EXPLOSIVE

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NOTES ON

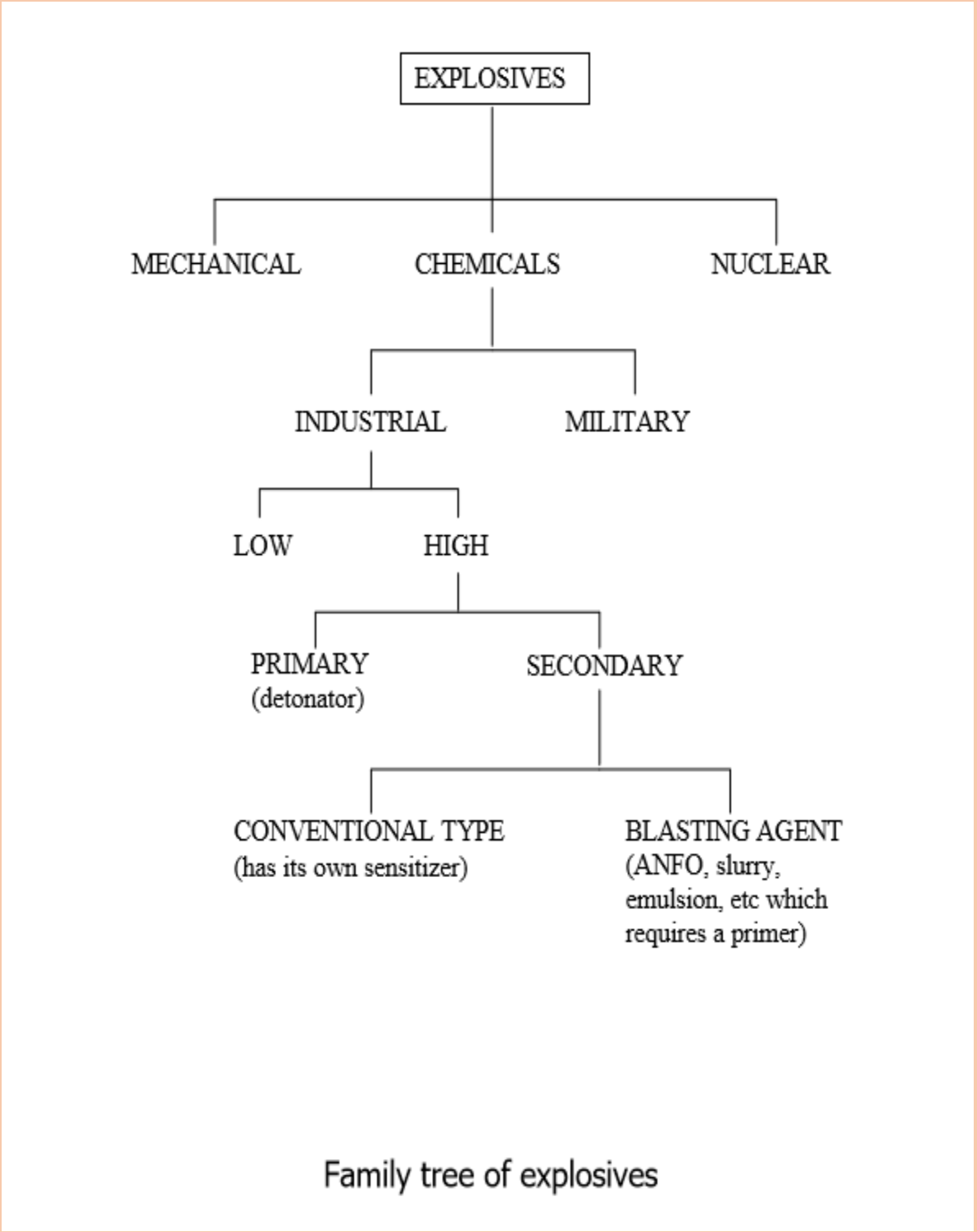
Development of safe explosives; permitted explosives; composition and testing of safe explosives; Milli-second detonators; alternatives of explosives. Use and safe handling of explosives in coal and stone drivages in gassy and non-gassy mines; blasting techniques and their relative efficiency, total cost concept.

EXPLOSIVES

Brief Introduction to Explosives

What is an explosive?

An explosive can be solid, liquid or a mixture of substances. When a suitable stimulus, (e.g. electric, flame, spark, percussion) is applied to the explosive substance it is capable of developing a sudden high pressure by the rapid formation or liberation of stable gases at high temperatures.



Family tree of explosives

Making Explosives

Factory made explosives are usually manufactured by a batch process.
Blasting problems may be the result of faulty explosives provided by the manufacturer, however most problems are due to poor rotation of explosives (i.e. storing for too long).
The manufacturers of explosives ensure that their products have a date of manufacture painted on the cases and packages just for effective stock rotation in the magazine. For example some shelf lives are follows:

	Maximum period
Delay electric detonators	2½ years
Detonating cord	4 years
Emulsion explosives	12 months

Low Explosives

A low explosive is generally defined as one which does not require a detonator to initiate it. This type of explosive is normally set off by a flame, heat, or a spark which is provided by the spit of a safety fuse, a wick or an electric fusehead
Black powder or gun powder is classified as a low explosive and it is a mechanical mixture of ingredients (do not combine chemically to form a new compound) where none of the ingredients is an explosive in itself. It is a mixture of charcoal, sulphur and potassium nitrate.
Black powder does not produce shock wave but burn rapidly producing large quantity of gas.
A simplified reaction is as follows:

$$2KNO_3 + S + 3C \longrightarrow K_2S + N_2 + 3CO_2$$

potassium nitrate — sulhur — charcoal — Potassium sulphide — nitrogen — Carbon dioxide

High Explosives

High explosives detonate at velocities which vary between 4,000 and 7,500 m/s depending on their composition, densities, degree of confinement, diameter etc.

They produce large volume of gas with the reaction being exothermic and consequently the temperatures of detonation are extremely high.

These explosives require a shock wave to initiate them and this is provided by a detonator. When confined in a drill hole, the explosive on detonation produces extremely high pressure gases which impart energy in the form of shock and heave into the surrounding rock.

The performance of a high explosive depends upon the volume and temperature of the gases produced and on the velocity of detonation (VOD).

Type of Explosives

Gelignites

An explosives that is based on nitroglycerine (NG), are manufactured in gelatinous or semigelatinous form.

For underground coal mine, a "permitted" or "permissible" type of explosives, so as to be safe from coal dust or methane gas explosion. This is achieved by adding sodium chloride (15% to 40%).Because of their relatively high cost and stricter safety requirements, the use of gelignites in the mining industry is decreasing.

Ammonium nitrate – Fuel Oil (ANFO)

Neither ammonium nitrate nor fuel oil is classified as explosive, but when mixed in correct proportion, the result is an effective blasting agent.

$3NH_2NO_3 + CH_2$ ___ $3N_2 + 7H_2O + CO_2$ ___ (3900 kJ/kg) (Ideal – 94.3% AN: 5.7% FO)

ANFO cannot be detonated by a detonator. It needs a primer i.e. a high explosive with a detonator.

Watergels

This group of explosives is sometimes referred to as slurries. Watergels were developed to overcome the deficiencies of ANFO in wet conditions. They consists of a mixture of:

a) gel base, with
b) ammonium nitrate, and sometimes
c) aluminium powder

Emulsions

Fine droplets of oxidizer salts such as ammonium, sodium or calcium nitrates are finely dispersed into the continuous phase of fuel oil. This water-in-oil emulsion is then stabilized against liquid separation by an emulsifying agent such as sodium oleate or sodium mono-

oleate. Dispersed gas can be put into the emulsion matrix for density control within a range of 0.70 to 1.35 g/cm^3. This is achieved with microballoons or by chemical gassing of the composition. Other salts such as perchlorates are added to improve sensitivity and shelf life.

The emulsions explosive have excellent water resistance. Heavy ANFO – mixtures of ANFO and high density non- explosives emulsion phase.

PERMITTED EXPLOSIVES

Only those explosives, which are included in the official list of authorised explosives issued by the Chief Controller of Explosives in India, may be used for blasting in mines. Only on passing the tests in an explosive approved as a "permitted" explosive. In India there are 3 types of permitted explosives, each group being designed for a particular type of operation to give maximum safety.

P-1 Type Permitted Explosives: These explosives can be used for drifting or ripping and simultaneously firing in an undercut/middlecut/overcut and in depillaring faces, in coal seams of first degree of gassiness.

P-3 Type Permitted Explosives: These are Equivalent-toSheathed Explosives used for drifting or ripping and simultaneously firing an undercut/middlecut/overcut and in depillaring faces, in coal seams of first degree of gassiness.

P-5 Type Permitted Explosives: These are special type of explosives with a higher degree of intrinsic safety against all types of likely hazards in delay blasting in coal and specially designed for Solid Blasting in conjunction with nonincendive copper short delay detonators.

NON PERMITTED EXPLOSIVES

For certain operations such as shaft sinking and stone drifting, where there is no gas or coal dust present, explosives other than permitted explosives can be used, subject to such conditions as may be laid down by the DGMS in specific instances.

Veolocities of Detonation

The VOD ranges for the four main groups of explosives are: ANFO 2200 – 4000 m/s

Watergels	3500 – 5000 m/s
Emulsions	4500 – 6100 m/s
NG based explosives	3500 –5500 m/s

Permitted Explosive

A permitted explosive is one that has been approved for use in coal mines where there is any possible risk of igniting combustible gases or coal dust

Characteristics of Explosives

1. Chemical stability or shelf life

This is the ability of an explosive to remain chemically unchanged when stored. The shelf life of explosives varies from a few hours to a few years depending on the composition, and is stated in the manufacturer's specification.

Chemical decomposition can occur during prolonged storage of explosives, particularly in humid and hot conditions. If decomposition occurs, the explosive eventually becomes either insensitive to detonation, or more sensitive and unsafe to use.

2. Density

The density of most commercial explosives is in the range of 0.8 g/cm^3 to 1.6 g/cm^3.
The optimum density range for the four common types of explosives are:

ANFO	0.8 to 1.0 g/cm^3
Watergels	1.2 to 1.4g/cm^3
Emulsions	1.1 to 1.3 g/cm^3
NG-based	1.3 to 1.6 g/cm^3

For NG-based explosives, high density indicates high energy concentration.

3. Velocity of detonation (VOD)

VOD is the rate at which the detonation wave passes through the explosive charge, and with most explosives it falls in the range of 2500 m/s to 5500 m/s.

Higher VOD are required for satisfactory fragmentation

4. Strength

The strength of an explosive is usually considered to be its ability to do useful work.
Various strength that are measured:

a) Weight strength is the strength of a given weight of an explosive compared with the strength of the same weight of ANFO
b) Bulk strength is the strength of a given volume of the explosive compared with the strength of the same volume of blasting gelatine.

5. Sensitivity

The sensitivity of an explosive describes the ease with which it will explode.

Sensitivity is most important when allowance is made for safety in handling and use of explosives.

It must be insensitive to shock or heat; as safe as possible to manufacture, handle and place in position yet sensitive enough (when directly initiated) to explode when required.

6. Fume characteristics

Toxic gases such as carbon monoxide and oxides of nitrogen are produced by the detonation of all explosives

7. Water Resistance

The ability of an explosive to resist water and to maintain its explosive properties in the presence of water can be described as excellent, good fair or poor

Initiation Systems

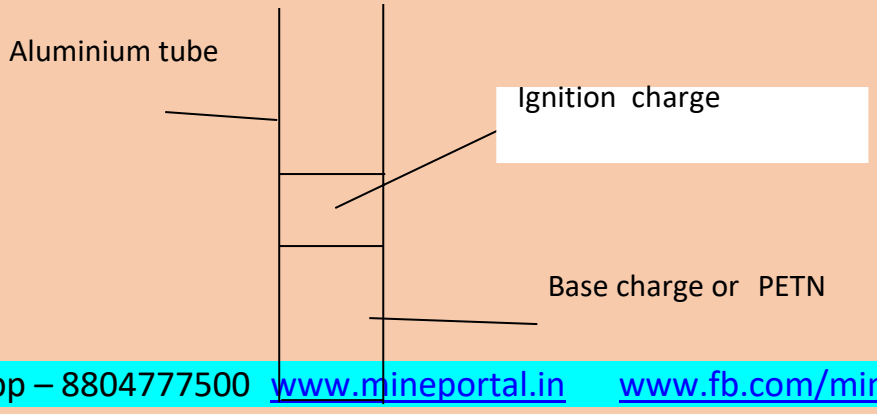
Explosives will detonate when subjected to: shock
friction
impact
heat

In an effort to make explosives reasonably safe to store, transport and use their sensitivity to shock, friction, impact and heat has been reduced, so that only an initiator can detonate an explosive.

Some form of initiation systems are needed. These are:

a) safety fuse and plain detonators
b) detonating cord
c) electric and electronic detonators
d) nonel or shock tube detonators safety fuse and plain detonators (capped fuse)

A plain detonator consists of an aluminium tube 42 mm long and 6.4 mm in diameter which contains an explosive charge pressed in the bottom of the tube.



Safety fuse consists of a centre cotton surrounded by a train of specially prepared gun powder enclosed in layers of jute yarn and waterproofing materials. One end of the safety fuse is fitted to the detonator and crimped with a crimper (made of non-ferrous material).

Safety fuse burns at a rate of 120 seconds per metre.

Detonating Cord

Safety fuse burns but detonating cord detonates.It detonates at a rate of 7000 m/s.

A detonating cord is carrier of detonating wave which is used to detonate the primer.
The core loadings is made of PETN and range from 5 to 10 g/m length of cord. In Malaysia the type available in the market are the 10g/m, 20g/m, 30g/m and 40g/m of PETN.

The detonating cord can be initiated by a detonator. There are many uses of detonating cord including production blasting to fire main shots, presplitting, smooth blasting, seismic exploration, cutting tree limbs and old pier piles.

Electric detonators

It looks the same as the plain detonators but the only difference is the two leg wires attached to the detonators. Most of the detonators has the resistance of 1 to 2 ohms and the current needed to detonate the detonators is 1.5 amperes.

There are two types of electric detonators which are the instantaneous type and the delay type.
The instantaneous will detonate at zero second upon initiation. The delay detonators are manufactured in the same way as the instantaneous but the only difference is the presence of a delay element.

Electric delay detonators series are: Half second series

The range of delays available is 1 to 12 giving a total of 12 detonators in series, where a half second interval between each delay

Millisecond series

Basically 25 ms delay time interval.

Carrick short delay series

These detonators complemented the permitted explosives and are specially designed for use n coal mines.

Electronic detonators are the latest innovation. The detonators can be programmed accurately with a delay between 0 ms to 800 ms with an interval of 1 ms.

Nonel system or shock tube system

The invention of a shock tube or signal tube is basically a modern version of safety fuse, where a flame can travel through the center of the tube.

The tube is made of plastic with 3mm OD and 2mm ID. An explosive powder called HMX covered the inside surface of the tube. .{You are reading it on mineportal.in}The powder detonates at a velocity of about 2000 m/s and this sends a detonating wave to the detonator. The plastic tube is not destroyed after detonation of the explosive powder.

The tube can only be initiated by a detonator or by a nonel exploder.

Its usage is more appropriate in areas where electric detonators are not advisable to be used.

Besides the initiating system, other accessories are needed to make a blasting round to work properly and safely. These are the following

Relay connectors

Relay connectors are blasting delay elements primarily for use in surface mining and quarrying operations. There are two main types: detonating relay connectors (DRC) Nonel trunkline delays (TLD)

A DRC consists of two delay detonators, of from 5 millisecond (ms) to 60 ms duration. The complete unit is in the shape of a sealed plastic dog bone. The DRC is inserted at an appropriate position in the detonating cord line.

A TLD unit consists of a plastic "bunch block" connector which houses a Nonel delay detonator attached to a length of signal tube. The delay periods vary, depending on the particular manufacturer's product. The relay type of each TLD, which functions unidirectionally, ensures true hole-by-hole initiation with correct sequencing.

Circuit Testers

When using electrical initiating system it is necessary to test the continuity of each detonator, the shotfiring cable, and the resistance of the entire blasting circuit.

This is done with an approved circuit tester or a blasting galvanometer, an instrument that applies a very low and safe electric current.

For example one such circuit tester can deliver a maximum current of 50 mA from the battery assembly when short circuited.

This amount of current is far below that required to fire one detonator. Such testing is always carried out from a place of safety.

Exploders

Exploders or blasting machines are used in the electrical initiation system. These are available depending on the number of electric detonators in the circuit. The common range is for 1, 12, 25 30 and 100 detonators.

Some exploders are compound-wound generator types, whereas others are battery operated capacitor-discharge types.

A type of dynamo-condenser exploder can fire 100 detonators in series. This is a hand-driven generator together with a condenser is incorporated in this exploder. A neon lamps indicates when the condenser is charged with a least 1200 volts AC, and a button switch applies the voltage from the condenser to the output terminals.

THEORY OF EXPLOSIVES

In general, an explosive has four basic characteristics: (1) It is a chemical compound or mixture ignited by heat, shock, impact, friction, or a combination of these conditions; (2) Upon ignition, it decom- poses rapidly in a detonation; (3) There is a rapid release of heat and large quantities of high-pressure gases that expand rapidly with sufficient force to overcome confining forces; and (4) The energy released by the detonation of explosives produces four basic effects; (a) rock fragmentation; (b) rock displacement; (c) ground vibration; and (d) air blast.

A general theory of explosives is that the detonation of the explosives charge causes a high-velocity shock wave and a tremendous release of gas. The shock wave cracks and crushes the rock near the explosives and creates thousands of cracks in the rock. These

cracks are then filled with the expanding gases. The gases continue to fill and expand the cracks until the gas pressure is too weak to expand the cracks any further, or are vented from the rock.

The ingredients in explosives manufactured are classified as:

Explosive bases. An explosive base is a solid or a liquid which, upon application or heat or shock, breaks down very rapidly into gaseous products, with an accompanying release of heat energy. Nitroglycerine is an example.

Combustibles. A combustible combines with excess oxygen in an explosive to achieve oxygen balance, to prevent the formation of nitrous oxides (toxic fumes), and to lower the heat of the explosion.

Oxygen carriers. Oxygen carriers assure complete oxidation of the carbon in the explosive mixture, which inhibits the formation of carbon monoxide. The oxygen carriers assist in preventing a lowering of the exploding temperature. A lower heat of explosion means a lower energy output and thereby less efficient blasting.

Antacids. Antacids are added to an explosive compound to increase its long term storage life, and to reduce the acidic value of the explosive base, particularly nitroglycerin (NG).

Absorbents. Absorbents are used in dynamite to hold the explosive base from exudation, seepage, and settle- ment to the bottom of the cartridge or container. Sawdust, rice hulls, nut shells, and wood meal are often used as absorbents.

Antifreeze. Antifreeze is used to lower the freezing point of the explosive.

Air gap sensitivity. Air gap sensitivity is a measure of an explosive's cartridge-to-cartridge sensitivity to deto- nation, under test conditions, expressed as the distance through air at which a primed half-cartridge (donor) will reliably detonate an unprimed half-cartridge (receptor).

Cap Sensitivity. Cap sensitivity is a measure of the minimum energy, pressure, or power required for initiation of a detonation; i.e., "cannot be detonated by means of a No. 8 test blasting cap when unconfined."

Strength Two strength ratings are used for commercial dynamites. Weight strength compares products on an equal-weight basis, and cartridge strength or bulk strength compares products on an equal-volume basis. Both are expressed in percent, using straight nitroglycerin dynamite as a standard. Complicating this picture is the variety of ingredient mixes among manufacturers, so that 40 percent gelatin dynamite and a 40 percent ammonia dynamite do their work differently; similarly, a 40 percent ammonia dynamite from two different manufacturers will give somewhat different results. Thus, a blaster who had always used one manufacturer's product could change suppliers and suddenly start complaining about "bad powder." To further confuse the issue, some manu- facturers continue to use the terms "weight strength" and "bulk strength" as a comparative numerical rating against ANFO at 100.

With the advent of new explosives, particularly the ANFOs and the slurries, the dynamite method of judg- ing strength failed to give relevant data. It became necessary to account not only for a product's relative stored energy, but also its rate of energy release, its gas volume potential, and its heat of detonation. A number of factors are currently used to judge an explosive's ability to do the work desired, and today's blaster must con- sider at least the following:

Detonation Pressure is a measure of the product's shock wave energy, influenced by the product's density (latent energy) and detonation velocity (rate of energy release).

Pressure Magnitude or **Gas Pressure** is a measure of the potential expanding-gas energy, influenced by the product's density (latent gas volume) and the heat and velocity of detonation (rate of gas production and expansion).

Though oversimplified, one way to think of "strength" is to compare an explosive to a mechanical means of breaking and moving rock. We can break rock with a sledgehammer, and a detonation pressure is our explosive hammer. As density increases, the "weight of the hammer" increases; as velocity increases, we "swing the hammer" faster and harder. We can move rock with a bulldozer, and gas pressure is our explosive dozer. As density increases, the dozer gets bigger; as velocity increases, the dozer runs faster—sometimes so fast that it outruns the rock it is trying to move.

BLASTING MECHANICS

Upon detonation, explosives affect rock by various interrelated means. While the following discussion simplifies a complex and (in some aspects) largely theoretical subject, it should provide a basic grasp of blast mechanics. The same mechanisms apply to whatever material is being blasted (wood, concrete, steel, soil, ice, etc.); however, results are highly dependent on material integrity. As a result, this discussion will con- sider only monolithic bedrock in order to avoid confusion.

1. Detonation Shock Wave

Upon initiation, the detonation (explosive oxidation) zone proceeds down the column of explosive at the product's detonation velocity. At the front of this detonation zone, an energy pulse or "shock wave" is generated and transmitted to the adjacent rock; any air space between the explosive and the rock absorbs wave energy and reduces its effect on the rock.

The shock wave travels outward as a compression wave in all directions from the borehole, moving at or near detonation velocity. The rock immediately surrounding the borehole is crushed to some extent, dependent on how much the force of the wave exceeds the compression strength of the rock. The force of the wave overcomes the elastic limits of the rock, causing it to bend outward and crack. These are radial cracks in that they radiate out from the borehole and they are generated at speeds related to the sonic velocity of the rock itself (+/–8,000 fps in hard rock, +/–1,500 fps in soft rock). If the rock mass is too large to permit bending, such as behind the borehole, no radial fracture occurs; the wave energy is simply absorbed by the rock.

2. Shock Wave Reflection

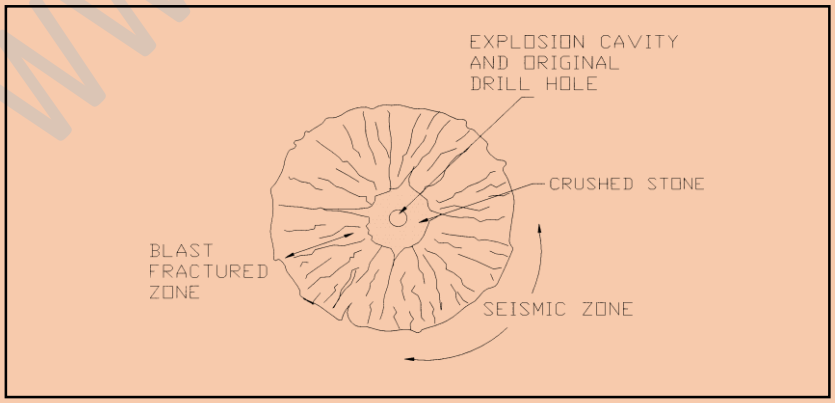
At this point, the result of the blast will only be very large wedge-shaped blocks, still interlocked. However, when the shock wave reaches a free face, the outward-bending compressive force releases, and the wave is reflected back into the rock as a tension wave. The speed of the shock wave has been slowed somewhat, and its energy lowered, but if the distance from the borehole to the free face is not too great, it still carries enough force to overcome the tensile strength of the rock.

Rock, like concrete, has far greater strength in compression than in tension (for instance, granite with a compression strength of 30,000 psi has a tensile strength of only 1200 psi). The reflected tension wave causes lateral cracking in the rock between the radial cracks, creating "fragmentation." Obviously, the greater the distance between the borehole and the free face, the more the wave energy is used along the way, and the larger those "fragments" will be. If there is no free face, such as behind the borehole, there will be no wave reflection and no lateral cracking. A point to remember is that any break in rock continuity will act as a free face; a crack or weather seam is as good as a quarry face in this regard.

3. Gas Pressure and Rock Movement

Upon detonation, along with the shock wave, the solid explosive is instantly converted to superheated gas that is trying to occupy a space 10,000 to 20,000 times its original solid volume, and exerting a pressure that can exceed 1.5 million psi. Without this gas pressure, the fractured rock would not move and would remain interlocked.

The fractured rock mass has a certain inertia (consider this a desire to stay where it is), which the gas pressure must initially overcome to start rock movement. Thus, there is "hesitation" between detonation and the start of rock movement, lasting roughly one millisecond per foot of distance between the borehole and the free face (i.e., if the distance is 10 feet, movement will start roughly 10 milliseconds after detonation). Once inertia is overcome, the rock moves outward away from the borehole at around one foot each 10 milliseconds, or between 40 and 70 mph, although smaller fragments can move faster and be shot out as flyrock. As with the detonation shock wave, nice even results in rock movement require rock continuity; cracks and weather seams will allow gas venting, and result in uneven and sometimes surpris- ing directions and distances of rock throw.



(Figure 2-1) The mechanics of blasting.

DETONATION VELOCITY

Detonation velocity is an important property to consider when rating an explosive. It may be ex- pressed as a confined or unconfined value and is normally given in feet per second (fps). The confined detonation velocity measures the speed at which the detonation wave travels through a column of explo- sive within a borehole or other confined space. The unconfined velocity indicates this rate when the explosive is detonated in the open. Because explosives generally are used under some degree of confine- ment, the confined value is more significant. Most manufacturers, however, measure detonation velocity in an unconfined column of explosive 1 1/4 inches in diameter, although some measurements are made within the confinement of an iron pipe or using a different diameter.

The confined detonation velocity of commercial explosives varies from 5000 to 25,000 fps (Tables 2-1 through 2-6). With cartridge explosives, the confined velocity is seldom attained because complete confinement is usually impossible. For blasting in hard rock, a high-velocity explosive is preferable. In a softer or highly jointed rock, a low-velocity explosive , for example,(ANFO) with a heaving action may give satisfactory results at a lower cost. Some explosives, and particularly blasting agents, are more sensitive to diameter changes than others. In charges with larger diameters, say six inches or more, the velocity may be medium to high. But as diameters get smaller, the velocity is reduced until, at the blasting agent's critical diameter,(approximately three inches for ANFO, propagation is no longer assured and misfires are likely).

PROPERTIES OF EXPLOSIVES

By knowing what properties are critical to performance, meaningful predictions can be made in blast design. These properties are: detonation velocity, density, detonation pressure, water resistance, and fume class. For a given explosive, these properties vary with the manufacturer

DENSITY

The density of an explosive may be expressed in terms of specific gravity. Specific gravity is the ratio of the density of the explosive to the density of water under standard conditions. The specific gravity of commercial explosives ranges from 0.6 to 1.7 g/cc. For free running explosives, the density is often specified as the pounds of explosives per foot of charge length in a given size borehole. With few exceptions, denser explosives give higher detonation velocities and pressures.

Density is an important consideration when choosing an explosive. For difficult blasting conditions or where fine fragmentation is required, a dense explosive is usually necessary. In easily fragmented rock or where fine fragmentation is not needed, a low-density explosive will often suffice. Low-density explosives are particularly useful in the production of riprap or other coarse products. The density of an explosive is also important when working under wet conditions. An explosive with a specific gravity of less than 1.0 will not sink in water.

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class*	Cartridge count
60	52	1.3	12,500	Fair	Good	110
50	45	1.3	11,500	Fair	Good	110
40	35	1.3	10,500	Fair	Good	110
30	25	1.3	9,000	Fair	Good	110
20	15	1.3	8,000	Fair	Good	110

(Figure 2-2) Properties of a high-density ammonia dynamite.

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class*	Cartridge count
65	50	1.2	8,100	Fair	Fair	120
65	45	1.1	7,800	Poor	Fair	129
65	40	1.0	7,500	Poor	Fair	135
65	35	1.0	7,200	Poor	Fair	141
65	30	.9	6,900	Poor	Fair	153
65	25	.9	6,500	Poor	Fair	163
65	20	.8	6,300	Poor	Fair	174

(Table 2-3) Properties of a low-density ammonia dynamite, low-velocity series.

(Figure 2-4) Properties of two-component explosives.

DETONATION AND BOREHOLE PRESSURE

Detonation pressure is a function of the detonation velocity and density of an explosive.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class	Shelf Life
Thermex Y	1.22	20,000	Package only	1	1
Kinestick	1.1	18,000	Package only	1	1

The nomograph (Figure 2-2) can be used to approximate the detonation pressure of an explosive when the detonation velocity and specific gravity are known. As can be seen, the detonation pressure is more dependent on detonation velocity than specific gravity. A high detonation pressure is necessary when blasting hard, dense rock. In softer rock, a lower pressure is sufficient. Detonation pressures of explosives range from 10 to over 140 Kilobars (l Kilobar = 14,504 psi).

WATER RESISTANCE

An explosive's water resistance is a measure of its ability to withstand exposure to water without deteriorat- ing or losing sensitivity. Sensitivity is the ease with which an explosive detonates.

In dry work, water resistance is of no consequence. If water is standing in the borehole,

and the time between loading and firing is fairly short, an explosive with a water-resistance rating of "good" is sufficient. If the exposure is prolonged, or if the water is percolating through the borehole, "very good" to excellent" water resistance is required.

In general, gelatins and emulsions offer the best water resistance. Higher-density explosives have fair to excellent water resistance, whereas low-density explosives and blasting agents have little or none. Brown nitro- gen oxide fumes from a blast often mean the explosive has deteriorated from exposure to water.

FUME CLASS

Ideally, detonation of a commercial explosive produces water vapor, carbon dioxide, and nitrogen. In addition, undesirable poisonous gases such as carbon monoxide and nitrogen oxides are usually formed. These gases are known as fumes, and the fume class of an explosive indicates the nature and quantity of the undesirable gases formed during detonation. Better ratings are given to explosives producing smaller amounts of fumes. For open work, fumes are not usually an important factor, In confined spaces, however, the fume rating of an explosive is important. In any case, the blaster should ensure that everyone stays away from fumes generated in a shot. Carbon monoxide gradually destroys the brain and central nervous system, and nitrogen oxides immediately form nitric acid in the lungs.

Fume classes can be from poor to good and are rated Class A or B by the Bureau of Mines and class 1, 2, 3, by IME. Class A and Class 1 typically emit less noxious fumes per gram of explosive than Class B or Classes 2 or 3.

SHELF LIFE

Shelf lives of various products described are listed in their respective tables. For most explosives products, a shelf life of one year is recommended, although satisfactory performance can be expected from most products two, three, and even four years later. Consult the appropriate manufacturer to determine shelf life ratings be- yond one year. *NPS-65* mandates a maximum shelf-storage of two years.

SELECTION OF EXPLOSIVES

There have been many systems developed to rate the strength or power or an explosive. Although these systems work, it is still not clear as to whether or not the information is useful to the field blaster.

There are many reasons for choosing an explosive. These reasons range from the specifications of the product, the price, availability, and reliability. Whatever the reason for selection, the blaster should consider the following properties:

Velocity - If fragmentation is desired, the best results are obtained when the detonation velocity is at or near the sonic velocity of the rock. If mass movement is more important (as in blast casting) or very large fragments are desired (as in riprap production or slabbing), detonation velocity should be notably below the rock's sonic velocity.

Sensitivity - When using charges in small diameter boreholes, the blaster needs sensitive products such as cap sensitive emulsions or water gels. The smaller the hole, the more sensitive the product needs to be. ANFO functions well in large diameter holes (four inches and above), but has trouble sustaining detonation in small holes.

Gas or Pressure Release - This is the amount of gas and pressure released when the explosive or blasting agent detonates. Generally, the more gas release, the more heave or displacement that is possible.

Water Resistance - In conditions where the holes are producing water or ground water is a problem, packaged ANFO, water gels or emulsions function best. There are also plastic borehole liners that can be used for bulk loading operations.

Fume Quality - When working in a poorly ventilated operation such as in a tunnel, mine, or deep trench, select a product with a good (Class I) fume rating. Even when working in the open, allow all evidence of smoke and dust to clear before reentering the blast area, and remember that the toxic gases produced are colorless, odor- less, and potentially lethal.

When selecting explosives there are four basic categories:

1. **Dynamites, including Granular Dynamite** (Straight Dynamite, High-Density Extra Dynamite, and Low- Density Extra Dynamite) and **Gelatin Dynamite** (Straight Gelatin Dynamite, Ammonia Gelatin Dynamite, and Semigelatin Dynamite). Use is prohibited by policy unless a case specific waver is obtained from the re- gional blasting officer.

2. **Water Gels, Emulsions, and Slurries** - Consisting of Cartridges and Bulk products.

3. **Dry Blasting Agents** - Consisting of Poured or Bulk ANFO, Aluminized ANFO, Densified ANFO, and Packaged (waterproof) ANFO.

4. **Binary Explosives** - Consisting of two-component products that are mixed in the field to form an explosive.

Use and safe handling of explosives in Mining Guidelines for use of explosive as per THE COAL MINES REGULATIONS, 1957(CMR,1957)

CHAPTER-XIV : Explosives an Shotfiring

159. Type of Explosives to be used in mines. – (1) No explosive shall be used in a mine except that provided by the owner, agent or manager. The explosives provided for use shall be of good quality an, as far as can be known, in good condition.

(2) No liquid oxygen explosives shall be used in any workings belowground.

160. Storage of explosives. – (1) No owner, agent or manager shall store, or knowingly allow any other person to store, within the premises of a mine any explosives otherwise than in accordance with the provisions of rules made under the Indian Explosives Act, 1884.

(2) Explosives shall not be taken into or kept in any building except a magazine duly approved by the Licencing Authority under the Indian Explosives Act, 1884 :

Provided that the Regional Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit the use of any store or premises specially constructed at or near the entrance to a mine for the temporary storage of explosives intended for use in the mine or of surplus explosives brought out of the mine at the end of a shift.

(3) Explosives shall not be stored below ground in amine except with the approval in writing of the Chief Inspector and subject to such conditions as he may specify therein. Such storage shall be done only in a magazine or magazines duly licenced in accordance with the provisions of rules made under the Indian Explosives Act, 1884.

(4) Every licence granted by the Licencing Authority under the Indian Explosives Act, 1884 for the storage of explosives, or a true copy thereof, shall be kept at the office of the mine.

161. Cartridges. (1) No explosive, other than a fuse or a detonator, shall be issued for use in mine, or taken into or used in any part of a mine, unless it is in the form of a cartridge. Cartridges shall be used only in the form in which they are received.

(2) The preparation of cartridges from loose gunpowder, the drying of gunpowder an the reconstruction of damp cartridges shall be carried out by a competent person and only in a place approved by the Licencing Authority an in accordance with the rules made under the Indian Explosives Act, 1884.

162. Magazines, stores and premises to store explosives. – (1) Every magazine, or store or premises, where explosives are stored shall be in charge of a competent person who shall be responsible for the proper receipt, storage an issue of explosives.

(2) Explosives shall not be issued from the magazine unless they are required for immediate use. If any explosives are returned to the magazine or store or premises, they shall be reissue before fresh stock is used.

(3) Explosives shall be issued only to competent persons upon written requisition signed by the blaster or by a official authorised for the purpose, and only against their signature or thumb impression. Such requisition shall be preserved by the person in charge of the magazine or store or premises.

(4) The person in charge of the magazine or store or premises shall maintain, in a bound paged book kept for the purpose, a clear and accurate record of explosives issued to each competent person and a similar record of explosives returned tot he magazine or store or premises.

163. Cases and containers for carrying explosives. (1) No explosive shall be issued from the magazine or taken into any mine except in a case or container of substantial construction and securely locked. Cases or containers made of iron or steel shall be heavily galvanised; and no case or container provided for carrying detonators shall be constructed of metal or other conductive material.

(2) No detonator shall be kept in a case of container which contains other explosives, materials or tools; and two or more types of detonators shall not be kept in the same case of container :

Provided that nothing in this sub-regulation shall restrict the conveyance of primer cartridges fitted with detonators in the same case or container for use in a wet working or in a sinking shaft.

(3) No detonator shall be taken out from a case or container unless it is required for immediate use.

(4)No case or container shall contain more than five kilogrammes or explosives, and no person shall have in his possession at one time in any place more than one such case or container :

Provided that the Chief Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit the carrying of a larger quantity of explosives in a single case or container, or the use, at one time in one place, of more than one such case or container.

(5) Every case or container shall be numbered; and as far as practicable, the same case or container shall be issue to the same blaster or competent person, as the case may be, every day.

(6)The key of every case or container shall be retained by the blaster in his own possession throughout his shift.

164. Transport of explosives. – (1) While explosives are being carried on a ladder, every case or container shall be securely fastened to the person carrying it.

(2) No person other than a shotfirer shall carry any priming cartridge into a shaft which is in the course of being sunk. No such cartridge shall be so carried except in a thick felt bag or other container sufficient to protect it from shock.

164A. Transport of explosives in bulk – Where explosives are transported in bulk for deephole blasting the provisions of this regulation shall apply.

(1) Transport of explosives from the magazine to the priming station or the site of blasting shall not be done except in day light and in the original wooden or card board packing case. The quantity of explosive transported at one time to the site of blasting shall not exceed the actual quantity required for use in one round of shots. The explosives shall be transported to the site of blasting not more than 30 minutes before the commencement of charging of the holes.

(2)(a) No mechanically propelled vehicle shall be used for the transport of explosives unless it is of a type approved in writing by the Chief Inspector, provided that a Jeep or Land Rover may be used for the transport of detonators from magazines of priming stations' subject to all the following conditions :

(i) not more than 200 detonators are transported in a vehicle at a time; (ii) the detonators are packed suitably in a wooden box; (iii) the wooden box containing detonators is placed inside an outer metal case of a construction approved by the Chief Inspector; (iv) the outer metal case shall be suitably bolted to the floor of the vehicle or otherwise fixed in a wooden frame

so that the container is not displaced while the vehicle is in motion; and (v) no person shall ride on the rear portion of the vehicle.

(b) Every vehicle used for the transport of explosives shall be marked or placarded, on both sides and ends, with the word ''EXPLOSIVES' in red letters not less than 15 centimetres high on a white background.

(c) Every mechanically propelled vehicle transporting explosives shall be provided with not less than two fire extinguishers (one of Carbon Tetra Chloride type for petroleum fire and the other of Carbon Dioxide under pressure type for electrical fire) suitably placed for immediate use.

(3)(a) The vehicle used for transport of explosives shall not be overloaded, and in no case shall the explosive cases be piled higher than the sides of its body.

(b) Explosives and detonators shall not be transported in the same vehicle.

(4)(a) No person other than the driver and his helper (not below 18 years of age) shall ride on a mechanically propelled vehicle used for the transport of explosives.

(b) A vehicle loaded with explosives shall not be left unattended.

(c) The engine of a vehicle transporting explosives shall be stopped and the brakes set securely before it is loaded/or unloaded or left standing.

(d) A vehicle transporting explosives shall not be driven at a speed exceeding 25 Kilometres per hour.

(e) A vehicle loaded with explosives shall not be taken into garage or repair shop and shall not be parked in a congested place.

(f) A vehicle transporting explosives shall not be refuelled except in emergencies even when its engine shall be stopped and other precautions taken to prevent accidents.

(g) No trailer shall be attached to a vehicle transporting explosives.

(5)(a) Every vehicle used for the transport of explosives shall be carefully inspected once in every 24 hours by a competent person, to ensure that :

(i) fire extinguishers are filled and in place; (ii) the electric wiring is well insulated and firmly secured;

(iii) the chasis, engine and body are clean and free from surplus oil and grease; (iv) the fuel tank and feed lines are not leaking; and (v) lights, brakes and steering mechanism are in good working order.

(b) A report of every inspection made under sub-clause (a) shall be recorded in a bound paged book kept for the purpose and shall be signed and dated by the competent persons making the inspection.

(6) All operations connected with the transport of explosives shall be conducted under the personal supervision of an overman solely placed in charge of blasting operations at the mine.

(7) The shotfirer shall personally search every persons engaged in the transport and use of explosives and shall satisfy himself that no person so engaged has in his possession any cigar, cigarette, 'biri' or other smoking materials or any match or any other apparatus of any kind capable of producing a light, flame or spark.]

165. Reserve Stations. – No case container containing explosives shall be left or kept below ground except in a place appointed by the manager or assistant manger or underground manager for the purpose and so situated that it is not frequented by workpersons. Every such place shall be kept clean, safe and adequately fenced and legibly marked 'RESERVE STATION'.

166. Shotfirers. – (1) The preparation of charges an the charging and stemming of holes shall be carried out by or under the personal supervision of a competent person, in these regulations referred to as a 'blaster'. The shotfirer shall fire the shots himself.

1[(2) No person shall be appointed to be shotfirer unless he holds :

(a) a Manager's or Overman's Certificate or a Sirdar's Certificate together with a Gas-testing Certificate of a gassy seam of the second or third degree; (b) a Manager's Overman's or Sirdar's Certificate or a Shot-firer's Certificate together with a Gas-testing Certificate in the case of gassy seam of the first degree; and (c) a Manager's Overman's or Sirdar's Certificate or a Shot-firer's Certificate in the case of open cast working.]

(3) If 30 or more persons are employed belowground at any one time in any mine or district under the charge of a competent person referred to in regulation 116, such person shall not perform the duties of a shot-firer.

(4) No person whose wages depend on the amount of mineral, rock or debris obtained by firing shots, shall be appointed to perform the duties of a shot-firer.

(5) The manger shall fix, from time to time, the maximum number of shots that a shot-firer may fire in any one shift. Such number, however shall be based on :

(i) the time normally require to prepare and fire a shot in accordance with the provisions of these regulations; (ii) the time required for that shot-firer to move between places where shots are fired; (iii) the assistance, if any, available to him in the performance of his said duties; and (iv) any other duties assigned to him, whether statutory or otherwise :

and shall not in any case exceed :

(a) in the case of a gassy seam of the second or third degree or a fiery seam, forty, if a single shot exploder is used and eighty, if a multy-shot exploder is used; (b) in the case of other seams fifty, in a single-shot exploder is used and hundred, if a multi-shot exploder is used; and

(c) in the case of open cast mines sixty, if a single shot exploder is used or if blasting is done with ordinary detonators and one hundred and twenty, if a multi-shot exploder is used:

Provided that, if thirty or more persons are employed below ground at any one time in any mine or district under the charge of any official who is qualified to perform the duties of the shotfirer, such official shall not fire or be permitted to fire more than half the maximum number of shots specified in Clause (a), (b) and (c) depending on the category of the seam or mine specified therein:

Provided further that where special conditions exist, the Regional Inspector may by an order in writing and subject to such conditions as he may specify therein permit a larger maximum to be fixed:

Provided further that where the Regional Inspector is of the opinion that, for the proper observance of the provisions of these regulations the number of shots so fired shall be reduced, and if he so required by an order in writing, the manager shall fix a lower maximum number of shots as specified by the Regional Inspector].

(6) The number of detonators issued to, and in the possession of, a shot-firer during his shift shall not exceed the maximum number of shots that he is permitted to fire under subregulation (5).

167. Shotfiring tools. - (1) Every blaster on duty shall be provided with –

(a) a suitable electric lamp or torch, and a stop watch; (b) a tool, made entirely of wood, suitable for charging and stemming shotholes; (c) a scraper made of brass or wood suitable for cleaning out shotholes; (d) where fuses are used, a knife for cutting off fuses an, unless machine-capped fuses are provided, also a pair of suitable crimpers for crimping detonators; and (e) where detonators are used, a pricker made of wood or a non-ferrous metal for priming cartridges. 1[(f) in every seam a tool of a type approved by the Chief Inspector for detecting cracks."]

(2) No tool or appliance other than that provided as above shall be used by a blaster.

168. Drilling, charging, stemming and firing of shotholes. – (1) No rill shall be used for boring a shothole unless it allows a clearance of at least 0.3 centimetre over the diameter of the cartridge of explosive which it is intended to use.

(2) No shothole shall be charged before it is thoroughly cleaned.

(3) Before any shothole is charged, the direction of the hole shall, where practicable, be distinctly marked on the roof or other convenient place.

(4) No detonator shall be inserted into a priming cartridge until immediately before it is to be use : however that in case of wt workings, priming cartridges may be prepared at the nearest convenient dry place; and such primed cartridges shall be cartied to the working place in a securely closed case or container. Detonators once inserted into a priming cartridge shall not be taken out.

(5) The charge in any shothole shall consist of one or more complete cartridges of the same diameter and the same type of explosive.

(6) The shotfirer shall, to the best of his judgment, ensure that no charge in a shothole is over-charged of under-charged, having regard to the task to be performed.

(7) No shothole shall be fired by a fuse less than 1.2 metres in length.

(8) Every shothole shall be stemmed with sufficient an suitable non-inflammable stemming so as to prevent the shot from blowing out. Only sand loosely filled in, or soft clay lightly pressed home, or a compact but not hard mixture of sand and clay or water shall be used as stemming.

(9) In charging or stemming a shothole, no metallic tool, scraper or rod shall be used; an no explosive shall be forcibly pressed into a hole of insufficient size.

(10) No shot shall be fired except in a properly drilled, charged an stemmed shothole.

(11) Blasting gelatine or other high explosives shall not be lighted in order to set fire to fuses.

(12) All surplus explosives shall be removed from the vicinity of a shothole before a light is brought near it for the purpose of lighting the fuse.

(13) As far as practicable, a shot shall be fired by the same blaster who charged it.

(14) In any mine in which explosives other than gunpowder are used, every shot shall, if so required by the Regional Inspector, be fired electrically.

(15) Except in a stone drift or a sinking shaft, not more than 10 shots shall be fired in any one round. Where more than six shots are to be fired in one round, they shall be fired electrically.

Provided that in the case of opencast working any number of shots can be fired in one round if they are fired electrically by an exploder of adequate capacity].

(16) No shothole shall be charge except those which are to be fired in that round; and all shotholes which have bee charged shall be fired in one round.

(17) Where a large number of shots has to be fired, a shotfiring shall, as far as practicable, be carried out between shifts.

(18) No person shall remove any stemming, or pull out any detonator lead, or remove any explosive, from a shothole either before firing or after a misfire, or bore out a hole that has once been charged, or deepen or temper with empty holes or sockets.

169. Electric Shotfiring. – Where shots are fired electrically, the following provisions shall have effect, namely :-

(1) (a) No shot shall be fired except by means of a suitable shotfiring apparatus; an the number of shots fired at any one time by the apparatus shall not exceed the number for whichit is designed. (b)Every electrical shotfiring apparatus shall b so constructed and used that – (i) it can only be operated by a removable handle or plug. This handle or plug shall not be placed in position until a shot is about to be fired and shall be removed as soon as a shot has been fired; and (ii) the firing circuit is made an broken either automatically or by means of a push-button switch. (c) (i) No apparatus shall be used which is defective; an every apparatus shall m

once at least in every three months, be cleaned an thoroughly overhauled by a competent person. (ii)If the apparatus fails to fire all the shots in a properly connected circuit, the blaster shall return the apparatus to the manger or assistant manager or underground manager as soon as possible, and it shall not be use again unless it has been tested on the surface and found to be in safe working order. (iii) The result of every overhaul test or repair is aforesaid shall be recorded in a bound paged book kept for the purpose an shall be signed an dated by the person making the overhaul, test or repair.

(2) No current from a signalling, lighting or power circuit shall be used for firing shots. (3) The blaster shall – (a) retain the key of the firing apparatus in his possession throughout his shift; (b) use a well-insulated cable of sufficient length to permit him to take proper shelter, and in no case, shall this cable be less than 20 meters in length; (c) before coupling the cable to the firing apparatus, couple up the cable himself to the detonator leads; (d) take care to prevent the cable from coming into contact with any power or lighting cable or other electrical apparatus; (e) take adequate precautions to protect electrical conductors and apparatus from injury; (f) himself couple the cable to the firing apparatus; an before doing so, see that all persons in the vicinity have taken proper shelter as provided under regulation 164; and (g) after firing the shots and before entering the place of firing, disconnect the cable from the firing apparatus.

Where more than one shot are to be fire at the same time :-

(a) care shall be taken that all connections are properly made; (b) all shots if fired belowground shall be connected in series; (c) the circuit shall be tested either for electrical resistance or for continuity before connecting it to the firing apparatus. Such a test shall be made with an apparatus specifically designed for the purpose and after the provisions of regulation 164 have been complied with; and (d) the cable to the shotfiring apparatus shall be connected last; 2[and] 2[(e) detonators of the same electrical resistance shall lonely be used.]

170. Taking shelter etc. – (1) The shot-firer shall, before a shot is charged, stemmed or fired, see that all persons other than his assistants, if any, in the vicinity, have taken proper shelter and he shall also take suitable steps to prevent any person approaching the shot and shall himself take adequate shelter, along with his assistants if any, before firing the shots.

(1-A) In the case of an opencast working the shot-firer shall not charge or fire a shot – (a) unless he has taken the precautions laid down in sub-regulation (1). (b) Unless sufficient warning, by efficient signals or other means approved by the manager, is given over the entire area falling within a radius of 300 metres from the place of firing (hereinafter referred to as the danger zone) an also he has ensured that all persons within such area have taken proper shelter, and (c) Where any part of a public road or railway lies within the danger zone, unless two persons are posted, one in either direction at the two extreme points of such road or railway which fall within the danger zone who have, by an efficient system of telephonic communication or hooter or loudspeakers or other means approved by the Chief Inspector or Regional Inspector intimated clearance of traffic to the blaster and have also warned the

passers by and whenever possible the vehicle also, if any, which have passed by such road or railway :

Provided that if blasting is done in such a manner approved in writing, by the Chief Inspector or Regional Inspector , that the flying fragments from blasting cannot project beyond a distance of ten metres from the place of firing, the provisions of clauses (b) and (c) need not be complied with,

(1-B) (a) In the case of an opencast working, where any permanent building or structure of permanent nature, not belonging to the owner, lies within the danger zone, the aggregate maximum charge in all the holes fired at one time shall not exceed two kilograms unless permitted in writing by the Chief Inspector of the Regional Inspector and subject to such conditions as he may specify therein :

Provided that if blasting is done with delay detonators or other means an that there is a delay of at least half a second between successive shots fired, a maximum charge of two kilograms can be used in each hole;

Provided further that if the shortest distance from the place of firing to any part of such building or structure is less than 50 metres irrespective of the amount of the charge, no blasting shall be done except with the permission in writing of the Chief Inspector or the Regional Inspector and subject to such conditions as he may specify therein.

(b)Notwithstanding anything contained in clause (a) the Chief Inspector may, by an order in writing and subject to such conditions as he may specify, exempt any mine or part thereof from the operation of all or any of the provisions of clause (a) on the ground that the observance of its provisions is not necessary or reasonably practicable on account of the special conditions existing thereat].

(2) Where the workings, either above or belowground, offer insufficient protection against flying fragments or missiles, adequate shelter or other protection shall be provided.

(3) When two working places belowground have approached within three metres of each other, the blaster shall not fire any shot in any one of the said workings unless all persons have been withdrawn from the other working place and the same has been so fenced off as to prevent persons inadvertently coming in direct line of the shot.

171. Precautions against dry coal dust. No shots shall be fired at any place belowground unless the place itself and all accessible places, including roof and sides, within a distance of 18 metres have been treated in the manner specified in sub-clause (b) of clause (4) of regulation 123 unless such places are naturally wet as defined in regulation 123].

172. Conditions requiring use of Permitted Explosives – (1) Notwithstanding anything contained in the regulations, two or more shots shall not be charged or fired in the same place simultaneously belowground if the explosive used is not a Permitted Explosive, except in –

(a) a stone-drift, if it does not contain dry coal dust; and

2[(b)] a shaft which is in the course of being sunk.

3[(2) In a gassy seam of the second or third degree no explosives other than the permitted sheathed explosives or other explosives equally safe or any device or apparatus for breaking coal approved by the Chief Inspector shall be used while in a gassy seam of the first degree permitted sheathed explosives or permitted explosives or any device for breaking coal approved by the Chief Inspector in writing may be used.

Provided that the Chief Inspector may by any order in writing and subject to such conditions as he may specify therein permit in any gassy seam of the first degree the use of any explosives other than the permitted explosives].

173. Precautions in the use of Permitted Explosives – In any mine in which the use of Permitted Explosives is required. 4 * -

(a) no shot shall be fire in coal unless –

(i) the coal has been undercut, overcut or sidecut; and (ii)the length of the shothole is at least 15 centimetres less the depth of the cut;

(b) no detonator shall be used, unless it is an electric detonator with a copper tube;

(c) where more shots than one are charged for firing, the shots shall be fire simultaneously; and

(d) the aggregate charge in 1[any shot to be fired] in coal shall not exceed such permissible maximum charge, as the Chief Inspector may, by a notification in the Official Gazette, lay down for the kind of Permitted Explosives used.

174. Approved shotfiring apparatus – Where Permitted Explosives are used under regulation 172, no shot shall be fired except by means of a shotfiring apparatus of a type approved by the Chief Inspector and subject to such conditions as he may from time to time lay down by notification in the Official Gazette:

Provided that where special conditions exist, the Chief Inspector may, by an order in writing and subject to such conditions as he may specify therein permit the use of any other shotfiring apparatus.

175. Precautions in gassy mines - IN any gassy seam the following additional precautions shall be taken] –

(1) If in a ventilating district, presence of inflammable gas is detected in any place, no shothole shall be charged, stemmed or fired in that place or in any other place situated on its return side till such place has been cleared of gas and declared safe.

4[(2)] Immediately before charging a shothole or a round of shotholes, and again before firing the shots the shotfirer shall carefully test for inflammable gas at all places within a radius of 18 metres of the place of firing.

4[(3)] No shothole shall be charged if any break is found therein, or if inflammable gas is found issuing therefrom.

4[(4)] If after charging a shothole, inflammable gas is found in any place within the prescribed radius no shot shall be fired until the place has been cleared of gas and declared safe.

4[(5)] No delay-action detonator shall be used, except with the previous permission in writing of the Chief Inspector and subject to such conditions as he may specify therein.

176. Inspections after shotfiring. – After a shot has been fired, no person other than the shotfirer or any other person enter the place until the area is free from dust, smoke or fumes. He shall, before any other person enters the place, make a careful examination and with his assistants, if any, make the place safe. No other person shall enter the place, and where guards have been declared safe in all respects. In the case of opencast workings, after shots have been fired, an all-clear signal shall be given except in the case of a misfire.

177. Misfires. – (1) The number of shots which explode shall, unless shots are fired electrically, be counted by the shotfirer and any another competent person authorized for the purpose; and unless it is certain that all the shots have been exploded, no person shall reenter or be permitted to re-enter the place until 30 minutes after the firing of shots :

Provided that where shots are fired electrically, this interval may be reduced to not less than five minutes after the source of electricity has been disconnected from the cable.

(2) In the event of a misfire, the entrance or entrances to the working place shall be fenced so as to prevent inadvertent access; and no work other than that of locating or relieving the misfire shall be done therein until the misfire has been located and relieved. In opencast workings, it shall be sufficient to mark the place of the misfire with a red flag.

(3) In the event of a misfire, a second charge shall not be placed in the same hole.

(4) If the misfire contains a detonator, the leads or fuse thereof shall be attached by a string to the shotfiring cable or some distinctive marker.

(5) Except where the misfire is use to faulty cable or a faulty connection, and the shot is fired as soon as practicable after the defect is remedied, another shot shall be fired in a relieving hole which shall be so placed and drilled in such a direction that at no point shall it be nearer than 30 centimetres from the misfired hole. The new hole shall be bored in the presence of a shotfirer, preferably the same person who fired the shot.

(6) After a relieving shot has been fired, a careful search for cartridges and detonators, if any, shall be made in the presence of the shotfirer, amongst the material brought down by the shot:

Provided that in the case of workings belowground if such cartridge or detonator is not recovered, the tubs into which the material is loaded shall be marked and a further search made on the surface. As far as possible, the search for the detonators and cartridges and the

loading of any coal, stone or debris which may contain a detonator, shall be carried out without the aid of tools.

(7) If a misfired hole is not dislodged by a relieving shot, ,the procedure laid down I subregulation (5) and (6) shall be repeated. A misfired hole which cannot be dealt with in the manner so prescribed, shall be securely plugged with a wooden plug; an no person other than a shotfirer, an official or a person authorised for the purpose shall remove or attempt to remove such plug.

(8) When a misfired shot is not found, or when a misfired shot is not relieved, the shotfirer shall, before leaving the mine, give information of the failure to such shotfirer or official as may relieve or take over charge from him. He shall also record, in a bound paged book kept for the purpose, a report on every misfire, whether suspected, and whether the shothole is relieved or not relieved. It shall be the responsibility of the relieving shotfirer or official also to sign the report and, to record in the said book the action taken for reliving the misfired shothole.

(9) The shotfirer of the next shifts shall locate and blast the misfired hole, but if after a thorough examination of the place, where the misfire was reported to have occurred he is satisfied that no misfire has actually occurred he may permit drilling in the place. 178. Special precautions in stone drifts – In stone drifts –

(a) after shots have been fired, all loose rock shall be removed from the face, and the area lying within a distance of 1.2 metres from the face shall be thoroughly cleaned or washed down with water and carefully examined for the presence of misfires or sockets. Unless the precautions herein specified have been taken, the next round of shots shall not be fired; and (b) if any socket is found, it shall be dealt with in the manner prescribed in regulation 177.

179. Duties of shotfirer at the end of his shift . - Immediately after the end of his shift, the shotfirer-

(a) shall return all unused explosive to the magazine, or where a store or premises is provided under regulation 160, to such store or premises; and (b) shall record, in a bound paged book kept for the purpose, the quantity or explosive taken, use and returned, the places where shots were fired and the number of shots fired by him, and misfires, if any.

Every such entry shall be signed and dated by him.

180. General precautions regarding explosives.- (1) No person, whilst handling explosives or engaged or assisting in the preparation of charges or in the charging of holes, shall smoke or carry or use a light other than an enclosed light, electric torch or lamp :

Provided that nothing in this sub-regulation shall be deemed to prohibit the use of an open light for lighting fuses.

(2) No person shall take any light other than an electric torch or an enclosed electric lamp into any explosive magazine or store or premises.

1[(3)(a) The owner, agent, or manager shall take adequate steps to prevent pilferage of explosives during its storage, transport and use in the mine.

(b) No person shall have explosives in his possession except as provided for in these regulations, or secrete or keep explosives in a dwelling house.]

(4) Any person finding any explosives in or about a mine shall deposit the same in the magazine or store or premises. Every such occurrence shall reported to the manager in writing.
