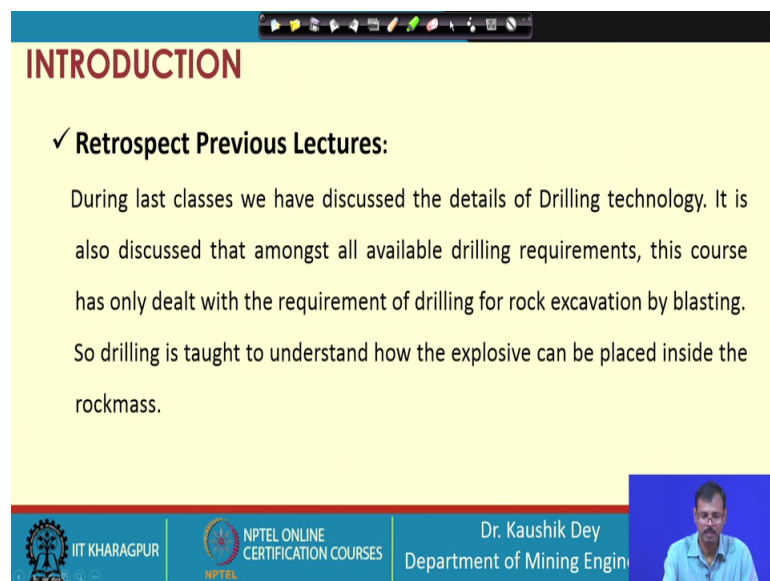


**Drilling and Blasting Technology**  
**Prof. Kaushik Dey**  
**Department of Mining Engineering**  
**Indian Institute of Technology, Kharagpur**

**Lecture – 16**  
**Explosives-1**

Let me welcome all of you to the 16th lecture of Drilling and Blasting Technology course and so far, most of the time we have covered the different aspects of drilling.

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**INTRODUCTION**

✓ **Retrospect Previous Lectures:**

During last classes we have discussed the details of Drilling technology. It is also discussed that amongst all available drilling requirements, this course has only dealt with the requirement of drilling for rock excavation by blasting. So drilling is taught to understand how the explosive can be placed inside the rockmass.

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Mainly in this, we have covered the last classes, we have discussed the details of drilling technology. And you know why we have discussed this drilling technology because, it is the most suitable way to place the explosive inside the rockmass. That means, in this if you are considering the drilling technology, this drilling technology is being talked in this course only to show you how you can place the explosive inside the rockmass, so that the explosive can be exploded for excavate the rock.

That means, the ultimate objective of this course is to excavate the rock by drilling and blasting method and to place the explosive inside the rock, we have to provide some means of small excavation, small pockets and that pockets is being drilled by the use of drilling technology. So, far all the 15 lectures is taken to make you understand how you can carry out the drilling process to place the explosive inside the rockmass. So, I expect that from the previous lecture, you already accustomed that how you can go for the

drilling and how you can place the explosive as per your wish inside the rockmass. Now, placing of explosive is not the problem inside the rockmass.

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But still you do not have any good knowledge how the blasting can be carried out by using the explosive.

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So, let us let us have some videography on that. You can see how the explosive which you cannot see previously because, it is inside the rockmass.

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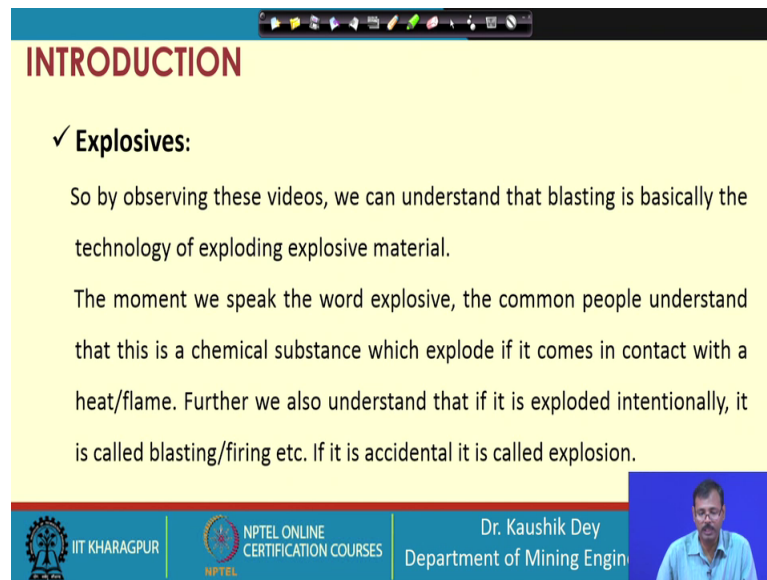
**INTRODUCTION**

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So, if you look into this see, the phase again, there is no trace of explosive because explosives are drilled and through this drilling, explosives are placed inside the rockmass. So, we cannot see this and you place this explosive inside the rockmass, then you keep yourself away from that place.

So, you initiate your explosive from that remote place, so that you can be safe and this explosive is being exploded. If you explode the explosive, if you explode the explosive, then you can see how the rocks are being fragmented on the explosion. So that means, basically blasting is the art of detonating the explosive, blasting is the art of detonating the explosive, explode the explosive while the explosives are placed judiciously inside the rockmass and on release of the energy from the explosives, the rocks are being fragmented.

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**INTRODUCTION**

✓ **Explosives:**

So by observing these videos, we can understand that blasting is basically the technology of exploding explosive material.

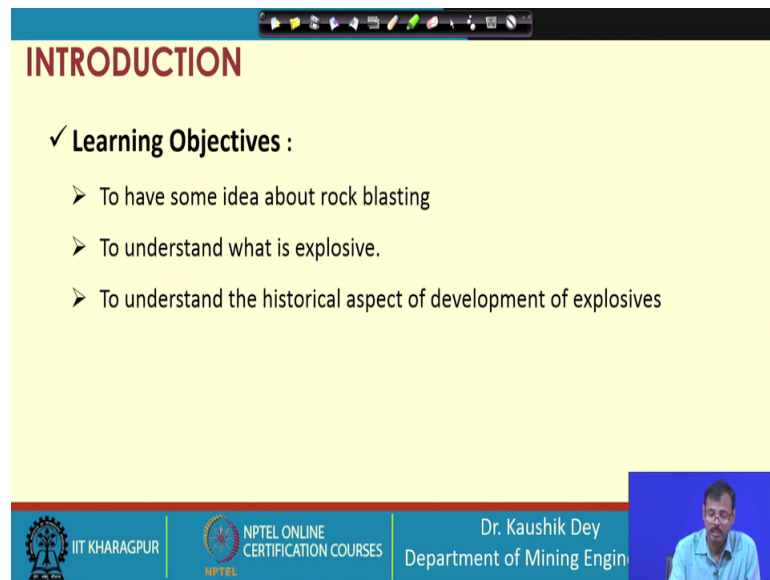
The moment we speak the word explosive, the common people understand that this is a chemical substance which explode if it comes in contact with a heat/flame. Further we also understand that if it is exploded intentionally, it is called blasting/firing etc. If it is accidental it is called explosion.

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So basically, so basically, we are using the explosive for exploding the rockmass. So, now, let us understand what is explosive, because our commonsense says, whatever crackers we are using that is the explosive say which is in the mouth of the mastic is explosive, but how the explosive can be technically defined if something is burning whether that will be called explosive, these confusions are there. If something is burning, say coal is being burning, wood is being burning, but can it be called explosive? No, these are not explosive. But essentially, explosive should have some property and that is why this is so much devastating, so much dangerous.

So, we should understand what is explosive and in doing so, I believe that you are able to understand the blasting is carried out by exploding the explosive. And the moment we speak the word explosive, the common people understand that this is a chemical substance which explode if it comes in contact with the heat or flame, but this is the common people understanding. This is not always the truth. Further you also understand that if it is exploded intentionally, it is called blasting. If it is accidentally exploded, then it is called explosion. So that means, you are under understanding; now that explosion is the unwanted exploding of the explosive.

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**INTRODUCTION**

✓ **Learning Objectives :**

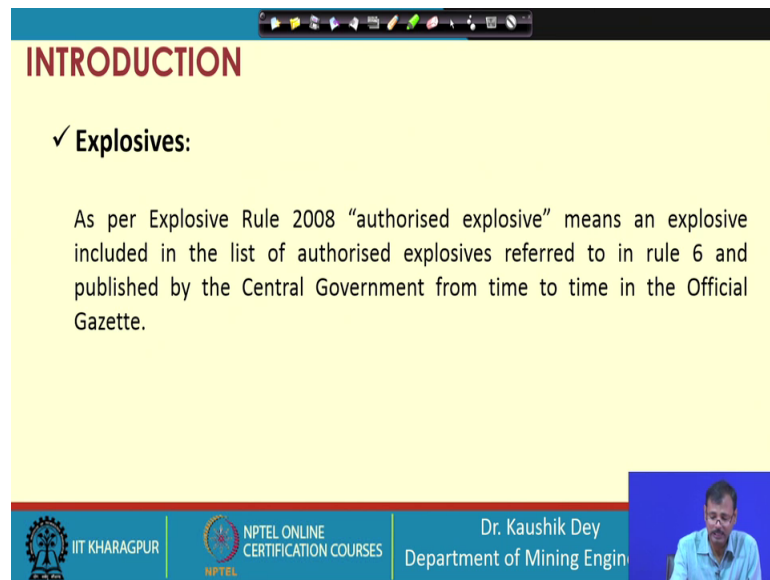
- To have some idea about rock blasting
- To understand what is explosive.
- To understand the historical aspect of development of explosives

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Department of Mining Engineering

And if we are willing to do that one, that is called blasting or firing, say military people are carrying out firing, mining people carried out blasting and other people if unintentional doing that, it is called Explosion. So, what is the learning objective of this today's class? In fact, today's class today's in this lecture we have to gather some idea about the rock blasting because we have seen in the video that the explosives are placed inside the rock and that by that release of that energy from that explosive we are able to blast the rock.

In this class, we will also understand what is explosive. And we will understand the historical aspect of development of explosive. In fact, people have spent throughout their life for improving the explosive for inventing the new explosive and those are basically the essential requirement which was asked by the industry.

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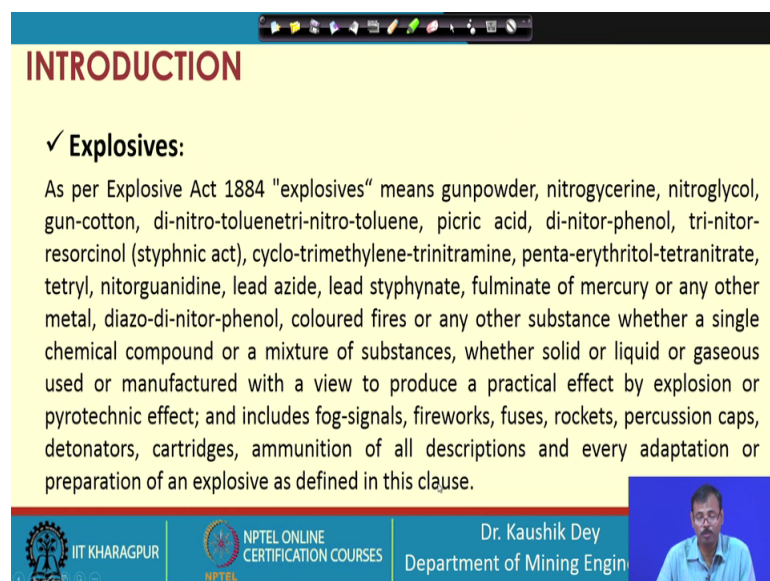
**INTRODUCTION**

✓ **Explosives:**

As per Explosive Rule 2008 "authorised explosive" means an explosive included in the list of authorised explosives referred to in rule 6 and published by the Central Government from time to time in the Official Gazette.

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**INTRODUCTION**

✓ **Explosives:**

As per Explosive Act 1884 "explosives" means gunpowder, nitroglycerine, nitroglycol, gun-cotton, di-nitro-toluenetri-nitro-toluene, picric acid, di-nitor-phenol, tri-nitor-resorcinol (styphnic act), cyclo-trimethylene-trinitramine, penta-erythritol-tetranitrate, tetryl, nitroguanidine, lead azide, lead styphynate, fulminate of mercury or any other metal, diazo-di-nitor-phenol, coloured fires or any other substance whether a single chemical compound or a mixture of substances, whether solid or liquid or gaseous used or manufactured with a view to produce a practical effect by explosion or pyrotechnic effect; and includes fog-signals, fireworks, fuses, rockets, percussion caps, detonators, cartridges, ammunition of all descriptions and every adaptation or preparation of an explosive as defined in this clause.

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So, basically we should understand what is explosive first, how it is technically called explosive, then we will go into the details of the historical perspective of the development of the explosive. So, first let us see what is explosive. As per explosive rule 2008 authorized explosive means an explosive included in the list of authorized explosive refer to the rule 6 and published by the central government from time to time in the official Gazette. So, this is the legal term of explosive; that means, legally a substance is called explosive, authorized explosive if it is listed in the government circular.

So, this is the legal term. And I believe that any student may not draw any conclusion from this term which one will be listed, which one will not be listed. Then let us see at the: what Explosive Act, 1884 is telling about explosive. Explosive Act, 1884 tells explosive means gunpowder, nitroglycerin, nitroglycol, gun-cotton, di-nitro toluene, tri-nitro-toluene, picric acid, di-nitro-phenol, tri-nitro-resorcinol, cyclo-trimethyl, tri trinitramine, penta-erythritol, tetranitrate, tetryl, nitro guanidine, lead azide, lead styphnate, fulminate of mercury, fulminate of other metals, nitro phenols.

These are the different chemicals it is listed in the Explosive 1884 or mixture of substance whether solid or liquid or gaseous used or manufactured with a view to produce a practical effect by explosion or pyrotechnic effect and includes fog signals, fireworks, fuses rockets, percussion caps, detonators, cartridges, ammunition of all descriptions and every adaptations or preparation of an explosive as defined in this clause.

So that means, again it is the host of different name of mineral and also it is including those minerals which can act as the explosive matter explosion the which can cause explosion can be considered as explosive. That means, if someone is looking at the technical destination of the explosive, our Explosive Act 1884, Explosive Rule 2008, is unable to provide a technical, good technical definition of explosive which can give some something in the mind of the student.

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**INTRODUCTION**

✓ **What is Explosives:**  
Explosive can be defined many way –  
A substance, that when subjected to a suitable stimuli, undergoes a violent chemical decomposition with the evolution of heat and gas (Stephen Miller)  
**OR**  
A material containing stored chemical energy, which can be rapidly released in the form of heat and high pressure gas, when triggered to do so  
**OR**  
Explosive is a chemical substance (sometimes may be a mixture of fuel and oxidizer) which releases huge quantity of shock and gas energy instantaneously on triggering by a detonation or so (Dey)

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So, let us see what different other researchers are telling. Some researchers specially, mister doctor Stephen miller, he is defining explosive as a substance that when subjected to a suitable stimuli undergoes a violent chemical decomposition with the evolution of heat and gas. So, basically Stephen miller is trying to tell you that a chemical substance, the moment you are giving a stimuli, the stimuli may be heat, the stimuli may be shock, the stimuli may be flame thus whichever it is if the stimuli is given to it, it can violently decompose and in this decomposition must be exothermic so that it will produce heat it must be it must produce gas so that, the gas will expand in the heat and create huge pressure.

So that means, it he is telling about the chemical which can be exploded to release the heat and gas. And another definition might be a material containing stored chemical energy which can be rapidly released in the form of heat and high gas pressure when triggered to do so. That means, the essential requirement of an explosive which can be commercially allowed or which can be authorized to allowed for the public use must have some control over it; that means, the triggering of the explosive must be within the control limit of the user.

So, the second definition which is given here, here it is told that the chemical energy that is the chemical substance which is releasing the energy in form of heat and the gas pressure when it is asked. But if someone ask me, I believe that explosive may be defined in some different way and this definition may be, explosive is a chemical substance often it may be a mixture of fuel, oxidizer something like that.

So, it is a chemical substance which release huge quantity of shock and gas energy instantaneously on triggering by a detonation or so. That means, it is essentially required that triggering must be within the control of the user, the chemical is there which is not only releasing the heat and gas that may also release the shock. In fact, nowadays people are trying that the explosive should be invented in such a manner the gas quantity, heat quantity may not be that much, but the shock quantity should be significant.

So that means, one property of the explosive should be that it is it should release the shock, apart from that it may release the gas energy also it may release, the heat also, but all these things should be released instantaneously. In fact, an explosive is so dangerous because it is energy easily being released instantaneously. This part is very very



important that means, the reaction time must be less almost instantaneous so that the energy can be released instantaneously.

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The slide is titled "INTRODUCTION" and compares a candle and an explosive cartridge. On the left is a lit candle, and on the right is a white explosive cartridge. A red box contains the following text: "8 times more heat energy", "4 times more gas generation", and "50000 times more reaction time". The slide footer includes the IIT KHARAGPUR logo, NPTEL ONLINE CERTIFICATION COURSES logo, and the name Dr. Kaushik Dey, Department of Mining Engineering. A small video inset of the speaker is visible in the bottom right corner.

If you go through the next slide probably, it will be more clear to you, see there is a candle, you can see in the left side there is a candle right side, there is an explosive cartridge. So, suppose you are taking one piece of candle say 100 gram of candle and you have taken one piece of explosive, 100 gram of explosive and you want to see which one is more dangerous, how much energy they are releasing and if you compare these two see their explosive reactions, see the how much heats are being generated, how much quantity gases are generated from each and if you are trying to calculate those things, if you will find that the candle is generating 8 times more heat energy than an explosive of similar weight.

If you measure these things, again you will find out candle is generating 4 times more gas quantity than the explosive is generating; that means, the gas quantity is more in the candle, heat energy released from the candle is more, but no one is fearing to lighting the candle. Everyone light can hold the candle when it is lit enough, no one is fearing on that, no one can use that the is the candle for breaking up the rocks, no one can use the candle to kill someone, but people are using explosive to kill someone, people are using explosive to blast the rock, people are using explosive to blast the building.

So, why explosive is dangerous because the candle is also taking 50000 more time for this reaction. That means, 8 times more heat energy is released, but that heat energy is released in 50000 more time duration. That means, instantaneously release of heat energy is very very insignificant in case of candle if you are considering the same for the explosive. So that means, the explosive is dangerous because it is energy is being released almost instantaneously that the reaction time is very very less. The energy stored is high; the high energy is being released almost instantaneously. So, that is why explosive is becoming so dangerous.

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**HISTORY OF EXPLOSIVES**

✓ **Gun Powder:**

- The Chinese first discovered and used explosives in the 3<sup>rd</sup> century B.C.
- Roger Bacon perfected the formula for gun powder in the 12<sup>th</sup> century (1242). Berthold Schwartz invented Gun in the 13<sup>th</sup> century.

75%	15%	10%
Potassium Nitrate	Charcoal	Sulfur
$\text{KNO}_3$	$\text{C}$	$\text{S}$

A SIMPLIFIED EQUATION FOR THE BURNING OF BLACK POWDER

$$10\text{KNO}_3 + 8\text{C} + 3\text{S} \rightarrow 2\text{K}_2\text{CO}_3 + 3\text{K}_2\text{SO}_4 + 6\text{CO}_2 + 5\text{N}_2$$

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Now, let us look into the historical perspective of the explosive. As you know Gunpowder, the common use of Gunpowder is in the crackers where commonly we use gunpowder wrap it with something and then we use a flame provide a flame and you find that gunpowder is being exploded. That means, it is burns instantaneously the heat energy released shock energy released creates the sound and light and we enjoy that sound and light and if you look into the history, this is the first explosive which was discovered in the third century before crashed by the Chinese people.

And you know this Chinese people; they usually worship the dragon etcetera. So, fire coming up from dragon for this purposes they have discovered gunpowder and they use the gunpowder for worshipping dragons etcetera. So, that was utilized by the invented by the Chinese people, utilized by the Chinese people and they concealed the gunpowder

technology amongst them since twelfth century Europeans stolen that one and roger bacon perfected the formula of gunpowder during the twelfth century.

So, first time this was stolen from the Chinese to the Europe and then the Europe started using the gunpowder and this time the use was different. It is not for the worshipping this is the use of the gunpowder was carried out for the battle fighting in the battles. The first gunpowder was started using in the artilleries where that artilleries are being fired using the gunpowder.

So, now the use of the gunpowder is being changed from the worshipping to the battle and later on it is transferred to the mining purpose in the 16th century. So, what is Gun Powder, let us look at that it is basically the nitrate either potassium or sodium nitrate mixed with the charcoal or carbon or sulfur. So, to react them instantaneously and which will generate the nitrogen, carbon dioxide like that and the sulfate and carbonate of the metals.

So, that was the basic use basically here the charcoal is given, of carbon is given as the which can be oxidized by the nitrate and sulfur is given for the increase the sensitivity of the gunpowder. So, basically these two are used and oxidizer is the nitrate and this is very very commonly used in the old days.

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**HISTORY OF EXPLOSIVES**

✓ **Gun Powder:**

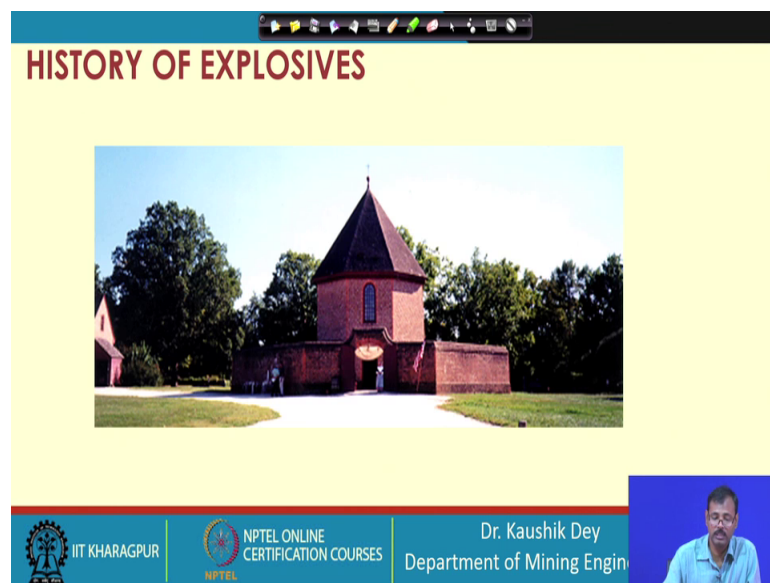
- Use of gun powder to loosen and fragment the rock in the mining began during 17<sup>th</sup> (1600s) century in Europe.
- Colonial Williamsburg, Verginia, 1715 this magazine was built to store the Gun powder. The first magazine of the history.

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And that was the only explosive say for a long period. So, gunpowder for loosening and fragmentation of rock is carried out in the 17th century. In fact, 1647 or something like that, in Europe and later on it is used in throughout the world for mining purpose till some high explosives has come out and our friend Alfred Nobel discovered the dynamite, before that gunpowder was the only explosive which was used for loosening or fragmenting the rock.

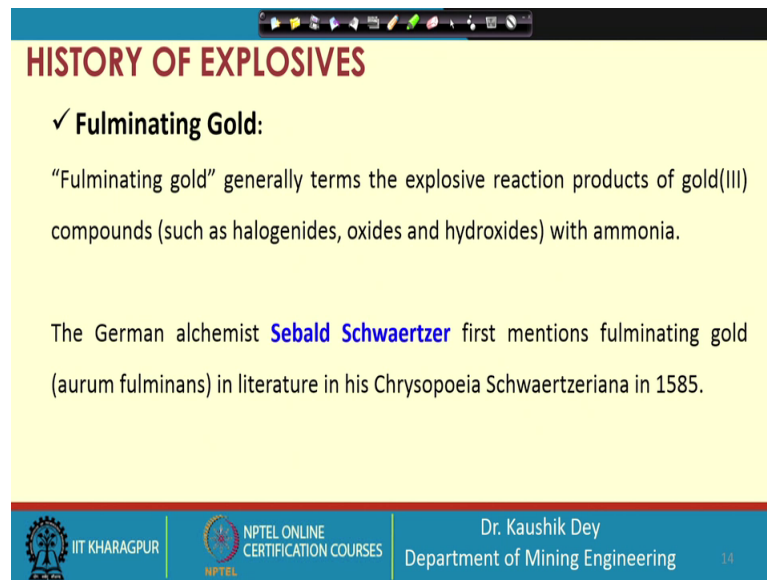
You commonly know that where the explosive are stored is called Magazine. So, the first magazine was set for storing the explosive in 1715 in the colonial Williamsburg Virginia where the first magazine was set. And again, you remember this magazine was set as the magazine for fighting the battle well while the battle was being carried out between the whites and the blacks in USA. So, this magazine was made to store the explosive and ammunition in the 1715.

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Now, this is a famous tourist spot and this is the first magazine of the world. So, I am very much interested to show you because this the these are.

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**HISTORY OF EXPLOSIVES**

✓ **Fulminating Gold:**

“Fulminating gold” generally terms the explosive reaction products of gold(III) compounds (such as halogenides, oxides and hydroxides) with ammonia.

The German alchemist **Sebald Schwartzer** first mentions fulminating gold (aurum fulminans) in literature in his Chrysopoeia Schwartzeriana in 1585.

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The development of the explosive, but first time the explosive made for inventing the explosive is the explosive which is called fulminating gold. It has been found while people are using gunpowder, the gunpowder has to be litten up with a flame and the moment if the gunpowder is moisty or the rainy situation you cannot go for exploding the gunpowder.

So, people found that there must be some other explosive which can be used for this type of cases where water or moisture should not be a problem. On this search, German alchemist he has accidentally developed the first man made explosive that is fulminating gold which is not only the man made of explosive by strength. This is very very high explosive as compared to the gunpowder.

But he has developed this in 1585 but the problem was found that though the explosive is developed, but how to use that explosive was not able to be known to the all the persons; so, no people got that idea that fulminating gold or mercury gold which have developed is explosive, but the commercial use of that explosive was not possible.

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**HISTORY OF EXPLOSIVES**

✓ **NG and TNT:**

Nitroglycerin (NG) was discovered by Ascanio Sobrero in 1846. Nitroglycerin is a mix of nitric acid, sulphuric acid, and glycerol.

$$\begin{array}{c} \text{CH}_2 \cdot \text{ONO}_2 \\ | \\ \text{CH} \cdot \text{ONO}_2 \\ | \\ \text{CH}_2 \cdot \text{ONO}_2 \end{array}$$

$\text{C}_3\text{H}_5(\text{ONO}_2)_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 + \text{O}_2$

(now Balance it)

$4\text{C}_3\text{H}_5(\text{ONO}_2)_3 \rightarrow 12\text{CO}_2 + 10\text{H}_2\text{O} + 6\text{N}_2 + \text{O}_2$

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So, still gun powder was the explosive used being used in the mine, but people are in search of different explosive. So, nitroglycerin was discovered in 1846. So, there is a long gap after fulminating gold which is accidentally discovered by the alchemists. You know this alchemist they were searching for the gold by mixing different chemicals. So, in that searching, he developed that explosive, but that use of that explosive was not possible at that time. Only it was in the knowledge domain that that explosive is possible.

But nitroglycerin was discovered as the explosive material and people has discovered it again they could not use the explosive for their purpose. And this is the chemical formula of the nitroglycerin and it has been found that if a shock is provided to this nitroglycerin, nitroglycerin disintegrates chemically reacted almost instantaneously in that shock and it explores to form carbon dioxide, water, nitrogen and oxygen almost instantaneously releasing huge quantity of shock and this shocks are such high it killed a number of persons. That means, if someone is having nitroglycerin, a test tube full of nitroglycerin as it is liquid and dropped that test tube from it is hand onto the table or onto the floor, all the persons standing nearby may die on that explosion.

It is such devastating explosive. So, anyway nitroglycerin is discovered, but still the problem is that no one knows how to use this nitroglycerin for the commercial purpose, the commercial use. Still that is the challenge to the explosive users and explosive users try to try their hard to develop some means.

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**HISTORY OF EXPLOSIVES**

✓ **NG and TNT:**  
TNT or Trinitrotoluene was invented by German chemist Joseph Wilbrand in 1863.

Upon **detonation**, TNT decomposes as follows:

$$2 \text{C}_7\text{H}_5\text{N}_3\text{O}_6 \rightarrow 3 \text{N}_2 + 5 \text{H}_2\text{O} + 7 \text{CO} + 7 \text{C}$$
$$2 \text{C}_7\text{H}_5\text{N}_3\text{O}_6 \rightarrow 3 \text{N}_2 + 5 \text{H}_2 + 12 \text{CO} + 2 \text{C}$$

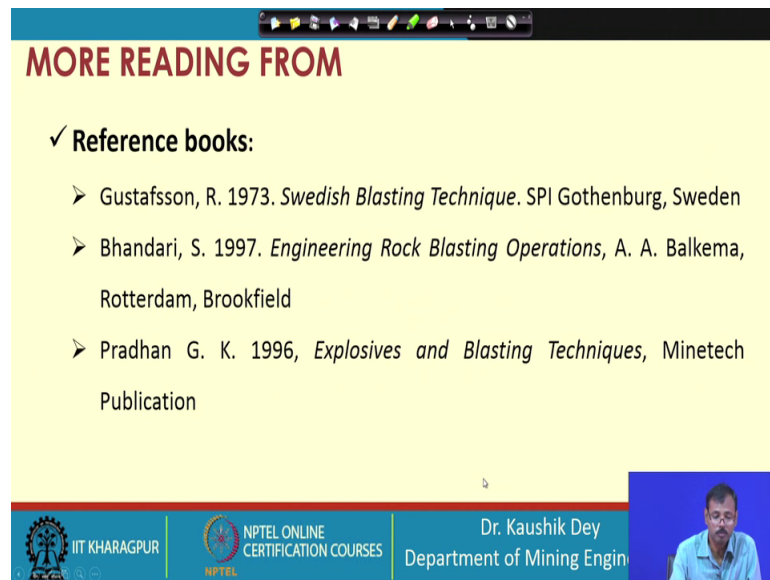
The slide also features a chemical structure of TNT (2,4,6-trinitrotoluene) and a small video inset of Dr. Kaushik Dey, Department of Mining Engineering, IIT Kharagpur.

To use the this type of explosives. Again trinitrotoluene that is TNT was developed in 1863 by the German chemist Joseph Wilbrand. And again it has been found this is also very explosive and this produced on explosion it produced nitrogen water carbon monoxide or oxides of carbon and unburned carbon molecule or oxides of different oxides of carbon-carbon dioxide, carbon monoxide like that.

On chemical reaction releasing huge shock, but then also it has been found none of this nitroglycerin, none of this TNT are sensitive to flame, but they are sensitive to shock. So, if the shock is provided to these explosives, they can be initiated otherwise they cannot be initiated by the flame and no one knows the technology how to initiate these explosives while it is intend to be used for the commercial purpose. So, that is the difficulty though the explosives are developed, the use of the explosives are not known to the human being. Specially, there is another problem with the nitroglycerin that it is liquid. In fact, it is very good explosive very high energy explosive, but the transportation of this is also very difficult.

TNT is the powdered form that is not that much difficult transportation, but the initiation of the TNT is difficult. Nitroglycerin initiation is not difficult because a little bit shock can initiate it, but anyway none of these are and within the control of the human being.

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**MORE READING FROM**

✓ **Reference books:**

- 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

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So, they cannot use these things in as per their wish in the commercial purpose, in the industrial purpose. So, complete Europe was in search of some techniques which can be used for the commercial use of these developed explosives. We will continue this historical perspective of the development of explosive; we will know how this can be how this can be utilized, how this can be utilized as per the intention of the human being.

In the next class we will discuss all these things, but before that I wish all who are attending this course, should have some reading on these reference books Gustafsson books, Bhandari books and GK Pradhan's books, these books so that, they can have some idea about the different explosives, composition of these explosives and mainly the properties of this explosives.

See, so far whatever we have discussed, you can see the first one is the gunpowder, gunpowder is not that much dangerous of dangerous explosive because you people are also using that explosive, you people are also using that explosive in during the while you are using the crackers. So, it is not that much dangerous if it is a exploded in your hand also, it is not creating a little bit burn may be created, but not that much danger thing occur.

So, its effect is limited, but it is a weak explosive. So, gunpowder is a weak explosive that is why those who are willing to use explosive for commercial purpose by for breaking the rocks, for breaking the structures, they want some high energy explosive



high shock energy which can be utilized for that. And that is why they have developed different explosives TNT, nitroglycerin, fulminating gold, but they yet not achieved any control over using those explosive.

In fact, during that time all a number of scientists who are using the who are working with nitroglycerin, TNT, fulminating gold died on experimentation because though those exploded immaturely and killed the all those scientists. That is the huge loss to the scientific community while they are they lost their life during the scientific investigations, but still people have carried out and finally, win over the technology which we will discuss in the next class.

Thank you.