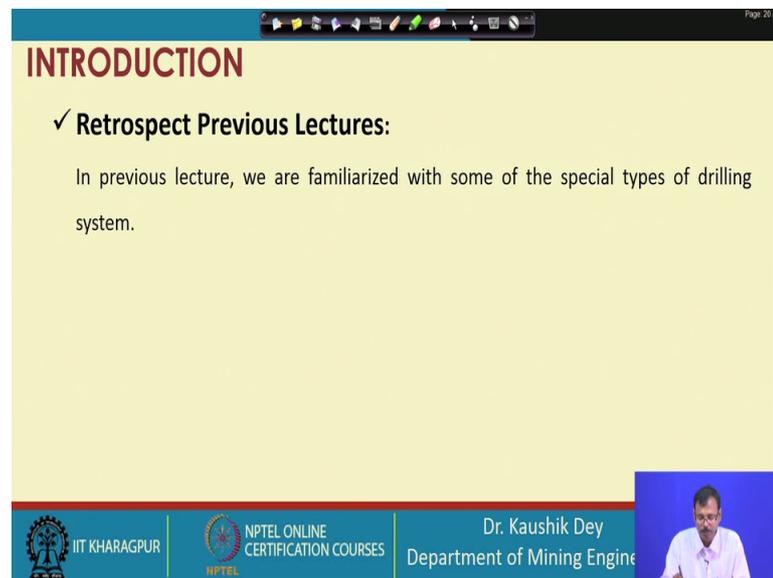


**Drilling and Blasting Technology**  
**Prof. Kaushik Dey**  
**Department of Mining Engineering**  
**Indian Institute of Technology, Kharagpur**

**Lecture – 15**  
**Special Drilling Methods – II**

Let me welcome you to the 15th lecture of Drilling and Blasting Technology course. We will continue this lecture of special drilling methods from our previous lecture. In previous lecture we are continuing with the special drilling methods, where we have discussed the large diameter drilling in vertical and the horizontal cases.

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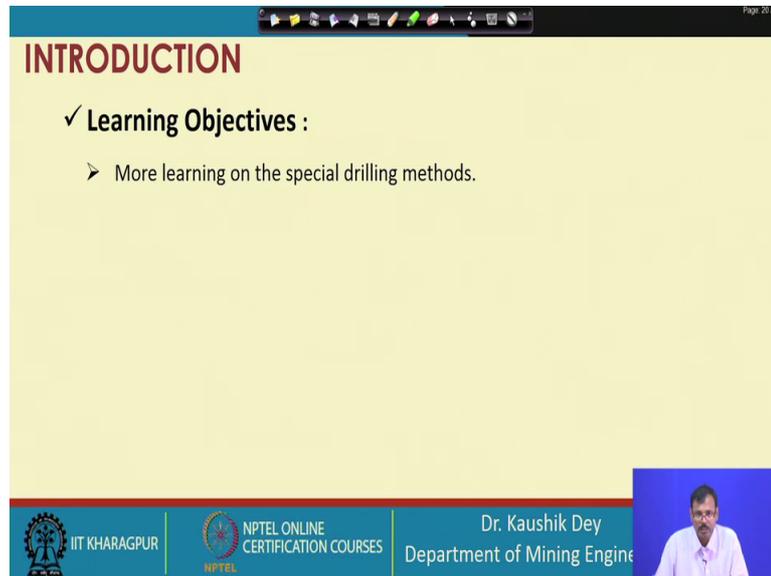
The image shows a presentation slide with a yellow background and a blue header. The header contains the word "INTRODUCTION" in red. Below the header, there is a checkmark followed by the text "Retrospect Previous Lectures:". Underneath, it says "In previous lecture, we are familiarized with some of the special types of drilling system." At the bottom of the slide, there are logos for IIT Kharagpur and NPTEL, along with the text "Dr. Kaushik Dey, Department of Mining Engineering". A small video inset of the speaker is visible in the bottom right corner.

Let us say retrospect our previous lecture. In the previous lecture we familiar we are familiarized with some of the special type of drilling methods. And in these drilling methods mainly we have covered the shaft boring the large diameter shafts are being bore directly using a full phase or half phase system.

And we have also discussed the raised boring which is also vertical large dia boring system, but that is limited to that is of limited distance, that is between two levels in the undergrounds, from one level to another level that is why the drilling distance is less. Whereas, in the shaft boring the drilling distance is very, very I often it increases 400, 500-meter depth also.

And we have discussed also the horizontal large diameter drilling; where we have observed the Tunnel Boring Machine, TBM is used for different conditions in the in horizontal drilling.

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**INTRODUCTION**

✓ **Learning Objectives :**

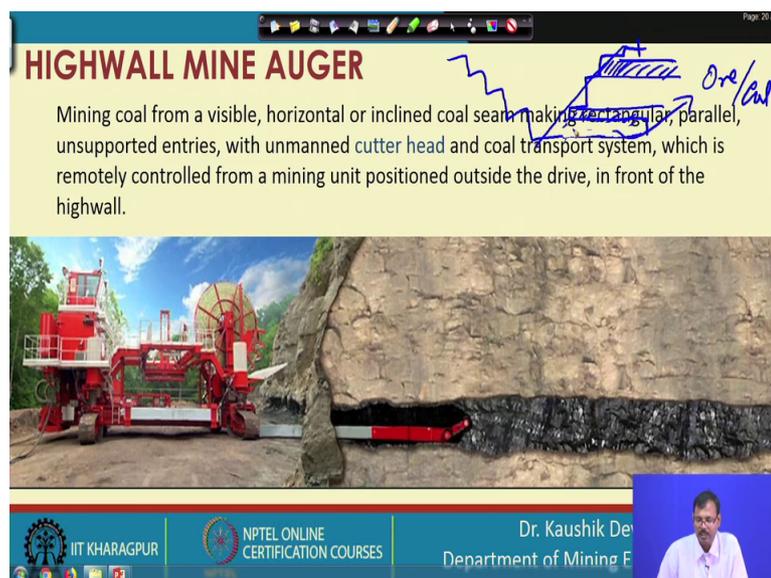
- More learning on the special drilling methods.

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This slide is a presentation slide with a yellow background. It features a title 'INTRODUCTION' in red, followed by a checkmark and the text 'Learning Objectives :'. Below this is a bullet point with a right-pointing arrow and the text 'More learning on the special drilling methods.'. At the bottom, there are logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, along with the name 'Dr. Kaushik Dey' and 'Department of Mining Engineering'. A small video inset of the speaker is visible in the bottom right corner.

And we have seen the benefits are very, very high while we are using this large diameter drilling, which is not basically not a drilling for drilling and blasting purpose, but which is a drilling basically for creating an opening for the underground space.

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**HIGHWALL MINE AUGER**

Mining coal from a visible, horizontal or inclined coal seam making rectangular, parallel, unsupported entries, with unmanned cutter head and coal transport system, which is remotely controlled from a mining unit positioned outside the drive, in front of the highwall.

*Handwritten notes: Ore/Cut*

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This slide is a presentation slide with a yellow background. It features a title 'HIGHWALL MINE AUGER' in red. Below the title is a paragraph of text describing the mining process. To the right of the text is a hand-drawn diagram in blue ink showing a rectangular entry with a zigzag line above it and the text 'Ore/Cut' next to it. Below the text is a photograph of a large red mining machine operating in a coal mine. At the bottom, there are logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, along with the name 'Dr. Kaushik Dey' and 'Department of Mining Engineering'. A small video inset of the speaker is visible in the bottom right corner.

The, our objective remains same. In this class we will continue the horizontal drilling, but in this case it is not a tunnel boring machine, where the drill cutting head is used for creating the opening. But instead of that this is called highwall miner, where a auger type of drilling is used for creating an opening. So, basically before doing this let us understand: what is highwall mining. In highwall mining what is carried what is happened? As we are creating our opening in a mine like this, and say our deposit is left at this position or maybe at this position in some more extends up to some more extension at these places, but our surface boundary ends here.

So, we cannot go for excavating those materials. So, what we do? We try to excavate this using a large dia boring or excavation system so that this material can be excavated at this position. And that will increase some quantity of ore or coal excavation. So, what is happened? This is our desired angle of slope which has to be maintained. But after maintaining this angle of slope also we are able to excavate some additional ore or additional coal from the mine. So, this type of excavation is called highwall mining; where an highwall is excavated through some underground creating some underground opening, and that is basically large dia drilling or a large dia excavation system.

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**HIGHWALL MINE AUGER**

Mining coal from a visible, horizontal or inclined coal seam making rectangular, parallel, unsupported entries, with unmanned cutter head and coal transport system, which is remotely controlled from a mining unit positioned outside the drive, in front of the highwall.

The slide features a photograph of a red highwall miner machine operating in a mine. The machine is positioned in front of a large, light-colored rock face (highwall). A dark, horizontal coal seam is visible at the base of the rock face. The machine has a large, circular cutter head and a conveyor system for coal transport. The slide also includes a small inset video of a man speaking in the bottom right corner.

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In this case we use Auger as a drill machine so in this case, we use auger as a drill machine, as you understand generally auger is an incremental screw system; where you have already seen in last class the screw conveyor, the basic principle is same, but auger

is start is starts with a pin pointed, pin pointed noze or pointed noze and gradually it is flank diameter is being increased. So, the material once it is penetrated, then the rest part of the material is being sheared and allowed to come out through these planks. So, that is the basic principle of operation of an auger. So, auger is basically considered a penetrating tool, or in other word you can consider auger is also a drill.

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**HIGHWALL MINE AUGER**

Mining coal from a visible, horizontal or inclined coal seam making rectangular, parallel, unsupported entries, with unmanned cutter head and coal transport system, which is remotely controlled from a mining unit positioned outside the drive, in front of the highwall.

*Highwall Miner*

The slide features a photograph of a red highwall miner operating in a coal seam. The machine is positioned in front of a highwall, and a coal transport system is visible. The slide also includes a small video inset of the presenter, Dr. Kaushik De, in the bottom right corner.

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So, basically mining of coal from a visible horizontal or inclined coal seam making rectangle parallel or unsupported entries with unmanned cutter head, and coal transport system which is remotely controlled from a mine unit positions outside the drive in front of the highwall is called highwall miner. This is called highwall miner.

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**HIGHWALL MINE AUGER**

✓ Auger mining system operation

- The auger mining system consists of the following items:
  - ✓ Cutting head
  - ✓ Auger flights
  - ✓ Latching mechanism
  - ✓ Auger fork

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So, basically in highwall miner if we use auger as a cutting head, or auger as a drilling system, then we can classify it like this is consisting of a cutting head, it is consisting of auger flights, it is consisting of latching mechanism, this is consisted of auger fork. So, these are the essential components of a auger cutting system or auger drilling system in a highwall miner.

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**HIGHWALL MINE AUGER**

Auger hubs, Auger shaft, Crank conveyor, Stock pile

0.5 m, 2 m, 1.5 m

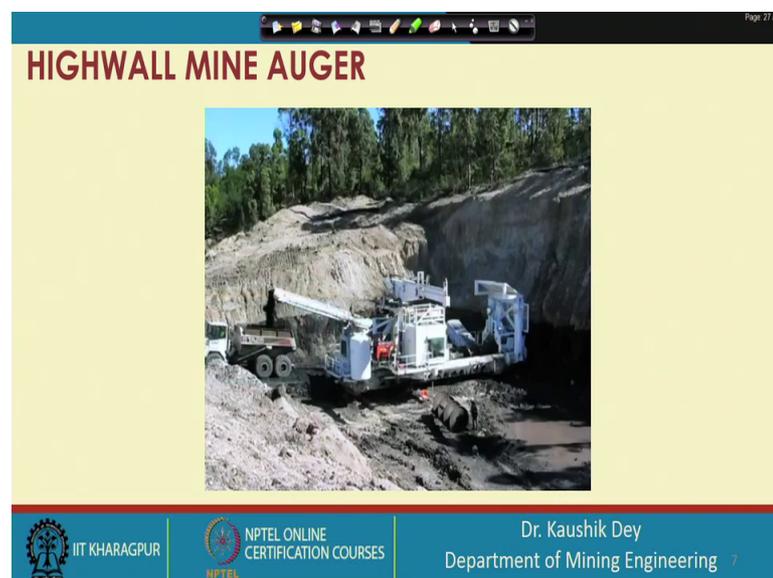
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So, let us observe some highwall miner photographs. You can see these are the openings, you can see these are the highwall openings created where the ribs are kept maybe 2

meter half meter, and the fixed diameter augers are used or the drill machines are used, that is 1.8-meter excavation is carried out. So, significant excavation if you are considering significant percentage of excavation, percentage of excavation may be achieved using the auger miner in the highwalls.

So, you can see these are the auger holes. These are the auger miner; these are the crawler conveyor after the auger material is coming out from the auger the material is discharged on to the crawler conveyor. And that is creating a stock pile which may be excavated at a later part. So, you can observe one such video which is also available in the open domain.

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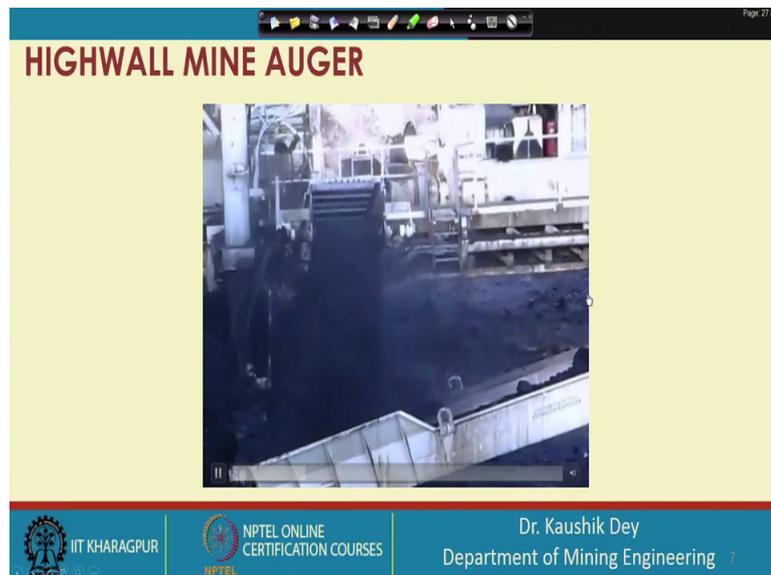
So, you can observe this one and you can see the auger planks are observed.

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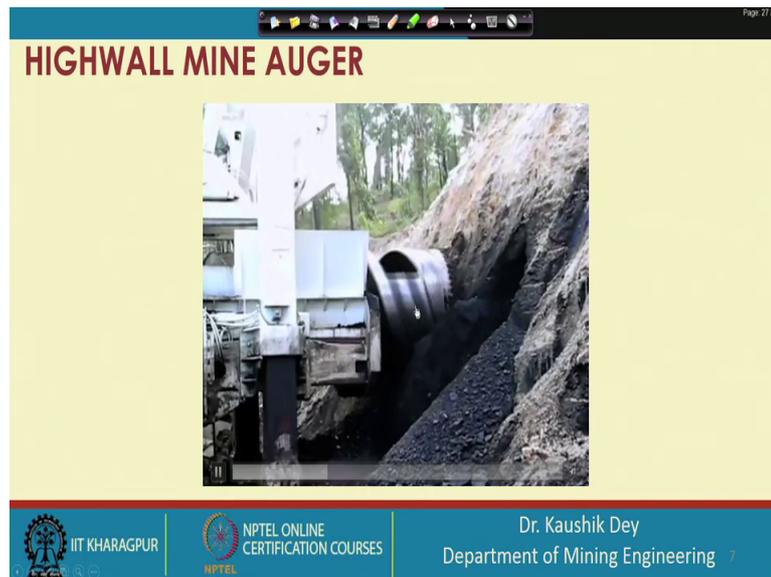
(Refer Time: 07:53). So, this is the material (Refer Time: 08:01), you can see this is the auger. You can see this is the auger as the auger is rotating the material is coming out and finally, discharging through this conveyor at this position and from this position to this position.

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Then see this is the conveyor which is dumping the material on this.

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So, this is the auger you can see outside is a supporting blade and auger is inside and material is being moved in the front direction through the auger. So, this is the material is coming out you can see so basically auger is penetrating in the front direction auger is penetrating in the front direction.

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You can observe the planks are moving in the forward direction so that is why auger is penetrating in the forward direction and material is coming out in the reverse direction.

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And once a significant length is achieved, then the another auger is attached to the mouth of the previous auger. So, that is why the auger lengths are can be increased gradually, and more depth can be achieved by this way.

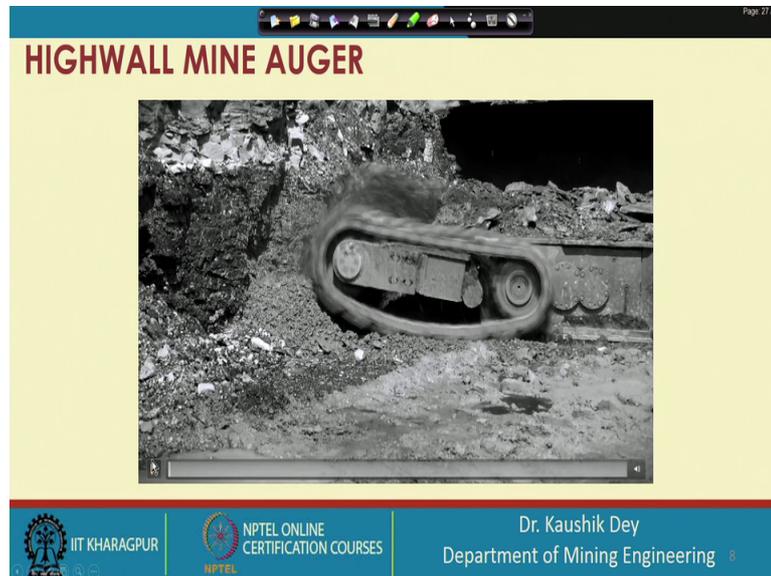
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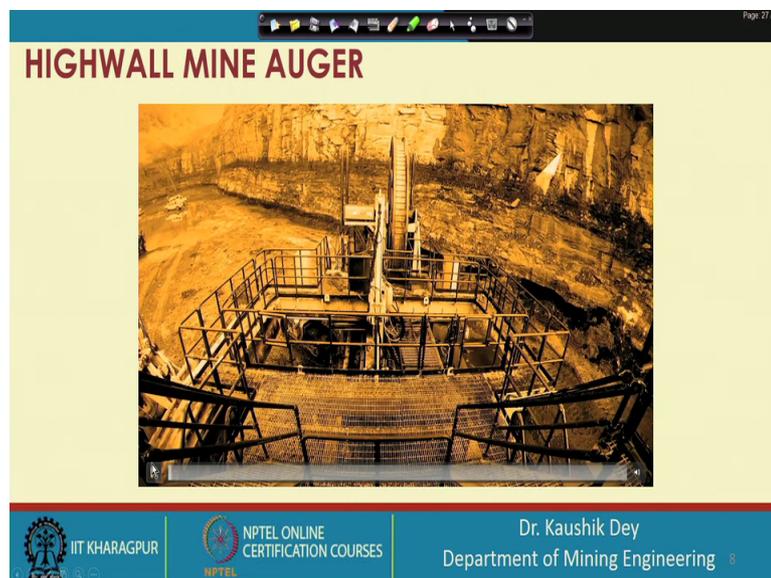
So, auger is basically pushed in the front direction hydraulically, often it may be a mechanically also it is pushed in the forward direction. And for that the highwall miner needs to have a good coupling with the ground so, that it cannot go in the backward direction with the force with the drilling force achieved by the auger.

So, that is why proper coupling of the highwall miner is essential. Let us observe another video.

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Where instead of auger the excavation is being carried out.

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Using some cutting drum system.

(Refer Time: 10:49) Mining system to reach those challenging closures in the most efficient in performer in Appalachia coal; from with the versatility desired by coal miners around the world.

Using some cutting drum system.

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So, basically it is not a drilling.

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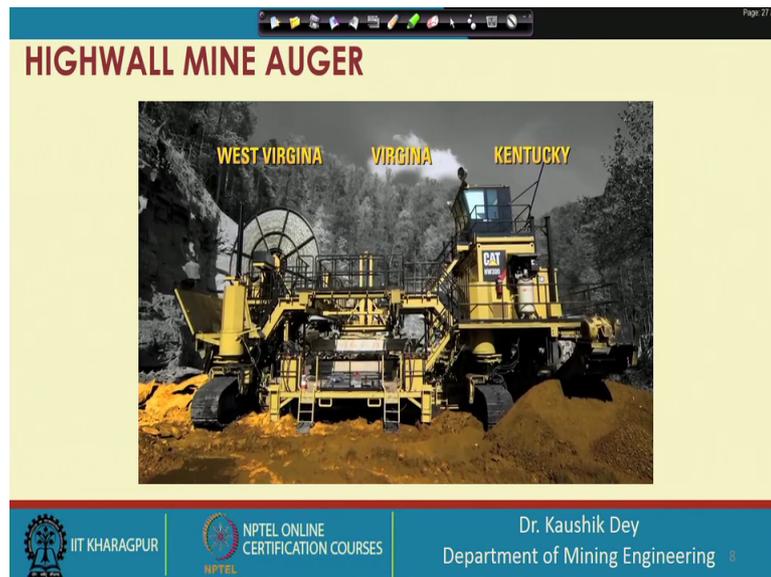
It is cutting drum excavation system.

And compact.

Where auger is not used in the highwall miner. So, this is basically.

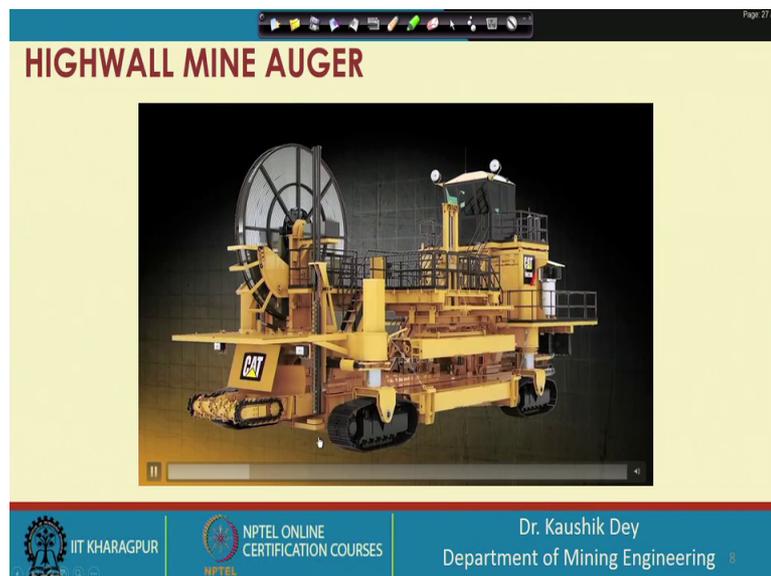
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A little bit different from the drilling system. (Refer Time: 11:19).

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But this is also continuous excavation system.

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And this is you can see this is the miner, this is the cutting head.

Mine operators rely on the HW 300 to perform in a variety applications and semites  
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You can see this is the cutting head in the mouth which basically cuts the material. And rest part is same, and the material is being transported using a chain conveyor placed between these two through a gathering arm loader. So, basically this is another type of highwall miner, but in our as far our drilling and blasting course this is not required, but highwall miner of auger type is very much a drilling specialized drilling method, which practiced in highwall mining for excavating the material.

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**JET PIERCING**

- This method originated in 1927, when Stores tried to apply it in Germany, in a mine with quartz veins.
- ✓ **Thermal drilling process**
  - This penetration process depends on one of the rock characteristics which is called spallability and is based on the differential thermal expansion capacity of the rock crystals.
  - The properties that affect spallability in rocks are complex but the following relationship can be established:

$$\text{Spallability} \propto \frac{\text{Thermal diffusivity} \times \text{Expansion (at } T_0) \times \text{Grain size}}{\text{Compressive strength (at } T_0)}$$

$T_0$  is critical temperature at which rock becomes plastic enough to prevent spaling

Rock  
Minerals  
1  
2  
3

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Next is basically use of thermal drilling use of thermal drilling process, and again it is for excavation. This penetration process depends on one of the rock characteristics which is called spallability and is based on the differential thermal expansion capacity of the rock crystals. So, what is happened basically rock as we have discussed in our earlier classes, rock is compositing n number of minerals. So, n number of minerals are basically forming a rock.

And this each minerals this each mineral 1, 2, 3 this each minerals are having different physicommechanical properties, physicommechanical properties. So, often they exhibit differential, differential thermal expansion and among these grains of different minerals. So, what will happen? If say suppose grain of first one is very adjacent to grain of second one, and then if we are subjecting this to a high temperature then as the expansion of this one and the expansion of this one is different, then a sear crack will generate between these two.

So, basically as the thermal expansions are different, thermal expansion are different into the different grains of the mineral, different crystals of the mineral then the cracks occur into the rock, and that basically utilized in this process to create the openings in the rock and then excavating that one or drilling that one. So, these properties that affect spallability in rocks are complex.

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**JET PIERCING**

- This method originated in 1927, when Stores tried to apply it in Germany, in a mine with quartz veins.

✓ **Thermal drilling process**

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But the following relationship can be established, where spallability is proportional to the thermal diffusivity, expansion at  $T_0$  grain size compressive strength at  $T_0$ , ok. Where  $T_0$  is the critical temperature at which rock became plastic enough to prevent spaling. So, basically this is the principle which is used in the thermal drilling purpose.

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**JET PIERCING**

✓ **Thermal drilling process**

- According to the previous equation, the rocks will be more easily drilled with this method when:
  - High thermal expansion exists below  $700^\circ\text{C}$ .
  - There is high thermal diffusivity below  $400^\circ\text{C}$ .
  - Granular interlocking structure with no fine clay, mica, or other alteration products.
  - Reduced percentage of soft, low temperature melting minerals, or those which decompose.

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And according to the previous equation, the rocks will be more easily drilled with this method when the high thermal expansion exists below 700 degree centigrade. There is a high thermal diffusivity below 400 degree centigrade, granular interlocking structure

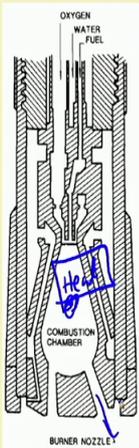
with no fine clay mica or other alteration products. Reduced percentage of soft low temperature melting minerals, and those which decompose so, these are the observations for from the which we can made from the previous equations.

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**JET PIERCING**

✓ **Thermal drilling process**

- The basic equipment, or burner, consists of a combustion chamber, where the fuel (gas oil) is atomized and mixed with oxygen as it is maintained under pressure.



Cross section of a burner

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So, this is one typical say system for thermal drilling where oxygen and fuel is used basically to in combustion chamber for creating the heat, or you can say flame, at this position. And this is the burner nozzle through which the flame is basically provided to the rock so that it can thermally diffuse.

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**JET PIERCING**

✓ **Thermal drilling process - Application**

- The most important applications for this method are:  
Blasthole enlargement
  - This procedure has the following advantages:
    - Lower volume of rock drilled per unit broken.
    - The explosive column configuration is better
    - Toe level breakage is improved, reducing subdrilling.

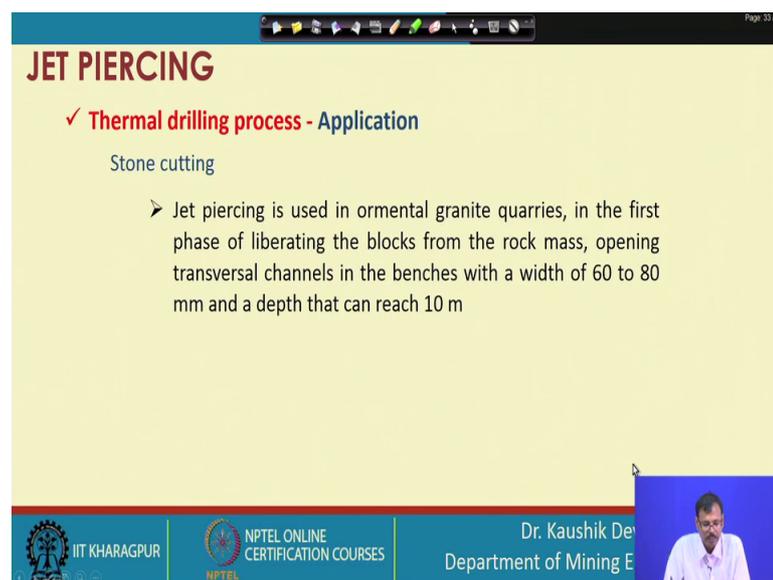
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And these are the different applications. The most important application for this methods are the blast hole enlargement. This process has the following advantages lower volume of the rock drilled per unit broken, the explosive column configuration is better because sidewall remain unaltered toe level breakage is improved and this reduces the sub drilling.

So however, because of because of non availability or the high cost of the jet drilling machine, this is not very popular one management of this is very difficult, second, and also if someone is using explosive in a hot hole use of explosive is also very, very difficult, that is why the thermal drilling is not very popular one. But, for your knowledge you can have some you can you can keep in your mind that this type of drilling is also possible, but because of the cost matter it is not at all popularly used any place in the drilling and where the drilling and blasting is being carried out.

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**JET PIERCING**

✓ **Thermal drilling process - Application**

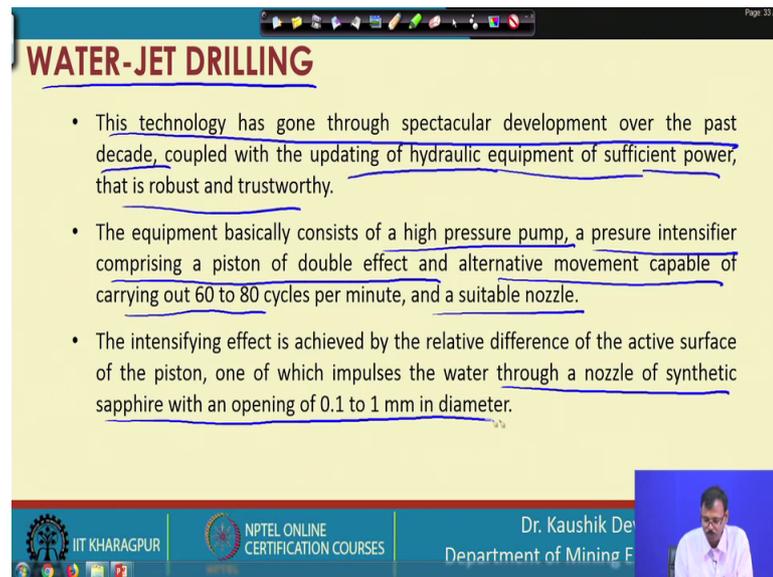
Stone cutting

- Jet piercing is used in ornamental granite quarries, in the first phase of liberating the blocks from the rock mass, opening transversal channels in the benches with a width of 60 to 80 mm and a depth that can reach 10 m

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So, this is the application of sometimes we go for stone cutting.

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**WATER-JET DRILLING**

- This technology has gone through spectacular development over the past decade, coupled with the updating of hydraulic equipment of sufficient power, that is robust and trustworthy.
- The equipment basically consists of a high pressure pump, a pressure intensifier comprising a piston of double effect and alternative movement capable of carrying out 60 to 80 cycles per minute, and a suitable nozzle.
- The intensifying effect is achieved by the relative difference of the active surface of the piston, one of which impulses the water through a nozzle of synthetic sapphire with an opening of 0.1 to 1 mm in diameter.

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That is another method of drilling is water jet drilling, where this technology has gone through spectacular development over the past few decade. This is also called hydro leaking, where the material is being excavated hydraulic using hydraulic equipments with sufficient water jet the equipment basically consists of high power high pressure pump; And a pressure intensifier comprising a piston of double effect and which able to give a 60 to 80 cycle per minute and a suitable nozzle.

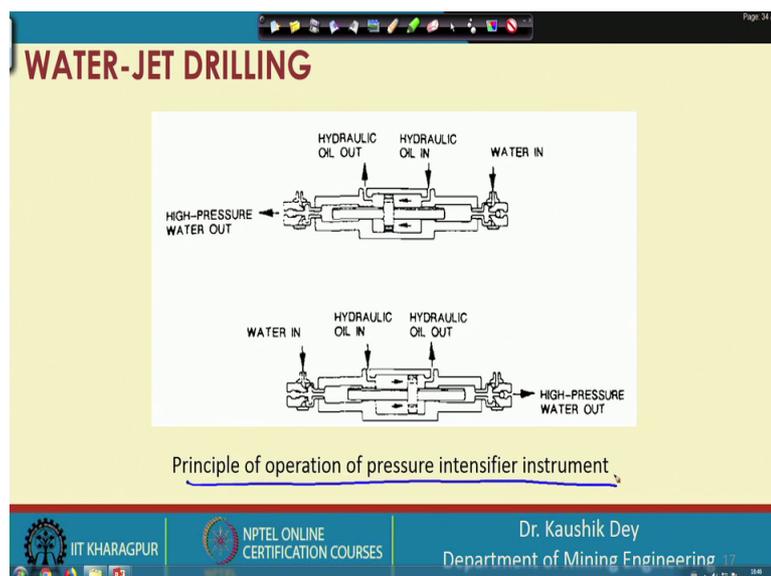
And using this we can send the water through a synthetic sapphire with an opening of 0.1 to 1 millimeter diameter. So, you can absorb this water cutting water jet cutting; in this video, this will give you better understanding about the piston.

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See how easy if it is the water get it cutting a iron beam to it is pressure only. And you can see this is just cutting just like a jet cutter. And that is why this cutting is very easily in many direction, it can be controlled computerized also. So now, you can rotate and we can cut it in this direction. So, you can see the complete cutting is carried out very fast, and then small hammer movement is able to cut that iron piece. So, this cutting is very, very easy and this is the benefit of using water jet cutting in the practical field.

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So, this is basically the schematic diagram how the water jet cutting can be carried out, this is the principle of the principle of operation of the pressure intensifier instrument.

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**WATER-JET DRILLING**

- The rock breakage, with a high pressure water jet, is produced by the impact and the microcracks that are created in consequence. At a speed of 300 m/s, the pressure created is around 150 MPa, close to the compressive strength of many rocks. With 500 m/s, values of 300 MPa are reached, which is above the compressive strength of the majority of rock materials.

Modification of blasthole geometry drilled with water jet

DRILL  
DISC  
CHAMBER  
REAM  
SLOT

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The rock breakage with a high pressure water jet is produced by the impact, and the microcracks that are created in consequence at a speed of 300 meter per second. The pressure created is around 150 mega Pascal, close to the compressive strength of many rocks. Or may be often it is higher than the compressive strength of most of the rocks.

And with 500 meter per second in value so increases to 300 mega Pascal; that means, almost all the rocks can be broke fractured using this hydraulic jet using this hydraulic jet pressure; So, that is all from the drilling section. We have covered most part of the drilling part now. These special methods are not very useful for our drilling and blasting course, but I have covered 2 lectures on this so that you are able to get some knowledge that there are some special methods of drillings available which are very, very specialized drilling and that can be adopted in different cases.

But our topic of this lecture drilling and blasting, where the main drilling of the smaller sizes holes up to 350 millimeter dia holes are carried out, and these holes are only made to place the explosive inside the rock moss. Then that will be blasted that is the purpose of the drilling for the drilling and blasting. And those drills are being carried out either by percussive or by rotary percussive or by rotary a drill machine.

So, those are mechanized machines a small machines, drilling depths are generally in general limited in most of the cases less than 15 meter. In some special blasting cases like overburden blasting of dragline benches etcetera; it may exceeds 30 meter or something like that. But most of the cases these drilling depths are less, and that is why the drilling is little bit very, very easy in the drilling and blasting technology. And that is why it is not that much problematic.

We will carry out some more drilling practices where we will solve different drilling problems, like penetration rate drilling rates, economics of drilling; at the end of the end at the end, in few lectures before that will cover of the basics of the explosive from the next lecture onward. So, I hope you will carry out more study related to drilling from different textbooks; like, a Jimeno drilling and blasting books of Jimeno, and like drilling books of (Refer Time: 24:00) and other drilling books available for different cases. So, you will carry on more reading on this. And from next class onward we will start our basics of explosive and blasting part.

Thank you.