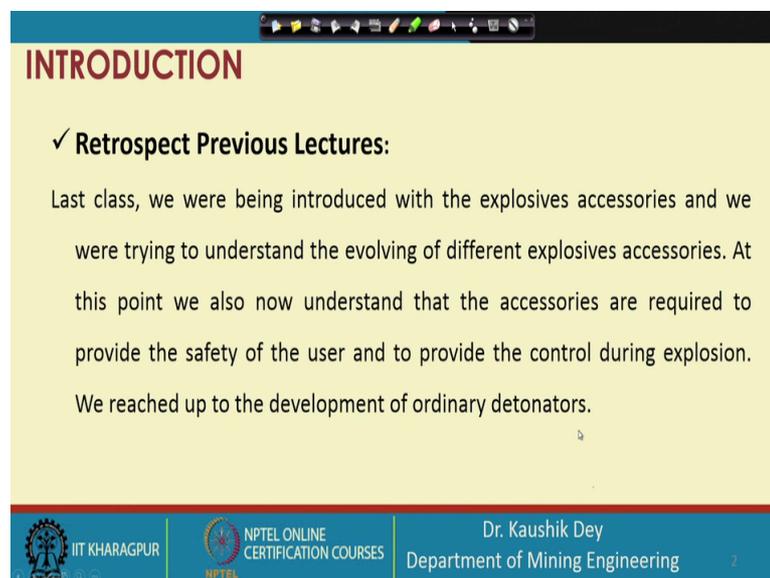


Drilling and Blasting Technology
Prof. Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture – 19
Explosives accessories-2

Let me welcome all of you to the 19th lecture of Drilling and Blasting Technology. Basically, this lecture is the continuation of the lecture number 18 where we were discussing about the explosive accessories or blasting accessories.

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INTRODUCTION

✓ **Retrospect Previous Lectures:**

Last class, we were being introduced with the explosives accessories and we were trying to understand the evolving of different explosives accessories. At this point we also now understand that the accessories are required to provide the safety of the user and to provide the control during explosion. We reached up to the development of ordinary detonators.

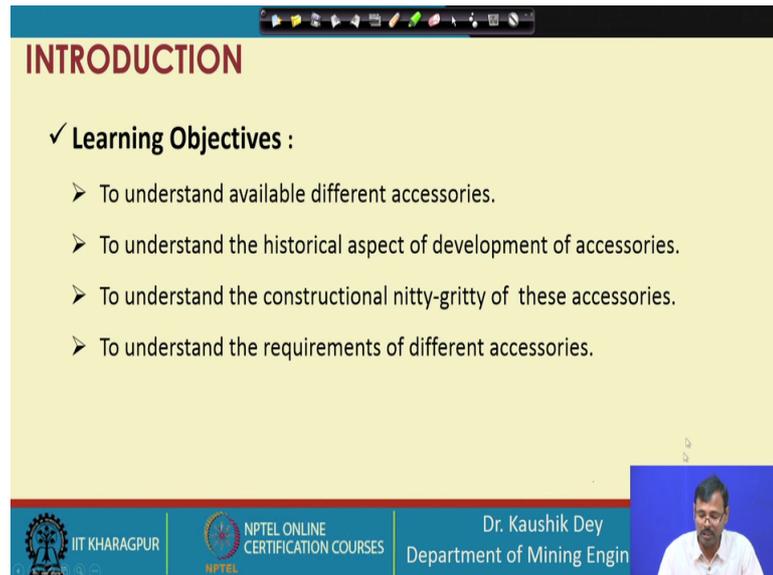
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Department of Mining Engineering

So, let us see what we carry out in our last class. So, last class we are being introduced with the explosive accessories and we are trying to understand the evolving of different explosive accessories. So, the example is that last class we have found that the detonator was evolved to accompany nitroglycerin based explosive that is dynamite as the explosive.

So, for that the detonator was ordinary detonator was developed at this point we also now understand that the accessories are required to provide the safety of the user because you understand during the explosive nitroglycerin was very very dangerous. And as this is high explosive if someone is trying to explode it being in the close proximity of the explosive then the environment will become unsafe for him.

So, for the personal safety it is required to remotely explore those explosive and for that the detonator was the essential requirement for the development. So, basically the explosive accessories are provided for the safety of the user and to provide the control during the explosion. So, now at the present point we have reached up to the development of the ordinary detonator and let us see what are the next.

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INTRODUCTION

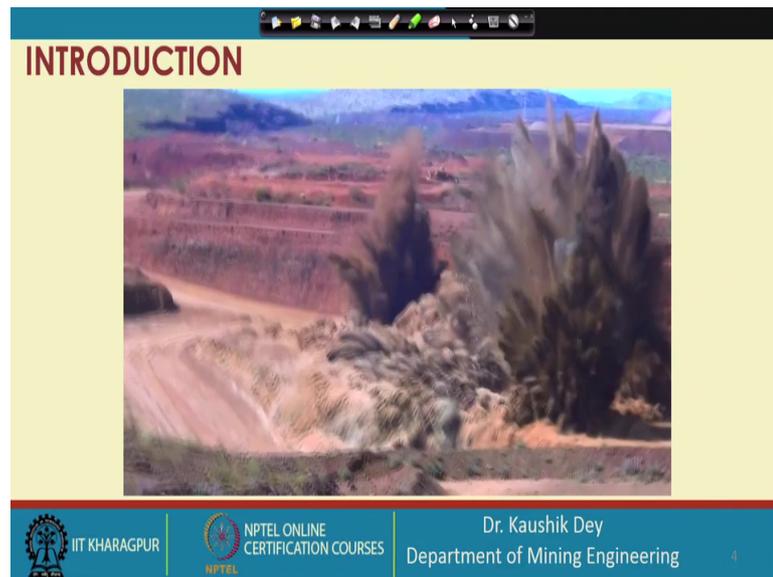
✓ **Learning Objectives :**

- To understand available different accessories.
- To understand the historical aspect of development of accessories.
- To understand the constructional nitty-gritty of these accessories.
- To understand the requirements of different accessories.

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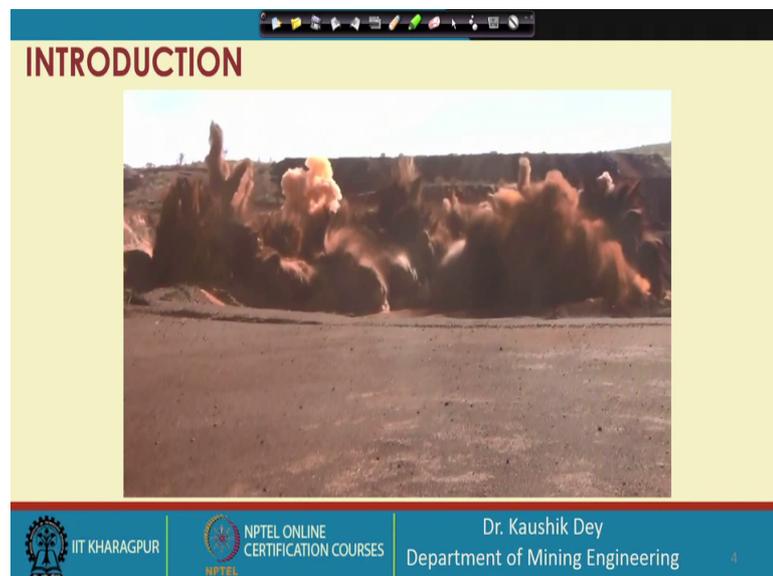
But before that, let us once again view what are the learning objectives and this is more or less same to the last lecture. So, learning objectives are to understand the different accessories to understand the historical aspect of the development of those accessories, to understand the constructional nitty-gritty of those accessories and to understand the requirement of the different accessories why they are required.

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So, let us see once again another blasting.

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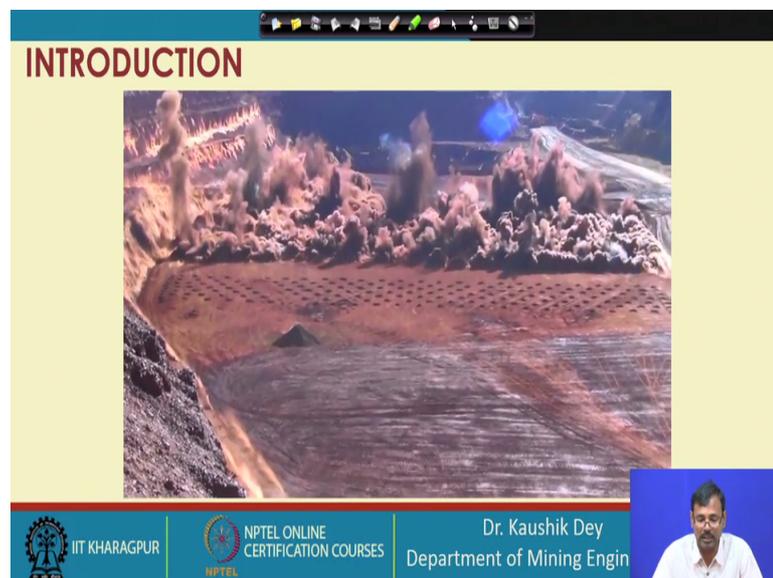
So, this is again another surface bench blasting where explosion is carried out in the iron ore mines and you can see huge number of holes are being blasted here. In fact, I want to insist you must understand that huge number of holes are being blasted in these cases.

So; that means, in the last class we understood that detonator is required to exploit the explosive so, that you can be at the certain distance and be safe. Now, what is happened if you are using detonator then for each hole you need to have one detonator and then

you need to have some flame to be provided in the mouth of the detonator. So, these things are very very difficult if you are carrying out in blasting in a number of holes, then the things will be not within your control because at a at a time giving the flame to a number of holes is very very difficult.

So, basically these things are creating problem, another is that if you look at this blasting you will find out the holes are blasted front holes are blasted ahead then the back holes are blasted after that. This is carried out so, that when the front hole will be blasted that time the front portion rock will be fragmented and moved out then the next portion of block will be fragmented.

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So, basically we want some damn time gap between the holes, but that was not possible in the development of the ordinary detonator. So, that is why we were in a need of some additional explosive accessories or blasting accessories which will give us the complete control about the blasting. What are those controls? That first control is that we should exactly know when the first initiation will be carried out. So, the first initiation will be within our hand; that means, when we are switching the on that switching on should be our control should be within our control.

Second one is that we want that the time difference between the explosive or we want the exact timing of blasting of the different explosive placed in the different blast holes. So, this exact timing of blasting of the different blast holes and that is not in the

simultaneously, that is in the different time frame. So, in the different time frame the explosion of the different explosive at different blast holes; are also the essential requirement. So, we were in a objective to achieve those targets and for that we need to develop some more explosive accessories or the blasting accessories.

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DETONATORS

Solid Pack Electric Type Blasting Cap

Diagram components: Fuse Wire Leads, Insulating Header, Primary Explosive, Output Explosive, Bridgewire.

Match or Fusehead Electric Type Blasting Cap

Diagram components: Fuse Wire Leads, Insulating Header, Electric Match, Pyrotechnic Ignition Mix, Primary Explosive, Output Explosive.

Electric detonator was developed in the year 1883 by the Company Dyno-Noble, which was set by Sir Alfred Noble. A number of modifications are made in the electric detonator with respect to its constructional and functional features.

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So, we are continuing with the detonator and last class we have seen the ordinary detonator, but later on it was found that to provide a flame to the ordinary detonator a person need to be stay in very close to the detonator, then he has to run away from the place prior to the flame is reaching to the mount of the primary explosive of the detonator. And it has been found it is almost very very unsafe condition, it is very very uncontrollable condition to run away from the place before this blasting. So, basically though we are able to blast using the ordinary detonator, but the exact time frame was not within the control of the user.

Second one is that if some novice person or some uneducated person or very very apprentice type person is using the initiation say operation in those cases he may not sufficiently control the flame. And before he is run away from the place the explosion may occur that that may become dangerous to him. So, it was failed that the exact time of blasting should be within the control of the person who is using that one and for that they felt that electrical blasting may be a good over the ordinary blasting where the flame is given.

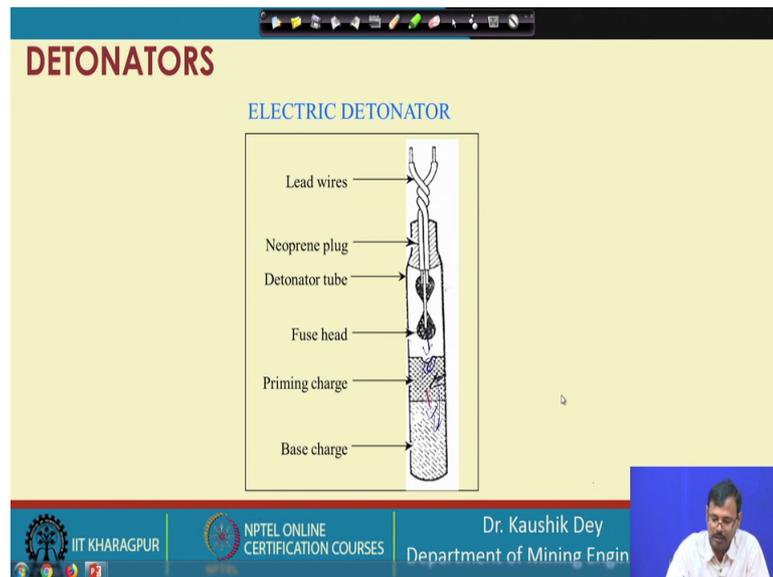
So, it was in 9th 1883 again the Dyno-Noble company which are initiated by sir Alfred Noble that company developed the first electric detonator and basically 2 types of detonator were developed initially. One is where the bridge wire is used the bridge wire gives the flame to the primary charge primary explosive and second one where the fuse head is used and fuse head is giving the flame to the primary explosive.

So, basically using these two type of technique the electric detonator was started in 1883 onward. In fact, by development of this electric detonator the user has now the control over exactly at what time the explosion should occur on to the detonator. So, now, they can provide the electrical signal by switching it on and the moment it is switching it on the fuser or the bridge wire is giving the flame to the primary charge and then the blasting will occur.

So, it is basically electric detonator is basically solving two problem, one is the multiple holes can be blasted because electrical wire can be can with the multiple holes in multiple detonators. And second one is that the multiple hole can be or electrical signal can be sent to this multiple hole simultaneously and the exact control on the time frame is now within the grip of the user.

So, basically electrical detonator is giving us the facility for controlling on the exact time of blasting and that is also stay in a remote place. That means, the lead wire we are taking the quantity of the lead wire giving us the distance it may be 100 meter, it may be 200 meter. So, that much lead wire are used for being in the safe area. But, this was lacks in two thing one is that it is not giving the different time of blasting for the different holes.

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But, before going to that let us see: what is the constructional feature. In this constructional feature you can see the lead wires are there in the mouth of that is the fuse head fuse head is very close to the primary charge the moment fuse head is generating the flame the primary charge is getting the flame. So, it will be expo convert the flame to the shock, the shock is coming to the base charge and then the base charge is basically base charge is basically being initiated.

So, from the fuse head the flame is coming to the primary charge and the primary charge it is coming to the base charge and by this way the explosion is carried out.

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DETONATORS

Electric Delay detonator was developed in the year 1900. This possible delay was included in the detonator by providing a pyrotechnique chemical column, which takes some burning time and thus delayed exploding the detonator.

The invented pyrotechnique chemicals allowed a minimum delay time of $\frac{1}{2}$ second only. *500 ms*

ELECTRIC DELAY DETONATOR

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So, the purpose where we are supposed to use the different time of blast for the different holes that was not able to be achieved because, all the holes are being blasted simultaneously. So, now, another development has been made in 1900 again by the same Dyno-Noble company that electric delay detonator was developed. What is this electric delay detonator? They are they provide some chemical element which takes some time to burn before the flame is reaching up to the primary charge.

So, basically it is some delay element pyrotechnic delay chemical is provided which gives the burning time and that burning time is basically the delay time. So, if you see the constructional nitty-gritty you can see first the lead wire is giving the electrical signal. So, electrical signal is coming to the fuse head and this fuse head is generating the flame and from the flame the flame is reaching to the pyrotechnic chemical.

So, this is the chemical so, this is the chemical which start burning the moment flame is coming and this burning of this column of chemical take some time. And by taking some time when the flame is reaching to the primary charge some time will be killed by that. So, the by this way some time gap is framed for initiating the different holes. But, using this technology it was it has been found only half second delay time could be achieved that time; that means, the minimum delay achieved by using this pyrotechnic chemical in 1900 was only half second; that means, 500 millisecond.

So, this was the first delay detonator developed and it was found significant because that time the production requirement was less and that is why and that is why the that was found sufficient.

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DETONATORS

However, mathematical calculation of delay time shows that $\frac{1}{2}$ second delay is very high for subsequent blast holes/(rows of holes) as 16 to 40 ms may be sufficient to achieve the best results.

Considering the above millisecond delay Electric Delay detonator was developed in the year 1943. The newly invented pyrotechnique chemicals allowed to achieve a minimum delay time of 16 - 25 milli second.

1900s
↑
 $\frac{1}{2}$ -Second Delay Electric Detonator

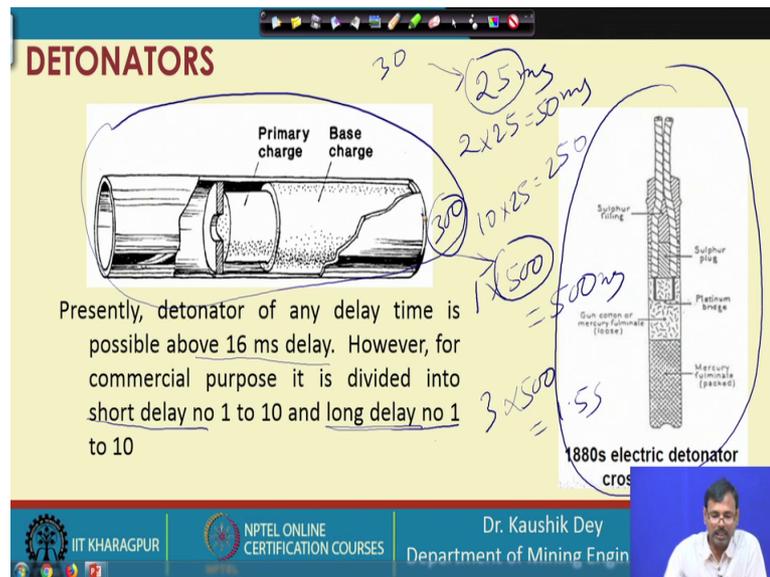
1943
↑
Millisecond Delay Electric Detonator

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But, this half second delay requirement was found very high because it has been found if 2 rows consecutive rows are being blasted rows of holes are being blasted then half second delay time is very very high as the burden movement speed is very less. So, mathematical calculation gives the 16 to 40 milliseconds may be sufficient for those consecutive holes and which could not be achieved by a half second delay detonator.

So, that is why this was not found very very suitable for blasting of the consecutive rows of holes and till 1943 people who are trying to developed such type of detonator delay detonator where 16 to 40 millisecond delay can be achieved. And in 1943 millisecond delay electric detonator where achieved, where some chemicals pyrotechnic chemicals were used whose column was able to give the delay time of 16 to 25 millisecond. So, 1943 onward 16 to 25 millisecond delay detonator were able to be developed.

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So, if you see the constructional features of this, you will find out this is the first electric detonator which is developed by the by Sir Alfred Noble the primary charge and base charge. And this is the first electric detonator which are developed you can see the mercury fulminate was the base charge that time and this delay detonators presently available which can give 16 millisecond delay that is the minimum delay present a possible with the pyrotechnic delay element.

And, we are having the technology that any millisecond delay above 16 millisecond can be provided, but it is very difficult for the commercial manufacturer to provide every type of delay sequence. So, commercially it is classified in two group, one is the short delay group and another is the long delay group. The short delay group is basically considered as the delay where 25 millisecond and it is multiplication of different number 1 to 10 that much delay is possible that much; that means, if someone is asking for a short delay of 1 he will able to get a 25 millisecond delay. If someone is asking for a short delay of 2 he will get a delay of 2 into 25; that means, 50 millisecond delay.

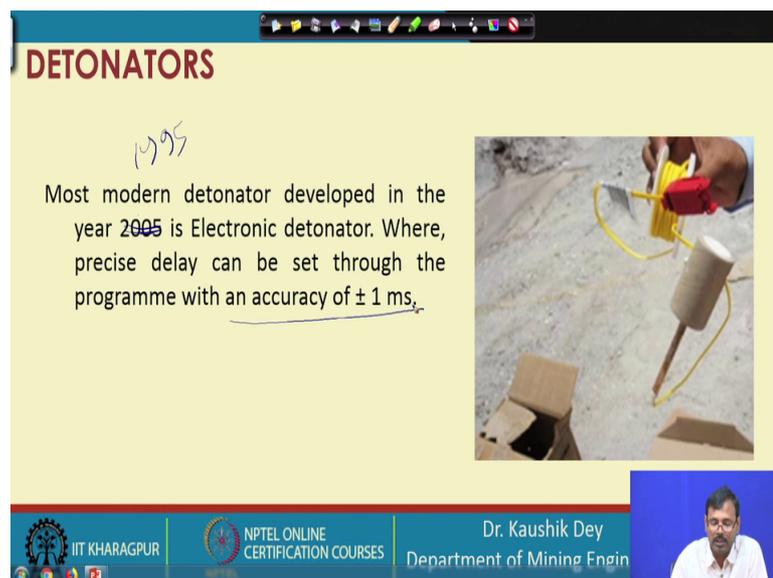
So, similarly 1 to 10; that means, up to 250 millisecond delay is commercially available. In fact, if you go through I have last class I have asked you to go through the different manufacturers site. If you have visited those manufacturers site you will find out some manufacturers are there those who are nowadays manufacturing instead of multiplication

of 25 millisecond it is the multiplication of 30 millisecond. In those cases it is 2 into 30 that is 60 millisecond, 10 into 30 means it is 300 millisecond.

So, that 25 to 250 milliseconds one to 10 delay numbers are commercially available with the manufacturer. If anyone wishes to have any delay between these in those cases he has to place a special order to the manufacturer, manufacturers are having the technology to manufacture that prototype delay a detonator. Similarly, long delay detonators are also available which is basically the multiplication or the initiation initially which is developed that is the half second delay. So, it is the multiplication of the half second delay. So, long delay one means it is the long delay 1 into 500. So, the delay time is 500 millisecond.

So, if someone is willing to have a long delay of 3; that means, it is 3 into 500; that means, 1.5 second is the delay time. So, like that way long delay 1 to 10 is available. So, 10 delay means it is 5 second delay can be achieved. Again if you visit the manufacturers site you will find out the long delays are available instead of multiplication of 500, it is the multiplication of 300 is also available. So, it will start from 300 millisecond to the 3 second; that means, 1 to 10. So, this type of is this type of different manufacturer commercially detonators delay detonators are also available.

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DETONATORS

Most modern detonator developed in the year 2005 is Electronic detonator. Where, precise delay can be set through the programme with an accuracy of ± 1 ms.

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Department of Mining Engin

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The slide features a yellow background with a blue header containing the title 'DETONATORS'. Below the title, there is a handwritten signature. The main text describes the development of the electronic detonator in 2005 and its precision. To the right, a photograph shows a person's hands holding a yellow cable connected to a cylindrical electronic detonator. At the bottom, there is a blue footer with logos for IIT Khargapur and NPTEL, along with the name and department of the speaker, Dr. Kaushik Dey.

But, later on it has been found that there are some problem with this pyrotechnic delay detonators. So, first problem is that if the manufacturer is claiming this detonator will

give you a 25 millisecond delay on the practical is it has been found that deviations are significantly large and 25 millisecond delay detonator may blast at 16 millisecond or may blast at 34 millisecond also. So, the deviations has been found it is high because mainly of to reason, the first reason is that it is a chemical material and the manufacturing of that chemical inherently having some heterogeneity in it is mixture. So, as the chemical is not consistent property the heterogeneity is there. So, that is why the burning rate is different.

So, burning rate changes from day to day manufacturing of that chemical and as that chemicals are being used in the detonator their delay timings, their burning timings are become different and that is why deviations are coming on that. To avoid these in 2000 in 1995 electronic delay detonator has been developed sorry it is mistake is there this is 1995. So, in 1995 electronic detonator was developed where the delay is provided by the electronic delay. And it has been found the delay can be said through the pogrom and the delay is having an accuracy of plus minus 1 millisecond.

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Let us see the construction nitty-gritty of this; you can see the delay detonator the delay detonator of electronic type basically taking the current from the lead wire. Then in that current there is a delay module provided ok; that means, it is the electronic delay programming said that the delay is provided in the movement of the electrical pulse.

And the basically the delay is electrical pulse delay prior to reaching it at the fuse head; that means, delay is provided in the electrical system instead of the burning system. And that is why this electrical delay through electronics programming it is provided and the fuse head the is getting the electrical pulse after that delay. Then the fuse head is giving the flame then the primary charge base charge is doing their respective work.

So, basically earlier in the pyrotechnic delay where the delay is provided by burning of the chemical, but here the delay is provided in the electrical pulse; that means, the electrical pulse is reaching with that particular delay to the fuse head. So, that much modification is carried out here and that is the constructional feature of the electronic detonator. And it has been found that the electronic system is very very sophisticated one, plus minus 1 millisecond delay can be achieved that is the plus point. Second point is the delay is now programmable as it is electronically said; that means, any delay can be programmed on the site itself.

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Electronic Delay Detonator	Pyrotechnique delay detonator
<ul style="list-style-type: none"> ✓ ± 1 ms accuracy in delay ✓ Extremely costly [not that manufacturing cost is high] ✓ Requirement of logger and huge cable connections ✓ Misfire chance is low 	<ul style="list-style-type: none"> ✓ Low precision ✓ Inherent Scattering in the delay interval ✓ Effect of physical factors in blasting such as length of time since manufacture, temperature and pre-conditioning by stress pulses from surrounding holes. ✓ Manufacturing defects

So, that is why that much benefit is that much benefit is observed in this case. So, now let us have a quick comparison about the electronic delay detonator and the pyrotechnic delay detonator. In electronic delay we are having plus minus 1 millisecond accuracy. But, pyrotechnic delay is very very low precision you we will see the deviation of the pyrotechnic delay in the next slide. But, electronic delay is little bit costly presently if you observe this these are costing around 700, 1200, 800 rupees per piece whereas,

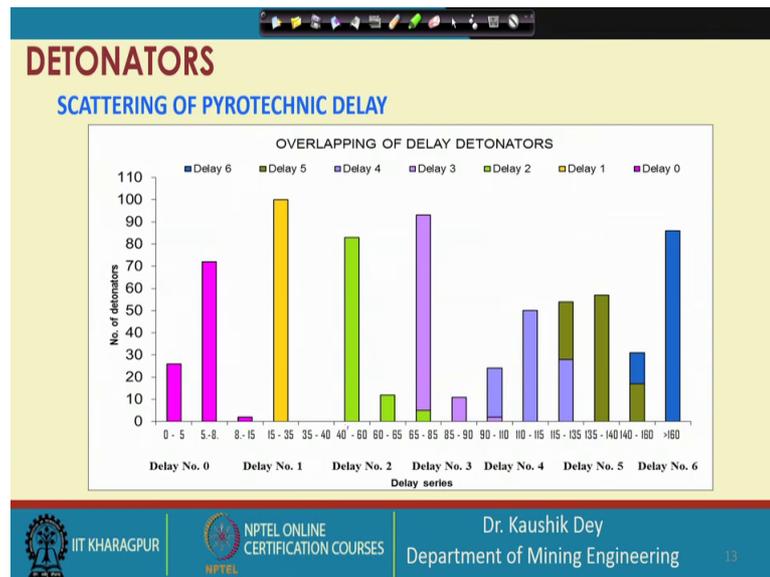
pyrotechnic delay detonators may be 5 rupees, 10 rupees like that cost are there. So, it is not that much costly.

However, the manufacturing cost of this electronic detonator is not very high, these cost is coming because of the technological development cost. So, it will become very less with the time frame. second is that electronic delay detonator require a logger and the cable connections those in the blasting those cable connections are will be destroyed. So, that is why the cable requirements are there and cable costings are more. But, another significant advantage is there in the electronic delay detonator that is the chances of misfire is almost 0 it is returned here low, but I claim it is almost 0.

So, that is why electronic detonator is very very superior though it is as presently unit price wise it is absorbed it is a little bit costly, but it is benefit as is very very high. So, electronic detonator delay detonator is very very at a advantageous point over the pyrotechnic delay. Because, the pyrotechnic delay is of low precision, it scattering is not within the control of the user. It may be scattered on either side of the designated delay time.

The physical factors in blasting such as length of time then etcetera are having significant role on the performance of this detonator say as with the time these chemicals are being not off to the quality as it is it is in the manufacturing time. So, in the time it is quality became deteriorated and the performance became deteriorated. So, that is why this is difficulties and manufacturing defects are very very high in this pyrotechnic delay detonators.

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So, let us see some already tested scattering of the pyrotechnic delay detonators how it is scattering. Say pyrotechnic delay detonators this testing's are carried out in the CIM for lab. And if you see these testing's are carried out with short delay detonators of number 1, number 2, number 3, number 4, number 5, number 6 and it has been found there is a huge scope of overlapping of these detonators. That means some detonators which is of 50 ms delay detonator may blast in between 65 to 85 millisecond. Simultaneously, some detonators which is of supposed to be blasted at 75 millisecond are being blasted at 65 to 85 millisecond.

So, that is why if some user is using in first hole the number 2 delay detonator that is 50 ms delay detonator. In the other hole the number 3 delay detonator that is the 75 ms delay detonator, it may happen that the number 3 delay the whole having the number 3 delay will be blasted ahead of the number 2 delay which is not as per the design requirement. So, there are chances where the overlappings may occur and wherever the overlapping occurs in those cases there is a chance that the lesser delay number will be blasted after the larger delay number.

That means, as per the design the hole which is supposed to be blasted ahead of the other hole the other hole may be blasted ahead of the first hole. So, those problems may occur whenever people are using this type of cases. So, this is very very difficult situation and

in pyrotechnic delay detonator this cannot be avoided and the chances blasting is carried out with this type of probabilities.

So, if anyone is having any one is having a scope of using a scope of using some less number of delays he can opt for the jumping delays. That means, he can opt for number 2 delay he then instead of number 3 opting for number 3 delay, he may opt for number 4 delay, then the chances of overlapping of the pyrotechnic delays may be avoided. But, often the that scope is not possible it is a supposed with the blast design it is expected that he must use all the delays.

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The slide is titled "DETONATORS" in large red letters. Below the title is a blue header "Recent Developments in Detonator Technologies". The main content is on a yellow background. It lists "Nano-material based delay element" with sub-points: "Cu tube", "Al tube", and "Fe tube". A handwritten box around "2005" is positioned above the text "Wireless/remote controlled electronic detonators". To the right is a 3D rendering of a detonator tube with a handwritten "latest" next to it. The bottom of the slide features logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, along with the name "Dr. Kaushik Dey, Department of Mining Engin" and a small video feed of the speaker.

So, this is one major problem with the pyrotechnic delay elements pyrotechnic delay detonators and in those cases the electronic delay may be a better option than the pyrotechnic delay detonators. If you see the recent development in the detonator technology people are trying to use nano material based delay elements. Say the tube of the detonator that is another very important factor, initially when it was developed the tube was kept copper tube so that it is considered to be the conductive one, but the copper is a costly material.

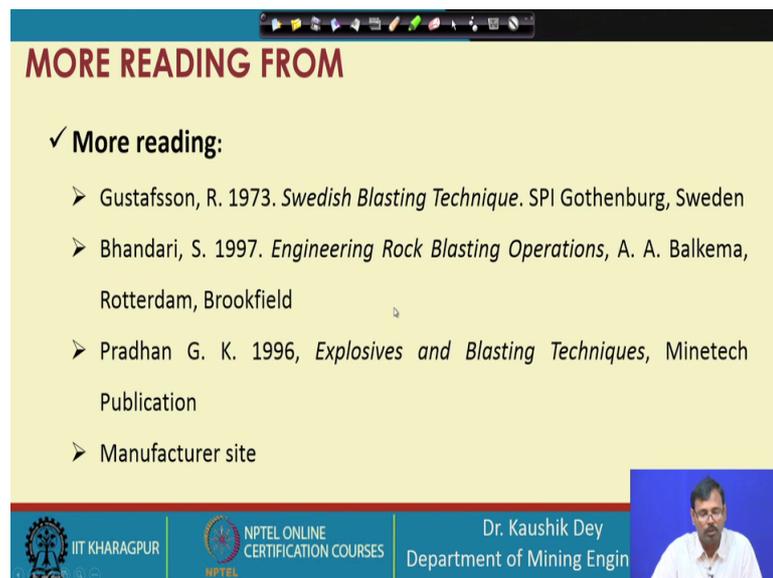
So, later on copper is replaced with the aluminum and nowadays we are having the option that the iron based tube Fe tubes are also available. So, basically using those tubes the prices of the detonators are reduced, but the we are achieving the same performance from the detonators. Another recent development has been carried out from 2005 onward

2005 onward the wireless detonator. So, this wireless detonator it is now commercially available also, where there is more lead wire is required. It is electronic based a detonator.

The, you have seen the drawback in the electronic detonator is that huge number of cables are required which are being destroyed during the blasting operation. So, that cable cost are very high, but this wireless detonator it is remote controlled the signal will be given from the wireless device and the detonator is receiving the signal and after receiving the signal it is exploded the explosive.

So, that is basically reducing the cable wire cost, but we are achieving the same performance. So, this wireless electronic detonator is the most latest detonator most latest detonator commercially available in the market. So, basically this is more or less about the detonators.

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MORE READING FROM

✓ **More reading:**

- Gustafsson, R. 1973. *Swedish Blasting Technique*. SPI Gothenburg, Sweden
- Bhandari, S. 1997. *Engineering Rock Blasting Operations*, A. A. Balkema, Rotterdam, Brookfield
- Pradhan G. K. 1996, *Explosives and Blasting Techniques*, Minetech Publication
- Manufacturer site

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And we will stop this class at this point there are other accessories you have seen in the last class where we have discuss the different accessories detonating fuses are there, detonating cords are there, NONELS are there, safety fuse are there. We will discuss about those accessories in the next class, but again it is desired that those who are attending this course should go for more reading from this more reading from these references. And I have again request you to visit the different manufacturers site to learn more from this learn more from this lecture.

Thank you.