality parameters inside the coal seam, or coal seam is very much thick or very much thin then gasification reaction may not happen as per our desire or design parameter similarly if there is any permeability or fault structure of the local strata is there if the coal layer is highly permeable And that means if coal is highly permeable, whatever the syn gas is produced, so that may not go to the production well, rather they can go to the other location and they can even come out at any other alternate location, maybe nearby the plant or maybe far away from the plant and in that location. This syn gas will be released and it will be extremely harmful per or hazardous if such syn gas is released at any other location other than the desired location of the plant. So, we need the exact data of the soil or rock characteristics regarding their permeability, coal properties, coal structure as well as is there any cracks or fault is there or if there is any other ground water or other things are there. So, all these information are required for smooth operation of this plant. And so, we need the geological data, hydrological data, whether is there any ground water or it is connected with some sea water level, everything we have to know before we install the plant. Otherwise, the operation of the plant will be very much difficult. So, this requires the dealing of pilot bore hole to coal seam depth and coring of the steam characterization and good quality seismic survey preferably 3D survey of the whole area is required.

So, whenever we want to install such a plan for underground coal gasification. We need complete information on the coal depth, coal properties, and up to what distance this coal is available, up to what length this coal depth exists. So, all this information is available, and as we are doing this gasification, there will be a loss of coal mass because the carbon material will react and come out as product gases. So, inside the earth's surface, there will be some open space, and that can cause earthquakes or other types of issues. So, we need a very good seismic surface to ensure that if we do this gasification, there will be no other consequences on the earth's surface. The entire rock characteristics of the area are also required; otherwise, landslides or other issues can happen if we remove the coal in this way. So, we need complete modeling, and hydrology is also required to determine whether this will create any problems with the groundwater level or water table below the earth's surface. So that it will not damage

or disturb the groundwater level, or contaminate the groundwater, or create problems with the gasification reactor. So, all this data about the site is required, and complete information in a 3D model is necessary for successful installation. Now, in the case of gasification, typically, seam thickness affects the gasification rate. If the seam thickness increases, the gasification rate decreases, and the heat value increases. If the seam thickness is high, then the gasification reactor efficiency decreases, and the heat value also increases. Typically, a seam length of 1.3 meters is required for satisfactory results, but if the thickness is 2 meters or more, then we have to prefer the long tunnel and large selection technology. Now, if the coal seam is very thin, the produced gases can easily pass through that seam and reach the production well. But if the coal seam is very thick, like two meters or more, then it is very difficult for the syngas to pass through this coal and reach the production well.

In such cases, some horizontal directional drilling is also required so that the products produced in gas can lead to the production well, and that is the main challenge here. Typically, all types of coal, including lignite and anthracite, can be gasified in this range. Low-rank coal is the easiest to gasify here, but underground trials have been successfully carried out even with anthracite coal, which is the highest-rank coal. Now, the produced syngas needs to be cleaned of H₂S, ammonia, and other gases before it can be used in the gas turbine or other plants that are similar to conventional coal gasification plants. Since the gasification occurs inside the coal mines, different coal mining activities and coal handling activities are not required to obtain the syngas.

As a result, UCG may save money. In other environmental pollution originating from the coal mine, during coal mining activity or mine installation, there is a lot of environmental impact, such as deforestation of the land, as well as air pollution or dust pollution, dust particles or suspended particles coming from the mining activities of the coal. So, there are many other environmental consequences whenever we install a coal mine at any particular location. But if you go for underground coal gasification, all these pollution-related issues from coal mining activities are not there. As we are not doing any mining activities at all, the coal is directly reacting, and we are getting the syngas. For starting coal mining activities, land requirements and other infrastructure related to coal can be avoided without impacting coal inflation. So, if you go for this underground coal gasification technology, we don't have to occupy or acquire land for this. As the land can be utilized for any other purpose, we are doing these coal mining activities indirectly, or we are utilizing the coal without actual mining. So, all this land requirement and other infrastructure development related to coal mining can be avoided, and

still, we can utilize the coal. In this way, there are several coal mines where mining activities are also difficult, as seen in some cases. Coal mines or coal properties of the mine are good, but operating any coal mine there is very difficult due to many other constraints. Constraints like difficult soil characteristics.

If the soil is not suitable for mining activities—if it is too soft or contains too much sand or groundwater— In such cases, if soil characteristics are not suitable for mining activities, we cannot install or operate any coal mine at all. Similarly, nearby rock characteristics are also important. If the rock is not suitable for mining activities, then it is also not possible to install or operate the mine in such cases. Also, in some cases, different types of gases are already present inside the coal seam. So if the coal contains harmful gases, whenever we extract or cut the coal, all these harmful gases come out of the coal surface, and they can be damaging or harmful to the workers or engineers working in the mine as well as the different equipments used in the mines and they are also harmful for the nearby forest also and even in some cases if they contain some type of harmful or combustible gases present in the coal seam. So, during mining activities coal seam also can catch fire, so these are the different type of constraint whenever we consider the conventional coal mining that means if coal is present there but the site selection is not suitable for mining activities we cannot go for the conventional mining. In such cases without doing such conventional coal mining we can easily install underground coal mining and that can be a very underground coal gasification unit that can be a very good alternative in such cases. And if we see the infrastructure development, it is too much costly for such plant. If we see the underground coal mining or underground coal gasification activities, where the infrastructure development is the major hurdle for successful installation and operation of underground coal gasification.

We have to get the complete information of the soil characteristics, rock characteristics of the coal mine. and we have to install different type of mining related that gasification related equipment their steam production unit, air purification unit to maintain the desired combustion rate. At the mine site itself we have to go for the gas cleaning equipments and whatever syn gas is produced that has to be utilized or that has to be purified sent to the other consumer. So that site overall, it takes a lot of infrastructure development. Here, the infrastructure related to the coal mining is not there, but infrastructure related to the coal gasification is required. And this gasification is happening below the earth's surface, maybe 1000 meters or 2000-meter depth.

So, it is not an easy task to develop all these things. And if the product syn gas quality is not of desired quality, then the economical value of the syn gas will also not be very much profitable so that is the major hurdle for whole gasification. If rocks are faulty then syn gas may come out from different location if rock there is some cracks or there is some other faults or openings or pores are there. So syn gas come out maybe at other location and which is extremely hazardous condition that can happen if this syn gas is reduced at other point than the collection well. So, the syn gas is the combustible gas, harmful gases containing carbon monoxide that can come at any location nearby that coal mines or maybe 10 50 20 kilometers away from the coal mines depending on the rock characteristics or soil characteristics of the plants. In such case it is very much harmful or very much hazardous for the entire area also supplied heat to the steam may be absorbed by the rock itself because we are supplying heat at thousand degrees centigrade so that heat can also be absorbed by the rock itself and rock get heated so exactly the coal they may not get the desirable temperature as the before the hole whatever the rocks or other materials are present they are absorbing the heat and that creates very much complexity if rock is heated at high temperature that may have other type of consequences, negative consequences and other. So, maintaining desirable gasification rate inside that gasification unit of 1000 meter depth is a very much difficult challenge. And particularly difficult in the drilling in the horizontal direction is difficult in many cases. If we see the previous picture here. Like coal seam we are doing this inlet hole here and we are installing the outlet hole here.

So, if this connection from inlet point to outlet point is not good we may have to do the drilling so that they are connected. And the surface we can do the drilling in this direction at very only few depths. We can do easily drift in this vertical direction to any distance. But at after some distance of 1 kilometer or 2 kilometers drilling at this direction is very much challenging part. We don't have all this such technology or very sophisticated technology is required which will accurately drill from this portion to this portion of the coal seam.

So that is the main challenge in this coal gasification unit that we should have suitable technology. Drilling is required particularly horizontal. It is very much difficult and much more accuracy is required. We need to get the exact rock characteristics, coal characteristics, its hardness, rock whether it is some difficult rock or hard rock or soft rock it is there. So, all these informations are required and particularly horizontal drilling is very much difficult. In this way, the nearby groundwater may also get contaminated. As we are drilling far below the earth's surface, we are drilling about 1 km or 1.5 km. In between, 2-3 layers of groundwater may be present. Because these groundwater tables are located below the earth's surface, ranging from

100 meters to 300 meters, 400 meters, 500 meters, or other depths. So different layers of groundwater are available, and all this groundwater may get contaminated by direct drilling activities as well as by the syngas that is released.

So, any impurities from the syngas, if they contaminate the groundwater, the nearby groundwater will be contaminated and cannot be used for any other purpose. So, it is also a major challenge or drawback for this underground coal gasification unit. And landslides due to coal extraction require geological information. Yes, we are performing this coal reaction below the earth's surface and heating the coal at 1000 to 1200 degrees centigrade for gasification.

So, at any time, a landslide can happen if the rock is not strong enough to withstand that heat or that load. So, it requires good geological information about landslides, land characteristics, soil characteristics, and rock characteristics. For smooth operation of the underground coal gasification unit. So, overall, if we see, this underground coal gasification is a very good technology that can replace conventional coal mining activities related to coal mining, disposal, and other units. It is a very useful technique where conventional coal mining is very difficult. Coal is available near the Earth's surface. We can do open gas mines or underground mines. But if coal is available below the Earth's surface or at great depth, then in such cases, conventional mining may not be possible, and we can opt for underground coal gasification. Here, the major advantage we will get is that. As coal sources or conventional coal sources are depleting, we have to go much deeper to get suitable types of fossil fuels. In such contexts, underground coal gasification is very useful to obtain gaseous fuel or syngas from coal.

Thank you.